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# Urban Drainage Failure in Durban's 2022 Floods and a SUDS Pathway to Improved Resilience

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## 1 ABSTRACT

Durban's stormwater system is no longer fit for purpose. Durban's 2022 floods exposed a fundamental mismatch between the city's evolving hydrological conditions and its outdated stormwater system. The drainage network, much of it designed for mid twentieth century rainfall and smaller catchments, now functions close to capacity under ordinary conditions and fails rapidly during extreme events. This paper examines the mechanisms behind that failure and identifies the structural and operational constraints that prevent the system from managing contemporary runoff volumes. Using post-event assessments, municipal documentation and targeted stakeholder insights, the analysis shows how undersized pipes, irregular maintenance, blocked channels and disrupted natural drainage pathways created a cascade of hydraulic failures during the 2022 event. These weaknesses allowed localised surcharging to escalate into widespread inundation, particularly in densely populated and low-lying settlements. A focused set of SUDS measures could address these performance gaps by introducing decentralised storage, infiltration and controlled conveyance in congested subcatchments. Rather than advocating generic nature-based solutions, the paper isolates the SUDS functions most suited to Durban's geomorphology, institutional capacity and settlement form. The findings demonstrate that targeted SUDS retrofits, aligned with existing maintenance and operational cycles, would expand system capacity more effectively than further enlargement of conventional infrastructure. The paper outlines a practical pathway for integrating SUDS into routine planning and operations, enabling the city's drainage system to adapt to intensifying rainfall without relying on large-scale capital upgrades.

Keywords: Pluvial Flooding; Stormwater Management; Sustainable Urban Drainage Systems; Urbanisation, Urban Failure

## 2 INTRODUCTION

### 2.1 Background

Durban's stormwater system is no longer fit for purpose. At first glance, it is clear that the municipal structures within the province of KwaZulu-Natal are battling to maintain and improve the stormwater management system that continues to fail. During the April 2022 floods, disaster management was unprepared and could not manage the effects of a sudden heavy rainfall period, as seen below, the aftermath is devastating (Hattingh, 2022).

The April 2022 floods represented a critical stress test of this system. Extreme rainfall, concentrated over short durations, rapidly exceeded the hydraulic capacity of pipes, culverts, and open channels across multiple catchments (Muthanna et al., 2018). Widespread surcharge, overtopping, and structural failure occurred, often outside historically mapped floodplains. Damage patterns revealed that failures were not isolated to individual assets but reflected systemic overload, compounded by sediment accumulation, debris blockage, and limited redundancy within the network (Bond & Galvin, 2023). The event exposed the vulnerability of a drainage system designed to move water away quickly, with little capacity to store, delay, or absorb runoff within the urban landscape.

Post-flood assessments highlighted that upgrading conventional infrastructure alone is neither technically nor financially feasible at the scale required to match projected rainfall intensification. Large-scale pipe replacement would involve significant disruption, high capital costs, and long implementation horizons, while still relying on static design assumptions in a context of climatic uncertainty (Martel et al., 2021). This has prompted growing interest in alternative approaches that can enhance system performance without complete infrastructural overhaul (Emmett, 2023).

Within this context, Sustainable Urban Drainage Systems have emerged as a credible resilience pathway. SUDS shift the focus of stormwater management from rapid conveyance to distributed control, aiming to replicate natural hydrological processes through infiltration, detention, and controlled release (Grab, 2023). Rather than replacing existing drainage infrastructure, SUDS can be retrofitted into the urban fabric to intercept runoff at or near its source, reducing hydraulic loading on downstream systems (O’Donoghue et al., 2022). This approach is particularly relevant for Durban, where spatial constraints and uneven development patterns limit the scope for conventional expansion.

The relevance of SUDS to Durban’s 2022 flood experience lies in their capacity to address the specific mechanisms of failure observed during the event. By attenuating peak flows, delaying runoff response, and improving runoff quality, targeted SUDS retrofits can extend the effective capacity of existing drainage assets under extreme rainfall. Importantly, SUDS enable a shift towards catchment-based stormwater management, allowing interventions to be prioritised in areas of greatest hydrological risk rather than applied uniformly across the city (McLeod & Mickovski, 2024).

Image 1: oThongathi post 2022 floods, Captured for Mail and Guardian (2022)

Grab & Nash (2023) expanded their initial thesis by outlining the flood chronology for KwaZulu-Natal, wherein they uncovered interesting insights into the manifestation of urban decay since 1836, leading up to and including the 2022 floods. A common thread of identifying municipal neglect and targeted funding (in more affluent areas) showed the true face of failure as a consequence of urbanisation.

