Integrating Surveying Strategies for Microtopography: Insights for Flood and Water Quality Management

Introduction

With increased urbanization and climate change, there is an alarming increase in the risk of surface water flooding leading to reduced water quality from point source pollution and altered flow regimes.

By 2055, properties at risk of surface water flooding increases by

- **35,000-95,000** due to **new development**
- **50,000-65,000** due to **increase in impermeable surface**
- **20,000-135,000** due to **increased rainfall Intensity**

In the UK, we primarily use combined sewer systems, where rainwater runoff enters storm drain inlets and carry both stormwater and sewage. During heavy rainfall, excess flows are discharged into rivers. Microtopography significantly influences surface water flow direction, velocity, runoff accumulation areas, and pollutant pathways.

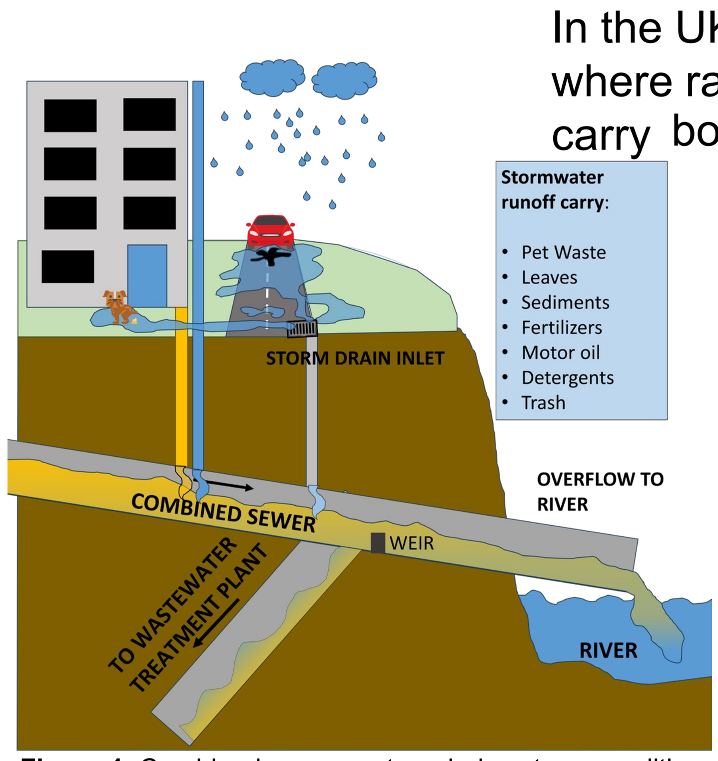


Figure 1. Combined sewer system during storm condition

What is microtopography? *Microtopography refers to the subtle variations in elevation, slope and terrain configuration on the ground surface, influenced by features such as road kerbs, speed bumps, storm drain inlets, flood gates, walls, steps, etc.*

Thus, accurate knowledge of local microtopography is crucial to better understanding of surface water pathways for both flood management and water quality protection during flood events.

This study explores how advanced surveying strategies can characterise microtopographic features that influence surface water flow paths

Comparison of Survey Strategies

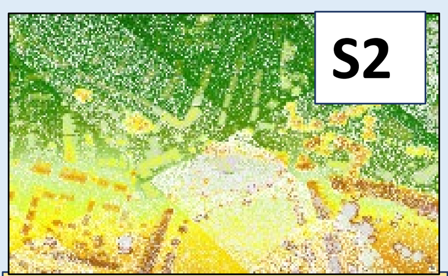
DATA

We conducted surveys using Unmanned Aerial Systems (UAS) and aircraft-based LiDAR to capture detailed microtopographic data in Cockermouth, Cumbria, UK.

