Assessing Agricultural Impacts on Watershed Hydrology: Insights from GULGUL5 Monitoring Data

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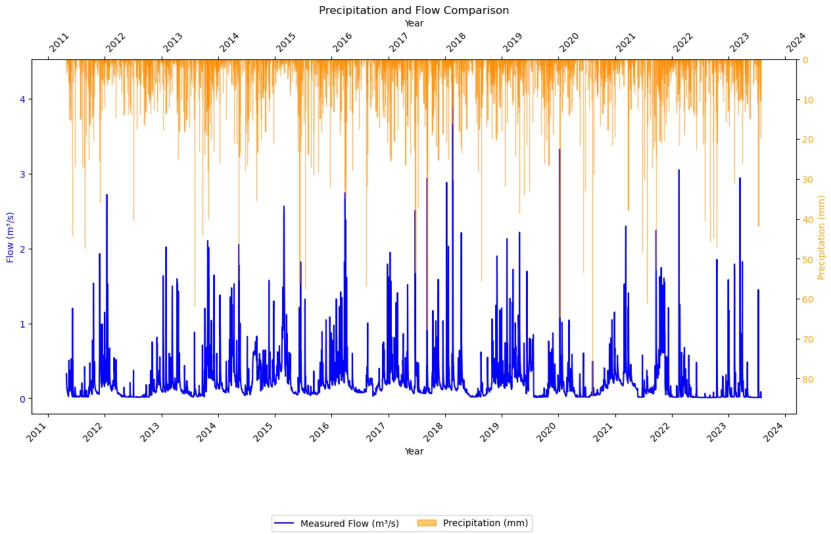
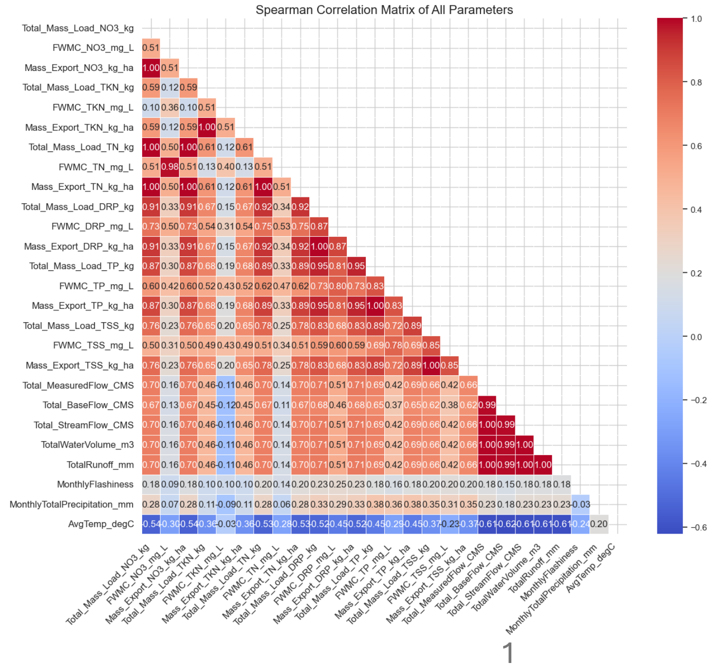
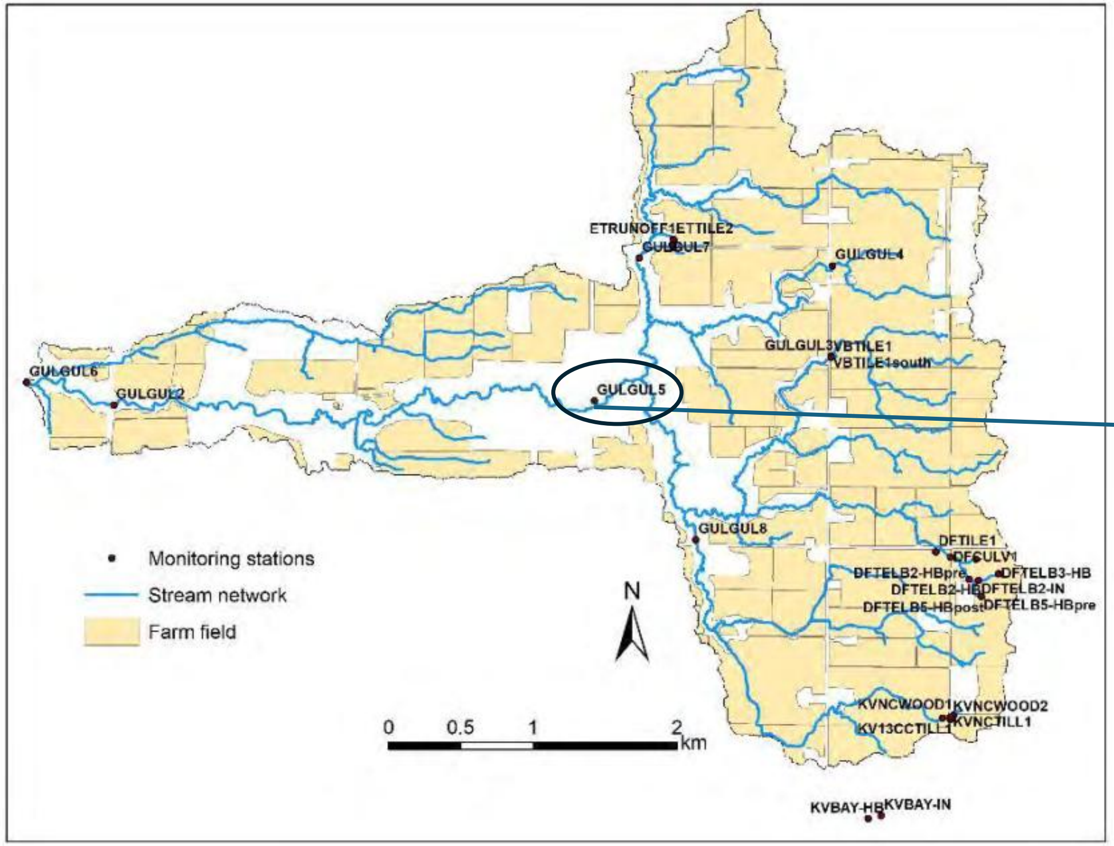
AUSABLE BAYFIELD CONSERVATION
CREATING AWARENESS | TAKING ACTION

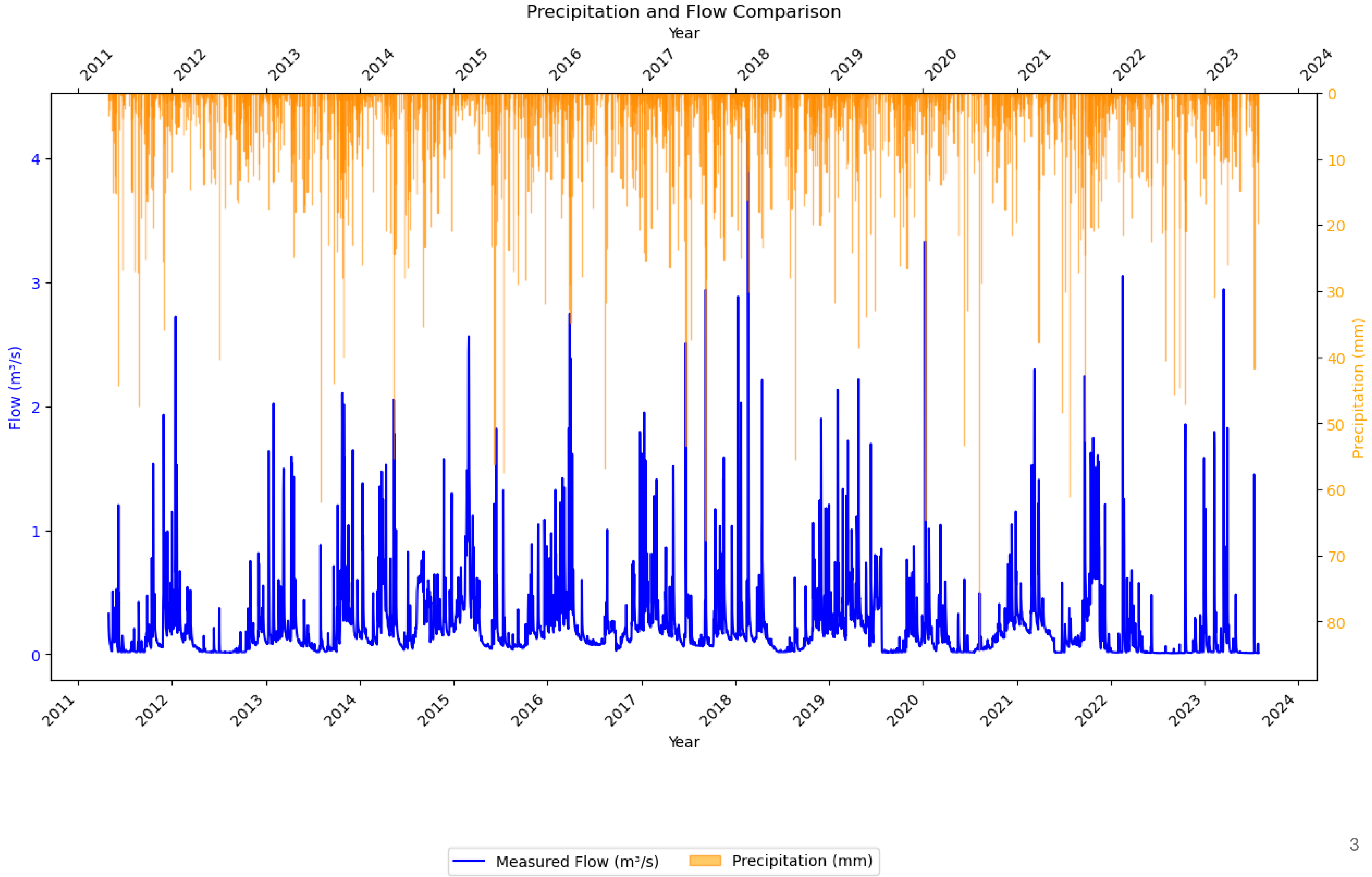


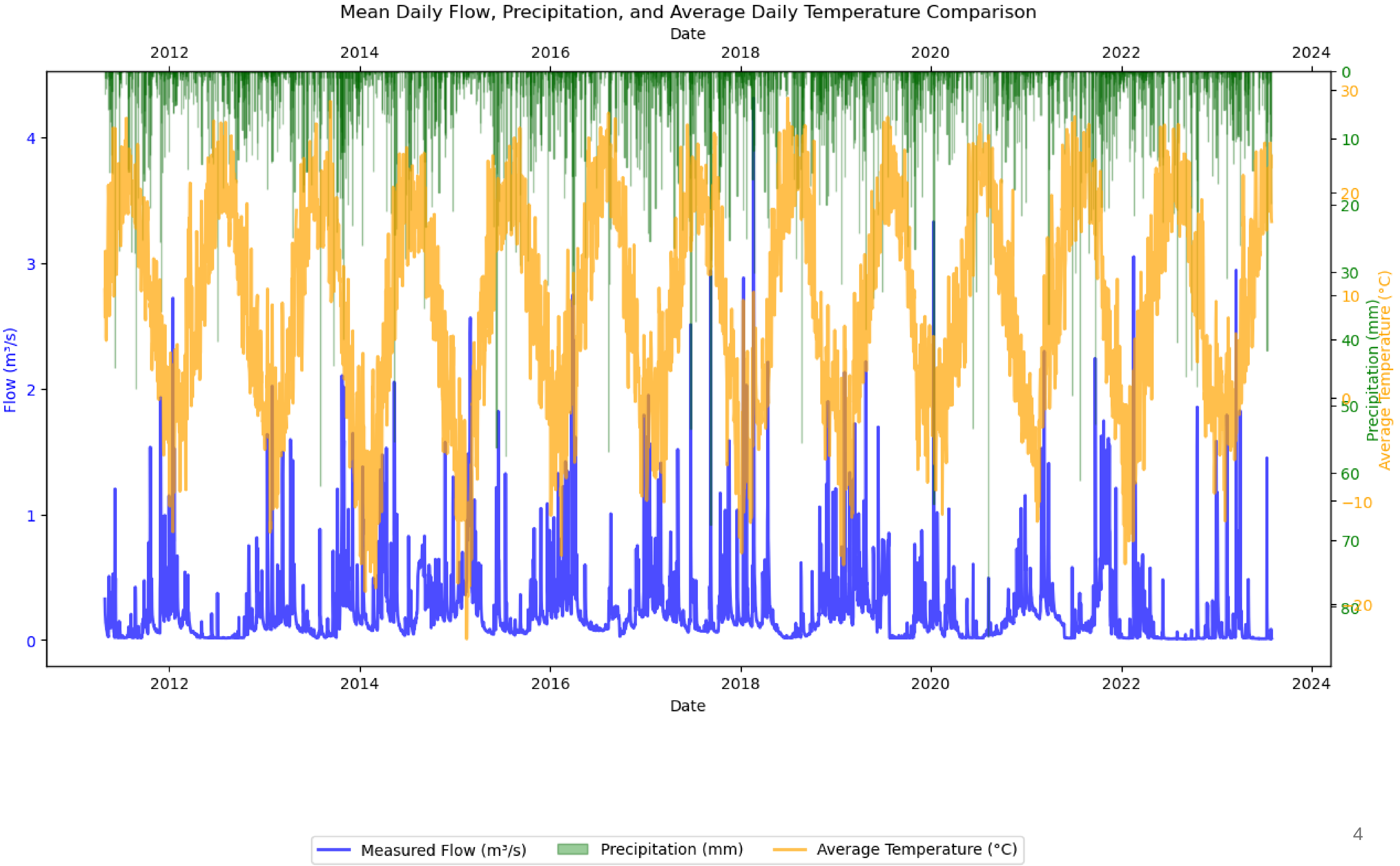


Monitoring station



- Hourly mean flow (15/04/2011 4:00:00 PM to 02/08/2023 11:00:00 AM)
- Calculated daily mean flow
- Daily precipitation (29/04/2011 to 31/07/2023)
- Daily average temperature (29/04/2011 to 10/01/2024)
- Water quality parameters in specific time and date (NO3, NO2, NO3-NO2, TN, DRP, TP, TSS) with specific flow data (18/04/2011 9:08:00 AM to 11/12/2021 11:31:00 AM)


Precipitation and Flow Comparison
Year
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Flow (m³/s)
0
1
2
3
4
Precipitation (mm)
0
10
20
30
40
50
60
70
80
Year
Measured Flow (m³/s)
Precipitation (mm)



Mean Daily Flow, Precipitation, and Average Daily Temperature Comparison
Date
2012
2014
2016
2018
2020
2022
2024
Flow (m³/s)
0
1
2
3
4
Precipitation (mm)
0
10
20
30
40
50
60
70
80
Average Temperature (°C)
30
20
10
0
−10
−20
Measured Flow (m³/s)
Precipitation (mm)
Average Temperature (°C)

Automated Base Flow Separation and Recession Analysis Techniques

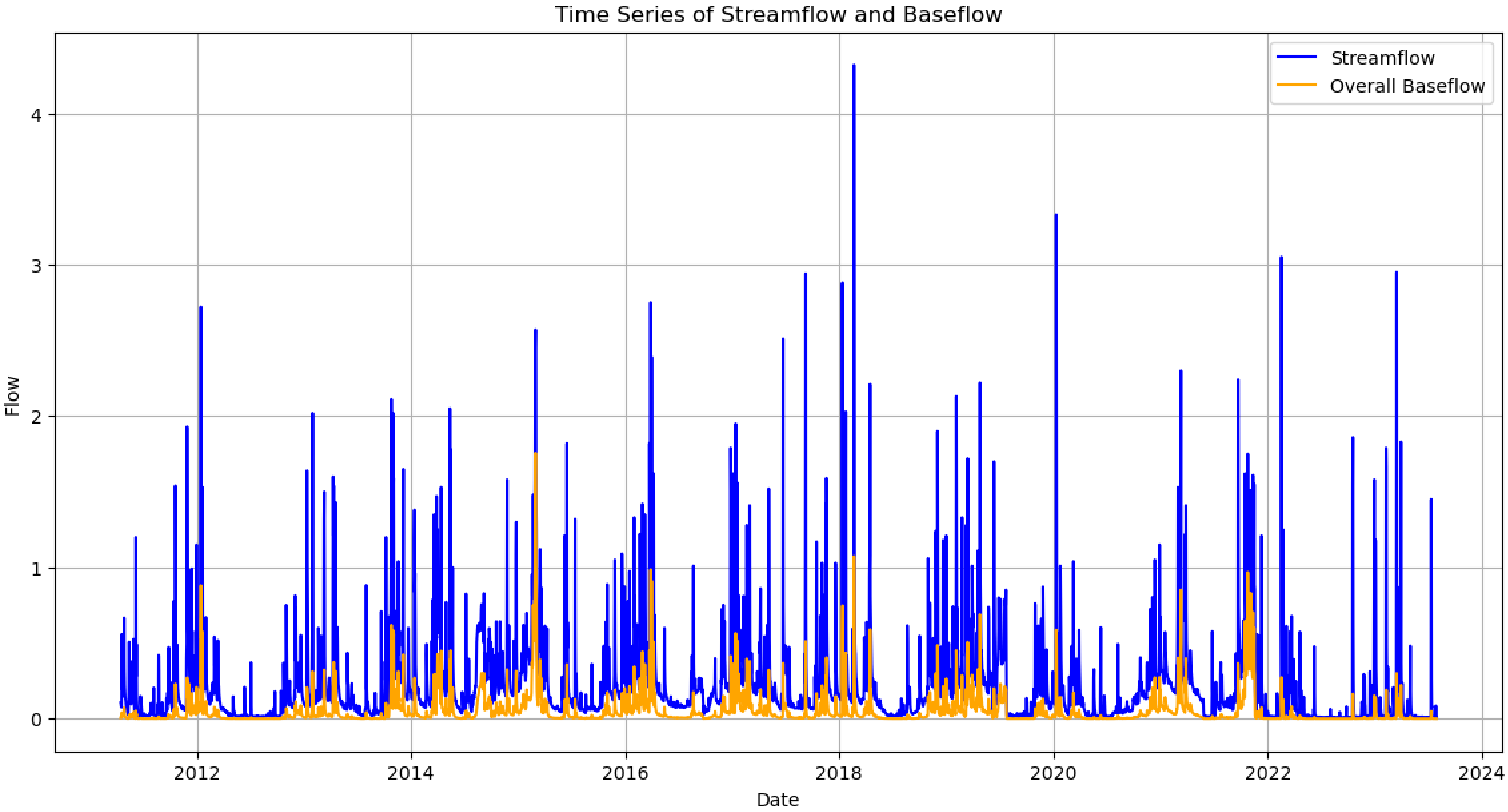
by J. G. Arnold[a], P. M. Allen[b], R. Muttiah[c], and G. Bernhardt[d]

https://ngwa.onlinelibrary.wiley.com/doi/epdf/10.1111/j.1745-6584.1995.tb00046.x

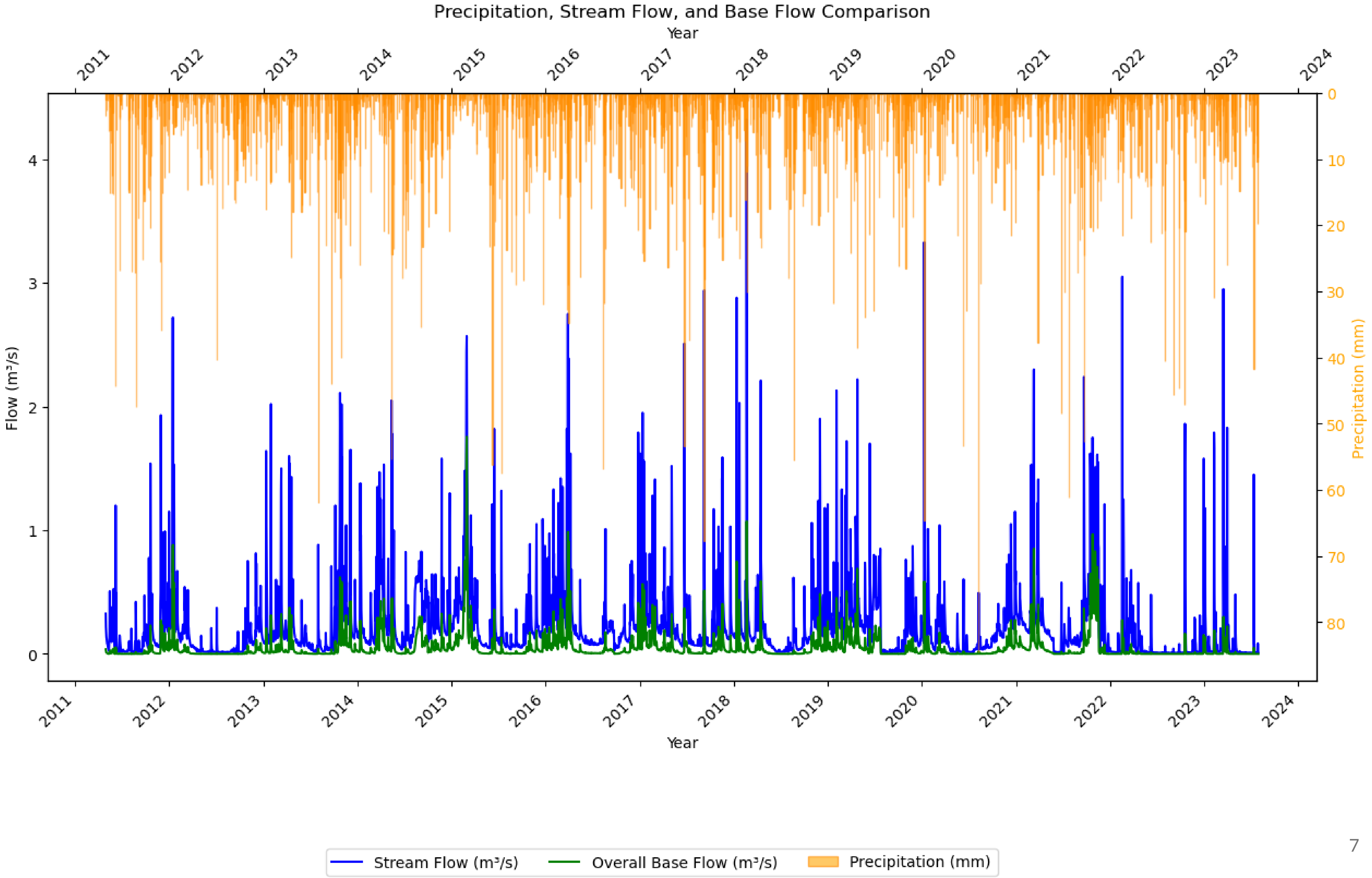
Abstract

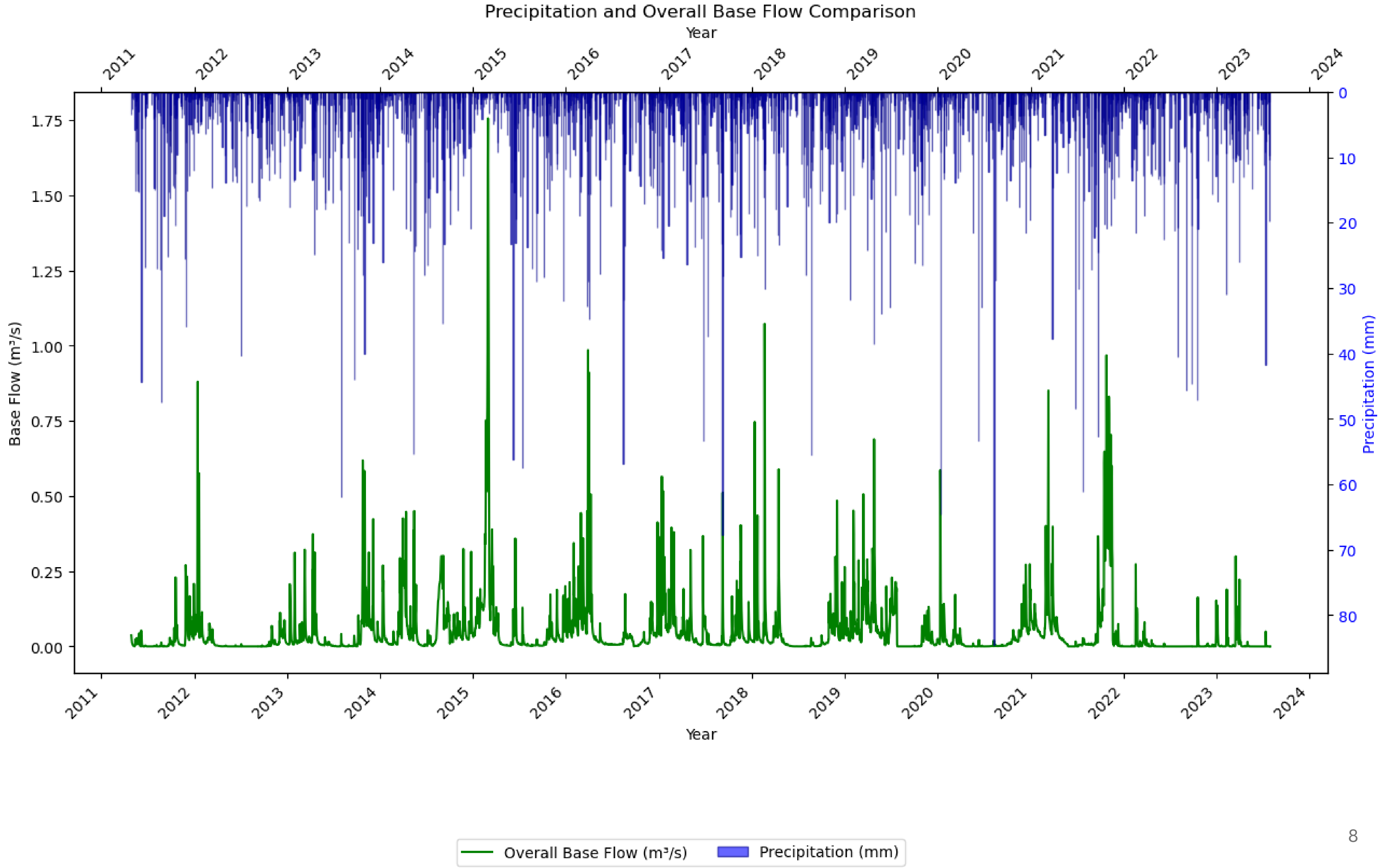
An automated base flow separation technique has been developed and tested. Base flow is considered to be the ground-water contribution to stream flow. Estimates of the amount of base flow can be derived from stream flow records. Such estimates are critical in the assessment of low flow characteristics of streams for use in water supply, water management, and pollution assessment. An automated base flow separation technique using a digital filter has been tested against three other automated techniques and manual separation methods. The filter appears to be comparable to other automated techniques in its ability to reproduce the results produced from graphical separation techiques. The filter technique is easy to use and has the added advantage in that it can be adjusted by the user to take into account personnel preferences in separation of stream flow into surface flow and base flow.

The slope of the base flow recession has been used to estimate the volume of water in storage in the basin above the level of the stream channel, the amount of recharge to the shallow aquifer, and as an input into water budget models. A second automated technique was developed to calculate the slope of the base flow recession curve from stream flow record. This technique is an adaptation of the Master Recession Curve procedure. The results of this method were compared to manual estimates with an efficiency of 74 percent.

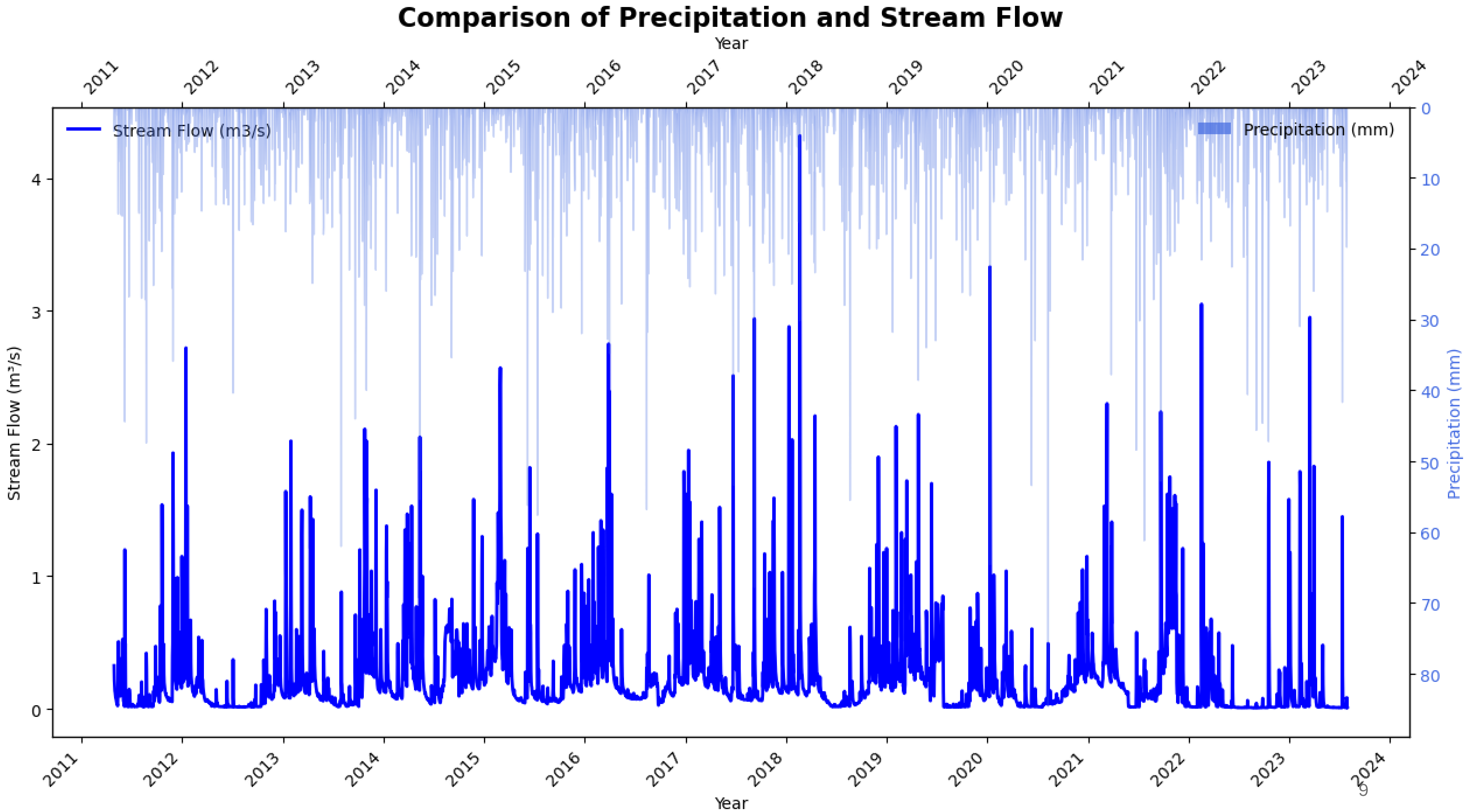


Time Series of Streamflow and Baseflow
Streamflow
Overall Baseflow
Flow
Date
0
1
2
3
4
2012
2014
2016
2018
2020
2022
2024


Precipitation, Stream Flow, and Base Flow Comparison
Year
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Flow (m³/s)
0
1
2
3
4
Precipitation (mm)
0
10
20
30
40
50
60
70
80
Year
Stream Flow (m³/s)
Overall Base Flow (m³/s)
Precipitation (mm)

