APPENDIX

F DETAILED ANALYSIS OF DIFFERENCES BETWEEN BASELINES

APPENDIX F: DETAILED ANALYSIS OF DIFFERENCES BETWEEN BASELINES

Appendix F summarises selected water quality parameters that have been identified as having statistical differences between the 2015-2016 and 2017-2019 baselines and which were not excluded following initial visual inspection. The methodology used to identify baseline differences can be found in Section 4.3.2 of the Addendum to Water Quality Baseline and is reviewed below.

Methodology for Baseline Comparison

Statistics are calculated for each baseline separately, and a comparison is made between the 2015-2016 and the 2017-2019 baselines, with the aim to determine whether or not the baselines are significantly different. Differences in the magnitude of parameters between the baselines are identified using the Mann-Whitney U test for non-normally distributed parameters. The null hypothesis for this test is that a randomly selected value from the historical baseline will be equal to a randomly selected value from the current baseline. The test statistic is calculated as follows:

$$U = n_1 n_2 + \frac{n_2(n_2+1)}{2} - \sum_{i=n_1+1}^{n_2} R_i$$

where n_1 and n_2 are the sizes of each sample and R_i is the rank of the sample size. The null hypothesis is rejected if the p-value is < α (0.05), indicating that the values between the two baselines are significantly different. The calculated test statistic (U) is the sum of the ranks of one of the baselines.

Parameters identified as having significant differences between the baselines are plotted as timeseries, and reasons for statistical differences are surmised. There will be a high degree of natural variability in parameter concentrations in natural waters. Therefore, we assess as to whether differences in the two baseline datasets is a result of that natural variability (i.e., there is a broad scatter in the data and no real difference between baselines) or reflects a change in the baseline conditions over time.

Table F-1 shows selected parameters with potential differences and the groupings in which they are found. As the Project area includes nutrient-sensitive rivers, figures are provided detailing nutrient parameters on the *same scale for each sample grouping* (i.e., even those showing no differences), so that comparisons can be easily made and for the identification of specific sample locations with multiple differences. Maps showing sample locations and their maximum parameter concentrations are also provided. Investigations were also undertaken as to whether there were potential relationships between concentrations and flow. Nutrients plotted against flow for the Owenreagh and Owenkillew River sample groupings are provided in the report.

Parameters where the majority of sample concentrations were found be below detection during either the 2015-2016 or 2017-2019 baselines are not graphed, except in cases where values exceed the project guideline values (i.e., orthophosphate).

Table F-1 Select parameters with potential differences between baselines and which are discussed in this Appendix.

Parameter	Unit	Grouping(s) with Baseline Differences
Parameters with differences in the 2017-2019 baseline		
AlkCaCO3	mg/l	Owenreagh, Owenreagh Tributaries, Owenkillew Tributaries, Strule River
Cl	mg/l	Owenreagh
Total Ammonia	mg/l	All groupings
NO3_N	mg/l	Owenreagh, Owenreagh Tributaries
Al_D	mg/l	Owenkillew Upstream, Owenreagh, Strule River
Parameters with majority of values < LOD in the 2015-2016 baseline		
As_D	mg/l	Owenreagh Tributaries
Co_D	mg/l	Owenkillew Upstream
V_D	mg/l	Owenkillew Upstream
Parameters with majority of values < LOD in the 2017-2019 baseline		
Cd_T	mg/l	Owenkillew Tributaries, Strule River
Cu_T	mg/l	Owenreagh Tributaries
Hg_T	mg/l	Owenreagh Tributaries
Mo_T	mg/l	Owenreagh Tributaries
Pb_T	mg/l	Owenkillew Upstream
PO4_PO4	mg/l	Owenreagh Tributaries

NUTRIENTS AND ANIONS

<u>Total Ammonia</u>

There are differences in total ammonia concentrations between the baselines for all sample locations (Figure F-1). With further analysis, this statistical difference is likely caused by a few sampling rounds which recorded elevated ammonia concentrations in most sampling locations (Figure F-2). The highest total ammonia concentration (non-outlier) is found for sampling location SWN10 (0.78 mg/l), located within the Owenreagh Tributaries grouping. The highest values are generally found on the tributaries of the Owenreagh River (see Figure F-1), close to the proposed infrastructure area, indicating elevated natural baseline concentrations in this area. In addition, there is no clear relationships between total ammonia concentration and flow in either the Owenkillew or Owenreagh rivers (Figure F-3).

Apart from these sampling rounds with elevated concentrations, the majority of the sampling rounds recorded similar ammonia concentrations between baselines. Therefore, with further analysis it is determined that there is no clear trend in the concentrations and that the differences likely reflect natural variability in total ammonia concentrations. Continued monitoring should be undertaken in order to gain a better understanding of any potential changes in the ammonia baseline across all sample locations.

<u>Total Alkalinity</u>

Total alkalinity (as $CaCO_3$) shows statistically significant differences in baselines for all sample locations except those in the main Owenkillew River (Figures F-4 and F-5). The highest alkalinity concentration is found from sampling location SW12 (212 mg/l), located downstream of the confluence of the Owenreagh and Owenkillew rivers. There are relatively high concentrations just downstream of the confluence of the Burn with the Owenkillew River (SW06). Total alkalinity concentration in the Owenkillew River decreases with increased flow until flow reaches ~5 m^3/s, after which there is no longer a strong relationship (Figure F-6a). The same appears to be true for alkalinity in the Owenreagh

River, with concentrations decreasing with increased flow, until flow reaches ~2 m^3/s (Figure F-6b). Higher concentrations of total alkalinity with reduced flow reflects the increased groundwater contribution during low flows. Given this relationship the differences in baselines are considered due to the natural variability in alkalinity and not reflective of a trend in total alkalinity concentrations.

Nitrate

Nitrate shows statistically significant differences in baseline concentrations along the Owenreagh River and its tributaries (Figures F-7 and F-8), with no significant differences on the Owenkillew River catchment, including the existing infrastructure area. The data shows elevated concentrations in sampling rounds in 2018.

Nitrate concentrations in watercourses can reflect loadings from diffuse agricultural sources or other man-made sources (e.g., sewage treatment), with baseline concentrations varying depending on flow conditions and timing of the application of fertilizer or farming practices. It is noted that summer 2018 was particularly dry and it may be that this impacted on the timing of loadings of nitrate to the watercourse. Although there are elevated concentrations, they are generally within the range of values considered for the PGV for nitrate, with limited change to the mean concentrations for the two sampling periods. Given the limited periods of sampling (2 years for the original baseline and a further 2 years for the 2017 to 2019 data) there is insufficient data to be able to identify a clear trend in the data, as the higher concentrations in 2018 may be a transient feature due to the catchment conditions in that year. Therefore, overall, there is no clear trend in the data, with the 2018 data potentially reflecting the dry conditions and representing natural variability.

Chloride

Chloride only shows significant baseline differences for the Owenreagh and Strule River sample groupings (Figures F-10 and F-11). Increasing chloride concentrations during winter sampling rounds (i.e., February and December 2017; February and December 2018) appears consistent with elevated loadings to the main Owenreagh River, impacting the main channel of the Owenreagh and then the Owenkillew River downstream of the confluence with the Owenreagh. As these sampling rounds take place in the winter when road salt is applied in the area, it is likely that increased chloride seen during these sampling rounds is the result of increased runoff of road salts into the Owenreagh River.

