The role of historical legacy in urban stream geomorphology: Insights from Quinzeh Creek

Lukman Adeboye Soboyejo[1]

1 Hydrobiology, Brisbane, Queensland, 4064. Corresponding author email: lukmansoboyejo@hydrobiology.com; lukmansoboyejo@gmail.com

Key points

- Historical geomorphic legacy strongly controls present-day channel adjustment in urbanising streams.
- Reach-scale variability reflects interactions between legacy conditions, geology, and altered flow pathways
- The most significant channel changes in Quinzeh Creek occurred independently of recent urbanisation

Abstract

Stream responses to urbanisation are commonly interpreted using space-for-time approaches that often overlook the influence of historical geomorphic legacy. This study investigates how past land-use disturbance and inherited channel conditions influence contemporary channel adjustment in Quinzeh Creek, Queensland Australia, a progressively urbanising catchment within the Logan River system. A combination of field observations and LiDAR-derived Digital Elevation Model of Difference (DoD) analysis (2009–2023) was used to quantify geomorphic change across nine distinct reaches. Results show that the most significant adjustment, including incision, lateral erosion, and headcut development, occurred in upstream reaches and was largely unrelated to recent urbanisation. Instead, these patterns reflect pre-existing instability associated with dispersive soils, vegetation clearance, and altered flow pathways. Downstream reaches exhibited lower rates of adjustment and greater sediment storage, indicating spatial variability in geomorphic response. The results suggest that urbanisation mainly worsens pre-existing channel instability rather than independently causing all observed and/or inferred changes. This study highlights the importance of explicitly accounting for historical geomorphic legacy in interpreting urban stream behaviour and in developing effective, process-based management strategies.

Keywords

Urban streams, Historical legacy, Channel adjustment, Geomorphology, Land-use change, Urbanisation, Headcut development, Digital elevation model

Introduction

Urban streams are widely recognised as highly altered systems, with urbanisation producing substantial changes in hydrology, channel morphology, sediment transport, water quality, and ecological function. These impacts are commonly described using the concept of "urban stream syndrome", which refers to the broadly degraded physical, chemical, and ecological condition of streams draining urban catchments (Walsh et al., 2005). Increased impervious cover, stormwater drainage networks, channelisation, and floodplain confinement typically increase runoff magnitude and frequency, resulting in channel incision, widening, bank erosion, sediment imbalance, and habitat degradation (Booth, 1991).

Despite decades of research, predicting geomorphic responses to urbanisation remains difficult and complex because stream adjustment is rarely controlled by urbanisation alone. Instead, channel responses emerge from interactions among hydrology, geology, sediment supply, riparian vegetation, channel confinement, engineering interventions, and inherited geomorphic conditions (Nelson et al., 2006). Consequently, many urban streams exhibit irregular or spatially discontinuous responses to urban development rather than systematic enlargement or incisional patterns alone (Soboyejo et al., 2025).

A key factor contributing to this uncertainty is the influence of historical legacy. In geomorphic terms, historical legacy refers to the persistent influence of past disturbances, land-use practices, and inherited channel conditions on contemporary channel form and process. Historical disturbances such as land clearing, agriculture, timber harvesting, damming, floodplain alteration, channelisation, infrastructure development, and in-channel modification can leave long-lasting geomorphic signatures that persist for decades to centuries after the original disturbance has ceased (Wohl, 2019). These inherited conditions may include legacy sediments, altered channel geometry, modified sediment regimes, buried floodplains, reduced large wood loading, entrenched channel forms, and altered floodplain connectivity that continue to influence contemporary adjustment trajectories (Miller et al., 2021).

While the concept of historical legacy has been widely explored in agricultural and forested catchments, its role in urban streams remains comparatively underexamined, largely due to the limited availability of long-term monitoring datasets. As a result, urban stream studies often rely on predictive geomorphic approaches, such as hydraulic geometry relationships, in which less urbanised catchments are used as proxies to infer the impacts of development (Soboyejo et al., 2025). Channel evolution models are also commonly invoked to infer stream instability trajectories in response to land-use disturbances. However, these approaches may inadequately capture legacy controls such as prior channel modification, historical sediment inputs, inherited geology and morphology, infrastructure constraints, and delayed geomorphic responses, thereby limiting their predictive capability and generalisation to other physiographic locations (Soboyejo et al., 2026). Failure to account for these factors may exaggerate the apparent effects of contemporary land use or obscure pre-existing channel conditions, leading to misinterpretation of urban impacts on stream geomorphology and, ultimately, ineffective management of urban streams.

