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UK-Flow15 Part 1: Development of a coherent national-scale 15-min flow dataset

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Abstract. High-resolution river flow data is essential for modelling flood dynamics and assessing hydrological change. In the UK, there are a wealth of sub-daily flow records that have been collected for more than 70 years. However, they remain scattered across multiple agencies and lack consistent quality assurance, limiting their use for large-sample and national-scale analysis. This paper presents UK-Flow15, a quality-controlled, 15-min, national scale, flow dataset for the UK, based on records from over 1,300 gauging stations and more than 1.8 billion observations. Data were collected via APIs and in conjunction with UK measuring authorities, then compiled into a single national dataset. Duplicate timestamps and inconsistencies in temporal resolution were systematically identified and resolved using a combination of automated filters and manual review. A comprehensive quality-control framework, specifically tailored for the dataset, was then applied to identify and document data anomalies; the full methodological development and evaluation of this framework are presented in the companion paper of this series. The final dataset is accompanied by transparent documentation of flagged issues and a suite of metadata files detailing data resolution, QC outcomes, and all processing decisions to support traceability and user interpretation. We demonstrate the dataset's utility through a practical case study by systematic removal of unreliable data, interpolation of anomalous spikes, and manual verification of significant high-flow and truncation events. These steps illustrate how the dataset can be effectively curated for detailed hydrological research and operational applications. This publicly accessible, robust, and transparent dataset significantly enhances capabilities for sub-daily hydrological research in the UK, offering essential resources for improved flood prediction, management strategies, and policymaking.

1 Background

Understanding large-scale hydrological processes is essential for improving society's preparedness for future and unforeseen events. Tools such as flood maps, produced at the national-scale, are critical for flood risk management, land-use planning, and flood defence strategies (De Moel et al., 2009; De Risi et al., 2020; Porter & Demeritt, 2012; Van Alphen et al., 2009). Likewise, decision support systems for water resources and drought management are typically developed at national or regional scales (Mohammed & Scholz, 2017; Vargas & Paneque, 2019). For both floods and droughts, climate change adaptation strategies also rely on large-scale governance and policies (Hurlbert & Gupta, 2016; Wasko et al., 2021). A common thread in these applications is the need for large-scale hydrological data (Cloke & Hannah, 2011; Hannah et al., 2011; Massei et al., 2020), of which flow data are a key component.

Flow data play a crucial role in representing hydrological processes by aggregating signals from a catchment for a specific measurement point in time, and this data is important for the calibration and evaluation of hydrological models. Direct observations, typically considered the gold standard in hydrology, consist of river stage measurements that are converted into flow estimates using rating curves, or more recently, direct measurements of flow velocity. There is a growing demand for observational flow datasets across large-scales and for large samples of catchments. This demand, driven by advances in computing power and the statistical robustness of large-sample studies, has led to many flow datasets being created at both national/regional and global scales. Observational products, such as the Global Streamflow Indices and Metadata Archive (GSIM - Do et al., 2018) and the UK benchmark network (Harrigan et al., 2018), focus on collecting dispersed direct flow measurements and applying quality control processes to ensure robust and consistent datasets. Alternatively, catchment hydrology datasets, such as the CAMELS family (e.g. Chagas et al., 2020) at the national scale and CARAVAN at the global scale (Kratzert et al., 2023), are designed to merge flow observations with other datasets, like precipitation time series and catchment attributes, to facilitate large-sample hydrological analyses. However, most of these products are limited to coarser, daily temporal resolution, with no sub-daily datasets currently available for the UK.

Nevertheless, the UK has a longstanding practice of recording sub-daily flows, offering untapped potential to advance hydrological understanding, provided the data can be systematically quality-controlled and made accessible. Flow data has been recorded across the UK at a high temporal resolution for more than 70 years with prioritisation in the archives of maintaining high-quality records of annual peak flows, with some of this data extending back to the 19th century. Daily flow records have also been systematically derived and are publicly accessible via platforms such as the National River Flow Archive (NRFA) and large-sample hydrology datasets like CAMELS-GB (Coxon et al., 2020). Both peak flow and daily data originate from continuous 15-min flow series; however, these high-resolution records are comparatively less accessible and are generally perceived to be of lower quality due to limited quality control and metadata availability. Consequently, UK flood studies have largely relied on peak flow data for extreme event analysis (Formetta et al., 2021; Hammond, 2021; Hannaford et al., 2021; Rodding Kjeldsen & Prosdocimi, 2023), and on daily data for continuous hydrological modelling (Hannaford et al., 2023; Lane et al., 2022; Lees et al., 2021).

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The lack of a reliable, quality-assured high-resolution flow dataset has hindered investigations of sub-daily hydrological processes, creating a significant gap in UK hydrology research (Fileni et al., 2023). The use of coarser temporal resolutions in hydrological simulations results in the omission of key physical processes, such as the signatures of convective storms (Fowler et al., 2021) and of walls of water (Archer et al., 2024), which can only be captured at sub-daily timescales. Recent events, such as the catastrophic flooding of the River Turia in Valencia—where >500 mm of rain fell in just 8 hours(Green et al., 2025), illustrate the importance of high-resolution rainfall and flow data. While localised rainfall events of this scale have not yet been recorded in the UK, even autumn/winter flood events, e.g. 2009 floods in Cumbria, showcase the need for high-resolution UK flow data. During the 2009 event in the Derwent catchment, Derbyshire, over 100 mm of rainfall was recorded in 6 hours, and nearly 400 mm fell within 36 hours (Stewart et al., 2012), illustrating that sub-daily flow data are critical for understanding flood wave dynamics in affected catchments (Miller et al., 2013). Furthermore, with climate change projected to increase the frequency and intensity of sub-daily rainfall extremes globally (Fowler et al., 2021), the need for high-resolution hydrological data will become even more critical.

The lack of sub-daily flow data has direct implications for flood risk policy and planning, yet the issue is often circumvented rather than addressed directly. For example, statistically based approaches rely solely on annual maximum flows to estimate extreme return period events (Kjeldsen, 2007); existing models used to estimate extreme flows are often calibrated using high-resolution data, but only for a limited number of catchments (Wallingford HydroSolution, 2019); and climate change adaptation relies on projections derived from daily-resolution data (Kay et al., 2021). These approaches area particularly problematic in catchments smaller than 100 km², where flood peaks typically occur over timescales of minutes to hours, evidenced by their sub-daily time-to-peak (Kjeldsen, 2007). Relying on daily-averaged flows in such contexts can lead to significant underestimations of peak discharge (Beylich et al., 2021; Yu et al., 2018). Given that most planning applications in the UK involve small catchments (Fileni et al., 2025a), there is a pressing need to revise current guidance and flood estimation methods to account for sub-daily hydrological variability.

For many years, the accessibility of high-resolution data has been a barrier. Obtaining continuous 15-min flow records typically required direct requests to individual measuring authorities, limiting their use to specialised studies. More recently, however, initiatives by UK measuring authorities have improved access to high-resolution flow data. APIs such as the SEPA Time Series Data Service and the Environment Agency Data Explorer now provide 15-min resolution hydrometric data for Scotland and England, facilitating research and model development. Yet, despite this progress, quality assurance is still carried out at the local level, resulting in inconsistencies in data values, quality control practices, and associated metadata for large sample datasets.