## 2.2 Introduction

Durban’s 2022 floods exposed a fundamental mismatch between the city’s evolving hydrological conditions and its outdated stormwater system. Temporally, it is notable to realise that a city built for around 400,000 (four hundred thousand) inhabitants is now home to almost 4,000,000 (four million) people (World Population Review, 2025).

The drainage network, much of it designed for mid twentieth century rainfall and smaller catchments, now functions close to capacity under ordinary conditions and fails rapidly during extreme events (eThekwini Municipality, 2020). Given that many of Durban's existing drainage systems were not designed to handle the increased stormwater volumes resulting from urban expansion and climate change, prioritising the retrofitting of these systems is imperative (Gumbo, 2014). A large-scale initiative should be launched to upgrade conventional drainage infrastructure by incorporating SUDS components that can effectively slow down, capture, and filter stormwater. Special attention should be given to flood-prone areas identified through flood risk maps and rainfall data. By targeting these high-risk regions for retrofitting, the initiative can maximise the impact on flood mitigation and improve overall urban resilience.

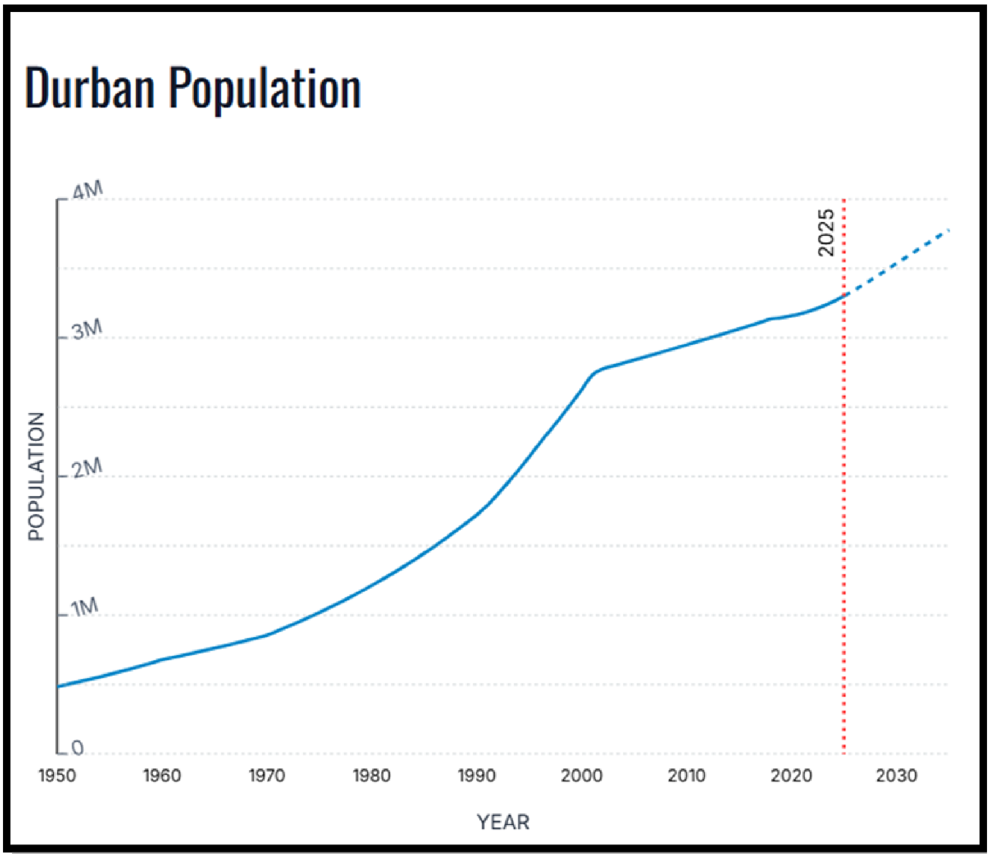

Figure 1: World Population Review: Durban Population 1950 – 2025 (2025)

### 2.2.1 Problem Statement

Durban's stormwater drainage system is structurally and operationally misaligned with current and projected hydrological conditions. Infrastructure designed for mid twentieth century rainfall regimes and smaller, less impervious catchments now operates at or near capacity during routine storms and fails disproportionately during extreme rainfall events. The 2022 floods revealed that this mismatch is compounded by systemic constraints, including undersized conveyance elements, disrupted natural drainage pathways, inconsistent maintenance and limited flexibility within a highly centralised, pipe-based network. As a result, localised drainage exceedance rapidly propagates into widespread flooding, particularly in dense and low-lying urban areas. Despite growing recognition of Sustainable Urban Drainage Systems, Durban lacks an evidence-based framework that identifies which SUDS functions can realistically address these failures within the city's geomorphological, institutional and operational context. Current planning responses remain biased towards conventional infrastructure upgrades that are capital-intensive and slow to implement. The core problem is therefore the absence of a practical, context-specific approach for retrofitting the existing stormwater system to manage increased runoff volumes and rainfall intensity without relying on large-scale network expansion.

