Consideration of geomorphology and room for the river concepts in adaptive urban stream management in South East Queensland

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Key Points

- The use of Room for the River and Geomorphological approaches to urban water management.
- Room for the River uses a holistic, integrated approach to achieve flood safety, and improvement of landscape, environmental and cultural values.
- Using geomorphology to understand, predict, and manage flood impacts.
- Adaptation of South East Queensland planning and policy to include holistic geomorphic considerations.

Abstract

- In February 2022, eastern Australia experienced, at the time, its costliest flood in history (ICA, 2022). The flooding differed from many previous floods in that "flooding occurred in the Brisbane River and creeks and through overland flow, all at once" (Margaret Cook pers comm.). North Brisbane and Moreton Bay Creeks particularly suffered.
- As a result of this rainfall, many of the creeks across South East Queensland suffered widespread erosion, failure of embankments/levees, isolated severe aggradation, and damage to private and public infrastructure.
- Responses to these damages and changes have traditionally been reactionary, site-specific, and limited by planning regulations.
- While flooding and flood interactions often dominate the conversation with regard to urban water management, there is recognition that floodplains provide an important community, economic and environmental resource. Management of these competing objectives in the urban environments is vital to achieving outcomes that provide benefits to all stakeholders.
- A bigger picture, Room for the River approach that considered alternatives (e.g. floodplain widening/lowering, allowance for migration, etc.) was investigated to address immediate flood response and future planning.
- The assessment showed that while there are competing objectives (i.e. urban expansion vs ecological health) there are opportunities throughout the South East Queensland region where expansion of river corridors can improve environmental outcomes within existing (or improved) urban planning frameworks.

Keywords

Room for the River, River Corridor, Geomorphology, River Characterisation, Urban Water Management, Water Policy, South East Queensland

Introduction

Dealing with flooding in South East Queensland (SEQ) is an ongoing and long-term issue and exacerbated by climate change, discussed at length in the seminal book *River with a City Problem* (Cook, 2023). In the book, Margaret Cook, a historian with significant experience in environmental and social history, provides an engrossing account of the history of Brisbane River flooding. In the book, Cook (2023) notes that our responses to flooding, particularly during recovery and future prevention, have failed in many respects, with the opportunity to adopt lessons learnt often masked by 'blame games' and blinkered operational dam management measures and urban expansion continuing in areas previously impacted by floods.

The Room for the River (RftR) concept introduced in the Netherlands is an attempt to manage flooding in highly populated areas using a range of engineering, hydraulic, geomorphological, and ecological approaches. Inclusion of geomorphology in this approach in a river corridor or riverscape concept (Glassic et al. 2023, Nelson et al. 2023) in combination with urban water management approaches that are multi-disciplinary and consider competing/complementary social/cultural, economic, and environmental objectives, has the potential to transform and improve urban water management in SEQ. This paper explores the RftR concept, geomorphologists' use of the river corridor in urban water management, and how these concepts can be adopted in policy and planning mechanisms, using the SEQ region as an example.

SEQ Experience

Flooding

SEQ has a long history of flooding that is well known and described in detail by Cook (2023). While several floods have occurred in SEQ in recent times (e.g., Ex-TC Oswald, TC Marcia, TC Debbie) (BOM 2013, 2015, 2017), the two most notable events over the last 15 years have been the 2011 and 2022 floods. The 2011 Queensland floods, including large parts of SEQ and the Brisbane River, caused almost $2.4 billion in damage (Carbone & Hanson, 2012). While floods occurred across the region, the flooding was described as a 'river' flood as the most damage (and a large part of the media attention) was focused on the Brisbane River and other major creeks/rivers. The February 2022 flooding across Eastern Australia (including SEQ) was, at the time, the costliest flood in Australian history (ICA, 2022). It reportedly resulted in $5.45 billion in damage (ICA, 2022) and inundated >20,000 homes in SEQ alone (Ludlow, 2022). In Brisbane, between 400 and 1,000 mm fell between 23 and 28 February, with several locations in the Brisbane City Council boundary receiving in excess of 400 mm in 24 hours (BOM, 2022). The flooding differed from many previous floods in that 'flooding occurred in the Brisbane River and creeks and through overland flow, all at once' (Margaret Cook pers comm. in Hutchins 2023). North Brisbane and Moreton Bay Creeks particularly suffered, with 893 mm falling in the Kedron Brook catchment (see Figure 1 for location).

