Supplement of Hydrol. Earth Syst. Sci., 29, 6445–6460, 2025
https://doi.org/10.5194/hess-29-6445-2025-supplement

Hydrology and Earth System Sciences
Open Access
EGU

Supplement of

Technical note: A low-cost approach to monitoring relative streamflow dynamics in small headwater streams using time lapse imagery and a deep learning model

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S1 Model Development Description

Several pre-processing steps are applied to the imagery during model training and batch inference to better allow the model to learn the relationship between image scene and apparent streamflow (**Figure S1**). Image pre-processing occurs on all images prior to prediction while image augmentations occur only on the images comprising the 80% of the annotation pairs used to develop the model. The purpose of image augmentation is to allow the model to better generalize to unseen imagery. Additional detail on the pre-processing and jittering steps are provided below:

Image Pre-Processing

Resizing: Resizes the input image to a maximum height of 480 pixels while maintaining the aspect ratio. This reduces the computational complexity and memory usage of the model by lowering the number of parameters it needs to learn.

Normalization: Standardizes the pixel values by adjusting them to have a mean of zero and a standard deviation of one. This ensures model inputs are on a similar scale, which stabilizes gradient calculations during training and accelerates model convergence.

Centre-cropping: Crops the central region of the image, excluding 10% of pixels from the edges (top, bottom, left, and right). This removes extraneous information such as camera metadata imprinted on the edges of the images, ensuring the model focuses on the stream features in the central portion.

Image Augmentations

Random Horizontal Flip: Randomly flips the image horizontally with a 50% probability.

Random Rotation: Rotates the image randomly between -10° and +10°. This accounts for minor rotational shifts that can occur due to camera slip over long deployment periods.

Random Cropping: Crops a random part of the image covering 80% of the image. This replaces centre-cropping during training and encourages the model to learn visual features from various parts of the image and makes it more robust to slight viewpoint changes that could be induced by camera movement or partial obstructions.

Colour Jittering: Randomly changes the brightness, contrast, saturation, and hue of an image to help the model become more robust to colour variations and lighting changes in real-world scenarios.

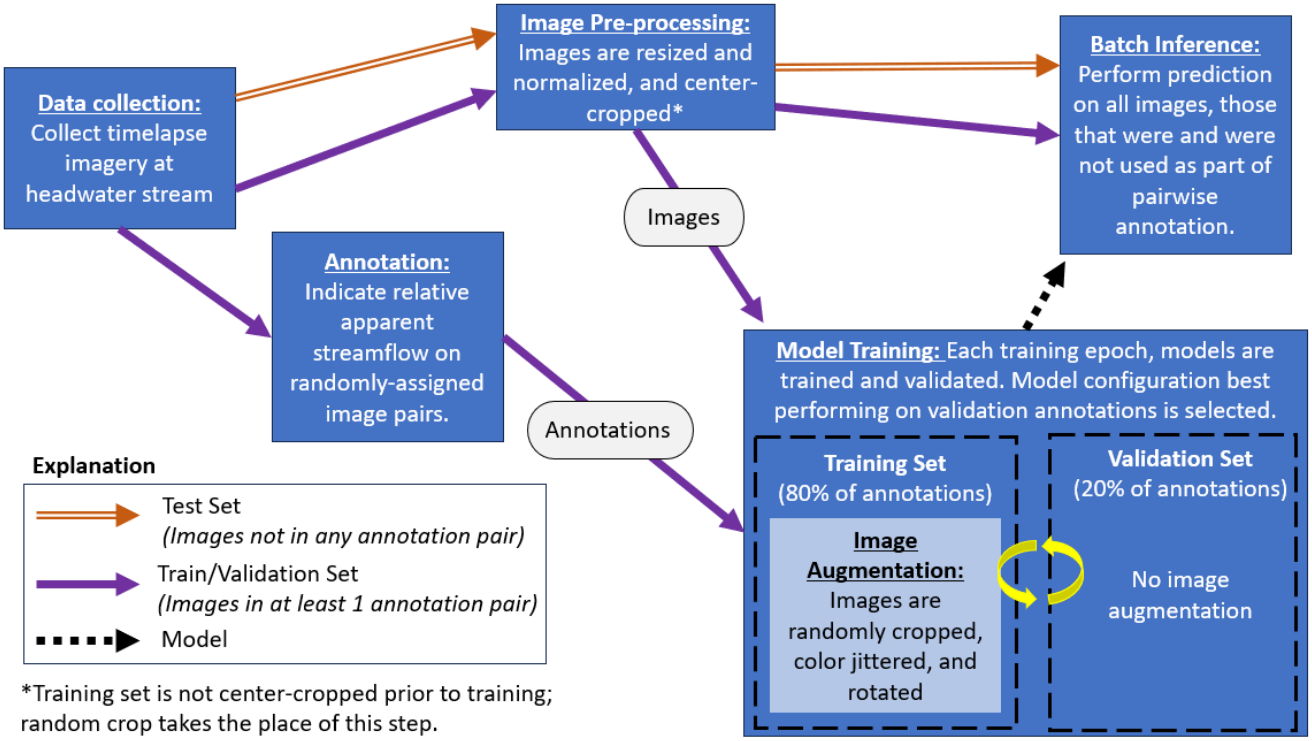


***Figure S1**: Diagram showing the handling of training, testing, and validation sets during model training.*

Model training used the same configuration as described in (Gupta et al., 2022), with the exception of the number of epochs considered during training (raised from 15 to 20). As in that study, we used a batch size of 64, a learning rate of 0.001, a stochastic gradient descent optimizer, and a learning rate scheduler that reduces the learning rate when the validation set loss plateaus. Model training occurred on the pretrained ResNet-18 model, with the body weights frozen for the first 2 epochs and then unfrozen to allow for fine tuning for the remaining epochs. Within the 20 training epochs considered, we selected the model with the lowest validation loss as the final model. **Table S1** shows the optimal number of epochs selected for each site, as well as the number of annotation pairs used for training, validation, and the proportion of annotator selections used for each site. Annotator selections of "Don't Know" were not stored or used during model development.

Location ID	Station Name	Number of Training Pairs	Number of Validation Pairs	Optimal Epochs Selected During Training	% of Annotator Selections		
					LEFT	RIGHT	SAME
ABB	Avery Brook Bridge	2512	635	18	43.0	42.0	15.0
ABL	Avery Brook River Left	1817	460	18	46.1	44.5	9.4
ABR	Avery Brook River Right	1773	441	16	45.1	46.7	8.2
ABS	Avery Brook Side	1955	486	20	40.5	44.7	14.8
GR	Green River	4059	995	20	48.0	45.3	6.7
SB	Sanderson Brook	3856	965	20	45.5	44.9	9.6
WBSR	West Branch Swift River	2838	715	20	46.2	41.2	12.6
WB0	West Brook 0	6365	1588	19	46.1	45.3	8.6
WBL	West Brook Lower	1809	447	18	43.4	49.0	7.6
WBR	West Brook Reservoir	1862	463	20	40.3	45.6	14.0
WW	West Whately	2007	503	19	41.2	45.7	13.1

Table S1*: Annotation pairs used in model development and number of training epochs for each model developed in this study.*

S2 Timeseries Predictions for all Sites

These figures display the timeseries of prediction for 10 camera sites and are the same as **Figure 6** in the main text, which shows the eleventh camera site. The top two panels show the streamflow, middle two panels show the predicted model score, bottom two panels show both when transformed to rank percentile. The left column indicates the full period of record, the right column is an inset. In the inset plots, daily means are plotted as dots and the 15-minute interval predictions are plotted with lines.