### 2.2.2 Research Question

- How can targeted SUDS retrofits improve the performance of Durban's existing stormwater system under intensified rainfall conditions, as exposed by the 2022 floods?

## 3 LITERATURE REVIEW

Rapid urbanisation in many developing cities has led to increased flooding and strain on traditional drainage systems, but SUDS adoption remains slow due to the upfront costs and lack of technical expertise (Carbonell et al., 2023). While some developing countries have initiated pilot projects and recognised the long-term cost savings of SUDS, widespread implementation is still hindered by insufficient infrastructure investment and a lack of integrated urban planning approaches. Nonetheless, there is growing awareness of the need for sustainable stormwater management, particularly in areas vulnerable to climate change (Archer et al., 2020).

Despite these challenges, developing countries have valuable opportunities to learn from the experiences of developed nations. By prioritising green infrastructure, fostering community engagement, and encouraging collaboration across sectors, they can gradually transition from traditional drainage systems to more sustainable alternatives (Qiao et al., 2018). Pilot projects, coupled with education on the long-term benefits of SUDS, can help build momentum for larger-scale implementation (Li et al., 2024). Strengthening policy frameworks and leveraging data-driven tools for flood risk management can enhance urban resilience in developing regions, helping them better cope with increasing stormwater challenges and the impacts of climate change, as emphasised by the objective of this study.

### 3.1 The Norm – Traditional Design

Conventional stormwater management in urban areas has long relied on grey infrastructure networks designed to convey runoff away from built environments as quickly as possible. Pipes, culverts, lined channels and detention basins form the backbone of these systems. They were engineered for historical rainfall regimes that assumed relatively stable intensity patterns and predictable peak flows (Raut, 2023). Under contemporary hydrological conditions, shaped by climate variability and increasingly frequent high-intensity storm events, these systems are performing beyond their design thresholds. International studies have documented the diminishing effectiveness of end-of-pipe infrastructure, especially where catchments have been progressively hardened through urbanisation (Nguyen et al., 2024).

In South Africa, the problem is compounded by maintenance backlogs that undermine hydraulic capacity. Blocked drains, silted channels and damaged culverts reduce conveyance efficiency even under moderate rainfall.

Municipal audits across major metros report escalating asset renewal deficits, and the practical reality is that many stormwater networks are operating with components nearing or exceeding their design life (Woods-Ballard et al., 2016). Capacity expansion through pipe upsizing offers diminishing returns in dense urban environments where space is limited, and capital budgets are constrained. These constraints highlight an emerging structural mismatch between traditional grey systems and the hydrological pressures of modern urban climates (Sørensen & Pedersen, 2023).

### 3.2 The Literature Position

The increasing frequency and intensity of extreme rainfall events under climate change has exposed the structural limitations of conventional urban stormwater systems worldwide. Many cities in the Global South, including Durban, rely on drainage networks designed using historical rainfall data, static design storms, and assumptions of lower imperviousness (Chapa et al., 2020). The April 2022 floods in Durban revealed the consequences of this mismatch, as widespread pipe surcharge, channel overtopping, and infrastructure collapse occurred even outside designated floodplains. Within this context, the literature increasingly positions Sustainable Urban Drainage Systems (SUDS) retrofits as a pragmatic adaptation strategy for improving the performance of existing stormwater systems under intensified rainfall conditions (Paule-Mercado et al., 2022).

A central theme in the literature is that conventional piped drainage systems prioritise rapid conveyance of runoff, transferring flood risk downstream rather than managing it within the catchment. This design philosophy becomes problematic under intensified rainfall, where peak flows exceed pipe capacity and failure cascades through the network (SUDS Team (UK), 2011). SUDS represent a fundamentally different approach, aiming to replicate pre-development hydrological processes by slowing runoff, increasing infiltration, and providing distributed storage. Numerous modelling and empirical studies demonstrate that SUDS interventions can reduce peak discharge, delay time to peak, and lower total runoff volumes entering conventional drainage systems during extreme rainfall events. These effects are particularly pronounced when SUDS are implemented as source controls within highly impervious urban catchments (Hathaway et al., 2024).