In response to various Brisbane floods, Cook (2023) noted that governments lost the chance, to some degree, to respond adequately to flooding impacts of 2011 (and subsequent events), largely due to over-reliance on using 'different' Wivenhoe Dam management (Wivenhoe Effect) as the tool to control flood impacts. Issues of land management and planning (e.g., property buy-back) were largely ignored (Cook 2023), perhaps attributable to a general reluctance of communities to accept governments' introduction of land use planning measures (Bird et al. 2013). Councils have, however, implemented a number of changes to their planning schemes to adapt to flood hazard, including altering allowable floor levels, allowing raising of houses beyond previously acceptable standards to protect homes from flooding, introducing property buyback schemes in particularly flood prone areas, updating of flood models to reflect new data, locating new growth areas remote from flood constraints, encouragement of new developments that are designed, sited and constructed with consideration of flood hazard.

Urban Expansion

There has been rapid urban development throughout SEQ over the last century, from development of former farming land in the inner circle of Brisbane post World War I, increased vigour of urbanization into greenfield sites in Ipswich, Logan, and Gold Coast in the 21st century, and increased density of housing throughout the region since World War II. Cook (2023) noted that a lot of this urban development occurred after the 1974 Brisbane River flood due to the Wivenhoe Effect, which has proven to be flawed in recent times. And despite the 2011 (and 2022) floods, the introduction of more resilient practices (e.g., controls on development in flood-prone areas, property buy back) was often hindered by what Cook (2023) describes as a 'blame game' and a general belief that flooding could and should be managed using better operation of upstream dams (Cook, 2023, Bird et al., 2013).