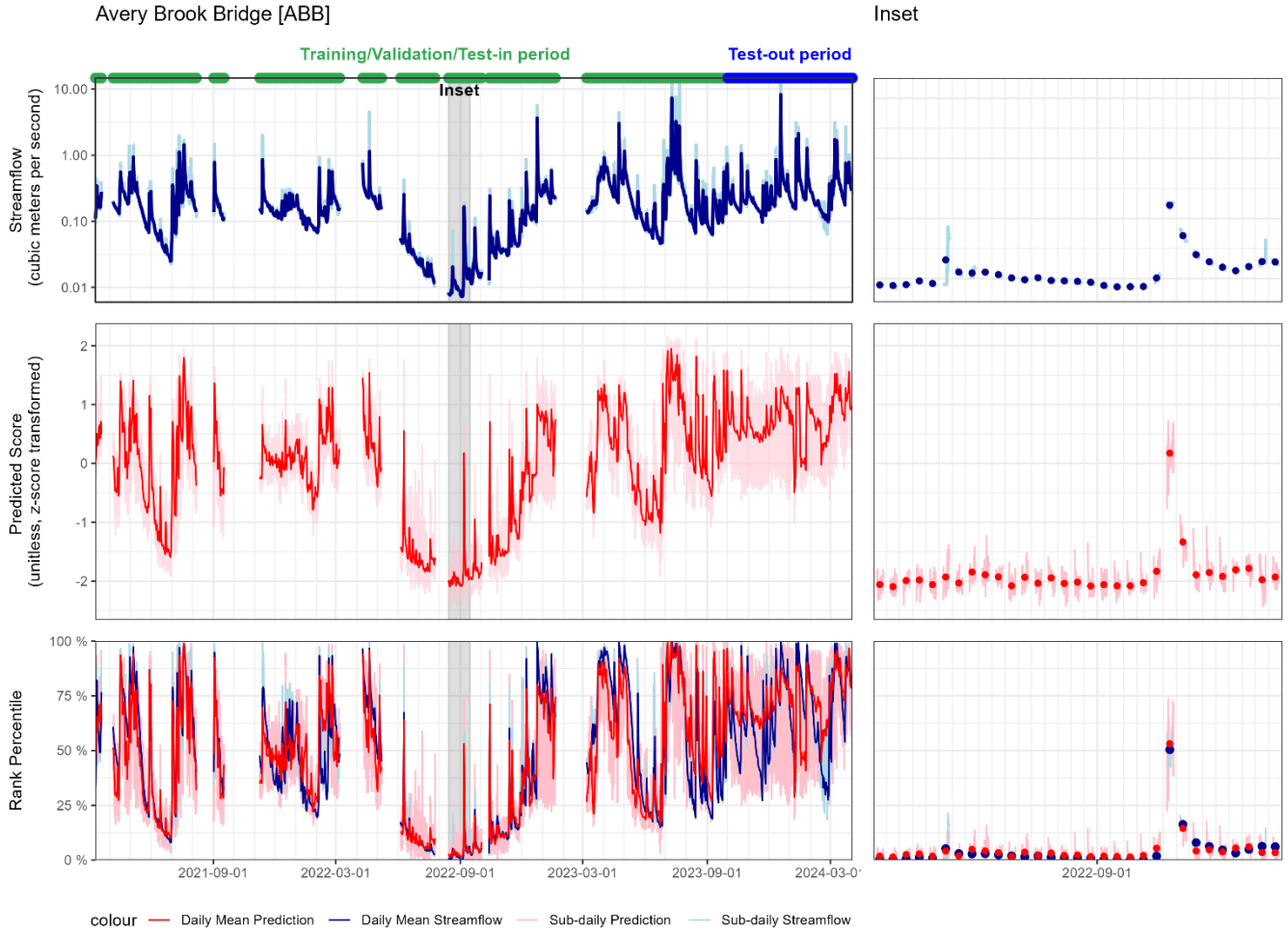


Figure S2: *Timeseries prediction at the Avery Brook Bridge site. Top two panels show the streamflow, middle two panels show the predicted model score, bottom two panels show both when transformed to rank percentile. The left column indicates the full period of record, the right column is an inset. In the inset plots, daily means are plotted as dots and the 15-minute interval predictions are plotted with lines.*