The Owenkillew River upstream of the confluence and minor tributaries show no increasing trend. The highest chloride concentration is found from sampling location SWN09 (42 mg/l), one of the tributaries to the Owenreagh River. Chloride concentration in the Owenreagh River appears increase with increasing flow (Figure F-12). With further analysis and the likely seasonal impact of road salt on chloride concentrations, the differences in the baseline data is considered to reflect natural variability and does not reflect a trend in chloride concentrations.

Orthophosphate

Orthophosphate concentrations show a statistically significant difference (here, decrease) between baselines in the Owenreagh River tributaries (Figure F-13). The majority of values are below detection in the 2017-2019 baseline, but above detection in the 2015-2016 baseline. The highest orthophosphate concentration (0.21 mg/l) is found from sampling location SW07, located on the Owenkillew River upstream of the existing infrastructure area.

Given the influence of detection limits in the analysis and the limited spatial extent of the observed differences, a significant trend in orthophosphate concentrations is not identified with further analysis.

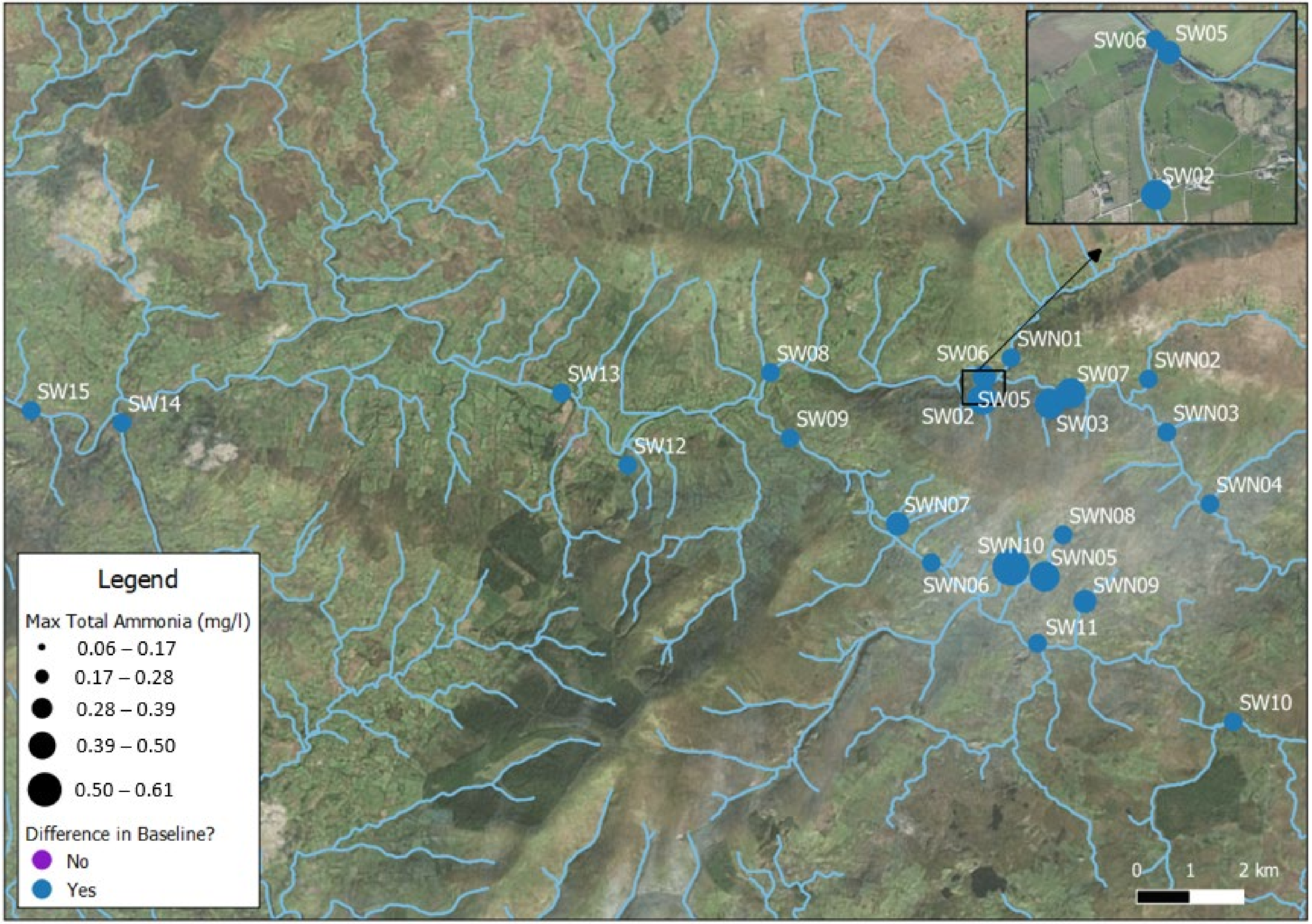

Figure F-1 Spatial distribution of sampling locations showing baseline differences in total ammonia and maximum concentrations.