To address this gap, this study aims to investigate how historical conditions influence present-day channel instability in an urbanising system. Long-term spatial datasets are analysed to quantify pre-development geomorphic change, supported by reach-based topographic assessment and field observations of contemporary stream channel condition. This approach enables the identification and characterisation of legacy-driven geomorphic processes, their ongoing influence on channel behaviour, as well as the cumulative and compounding effects of urbanisation together with historical legacy. In doing so, the study highlights the role of historical legacy in shaping contemporary channel form and dynamics, with implications for urban waterway planning, management, and restoration. This study addresses the following research questions:

1. How do historical geomorphic legacies influence present-day channel adjustment and sensitivity in urbanising streams?
2. To what extent do past land-use disturbances and inherited channel conditions shape contemporary geomorphic responses? and
3. What are the implications of historical geomorphic legacy for urban stream management, planning, and restoration strategies?

Materials and methods

Description of study area

The study was conducted in the Quinzeh Creek catchment, located within the Yarrabilba Priority Development Area (PDA) in Logan City, south-east Queensland, Australia. Quinzeh Creek forms part of the upper Logan-Albert River system, flowing generally northward before discharging into the Logan River (Figure 1). The catchment lies within a rapidly urbanising growth corridor identified in the Southeast Queensland Regional Plan, with Yarrabilba representing a major master-planned development expected to accommodate approximately 45,000 residents upon completion.

The catchment is characterised by gently undulating terrain, with elevations ranging from approximately 100 m AHD in the upper catchment to about 23 m AHD near the downstream extent. Slopes are typically moderate (2 to 6%) in upland areas, transitioning to low-gradient floodplain environments (<1%) along Quinzeh Creek. The drainage network consists of Quinzeh Creek (Reaches 1, 2, 3, 4, 7, 8) and several ephemeral mid-tributaries (Reaches 5, 6, 9).

The climate of the area is characterised by warm to hot, wet summers driven by convective storms and occasional tropical systems, and mild, relatively dry winters (Peel et al., 2007). Rainfall is highly seasonal and variable, with the majority of precipitation occurring during summer months. The catchment is underlain by a combination of sedimentary and alluvial geological units, including the Woogaroo Subgroup, Ipswich Coal Measures, and Quaternary alluvial deposits. These geological units give rise to soils that are predominantly sandy and silty, often overlying dispersive clay horizons and weathered sandstone.