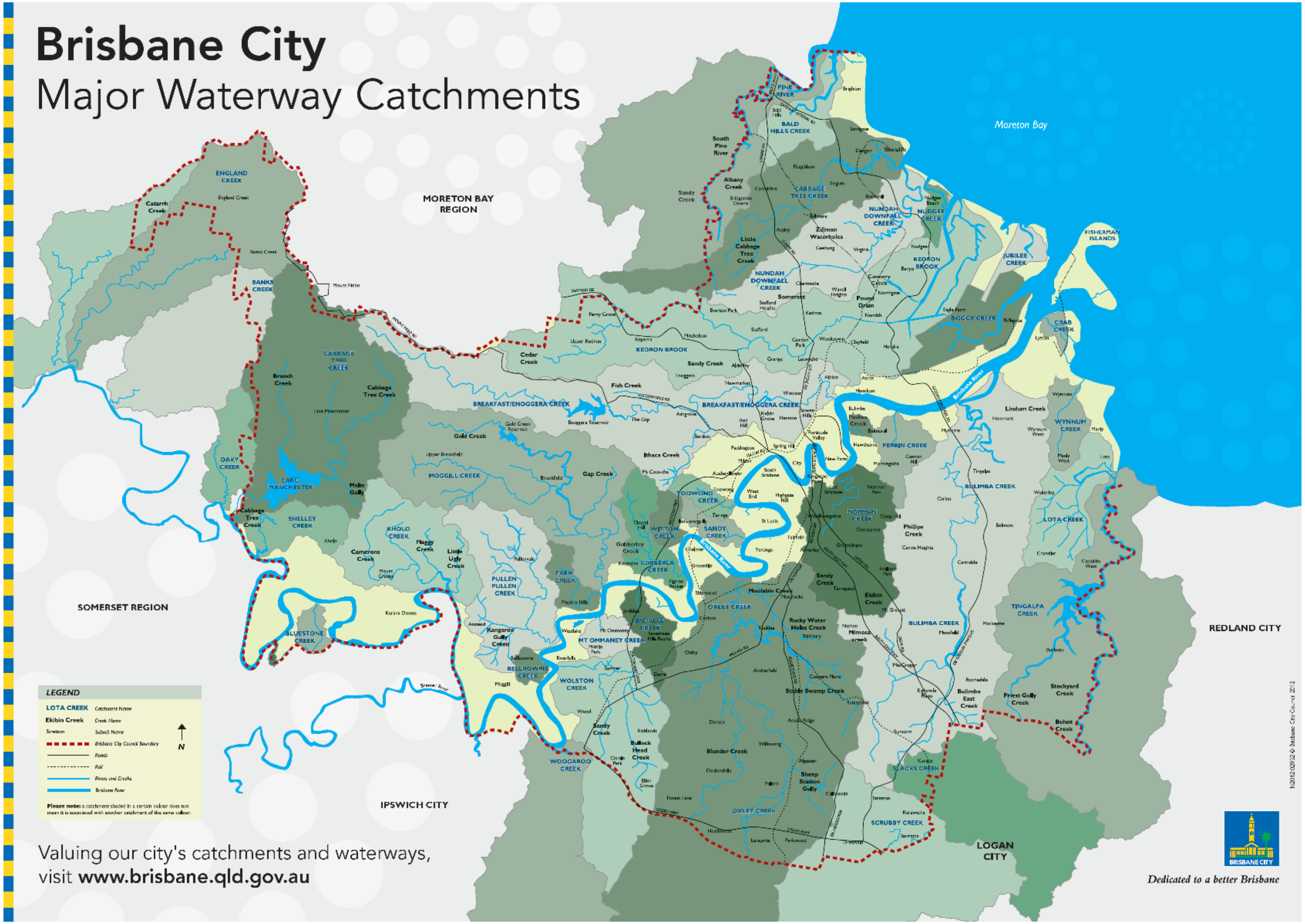

Figure 1. Brisbane City catchments. Source: Brisbane City Council website (2024)

Irrespective of the reliance on dam management, much of this urban expansion has occurred in areas without water regulation. For instance, as part of a presentation to Stormwater Queensland on the RftR approach, Pearson (2023) mapped the 2022 Kedron Brook flood extent, the approximate 1925 Kedron Brook floodplain (based on 1925 army topographic maps), and open space versus urban footprint in the catchment. Figure 1 shows the results of this mapping and, while the 1925 floodplain is approximate (based on 20 m contours), there is clear confinement of the floodplain over the last century, intrusion of housing and other urban landuses into both the 1925 floodplain and current flooded areas, and significant opportunities for adoption of a geomorphologically driven RftR/river corridor approach. This could include lowering open space land to increase flood storage and opportunities for waterway migration, buyback of properties particularly at risk of flooding or shifts in channel morphology, and adoption of threshold versus alluvial based river management (NRCS, 2007).

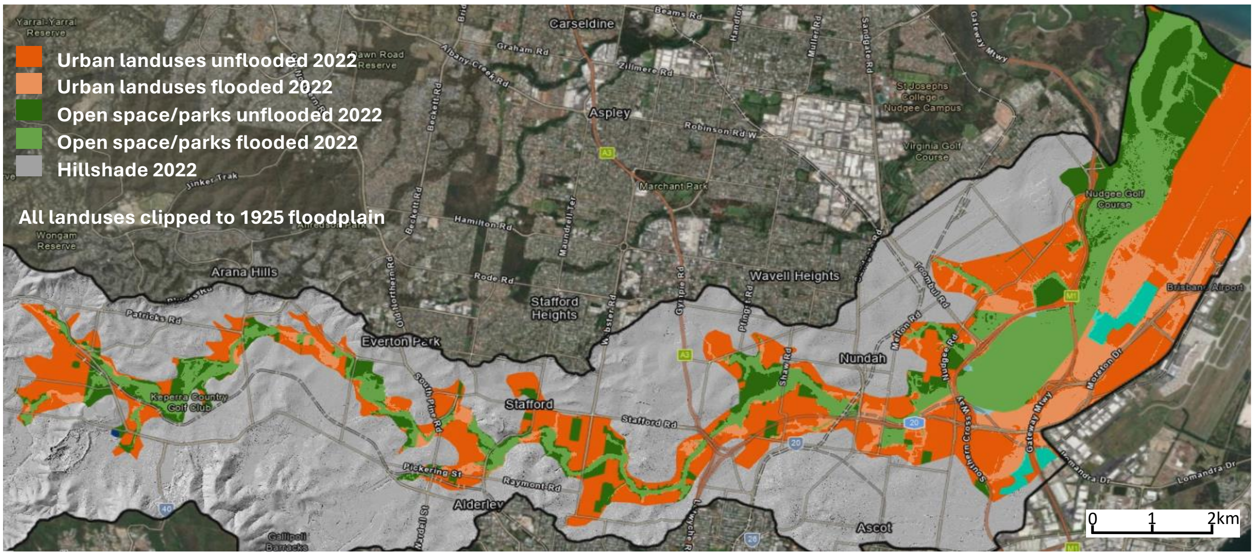

Figure 2. Kedron Brook floodplain changes since 1925. Sources: Nearmap, 2024; BCC, 2017, 2020, 2023; State of Queensland, 2023.