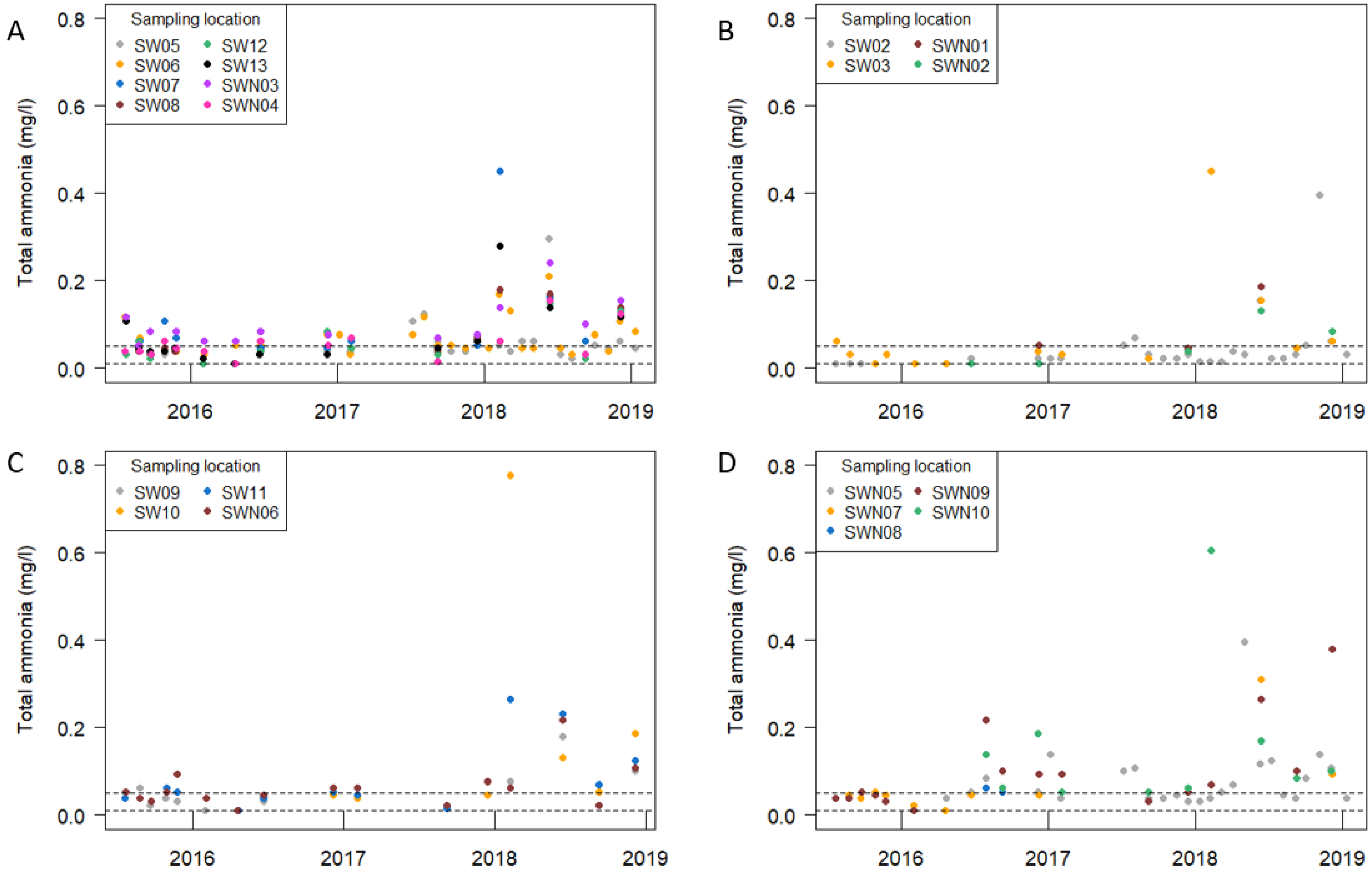

Figure F-2 Total ammonia concentration for the (a) Owenkillew River, (b) Owenkillew Tributaries, (c) Owenreagh River and (d) Owenreagh Tributaries groupings. Sampling locations SW12 and SW13 are plotted in the Owenkillew River groupings. Dashes lines indicate PGV.

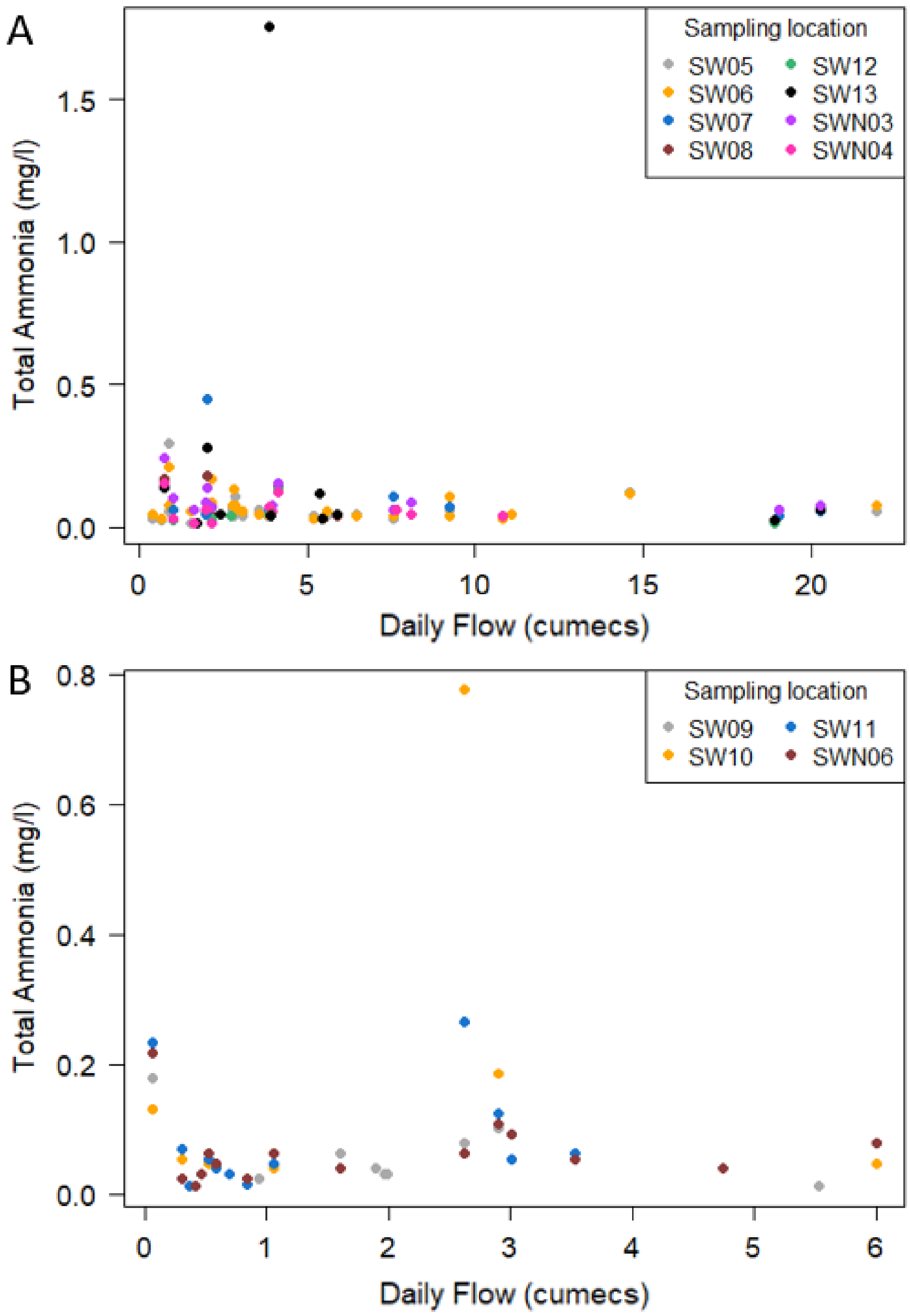

Figure F-3 Total ammonia versus daily flow for the (a) Owenkillew (Gauge FL05) and (b) Owenreagh (FL09) rivers.