Recognising the critical need for high-resolution flow data at a national scale, we have created a dataset tailored to support reproducible, high-quality hydrological research in the UK. Reproducibility and transparency remain persistent challenges in

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the scientific community (Baker, 2016; Wilkinson et al., 2016), and hydrology is no exception (Stagge et al., 2019). To address these challenges, this work emphasises clear documentation of data provenance, processing decisions, and quality-control outcomes, enabling users to evaluate data suitability and apply the dataset confidently across a wide range of hydrological applications.

This paper describes the development and contents of UK-Flow15, a national 15-minute river flow dataset for the UK. It begins in section 2 by describing the data received and the sources used to compile a coherent national 15-min flow product. In section 3, the methods used to produce the dataset are then outlined. This is followed in section 4 by a comprehensive description of the resulting dataset and the tools made available to audit and evaluate its contents. In section 5 we demonstrate how these tools can be used to curate the dataset for a specific case study on high flows. Finally, in section 6 we draw some conclusions.

2 Overview of the data available

2.1 High Resolution Flow Data

To compile the largest dataset possible, we collected data from the major measuring authorities without restrictions on date range, seeking to obtain records from the earliest available date up to the present-day. Data were acquired via two methods: direct download from APIs, where available – such as for all stations from the Scottish Environment Protection Agency (SEPA) via their timeseries data service (Scottish Environment Protection Agency, 2025), and most stations from the Environment Agency (EA) – via the Hydrology Data Explorer (Department for Environment Food & Rural Affairs, 2025). For EA stations not accessible through the API, data were obtained with the assistance of agency staff. Data from Natural Resources Wales (NRW), the Department for Infrastructure, Northern Ireland (DfI) and the UK Centre for Ecology and Hydrology (UKCEH) were also acquired through direct communication with the respective institutions.

In total, data for 1369 flow stations was compiled, with 941 from the EA, 286 from SEPA, 93 from NRW, 40 from DfI and 9 from UKCEH, totalling slightly more than 1.8 billion observations. We limited the dataset to stations with a National Identifier (National River Flow Archive ID) to avoid potential confusion in nomenclature or the creation of a new identifier. The NRFA ID is a six-digit code: the first three digits corresponding to the hydrometric area (National River Flow Archive, 2014) where the station is located, and the last three digits identifying individual catchments within that area.

The stations had on average 40 years with data, with the earliest high-resolution records dating back to 1948. Since then, the number of flow stations in the UK has grown substantially (Figure 1.a). The expansion of the network has been closely linked to funding initiatives. Notably, the Water Resources Act 1963 (c.38) and consequently, the formation of the Water Resources Board enabled the approval of grant-aided hydrometric schemes, which facilitated the rapid increase in the number of gauging stations from the 1960s to the 1980s. Since the 1990s, however, network growth has stagnated, despite a continued net increase,

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fewer new gauges have been commissioned, and some existing stations have been decommissioned. Spatially, stations are concentrated in densely populated areas and along major rivers (Figure 1.b). The Thames catchment, hydrometric area 39, has the highest number of measurement stations – 125 stations; while remote regions and smaller rivers often have very little data available, such as the Wick River in northern Scotland, hydrometric area 1, which has only one measurement station.

The dataset covers a wide range of catchment sizes, from less than 1 km² to nearly 10,000 km². Over 80% of stations lie within catchments between 10 and 1,000 km², with more than 60% concentrated within the 50–500 km² range (Figure 1.c). Smaller catchments are underrepresented due to limited instrumentation, caused by several factors, such as cost-effectiveness of small-catchment telemetry, as well as logistical challenges including restricted access or limited signal availability.. Meanwhile the number of large catchments is naturally constrained by geography.

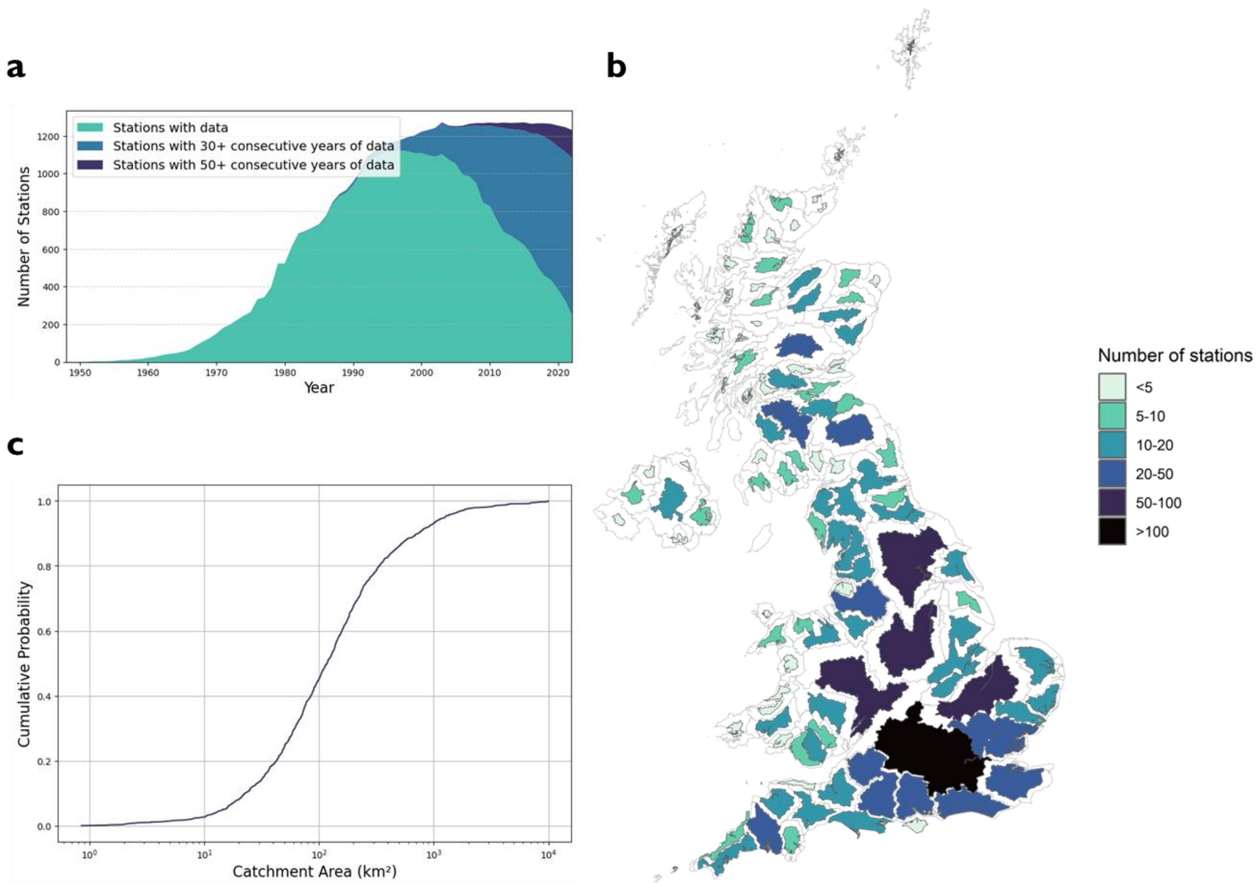

Figure 1: Dataset by (a) Temporal distribution: stacked area chart with the number of stations with more than 0|30|50 years with data in a row; (b) Spatial distribution: cartogram representing the density – the closer the fill is to real size the denser the region is, and number of stations in each hydrometric area of the UK; (c) Catchment area: cumulative distribution function of catchment sizes.