RftR Concepts

The RftR concept is not a new one. It is based on a 'holistic, integrated approach embracing a multi-functional river in which flood safety is realized in combination with other values such as landscape, environmental and cultural values' (Zverenbergen, 2015). However, its development particularly took flight in the early 2000s in the Netherlands and the development of the concept was largely driven by management of flood issues with benefits to other aspects. Strategies included deepening the main river channel and/or lowering groynes to improve flow conveyance, removal/modification of channel obstacles to increase discharge capacity, water storage to reduce the lateral peak inflows, levee relocation or reinforcement to widen the floodplain and increase RftR, lowering/excavation of floodplains (including construction of by-pass or secondary channels) to increase flood storage, reduce velocities, and improve habitat diversity, implementation of proper land use planning to reduce the likelihood of human-flood interaction, and increased use of vegetation and other nature-based solutions.

Since its development in the Netherlands, it has been further implemented around the world, with some examples specifically based on the original concept (e.g., Living with Water, the Greater New Orleans Urban Water Plan), and others addressing specific flooding or multi-disciplinary issues (e.g., Making Space for Water, the Auckland City Council response to major flooding in 2023; Brisbane City Council Masterplanning, e.g., Oxley Creek Transformation) through the reference to RftR themes (although not specifically referencing the Netherlands experience). While these programs have largely been driven by addressing flood mitigation issues, they have also aimed at improving environmental, economic, and social outcomes.

RftR Geomorphology

While not specifically addressed in the original RftR key strategies, RftR certainly considers geomorphic processes. A holistic approach that allows floodplain space (or a river corridor) for waterway migration or evolution in response to changes in geomorphic drivers is central to the sustenance of key river functions. Nelson et al. (2023) noted that RftR style approaches that concentrate on specific outcomes were unlikely to result in good eco-geomorphic outcomes. Indeed, the holistic view of rivers that accompanies a geomorphological interpretation, including consideration of the process-form relationship, the role that river character (or River Styles), behaviour, and trajectory play in defining the amount of room a river requires or its likelihood of adjustment (Brierley et al., 2002, O'Brien et al., 2017), the importance of vegetation in improving geomorphic outcomes, and the role of thresholds, lag times, and complex responses, enables a more thorough appreciation of the importance of room for rivers and the multi-disciplinary approach that is required to achieve well managed, healthy fluvial systems.

Inclusion of geomorphology in the RftR approach leads to:

- A better understanding of river characteristics (e.g., confinement, boundary material) and processes (e.g., hydraulics) that drive river behaviour and thus how they will respond to hydrologic, vegetative and sediment supply changes or to management measures both within and between morphologically disparate reaches (O'Brien at al., 2017).
- Channel migration and morphological shifts consistent with undisturbed channels, which in turn results in improved channel health and habitat diversity (Williams et al., 2020).
- Improved ecological-geomorphic interactions (Castro and Thorne, 2019, Johnson et al., 2019, Nelson et al., 2023), including encouragement of floodplain development or rejuvenation, development of riparian habitat and introduction of wood (Collins, et al., 2012), maximization of flood protection and conveyance (Church, 2006), resilience against confinement (natural or anthropogenic) where it occurs, and increased complexity of channel morphology and hydraulics that allows for improved ecological health (Nelson et al., 2023).
- An understanding that the effect of riparian vegetation on waterway health and performance is independent of the level of urbanization (Hession et al., 2015).
- Identification, and better management, of geomorphologically sensitive reaches that inherently aids in reach prioritisation across a catchment (Wheeler et al., 2022).