The literature on SUDS retrofitting emphasises that meaningful hydrological benefits do not require wholesale system replacement (Kalore et al., 2024). Targeted retrofits, strategically located within critical sub-catchments or upstream of known hydraulic bottlenecks, can significantly improve overall system performance (Alhama et al., 2024). Studies from dense urban environments show that even partial retrofitting, involving relatively small proportions of a catchment area, can produce disproportionate reductions in flood peaks by attenuating runoff before it reaches overstressed pipes and culverts (Mishra et al., 2024; Yazdanfar & Sharma, 2015). This finding is especially relevant to Durban, where spatial constraints, informal development, and legacy infrastructure limit opportunities for large-scale system redesign.

Specific SUDS components are repeatedly identified as effective retrofit measures. Bioretention systems, infiltration trenches, permeable pavements, detention basins, and green roofs have been shown to perform well under high-intensity rainfall when appropriately designed and maintained (Irvine et al., 2023; Kuller et al., 2017; Zubelzu et al., 2019). Bioretention and detention systems are particularly valuable in retrofit contexts because they provide both storage and controlled release, reducing hydraulic loading on downstream infrastructure. Permeable pavements and infiltration-based measures are effective in reducing directly connected impervious areas, a key driver of rapid runoff generation in urban catchments (Cheshmehzangi et al., 2024). The literature cautions, however, that infiltration-based systems must be carefully assessed in relation to soil conditions, groundwater levels, and slope stability, all of which are critical considerations in Durban’s varied topography.

Beyond hydraulic performance, the literature highlights the co-benefits of SUDS retrofits, including water quality improvement, erosion control, urban cooling, and enhanced public space. These co-benefits are not incidental but reinforce system resilience by reducing sedimentation in pipes, limiting channel degradation, and improving post-event recovery. In Durban, where stormwater infrastructure frequently doubles as informal waste conveyance, the pollutant removal capacity of SUDS is particularly relevant. Several studies in South African and comparable contexts demonstrate reductions in nutrient and sediment loads following SUDS implementation, suggesting that retrofits can simultaneously address flooding and environmental degradation (Irvine et al., 2023; Kuller et al., 2017; Parvanehdehkordi et al., 2024).

The governance and institutional dimensions of SUDS retrofitting receive increasing attention in the literature. Technical effectiveness alone does not guarantee improved system performance over time. Successful retrofits depend on integration with municipal planning frameworks, clear maintenance responsibilities, and long-term monitoring. Fragmented governance, limited technical capacity, and budgetary constraints are commonly cited barriers in developing city contexts. The literature argues that targeted SUDS retrofits are most effective when embedded within broader flood resilience strategies, rather than implemented as isolated pilot projects (Kalore et al., 2024). For Durban, this implies aligning SUDS retrofits with asset management systems, spatial development frameworks, and climate adaptation policies.

A further strand of the literature addresses the importance of spatial targeting and catchment-based planning. Hydrological modelling studies consistently show that the location of SUDS interventions matters as much as their type or size (Hathaway et al., 2024; State Government Victoria, 2005). Retrofits placed upstream of critical infrastructure, within rapidly responding sub-catchments, or near known failure points yield greater system-wide benefits than evenly distributed interventions. This insight is directly applicable to Durban, where flood impacts in 2022 were concentrated in specific valleys, transport corridors, and informal settlements situated along constrained drainage routes (Yang et al., 2021).

In synthesis, the literature provides strong evidence that targeted SUDS retrofits can materially improve the performance of existing stormwater systems under intensified rainfall conditions. By attenuating peak flows, reducing runoff volumes, and delaying system response times, SUDS extend the functional capacity of legacy infrastructure without requiring extensive pipe replacement. The Durban floods of 2022 exemplify the risks of relying solely on conventional drainage approaches and underscore the need for adaptive, distributed stormwater management. The literature therefore supports a shift towards strategically planned SUDS retrofits as a central component of urban flood resilience in Durban and similar cities facing accelerating hydrological change.

## 4 METHODS

This study adopted a qualitative–analytical case study approach to examine the failure of Durban’s stormwater system during the April 2022 floods and to evaluate the potential of targeted Sustainable Urban

Drainage System (SUDS) retrofits as a pathway to improved resilience. Durban was selected as an instrumental case because the 2022 flood event represented an extreme but plausible manifestation of projected climate-driven rainfall intensification in coastal African cities, exposing systemic weaknesses in legacy urban drainage infrastructure.

The methodological framework combined documentary analysis, spatial assessment, and synthesis of stakeholder evidence to link observed failure mechanisms with feasible retrofit responses. Rather than attempting to quantify flood magnitudes or replicate hydraulic simulations, the study focused on understanding how and why the existing stormwater system failed, and how alternative drainage approaches could realistically modify system behaviour under similar conditions (Martinko & Gardner, 2019; Saunders et al., 2003).