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It is important to note the heterogeneity of the dataset. Flow data are managed by local measuring authorities — a sub-branch of the national authority— leading to variations in measurement standards. Key examples are the number of decimal places and the quality code for the flow measurements used. Instrumentation is also varied, while most stations still rely on traditional methods such as velocity-area techniques, weirs, and flumes, a significant number also use ultrasonic sensors or other devices (see also Coxon et al, 2015). In some cases, a mix of several techniques, either due to changes in instrumentation during the station's lifespan or the use of different types of instruments for different flows, e.g., a weir for low flows and an ultrasonic gauge for high flows. Data recording systems have also evolved. Currently, all the data is digitally logged at fixed intervals, while older records – up until the 2000s and all pre-1980s data – were recorded using analogue equipment such as paper charts or punch tape recorders. During digitisation, some stations had different data versions, with what was called an irregular (EA) or 0s (NRW) version, featuring instances of instantaneous measurements at irregular timesteps smaller than 15 minutes, alongside a constant record with equal timesteps, designated as '15-min'.

2.2 Auxiliary Datasets

In addition to the 15-min data that is the focus of our study, other UK datasets were used for the purpose of comparison and validation of the data. These data are freely available and downloadable from the National River Flow Archive (NRFA), and consists of the following:

- **Daily flow timeseries:** Used to determine whether there is agreement between the 15-min series and the product derived from it, in the daily NRFA data.
- **Annual maxima (AMAX) and peaks over threshold (POT) series:** Manually curated high-flow series commonly used in UK hydrology, employed here for cross-validation.
- **Catchment average daily rainfall series:** Used for further quality checks and to assess the temporal alignment between rainfall and flow events at each station.

3. Methods for creating a national coherent product

The data collected varies significantly in quality and organization level. The decentralized nature of data collection and storage in the UK poses significant challenges for curation, requiring considerable effort to compile a coherent national dataset. In the following steps, we focus on ensuring that all stations meet a minimum standard and are compiled in a consistent format. At the individual station level, it is essential to ensure that each data instance has a single, continuous time series without duplicated data.

3.1 Uneven resolutions

Although most UK flow data is recorded at a 15-min resolution, older records were often recorded at different time-intervals. These are the most common occurrences of data not at 15-min resolution:

- Pre-2003 data has some instances of data at coarser resolutions: most commonly hourly, but also at 30-min, 45-min, 2-hr, 3-hr, 4-hr, 6-hr, 12-hr and daily intervals.
- Small gaps in records, where one or two timesteps are missing.
- Inconsistencies caused by timestamps of 23:59:59 appearing instead of or alongside 00:00:00 – most often occurring in older records.
- Records with higher uneven resolution during a high-flow event – these records originate from the irregular-timeseries files (records pre-2003) – some of the measurements were digitized with non-uniform time steps, not following any pattern.

We have focused on producing a dataset with uniform 15-min intervals, as this is the most common and highest continuous resolution available. For interpolating data of finer resolution than 15 minutes, we used the average of the values as this preserves the flow volume closest to the original records. Furthermore, when higher-resolution data exhibits constant values over multiple records, these are not treated as missing but instead flagged for their non-standard resolution.

3.2 Checks on duplicated datetimes with different flow values

Due to historical storage practices, some stations have overlapping records stored in multiple files, typically "irregular" time series alongside standardised 15-min data. In such cases, duplicate timestamps sometimes contain conflicting flow values, often resulting from updates applied to only one version.

These discrepancies were manually reviewed as there was no discernible pattern for their occurrence. Some files displayed prolonged periods of duplicated data; others displayed short periods (hours to months) with divergences, usually around 2003–2004; furthermore, recurring issues could appear consistently at specific times over extended periods; finally, in certain cases, the discrepancies seemed to result from the application of different rating curves across the two files. Although most discrepancies were minor and had limited analytical impact, the most accurate version of the data was retained using the following criteria: first a comparison was made with the other UK products – the flow series that most aligned with NRFA AMAX or POT values was kept. If no AMAX or POT values were recorded, the series with better alignment to NRFA daily values was kept. Quality codes from the measuring authority were also used when evaluating the decision, with 'Good' quality codes being prioritised. Finally, if no other indicators were available, the most recent dataset was kept.

3.3 Assuring data quality

Historical flow records are inherently complex and often inconsistent. While our aim was to make as much data publicly available as possible, it was also essential to identify records that may be unsuitable for specific types of analysis. To ensure the reliability of the dataset, we used a combination of manual review and automated checks to identify suspect data. Instead of removing or altering observations, we adopted a flagging approach designed to maximise transparency, minimise subjective

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decisions, and allow users to select the level of curation appropriate for their needs. To achieve this, we developed and applied a structured quality-control (QC) framework tailored to sub-daily river flow data in the UK. The quality control is structured in four parts:

1. **Visual inspection**: Several issues present in historical hydrometric archives cannot be reliably detected by automated routines, as they are often a consequence of undocumented changes in gauges, early digitisation artefacts, or long-term sensor issues. Each station was visually assessed by plotting monthly summaries and the full 15-minute series to identify structural irregularities. The visual checks identified major structural irregularities: truncated values, continuity issues, gaps, and other unusual long-term patterns. With each station assigned an overall classification indicating the extent of the problems.
2. **Verification with other UK products**: We cross-checked the 15-minute data against NRFA daily mean flows and peak-flow datasets (AMAX and POT). These products go through annual quality control procedures and were used as references for detection of potential inconsistencies in the sub-daily archive. Discrepancies between the records, such as mismatched daily totals or peaks not reflected in AMAX/POT, were flagged and documented in the metadata.
3. **Traditional quality control:** We applied a set of automated "traditional" quality-control checks to flag values that are physically unrealistic or inconsistent with expected hydrological behaviour. These routines include tests for negative values and unrealistic flows, relative and absolute spikes in discharge between consecutive timesteps, abrupt drops, recurrent fluctuations in flow over short periods, and both low-flow and high-flow truncations. Together, these checks provide a consistent baseline assessment of data quality across all stations.
4. **High flow quality control:** High flows were screened using a dedicated set of extreme-value checks. We identified outlying events within each station (e.g. annual maxima that were much larger than the rest of the record or exceeded a 0.001 annual exceedance probability from a fitted GEV) and then assessed whether events rarer than 0.1 per year were consistent with nearby gauges and antecedent catchment rainfall. Extreme events that did not coincide with corresponding peaks at other stations in the same hydrometric area, or that occurred without substantial catchment rainfall, were flagged as potentially spurious.

The specific thresholds and decision rules used in these checks were selected following extensive testing, comparison of alternatives, and evaluation of false positives and false negatives. A full description of how each threshold was derived, including sensitivity analyses, parameter optimisation, and justification of the hydrological assumptions is provided in the companion quality control paper (Part 2 – Fileni et. al submitted).

4. Data Records

The high-resolution, quality-assured flow dataset for the UK is supplemented by a comprehensive suite of metadata files and additional information. These materials are designed to support both the application of the dataset in hydrological research and the evaluation of its reliability. The metadata facilitates station identification, flags potential data issues, and provides traceability for all procedures applied to the data prior to release. In the following sections, we describe the contents and structure of these files to support their effective interpretation and use.