RftR in Policy and Planning in Response to Floods

RftR Inclusions

While flooding and flood interactions often dominate the conversation with regard to urban water management, there is recognition that floodplains provide an important community, economic and environmental resource. Management of these competing objectives in the urban environments is vital to achieving outcomes that provide benefits to all stakeholders. As a result, there is increasing attention on the inclusion of RftR approaches in urban (and rural) water management in Australia. Specifically, there is increasing attention in SEQ, including:

- Brisbane City Council flood and waterway corridor overlays (BCC, 2023) that, through the enforcement of performance outcomes, are designed to protect waterway health (including bank stability), flood storage and conveyance, and cumulative impact on floods. Specifically, bank stability is protected through various setback distances, implantation of natural waterway design principles to improve waterways near development, and restrictions on new and existing development in waterway corridors and flood prone areas.
- The Moreton Bay Regional Water Strategy (MBRC, 2015), that promotes the importance of managing waterways by adapting urban form to water movement, protection of ecological health and biodiversity of waterways, managing flood hazard, adoption of improved modelling and evaluation techniques, balancing competing objectives (social vs environmental vs economic vs flood risk), limiting uncontrolled development that is inconsistent with flood risk, and management of

hazard/damage to existing development, among other measures. The council has similar waterway corridors as those adopted in Brisbane to manage this.

- Similar policies and planning mechanisms as those described above in other councils in the region (e.g., Redland, Logan, Gold Coast, etc.).
- Internal waterway management measures developed by private and government-owned corporations, including utilities companies (e.g., Seqwater, Urban Utilities) that have varied success (e.g., river rehabilitation measures using hard and/or soft engineering approaches).
- Resilient Rivers Initiative, which is an organization that adopts a coordinated approach to catchment management that has signatories include the Council of Mayors (SEQ), Queensland Government, Seqwater, Healthy Land and Water, Unitywater and Queensland Urban Utilities. They focus on delivering a coordinated approach to catchment management in the region, improving resilience of waterways in both current and changed climates, and promoting collaboration through partnerships between organisations.
- Queensland Reconstruction Authority's *Queensland Strategy for Disaster Resilience 2022–2027* (QRA, 2022), which was introduced in response to a number of recent flood events in the state, focuses on themes of risk reduction, flood mitigation, and human and environmental resilience. It encourages partnerships and collaboration, climate change adaptation and resilience programs.
- The SEQ Regional Plan 2009-2031, which includes themes that focus on water sensitive cities, coordination of catchment management through the Resilient Rivers Initiative, minimization of impacts of land development to the hydrological cycle and water quality/quantity, replicating natural cycles, encouraging water conservation including sustainable extraction and reuse, and improvement of water quality. Further research on the implications of these practices on flood impacts is needed to assess their effectiveness.

Opportunities for Policy Improvements

Despite the focus above, there is still often greater attention on protection of assets/infrastructure (rather than the impact of these assets on channel health or flood extent/impact). There is still a widely held consensus amongst many lay people and water professionals that flooding can be controlled or 'tamed'/'harnessed' with little public support of 'non-structural mitigation options' (Cook, 2023). There is an over-reliance on engineered solutions rather than consideration of geomorphology in development of management issues or, probably more importantly, the inclusion of First Nations' knowledge of waterway processes (Cook, 2023). While waterway and flood overlays in councils' planning schemes certainly mention waterway health and channel stability, there often appears to be more focus on using hydraulic modelling to show no or minimal impact to performance outcomes in policies or use of offsets to counteract any impacts. This is a generalization and there are certainly examples in policies where this is not the case, but urban development within waterway corridors and flood prone areas still occurs (and likely due to meeting acceptable outcomes based on evidence provided). This falls short from an urban water management perspective as it:

- Ignores the purpose of such regulations limiting development in flood-prone areas.
- May ignore the fact that there is inherent error in hydraulic models. Summaries by expert reviews of Brisbane River flood modelling errors suggest that this can have a major impact on flood extent (Anon, 2011, QFCI, 2012). Anon (2011) noted, for example, that adopted flood planning levels at the Brisbane City Gauge varied from the adopted level (in 2011) of 3.7m between 2.8 and 3.8 m, while QFCI (2012) noted that there were a number of assessments that predicted levels up to 5.34 m.
- Often uses a single flood event to dictate urban planning decisions, whereas from a geomorphic perspective, the currently used design event tells us less about potential geomorphic work than more frequent smaller events. QFCI (2012) noted this in their review of Brisbane flooding.
- May ignore the fact that waterways are dynamic and likely to change over time, including lateral migration/avulsion, deepening, widening etc. Any changes that do occur (or indeed any cumulative urban land use changes) will invalidate any hydraulic model outputs used in the decision-making process.