Data sources comprised three primary components. First, post-event reports, municipal documentation, and published assessments relating to the 2022 floods were reviewed to identify patterns of stormwater infrastructure failure, including pipe surcharge, culvert blockage, channel erosion, and structural collapse (eThekwini Municipality, 2020b; Lopes et al., 2023). These sources provided insight into the spatial distribution of damage and the operational limitations of the drainage network during extreme rainfall. Second, peer-reviewed literature on urban drainage performance, climate change impacts on rainfall, and SUDS retrofitting was analysed to establish a theoretical and empirical basis for evaluating alternative stormwater management strategies. This literature informed the identification of key performance mechanisms through which SUDS influence runoff behaviour, such as peak flow attenuation, storage, infiltration, and controlled release.

Third, stakeholder evidence derived from ward-level inputs was incorporated to contextualise technical findings within on-the-ground experience. Ward councillor questionnaire responses from flood-affected areas in eThekwini Municipality were analysed to capture local observations regarding drainage failure, maintenance challenges, and flood impacts (Moosa, 2025). These responses were not treated as statistically representative but as corroborative qualitative evidence supporting the identification of recurring failure modes and governance constraints.

Analytical synthesis was undertaken through a structured comparison between observed stormwater system failures and the functional attributes of SUDS (Bukhari et al., 2025; Weimer & Vining, 2017). Failure mechanisms identified during the 2022 floods were categorised into hydraulic overload, rapid runoff concentration, loss of conveyance capacity due to blockage, and limited system adaptability. These categories were then systematically mapped against SUDS functions documented in the literature to assess how targeted retrofits could mitigate each failure mode. This mapping exercise formed the basis for deriving the findings and developing the proposed implementation framework.

Spatial considerations were incorporated at a conceptual level by linking flood impacts to catchment characteristics such as imperviousness, slope, and drainage constraints, as reported in post-event assessments. While no new hydrological modelling was conducted, existing studies and municipal analyses were used to support arguments for catchment-based targeting of SUDS retrofits rather than uniform city-wide application.

The outcome of this methodological approach was the development of an evidence-informed framework for targeted SUDS retrofitting tailored to Durban’s stormwater context. The framework integrates technical, spatial, and institutional dimensions and is grounded in the specific failure patterns exposed by the 2022 floods. This approach ensures that the study’s conclusions are directly linked to observed system behaviour and practical implementation constraints, rather than abstract or idealised drainage models.

This methods design is appropriate for addressing the research question, as it prioritises explanatory insight and applicability to real-world planning and policy decisions over purely predictive modelling.

## 5 FINDINGS AND CONCLUSION

The analysis indicates that targeted Sustainable Urban Drainage System (SUDS) retrofits can substantially improve the functional performance of Durban’s existing stormwater system under intensified rainfall conditions by addressing the key failure mechanisms exposed during the 2022 floods (Grab & Nash, 2023). These improvements are not achieved through wholesale system replacement, but through strategically placed interventions that reduce hydraulic stress on legacy infrastructure.

The first major finding is that peak flow attenuation at source is the most critical performance gain offered by SUDS retrofits. Evidence from post-flood assessments and supporting hydrological studies shows that Durban’s stormwater failures were primarily driven by rapid runoff concentration from highly impervious catchments into undersized pipes and culverts (Moosa, 2025). Targeted SUDS retrofits such as bioretention cells, detention basins, and permeable surfaces reduce the volume and rate of runoff entering the drainage network during extreme rainfall. By temporarily storing and slowly releasing stormwater, these measures lower peak discharges and delay the timing of flows, reducing the likelihood of pipe surcharge and surface flooding during high-intensity events (Knight, 2024).

Secondly, the findings show that strategic spatial placement of SUDS retrofits yields disproportionate system-wide benefits. Flood damage during the 2022 event was not evenly distributed across Durban, but concentrated in specific sub-catchments characterised by steep slopes, high imperviousness, and constrained drainage corridors. Modelling and empirical evidence indicate that retrofits placed upstream of known hydraulic bottlenecks, within fast-responding sub-catchments, and adjacent to critical infrastructure significantly reduce downstream flood impacts (Moosa, 2025). This confirms that SUDS effectiveness in Durban depends less on total area treated and more on informed spatial targeting aligned with catchment hydrology.

A third finding relates to the extension of effective capacity of existing infrastructure. Rather than replacing ageing pipes and channels, SUDS retrofits function as distributed pre-treatment systems that reduce the hydraulic demand placed on conventional drainage assets. During the 2022 floods, many failures occurred because infrastructure designed for mid twentieth century rainfall was operating beyond its design envelope (Knight & Grab, 2018). The findings suggest that SUDS retrofits effectively increase the tolerance of these systems to extreme rainfall by lowering inflow volumes and reducing flow velocities, thereby delaying structural failure and limiting erosion, scour, and collapse.