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4.1 Observations

Each gauging station is represented by a file consisting of four primary columns designed to facilitate comprehensive data use and quality interpretation. The core data columns are: "datetime" - containing the timestamp in a YYYY-MM-DD HH:MM:SS format - and "value" - column representing containing the flow at the station in $m^3 s^{-1}$. Two additional columns, "resolution" and "QC_code", provide critical information on the observation quality and resolution consistency. The resolution column records the original temporal interval between each observation in minutes. Regular intervals are indicated numerically, for instance, 120 representing a two-hour interval. Special cases include irregular time intervals, which are coded as 0, and intervals with an anomalous one-second gap, coded as 1 (Figure 2). The QC_code column gives information on the checks that were performed on the data, encapsulated within a three-digit numeric code (XYZ). Each digit corresponds to a distinct QC procedure, systematically capturing the potential discrepancies with other UK products, standard QC anomalies, and high-flow event validations (Figure 2).

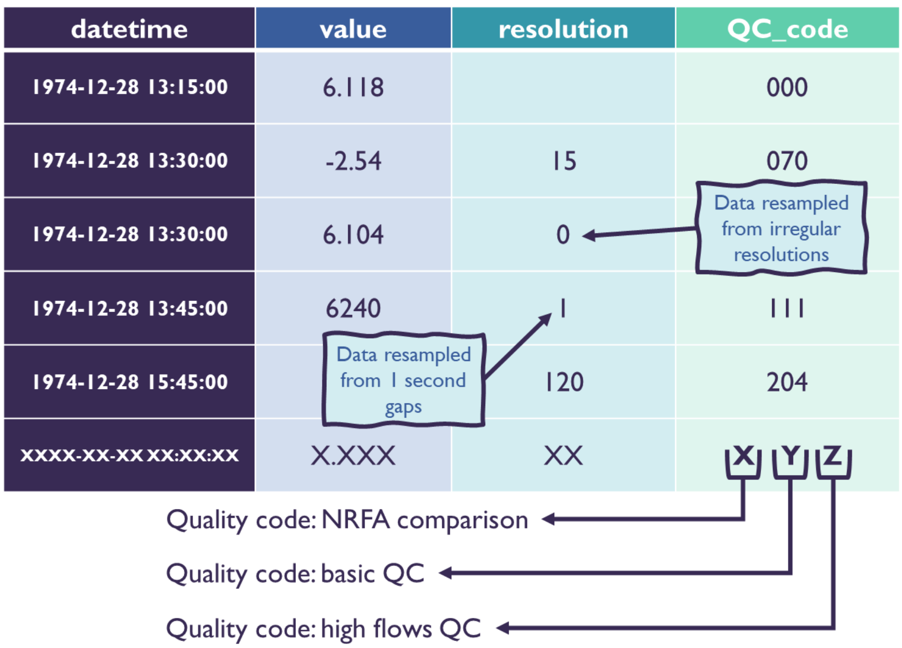

Figure 2: Example of a station flow file with the four key columns

The first digit (X) reflects the consistency of the dataset against established UK hydrological products, specifically daily flows (NRFA daily), Annual Maxima (AMAX), and Peaks Over Threshold (POT) values (Table 1). These codes identify discrepancies exceeding a 5%, for NRFA daily, or a 20% threshold, for AMAX and POT compared to these established references. In the instances that the AMAX and POT flags coincided, the AMAX flag has been given priority as, except for on very rare occasions, the AMAX generally encapsulate POT events, a value based on averaging the top 5 events per year for the station.

Table 1: Consistency Check Codes Against Established UK Hydrological Products

QC code	Meaning
0	Data is in sufficient agreement with other UK products
1	Mismatch >5% between 15-min values and NRFA daily values
2	Mismatch >20% between 15-min values and POT values
3	Mismatch >20% between 15-min values and AMAX values
4	Combination of 1 and 3 — mismatch with both daily and POT values
5	Combination of 1 and 2 — mismatch with both daily and AMAX values

The second digit (Y) indicates any anomalies identified through traditional quality control procedures (Table 2). This includes negative values, relative and absolute spikes, sudden drops, unusual fluctuations, and truncated low or high flows. To effectively handle overlapping anomalies, combined flags, codes 8 and 9, were created, denoting particularly significant issues. Other anomaly types that co-occur were prioritised based on their severity and likelihood of representing spurious data. We found that flow shifts often happen in combination with several flags. Here, as they are a recurrent flag, occurring on several timesteps in a row, we prioritised transient issues (Flags 1 to 4). Sudden drops in flow also received lower priority over spikes (sudden increases in flow) as they represent softer anomalies that are less likely to be spurious data. For guidance on using these codes for data selection, see Section 5.2 and 5.3.

Table 2: Traditional Quality Control (QC) Anomaly Codes

QC code	Meaning
0	No issues found
1	Negative value
2	Relative spike
3	Absolute spike
4	Drop
5	Fluctuation
6	Truncated low flows
7	Truncated high flows
8	Combination of 2 and 3 — relative and absolute spike
9	Combination of 4 with 1 or 6 — drop plus negative/truncated low flows

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The third digit (Z) is related to high flow quality checks (Table 3). We check the plausibility of high-flow events by examining factors such as antecedent rainfall and concurrent high-flow within a regional hydrometric context. Clearly unrealistic events flagged as 1 are assigned the highest priority as these events are spurious. The remaining flags indicate how likely the event is to be real, for instance flag 8 represents a very unrealistic scenario, while other flags, such as 6 and 9, represent very plausible events. For guidance on using these codes for data selection, see Section 5.4.

Table 3: High-Flow Event Validation Codes

QC code	Meaning
0	Not a high flow
1	Unrealistically high event
2	Exceptionally high event
3	Event with >0.1 annual likelihood and no antecedent rainfall
4	Event with >0.1 annual likelihood and no concurrent high flow in the hydrometric area
5	Combination of 3 and 4 - event with no antecedent rainfall | high flows in hydrometric area
6	Event with >0.1 annual likelihood with both antecedent rainfall and concurrent regional high flow - flow is considered "validated"
7	Combination of 2 and 3 or 4 - exceptionally high event with no antecedent rainfall | high flows in hydrometric area
8	Combination of 2 and 5 - exceptionally high event with no antecedent rainfall & high flows in hydrometric area
9	Combination of 2 and 6 - flow is considered "validated"

4.2 Metadata

To ensure clarity and usability, metadata has been separated into thematic files grouped into three categories: Station identification, quality control, and traceability metadata (Table 4). All metadata files are linked using the Station ID corresponding to the NRFA station identifier.

Table 4: Description of every available metadata file from the quality control procedure

Section	File	Description
Station identification metadata	station_id_meta	Provides essential context for each gauging station, including station name, river name, UK national grid coordinates (Easting and

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		Northing), the number of missing values, start/end dates of the 15-min record and the NRFA quality status.
Quality Control metadata	visual_inspection_anomalies_meta	Identifies stations with truncations, issues on continuity and some specificities that could be visually verified.
	uk_products_meta	Comparison between the 15-min series and the other UK products: NRFA AMAX, POT and daily series
	traditional_qc_meta	Results of the traditional quality control procedure.
	high_flows_qc_meta	Results of the high-flow quality control procedure.
Traceability of procedures metadata	resolution_meta	Identifies stations where different, non-15-min, timesteps occur.
	duplicates_meta	Identifies the stations that had timesteps where two merged periods had different values, together with the decision taken and reasoning for the decision

4.2.1. Station Identification Metadata

The key objective of the information metadata is to provide information that allows the user to identify the station in the national context. It aims to provides a global perspective on the data and the specific data issues of each station. The start, end date and missing values were derived from the 15-min flow series whilst the remaining information was extracted from the NRFA database of stations.