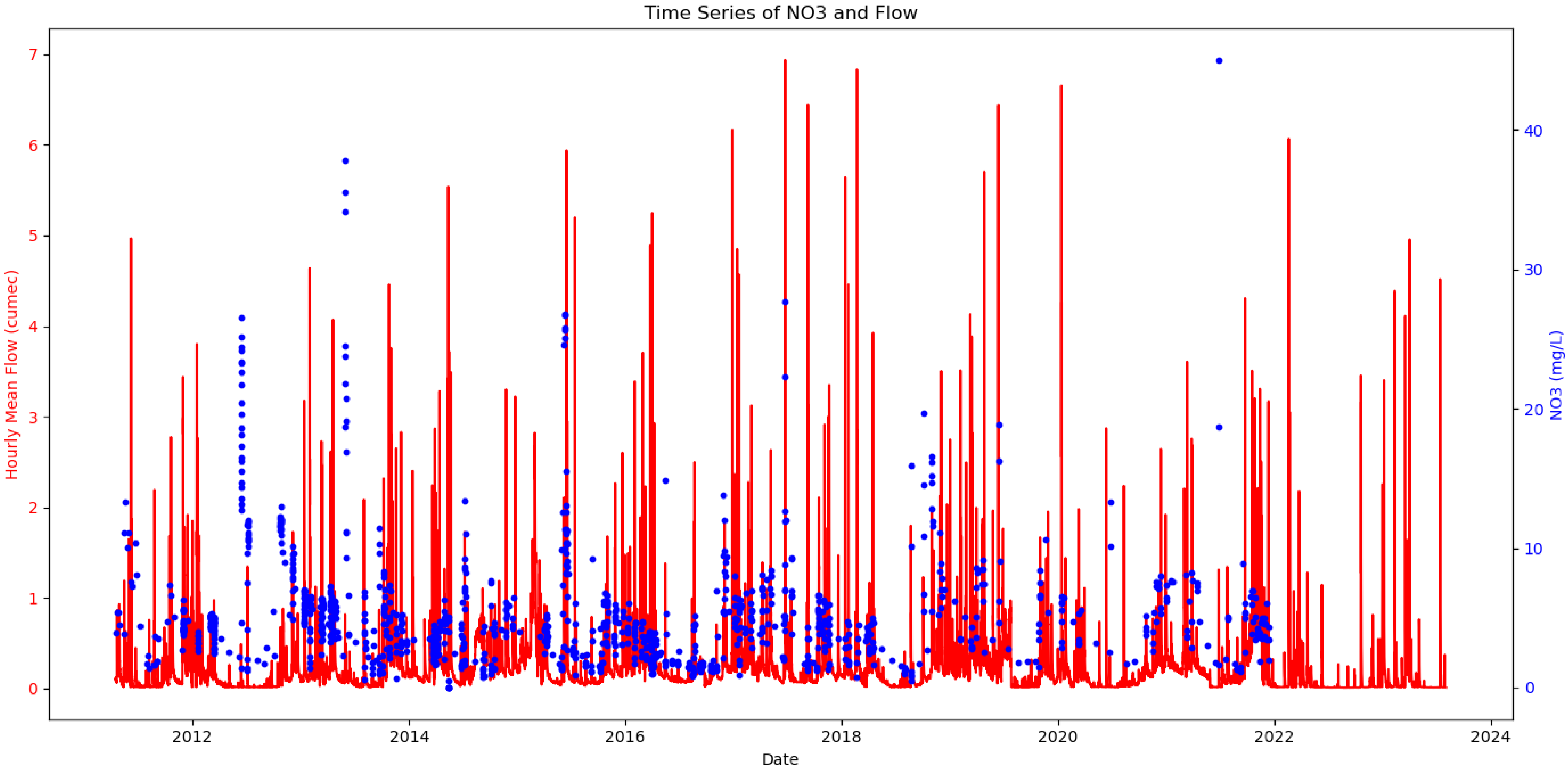


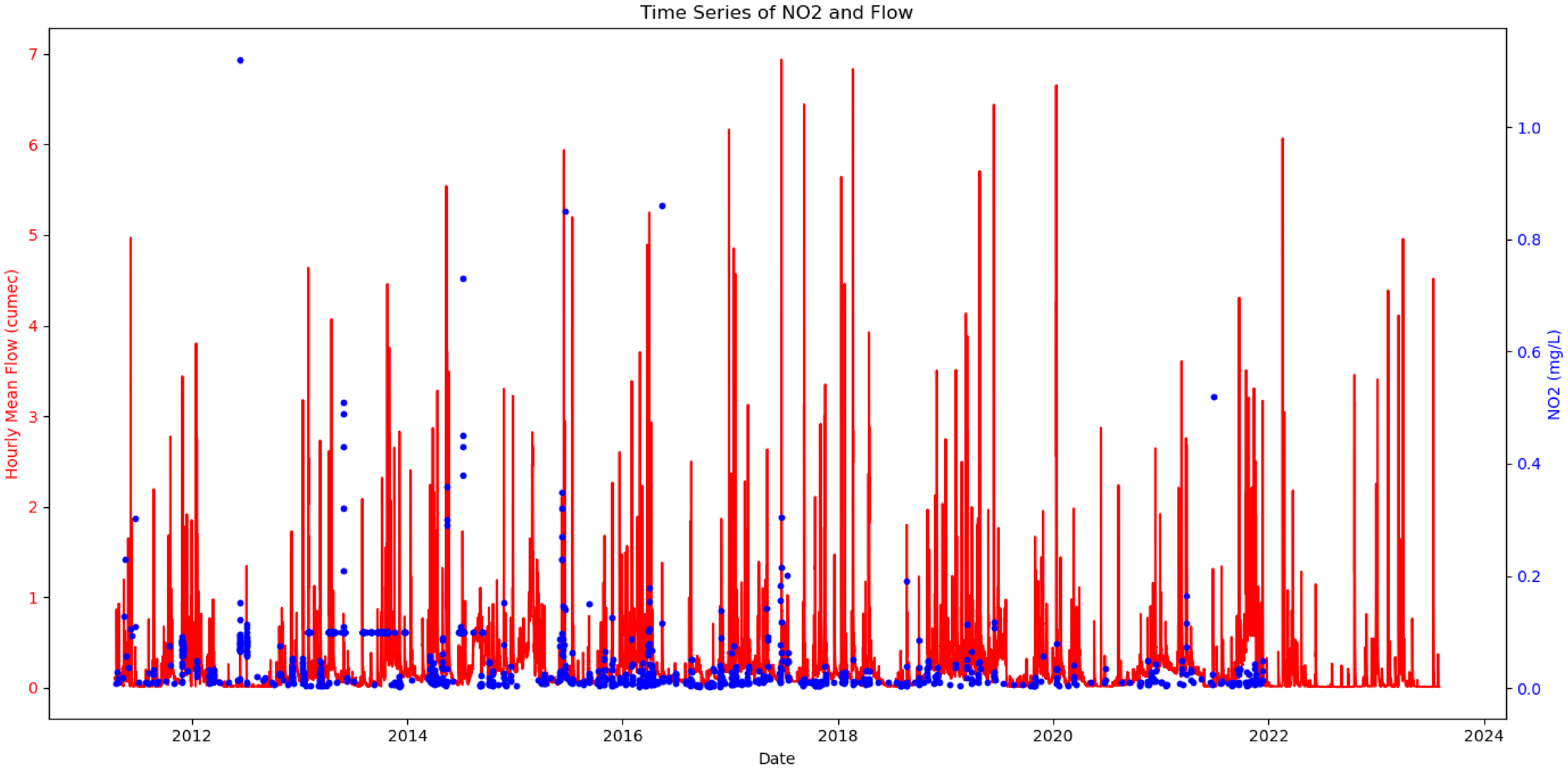
Precipitation and Overall Base Flow Comparison
Year
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Base Flow (m³/s)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
Precipitation (mm)
0
10
20
30
40
50
60
70
80
Year
Overall Base Flow (m³/s)
Precipitation (mm)

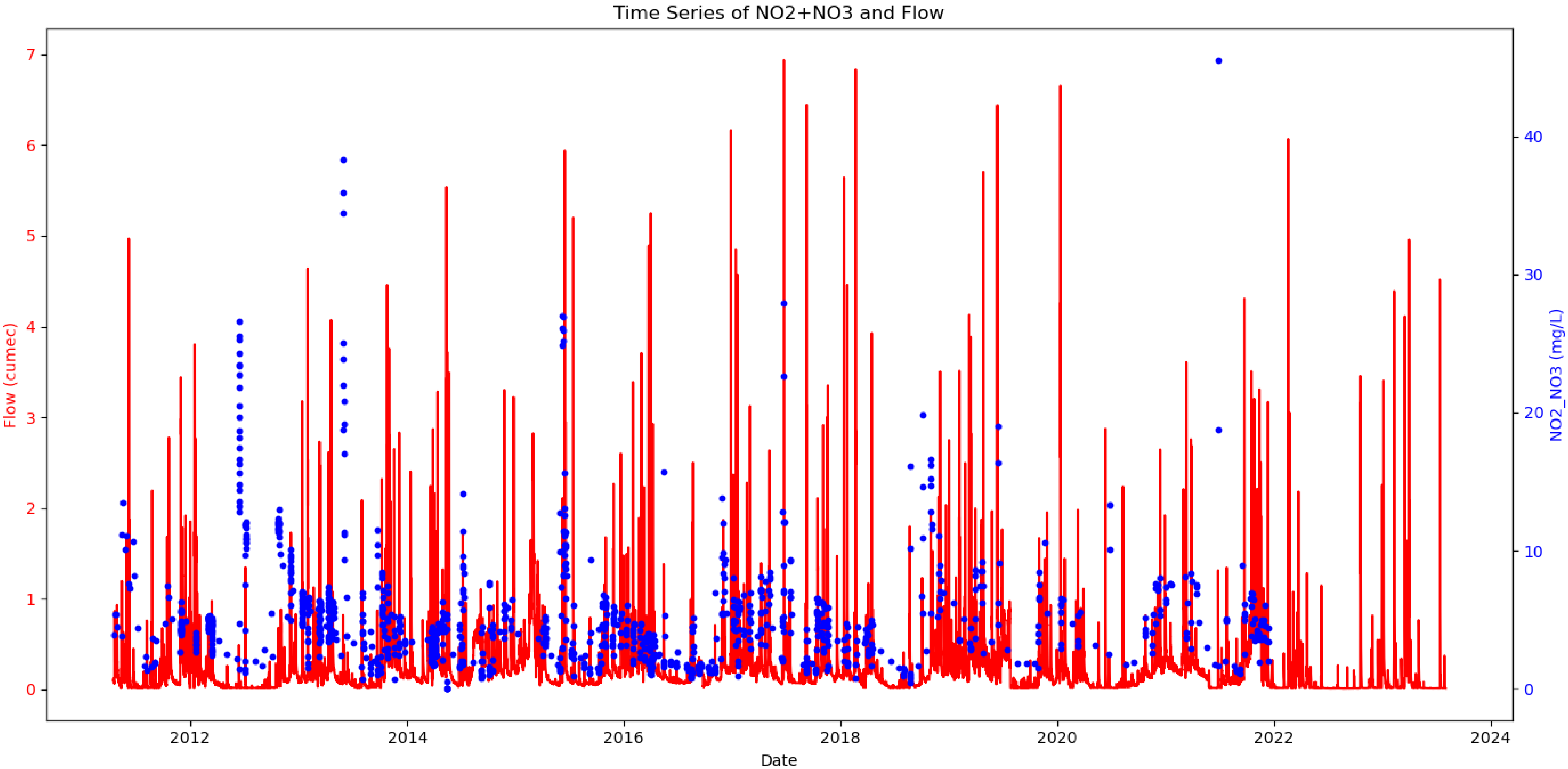

Comparison of Precipitation and Stream Flow
Year
Stream Flow (m3/s)
Precipitation (mm)
Stream Flow (m³/s)
Precipitation (mm)
Year
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
0
1
2
3
4
0
10
20
30
40
50
60
70
80

Time series analysis

Hourly mean flow vs water quality parameters

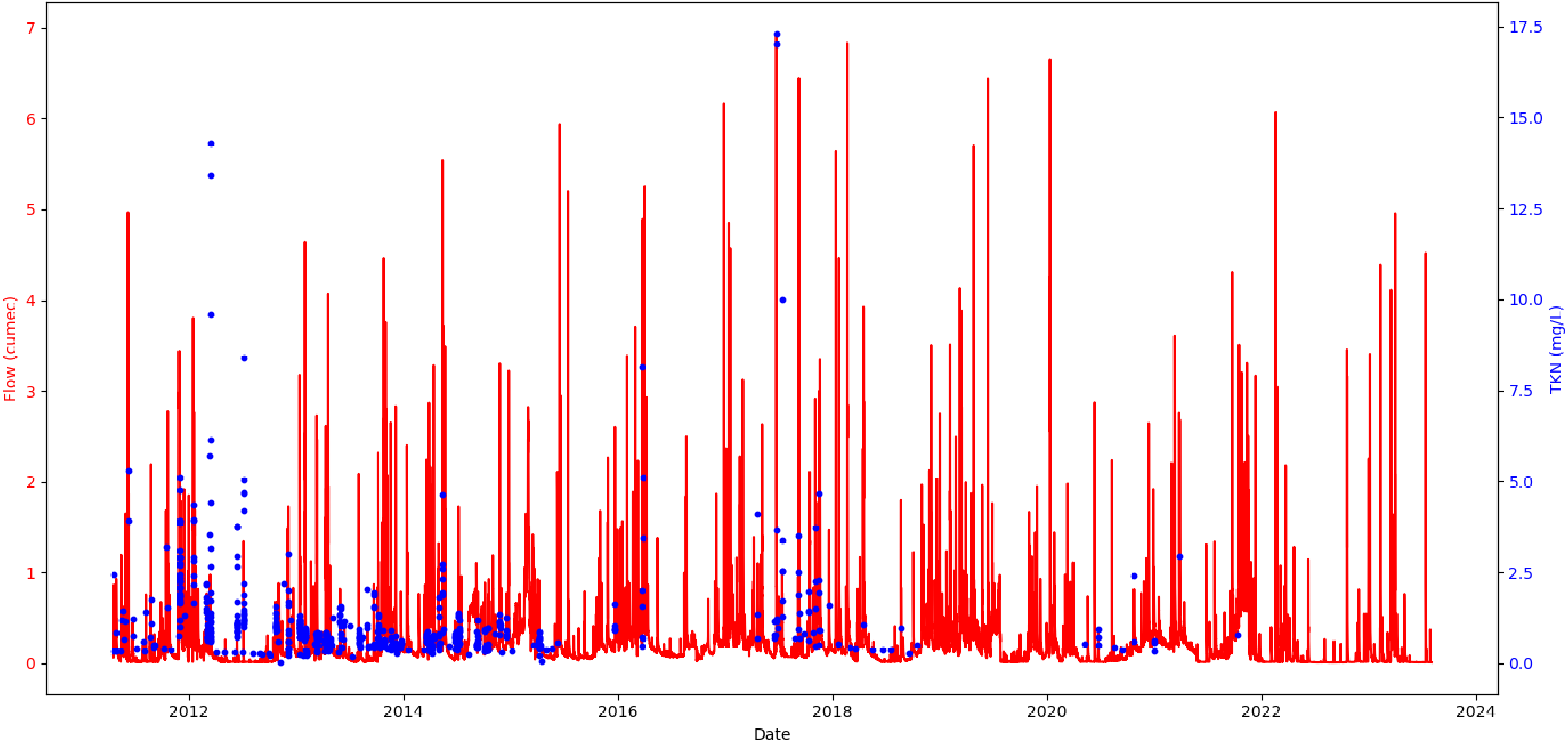

Time Series of NO3 and Flow
Hourly Mean Flow (cumec)
NO3 (mg/L)
Date
0
1
2
3
4
5
6
7
10
20
30
40
2012
2014
2016
2018
2020
2022
2024

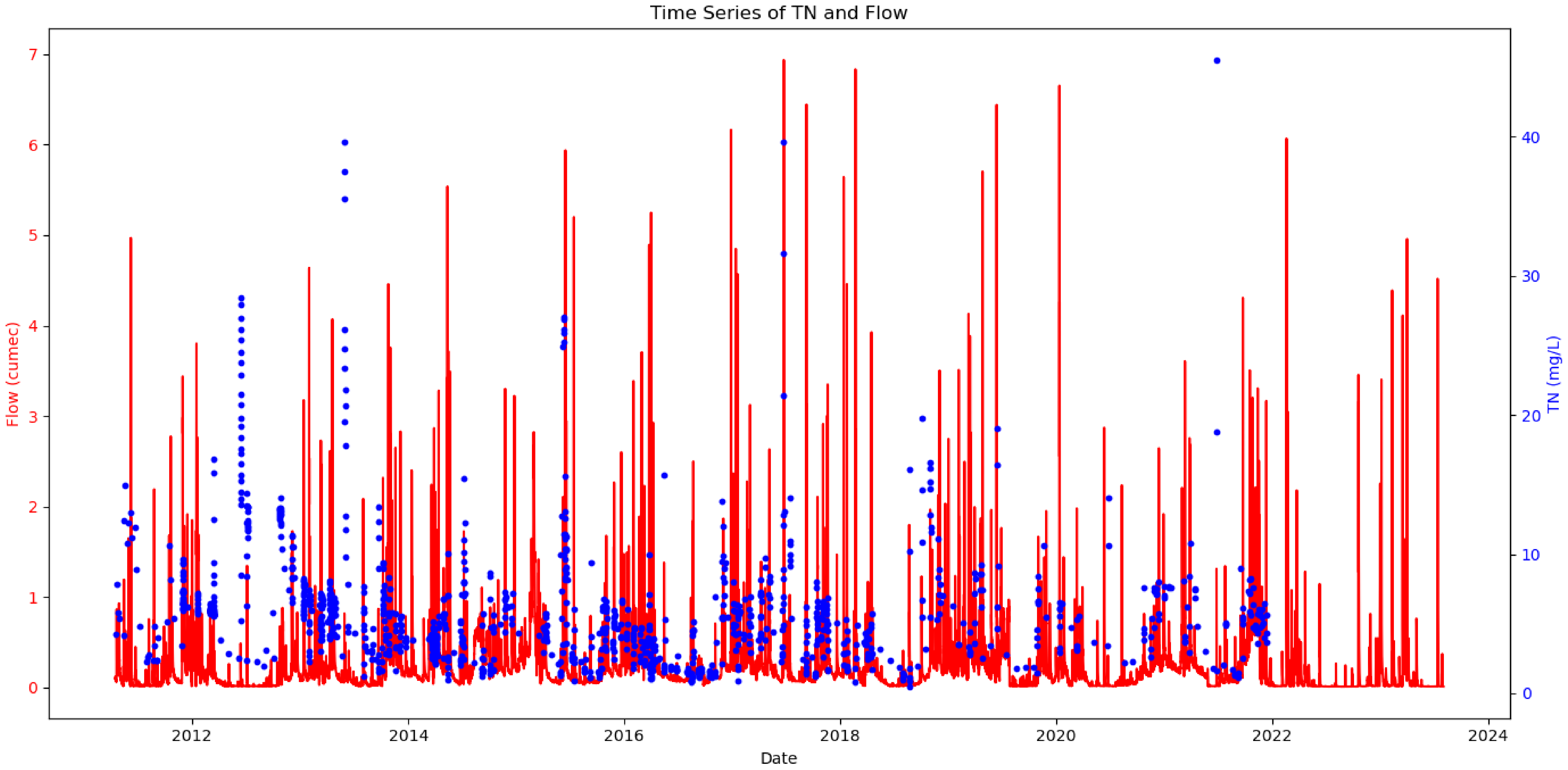

Time Series of NO2 and Flow
Hourly Mean Flow (cumec)
NO2 (mg/L)
Date
0
1
2
3
4
5
6
7
0.0
0.2
0.4
0.6
0.8
1.0
2012
2014
2016
2018
2020
2022
2024



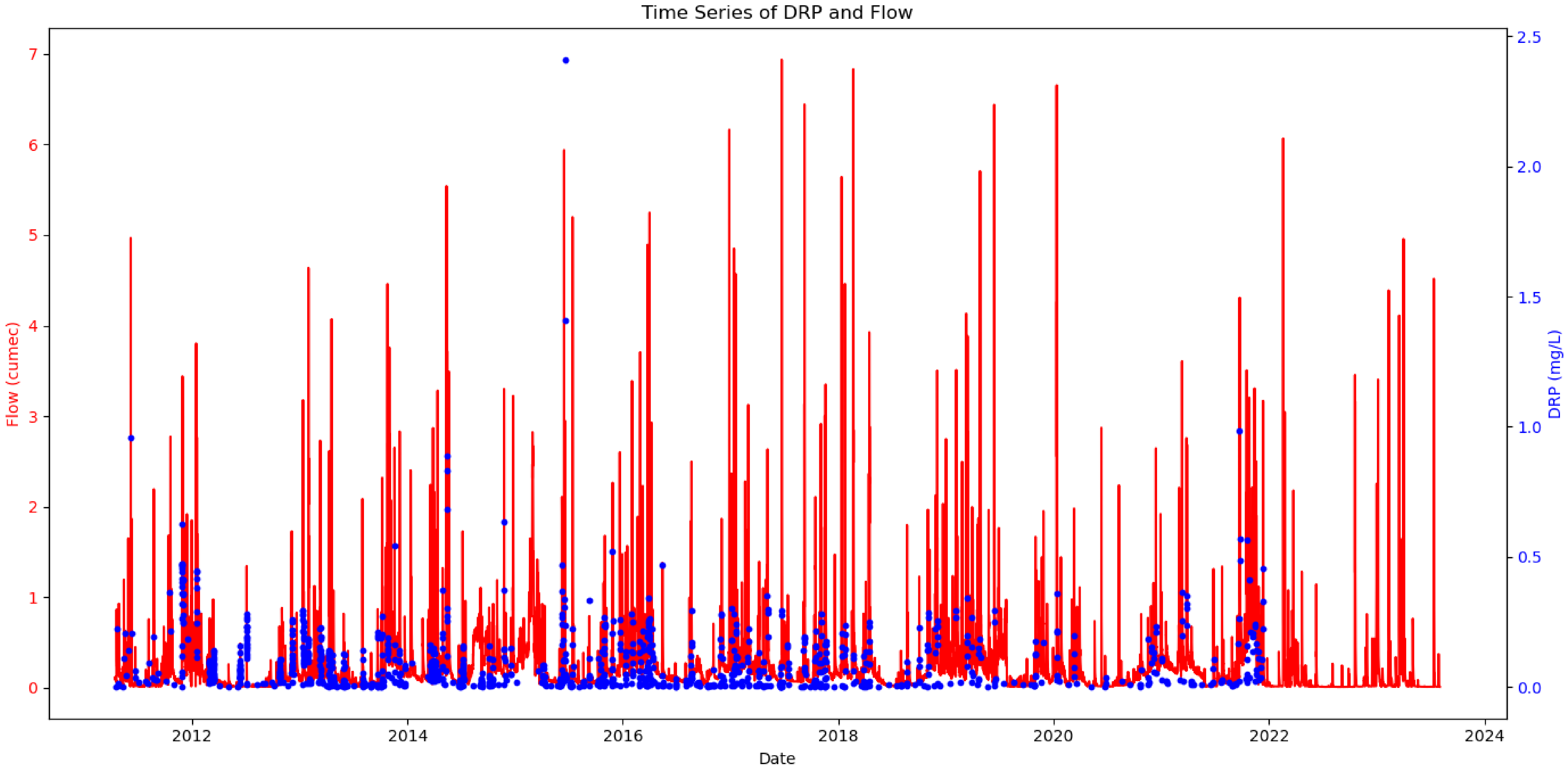
Time Series of NO2+NO3 and Flow
Flow (cumec)
NO2_NO3 (mg/L)
Date
0
1
2
3
4
5
6
7
0
10
20
30
40
2012
2014
2016
2018
2020
2022
2024

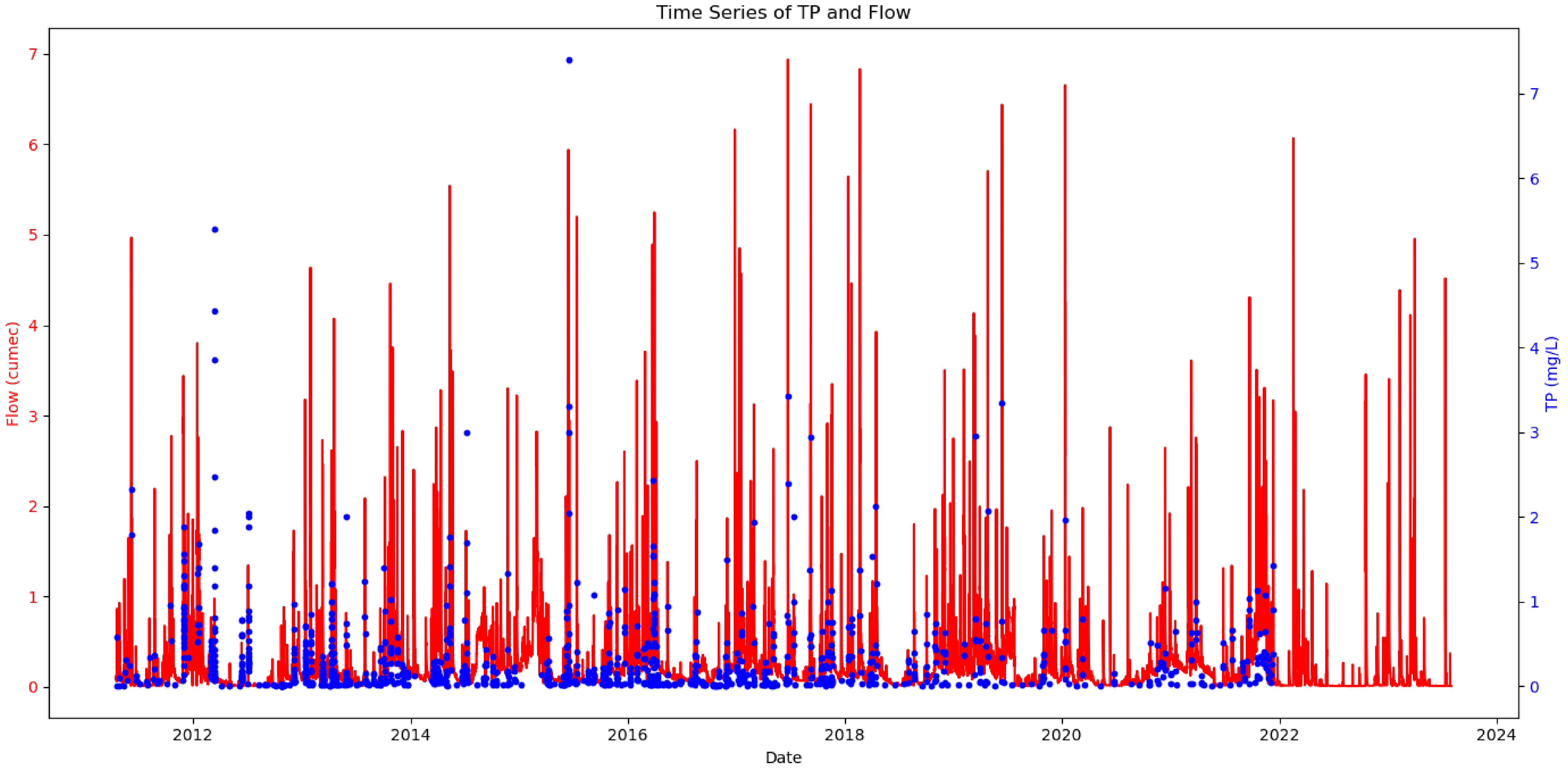
Time Series of TKN and Flow

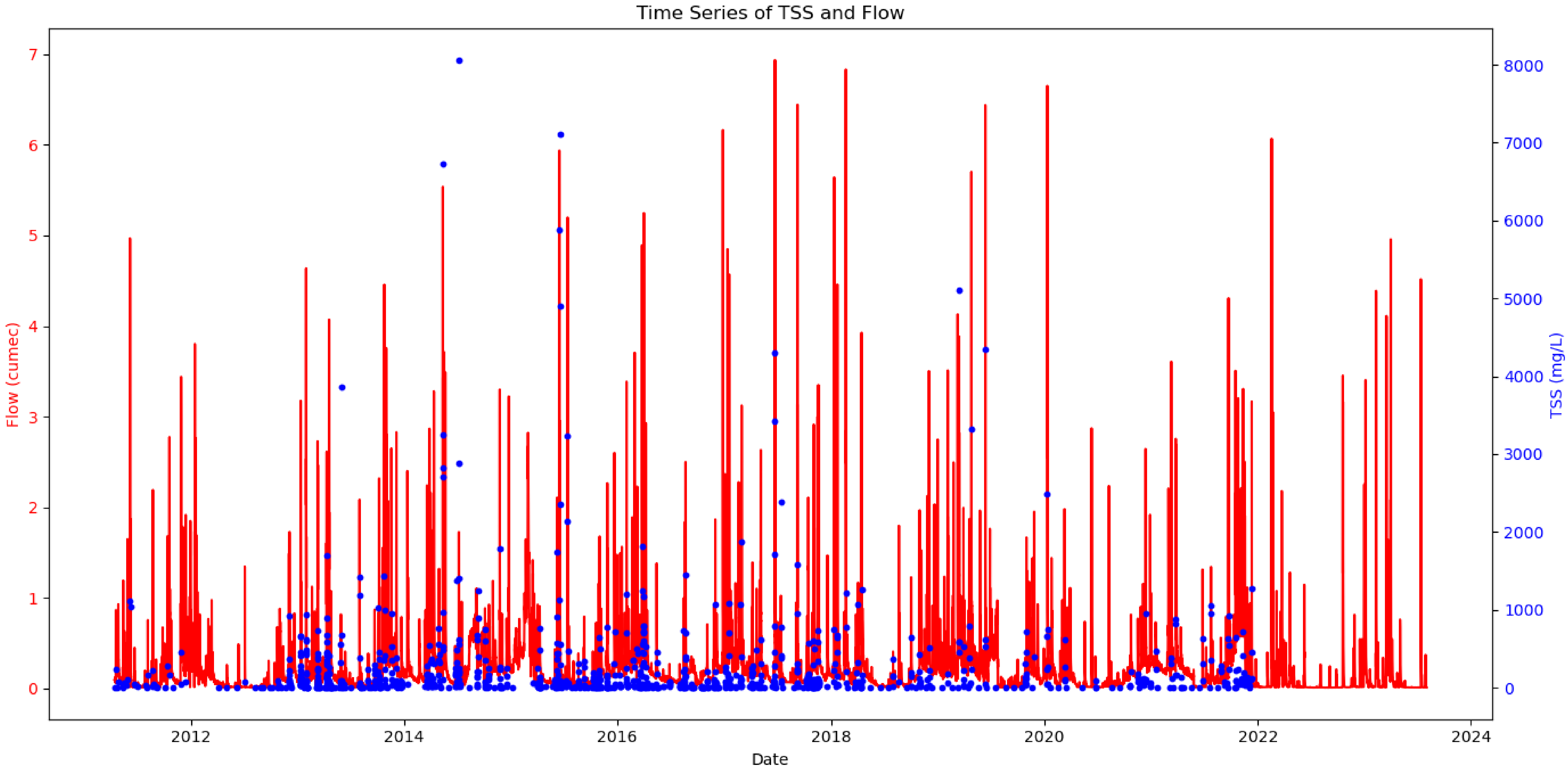




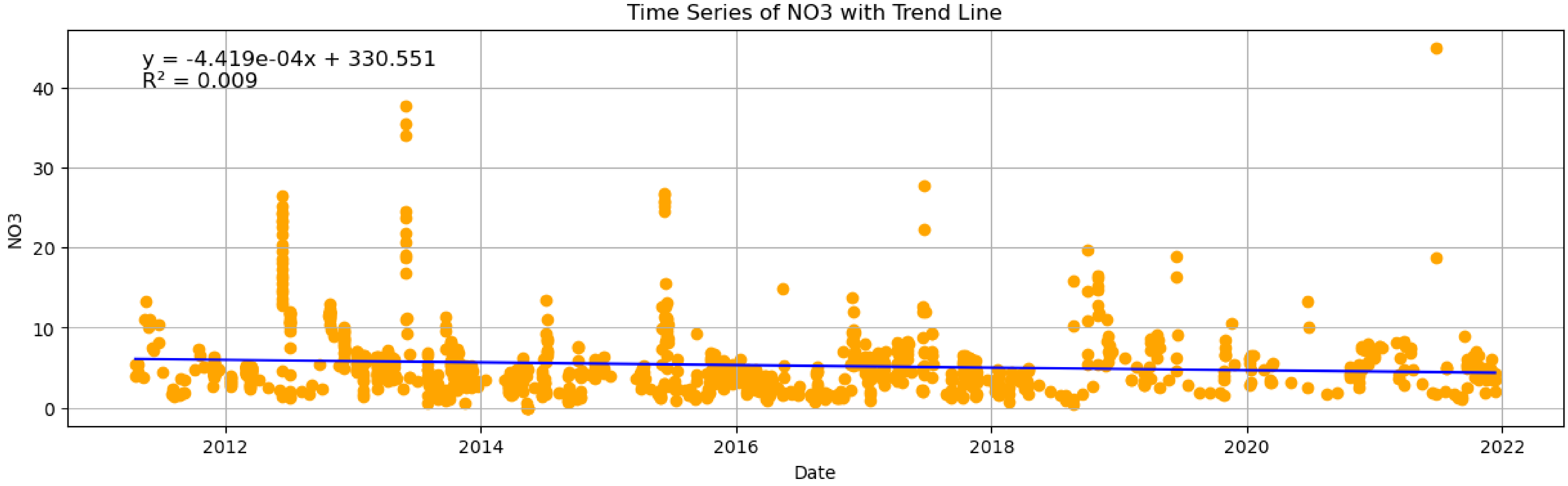
Time Series of TN and Flow
Flow (cumec)
TN (mg/L)
Date
0
1
2
3
4
5
6
7
10
20
30
40
2012
2014
2016
2018
2020
2022
2024

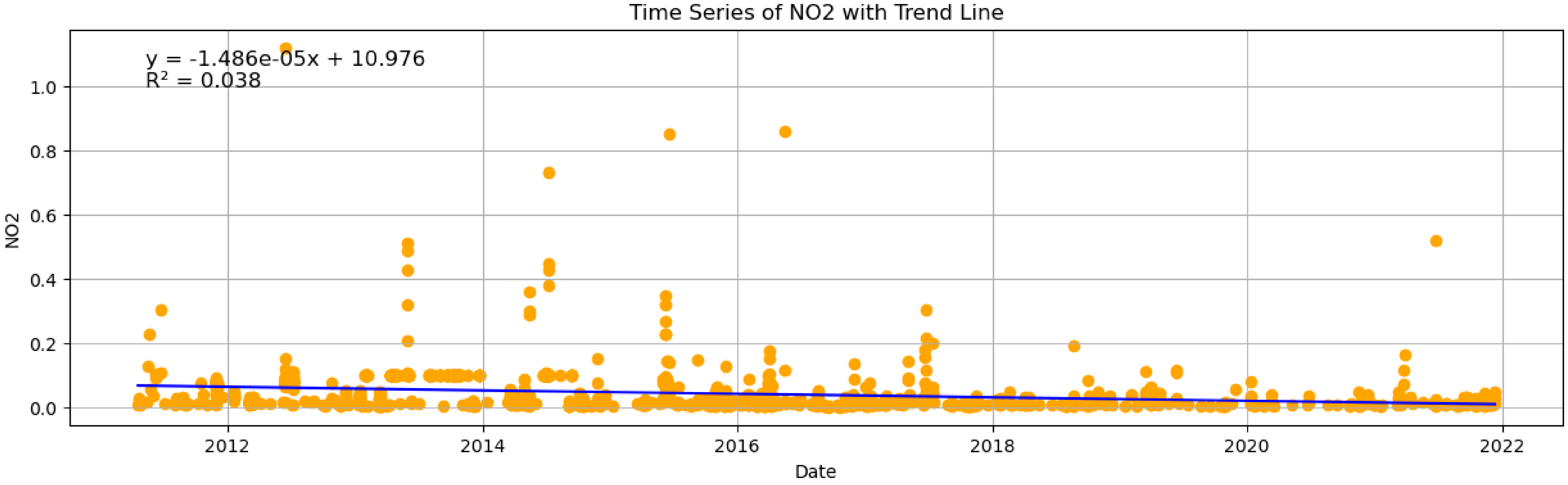

Time Series of DRP and Flow
Flow (cumec)
DRP (mg/L)
Date
0
1
2
3
4
5
6
7
0.0
0.5
1.0
1.5
2.0
2.5
2012
2014
2016
2018
2020
2022
2024

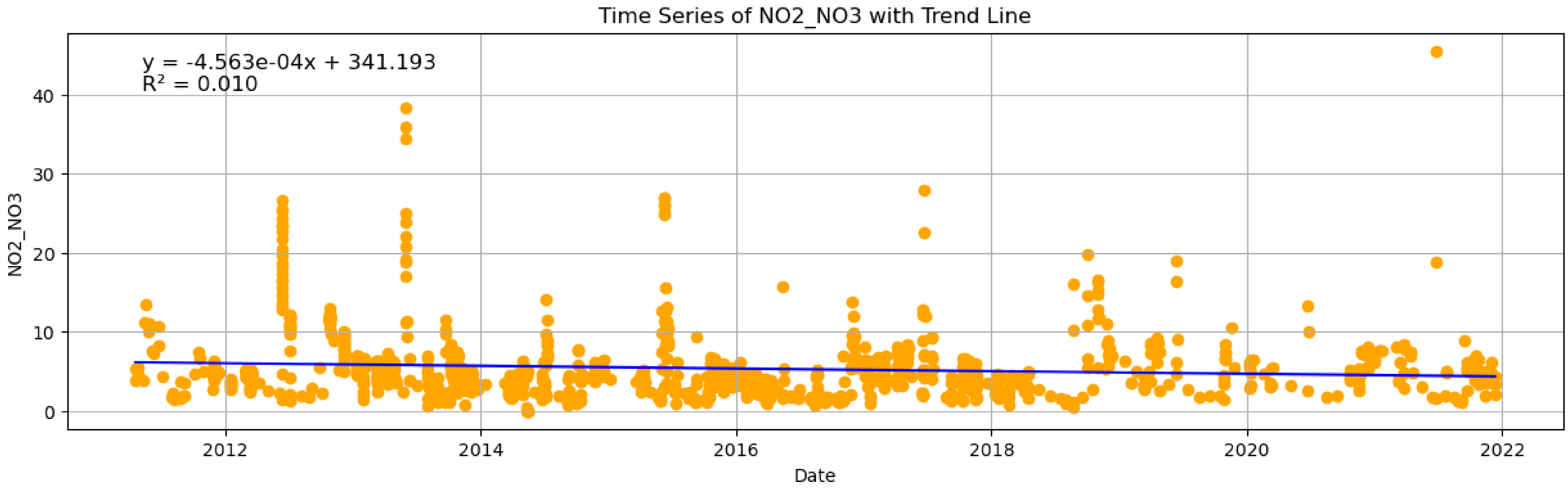

Time Series of TP and Flow
Flow (cumec)
TP (mg/L)
Date
0
1
2
3
4
5
6
7
2012
2014
2016
2018
2020
2022
2024