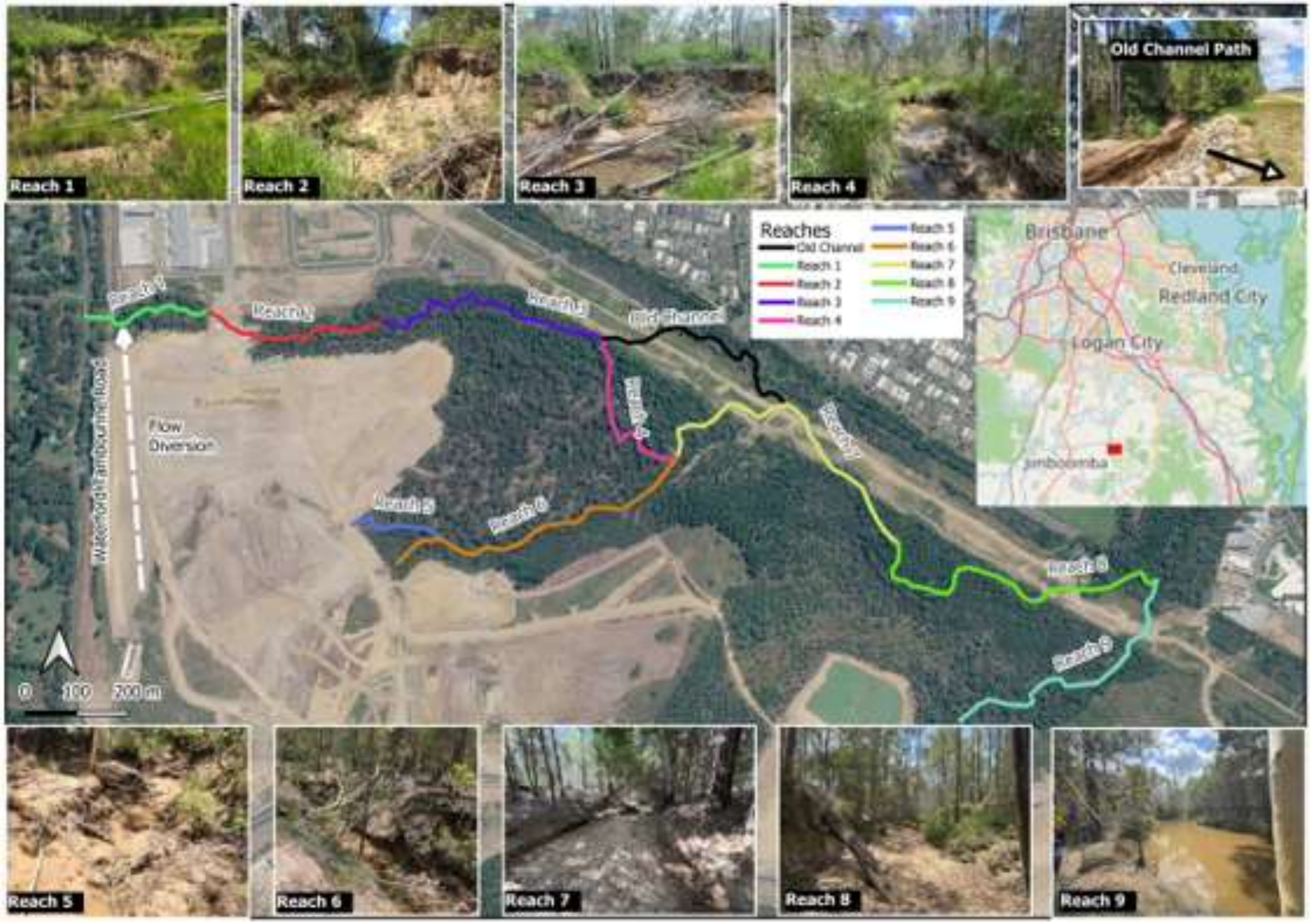

Figure 1 Overview of the study area reaches, including surveyed reaches, planned flow diversion location, regional context, and representative field photographs (Reaches 1–9)

History of land-use

The study area has undergone a clear transition from a rural and forestry-dominated landscape to an increasingly urbanised catchment (Figure 2). Around 1980, the area was mainly characterised by pine plantation forestry, cleared grassland, rural access tracks, and vegetation associated with creek lines and drainage corridors.

By 1995, these land uses remained dominant, although the landscape had already been modified by forestry management, access tracks, and rural land-use activities. By 2015, urban development associated with the Yarrabilba Masterplan had further altered the surrounding catchment. This included civil earthworks, bulk grading, road construction, development of adjoining residential precincts, and clearing within and near the Quinzeh Creek corridor. These changes marked a shift from rural and forestry land uses towards a more developed urban setting.

Between 2023 and 2026, development within and around the study area continued to expand, putting pressure on the Creek. Future development associated with the Precinct will further contribute to this transition. Proposed works include stormwater management systems, water-sensitive urban design measures, internal roads, footpaths, streetscaping, and the rehabilitation and protection of riparian vegetation corridors. These changes highlight the continuing transformation of the study area into an urbanised catchment, where stormwater management, protection of creek-line vegetation, and other reach-scale measures will be critical to maintain the condition of Quinzeh Creek as catchment development progresses.

Figure 2 Historical land-use and development changes within the Quinzeh Creek catchment and surrounding Yarrabilba development area from approximately 1980 to 2026

Data acquisition and elaboration

This study employed a combination of field-based geomorphic assessment, historical analysis, and LiDAR-derived Digital Elevation Models of Difference (DoD) to examine patterns of channel change and geomorphic sensitivity over time. Datasets were sourced from various government websites, including publicly accessible Queensland spatial websites (QGlobe; https://qldglobe.information.qld.gov.au/) and ELVIS. Spatial analysis was performed using QGIS (V3.44.7) and R Statistical Software (V4.6.0).

Reach breakdown

Initially, Quinzeh Creek and its tributaries were divided into nine discrete geomorphic reaches prior to detailed assessment to account for spatial variability in channel condition and geomorphic behaviour (Figure 1). Reach delineation was based on observable breaks in geomorphic character, including changes in channel morphology, valley setting, tributary confluences, and planform adjustment.

Digital elevation analysis

Digital Elevation Model (DEM) analysis was undertaken to quantify historical topographic adjustment and evaluate long-term geomorphic change within the creek system. ELVIS LiDAR-derived DEMs with a 1 m spatial resolution and a vertical accuracy of ±0.15 m (67% confidence level) from multiple years (2009, 2013, 2017, 2021, and 2023) were analysed to assess changes in channel elevation along the categorised reaches.