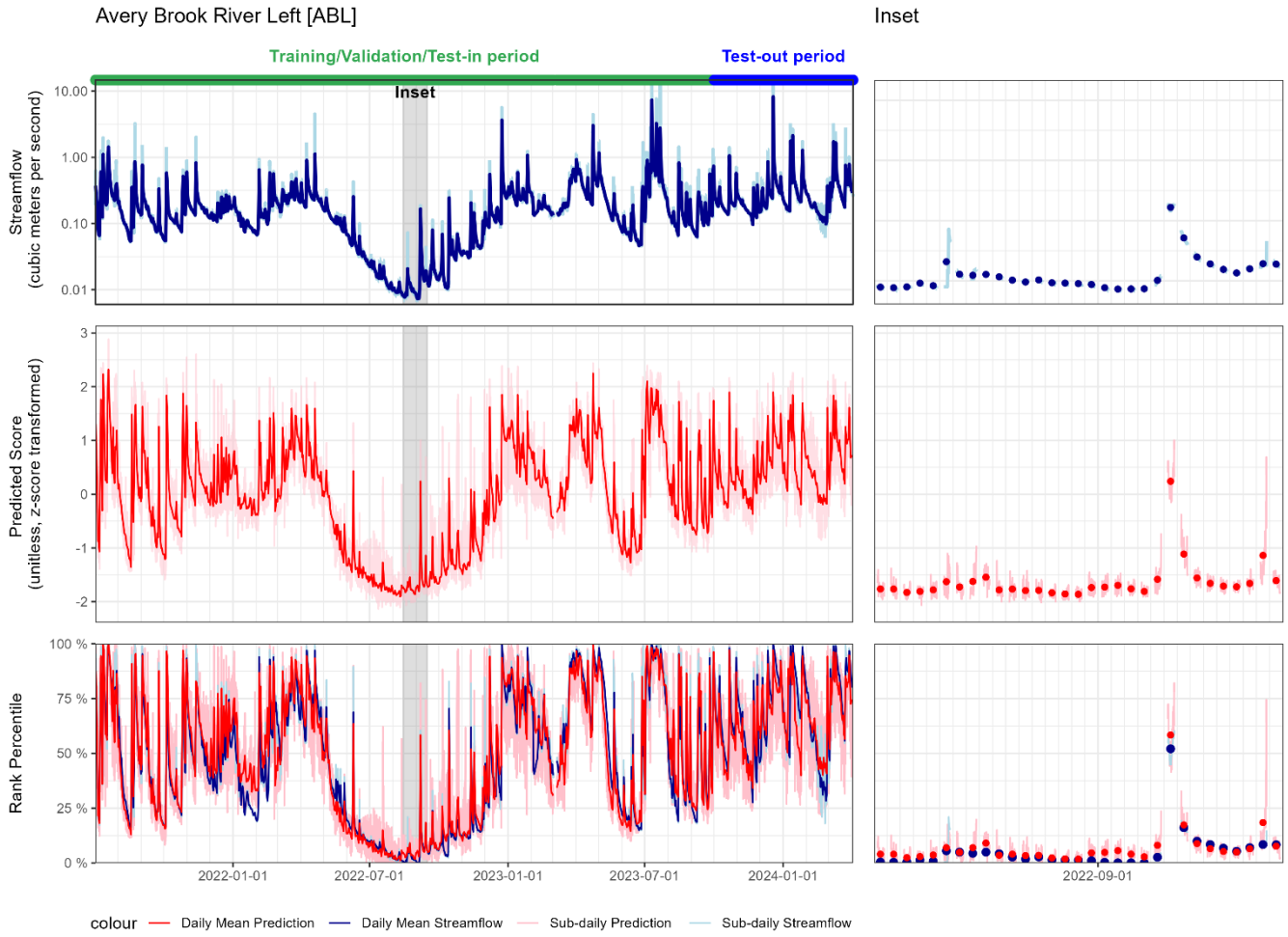


Figure S3*: Timeseries prediction at the Avery Brook Left site. Top two panels show the streamflow, middle two panels show the predicted model score, bottom two panels show both when transformed to rank percentile. The left column indicates the full period of record, the right column is an inset. In the inset plots, daily means are plotted as dots and the 15-minute interval predictions are plotted with lines.*

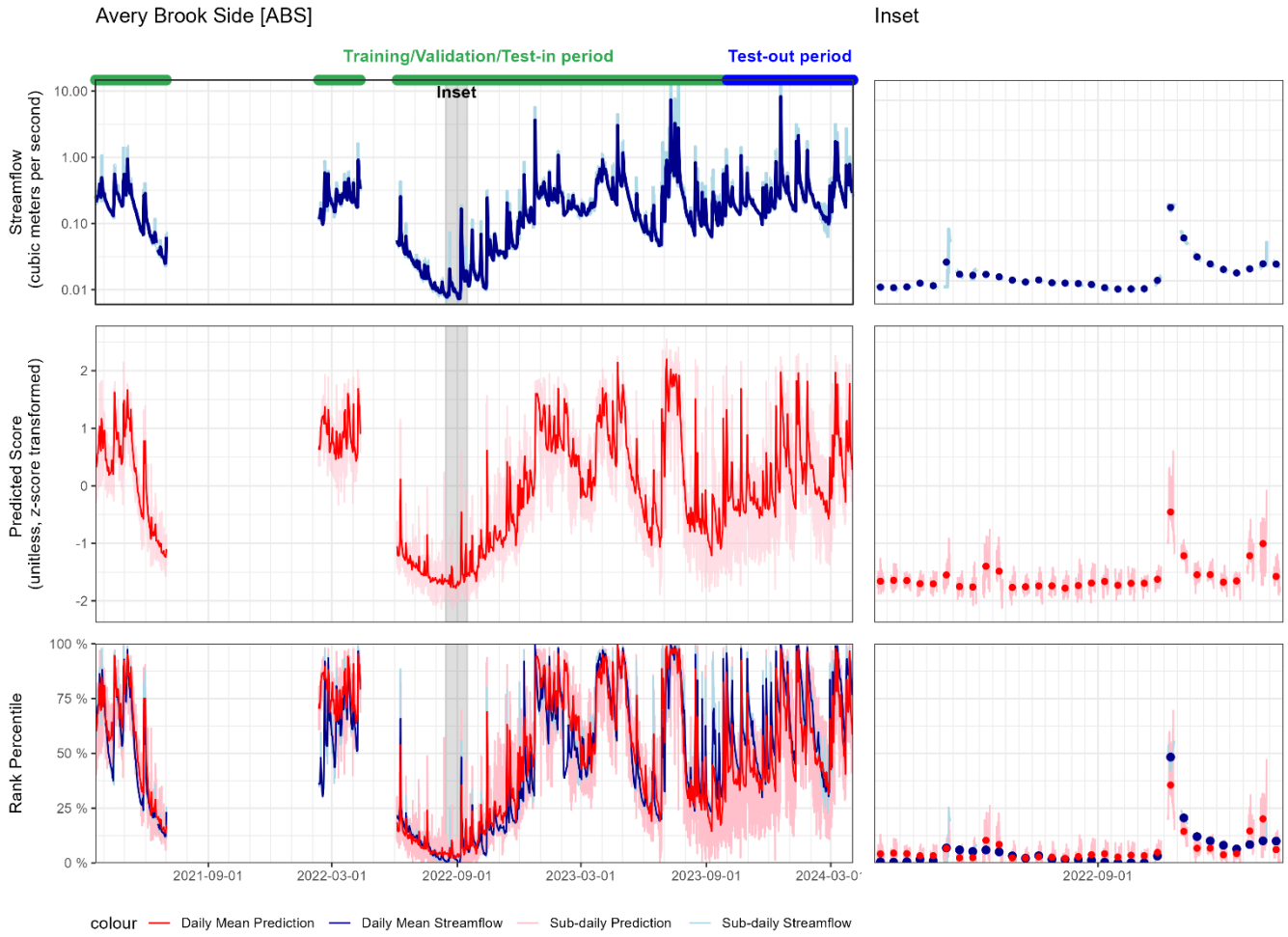


Figure S4: *Timeseries prediction at the Avery Brook Side site. Top two panels show the streamflow, middle two panels show the predicted model score, bottom two panels show both when transformed to rank percentile. The left column indicates the full period of record, the right column is an inset. In the inset plots, daily means are plotted as dots and the 15-minute interval predictions are plotted with lines.*