Aerial image from Unmanned Aerial System (UAS) to point cloud by photogrammetry

Real Time Kinematic positioning (RTK-GPS (Ground truth data)

Ground Control Points= 20
Check point= 2031



LiDAR point cloud data from Manned Aircraft

The point clouds were rasterised to DSMs using the 'LAS dataset to Raster' function in ArcGIS Pro

DATA ANALYSIS

The data analysis was carried out in ArcGIS Pro and R studio

Accuracy assessment of UAS-DEM and LIDAR-DEM on microtopographic features that influence surface water flooding

S1-Ground truth | S2-Ground truth | S1-S2

Kerb | Road | Drain | Brick Wall | Vegetated crest | Grassland | Flood Gate | Step

Microtopographic features that influence surface flow

Key findings

For the full dataset, the absolute mean error (excluding the outliers) and the median were approximately the same for S1 and S2 and always below 10 cm

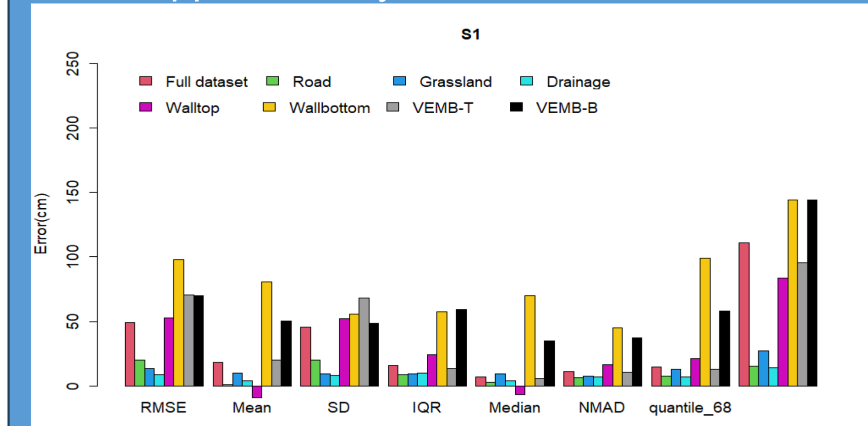


Figure 2. Plot summarising traditional and robust statistical metrics (Table 3) for S1 and S2 for all classes combined as well as per land class and microtopographic feature

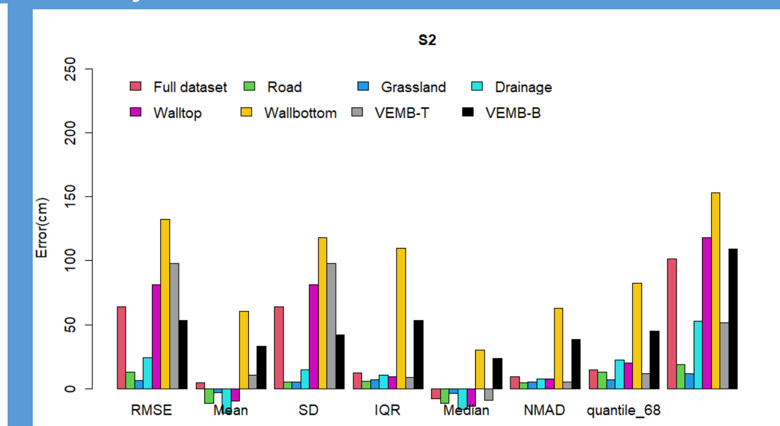


Figure 3. Plot summarising traditional and robust staticsal metrics (Table 3) for S1 and S2 for all classes combined as well as per land class and microtopographic feature

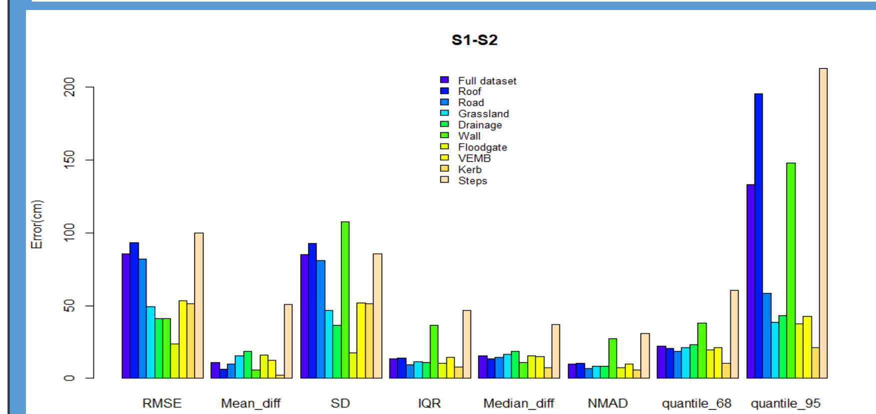


Figure 4. Plot showing traditional and robust statistical metrics of the difference in elevation between S1 and S2 for all classes combined and also per land class and microtopographic features

The results showed that the difference in elevation between S1 and S2 varies between 11 and 37cm on different land use and microtopographic flood features. Similarly, the accuracy of S1 ranges between 3 cm to 70 cm, and the accuracy of S2 ranges between 3.8 cm to 30.3 cm on different microtopographic flood features.