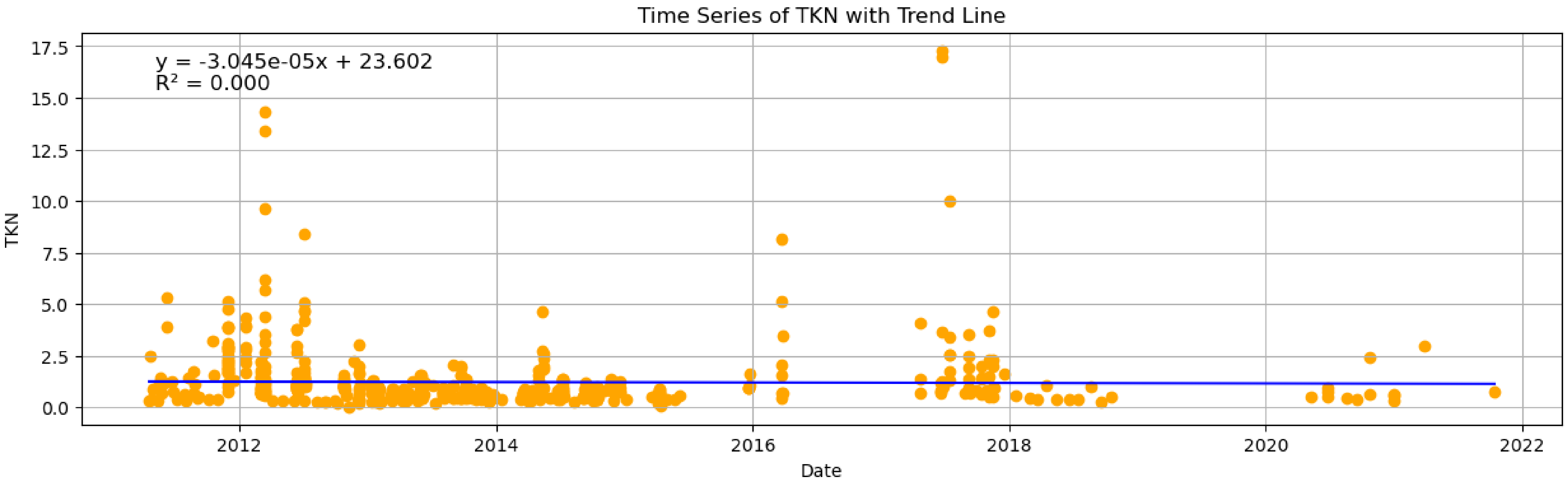
Time Series of TSS and Flow
Flow (cumec)
TSS (mg/L)
Date
0
1
2
3
4
5
6
7
0
1000
2000
3000
4000
5000
6000
7000
8000
2012
2014
2016
2018
2020
2022
2024

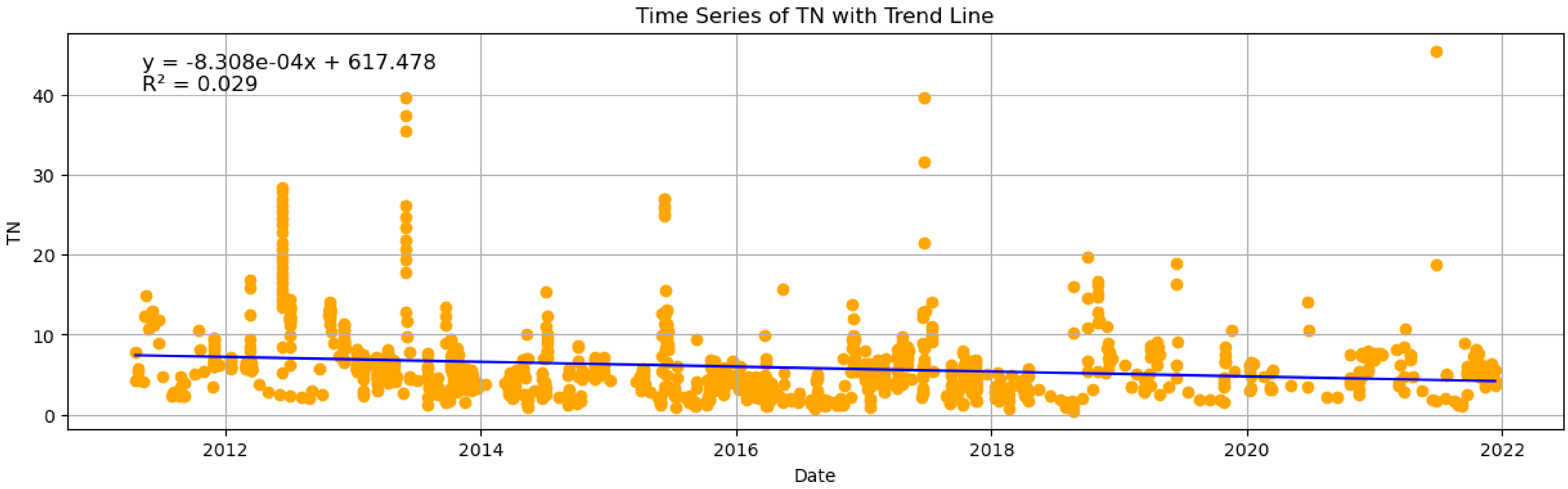

Time Series of NO3 with Trend Line
y = -4.419e-04x + 330.551
R² = 0.009
40
30
20
10
0
NO3
2012
2014
2016
2018
2020
2022
Date

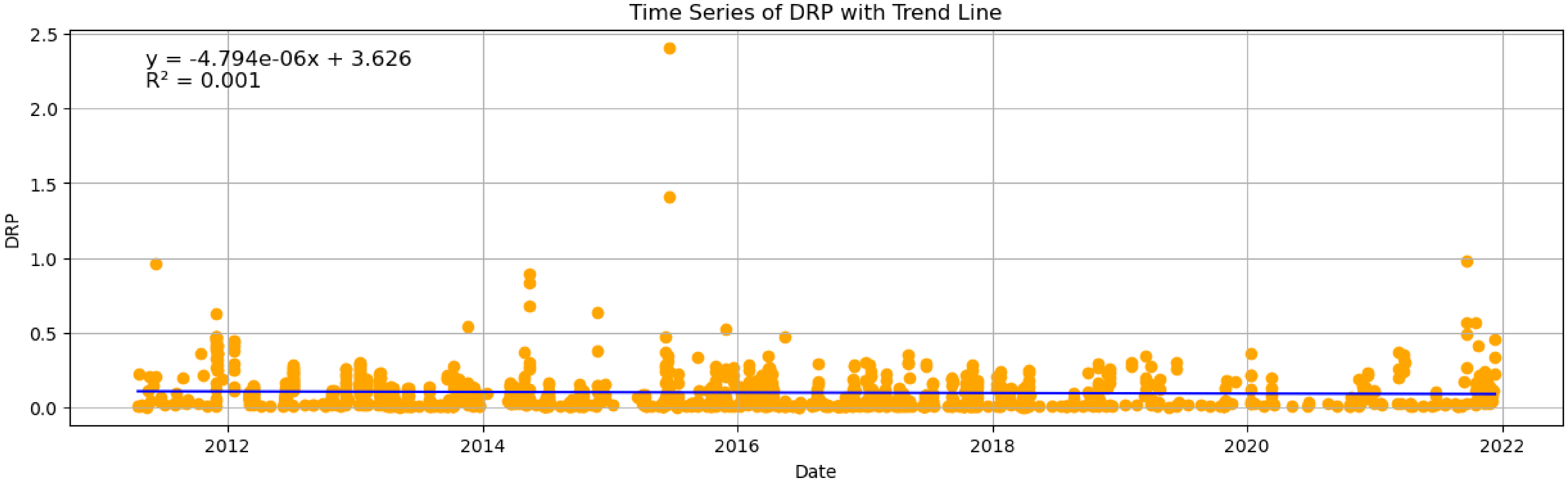

Time Series of NO2 with Trend Line
y = -1.486e-05x + 10.976
R² = 0.038
NO2
0.0
0.2
0.4
0.6
0.8
1.0
Date
2012
2014
2016
2018
2020
2022

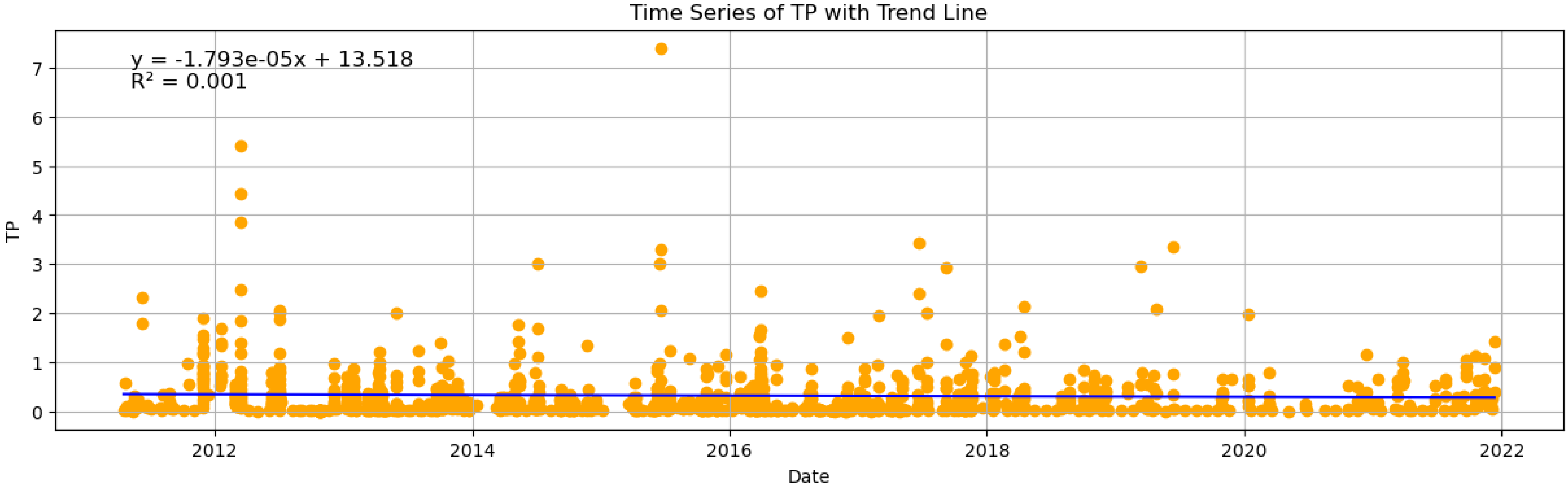


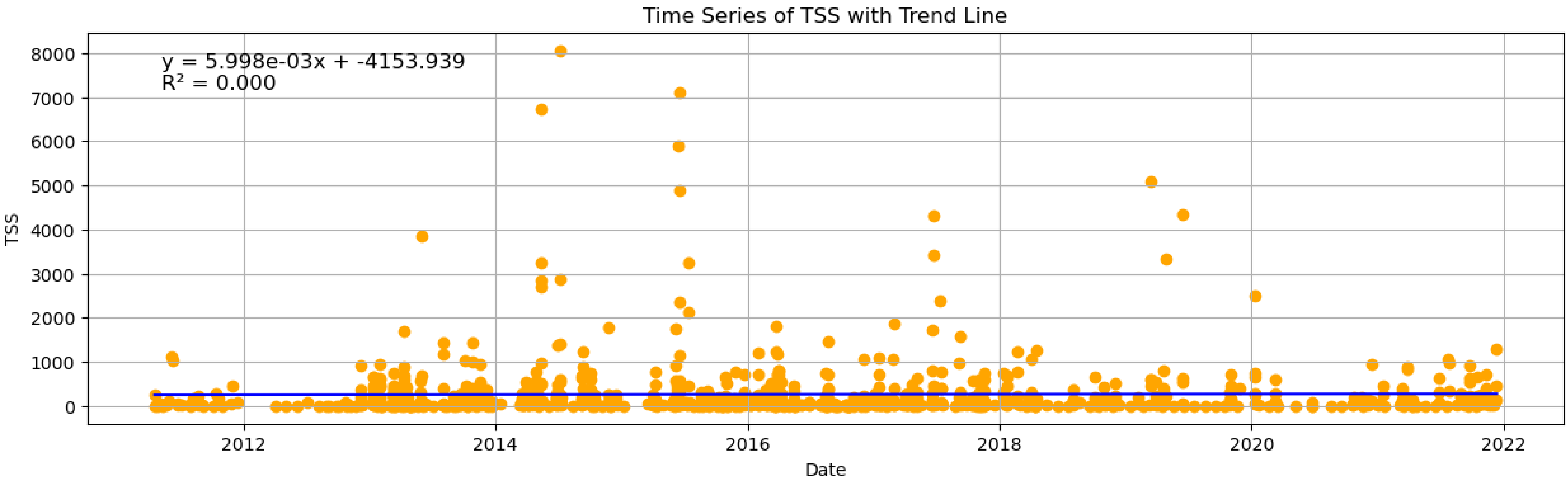
Time Series of NO2_NO3 with Trend Line
y = -4.563e-04x + 341.193
R² = 0.010
NO2_NO3
0
10
20
30
40
2012
2014
2016
2018
2020
2022
Date


Time Series of TKN with Trend Line
y = -3.045e-05x + 23.602
R² = 0.000
TKN
Date
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
2012
2014
2016
2018
2020
2022


Time Series of TN with Trend Line
y = -8.308e-04x + 617.478
R² = 0.029
TN
0
10
20
30
40
2012
2014
2016
2018
2020
2022
Date

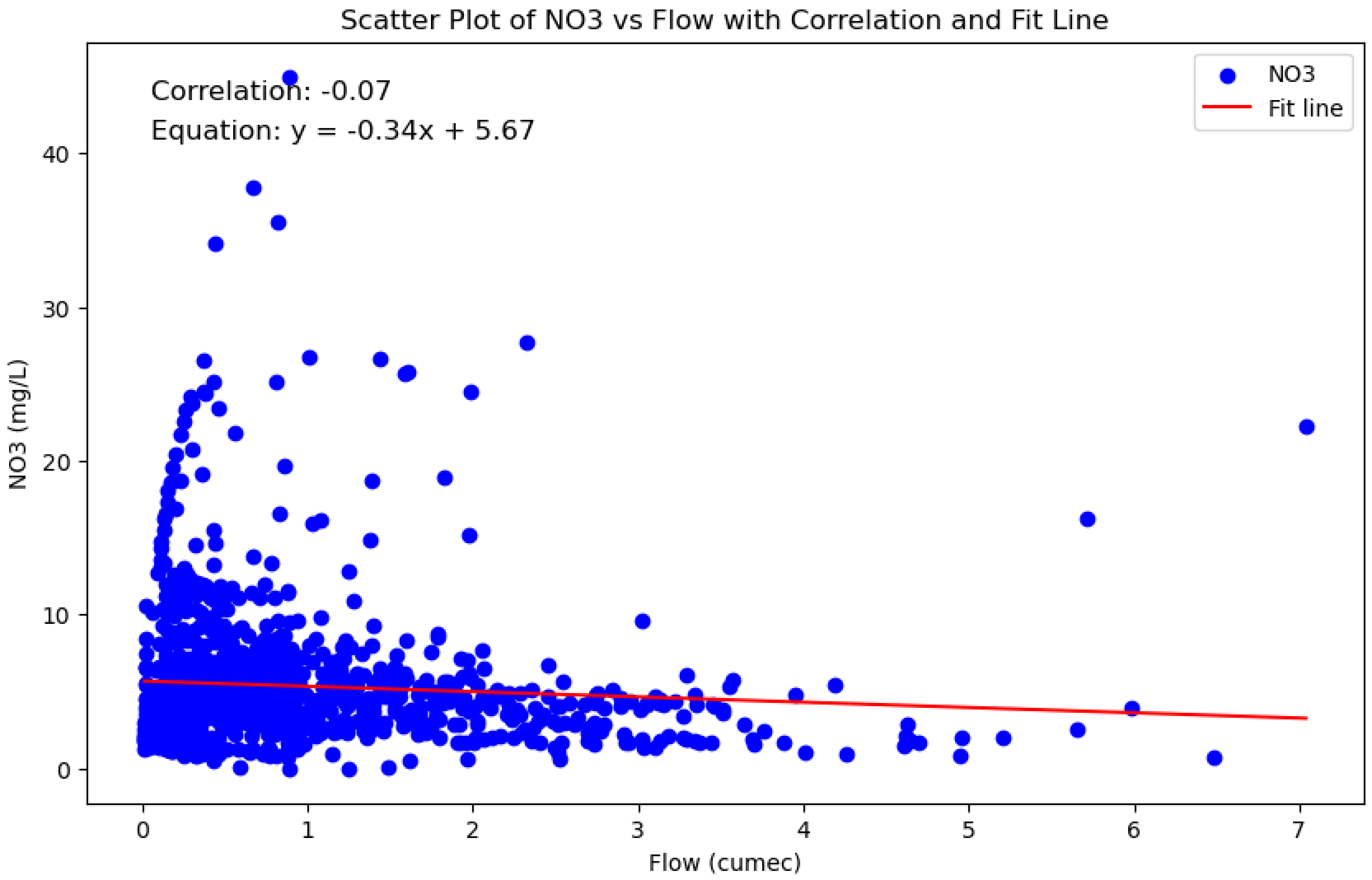

Time Series of DRP with Trend Line
y = -4.794e-06x + 3.626
R² = 0.001
DRP
Date
0.0
0.5
1.0
1.5
2.0
2.5
2012
2014
2016
2018
2020
2022

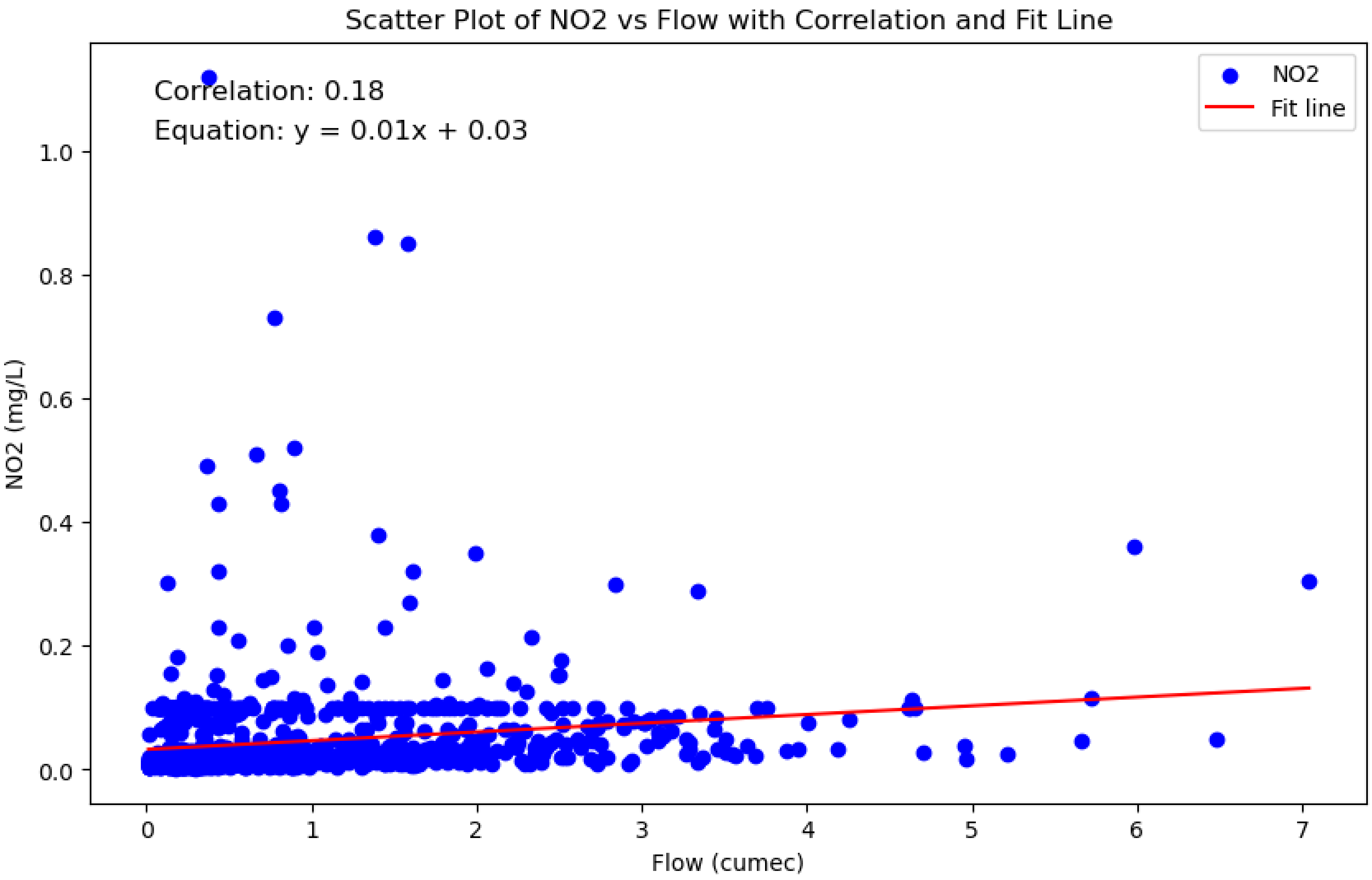

Time Series of TP with Trend Line
y = -1.793e-05x + 13.518
R² = 0.001
TP
Date
0
1
2
3
4
5
6
7
2012
2014
2016
2018
2020
2022


Time Series of TSS with Trend Line
y = 5.998e-03x + -4153.939
R² = 0.000
TSS
8000
7000
6000
5000
4000
3000
2000
1000
0
2012
2014
2016
2018
2020
2022
Date

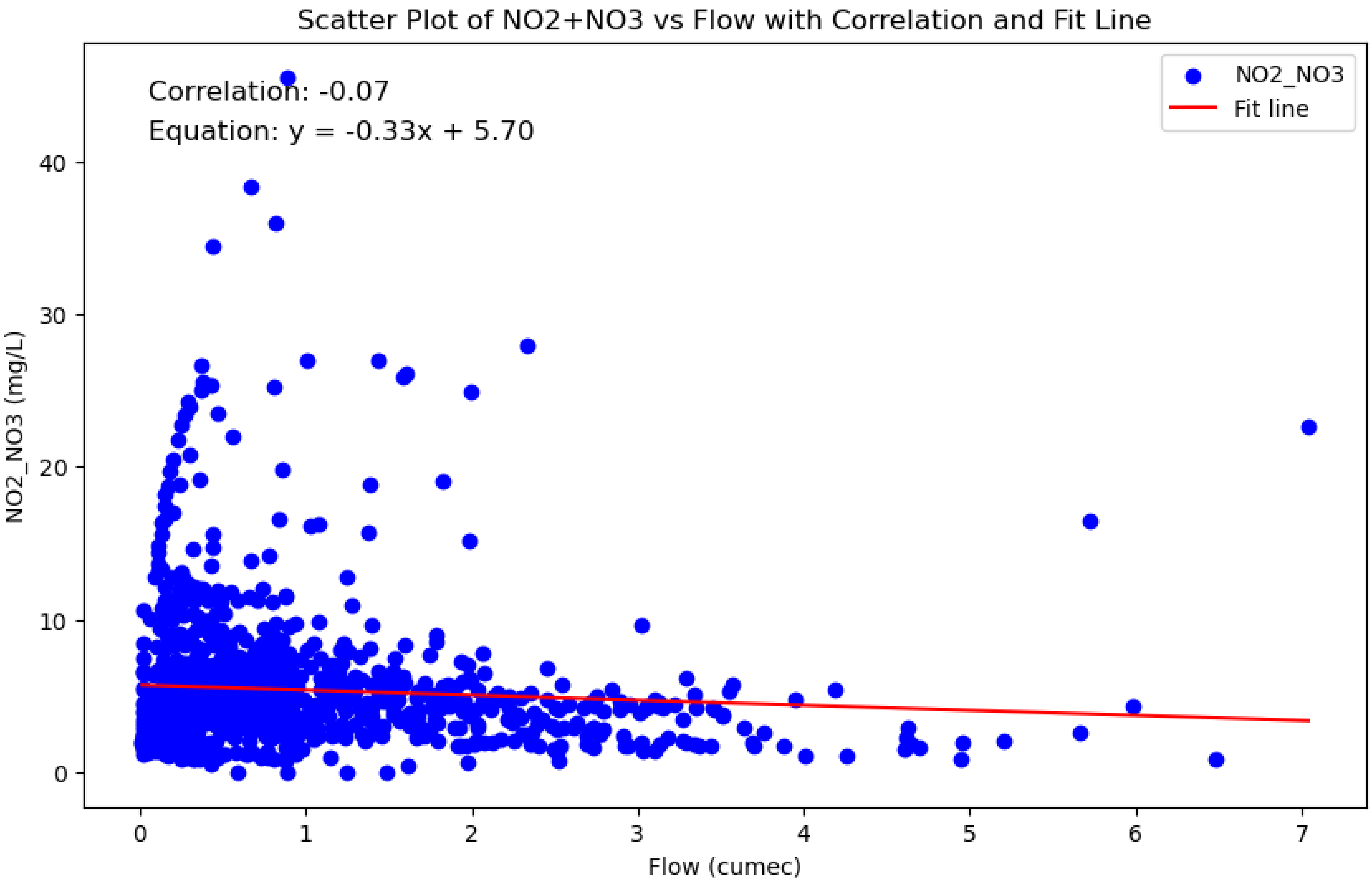
Scatter plot of WQ parameter and Flow in specific times

DatetimesWQ	TN[mg/L]	DatetimesF	Flow[cumec]
18/04/2011 9:08	4.26	18/04/2011 9:10	0.081
20/04/2011 9:15	7.85	20/04/2011 9:15	0.616
26/04/2011 9:26	5.78	26/04/2011 9:25	0.149
27/04/2011 12:38	5.36	27/04/2011 12:40	0.324
12/05/2011 10:16	4.19	12/05/2011 10:15	0.018
15/05/2011 12:21	12.39	15/05/2011 12:20	0.408
19/05/2011 10:51	14.92	19/05/2011 10:50	0.432
24/05/2011 9:13	10.76	24/05/2011 9:15	0.149
30/05/2011 9:34	12.25	30/05/2011 9:35	0.49
07/06/2011 9:45	12.96	07/06/2011 9:45	1.75
09/06/2011 9:25	11.22	09/06/2011 9:25	0.567
23/06/2011 11:06	11.91	23/06/2011 11:05	0.126
24/06/2011 11:32	8.94	24/06/2011 11:30	0.101
05/07/2011 9:39	4.82	05/07/2011 9:40	0.018
[illegible]	[illegible]	[illegible]	[illegible]

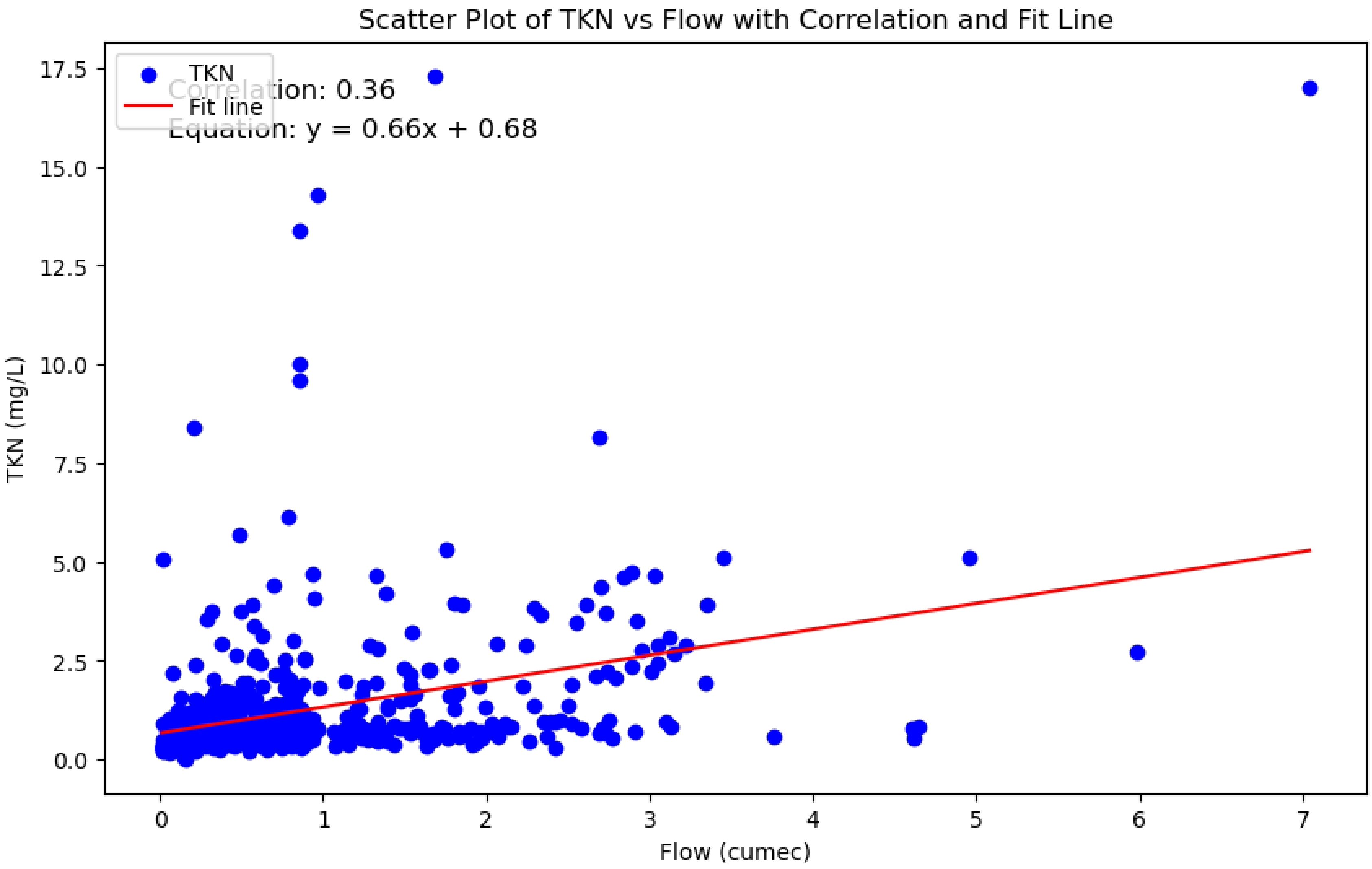

Scatter Plot of NO3 vs Flow with Correlation and Fit Line
Correlation: -0.07
Equation: y = -0.34x + 5.67
NO3
Fit line
NO3 (mg/L)
Flow (cumec)
0
10
20
30
40
0
1
2
3
4
5
6
7



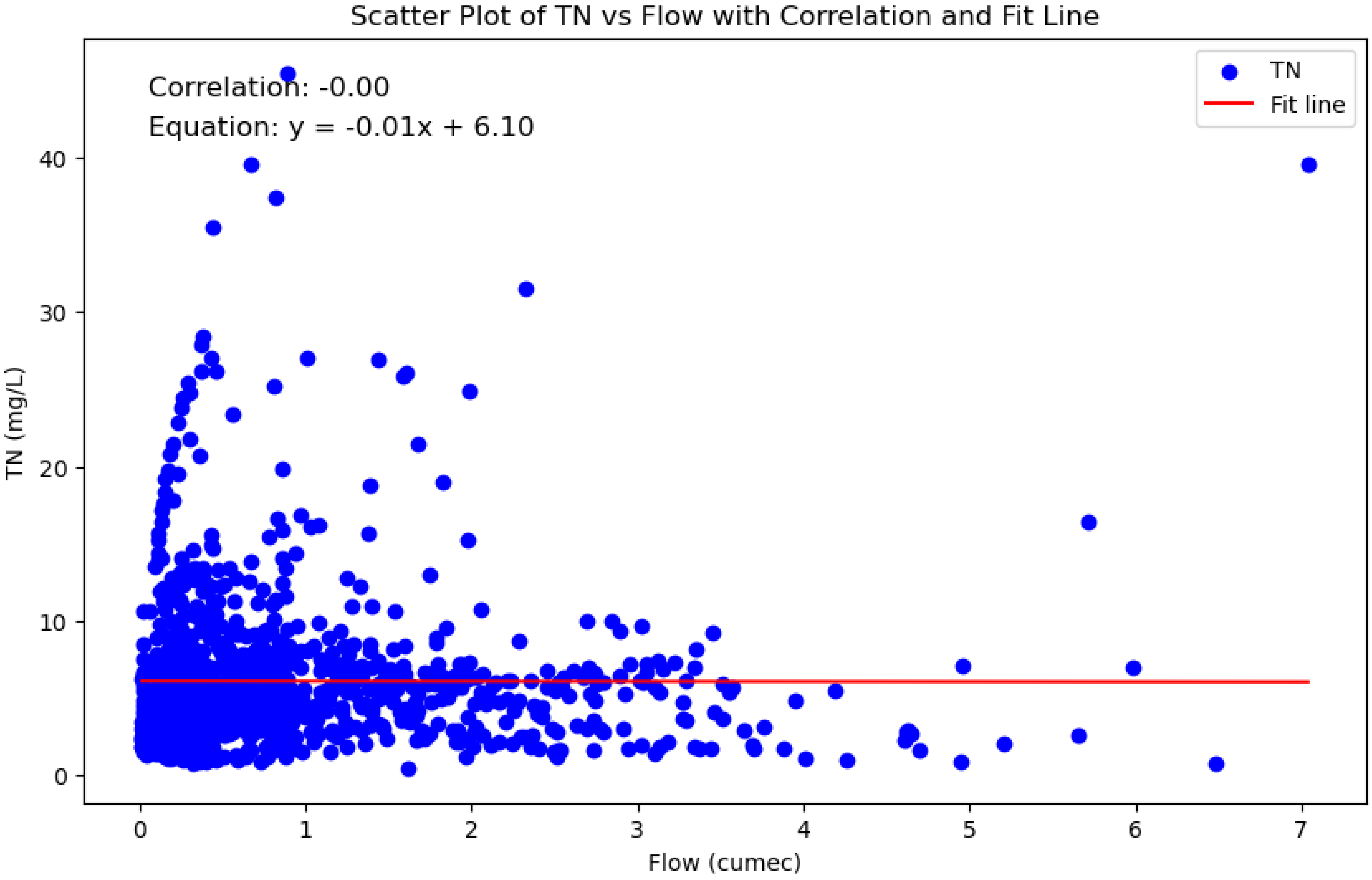
Scatter Plot of NO2 vs Flow with Correlation and Fit Line
Correlation: 0.18
Equation: y = 0.01x + 0.03
NO2
Fit line
NO2 (mg/L)
Flow (cumec)
0.0
0.2
0.4
0.6
0.8
1.0
0
1
2
3
4
5
6
7