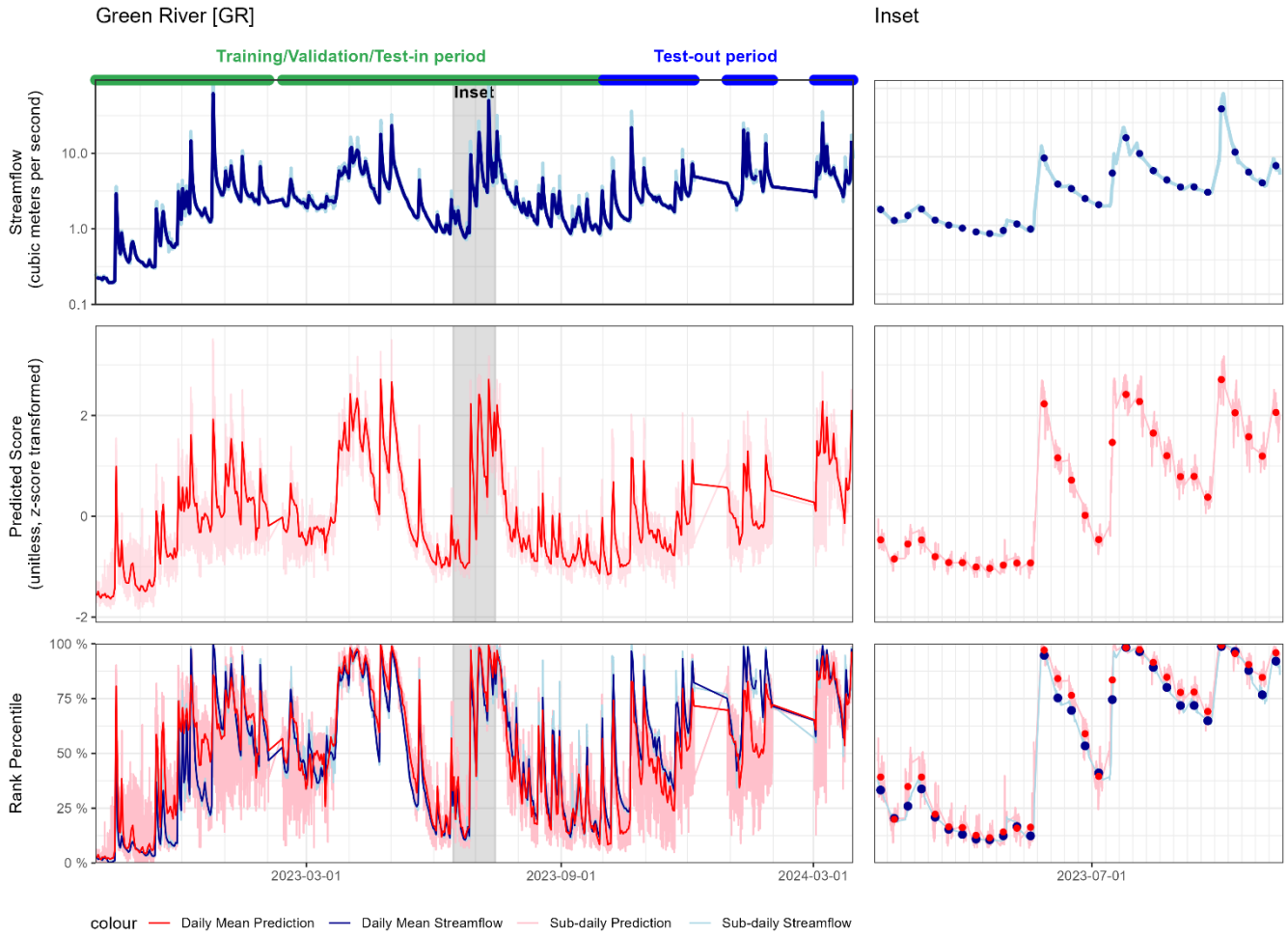
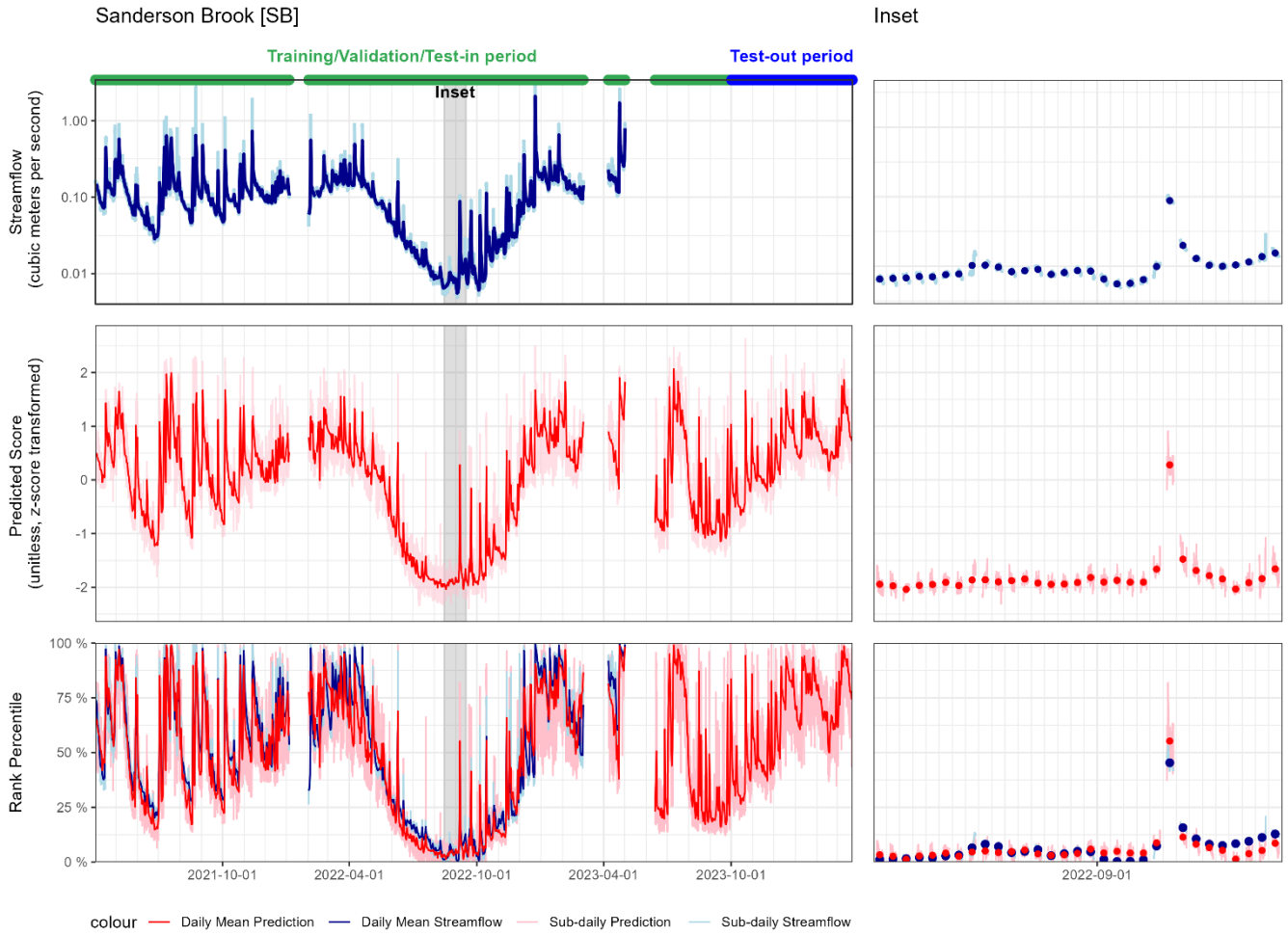


Figure S5: *Timeseries prediction at the Green River site. Top two panels show the streamflow, middle two panels show the predicted model score, bottom two panels show both when transformed to rank percentile. The left column indicates the full period of record, the right column is an inset. In the inset plots, daily means are plotted as dots and the 15-minute interval predictions are plotted with lines.*



85 ***Figure S6****: Timeseries prediction at the Sanderson Brook site. Top two panels show the streamflow, middle two panels show the predicted model score, bottom two panels show both when transformed to rank percentile. The left column indicates the full period of record, the right column is an inset. In the inset plots, daily means are plotted as dots and the 15-minute interval predictions are plotted with lines.*