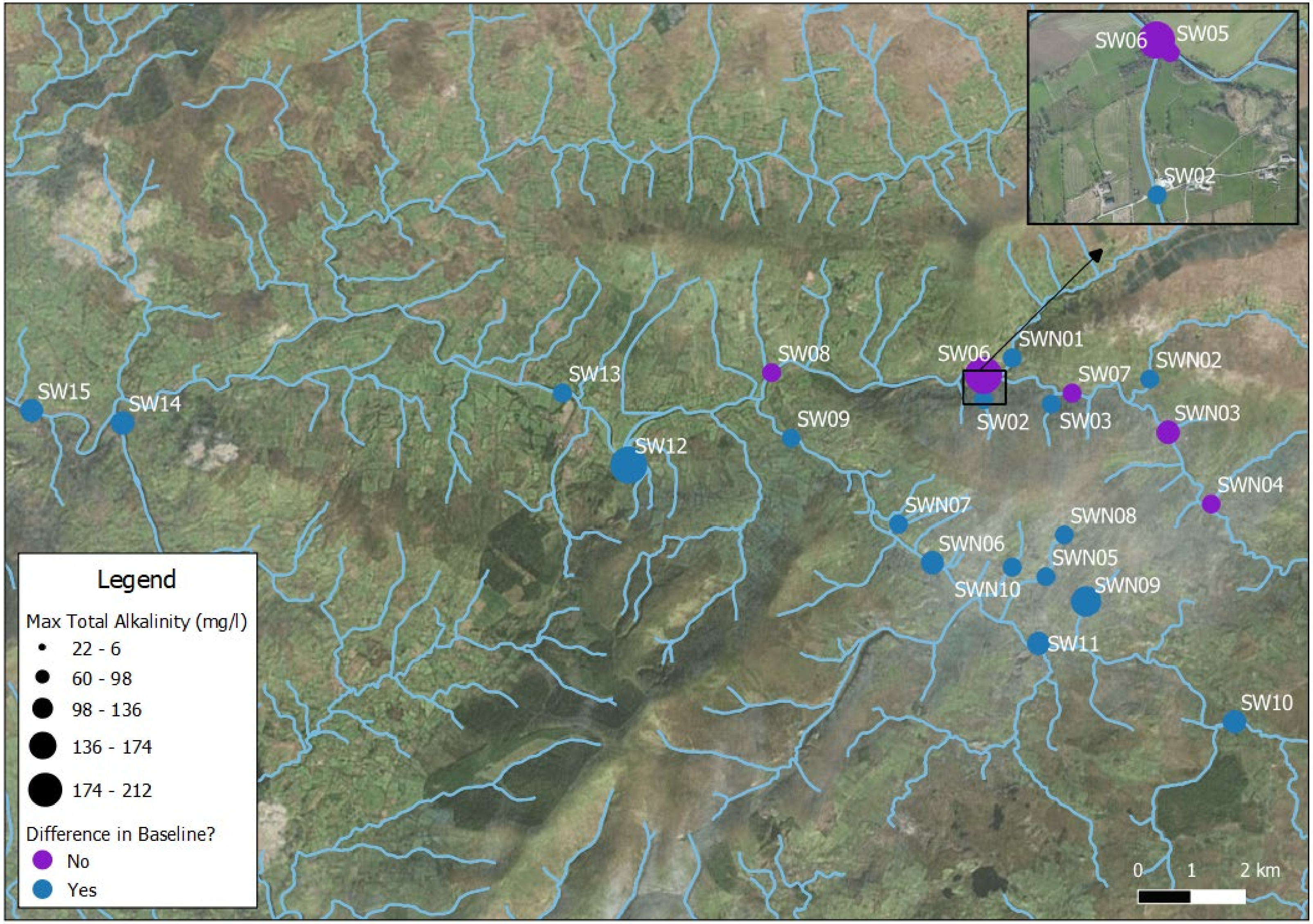

Figure F-4 Spatial distribution of sampling locations showing baseline differences in total alkalinity (as $CaCO_3$) and maximum concentrations.

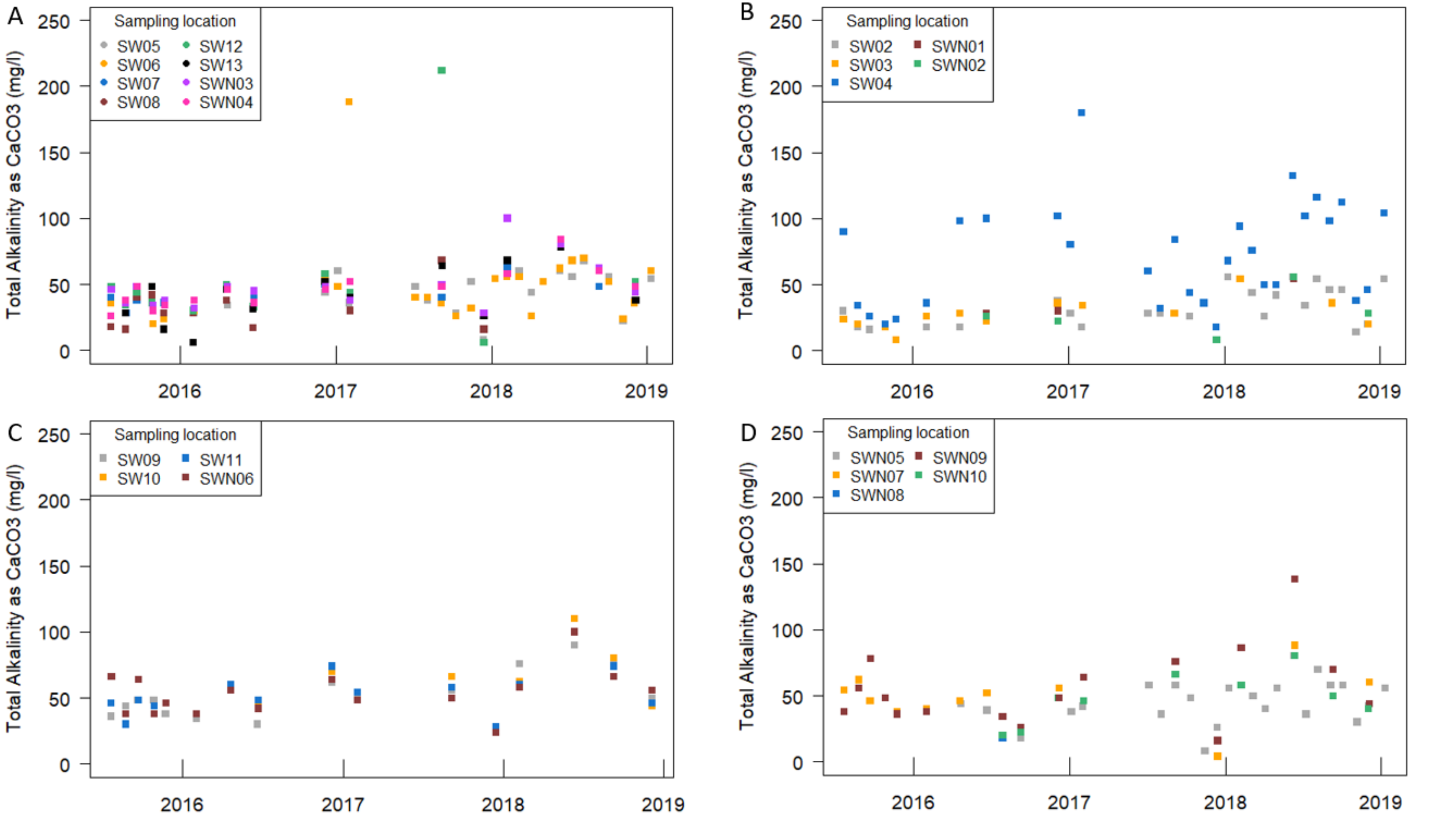

Figure F-5 Total alkalinity (as $CaCO_3$) concentration for the (a) Owenkillew River, (b) Owenkillew Tributaries, (c) Owenreagh River and (d) Owenreagh Tributaries groupings. Sampling locations SW12 and SW13 are plotted in the Owenkillew River groupings.