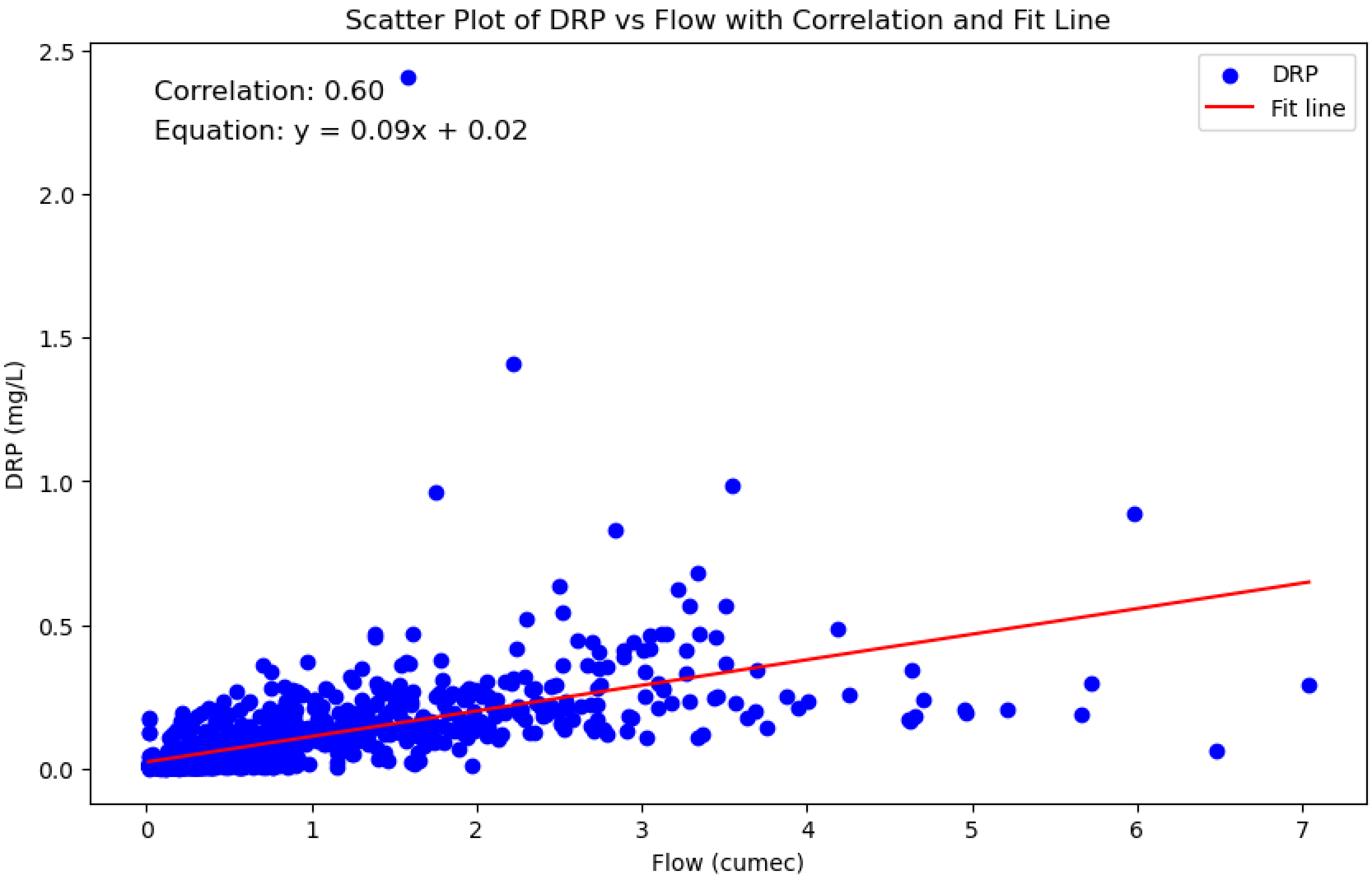
Scatter Plot of NO2+NO3 vs Flow with Correlation and Fit Line
Correlation: -0.07
Equation: y = -0.33x + 5.70
NO2_NO3
Fit line
NO2_NO3 (mg/L)
Flow (cumec)
0
10
20
30
40
0
1
2
3
4
5
6
7

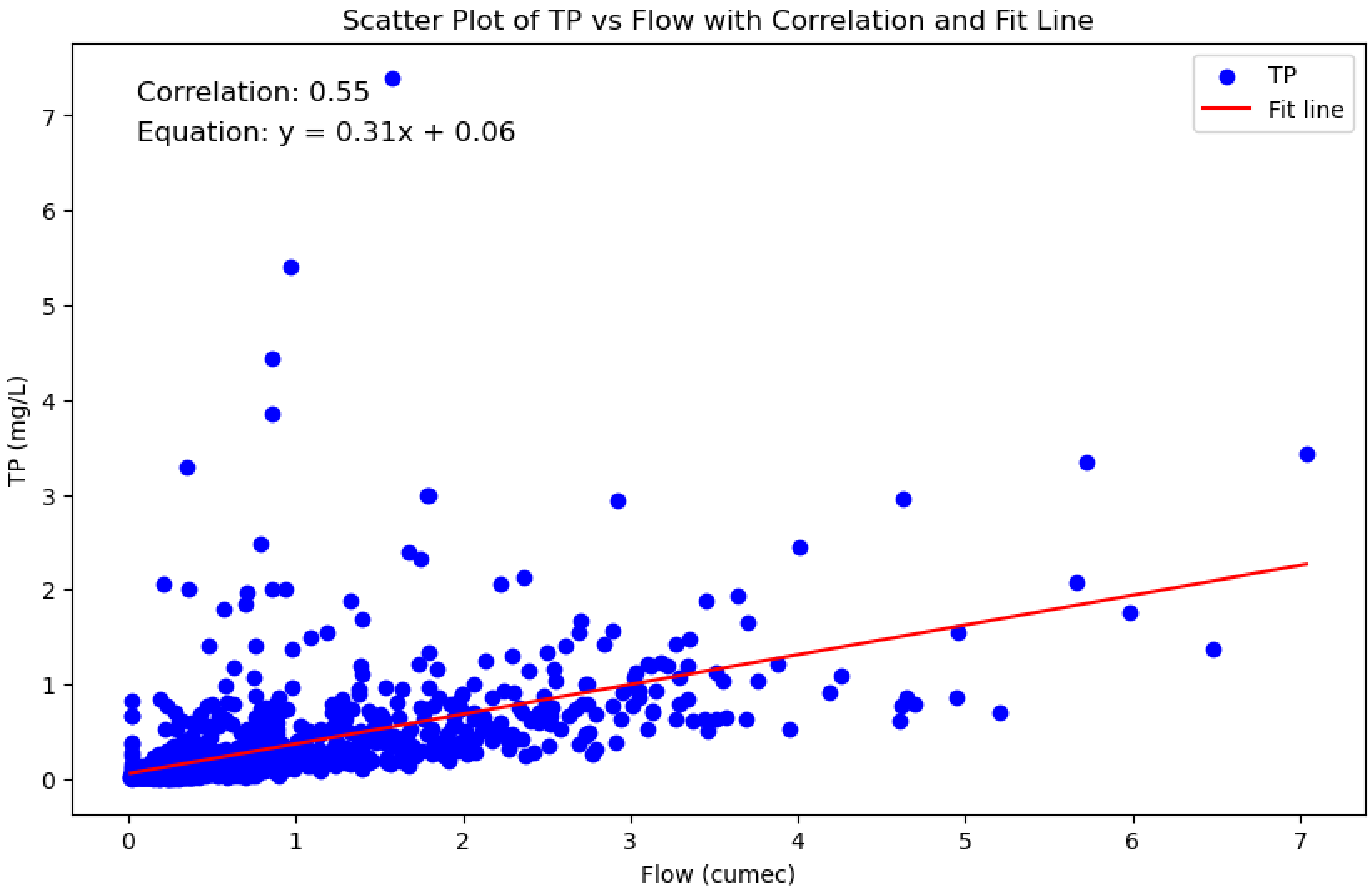


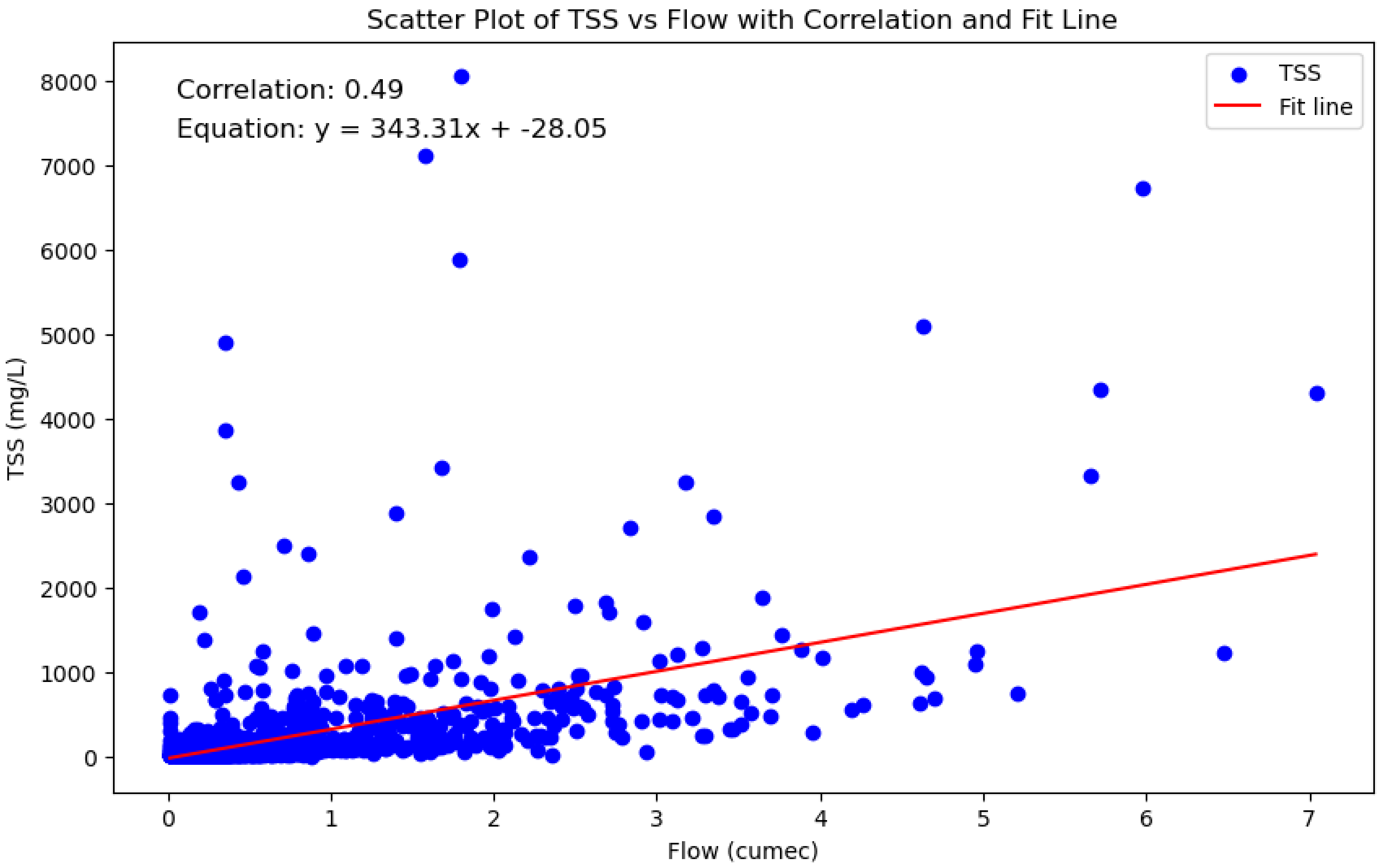
Scatter Plot of TKN vs Flow with Correlation and Fit Line
TKN
Fit line
Correlation: 0.36
Equation: y = 0.66x + 0.68
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
TKN (mg/L)
0
1
2
3
4
5
6
7
Flow (cumec)

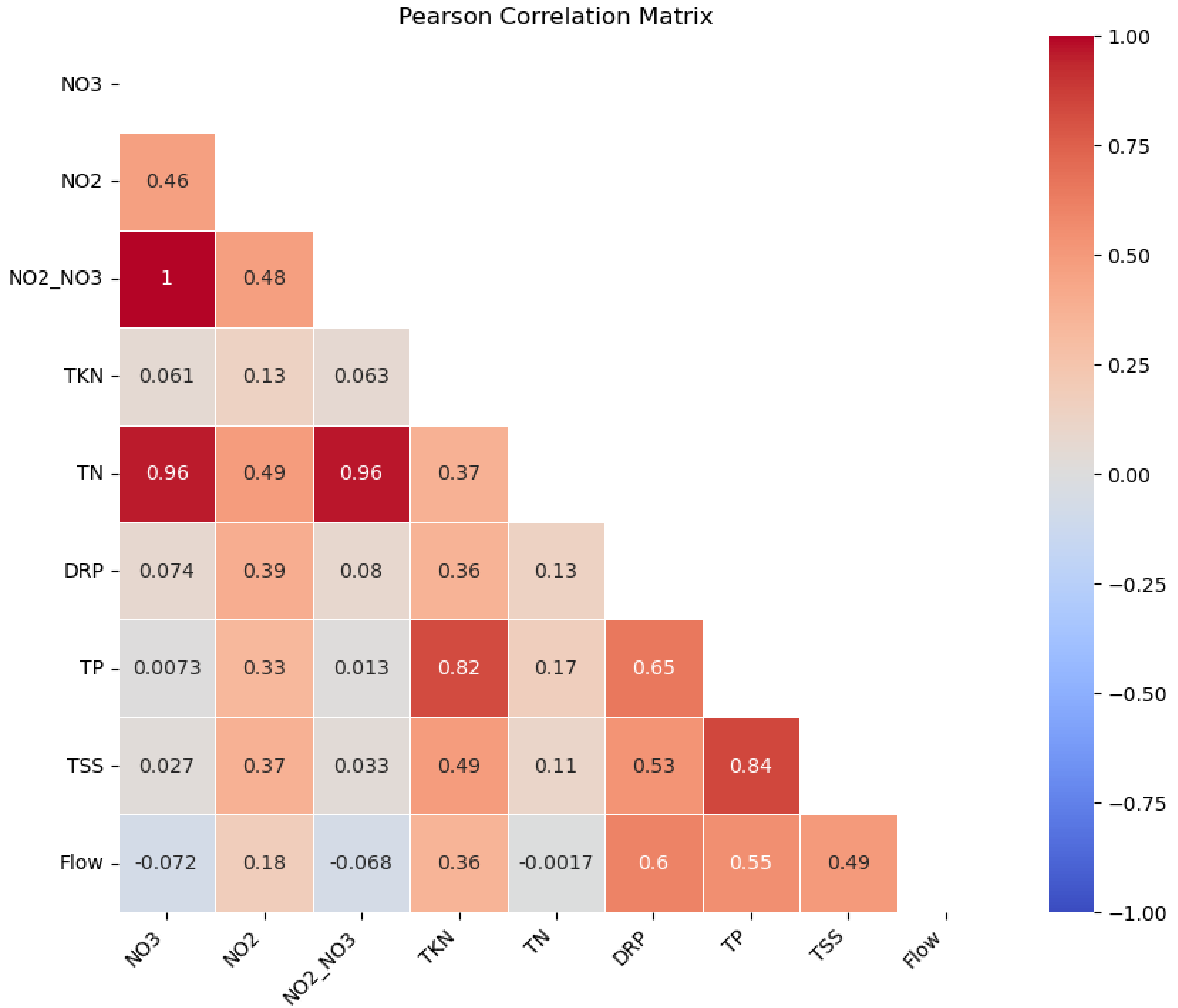


Scatter Plot of TN vs Flow with Correlation and Fit Line
Correlation: -0.00
Equation: y = -0.01x + 6.10
TN
Fit line
TN (mg/L)
Flow (cumec)
0
10
20
30
40
0
1
2
3
4
5
6
7

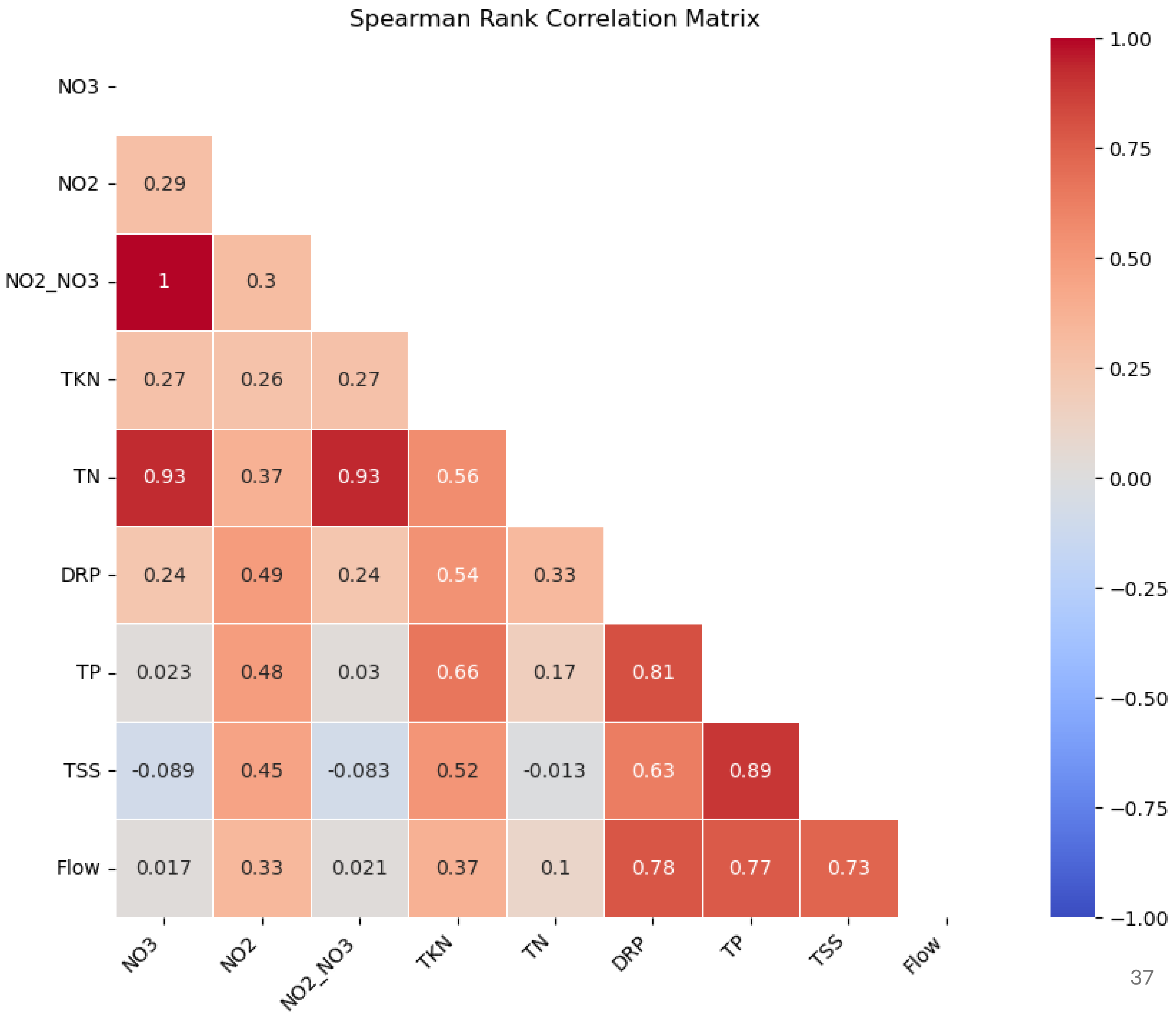

Scatter Plot of DRP vs Flow with Correlation and Fit Line
Correlation: 0.60
Equation: y = 0.09x + 0.02
DRP
Fit line
DRP (mg/L)
Flow (cumec)
0.0
0.5
1.0
1.5
2.0
2.5
0
1
2
3
4
5
6
7


Scatter Plot of TP vs Flow with Correlation and Fit Line
Correlation: 0.55
Equation: y = 0.31x + 0.06
TP
Fit line
TP (mg/L)
Flow (cumec)
0
1
2
3
4
5
6
7


Scatter Plot of TSS vs Flow with Correlation and Fit Line
Correlation: 0.49
Equation: y = 343.31x + -28.05
TSS
Fit line
TSS (mg/L)
Flow (cumec)
0
1000
2000
3000
4000
5000
6000
7000
8000
0
1
2
3
4
5
6
7


Pearson Correlation Matrix
NO3
NO2
NO2_NO3
TKN
TN
DRP
TP
TSS
Flow
0.46
1
0.48
0.061
0.13
0.063
0.96
0.49
0.96
0.37
0.074
0.39
0.08
0.36
0.13
0.0073
0.33
0.013
0.82
0.17
0.65
0.027
0.37
0.033
0.49
0.11
0.53
0.84
-0.072
0.18
-0.068
0.36
-0.0017
0.6
0.55
0.49
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00

Unlike the Pearson correlation, which measures linear relationships, Spearman's correlation measures the strength and direction of the association between two ranked variables. This method is particularly useful for identifying monotonic relationships.



Mass Loads

Mass loads are the product of stream flow (volume per time) and concentration (mass per volume). A mass load (Equation 1) is a calculation of the total mass of a substance, usually expressed in kilograms, that is transported past a particular point on a stream or river over a given time period, often annually (Cooke 2000). In this study, monthly and annual loads were calculated.

Equation 1

$$\text{Mass Load (kilograms)} = \sum_{i=1}^{n} \frac{c_i + c_{int}}{2} q_j$$

Where,

n = total number of samples
i = number of a particular sample
c_i = concentration measured at the day and time of the ith sample
q_j = inter-sample mean flow
c_{int} = linearly interpolated concentration value between samples

Flow-Weighted Mean Concentrations

In a flow-proportionate sampling program, an individual water sample does not characterize the event or low-flow period. To estimate the average concentration, each sample must be weighted to represent a particular portion of the hydrograph (Equation 2; Cooke 2000). Flow-weighted mean concentrations (FWMC) are concentrations that are weighted by streamflow over a given period – in this study, the length of the month or water year. This computation allows for comparisons between streams with different flows or the same stream at different times.

Equation 2

$$\text{Flow-Weighted Mean Concentration (mg/L)} = \frac{Mass\ Load\ (kg)}{Total\ Stream\ Flow\ Volume\ (L)} \times 1000$$

Mass Export Loads

The total mass export load or unit-area load (Equation 3) is an estimate of the amount of the constituent that is lost per hectare of watershed for a given time period. This computation allows for comparisons between streams with different flows or the same stream at different times.

Equation 3

$$\text{Mass Export (kg/ha)} = \frac{Mass\ Load\ (kg)}{Watershed\ Area\ (ha)}$$

Watershed area= 1430 Hectare

Stream Flashiness Index

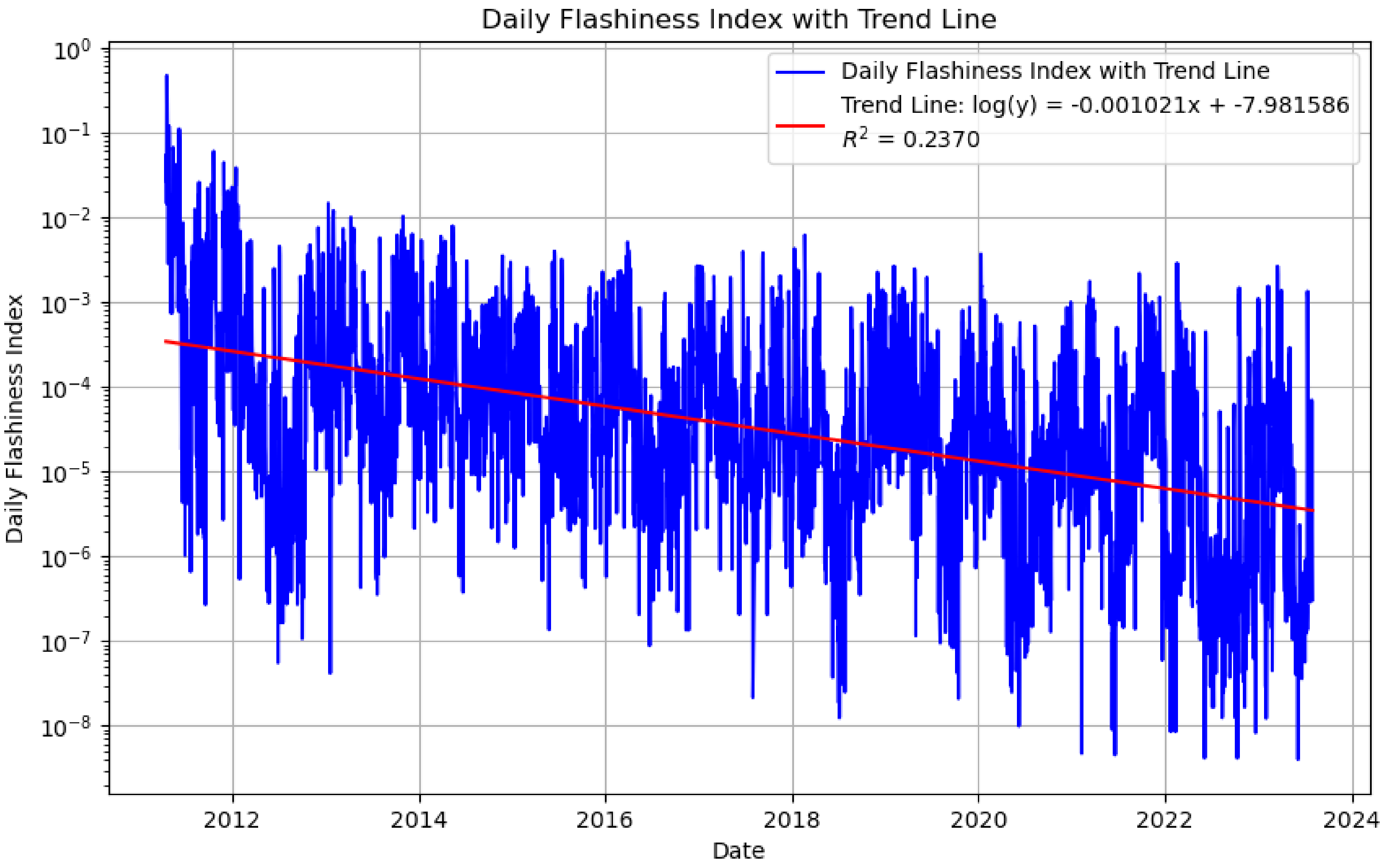
Stream flashiness reflects how streamflow responds during runoff events, and includes factors, such as the magnitude and frequency of floods and low-flow periods and the rates of change of flow during those periods (Baker *et al.* 2004). Streams characterized as 'flashy' respond rapidly to precipitation events. Changes in land use (*e.g.*, conversion of forestland to cropland), land management practices (*e.g.*, improvements in agricultural drainage, adoption of conservation tillage, or implementation of structural BMPs), or hydrologic regimes largely influence how a stream will respond to precipitation events (Baker *et al.* 2004). The Richards-Baker (R-B) Stream Flashiness Index measures a stream's flashiness based on mean daily flows, and is calculated by dividing the sum of the absolute values of day-to-day changes in mean flow by total discharge during that time interval (Equation 4). A large value indicates greater streamflow variability between days.

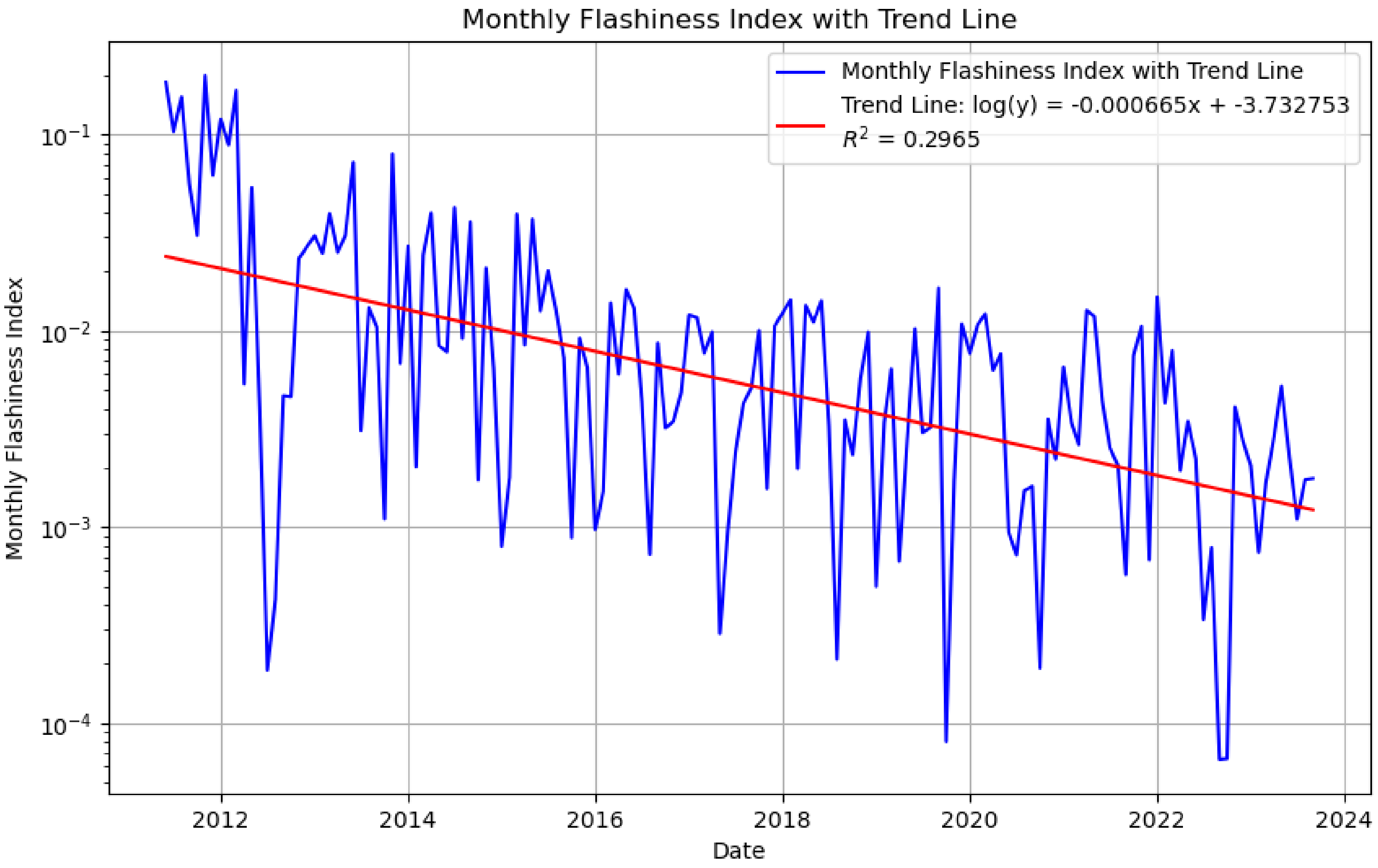
Equation 4

R-B Flashiness Index (dimensionless) $= \frac{\sum_{i=1}^{n}|q_i - q_{i-1}|}{\sum_{i=1}^{n} q_i}$

Where,

q_i = mean daily streamflow on a given day (in m^3/s)


Daily Flashiness Index with Trend Line
Daily Flashiness Index with Trend Line
Trend Line: log(y) = -0.001021x + -7.981586
R^2 = 0.2370
Daily Flashiness Index
Date
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
2012
2014
2016
2018
2020
2022
2024



Monthly Flashiness Index with Trend Line
Monthly Flashiness Index with Trend Line
Trend Line: log(y) = -0.000665x + -3.732753
R^2 = 0.2965
Monthly Flashiness Index
10^{-1}
10^{-2}
10^{-3}
10^{-4}
2012
2014
2016
2018
2020
2022
2024
Date