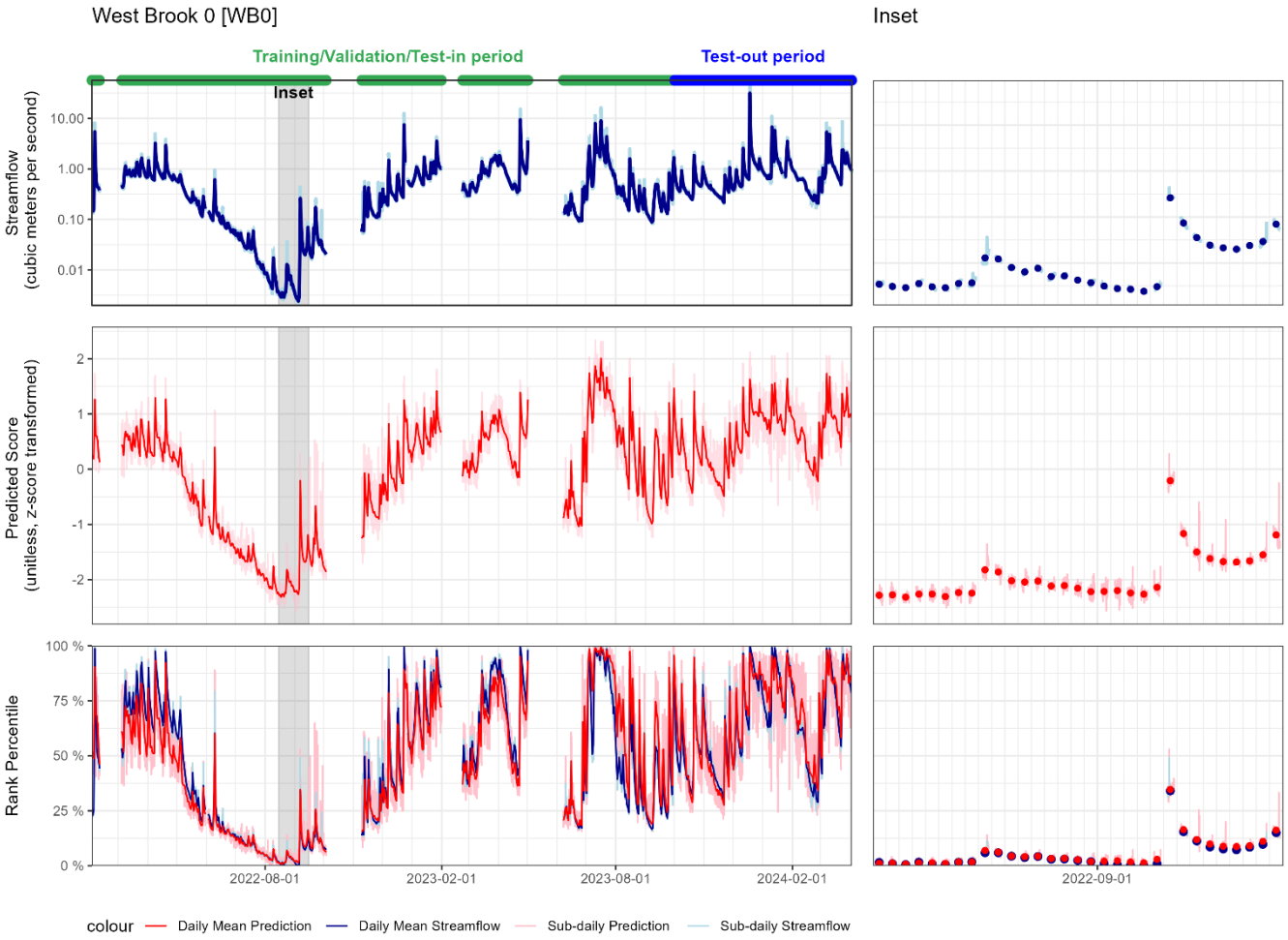


Figure S7*: Timeseries prediction at the West Brook 0 site. Top two panels show the streamflow, middle two panels show the predicted model score, bottom two panels show both when transformed to rank percentile. The left column indicates the full period of record, the right column is an inset. In the inset plots, daily means are plotted as dots and the 15-minute interval predictions are plotted with lines.*