Geomorphic change detection

Geomorphic change detection was undertaken using DEM differencing to identify spatial patterns of erosion and deposition across the study area. DEM differencing was performed in Geomorphic Change Detection (GCD) software (Wheaton 2010), applying a minimum level of detection (minLoD) threshold of ±0.20 m to account for propagated vertical uncertainty in the input DEMs. Elevation change values below this threshold were treated as indistinguishable from noise and excluded from the analysis. This approach enabled direct assessment of geomorphic adjustment over the 2009–2023 period.

Field observations

Field investigations formed a central component of the geomorphic assessment and were undertaken during site inspections in December 2025 and February 2026. These inspections involved detailed walk-through assessments of Quinzeh Creek and associated tributaries to document present-day channel condition, geomorphic processes, and evidence of historical disturbance. Field observations focused on identifying indicators of instability and geomorphic activity, including bank erosion, incision, headcuts, avulsions, sediment deposition, undercutting, gully erosion, and riparian condition.

Findings

The geomorphic assessment of Quinzeh Creek demonstrated that the channel system was actively eroding, with substantial historical and ongoing change evident from elevation data from 2009 to 2023 and from field observations undertaken in 2025/2026. The most pronounced geomorphic change, such as bed-level lowering, occurred in the upstream reaches, particularly Reaches 1 to 3, where widespread incision, lateral erosion, bank undercutting, and headcut development were observed (Figure 3).

In Reach 1, bed-level lowering varied locally with up to 7 m of incision observed, with active scour, lateral erosion, bank undercutting, and headcut development associated with an inherited road crossing (Waterford Tambourine Road), 4WD track, vegetation removal, ongoing urbanisation, and dispersive soils. Reach 2 showed approximately 1-2 m of base-level lowering, together with lateral erosion, undercutting, headcut development, dispersive soils, and local bedrock controls. Local bedrock controls (sandstone) are likely to have inhibited further incision. Reach 3 had approximately 1-2.5 m of bed lowering, with bank undercutting, lateral erosion, and headcut development that appeared to be linked to upstream channel erosion, dispersive soil, and avulsion processes in Reach 4. Reach 4 showed a subdued level of lowering of approximately 0.5-1.5 m, indicating continued downstream instability associated with altered flow pathways and upstream sediment delivery. Field observations also indicated that a headcut had begun to develop in the middle section of Reach 4.