Year_Month	Total_Mass_Load_NO3_kg	FWMC_NO3_mg_L	Mass_Export_NO3_kg_ha	Total_Mass_Load_TKN_kg	FWMC_TKN_mg_L	Mass_Export_TKN_kg_ha	Total_Mass_Load_TN_kg	FWMC_TN_mg_L	Mass_Export_TN_kg_ha	Total_Mass_Load_DRP_kg	FWMC_DRP_mg_L	Mass_Export_DRP_kg_ha	Total_Mass_Load_TP_kg	FWMC_TP_mg_L	Mass_Export_TP_kg_ha	Total_Mass_Load_TSS_kg	FWMC_TSS_mg_L	Mass_Export_TSS_kg_ha	Total_MeasuredFlow_CMS	Total_BaseFlow_CMS	Total_StreamFlow_CMS	TotalWaterVolume_m3	TotalRunoff_mm	MonthlyFlashiness	MonthlyTotalPrecipitation_mm	AvgTemp_degC
2011-05	12570.29	0.016893	8.790409	3007.917	0.004042	2.103439	15689.04	0.021084	10.97136	483.7425	0.00065	0.338281	1088.274	0.001462	0.76103	498811.2	0.670331	348.819	5.047	0.349263	5.046174	435989.4	30.48877	0.184947	90.8	14.01129
2011-06	5623.881	0.005131	3.932784	2032.824	0.001855	1.421555	7765.314	0.007085	5.430289	175.5124	0.00016	0.122736	817.4179	0.000746	0.571621	444721.6	0.40578	310.9942	3.386	0.148801	3.389496	292852.4	20.47919	0.103433	90.4	17.7
2011-07	464.4289	0.00604	0.324775	77.57284	0.001009	0.054247	543.7243	0.007072	0.380227	3.408562	4.43E-05	0.002384	7.882293	0.000103	0.005512	3369.476	0.043824	2.356277	0.847	0.016169	0.849413	73389.29	5.132118	0.155282	42.6	21.48871
2011-08	784.6452	0.00151	0.548703	424.1285	0.000816	0.296593	1217.026	0.002343	0.851067	29.5132	5.68E-05	0.020639	81.66404	0.000157	0.057108	35119.86	0.067602	24.55934	1.846	0.051266	1.845448	159446.7	11.15012	0.055462	118.4	19.65484
2011-09	703.1465	0.00612	0.491711	83.13189	0.000724	0.058134	788.4962	0.006863	0.551396	6.86603	5.98E-05	0.004801	8.941009	7.78E-05	0.006252	760.9485	0.006623	0.532132	2.444	0.107157	2.441896	210979.8	14.75383	0.030579	116	16.48
2011-10	13862.8	0.00573	9.694266	3674.581	0.001519	2.569637	17627.97	0.007286	12.32725	431.0938	0.000178	0.301464	1106.07	0.000457	0.773475	331455.9	0.136996	231.7873	8.481	1.057232	8.475348	732270.1	51.2077	0.199898	98.8	10.9371
2011-11	10352.24	0.004016	7.239326	3198.127	0.001241	2.236453	13641.5	0.005291	9.539512	425.1458	0.000165	0.297305	854.4343	0.000331	0.597506	12993.4	0.00504	9.086296	6.045	0.71869	6.051513	522850.7	36.56299	0.061973	85.4	6.66
2011-12	13372.8	0.005385	9.351608	4468.671	0.0018	3.124945	17919.97	0.007217	12.53145	448.3768	0.000181	0.31355	1305.878	0.000526	0.913202	233699.4	0.094113	163.4262	11.993	2.338102	11.99031	1035963	72.44494	0.119599	71.9	0.641935
2012-01	14381.61	0.002493	10.05707	6942.97	0.001204	4.855224	21398.66	0.00371	14.9641	557.9846	9.67E-05	0.390199	1684.393	0.000292	1.177897				17.801	5.043547	17.7914	1537177	107.4949	0.088461	49.5	-1.6371
2012-02																			5.381	0.703469	5.380739	464895.9	32.5102	0.168286	23.1	-0.66207
2012-03	2890.6	0.003143	2.021398	875.6838	0.000952	0.612366	3774.813	0.004104	2.63973	20.1345	2.19E-05	0.01408	182.7576	0.000199	0.127802				5.367	0.622942	5.36563	463590.5	32.41891	0.005366	34.5	7.077419
2012-04	220.8922	0.002124	0.15447	22.87127	0.00022	0.015994	244.575	0.002351	0.171031	0.309869	2.98E-06	0.000217	0.700894	6.74E-06	0.00049	106.9785	0.001028	0.07481	1.128	0.036109	1.128961	97542.22	6.821134	0.053594	37.6	5.896667
2012-05	117.762	0.002226	0.082351	14.9888	0.000283	0.010482	133.4003	0.002522	0.093287	0.152386	2.88E-06	0.000107	0.449664	8.50E-06	0.000314	87.43466	0.001653	0.061143	0.844	0.016741	0.842526	72794.25	5.090507	0.004059	37.29	14.60806
2012-06	1198.526	0.006508	0.83813	283.806	0.001541	0.198466	1489.132	0.008086	1.041351	4.453508	2.42E-05	0.003114	42.55239	0.000231	0.029757	110.9974	0.000603	0.077621	0.839	0.015201	0.838326	72431.37	5.065131	0.000186	63.9	18.61333
2012-07	1695.456	0.003563	1.185634	252.3193	0.00053	0.176447	1954.414	0.004107	1.366723	21.40651	4.50E-05	0.01497	57.41813	0.000121	0.040153	82.43594	0.000173	0.057648	0.91	0.016453	0.909574	78587.19	5.495607	0.000429	83.6	21.09194
2012-08	74.77702	0.002091	0.052292	10.3278	0.000289	0.007222	85.77327	0.002398	0.059981	0.485047	1.36E-05	0.000339	0.718346	2.01E-05	0.000502	106.7472	0.002985	0.074648	0.52	0.007677	0.519587	44892.31	3.139323	0.004664	37.6	19.87097
2012-09	180.0721	0.004095	0.125925	11.33019	0.000258	0.007923	191.9731	0.004366	0.134247	0.730822	1.66E-05	0.000511	0.776091	1.76E-05	0.000543	60.30327	0.001371	0.04217	0.872	0.015624	0.870961	75251.02	5.262309	0.004606	93.8	15.71667
2012-10	7195.431	0.018369	5.03177	531.6223	0.001357	0.371764	7743.292	0.019768	5.414889	52.93722	0.000135	0.037019	15.77533	4.03E-05	0.011032	30245.76	0.077214	21.15088	2.903	0.12319	2.902565	250781.6	17.53718	0.023326	102.6	10.47097
2012-11	2839.892	0.010145	1.985939	469.2494	0.001676	0.328146	3312.962	0.011835	2.316757	8.704984	3.11E-05	0.006087	11.6773	4.17E-05	0.008166	1438.406	0.005139	1.005878	5.1	0.470668	5.101239	440747.1	30.82147	0.026652	32.3	3.635
2012-12	10739.84	0.009463	7.510377	1221.161	0.001076	0.853958	11977.77	0.010554	8.376062	65.16968	5.74E-05	0.045573	115.9656	0.000102	0.081095	104216.9	0.091825	72.87893	8.32	1.22367	8.317961	718671.8	50.25677	0.030452	56.2	1.3
2013-01	7832.722	0.00431	5.477428	974.3485	0.000536	0.681363	8880.092	0.004887	6.209854	163.0018	8.97E-05	0.113987	319.2563	0.000176	0.223256	229843.6	0.126486	160.7298	10.968	1.524105	10.95926	946880.1	66.21539	0.024842	84.8	-2.0871
2013-02	2466.651	0.006409	1.724931	180.3095	0.000468	0.126091	2652.416	0.006891	1.854836	7.701644	2.00E-05	0.005386	9.458254	2.46E-05	0.006614	1564.04	0.004064	1.093734	5.807	0.742652	5.806239	501659.1	35.08105	0.039624	53.9	-4.40536
2013-03	3918.426	0.004677	2.740158	479.1108	0.000572	0.335043	4407.902	0.005262	3.082449	57.18626	6.83E-05	0.03999	72.79753	8.69E-05	0.050907	74881.83	0.089386	52.36492	9.56	1.647128	9.552196	825309.7	57.71397	0.025108	17	-0.51774
2013-04	6061.659	0.004872	4.238923	668.1783	0.000537	0.467258	6827.869	0.005488	4.774734	68.66865	5.52E-05	0.04802	251.131	0.000202	0.175616	193578.6	0.15558	135.3697	13.373	2.599244	13.36424	1154670	80.74617	0.030541	123.4	5.848333
2013-05	4558.44	0.013043	3.187721	318.4661	0.000911	0.222704	4973.919	0.014232	3.478265	6.149834	1.76E-05	0.004301	33.69391	9.64E-05	0.023562	33101.1	0.094714	23.14762	3.512	0.278598	3.514196	303626.5	21.23262	0.072228	71	13.70323
2013-06	1696.607	0.005475	1.186438	239.8952	0.000774	0.167759	1946.688	0.006282	1.36132	2.260535	7.29E-06	0.001581	8.587596	2.77E-05	0.006005	3698.429	0.011934	2.586314	2.946	0.192644	2.947013	254621.9	17.80573	0.003097	62	17.225
2013-07	147.2	0.001021	0.102937	108.7028	0.000754	0.076016	198.8515	0.001379	0.139057	0.31868	2.21E-06	0.000223	15.06303	0.000104	0.010534	9308.943	0.06455	6.509751	1.128	0.028417	1.125139	97212.02	6.798043	0.013116	122	20.25161
2013-08	1016.037	0.003522	0.710515	254.793	0.000883	0.178177	1303.486	0.004519	0.911528	9.751678	3.38E-05	0.006819	67.19483	0.000233	0.046989	63342.83	0.219582	44.29569	2.682	0.115046	2.681839	231710.9	16.20356	0.010389	59	18.34516
2013-09	2103.375	0.004707	1.470892	450.2542	0.001007	0.314863	2590.731	0.005797	1.8117	22.67007	5.07E-05	0.015853	47.74138	0.000107	0.033386	23571.96	0.052745	16.48389	2.759	0.125396	2.759909	238456.1	16.67525	0.001098	78	15.66333
2013-10	7110.96	0.004838	4.972699	695.3131	0.000473	0.486233	8030.348	0.005464	5.615628	119.8649	8.16E-05	0.083822	363.1598	0.000247	0.253958	293059.7	0.199391	204.9369	16.401	3.528081	16.39299	1416354	99.04577	0.079588	217	11.28387
2013-11	5676.375	0.005914	3.969493	642.0248	0.000669	0.448968	6330.885	0.006596	4.427192	60.15231	6.27E-05	0.042065	120.7331	0.000126	0.084429	102137.7	0.106414	71.42494	14.491	4.192713	14.4902	1251953	87.54918	0.00683	103.5	2.566667
2013-12	6831.673	0.00434	4.777394	890.2288	0.000566	0.622538	7817.948	0.004967	5.467096	140.9635	8.96E-05	0.098576	220.8487	0.00014	0.15444	83796.68	0.053237	58.59908	9.795	1.903772	9.790639	845911.2	59.15463	0.02696	101.6	-3.7
2014-01	9145.051	0.002138	6.395141	985.883	0.000231	0.689429	10174.31	0.002379	7.114904	178.1162	4.16E-05	0.124557	258.9586	6.05E-05	0.18109	69274.71	0.016197	48.44386	9.4	1.619497	9.396465	811854.6	56.77305	0.002028	50.6	-8.30645

Estimated missing values using linear interpolation and multiple imputation based on the other available data points.

All_MonthlyInterpolatedData.csv
Timeline: 2011-05 to 2021-12

Year_Month	Total_Mass_Load_NO3_kg	FWMC_NO3_mg_L	Mass_Export_NO3_kg_ha	Total_Mass_Load_TKN_kg	FWMC_TKN_mg_L	Mass_Export_TKN_kg_ha	Total_Mass_Load_TN_kg	FWMC_TN_mg_L	Mass_Export_TN_kg_ha	Total_Mass_Load_DRP_kg	FWMC_DRP_mg_L	Mass_Export_DRP_kg_ha	Total_Mass_Load_TP_kg	FWMC_TP_mg_L	Mass_Export_TP_kg_ha	Total_Mass_Load_TSS_kg	FWMC_TSS_mg_L	Mass_Export_TSS_kg_ha	Total_MeasuredFlow_CMS	Total_BaseFlow_CMS	Total_StreamFlow_CMS	TotalWaterVolume_m3	TotalRunoff_mm	MonthlyFlashiness	MonthlyTotalPrecipitation_mm	AvgTemp_degC
2011-05	12570.29	0.016893	8.790409	3007.917	0.004042	2.103439	15689.04	0.021084	10.97136	483.7425	0.00065	0.338281	1088.274	0.001462	0.76103	498811.2	0.670331	348.819	5.047	0.349263	5.046174	435989.4	30.48877	0.184947	90.8	14.01129
2011-06	5623.881	0.005131	3.932784	2032.824	0.001855	1.421555	7765.314	0.007085	5.430289	175.5124	0.00016	0.122736	817.4179	0.000746	0.571621	444721.6	0.40578	310.9942	3.386	0.148801	3.389496	292852.4	20.47919	0.103433	90.4	17.7
2011-07	464.4289	0.00604	0.324775	77.57284	0.001009	0.054247	543.7243	0.007072	0.380227	3.408562	4.43E-05	0.002384	7.882293	0.000103	0.005512	3369.476	0.043824	2.356277	0.847	0.016169	0.849413	73389.29	5.132118	0.155282	42.6	21.48871
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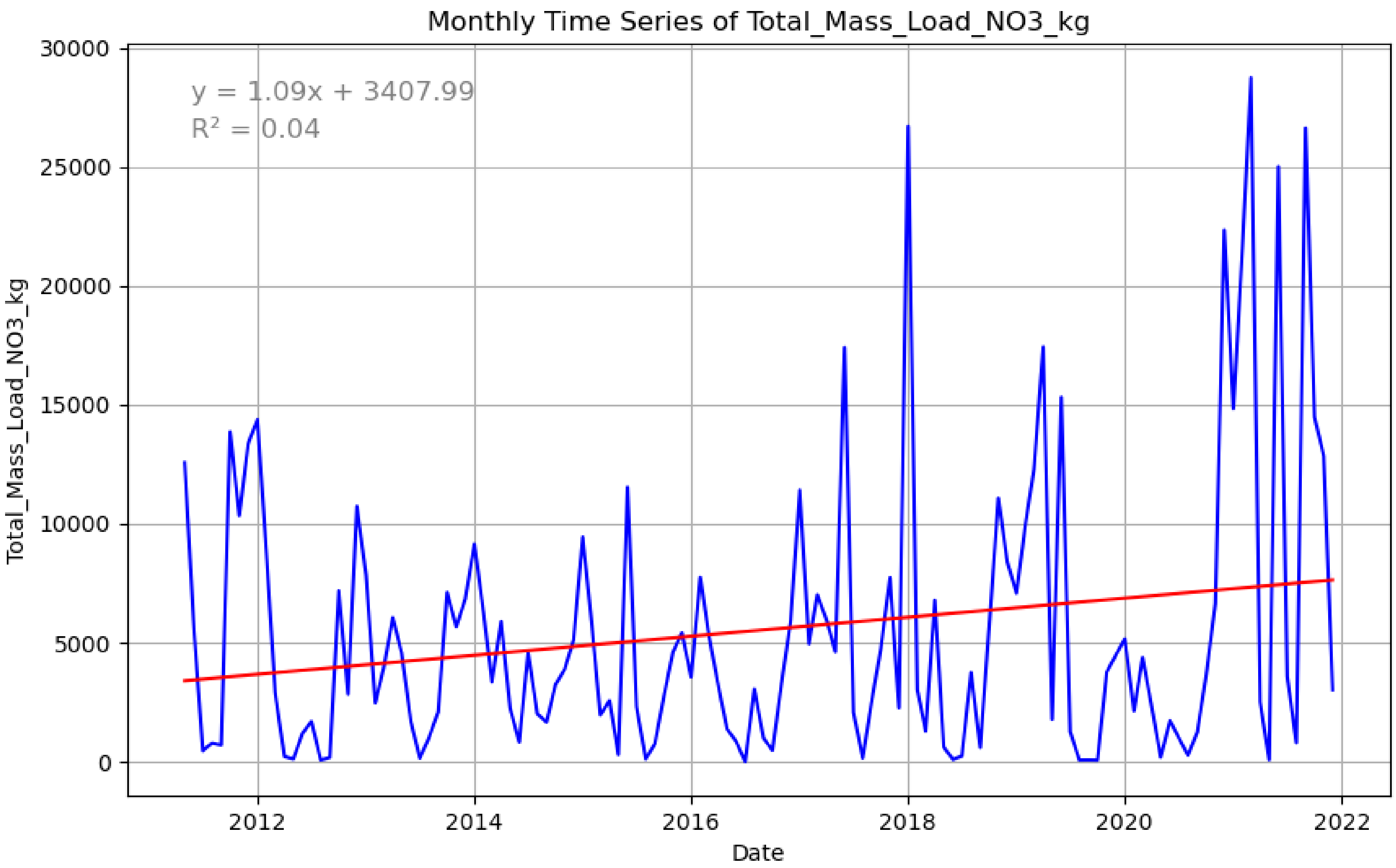
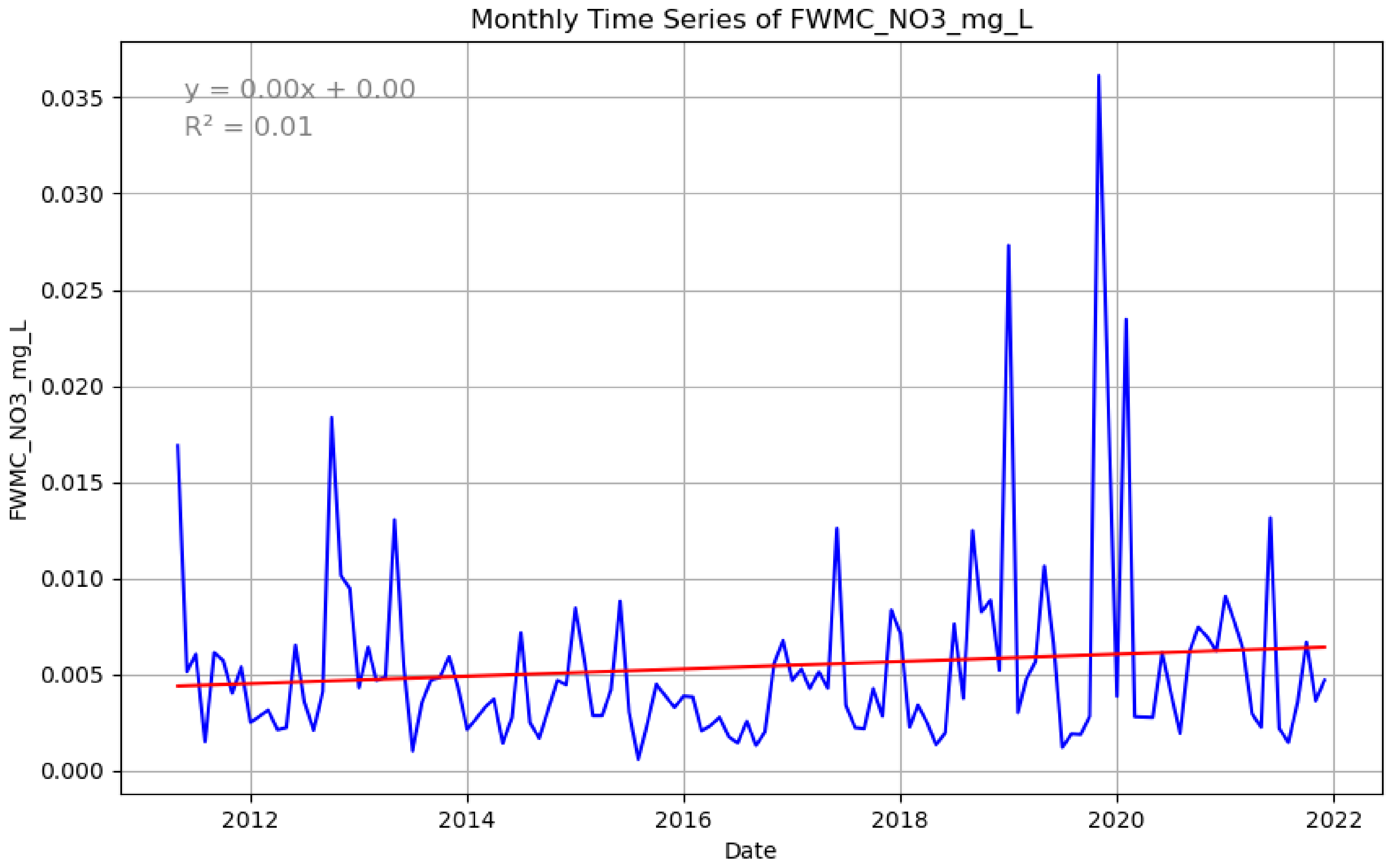
2011-09	703.1465	0.00612	0.491711	83.13189	0.000724	0.058134	788.4962	0.006863	0.551396	6.86603	5.98E-05	0.004801	8.941009	7.78E-05	0.006252	760.9485	0.006623	0.532132	2.444	0.107157	2.441896	210979.8	14.75383	0.030579	116	16.48
2011-10	13862.8	0.00573	9.694266	3674.581	0.001519	2.569637	17627.97	0.007286	12.32725	431.0938	0.000178	0.301464	1106.07	0.000457	0.773475	331455.9	0.136996	231.7873	8.481	1.057232	8.475348	732270.1	51.2077	0.199898	98.8	10.9371
2011-11	10352.24	0.004016	7.239326	3198.127	0.001241	2.236453	13641.5	0.005291	9.539512	425.1458	0.000165	0.297305	854.4343	0.000331	0.597506	12993.4	0.00504	9.086296	6.045	0.71869	6.051513	522850.7	36.56299	0.061973	85.4	6.66
2011-12	13372.8	0.005385	9.351608	4468.671	0.0018	3.124945	17919.97	0.007217	12.53145	448.3768	0.000181	0.31355	1305.878	0.000526	0.913202	233699.4	0.094113	163.4262	11.993	2.338102	11.99031	1035963	72.44494	0.119599	71.9	0.641935
2012-01	14381.61	0.002493	10.05707	6942.97	0.001204	4.855224	21398.66	0.00371	14.9641	557.9846	9.67E-05	0.390199	1684.393	0.000292	1.177897	205639.5	0.407174	143.8039	17.801	5.043547	17.7914	1537177	107.4949	0.088461	49.5	-1.6371
2012-02	8636.107	0.002818	6.039235	869.438	0.000853	0.607999	12586.74	0.003907	8.801915	289.0595	5.93E-05	0.20214	933.5752	0.000245	0.65285	205639.4	0.137157	143.8038	5.381	0.703469	5.380739	464895.9	32.5102	0.168286	23.1	-0.66207
2012-03	2890.6	0.003143	2.021398	875.6838	0.000952	0.612366	3774.813	0.004104	2.63973	20.1345	2.19E-05	0.01408	182.7576	0.000199	0.127802	205641.4	0.137188	143.8052	5.367	0.622942	5.36563	463590.5	32.41891	0.005366	34.5	7.077419
2012-04	220.8922	0.002124	0.15447	22.87127	0.00022	0.015994	244.575	0.002351	0.171031	0.309869	2.98E-06	0.000217	0.700894	6.74E-06	0.00049	106.9785	0.001028	0.07481	1.128	0.036109	1.128961	97542.22	6.821134	0.053594	37.6	5.896667
2012-05	117.762	0.002226	0.082351	14.9888	0.000283	0.010482	133.4003	0.002522	0.093287	0.152386	2.88E-06	0.000107	0.449664	8.50E-06	0.000314	87.43466	0.001653	0.061143	0.844	0.016741	0.842526	72794.25	5.090507	0.004059	37.29	14.60806
2012-06	1198.526	0.006508	0.83813	283.806	0.001541	0.198466	1489.132	0.008086	1.041351	4.453508	2.42E-05	0.003114	42.55239	0.000231	0.029757	110.9974	0.000603	0.077621	0.839	0.015201	0.838326	72431.37	5.065131	0.000186	63.9	18.61333
2012-07	1695.456	0.003563	1.185634	252.3193	0.00053	0.176447	1954.414	0.004107	1.366723	21.40651	4.50E-05	0.01497	57.41813	0.000121	0.040153	82.43594	0.000173	0.057648	0.91	0.016453	0.909574	78587.19	5.495607	0.000429	83.6	21.09194
2012-08	74.77702	0.002091	0.052292	10.3278	0.000289	0.007222	85.77327	0.002398	0.059981	0.485047	1.36E-05	0.000339	0.718346	2.01E-05	0.000502	106.7472	0.002985	0.074648	0.52	0.007677	0.519587	44892.31	3.139323	0.004664	37.6	19.87097
2012-09	180.0721	0.004095	0.125925	11.33019	0.000258	0.007923	191.9731	0.004366	0.134247	0.730822	1.66E-05	0.000511	0.776091	1.76E-05	0.000543	60.30327	0.001371	0.04217	0.872	0.015624	0.870961	75251.02	5.262309	0.004606	93.8	15.71667
2012-10	7195.431	0.018369	5.03177	531.6223	0.001357	0.371764	7743.292	0.019768	5.414889	52.93722	0.000135	0.037019	15.77533	4.03E-05	0.011032	30245.76	0.077214	21.15088	2.903	0.12319	2.902565	250781.6	17.53718	0.023326	102.6	10.47097
2012-11	2839.892	0.010145	1.985939	469.2494	0.001676	0.328146	3312.962	0.011835	2.316757	8.704984	3.11E-05	0.006087	11.6773	4.17E-05	0.008166	1438.406	0.005139	1.005878	5.1	0.470668	5.101239	440747.1	30.82147	0.026652	32.3	3.635
2012-12	10739.84	0.009463	7.510377	1221.161	0.001076	0.853958	11977.77	0.010554	8.376062	65.16968	5.74E-05	0.045573	115.9656	0.000102	0.081095	104216.9	0.091825	72.87893	8.32	1.22367	8.317961	718671.8	50.25677	0.030452	56.2	1.3
2013-01	7832.722	0.00431	5.477428	974.3485	0.000536	0.681363	8880.092	0.004887	6.209854	163.0018	8.97E-05	0.113987	319.2563	0.000176	0.223256	229843.6	0.126486	160.7298	10.968	1.524105	10.95926	946880.1	66.21539	0.024842	84.8	-2.0871
2013-02	2466.651	0.006409	1.724931	180.3095	0.000468	0.126091	2652.416	0.006891	1.854836	7.701644	2.00E-05	0.005386	9.458254	2.46E-05	0.006614	1564.04	0.004064	1.093734	5.807	0.742652	5.806239	501659.1	35.08105	0.039624	53.9	-4.40536
2013-03	3918.426	0.004677	2.740158	479.1108	0.000572	0.335043	4407.902	0.005262	3.082449	57.18626	6.83E-05	0.03999	72.79753	8.69E-05	0.050907	74881.83	0.089386	52.36492	9.56	1.647128	9.552196	825309.7	57.71397	0.025108	17	-0.51774
2013-04	6061.659	0.004872	4.238923	668.1783	0.000537	0.467258	6827.869	0.005488	4.774734	68.66865	5.52E-05	0.04802	251.131	0.000202	0.175616	193578.6	0.15558	135.3697	13.373	2.599244	13.36424	1154670	80.74617	0.030541	123.4	5.848333
2013-05	4558.44	0.013043	3.187721	318.4661	0.000911	0.222704	4973.919	0.014232	3.478265	6.149834	1.76E-05	0.004301	33.69391	9.64E-05	0.023562	33101.1	0.094714	23.14762	3.512	0.278598	3.514196	303626.5	21.23262	0.072228	71	13.70323
2013-06	1696.607	0.005475	1.186438	239.8952	0.000774	0.167759	1946.688	0.006282	1.36132	2.260535	7.29E-06	0.001581	8.587596	2.77E-05	0.006005	3698.429	0.011934	2.586314	2.946	0.192644	2.947013	254621.9	17.80573	0.003097	62	17.225
2013-07	147.2	0.001021	0.102937	108.7028	0.000754	0.076016	198.8515	0.001379	0.139057	0.31868	2.21E-06	0.000223	15.06303	0.000104	0.010534	9308.943	0.06455	6.509751	1.128	0.028417	1.125139	97212.02	6.798043	0.013116	122	20.25161
2013-08	1016.037	0.003522	0.710515	254.793	0.000883	0.178177	1303.486	0.004519	0.911528	9.751678	3.38E-05	0.006819	67.19483	0.000233	0.046989	63342.83	0.219582	44.29569	2.682	0.115046	2.681839	231710.9	16.20356	0.010389	59	18.34516
2013-09	2103.375	0.004707	1.470892	450.2542	0.001007	0.314863	2590.731	0.005797	1.8117	22.67007	5.07E-05	0.015853	47.74138	0.000107	0.033386	23571.96	0.052745	16.48389	2.759	0.125396	2.759909	238456.1	16.67525	0.001098	78	15.66333
2013-10	7110.96	0.004838	4.972699	695.3131	0.000473	0.486233	8030.348	0.005464	5.615628	119.8649	8.16E-05	0.083822	363.1598	0.000247	0.253958	293059.7	0.199391	204.9369	16.401	3.528081	16.39299	1416354	99.04577	0.079588	217	11.28387
2013-11	5676.375	0.005914	3.969493	642.0248	0.000669	0.448968	6330.885	0.006596	4.427192	60.15231	6.27E-05	0.042065	120.7331	0.000126	0.084429	102137.7	0.106414	71.42494	14.491	4.192713	14.4902	1251953	87.54918	0.00683	103.5	2.566667
2013-12	6831.673	0.00434	4.777394	890.2288	0.000566	0.622538	7817.948	0.004967	5.467096	140.9635	8.96E-05	0.098576	220.8487	0.00014	0.15444	83796.68	0.053237	58.59908	9.795	1.903772	9.790639	845911.2	59.15463	0.02696	101.6	-3.7
2014-01	9145.051	0.002138	6.395141	985.883	0.000231	0.689429	10174.31	0.002379	7.114904	178.1162	4.16E-05	0.124557	258.9586	6.05E-05	0.18109	69274.71	0.016197	48.44386	9.4	1.619497	9.396465	811854.6	56.77305	0.002028	50.6	-8.30645

Mass Loads

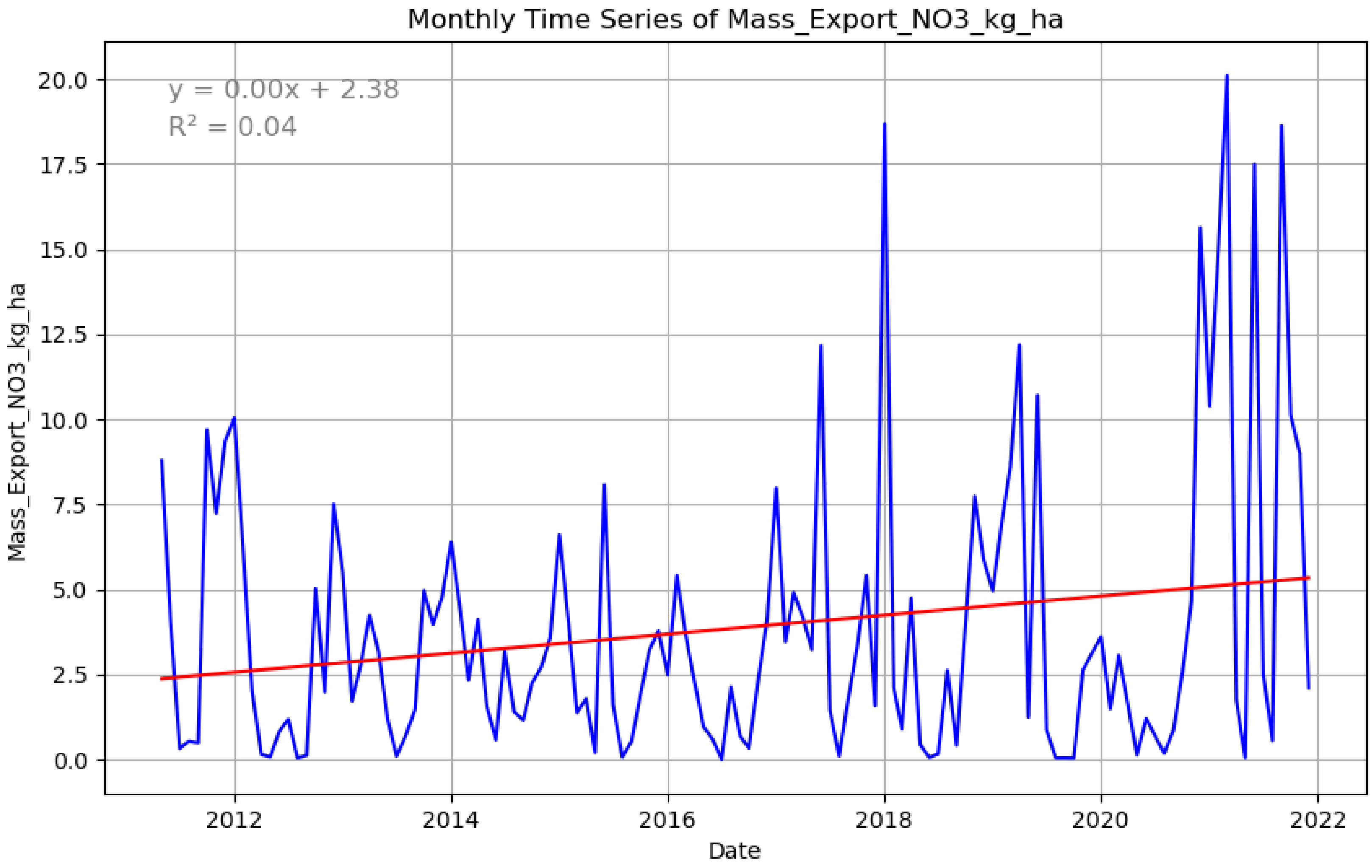


Monthly Time Series of Total_Mass_Load_NO3_kg
y = 1.09x + 3407.99
R² = 0.04
Total_Mass_Load_NO3_kg
0
5000
10000
15000
20000
25000
30000
2012
2014
2016
2018
2020
2022
Date