- Fails to effectively address the physical processes by which river channels are formed and maintained, and the importance of history, catchment drivers, cumulative impacts, and site-specific conditions, which are critical to successful river management and restoration. O'Brien et al. (2017, p369) noted that many river restoration efforts are 'opportunistic, pursued at a reach scale without knowledge of the watershed context of geomorphic condition and recovery potential'.
- Is still underpinned by an underlying theme of patchwork river rehabilitation contributed by council boundaries, competing interests (both within and between councils), and the lack of an independent organization that might oversee waterway management across multiple jurisdictions. This is despite valiant attempts at managing the region's waterways in a collaborative approach (e.g., Resilient Rivers Initiative). Government led initiatives have provided positive outcomes but will always lack the resources required to monitor these works.
- May use offsets (or compensatory cut) to mitigate impacts, which need to be considered carefully in terms of cumulative impacts. The authors are aware that this process is monitored very closely by council officers in undertaking their assessments.
- Waterway corridors often do not reflect defined flood extents and may result in decisions that conflict with geomorphic principles. Figure 2 shows two examples of this misalignment in lower Oxley Creek.
- Still allows development within waterway corridors/flood prone areas, where the development is seen to meet objectives. For example, the development shown in Figure 3 was constructed within undeveloped floodplain (old farming land) and within BCC's own waterway corridor and flood overlays. The authors are not aware of the details of this decision and make no judgement on how the development was approved or whether there were offsets/compensatory cuts employed to mitigate against any impact. However, from a geomorphic perspective, this development has the potential to impact or be impacted by channel migration, sediment fluxes and altered sediment regimes and their influence on future flood behaviour. This is particularly the case when channel trajectory is considered. Based on reviews of planning documents, there is currently little that could be done to address these aspects in the decision-making process.

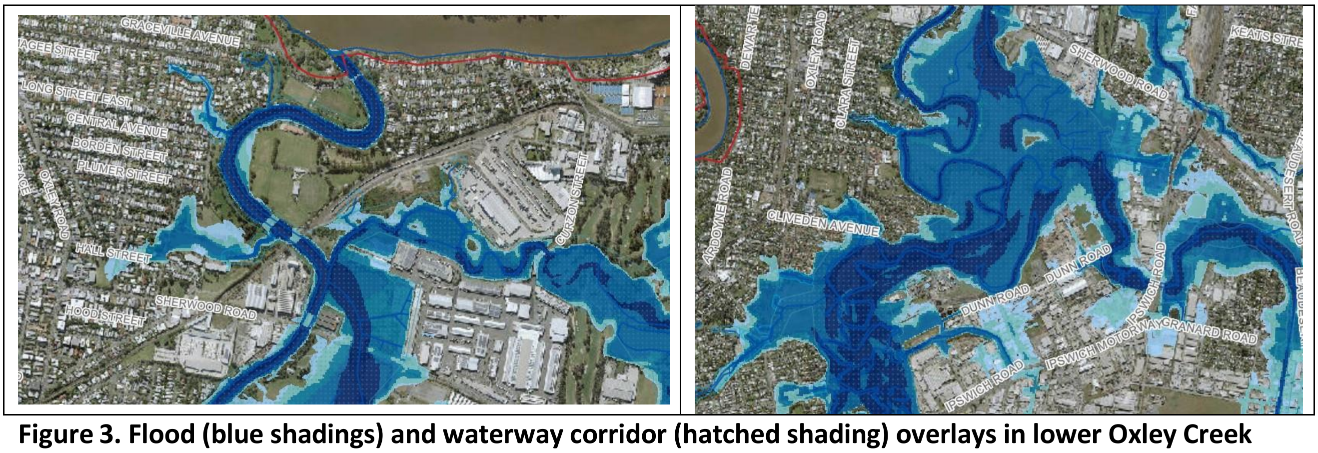

Figure 3. Flood (blue shadings) and waterway corridor (hatched shading) overlays in lower Oxley Creek catchment, showing larger flood overlay areal extent. Source: Nearmap, 2024, State Government, 2023, BCC, 2013, 2017, 2023.

Figure 4. Land development (in the red circle) within the waterway corridor (and flood prone) areas. This development was deemed as acceptable despite being within these planning polygons. Source: Google Earth, 2024, State Government, 2023, BCC 2013, 2017, 2023.