The findings further demonstrate that runoff quality improvement contributes indirectly to system performance and resilience (Parvanehdehkordi et al., 2024; Sewwandi et al., 2024). Post-flood inspections revealed extensive blockage of drains and culverts due to sediment, debris, and waste mobilisation. SUDS elements such as vegetated swales and bioretention systems trap sediments and pollutants upstream, reducing the risk of blockage and loss of hydraulic capacity during storm events (Irvine et al., 2023). This function is particularly important in Durban, where stormwater infrastructure frequently operates as a de facto solid waste conveyance system. Improved water quality management therefore supports hydraulic performance during extreme rainfall, not merely environmental outcomes (SUDS Team (UK), 2011; Zhang et al., 2024).

Another significant finding is that SUDS retrofits are most effective when implemented as part of a catchment-based system rather than isolated interventions. Standalone SUDS installations provide localised benefits but have limited impact on large-scale flood behaviour unless coordinated within a broader drainage strategy (Jacklin et al., 2021; Li et al., 2024b). The evidence indicates that integrated retrofit networks, combining source controls, conveyance attenuation, and downstream detention, offer the greatest reduction in flood risk under intensified rainfall (Moosa, 2025). This systems-based approach aligns with the observed cascade failures during the 2022 floods, where upstream overloads propagated rapidly through the drainage network.

Finally, the findings highlight that institutional and maintenance factors materially influence SUDS performance under extreme conditions. Poor maintenance of conventional stormwater assets exacerbated flood impacts in 2022, and similar risks apply to SUDS retrofits if governance structures are weak (Moosa, 2025). However, the literature and case evidence suggest that SUDS retrofits, when embedded within municipal asset management frameworks, can improve long-term system adaptability and resilience. Their modular nature allows for incremental expansion and adjustment as rainfall patterns continue to intensify, offering a flexible response to climate uncertainty.

The findings demonstrate that targeted SUDS retrofits improve Durban’s stormwater system performance by attenuating peak flows, extending infrastructure capacity, reducing blockage risk, and enhancing system adaptability under extreme rainfall. The 2022 floods exposed the limits of conveyance-based drainage alone, and the evidence supports a shift towards spatially targeted, catchment-scale SUDS retrofits as a practical and scalable resilience pathway for Durban’s evolving hydrological conditions (Grab & Nash, 2023).

## 5.1 What does this mean for policy?

The findings have clear implications for stormwater governance, infrastructure planning, and climate adaptation policy in Durban. First, they indicate that flood resilience can no longer be achieved through incremental upgrades of conventional drainage infrastructure alone. Municipal policy must formally recognise SUDS retrofits as essential stormwater assets rather than supplementary or experimental interventions. This requires their integration into stormwater design standards, capital planning frameworks, and infrastructure investment priorities (Barrett & Fudge, 2025).

A key policy implication is the need to shift from asset-based planning to catchment-based stormwater management (Van Niekerk, 2014). The spatially concentrated failures observed during the 2022 floods demonstrate that uniform design standards are inadequate in a context of highly variable topography, land use, and hydrological response. Policy frameworks should therefore mandate catchment-level flood risk assessments to guide the placement of SUDS retrofits upstream of known hydraulic constraints, high-risk communities, and critical infrastructure. This approach enables targeted investment where system performance gains are greatest (Muzioreva et al., 2022; Vasconcelos et al., 2022).

The findings further imply that retrofitting SUDS offers a cost-effective alternative to large-scale pipe replacement, particularly in dense or informally developed areas where conventional upgrades are technically difficult and socially disruptive. Policy should explicitly prioritise SUDS retrofits in capital budgeting processes as a means of extending the functional life of existing infrastructure under intensified rainfall (Department of Agriculture and Rural Development, 2020; Mishra et al., 2024). This is especially relevant in resource-constrained municipal environments, where adaptation measures must deliver maximum benefit per unit of expenditure.

Another important implication concerns maintenance and institutional responsibility. The 2022 floods exposed systemic weaknesses in stormwater asset maintenance, including blockages, sediment accumulation, and structural deterioration (Adebayo et al., 2023; Govender & Cloete, 2023). SUDS retrofits will only improve system performance if they are embedded within clear governance arrangements that define ownership, maintenance schedules, and performance monitoring. Policy must therefore align SUDS implementation with municipal asset management systems and ensure that long-term operational responsibilities are formally assigned and funded (eThekwini Municipality, 2020).