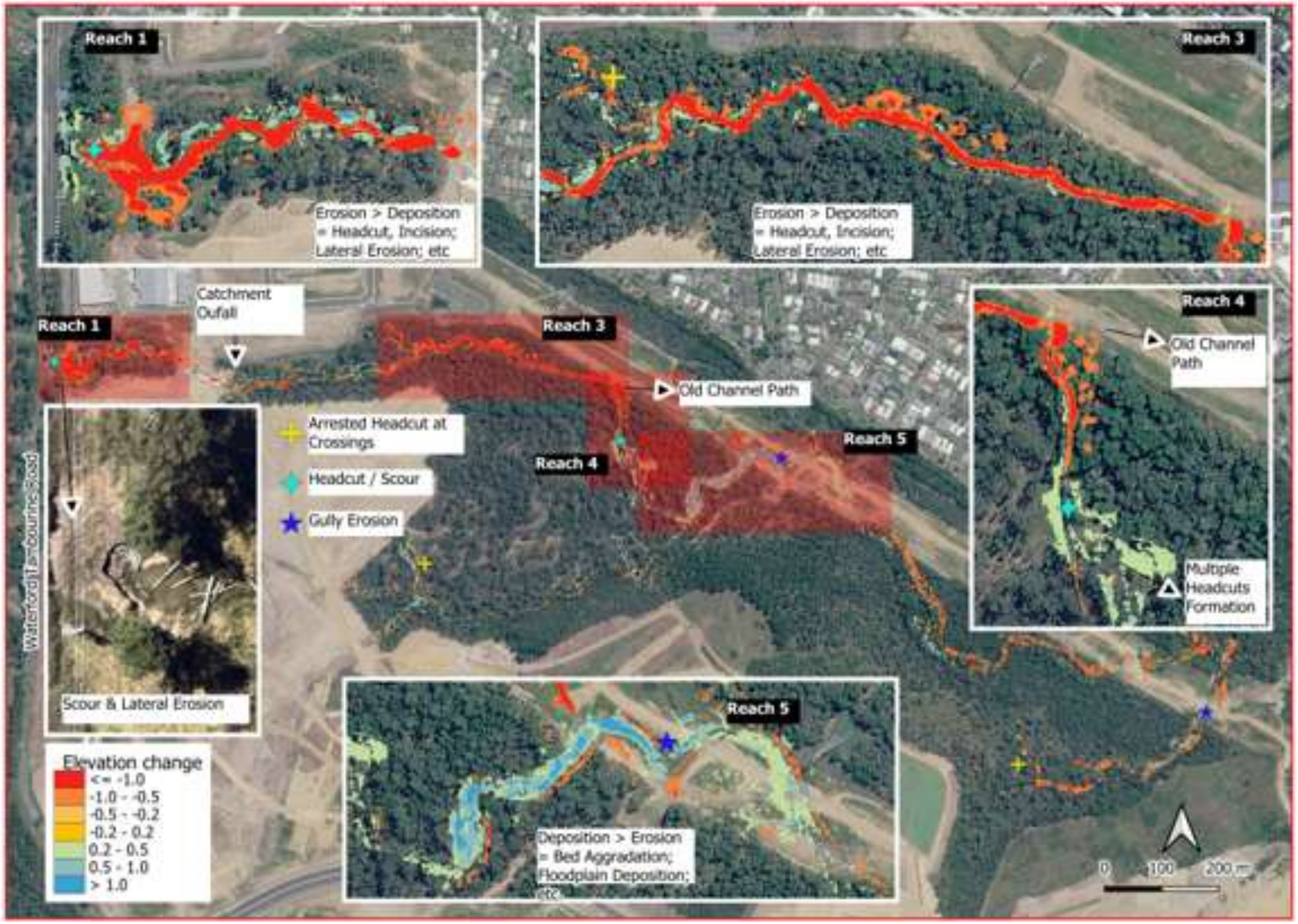

Figure 3 Spatial distribution of elevation changes and longitudinal bed-level profiles for Quinzeh Creek between 2009 and 2023

A downstream transition in geomorphic behaviour was evident across Reaches 5–7, although the magnitude of adjustment was substantially lower than in Reaches 1–4 (Figure 3). These downstream reaches were characterised by greater channel complexity, discontinuous flow, ponds, and localised infrastructure controls. These features are typical of a cut-and-fill system, where channel form reflects alternating phases of erosion and deposition. The lower level of downstream erosion may therefore reflect natural cyclic variability. However, evidence of bed-level lowering between 2009 and 2023, particularly in Reaches 8 and 9, suggests that the system has gradually shifted from a cut-and-fill regime to a more degraded condition, in which erosion increasingly exceeds aggradation.

Overall, the results indicate that current channel behaviour is controlled mainly by inherited geomorphic conditions rather than by recent urbanisation alone. Urbanisation appears to act as a secondary influence that may intensify existing instability as development continues. Without appropriate management, further headcut migration, sediment redistribution, bank erosion, and channel widening are likely.

Discussion

Influence of historical geomorphic legacies on present-day channel adjustment

The findings indicate that historical geomorphic legacies strongly influence present-day channel adjustment in Quinzeh Creek. The greatest observed geomorphic change occurred in Reaches 1–4, where substantial incision, lateral erosion, bank undercutting, and headcut development were recorded between 2009 and 2023. However, these reaches may have undergone their primary phase of adjustment before the 2009 baseline. Geomorphic changes were not spatially uniform across the catchment, suggesting that channel responses were influenced by historical land use, including vegetation clearance, and inherited local conditions, such as geology and road crossings, rather than by urbanisation alone. This spatial variability is consistent with previous studies showing that urban stream responses are often highly variable and strongly influenced by geology, historical land use, sediment supply, infrastructure, and pre-existing channel morphology, rather than by impervious cover alone (Nelson et al., 2006; Soboyejo et al., 2025).

The upstream reaches appear to be particularly sensitive to further change because historical and inherited disturbances have lowered the channel bed, increased bank height, and created conditions favourable for continued headcut migration. In Reach 1, bed-level lowering of approximately 4–7 m suggests that the channel may have crossed a geomorphic threshold. This distinguishes Reach 1 from reaches adjusting within an existing channel state, as it appears to represent a fundamental shift in channel form and process following threshold exceedance. This interpretation is consistent with channel evolution models in which disturbance initially causes incision, followed by bank instability, widening, and sediment redistribution (Schumm et al., 1984). Booth and Fischenich (2015) similarly emphasised that urban channels cannot be interpreted from their present form alone, because similar forms may reflect different evolutionary trajectories depending on their inherited disturbance history. Historical road crossings, informal tracks, vegetation clearance, and dispersive soils have therefore created a channel system already susceptible to incision and widening, influencing how it responds to subsequent disturbance. Urban development may increase hydraulic stress, but the observed spatial pattern suggests that urbanisation is acting on a channel system that was already unstable.