4.2.2. Quality Control metadata

The file 'visual_inspection_anomalies_meta' contains the results of the visual inspection.. For each station, identified issues are annotated with codes. These codes are designed to standardise the classification of issues affecting the continuity, integrity, and usability of time series data. They follows a name convention structured as '[scope]_[issue_type]_[confidence_level]' (Table 5), where: scope refers to the portion of the time series affected, using full to describe the entire record and partial, a subset of the record; issue_type indicates the nature of the problem, including continuity, truncation, short timeseries and traces of data; confidence_level qualifies the degree of confidence in the assessment: confirmed, precautionary, or suspected. Further detail regarding each issue is provided in the 'comment' column of the metadata for every station. If the issue is confined to a particular segment of the series, the 'split' column identifies the year when the issue begins or ends, offering temporal context for partial-quality concerns. For guidance on using these codes for data selection, see Section 5.1 below.

Table 5: Summary of all the codes used to classify the visual inspection anomalies checks

Code	**Issue**

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full_continuity_confirmed	The entire time series exhibits clear continuity issues, such as abrupt changes in flow regimes or prolonged gaps inconsistent with expected patterns.
partial_continuity_confirmed	A distinct portion of the time series has evident continuity issues or there are two very distinct segments in the dataset
partial_continuity_precautionary	Continuity issues are not definitively confirmed but likely enough to warrant caution.
partial_continuity_suspected	The time series presents features suggestive of continuity issues, but the evidence is not sufficient for a definitive judgment.
full_truncation_confirmed	The entire record shows clear signs of data truncation.
partial_truncation_confirmed	Truncation affects a specific part of the time series.
full_truncation_suspected	Truncation of the timeseries is suspected but not confirmed.
full_shorttimeseries_confirmed	The time series contains fewer than five years of data, limiting its suitability for robust hydrological analysis.
partial_tracedata_confirmed	The dataset includes short, disjoint traces of data prior to the main period of record; these are often of limited value or contextually ambiguous.
full_other_issues_confirmed	The entire time series is affected by issues not captured by other categories, such as noise or anomalous variability
partial_other_issues_confirmed	A segment of the time series is affected by unclassified issues
full_other_issues_suspected	Suspicion that a segment of the time series is affected by unclassified issues

The file 'uk_products_meta' documents discrepancies between the 15-min dataset and the corresponding NRFA products.Additional to the timestep-level QC coding applied within individual station files, this metadata also provides station-level summaries, including information on the periods during which the 15-min series overlaps with the NRFA daily records. While the NRFA daily time series typically span longer periods than the 15-min data, there are cases where the high-resolution records pre-date the earliest available daily flows. To quantify consistency, three summary metrics are reported for each station: the median (med) and maximum (max) percentage differences between the 15-min and NRFA values, and the threshold value, which indicates the proportion of 15-min observations that deviate from the NRFA series by more than an established percentage.

The 'traditional_qc_meta' file presents the results of standard anomaly detection procedures corresponding to the Y-digit of the QC code described earlier. While the Z-digit QC codes within the data files provide a summary classification for extreme high flow events, the 'high_flows_qc_meta' metadata file offers a more detailed account of the conditions under which events have been flagged. Specifically, it reports which statistical threshold the event has exceeded to be considered exceptionally high: more than 6 standard deviations from the mean, events above a 0.001 annual occurrence, or maximum events that are

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twice as large as the second largest flow on record. In addition to these statistical indicators, the metadata also further detail checks that assess the hydrometeorological plausibility of each event. The metadata provides guidance on whether another significant event occurred concurrently, either in terms of antecedent rainfall or at nearby gauging stations, and from the ratio test, which evaluates proportional plausibility by comparing the magnitude of the flagged event to that of another event with a much higher probability of occurrence (i.e., check if rainfall occurring for event generation is at least 20 times more likely).

4.2.3 Traceability of procedures metadata

One of the main challenges in producing the dataset was the need to understand the structure of the data received. In the dataset processing, to ensure that the data was both comprehensible and suitable for analysis, it was necessary to apply several modifications but to retain full transparency these were documented in dedicated metadata files. These allow users to trace each processing step, enabling informed use of the data and facilitating scrutiny of the resulting dataset.

In 'resolution_meta' we provide information to help understand the resolution of the data in the original data files; specifically, where non-15-min records occur. Steps at higher resolution than 15 minutes that have been interpolated are tracked as two types: sub-15-min steps, where records occur at irregular intervals between the expected quarter-hour timestamps (Figure 3.a); and 1-second-resolution steps (Figure 3.b), where a timestamp appears exactly one second before or after an expected quarter-hour time.

Furthermore, the resolution metadata also aims to complement the basic metadata on missing data, providing information on different data resolutions and large gaps in the timeseries. The following columns have also been made available as part of the dataset: The number of steps with sub-hourly resolution are steps that had a resolution smaller than 1 hour but bigger than 15-min (Figure 3.c); The number of steps with hourly resolution represent steps that had a resolution of one hour (Figure 3.d); The number of steps with super-hourly resolution are steps that had a resolution bigger than 1 hour (Figure 3.e); The number of gaps in the timeseries: represents the number of times a timeseries presented a gap in resolution (Figure 3.f); The biggest gap in the timeseries (min) showcases the largest gap occurrence, e.g. station 7004 (Figure 3.f) has a max a gap of 240 minutes..

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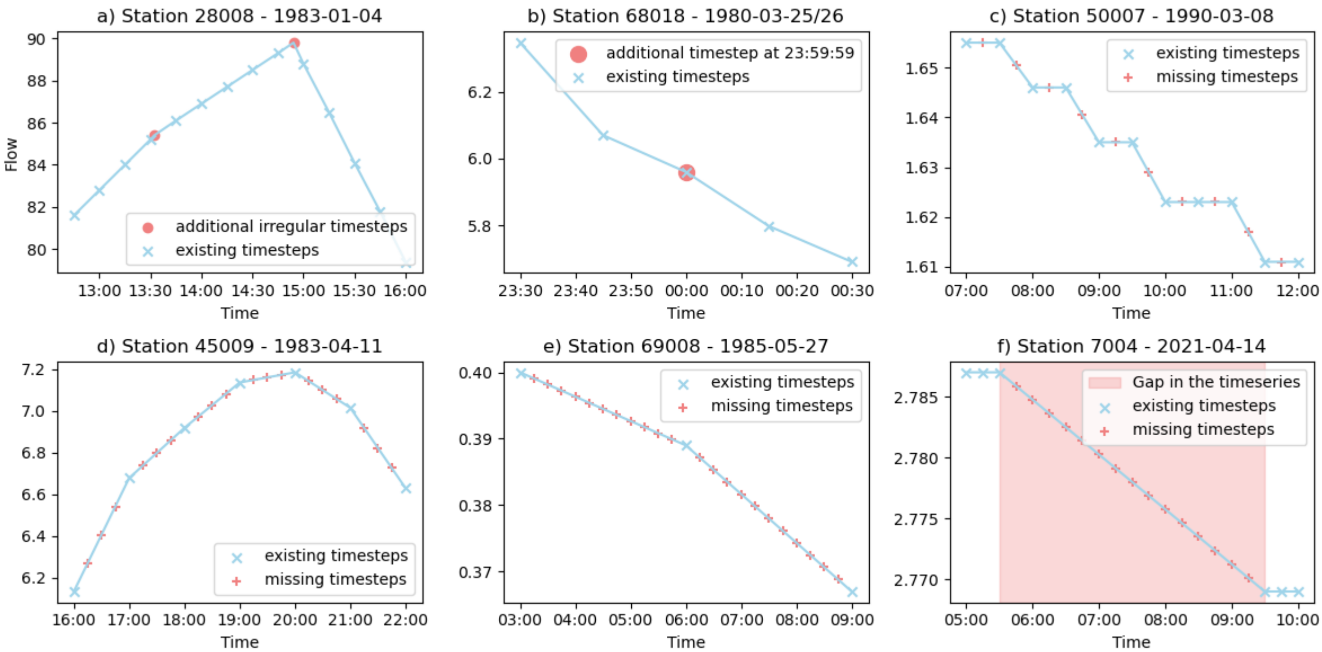