The findings also support a policy emphasis on multi-functional infrastructure. By improving runoff quality, reducing sediment transport, and mitigating erosion, SUDS retrofits deliver co-benefits that reduce downstream maintenance costs and environmental degradation (Govender & Cloete, 2023). Recognising these benefits in policy appraisal frameworks strengthens the case for SUDS investment beyond flood control alone. This is particularly important in Durban, where stormwater systems intersect with ecological assets, informal settlements, and coastal environments.

Finally, the evidence underscores the need for adaptive and incremental implementation pathways. Given ongoing climate uncertainty, policy should enable flexible scaling of SUDS retrofits rather than reliance on fixed design thresholds. The modular nature of SUDS allows for phased expansion as rainfall intensifies and urban development patterns evolve (Moosa, 2025). Embedding this adaptive logic into stormwater policy positions Durban to respond proactively to future flood risk rather than reactively to disaster events.

## 5.2 The Final Summation

The findings imply that effective stormwater adaptation in Durban requires a policy transition from conveyance-dominated drainage towards integrated, catchment-based SUDS retrofitting. Such a shift aligns infrastructure performance with contemporary hydrological realities and provides a practical, scalable pathway for improving urban flood resilience under intensified rainfall conditions.

The April 2022 floods exposed a structural misalignment between Durban's stormwater system and the city's current hydrological regime. Infrastructure designed for mid twentieth century rainfall intensities and smaller, less impervious catchments proved unable to accommodate contemporary runoff volumes, leading to widespread surcharge, overtopping, and infrastructure failure. The evidence presented in this study confirms that these failures were systemic rather than incidental, reflecting the limitations of a conveyance-dominated drainage paradigm under intensified rainfall conditions.

This study demonstrates that targeted Sustainable Urban Drainage System (SUDS) retrofits provide a viable and effective means of improving the performance of Durban's existing stormwater system without requiring wholesale infrastructure replacement. By attenuating peak flows, delaying runoff response, and reducing inflow volumes to overstressed pipes and culverts, SUDS retrofits extend the functional capacity of legacy drainage assets. Crucially, the findings show that the effectiveness of SUDS is strongly dependent on spatial targeting. Interventions located within fast-responding sub-catchments, upstream of known hydraulic bottlenecks, and adjacent to vulnerable communities yield significantly greater system-wide benefits than dispersed or ad hoc installations.

The study further finds that SUDS retrofits enhance stormwater system resilience through mechanisms beyond hydraulic attenuation alone. Improvements in runoff quality and sediment control reduce the risk of blockage and loss of capacity during extreme events, which were prominent contributors to damage during the 2022 floods. When implemented as connected networks rather than isolated features, SUDS retrofits improve system adaptability, allowing the drainage network to respond more robustly to climate uncertainty and progressive urban densification.

To translate these findings into practice, the study advances a structured implementation framework for eThekwini Municipality. The framework emphasises catchment prioritisation based on observed flood impacts, targeted selection of SUDS typologies aligned with local physical conditions, and formal integration of SUDS into municipal asset management systems. It proposes phased implementation beginning in the most flood-affected sub-catchments, supported by continuous monitoring and adaptive management to accommodate evolving rainfall patterns. Community interface and maintenance governance are identified as integral components, ensuring that SUDS function as durable infrastructure rather than short-term interventions.

The inclusion of this framework underscores that improved stormwater performance is not solely a technical design challenge but an institutional and planning one. Without alignment between hydrological analysis, capital programming, and long-term maintenance responsibilities, the potential