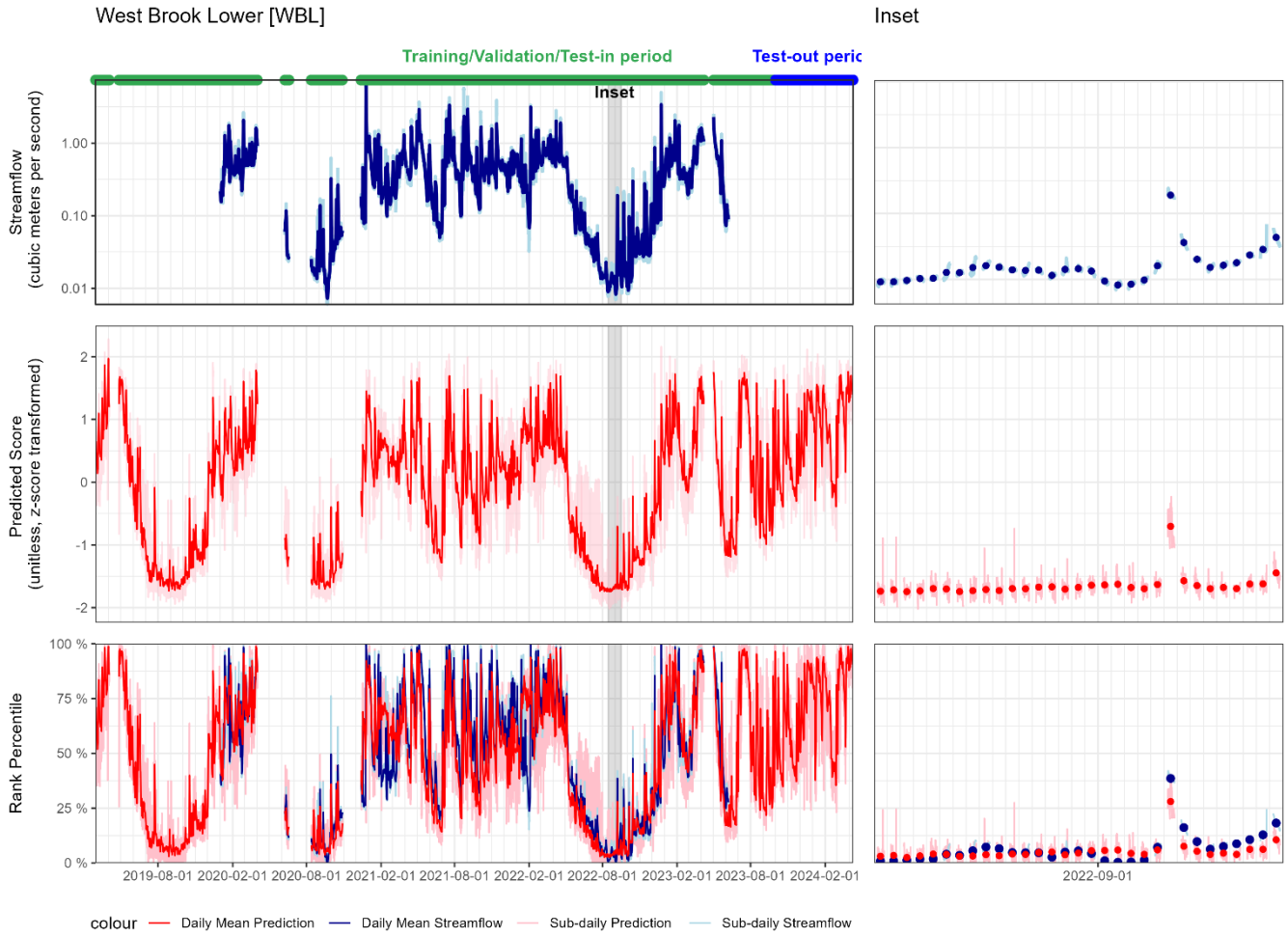


Figure S8: *Timeseries prediction at the West Brook Lower site. Top two panels show the streamflow, middle two panels show the predicted model score, bottom two panels show both when transformed to rank percentile. The left column indicates the full period of record, the right column is an inset. In the inset plots, daily means are plotted as dots and the 15-minute interval predictions are plotted with lines.*

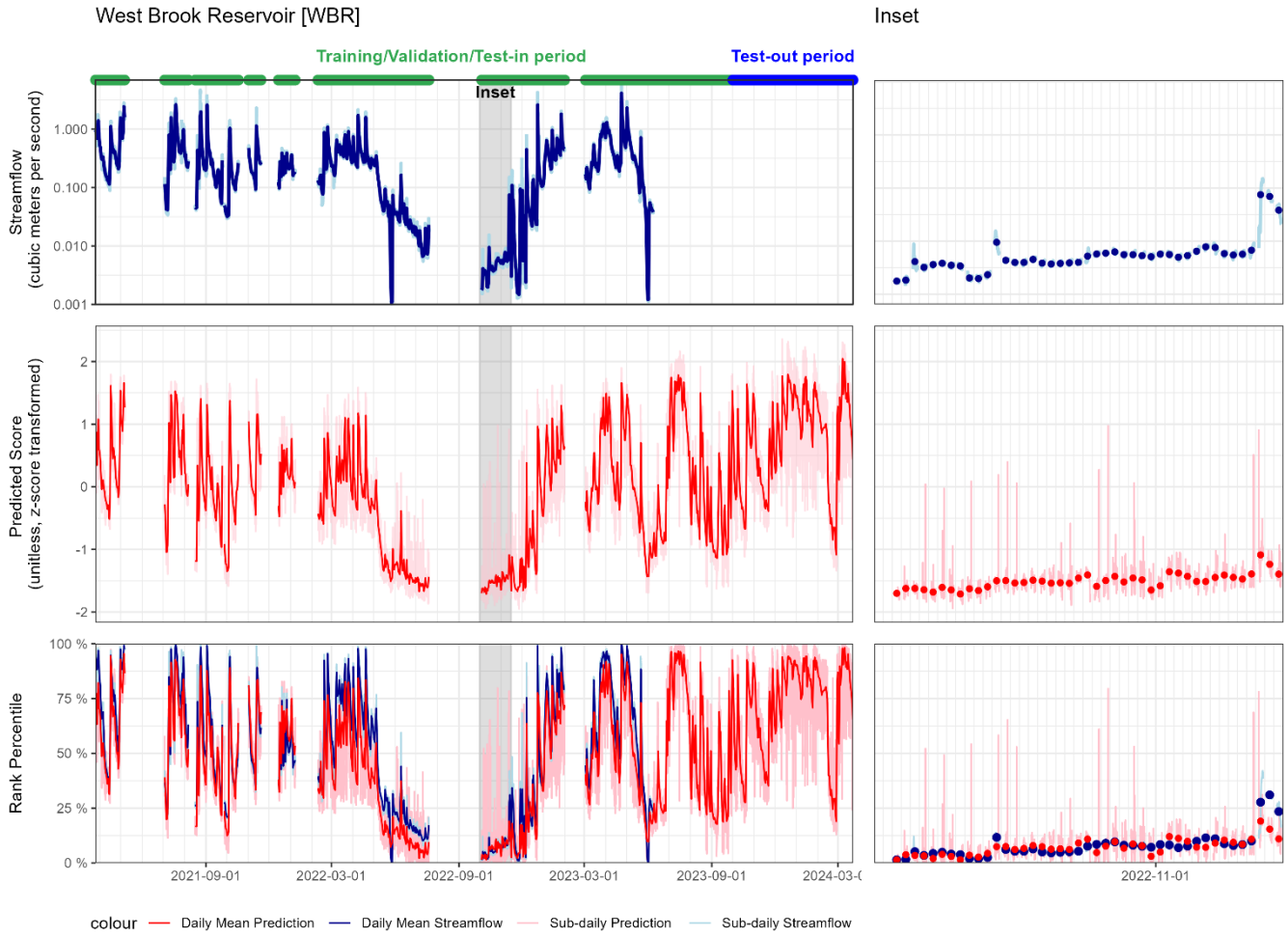


Figure S9*: Timeseries prediction at the West Brook Reservoir site. Top two panels show the streamflow, middle two panels show the predicted model score, bottom two panels show both when transformed to rank percentile. The left column indicates the full period of record, the right column is an inset. In the inset plots, daily means are plotted as dots and the 15-minute interval predictions are plotted with lines.*