Figure 3: Examples of artifacts communicated in resolution meta: a) Station with additional irregular timesteps; b) 1s resolution timesteps; c) Sub-hourly gaps; d) hourly gaps; e) super hourly gaps; f) gap in the timeseries

For many stations, multiple data files were provided, and in many cases these files contained data with different values for the same period, these files are recorded in the 'duplicates_meta' file. The 'keep' column documents which version has been retained, with a rationale provided in the 'comment_keep' column. An 'API' value means that the kept value was extracted from the series available online in the Environment Agency Hydrology Explorer, while 'Irregular' means that the value kept came from an Irregular timeseries file, obtained through a FOI request.

5. Usage Notes: Example of File Preparation for High Flow Analysis

As acknowledged, the flow dataset is provided in full, without the removal of suspicious data or, in some cases, issues that may influence specific types of analysis. To support users in making informed decisions about which stations and data to include based on their study objectives, extensive metadata on data quality issues is provided. We now present an example of a rule-based application to the dataset, specifically aimed at removing spurious high-flow events in a time series spanning from 1990 to 2023. Following the checks outlined in this section, we consider the station ready for high-flow analysis.

5.1. Usage of the visual metadata to remove stations with relevant issues on high flows

As part of the dataset curation process, we used the visual inspection anomalies metadata file to identify and exclude stations with major high-flow data issues. The 'issue classification' column was used to flag potential artefacts affecting high flows,

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while the 'comment' column provided station-specific descriptions that we reviewed to verify and contextualize each issue. The 'split_year' column, which records the year an issue was observed or believed to have ended, helped determine whether the issue occurred within our study period (1990 to 2023).

Based on this information, we made decisions to fully remove, partially remove, or retain data for each station. Stations clearly exhibiting full truncation, identified by the code 'full_truncation_confirmed' are systematically removed, as are partially truncated records tagged 'partial_truncation_confirmed'. Additional issues related to data continuity: 'full_continuity_confirmed' and 'partial_continuity_confirmed'; and other major anomalies: 'full_other_issues_confirmed' and 'partial_other_issues_confirmed' were reviewed, though no cases of the latter are observed in the analysed period. The following paragraphs present examples of our approach.

A decision then has to be made based on the visual metadata comments to completely remove a station or to only partially exclude data. Stations 41009 and 39106 are removed due to full and partial truncations, respectively (Figure 4.a,b). These truncations generally occur when the measuring device reaches the floor of a station, artificially limiting the recorded peak flow and leading to unrealistic peak flow records for analysis. Continuity issues led to the exclusion of data in stations such as 40006 and 40027. From the common check anomalies metadata, station 40006 (Figure 4.c) is known to have extensive problems across the entire record, including three data splits and persistent gauging issues; thus, its entire time series was discarded. Station 40027 also has continuity issues (Figure 4.d), with a gauge transition from a flume to an electromagnetic sensor. While its record is more coherent, the pre-2006 data is distinctly differentfrom the remainder of the series, leading to partial removal of this data. Other stations, such as 39852, exhibit anomalous flow patterns that deviate from the typical pattern of gauged flow data such as having seasonal variations, a stable minimum, and sporadic peaks (Figure 4.e). These stations are also removed.

For stations with partial exclusions, we remove data from all water years prior to October of the split year indicated in the visual inspection anomalies metadata. Additionally, ten stations had no data observed for the selected period and are naturally removed from the analysis. As a result of this quality control, 68 stations have been removed, and another 24 have had data partially removed, leaving 1,301 flow stations in the curated dataset.

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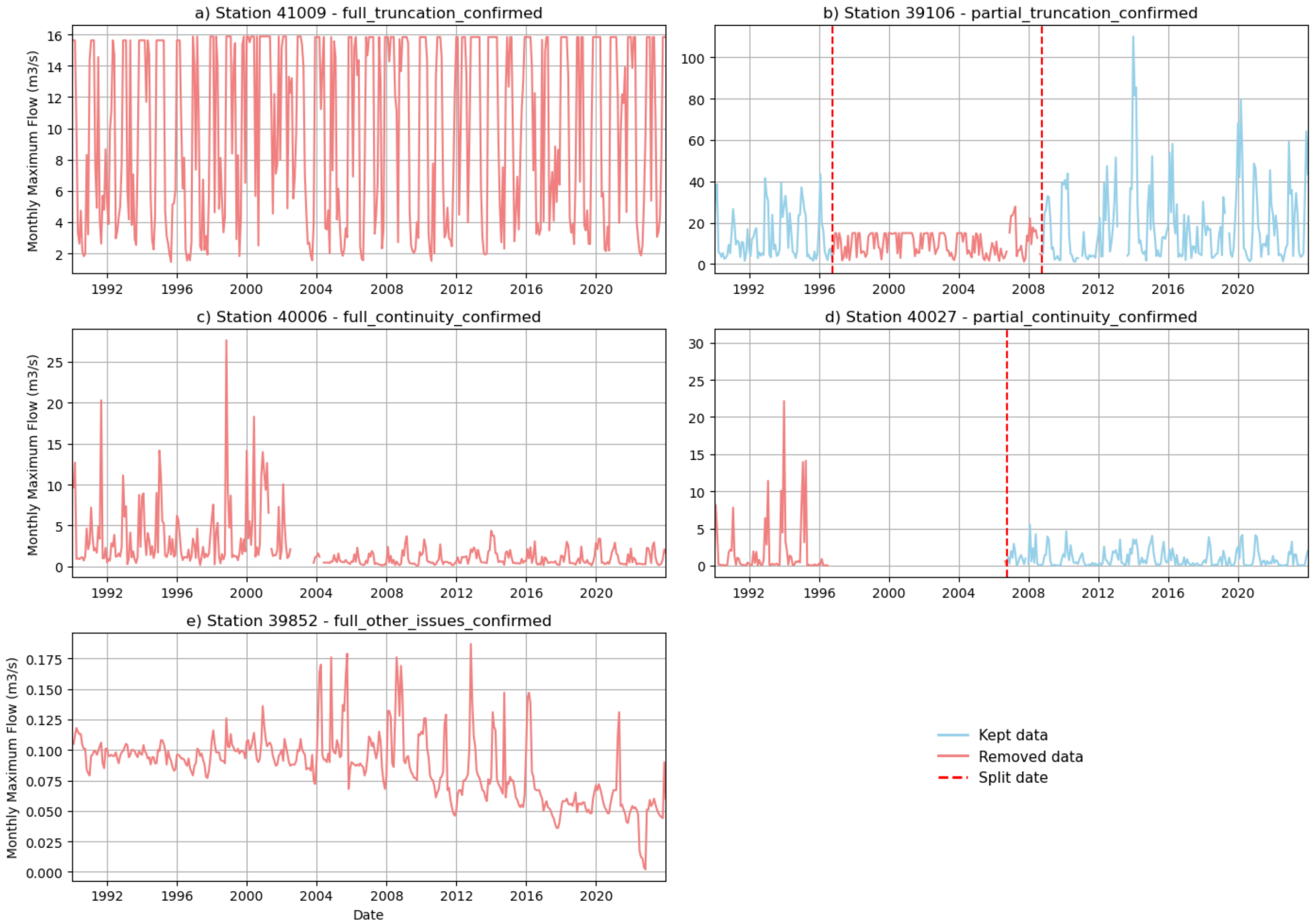