Conclusion

Survey Decision Framework

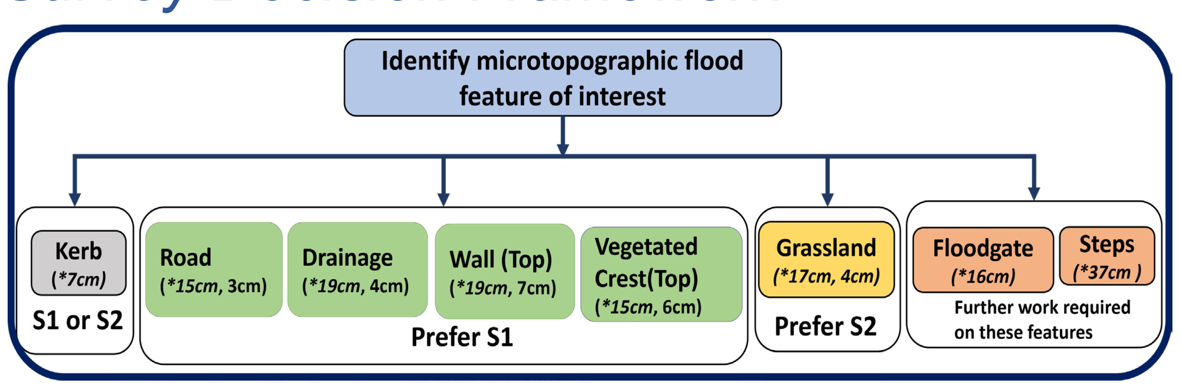


Figure 5. Survey decision framework for S1 and S2 for the characterisation of microtopographic features. Values in brackets show the (*) median elevation difference between S1 and S2 and the elevation accuracy

- **Framework goal:** Determines if S1 and S2 can be used interchangeably or feature specific
- **Decision criteria:** Driven by the features of interest, their accuracies and error-threshold.
- **Benefit:** Guides practitioners in choosing the appropriate surveying strategy based on the features they need to map and optimizing data collection
- **Limitation:** The study is carried out only on limited flood features, and the inclusion of other relevant flood features should be further explored, and the framework is limited to a single criterion of accuracy and elevation difference between the two survey strategies.

Contribution to Flood and Water Quality Management

- **Identifying High Flood Risk Areas**: High-resolution data pinpoints localized flooding zones, aiding targeted flood mitigation.
- **Improving Water Quality Management:** Understanding microtopography reveals pollutant sources and pathways, enabling actions to prevent contamination.
- **Managing Drainage Assets:** Microtopography insights enhance understanding of the effectiveness of existing urban drainage systems
- **Sustainable Drainage Systems (SuDS):** Microtopographic insights aids better planning of SuDS to store, filter and release runoff, thus reducing contamination

Further research

We are also exploring potential use of AI to identify underperforming storm drain inlets along roads and paved areas. Initial results have produced AI algorithms for rapid, automated detection of gullies from high-resolution UAS imagery.

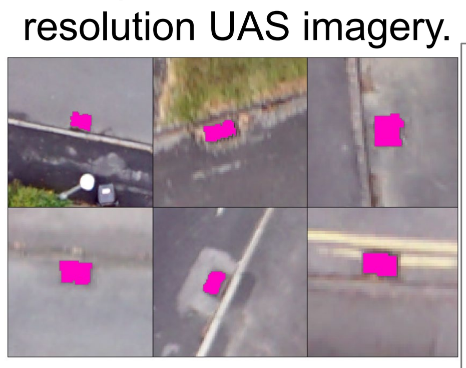


Figure 6. Example of gullies identified using AI algorithms from high-resolution Unmanned Aerial Vehicle imagery

- Extracting flood features of interest from image could help in choosing appropriate survey strategy or integrating different dataset.
- Identifying ineffective drains help in targeted maintenance of storm drain inlets and timely intervention to manage pollutants entering waterbodies.

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