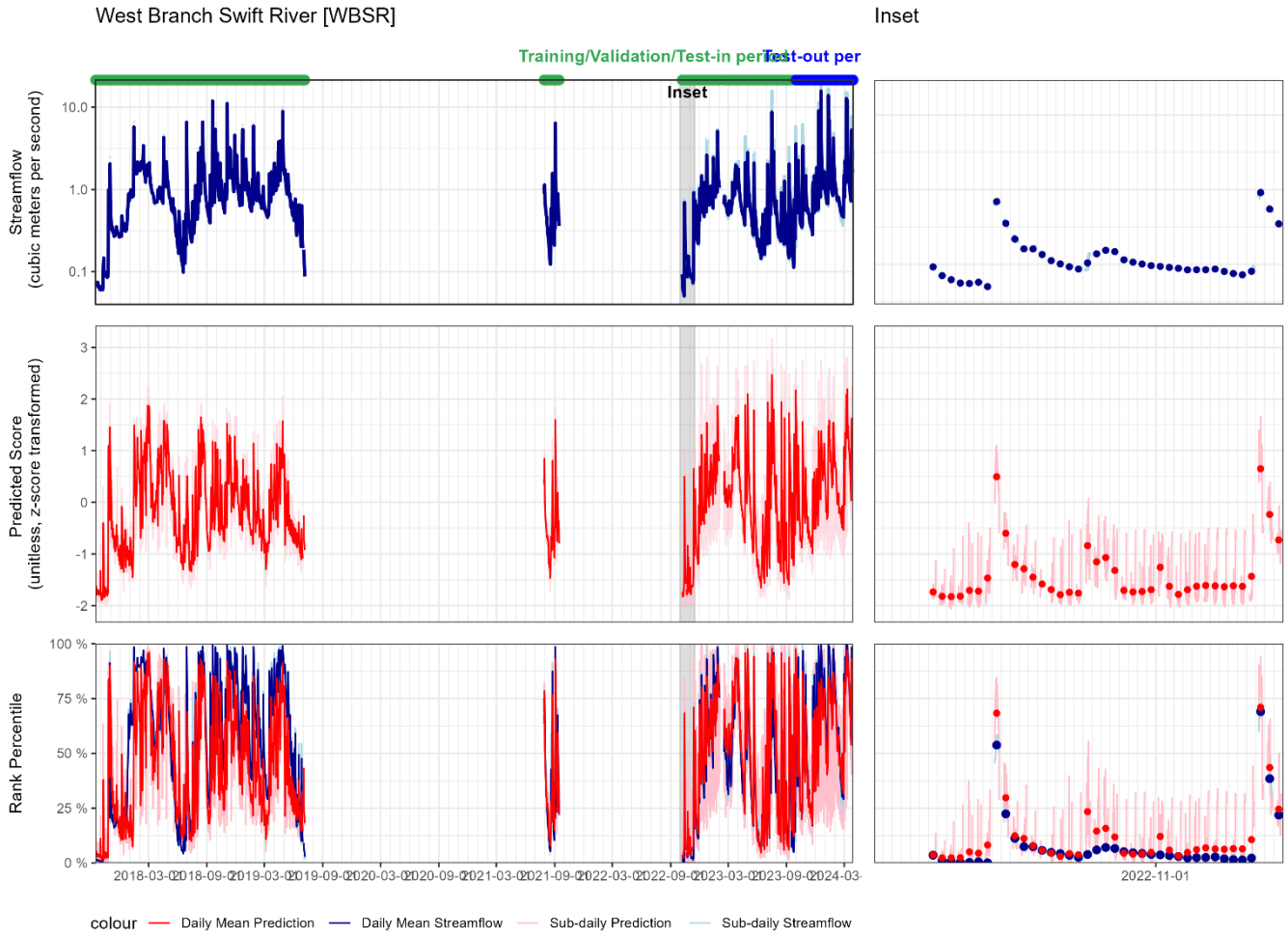
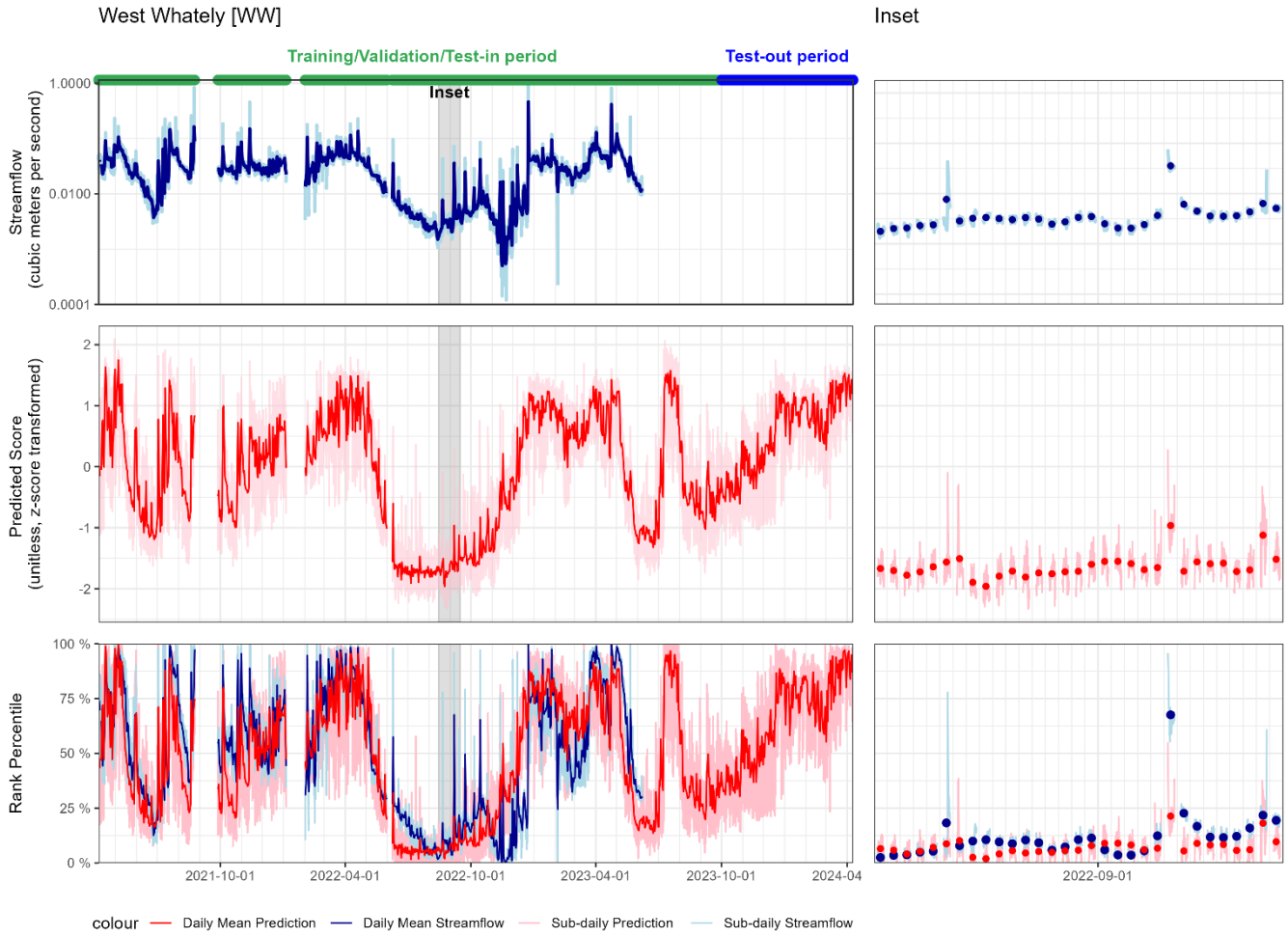


Figure S10: *Timeseries prediction at the West Branch Swift River site. Top two panels show the streamflow, middle two panels show the predicted model score, bottom two panels show both when transformed to rank percentile. The left column indicates the full period of record, the right column is an inset. In the inset plots, daily means are plotted as dots and the 15-minute interval predictions are plotted with lines.*



115 ***Figure S11****: Timeseries prediction at the West Whately site. Top two panels show the streamflow, middle two panels show the predicted model score, bottom two panels show both when transformed to rank percentile. The left column indicates the full period of record, the right column is an inset. In the inset plots, daily means are plotted as dots and the 15-minute interval predictions are plotted with lines.*

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S3 Predicted vs. Observed plots for all sites (rank percentiles)

These figures show predicted vs. observed rank percentile for each image in the train, validation, test-in, and test-out sets for all 11 camera sites. Sites are labelled with their abbreviations which are provided in **Table 1** of the main text.