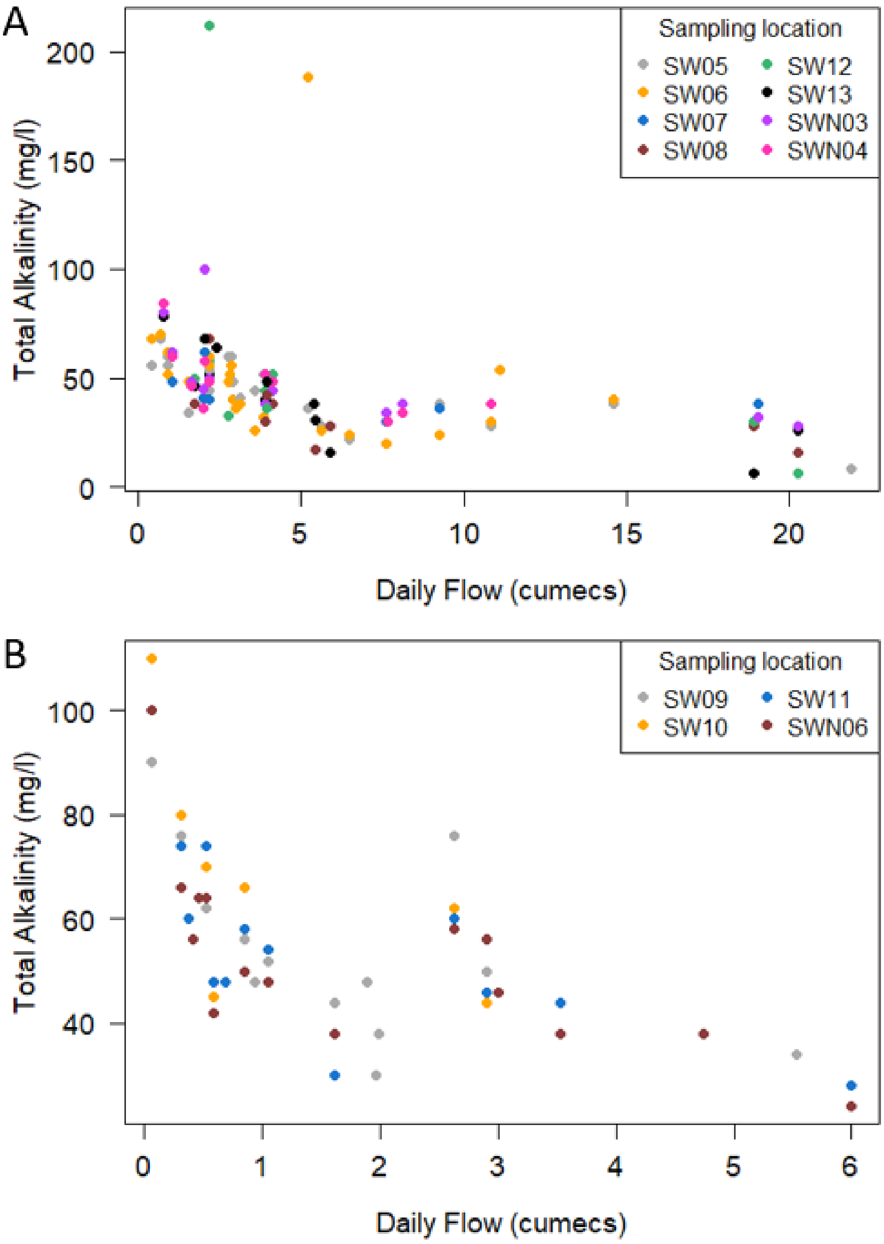

Figure F-6 **Total alkalinity (as $CaCO_3$) versus daily flow for the (a) Owenkillew (Gauge FL05) and (b) Owenreagh (FL09) rivers.**

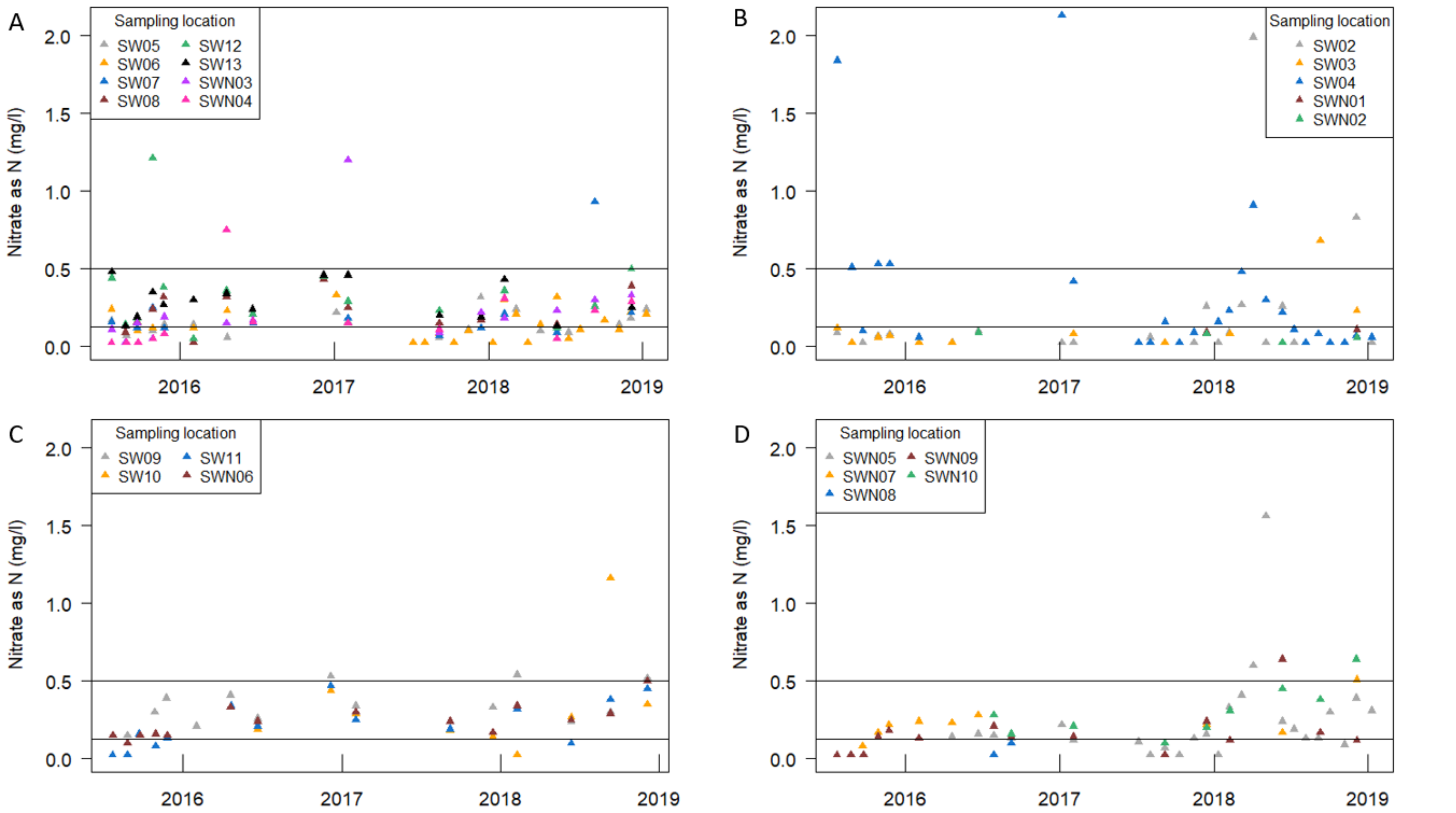

Figure F-7 Nitrate concentration for the (a) Owenkillew River, (b) Owenkillew Tributaries, (c) Owenreagh River and (d) Owenreagh Tributaries groupings. Sampling locations SW12 and SW13 are plotted in the Owenkillew River groupings. Solid lines indicate PGVs.