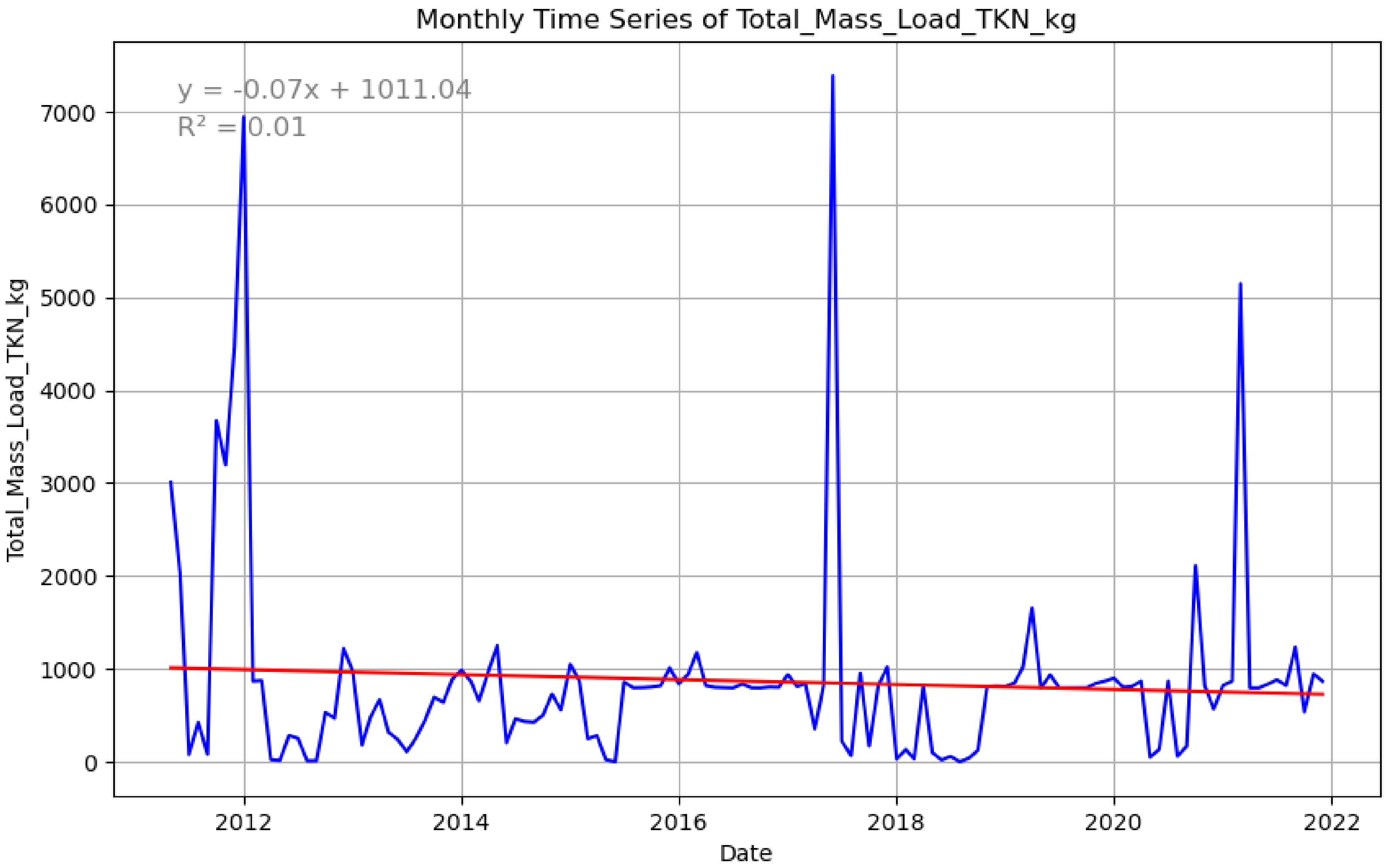
Flow-Weighted Mean Concentration



Mass Export Loads

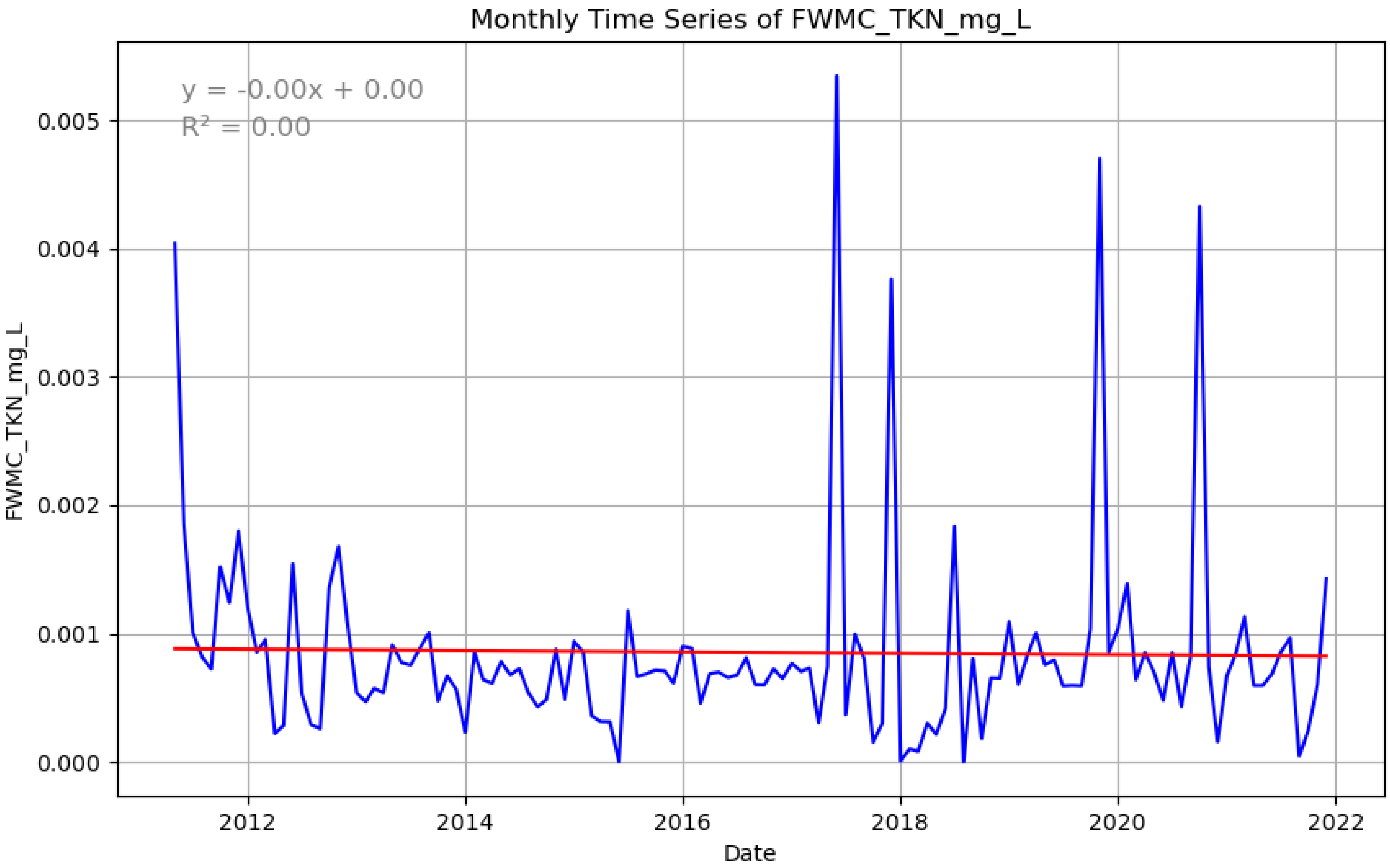


Mass Loads

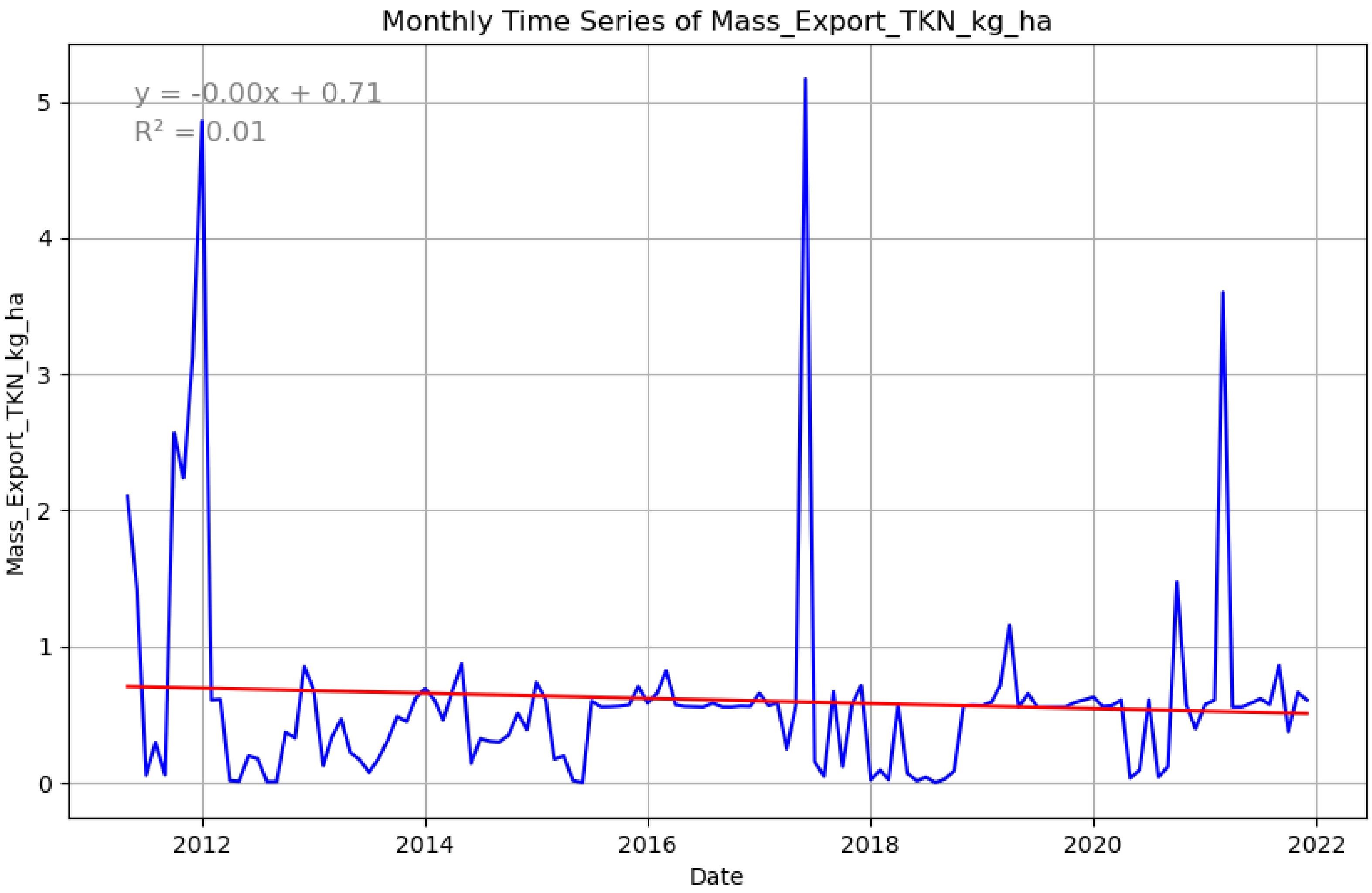


Monthly Time Series of Total_Mass_Load_TKN_kg
y = -0.07x + 1011.04
R² = 0.01
Total_Mass_Load_TKN_kg
0
1000
2000
3000
4000
5000
6000
7000
2012
2014
2016
2018
2020
2022
Date

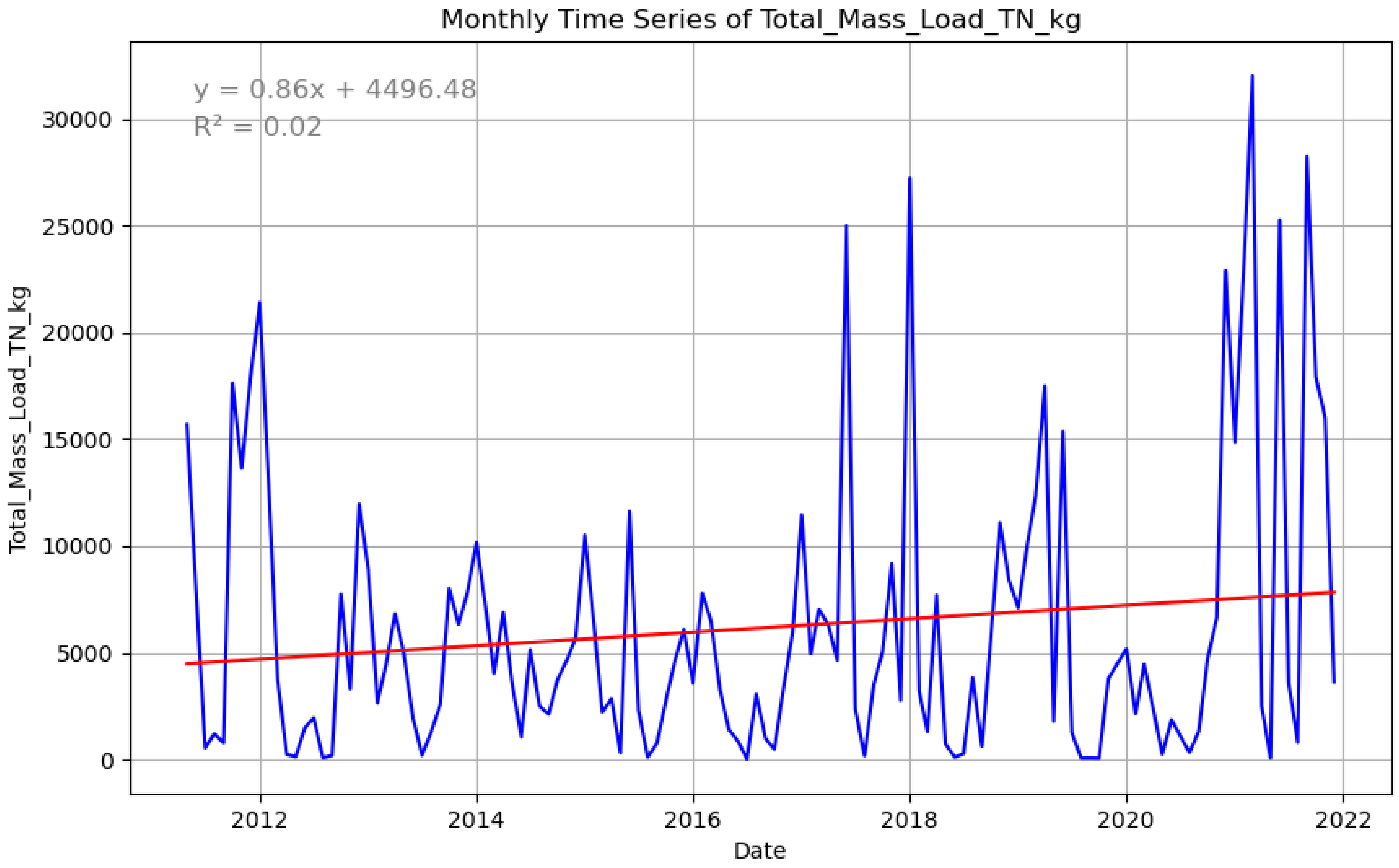
Flow-Weighted Mean Concentration



Mass Export Loads

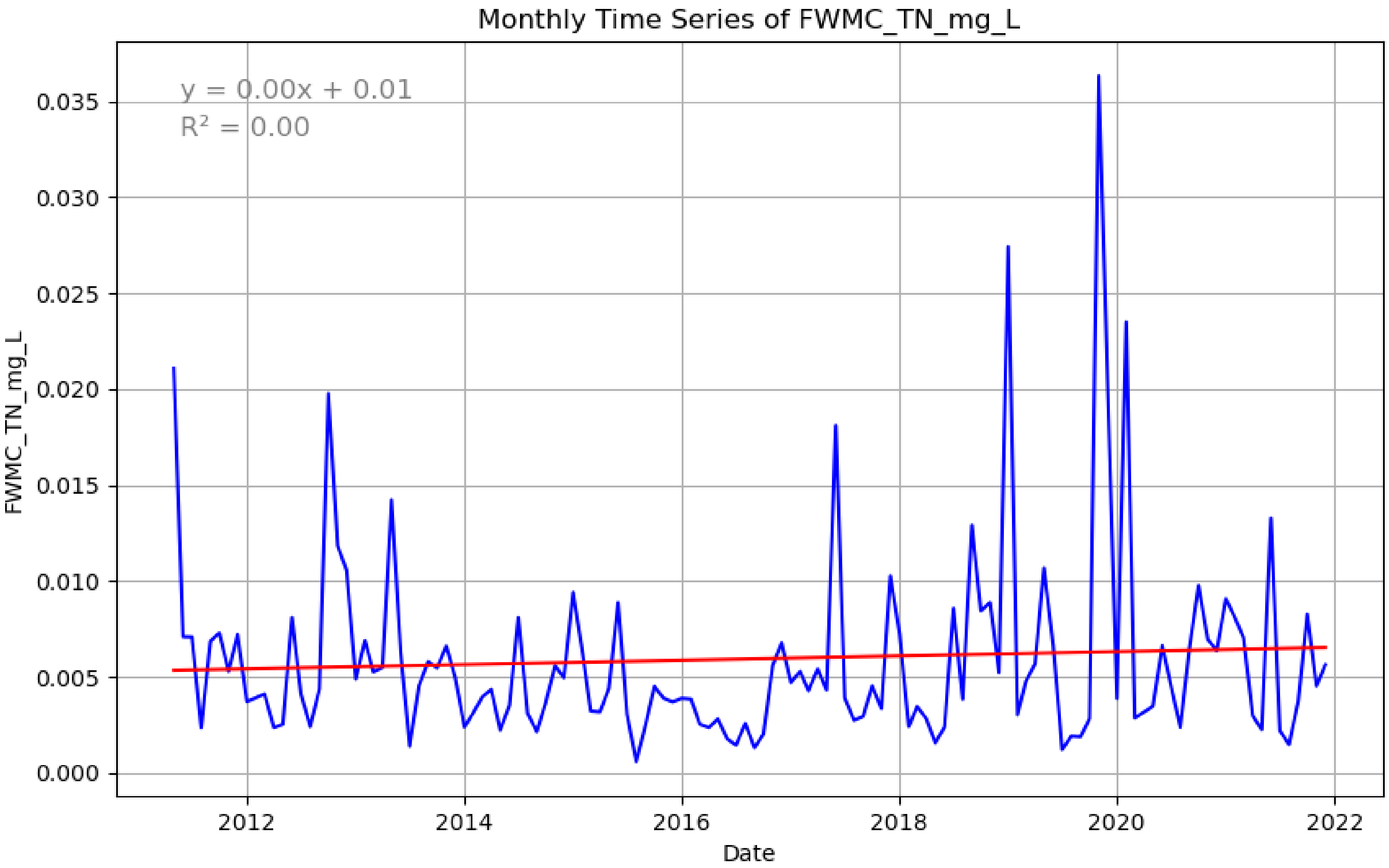


Mass Loads

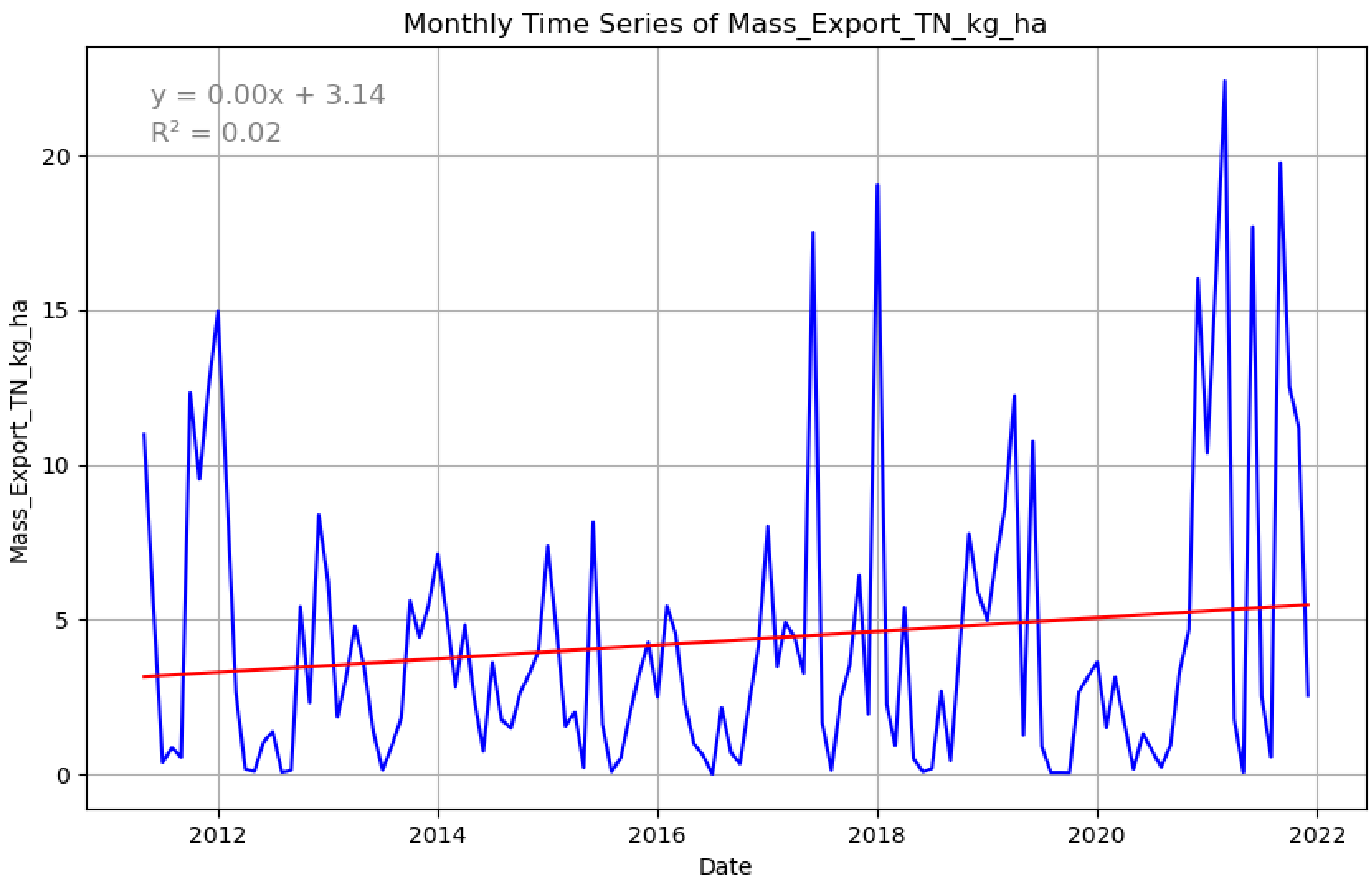


Monthly Time Series of Total_Mass_Load_TN_kg
y = 0.86x + 4496.48
R² = 0.02
Total_Mass_Load_TN_kg
0
5000
10000
15000
20000
25000
30000
2012
2014
2016
2018
2020
2022
Date

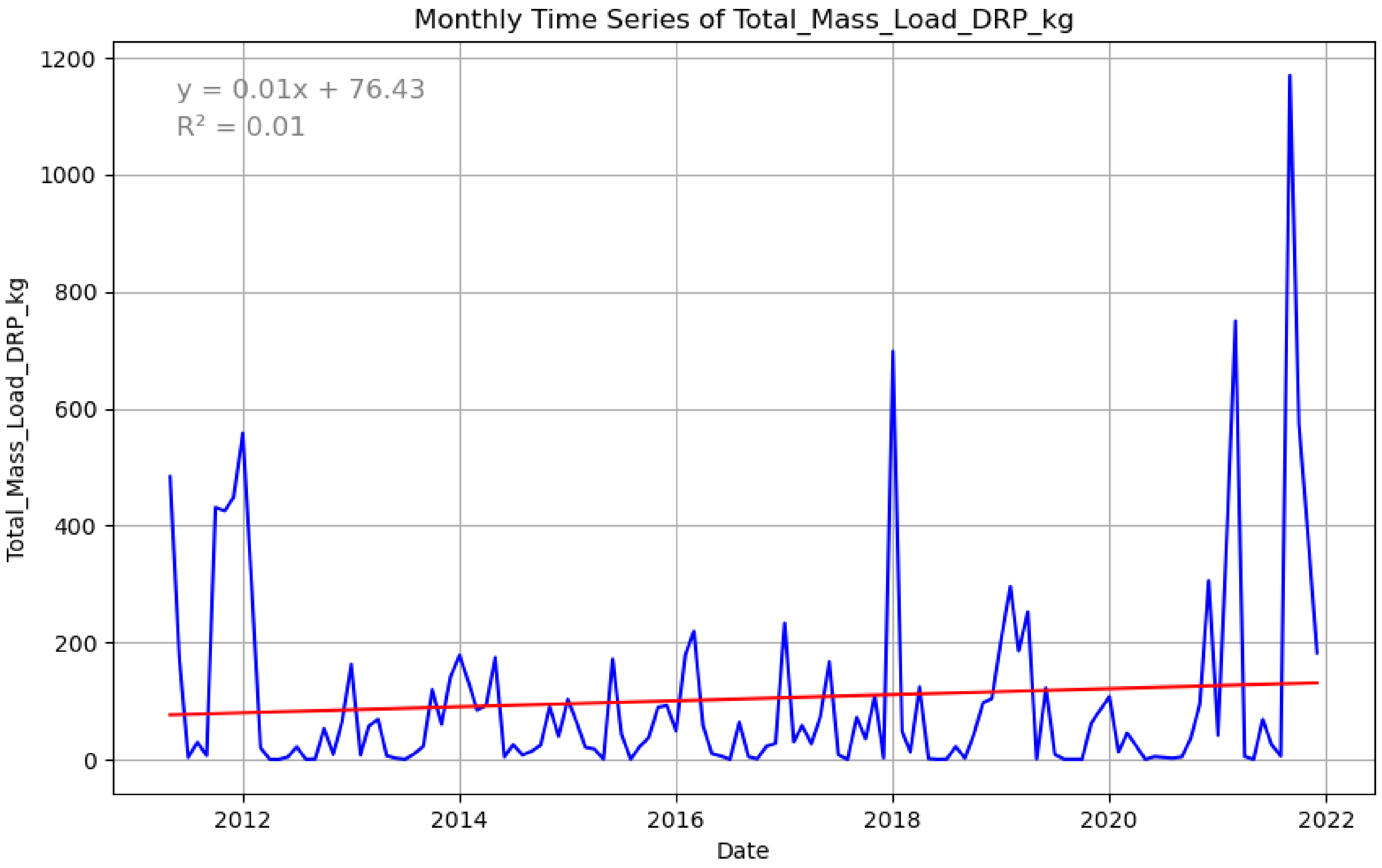
Flow-Weighted Mean Concentration



Mass Export Loads

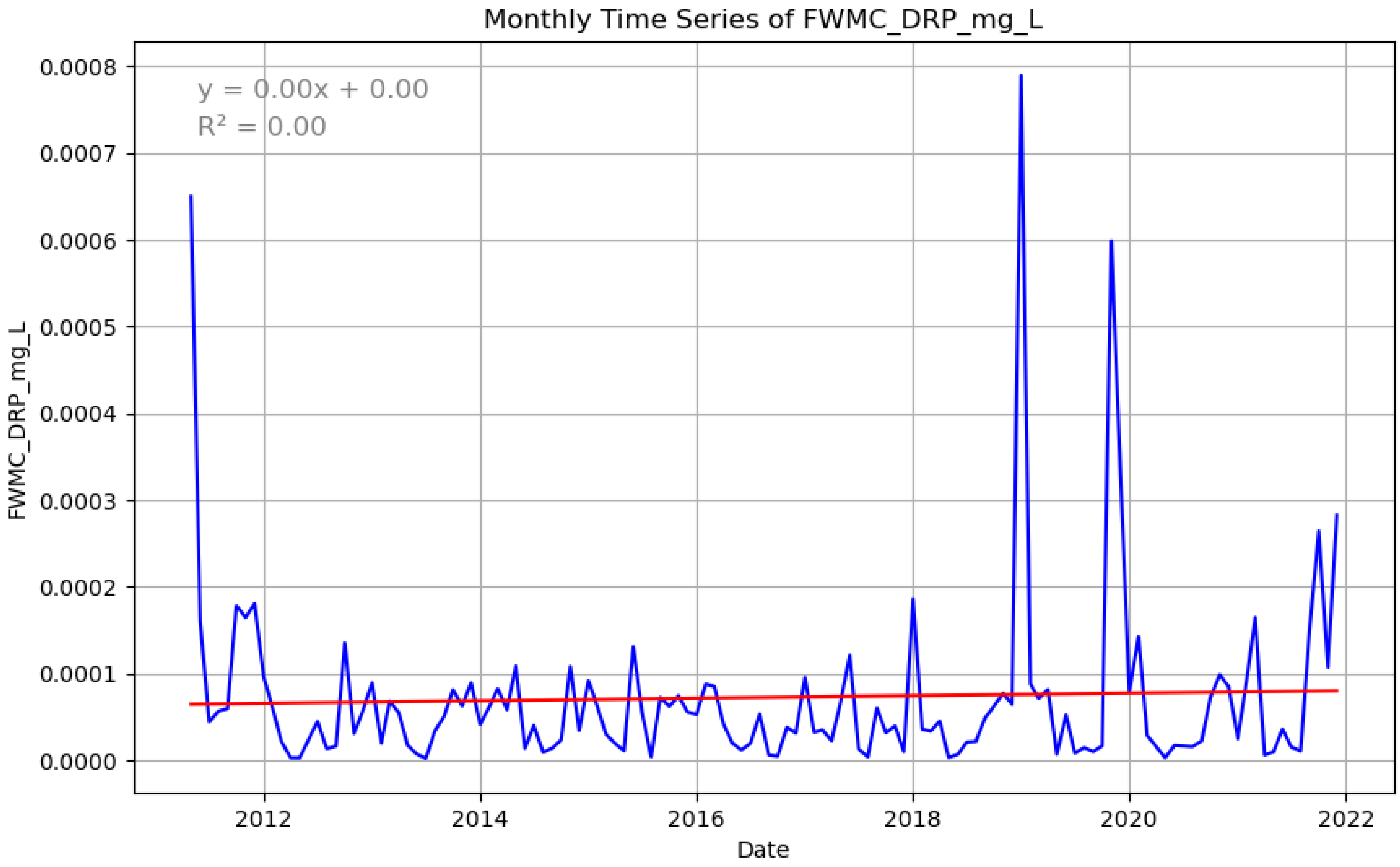


Mass Loads

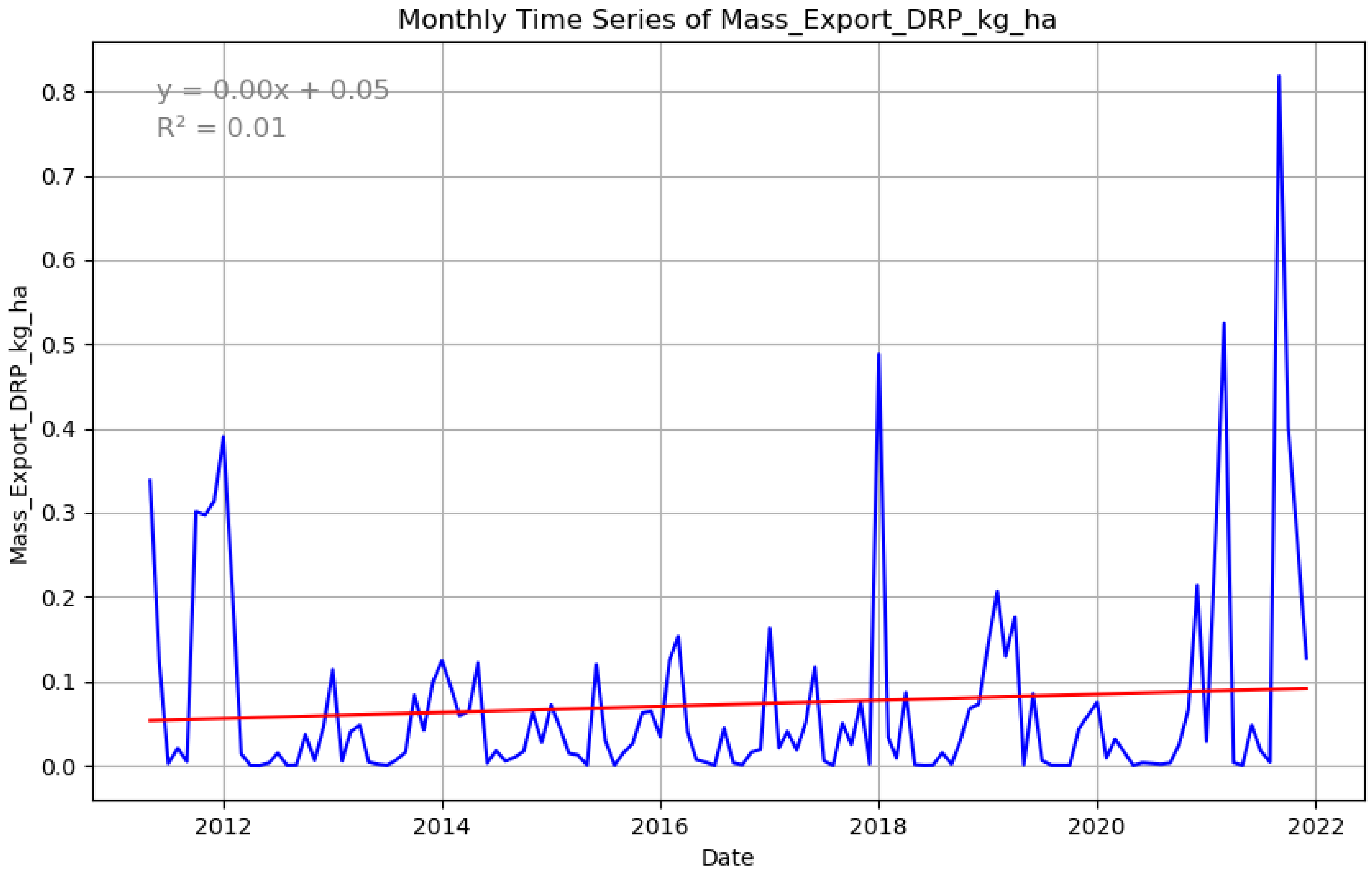


Monthly Time Series of Total_Mass_Load_DRP_kg
y = 0.01x + 76.43
R² = 0.01
Total_Mass_Load_DRP_kg
0
200
400
600
800
1000
1200
2012
2014
2016
2018
2020
2022
Date