Figure 4: Examples of removed stations from the high-flow dataset curation. Each plot shows monthly flow maxima for the observed period. Subtitles indicate the station ID and associated issue. Red denotes excluded data; blue indicates retained data. The issues are a) full truncations; b) partial truncations; c) full continuity issues; d) partial continuity issues; e) full other issues.

5.2. Interpolation of spikes

Both absolute and relative spikes, i.e. rapid increases and decreases of flows, have been systematically removed then interpolated as part of high-flow dataset curation, based on visual inspection of their characteristics. Three types of spikes are identified: Spurious high-flow values (Figure 5.a); Spurious flows during timesteps unlikely to affect high-flow analyses (Figure 5.b); Plausible low-flow variations flagged by the relative spike QC (Flag X2Z in the timeseries) due to low baseline values (Figure 5.c). The rationale for systematic interpolation aligns with the objective of producing a quality-controlled high-flow dataset. Type 1 spikes have been removed as erroneous data. Types 2 and 3 are not expected to affect high-flow or flood analyses and are thus interpolated for completeness. The outcome of this procedure was the interpolation of a total of 60671 values, the vast majority (72%) only influencing low flows, with values smaller than 1 $m^3 s^{-1}$.

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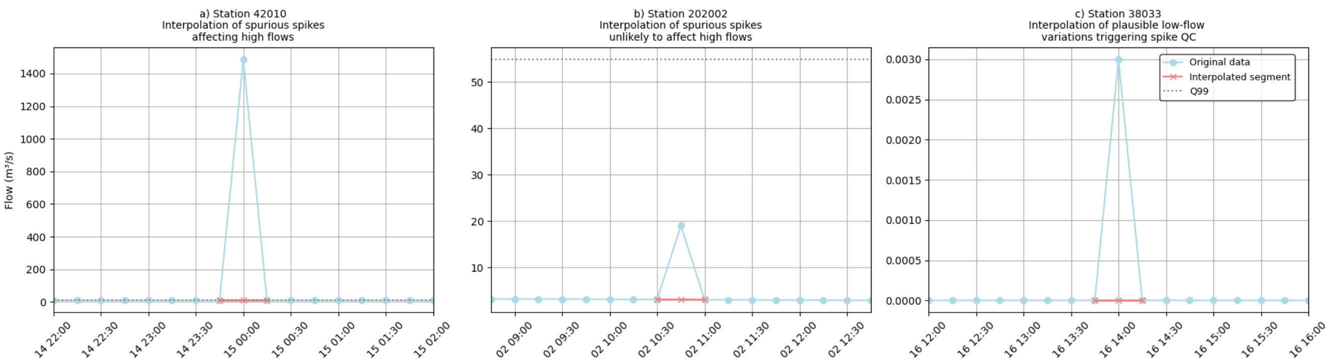

Figure 5: Illustrative examples of Spike Interpolation in High-Flow Data Curation, (a) Spurious high-flow spikes interpolated; (b) low-impact spurious events interpolated; (c) plausible low-flow variations triggering spike QC. Observations are shown in light blue, interpolated points in light red, and the 99th-percentile threshold (Q99) as a grey dotted line, when relevant.

5.3. Verification of high truncation and high flows

High truncations (Flag X7Z - 84 instances) and high-flow values (Flag XY2 - 1490 instances) were manually reviewed. These values required careful assessment, as they could represent genuine hydrological events. Our verification did not focus on the magnitude of the flow but rather on the plausibility of the event shape, specifically, whether it exhibited a realistic hydrograph pattern.

Truncations are common in baseflow-dominated catchments or in systems influenced by large reservoirs. For instance, Station 41033 measures flow in a small catchment with a high baseflow index. In the example there are two truncation events spanning multiple days (Figure 6.a). These were retained as they were consistent with the hydrological behaviour expected from such stations. Two caveats remain for these types of stations: 1) due to the small size of the catchment and the relatively low flow magnitudes, the recording instrument may not be sensitive enough to detect minor variations in flow, which results in truncations over the same value; and 2) in baseflow- or reservoir-dominated systems, flow changes tend to occur over longer timescales, making a 15-min resolution record potentially excessive. In contrast, Station 54014 shows a truncation that is clearly spurious. The flow series possess normal behaviour until a sharp discontinuity around 00:00 on 12 September (Figure 6.b), followed by a flat truncation and abrupt drop. These characteristics suggest instrumentation failure, and this segment and the present and subsequent day were removed.

Stations 28103 and 37024 are examples of stations analysed for having exceptionally high flows, with decisions based on whether the flow patterns appeared hydrologically plausible. Natural flood events typically display a progressive rising limb followed by a gradual recession (Figure 6.c), while spurious records often feature abrupt changes inconsistent with expected dynamics. Figure 6.d illustrates one such example, an abrupt drop from a high value to near-zero flow, highlighting erroneous patterns.