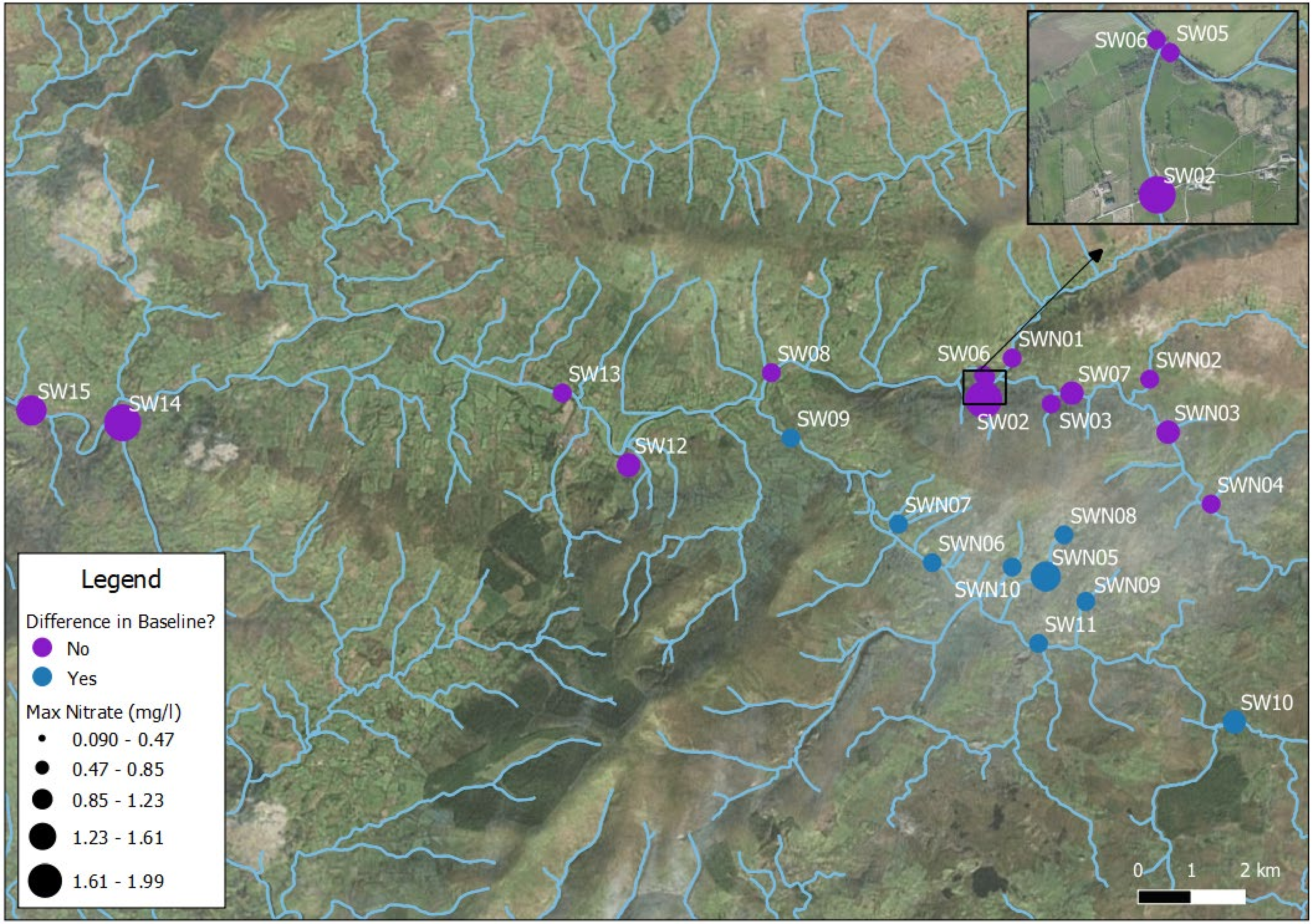

Figure F-8 Spatial distribution of sampling locations showing baseline differences in nitrate and maximum concentrations.

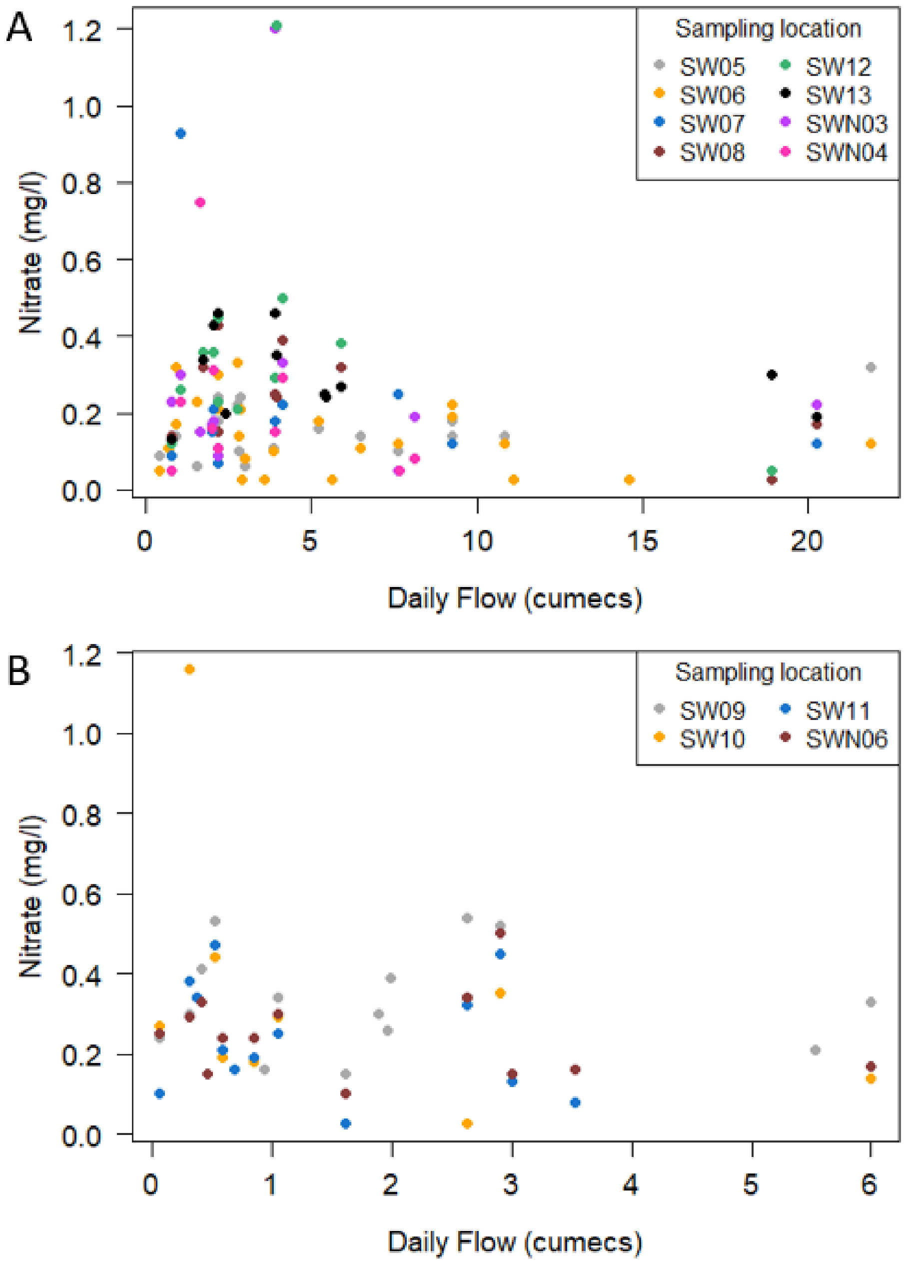

Figure F-9 Nitrate versus daily flow for the (a) Owenkillew (Gauge FL05) and (b) Owenreagh (FL09) rivers.