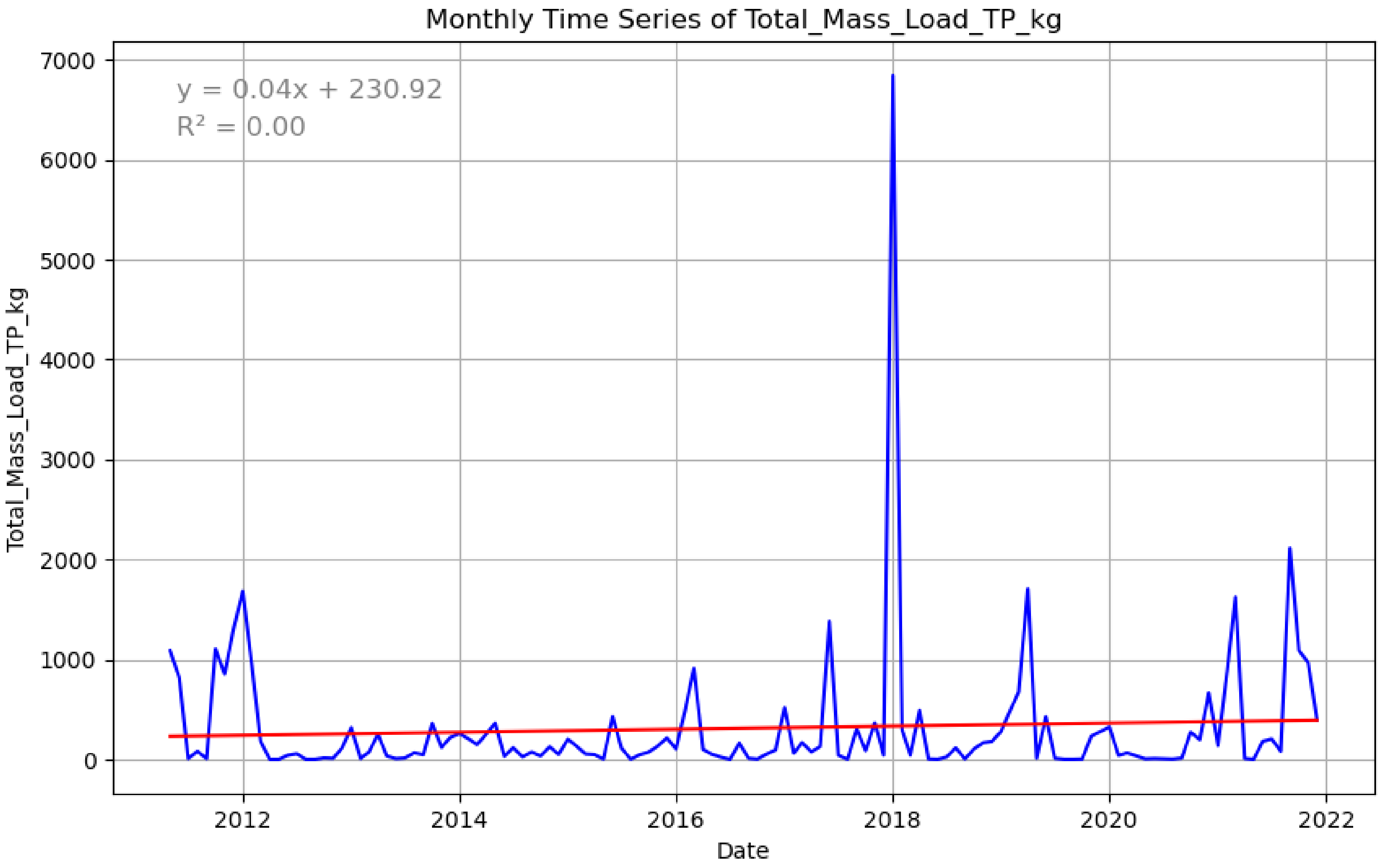
Flow-Weighted Mean Concentration



Mass Export Loads

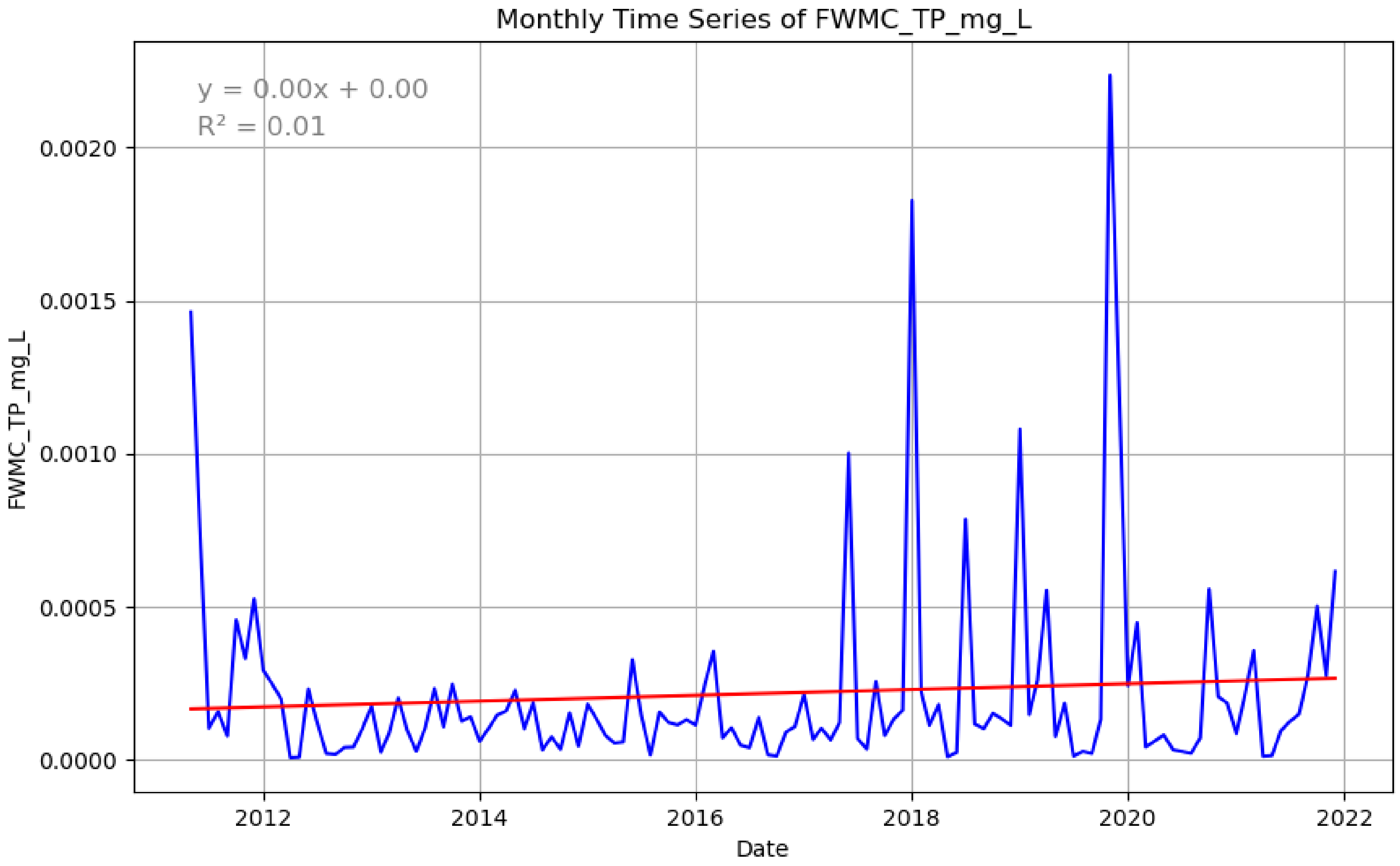


Mass Loads

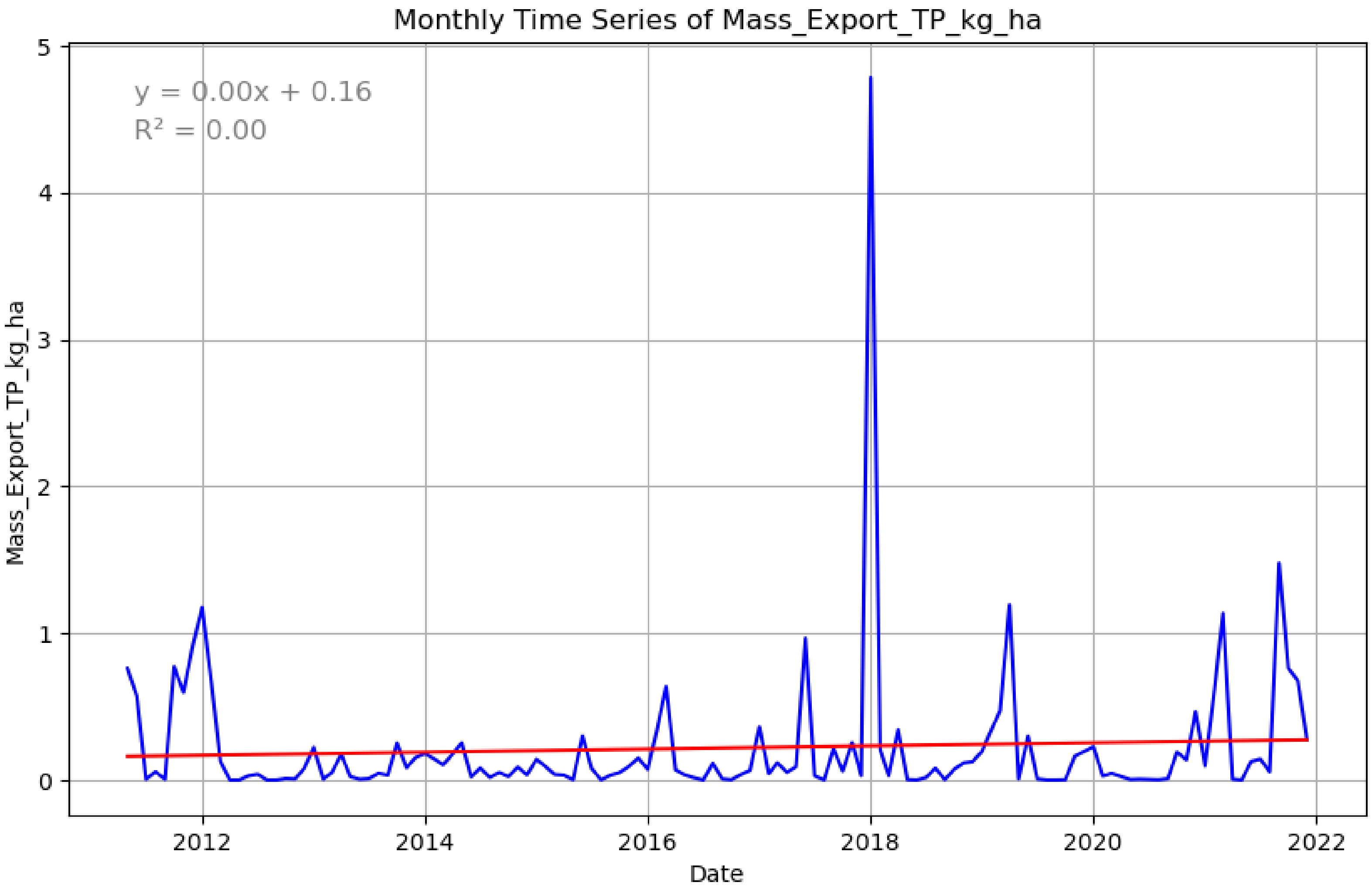


Monthly Time Series of Total_Mass_Load_TP_kg
y = 0.04x + 230.92
R² = 0.00
7000
6000
5000
4000
3000
2000
1000
0
Total_Mass_Load_TP_kg
2012
2014
2016
2018
2020
2022
Date

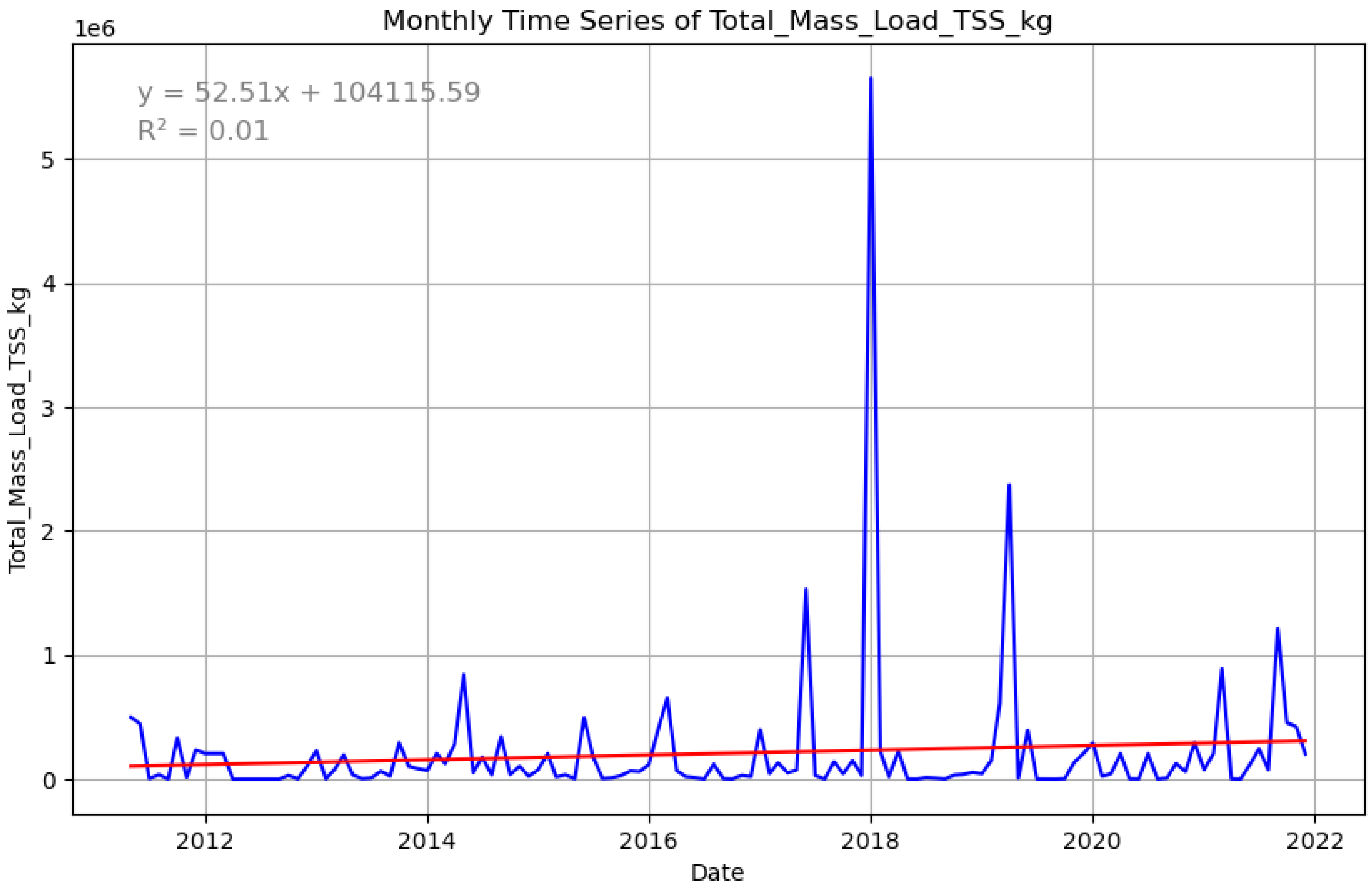
Flow-Weighted Mean Concentration



Mass Export Loads

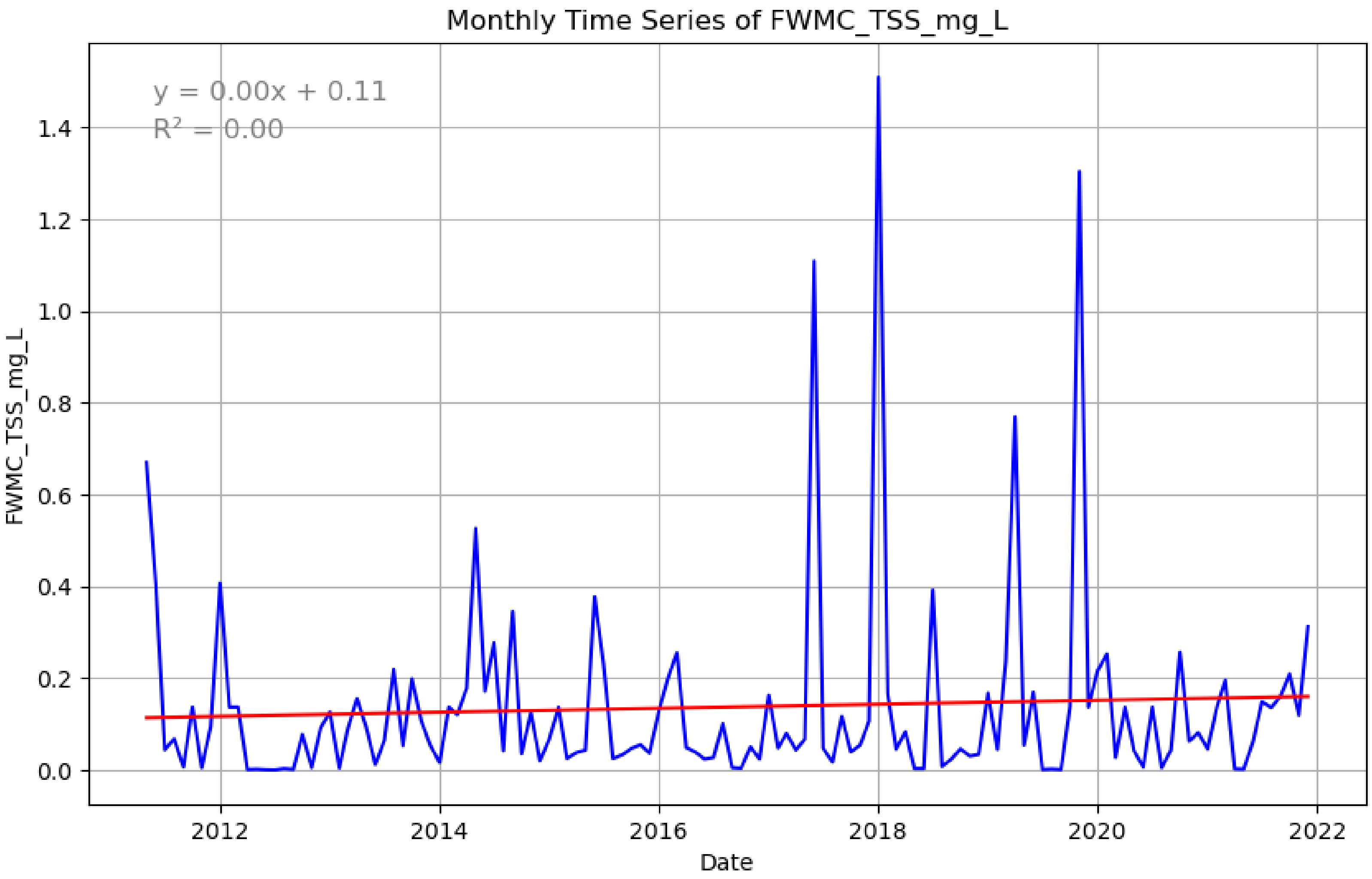


Mass Loads

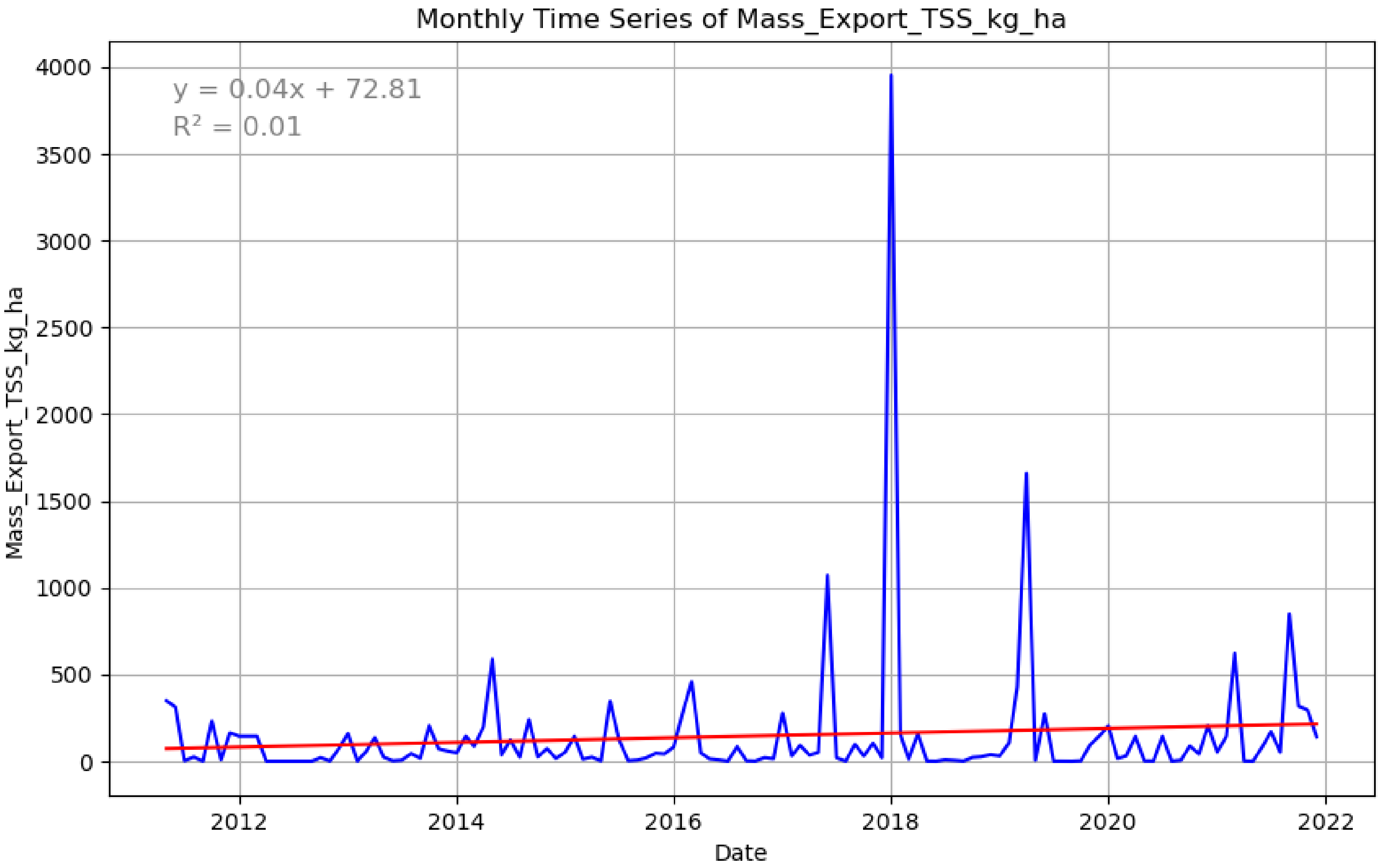


Monthly Time Series of Total_Mass_Load_TSS_kg
1e6
y = 52.51x + 104115.59
R² = 0.01
0
1
2
3
4
5
Total_Mass_Load_TSS_kg
2012
2014
2016
2018
2020
2022
Date