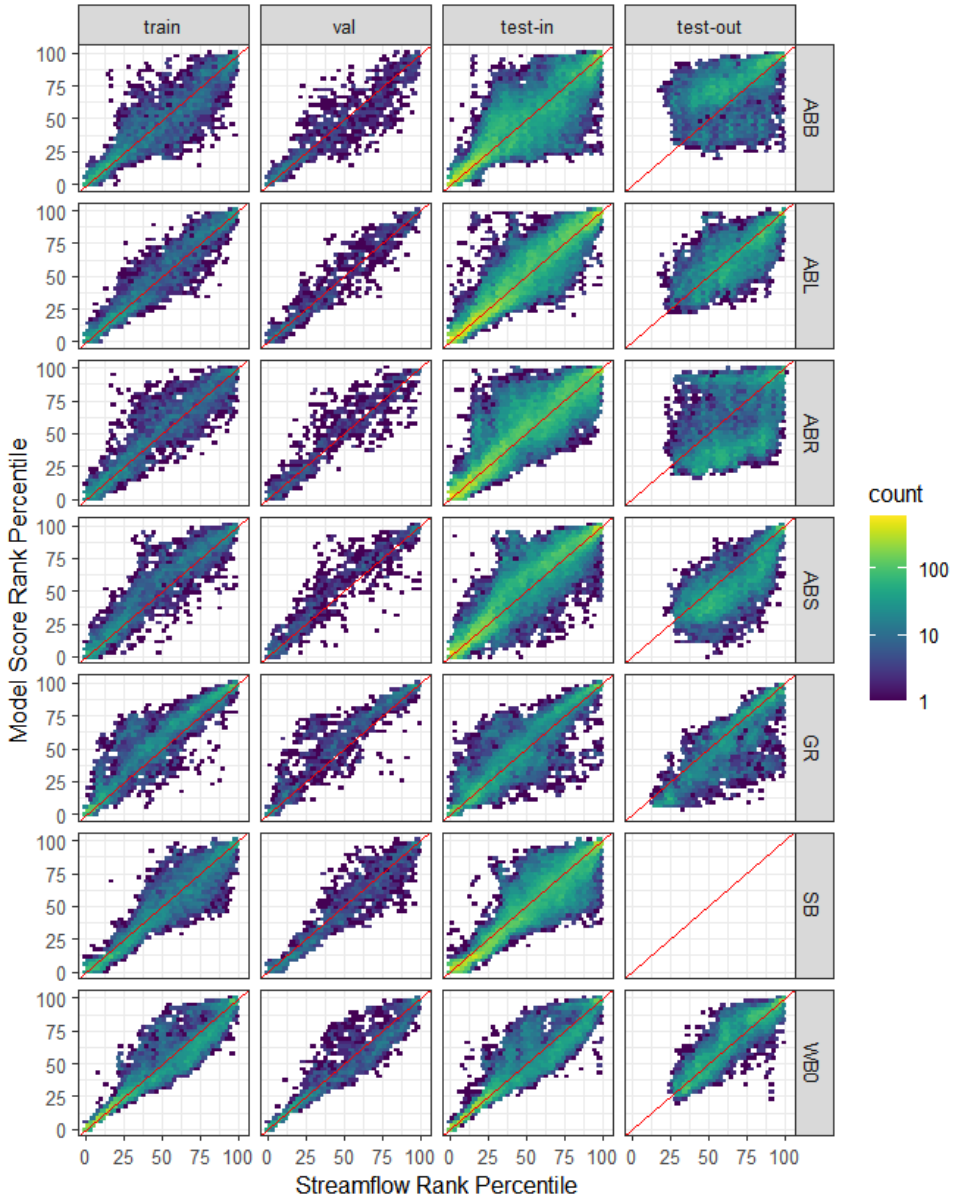

Figure S12: *Predicted versus observed rank percentiles for each location and data split, shown as two-dimensional density plots. Colour indicates the number of 15-minut observations in each bin and is on a logarithmic scale. The red line is a 1:1 line. This first panel shows seven of the eleven camera sites.*

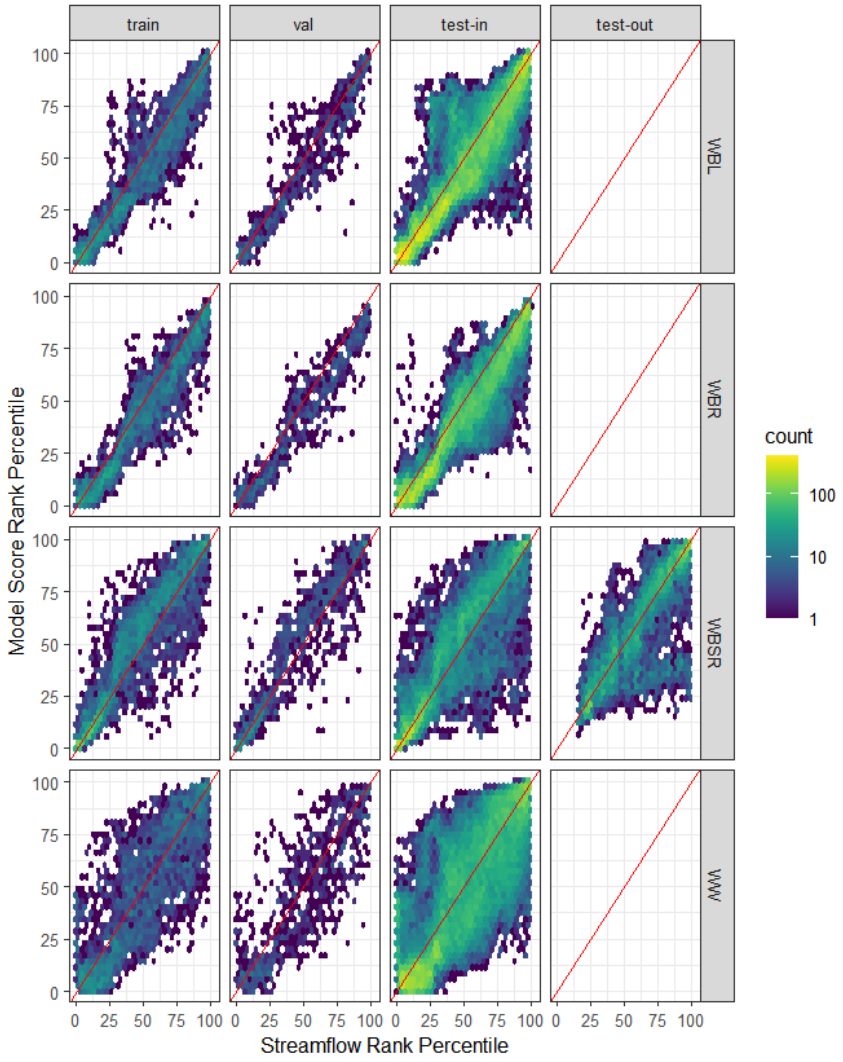

Figure S13: *Predicted versus observed rank percentiles for each location and data split, shown as two-dimensional density plots. Colour indicates the number of 15-minut observations in each bin and is on a logarithmic scale. The red line is a 1:1 line. This second panel shows four of the eleven camera sites.*

S4 Multi-panel figure showing view from all sites

This figure displays a representative view from all 11 camera sites (at eight locations).

145 ***Figure S14:*** *Images captured at each site at between 7am and 8am on September 5th, 2023, during a period of low flow. The photos are provided to show general view for each location. Photo credit U.S. Geological Survey.*