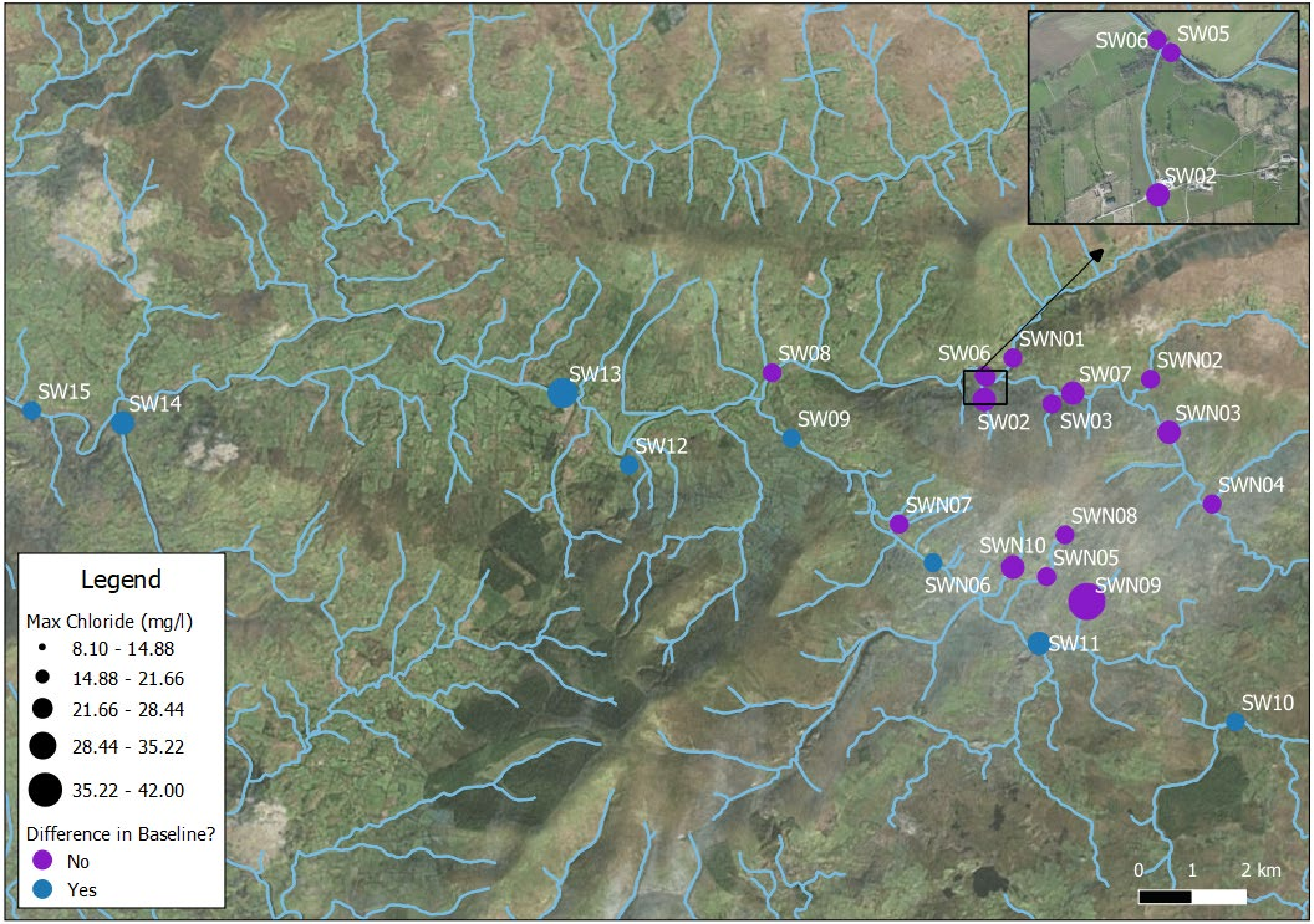

Figure F-10 Spatial distribution of sampling locations showing baseline differences in chloride and maximum concentrations.