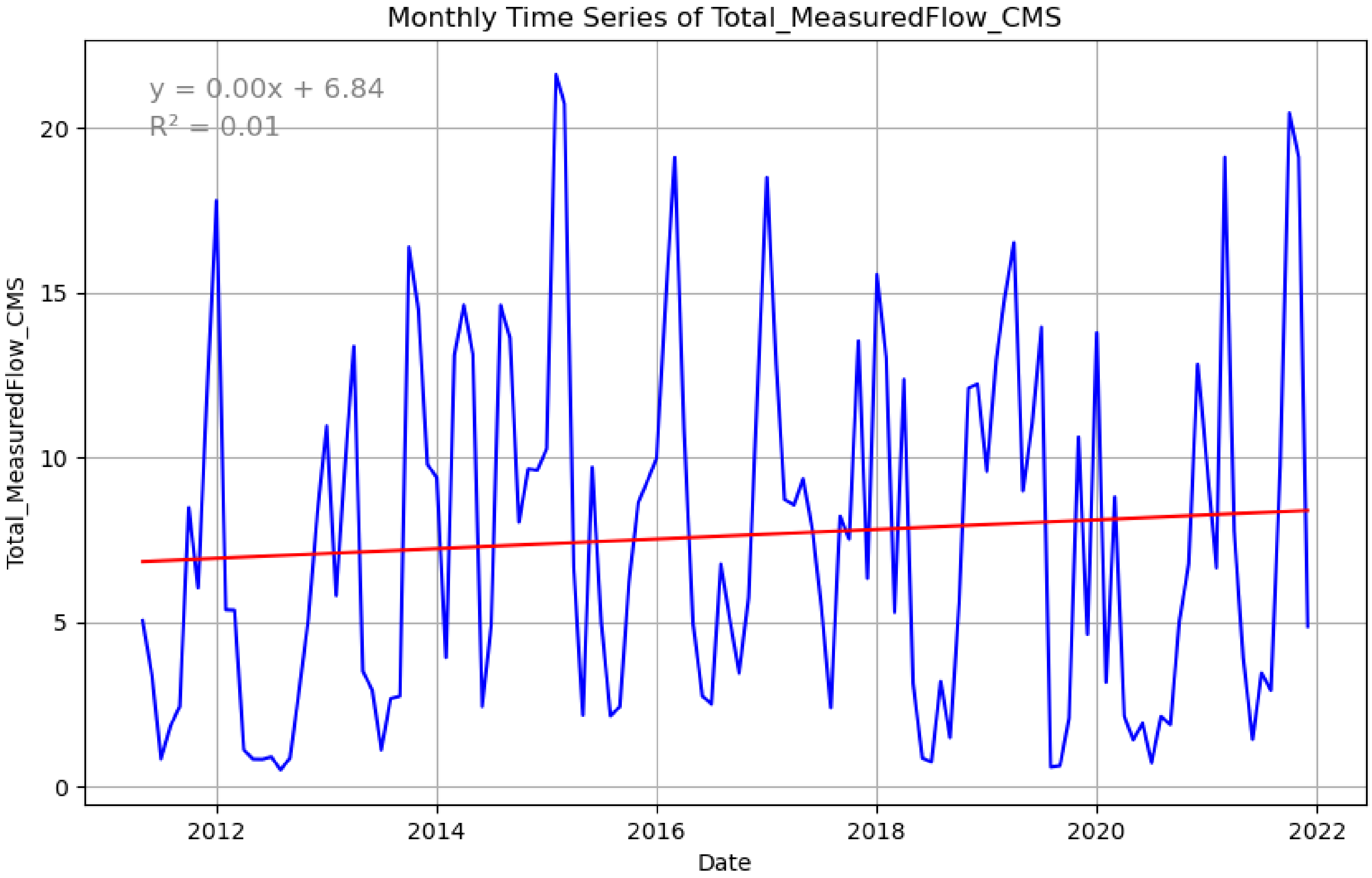
Flow-Weighted Mean Concentration



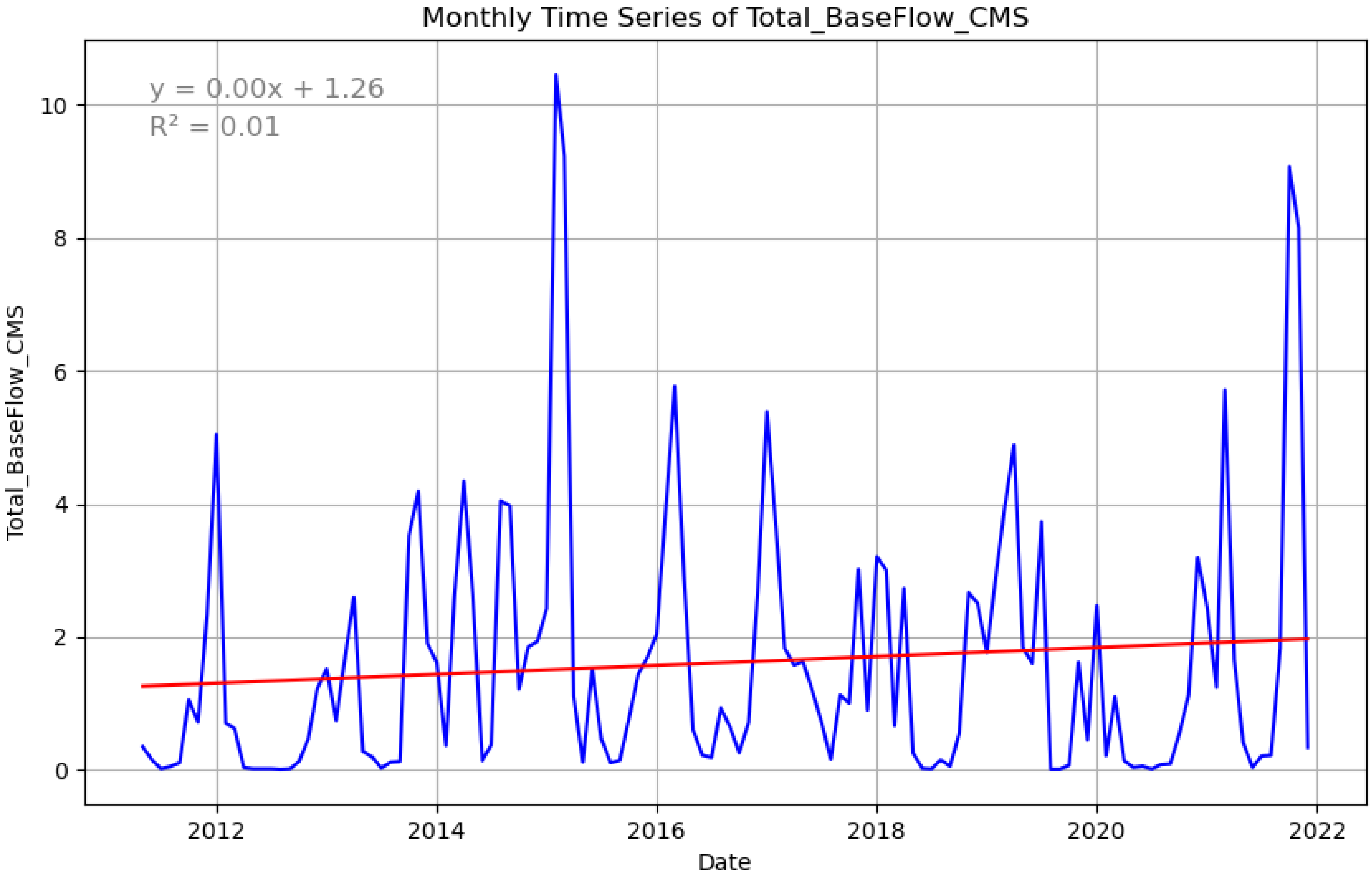
Mass Export Loads



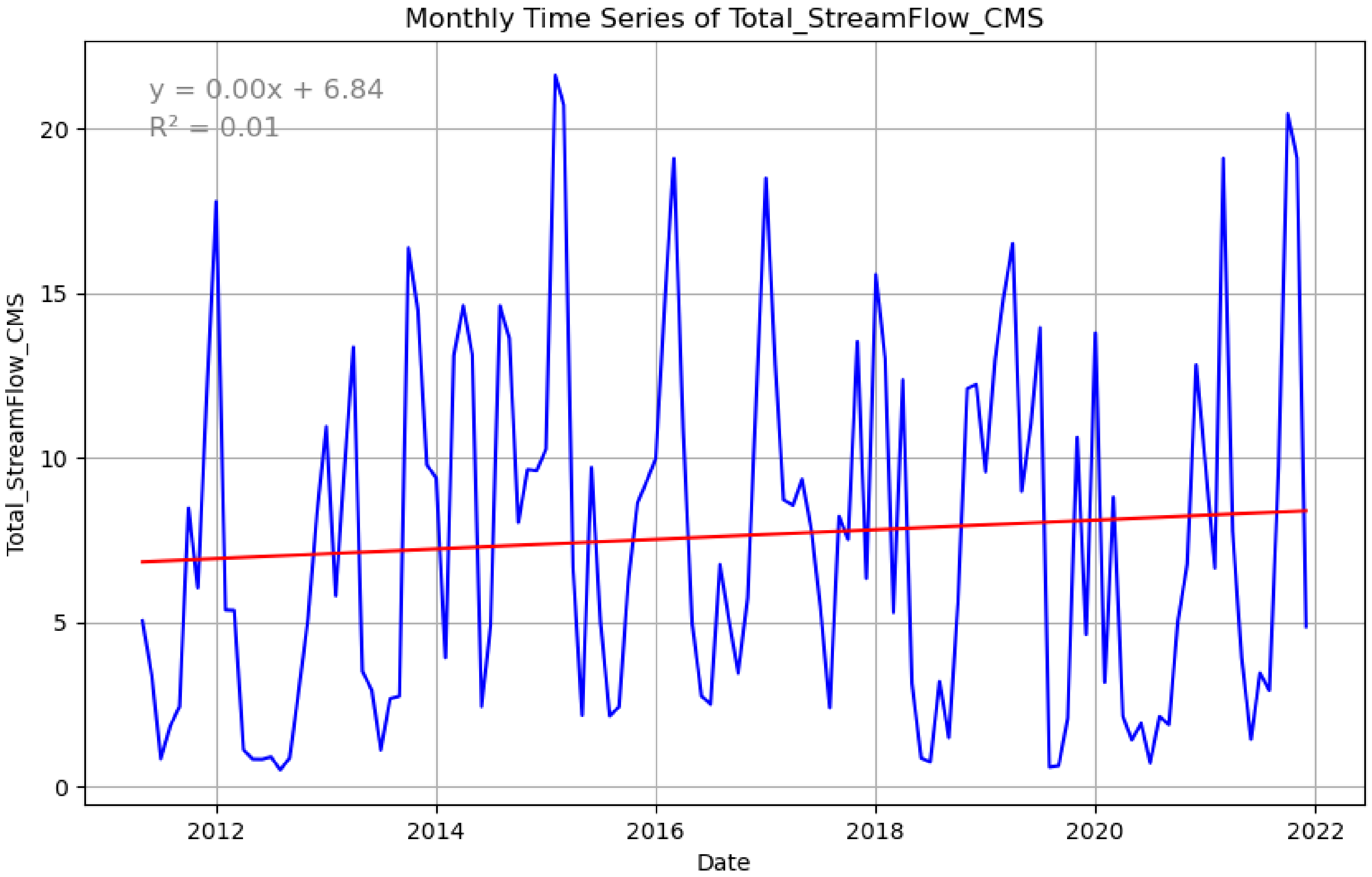
Monthly Total Measured Flow



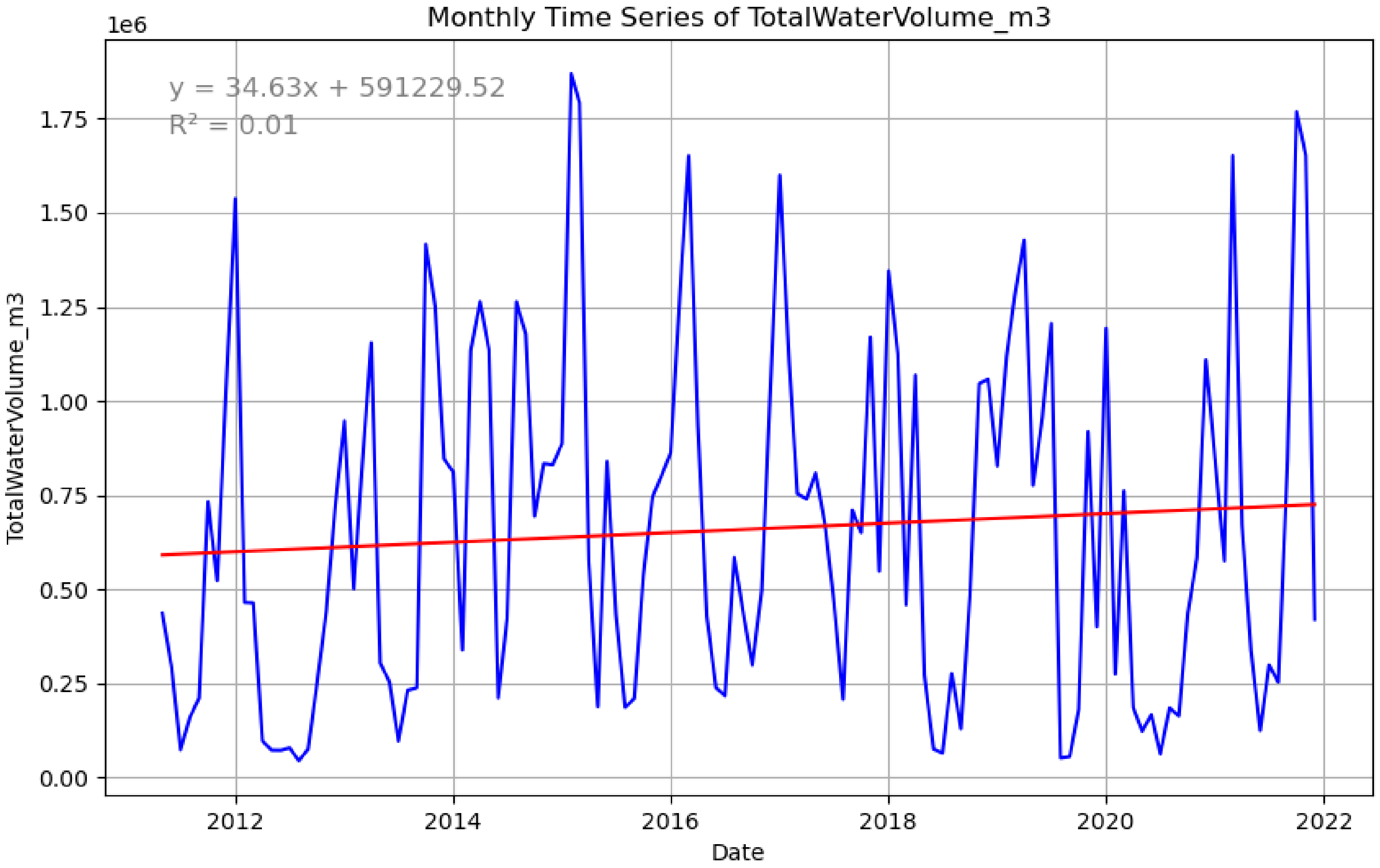
Monthly Total Base Flow



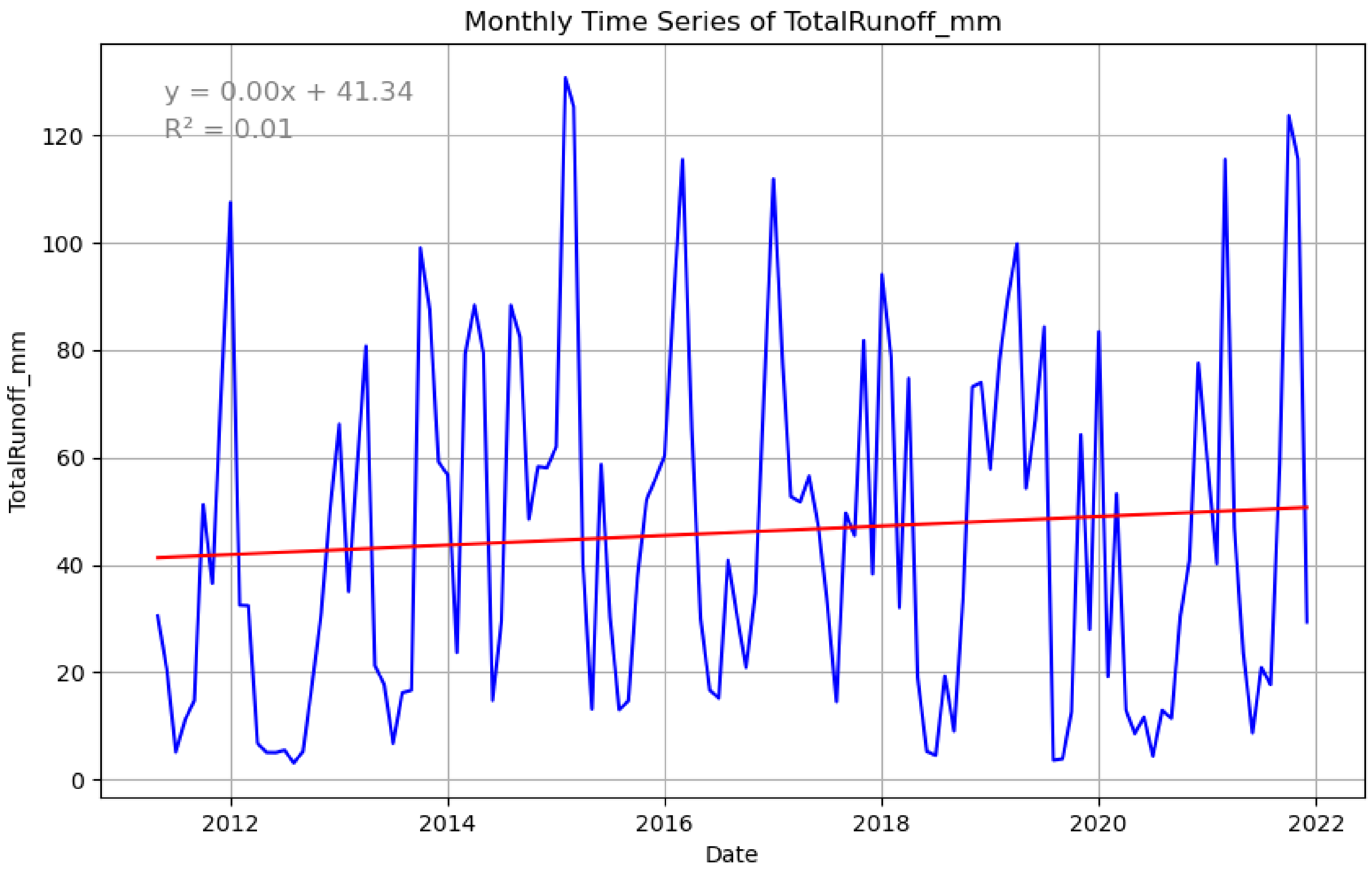
Monthly Total Stream Flow



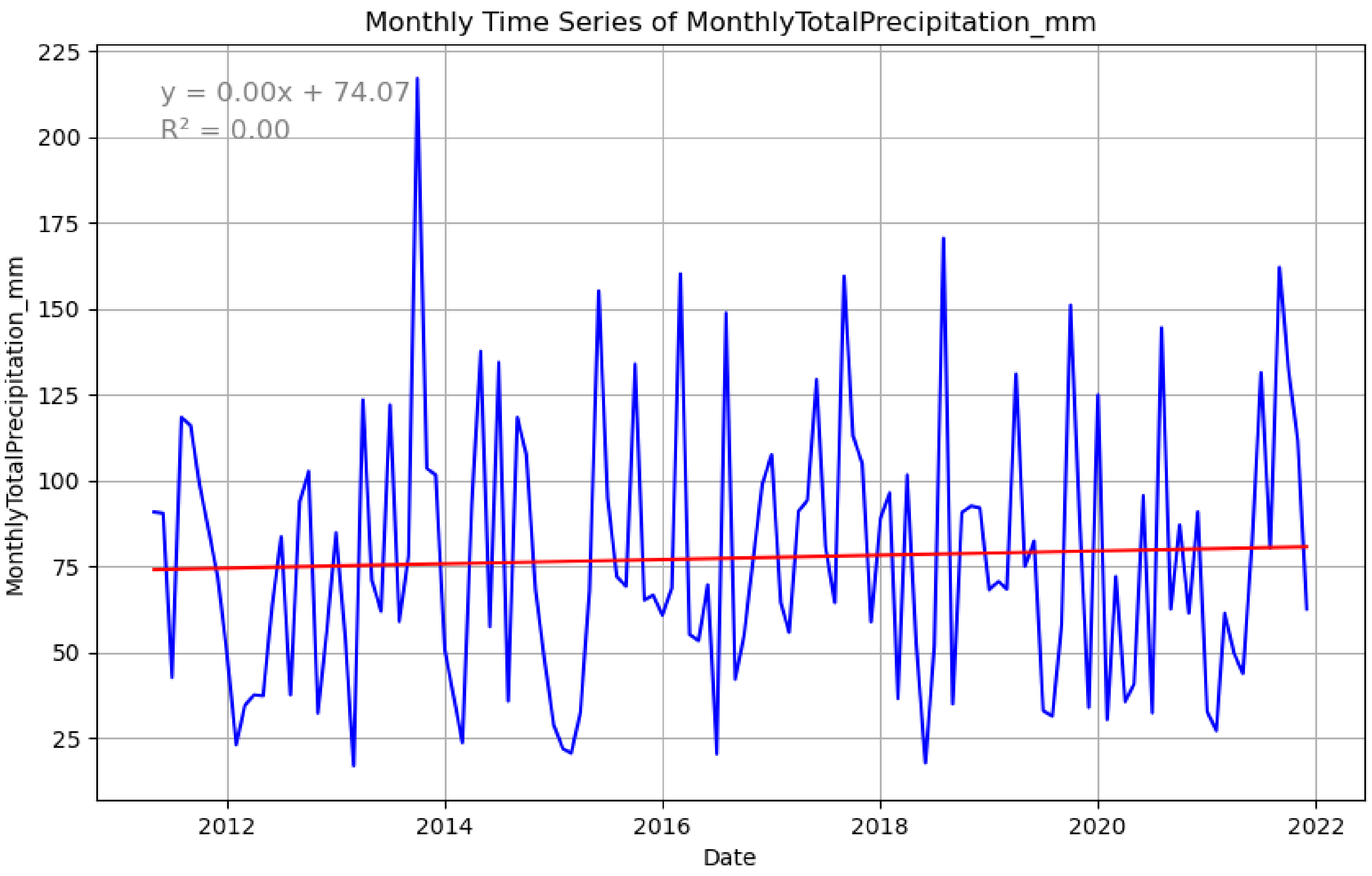
Monthly Total Water Volume



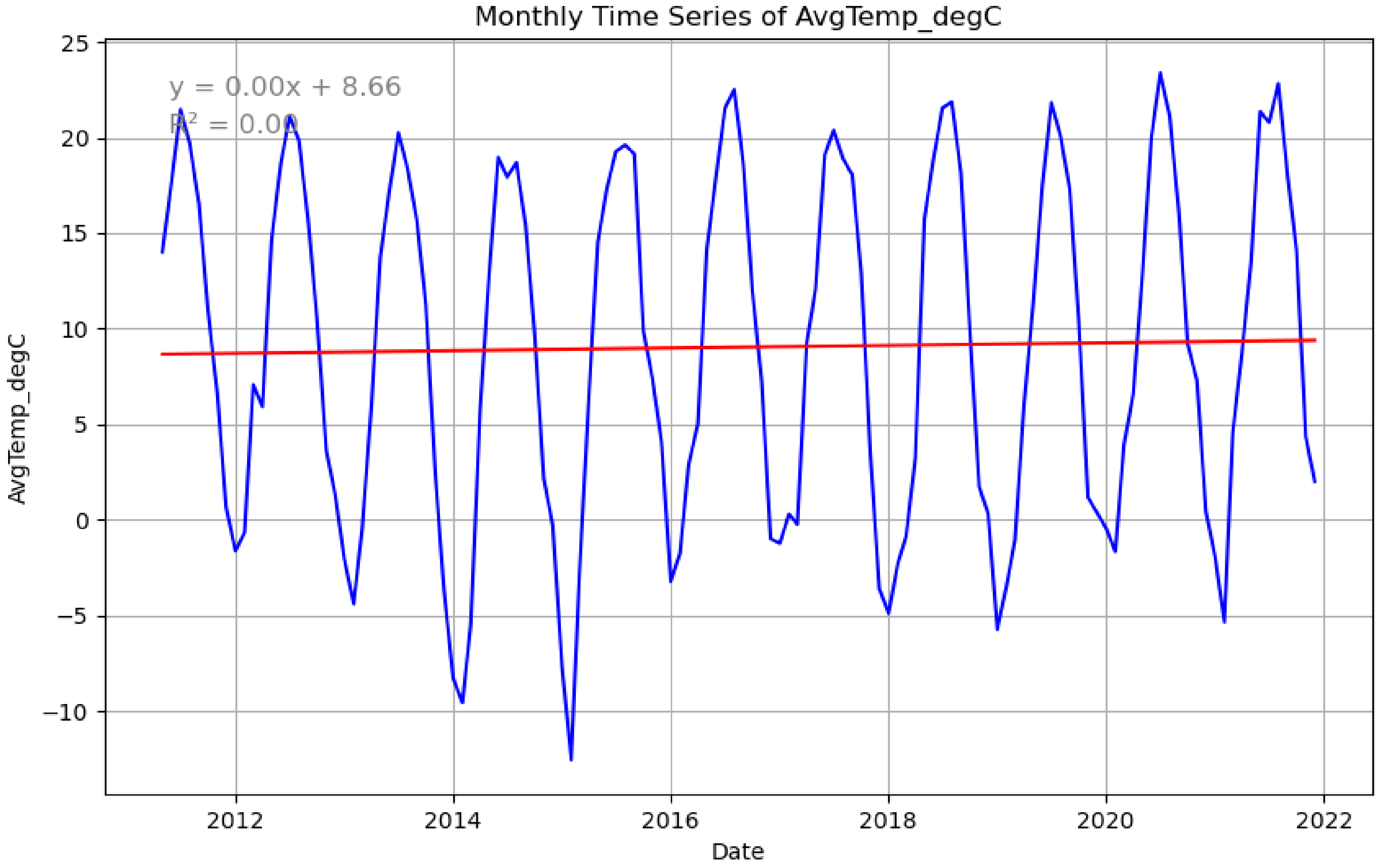
Monthly Total Runoff



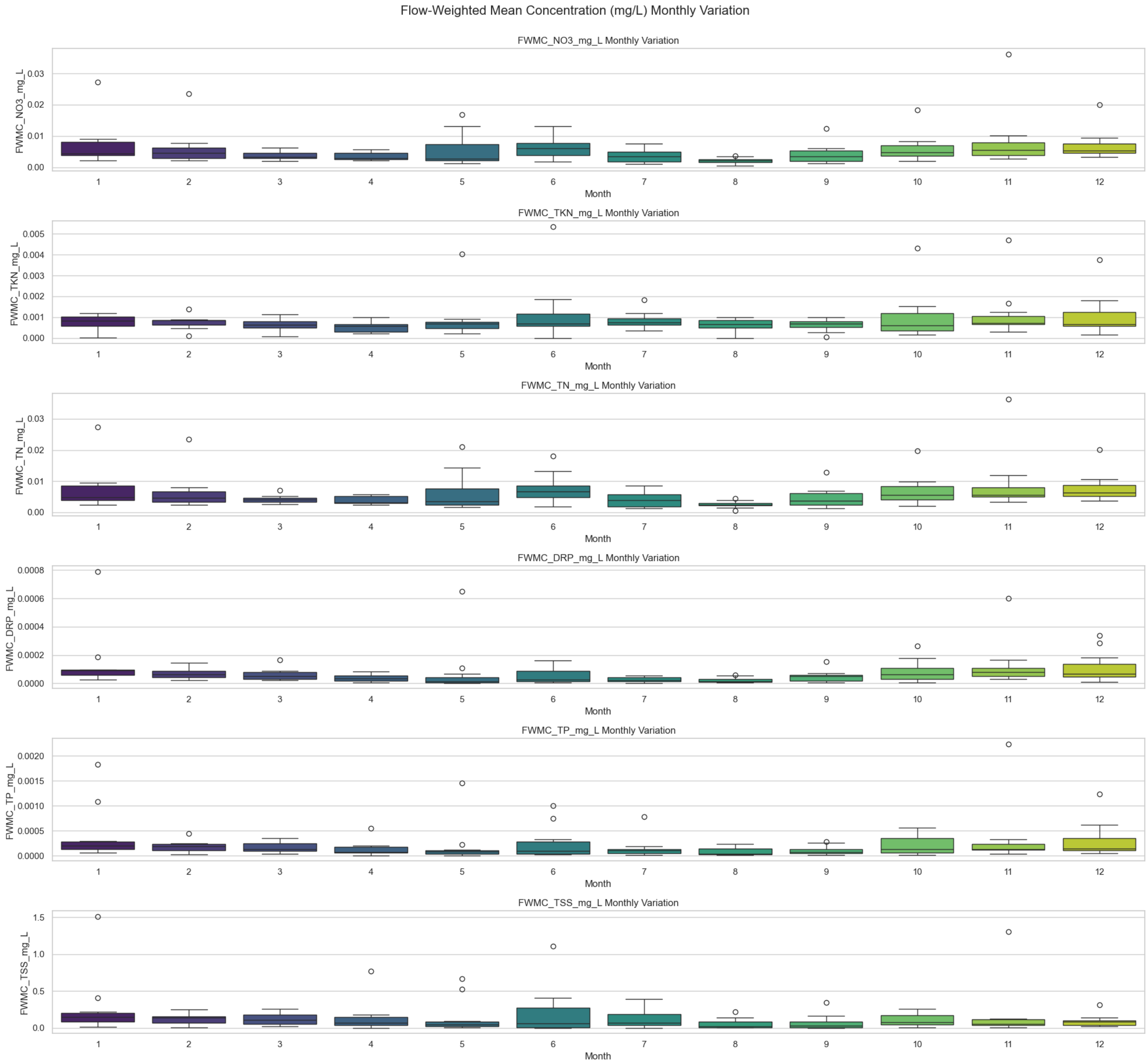
Monthly Total Precipitation



Monthly Average Temperature

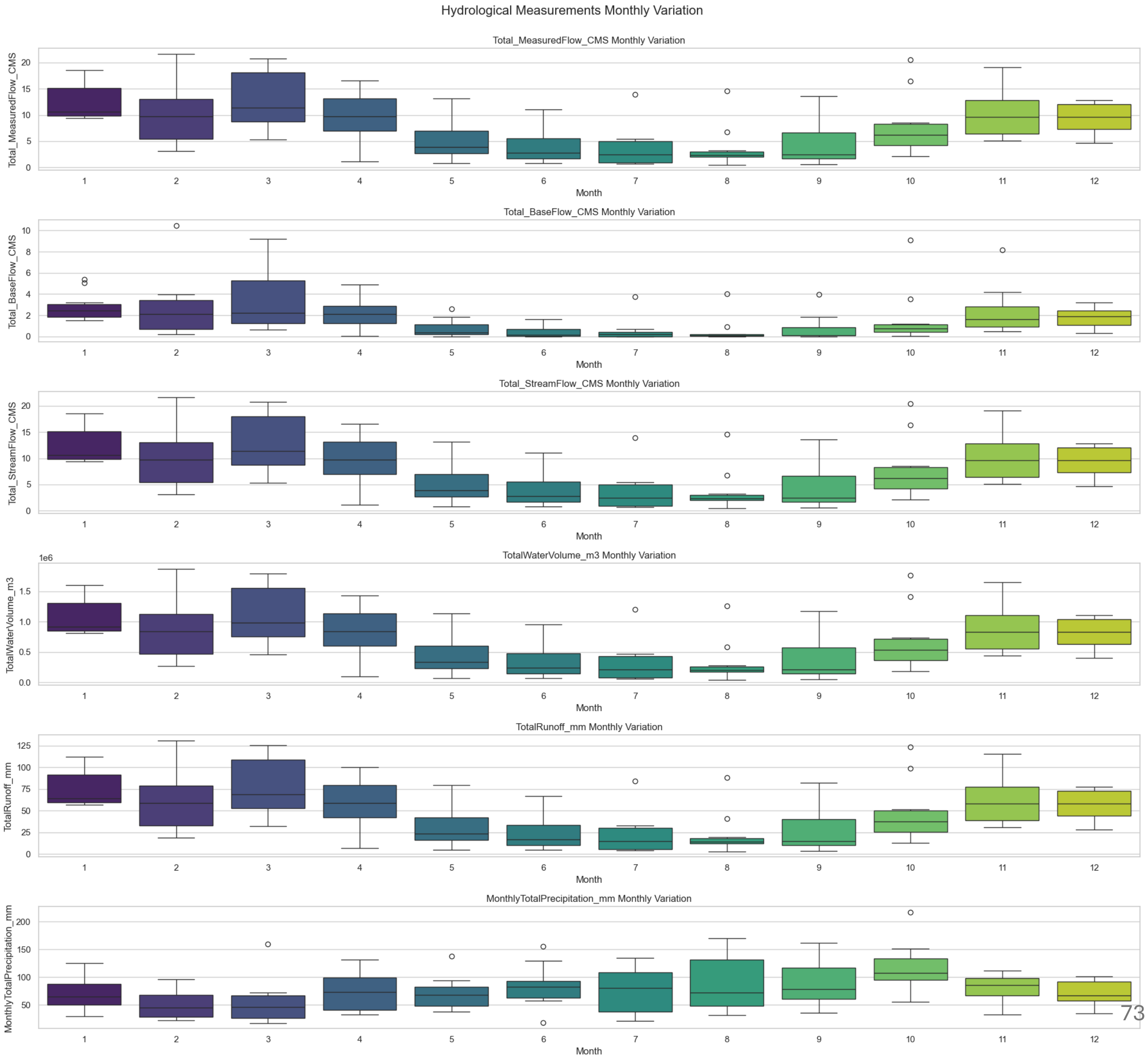


Monthly variations of FWMC



Monthly variations of Mass Export Loads

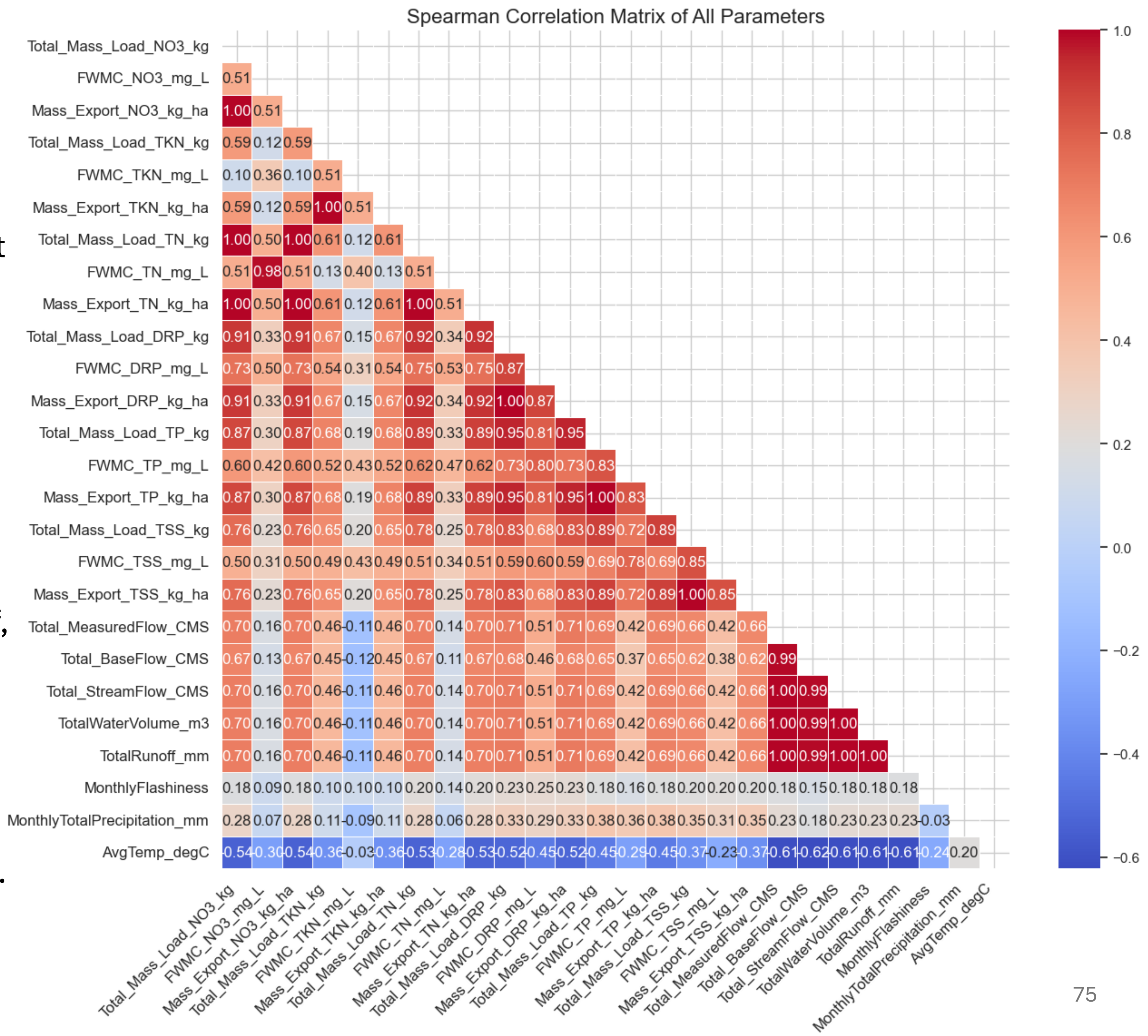
Monthly variations of Hydrologic parameters



Overall correlation and Regression analysis

Measured and calculated monthly data (May 2011 to December 2021)

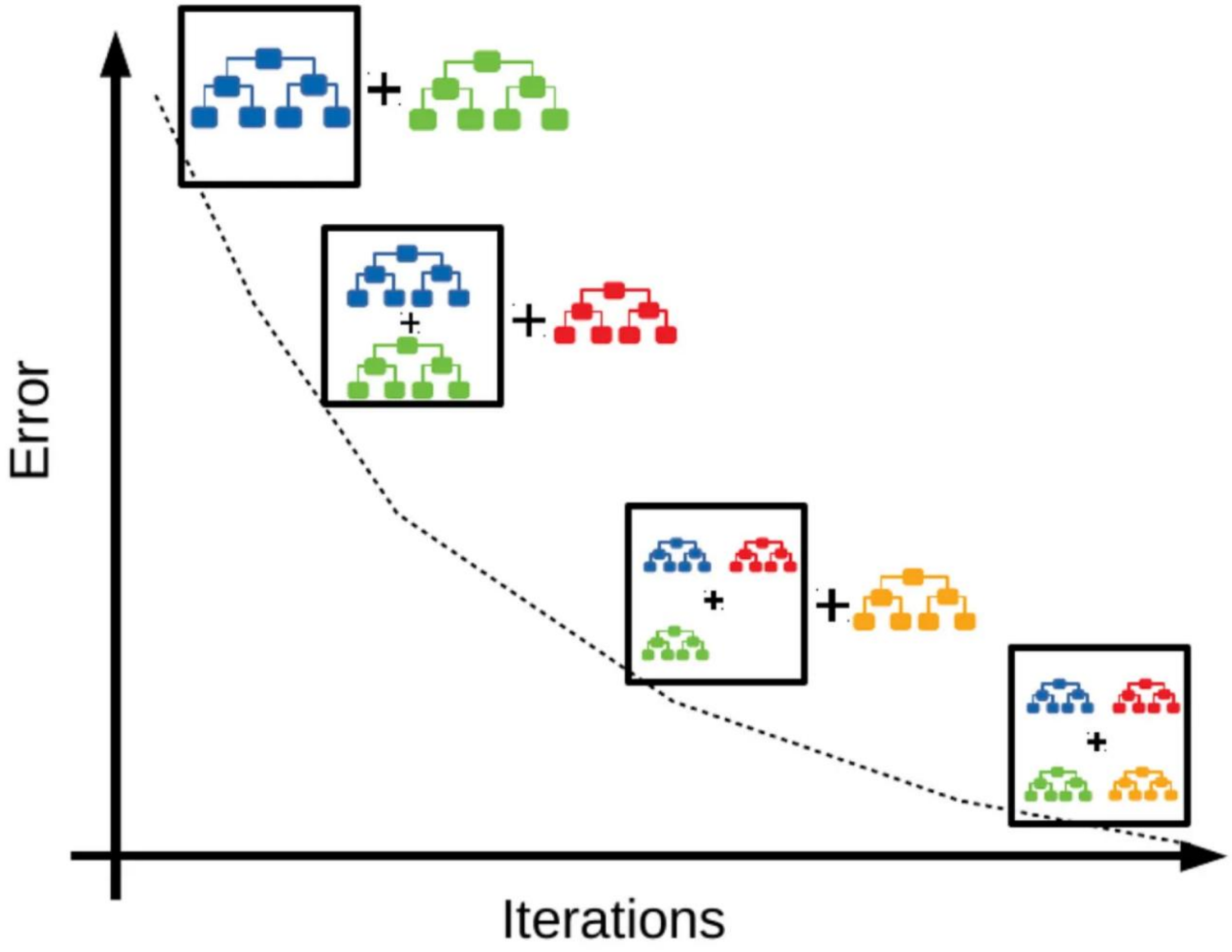
- Strong positive correlations between nutrient loads and exports, particularly for nitrogen and phosphorus, indicating nutrient transport linked to agricultural runoff.
- Significant linkage between sediment exports and nutrient dynamics.
- Clear correlation between watershed water volume and runoff, highlighting the impact on nutrient and sediment transport.
- Highlights the importance of adaptive management strategies based on real-time monitoring data.



Machine learning: Gradient Boost Regression

Powerful machine learning technique that builds predictive models from an ensemble of weaker models, typically decision trees.

Provides insights into the importance of each feature in making predictions, aiding in understanding the driving factors behind the predictions.



Source: https://medium.com/@weidagang/gradient-boosting-from-scratch-84921eb64c3c

Results of Gradient Boosting

Execution of the Gradient Boosting models offers insights into the predictive performance and feature importance of various hydrological and meteorological factors on different nutrient load metrics in a watershed

```
Results for Mass_Export_TP_kg_ha:
MSE: 0.7839296781648639
R²: 0.08200532208166589
Feature Importance:
Total_BaseFlow_CMS: 0.09
Total_StreamFlow_CMS: 0.13
MonthlyTotalPrecipitation_mm: 0.28
AvgTemp_degC: 0.14
TotalWaterVolume_m3: 0.17
TotalRunoff_mm: 0.18


Results for Mass_Export_TN_kg_ha:
MSE: 20.97895829470219
R²: 0.311328449647845
Feature Importance:
Total_BaseFlow_CMS: 0.19
Total_StreamFlow_CMS: 0.13
MonthlyTotalPrecipitation_mm: 0.31
AvgTemp_degC: 0.22
TotalWaterVolume_m3: 0.08
TotalRunoff_mm: 0.08


Results for Mass_Export_DRP_kg_ha:
MSE: 0.012220013270798219
R²: 0.4250401664580211
Feature Importance:
Total_BaseFlow_CMS: 0.14
Total_StreamFlow_CMS: 0.13
MonthlyTotalPrecipitation_mm: 0.25
AvgTemp_degC: 0.19
TotalWaterVolume_m3: 0.11
TotalRunoff_mm: 0.17
```

```
Results for Mass_Export_NO3_kg_ha:
MSE: 22.075295155498473
R²: 0.1518826220078623
Feature Importance:
Total_BaseFlow_CMS: 0.21
Total_StreamFlow_CMS: 0.10
MonthlyTotalPrecipitation_mm: 0.31
AvgTemp_degC: 0.14
TotalWaterVolume_m3: 0.15
TotalRunoff_mm: 0.08


Results for Mass_Export_TKN_kg_ha:
MSE: 0.6487924215875177
R²: -0.3920919775513565
Feature Importance:
Total_BaseFlow_CMS: 0.17
Total_StreamFlow_CMS: 0.14
MonthlyTotalPrecipitation_mm: 0.18
AvgTemp_degC: 0.20
TotalWaterVolume_m3: 0.15
TotalRunoff_mm: 0.16


Results for Mass_Export_TSS_kg_ha:
MSE: 541554.7743813223
R²: 0.04922210396476501
Feature Importance:
Total_BaseFlow_CMS: 0.06
Total_StreamFlow_CMS: 0.03
MonthlyTotalPrecipitation_mm: 0.75
AvgTemp_degC: 0.05
TotalWaterVolume_m3: 0.05
TotalRunoff_mm: 0.06
```

Mass Export Loads of TP_kg/ha (Total Phosphorus kg per hectare)

- MSE (Mean Squared Error): 0.784 indicates moderate prediction error.
- R^2 (Coefficient of Determination): 0.082 suggests low model accuracy, indicating only a small proportion of variance in TP is explained by the model.
- Feature Importance: Precipitation (28%), runoff (18%), and water volume (17%) are the most influential predictors, suggesting that TP loads are significantly impacted by rainfall events and resultant water flow dynamics.

Mass Export Loads of TN_kg/ha (Total Nitrogen kg per hectare)

- MSE: 20.979 suggests a higher prediction error.
- R^2: 0.311 indicates moderate model accuracy.
- Feature Importance: Base flow (19%), precipitation (31%), and temperature (22%) have significant impacts, indicating that both climatic conditions and base water flow influence TN loading.

Mass Export Loads of DRP_kg/ha (Dissolved Reactive Phosphorus kg per hectare)

- MSE: 0.0122 indicates a low prediction error.
- R^2: 0.425 suggests better model performance compared to TP and TN.
- Feature Importance: Similar to TP, DRP load predictions are significantly influenced by precipitation (25%), temperature (19%), and runoff (17%), underlining the role of water flow and climatic conditions.

Mass Export Loads of NO3_kg/ha (Nitrate Nitrogen kg per hectare)

- MSE: 22.075 indicates a high prediction error.
- R^2: 0.152 shows low model accuracy.
- Feature Importance: Precipitation (31%) is the most significant predictor, followed by base flow (21%) and water volume (15%), emphasizing the role of hydrological dynamics in nitrate loading.

Mass Export Loads of TKN_kg/ha (Total Kjeldahl Nitrogen kg per hectare)

- MSE: 0.649 indicates moderate prediction error.
- R^2: -0.392 suggests that the model performs poorly, possibly indicating model misspecification or data issues.
- Feature Importance: Temperature and monthly precipitation are notable, suggesting a complex interaction between weather conditions and TKN loads.

Mass Export Loads of TSS_kg/ha (Total Suspended Solids kg per hectare)

- MSE: 541,554.774 indicates a very high error, reflecting challenges in predicting TSS.
- R^2: 0.049 shows very low model accuracy.
- Feature Importance: Dominated by precipitation (75%), indicating that rainfall heavily influences sediment transport.

Summary of Gradient Boosting Modeling exercise

- The substantial role of precipitation and temperature across nutrient types suggests that climate factors heavily influence nutrient transport processes.

- The low R-squared values indicate that the current model setup does not capture other unmodeled factors (landuse, soil, agricultural management practices, temporal dynamics of nutrient application and crop uptake cycles etc.) that might influence nutrient loads or non-linear relationships.

Summary of Gradient Boosting Modeling exercise

- The models suggest varying degrees of influence from base flow and stream flow, indicating that tile drainage might enhance the subsurface flow paths that quickly transport soluble nutrients (like nitrate and DRP) into the stream systems, bypassing much of the soil's filtering capacity.

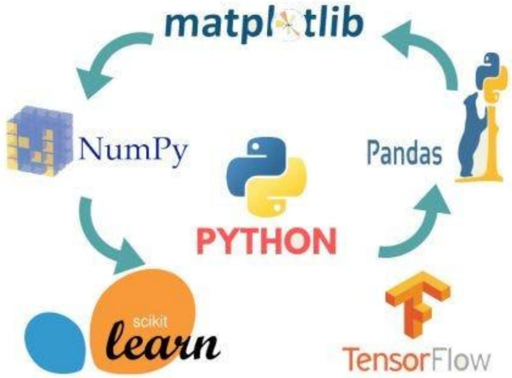
- The variable model performances and high significance of rainfall and temperature in predicting nutrient loads suggest that management practices must be dynamically adapted to weather conditions and hydrological responses. Practices such as controlled drainage with cover cropping could be promoted to mitigate the quick transport of nutrients via tile drains.

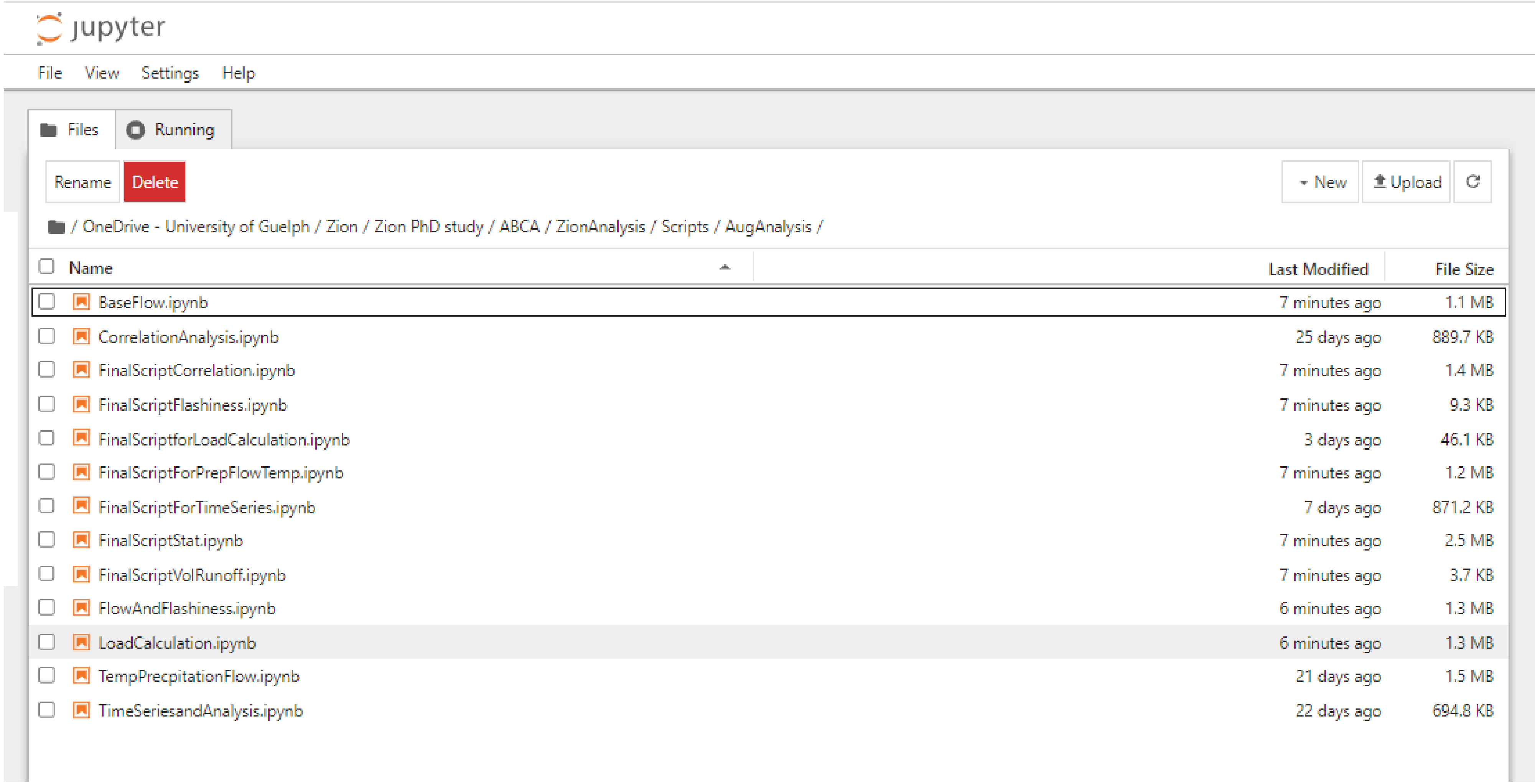
Main Message

Adaptation of Best Management Practices (BMPs) is essential for maintaining water quality in tile-drained dominated watersheds of Lake Huron, Ontario, under changing climatic conditions.

Our analysis indicates a concerning trend in nutrient loads, which are increasing with notable peaks in recent years despite initial reductions from 2013 to 2017, likely due to Best Management Practices (BMPs). While initially effective, these practices are now challenged by landscape modifications and extreme climatic events that enhance nutrient transport via tile drainage. BMPs effectively reduce nutrient loads under normal climatic conditions but are ineffective against increased tile drainage and climatic variability. To address this, it is crucial to adapt BMPs dynamically, integrating controlled drainage and cover cropping to mitigate rapid nutrient transport in growing and nongrowing seasons and respond effectively to changing weather conditions and hydrological responses.

Tool used: python libraries in jupyter notebook





Final Outputs

SepInputOutput

Scripts

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Input data and outputs

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Thank you for the opportunity!