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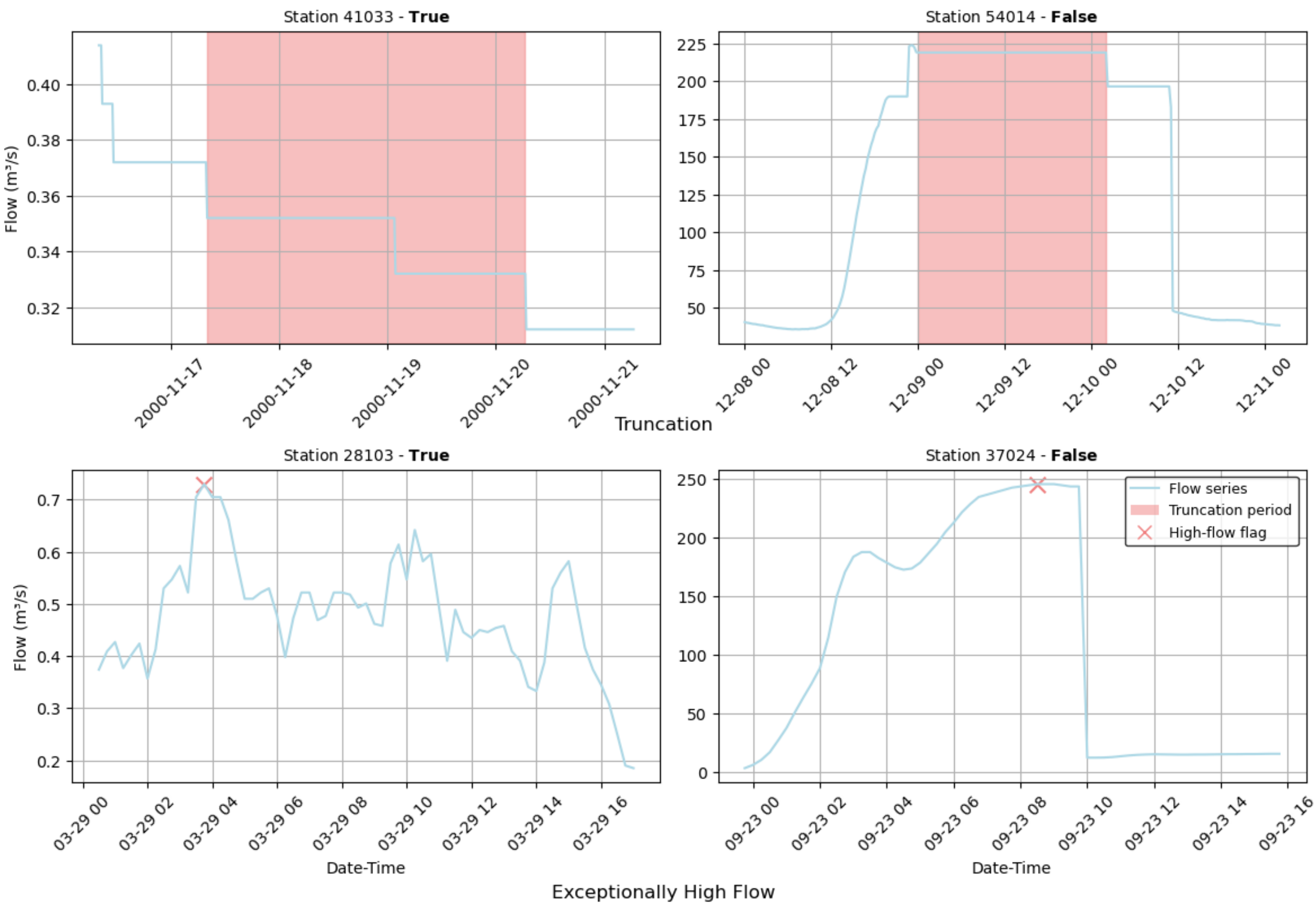

Figure 6: Examples of manual verification of high truncations and high-flow events. On the left a) Station 41033, and c) Station 28103, example of stations where the timesteps were kept; On the right b) Station 54014 and d) Station 37024 example of stations with spurious data that was removed

The manual verification of the flows resulted in the removal of two stations that had high flows truncated and removal of timesteps in other stations that were obviously wrong. As an outcome of the manual verification of truncations, we have removed 19 instances of data, to a total of 9934 timesteps. Exceptionally high flow values verification resulted in the removal of 47 instances of data, and a total of 8078 timesteps.

5.4. Verification of NRFA POT divergencies and high flows hydrological QC

Divergences between the curated dataset and NRFA POT and AMAX (Flags 1YZ, 2YZ, 4YZ and 5YZ) data fall into two categories. Timestamp simplifications are events that occur at various times but are often recorded at 00:00:00 in NRFA data, introducing inconsistencies. Magnitude mismatches are events where NRFA-reported peaks systematically diverge, with either higher or lower flows, than the curated flow time series. These are potential indicators of magnitude flow record errors.

Verification of high-flow QC records (Flags XY3 to XY9) led to the same conclusion: despite possible magnitude inconsistencies, available evidence was insufficient for data exclusion.

Following verification, we retained the divergences with the NRFA POT and AMAX datasets and the flagged data from the high-flow hydrological QC, as the events consistently exhibited realistic hydrological behaviour. Nevertheless, we emphasise that such divergences often occur during specific periods within the time series. These discrepancies may lead to different results for certain types of analyses, including studies of stationarity and model calibration, compared to those obtained using the POT or AMAX series, which are manually curated and generally considered more accurate.

6. Conclusions

We have produced a coherent and standardised high-resolution (15-min) flow dataset for the UK. This dataset consolidates over 1300 stations and more than 50 thousand years of hydrometric records from multiple measuring authorities into a coherent, standardised, and transparent product. Historically, sub-daily flow data in the UK is stored in a decentralised fashion, with inconsistent formatting, and subject to heterogeneous quality assurance practices, factors that have significantly constrained their use in research and operational contexts. We have addressed these limitations through a structured framework of visual inspections, automated checks, and metadata consolidation, producing an readily available and verifiable dataset.

The resulting dataset fills a long-standing gap in UK hydrology by providing a robust, quality-assured collection of high-resolution flow data, enabling national-scale, sub-daily analysis of hydrological processes such as flash floods, convective storm responses, and other short-duration extremes. Furthermore, the accompanying metadata and quality-control layers provide users with the tools necessary to assess data provenance, to identify anomalies, and to tailor the dataset to specific research or operational needs. This level of transparency facilitates reproducibility and supports informed decision-making across a range of hydrological applications. To further support dataset usage, we provide an example of how the quality control metadata and flags can be used to identify suitable stations, and suitable data, for specific hydrological analysis. While this may often be a time-consuming exercise, it is essential to ensure the data used are suitable for the purpose.

While this dataset marks a significant step forward, we recognise these methods to be the initial steps amongst a broader range of potential improvements. First, feedback should be provided to the measuring authorities, particularly for stations flagged with severe issues or missing data, as this may help recover additional data and improve future data provision. Since this is the first time these stations have been systematically audited with the intention of creating a national-scale database, a feedback process is key for the amelioration of data in the UK. Second, we recommend incorporating an additional layer of information, that of 15-min stage/level data. Doing so would further benefit the assessment of station quality, helping to identify rating curve mismatches. As stage is an important metric, providing a complementary quality-controlled stage dataset, would itself be valuable for the UK hydrology community.

Overall, this work represents a foundational contribution to large-sample hydrology in the UK. It enables previously unattainable analyses of high-resolution processes and offers a replicable model for other countries with decentralised or under-utilised sub-daily flow archives. Future research may build upon this foundation by integrating this dataset with other important hydrological dataset to examine catchment response characteristics at finer temporal and spatial scales, thereby deepening our understanding of hydroclimatic extremes in a changing world.

Data availability

UK-Flow15 is available at https://doi.org/10.5285/211710ac-f01b-4b52-807f-373babb1c368 (Fileni et al., 2025b)

Code availability

Code for section 5 of this paper is available at https://github.com/felipef93/UK-Flow15-Usage_Notes

Author contribution

FF: Conceptualization, Data Curation, Methodology, Formal Analysis, Investigation, Visualization, Software, Writing (original draft preparation); HJF: Conceptualization, Funding Acquisition, Methodology, Project Administration, Supervision, Writing (review and editing); EL: Conceptualization, Supervision, Methodology, Writing (review and editing); FM: Conceptualization, Supervision, Methodology, Writing (review and editing); GC: Supervision, Writing (review and editing); DA: Methodology, Supervision, Writing (review and editing); EB: Supervision, Writing (review and editing); LY: Conceptualization, Supervision, Methodology, Writing (review and editing); MF: Data curation, Supervision, Writing (review and editing); HC: Data curation, Writing (review and editing); OS: Data curation

Competing interests

The authors declare that they have no conflict of interest.

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