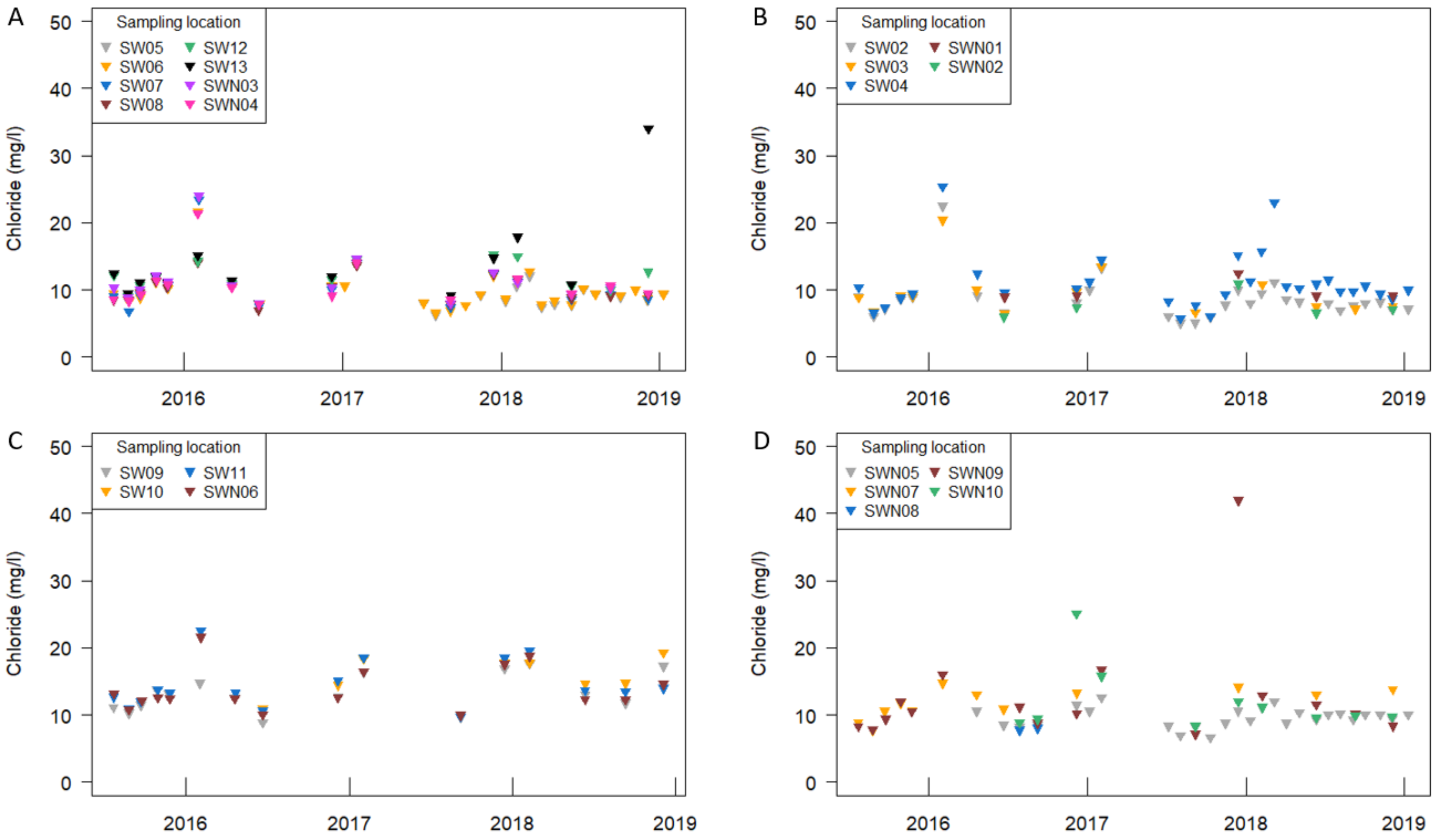

Figure F-11 Chloride concentration for the (a) Owenkillew River, (b) Owenkillew Tributaries, (c) Owenreagh River and (d) Owenreagh Tributaries groupings. Sampling locations SW12 and SW13 are plotted in the Owenkillew River groupings.

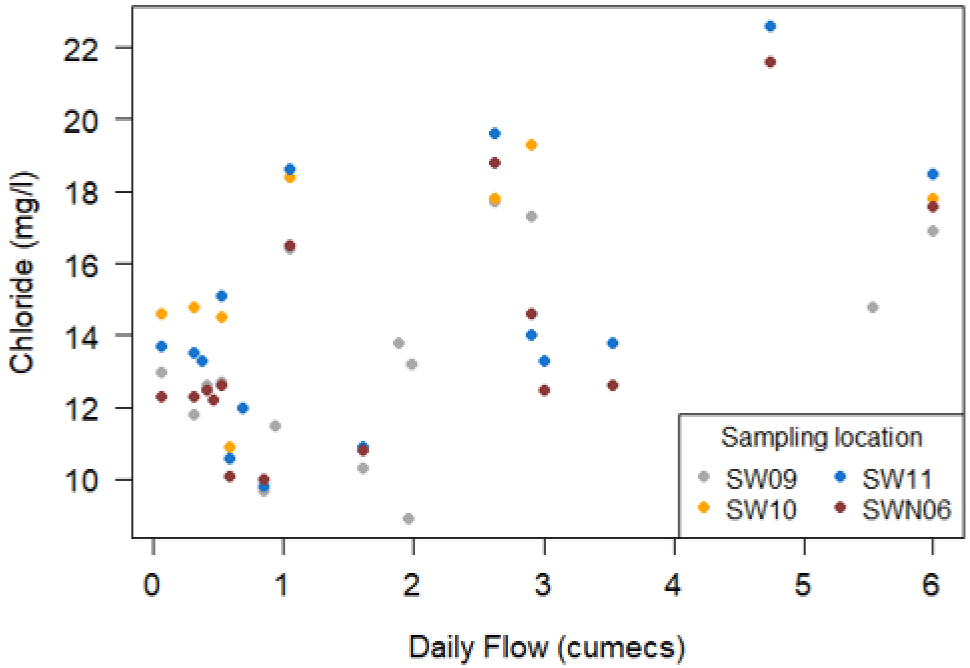

Figure F-12 Chloride versus daily flow for the Owenreagh (FL09) River.

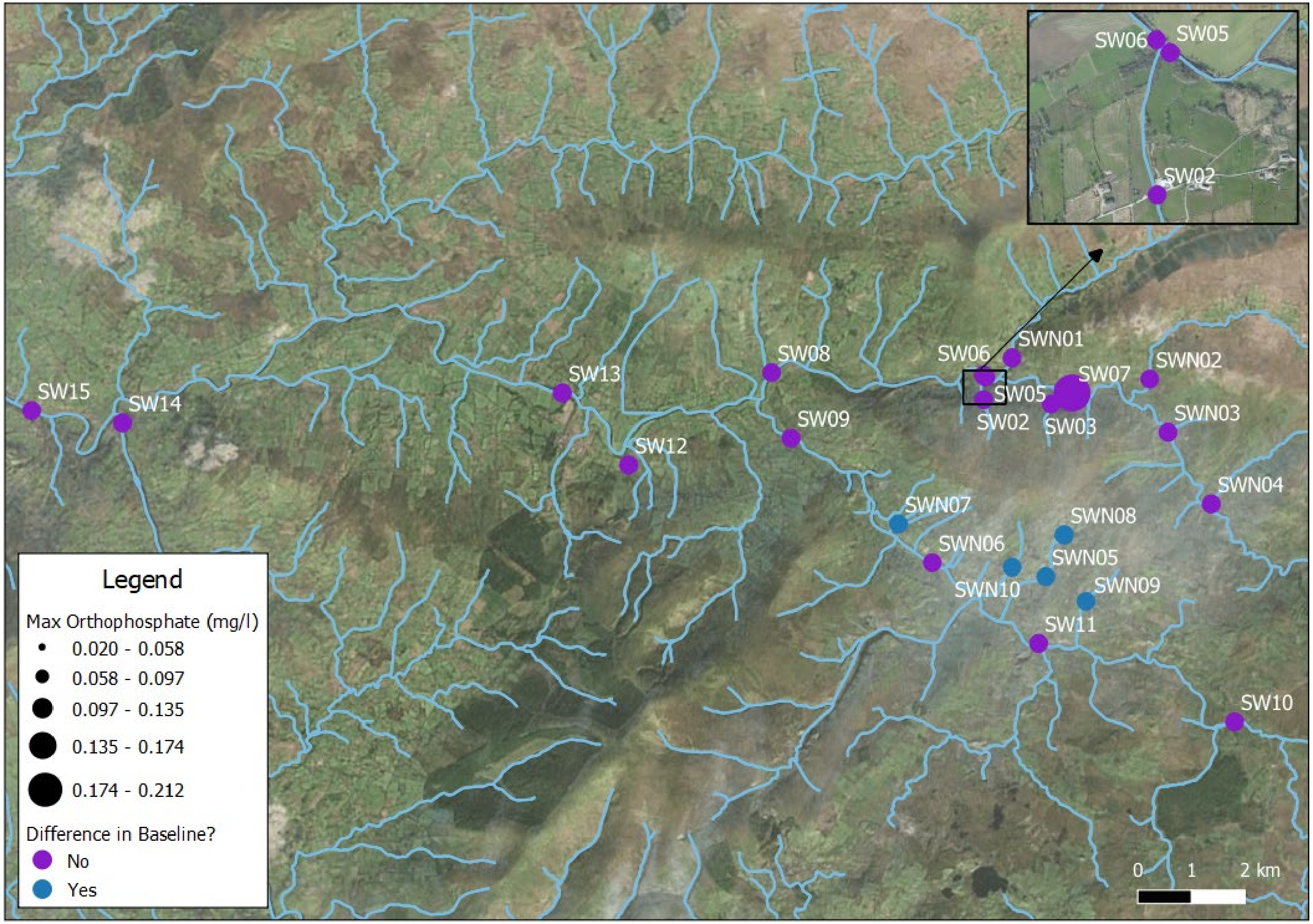

Figure F-13 Spatial distribution of sampling locations showing baseline differences in orthophosphate and maximum concentrations.