Relationship to urban stream syndrome and predictive limitations

The results show some characteristics associated with urban stream syndrome but complicate its conventional interpretation. Urban stream syndrome concept suggests geomorphic instability, poor water quality, and ecological degradation associated with poorly managed urban development (Walsh et al., 2005). Quinzeh Creek shows several of these symptoms, including incision, widening, bank erosion, and sediment mobilisation. However, in this context, it is useful to distinguish between channel adjustment – responses such as incision, widening, or bank erosion within an existing geomorphic trajectory – and more fundamental river change involving a reorganisation of channel form or dominant processes.

At Quinzeh Creek, recent urbanisation appears to be driving adjustment within a system that had already experienced substantial change from past vegetation clearance and land use. This spatial pattern suggests that channel responses cannot be attributed only to recent urbanisation. Many predictive approaches assume that channel enlargement increases systematically with urbanisation or impervious cover. The Quinzeh Creek findings instead align with studies showing that urban stream responses are often discontinuous because local controls, historical disturbance, and infrastructure modify channel sensitivity (Nelson et al., 2006; Soboyejo et al., 2025). The greatest geomorphic change occurred where historical disturbance, dispersive soils, culvert effects, and altered flow paths interacted. Therefore, imperviousness or urban development stage alone provides an incomplete explanation of channel behaviour. This also supports the argument that space-for-time approaches can be misleading when historical legacies are ignored. A less urbanised reach may not represent a pre-disturbance condition if it has already been affected by forestry, clearing, informal tracks, or drainage alteration. Likewise, a highly urbanised reach may appear severely degraded because urbanisation is amplifying an existing instability. In such systems, the conventional urban stream syndrome concept may not fully explain the observed channel response.

Implications for management, planning, and restoration

The findings have direct implications for urban stream management and planning. First, management should not assume that all observed erosion is caused by current or future urbanisation. In Quinzeh Creek, several reaches were already actively adjusting before urban development, meaning that management strategies must address inherited instability as well as future stormwater impacts. Wohl (2019) argued that failure to recognise historical legacies can distort perceptions of natural channel form and lead to ineffective restoration targets.

Second, intervention priorities should be reach-specific. Reaches 1 to 4 require more urgent attention because they show active incision, widening, and headcut development. Local stabilisation alone may be insufficient where channel beds are still lowering or where headcuts are migrating. In contrast, downstream reaches with greater sediment storage and floodplain connectivity may require protection of existing geomorphic complexity rather than heavy structural intervention.

Third, the findings support catchment and reach scale process-based rather than symptom-based management. Vietz et al. (2016) argued that urban stream restoration often fails when it treats channel erosion symptoms without addressing catchment-scale causes such as excess stormwater runoff, altered sediment supply, lack of riparian space, and legacy impacts. For Quinzeh Creek, this means that future planning should combine stormwater flow attenuation, riparian vegetation protection, headcut control, and careful design of crossings and drainage outlets.

Finally, the study highlights the need for historical assessment as a routine part of urban waterway planning. Historical understanding of geomorphic responses prior to development allowed pre-existing instability to be separated from more recent development impacts. This is valuable for councils, developers, and catchment managers because it helps identify where intervention is needed, where natural recovery may be possible, and where development could accelerate existing instability.

Conclusion

This study demonstrates that channel adjustment in Quinzeh Creek is primarily controlled by historical legacy effects, with urbanisation acting as a secondary driver that amplifies pre-existing geomorphic instability. Upstream reaches exhibited significant incision, headcut development, and lateral erosion, while downstream reaches showed greater sediment storage and reduced adjustment, reflecting spatial variability in inherited conditions.

Past land-use disturbances, including forestry, clearing, and flow modification, have played a critical role in shaping present-day channel behaviour. These findings highlight the limitations of attributing channel change solely to urbanisation and emphasise the need to incorporate historical context into interpretation. Effective management therefore requires reach-specific, process-based strategies that address both legacy impacts and future urban development pressures.

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