A Tried and Trusted Geomorphological Method Solution

We have used a geomorphological approach, that is at its heart driven by River Styles-based principles (Brierley & Fryirs, 2005), to understand urban catchment geomorphology, account for competing interests, and propose a number of considerations for future river management in urban environments and in policy adoption. The approach considers stream characterisation (catchment and valley conditions, planform character, geomorphic units and structural elements, bank/bed material, longitudinal slope variation), catchment sediment regime and the importance of sediment fluxes in driving geomorphic change, regime modelling to assist in understanding ideal channel morphology, channel stability (past changes, current stability/instability, modelling future trajectory), longitudinal hydraulic variations, urban confinement and proximity to infrastructure, competing environmental, economic, and social interests (e.g., stormwater infrastructure, flood mitigation, bridges, roads, housing, sporting fields, etc.), and complementary interests (e.g., First Nations management, protected areas, etc.).

Improvements to Water Management and Policy

Using the above approach, opportunities for urban water improvement can be implemented that consider a multi-disciplinary river corridor approach that provides an ultimate nature-based solution (Nelson et al., 2023), addresses RftR objectives, considers conflicting/complementary interests, and uses less sustainable approaches, where absolutely necessary. The above has been used to develop a number of recommendations that have been put forward as potential future urban water management measures in South East Queensland, specifically, but also potentially further afield. They have been developed from our knowledge of ecological-geomorphological-hydrological interactions and other research and best-practice management adopted worldwide. The recommendations include:

- Waterway characterisation, to improve forecasting of potential geomorphic change and its influence on future flooding and channel migration (Fryirs et al., 2016).
- Quantification of lateral channel migration (historical, current, future), particularly in areas where waterway corridors are limited by surrounding urban development. In doing so, there should be consideration of thresholds, lag times, and complex river responses (Thorne et al. 1997).
- Quantification of sediment regimes to enable better understanding of their influence on flooding and future geomorphic change.
- Increasing our understanding of the influence of floodplain extents on specific urban catchments (e.g., 'narrow' Kedron Brook versus 'wide' Oxley Creek).
- Discussions that encompass both geomorphology and other competing/complementary interests (social, environmental, economic) to enable better management decisions that are governed increasingly by an understanding of historical and future waterway condition (Nelson et al., 2023).
- Use of geomorphic regime models to predict 'ideal' geomorphic form (Eaton et al., 2004).

- Provision of opportunities for room for movement (including acceptance that waterways will move), including greater encouragement of setbacks/buffers in policy (Wheeler et al., 2023) and lowering of raised floodplain surfaces.
- Greater consideration of the effects of climate change on potential waterway movement (Wheeler et al., 2023), including 'adaptation to future events and a changed hazard landscape' (Bird et al., 2013).
- Continued and extended implementation of property buyback schemes in both flood prone areas and areas where channels are predicted to be mobile (Wheeler et al., 2023). Cook (2023) noted that land resumption was not a recent phenomenon, having been haphazardly implemented following the 1893 Brisbane River flood, but that an extended, formalized system would provide excellent mechanisms for floodplain renaturalisation.
- Improved household adaptation schemes that increase adoption of the schemes to reduce impacts of existing (and unresumed) properties on floods (and vice versa). Bird et al. (2013) noted poor adoption of introduced schemes for several aesthetic, financial, or future flood proofing related reasons.
- Greater inclusion of geomorphology in planning policy and development approvals and adoption of network scale riverscape (channel, floodplain, and catchment) solutions (Glassic et al., 2023), including mapping of sensitive areas to allow residents to make informed decisions over the risk of their current or future properties (Wheeler et al., 2023).
- Implementation of an independent body that oversees the prioritisation of waterway management schemes, particularly where these schemes are within the same riverscape as other jurisdictions.

Conclusions

Current urban water management in South East Queensland has shown that while immediate responses are required following floods to ameliorate safety issues, improve waterway asset functioning (i.e., maintenance of floodway conveyance), and replace/repair damaged infrastructure, consideration of Room for the River concepts were required in the longer term to improve waterway resilience. However, these concepts don't align with current planning regulations which inadvertently promote channel/site-specific solutions. 'We need to learn to live with the river' (Cook, 2023), reduce flood (and geomorphic) hazard, and improve our flood (and geomorphic) resilience, rather than control it. Specifically, we need to learn from lessons past as 'truly adaptive societies do not choose to suffer the same calamities time and again' (Powell, 1991).

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