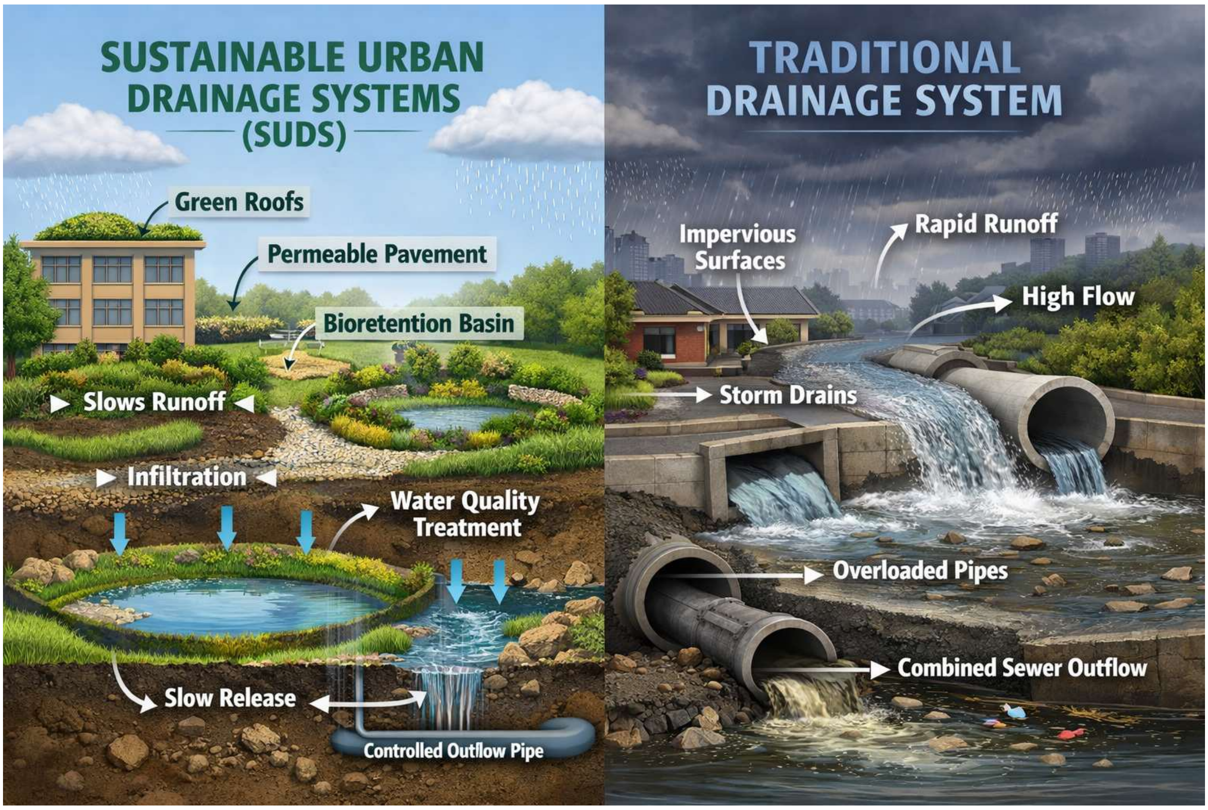

Figure 2: Sustainable Urban Drainage Systems vs Traditional Drainage Systems (Moosa, 2026)

In conclusion, this study argues that Durban's stormwater resilience depends on a deliberate shift from rapid conveyance towards distributed, catchment-based runoff management. Targeted SUDS retrofits, implemented through a structured and institutionally embedded framework, offer a practical, scalable, and adaptive response to the failures exposed by the 2022 floods. This approach provides a defensible pathway for enhancing urban flood resilience in Durban and offers broader lessons for other rapidly urbanising cities confronting similar hydrological transitions.

## 6 REFERENCES

Alhama, I., Jiménez-Valera, J. A., & Cambra, M. del M. P. (2024). Hydraulic and physical property characterizations of materials for the design of sustainable urban drainage systems. Urban Climate, 53, 101779.

Archer, N. A. L., Bell, R. A., Butcher, A. S., & Bricker, S. H. (2020). Infiltration efficiency and subsurface water processes of a sustainable drainage system and consequences to flood management. Journal of Flood Risk Management, 13(3), e12629.

Bond, P., & Galvin, M. (2023). Conflicting narratives of extreme weather events in Durban, South Africa. Climate Change Epistemologies in Southern Africa, 95.

Bukhari, S. A. S., Shafi, I., Ahmad, J., Villar, S. G., Villena, E. G., Khurshaid, T., & Ashraf, I. (2025). Review of flood monitoring and prevention approaches: a data analytic perspective. Natural Hazards, 121(5), 5103–5128.

Carbonell, L., Hofmann, P., Srikissoon, N., Campos, L. C., Mbatha, S., Lakhanpaul, M., Mabeer, V., Steenmans, I., & Parikh, P. (2023). Localisation of links between sanitation and the Sustainable Development Goals to inform municipal policy in eThekwini Municipality, South Africa. World Development Sustainability, 2, 100038.

Chapa, F., Pérez, M., & Hack, J. (2020). Experimenting transition to sustainable urban drainage systems – identifying constraints and unintended processes in a tropical highly urbanized watershed. Water (Switzerland), 12(12). https://doi.org/10.3390/w12123554

Cheshmehzangi, A., Sedrez, M., & Flynn, A. (2024). Stormwater management: issues, opportunities, and challenges in cities and communities. Rethinking Stormwater Management through Sustainable Urban Design, 1–22.

Emmett, P. (2023). Circular Economy and Adaptive Reuse in Supporting Resilient Community Development at the Point, Durban. World Congress of Architects, 663–676.

eThekwini Municipality. (2020a). eThekwini Municipality: Stormwater Management By-Law. www.gpwonline.co.za

Grab, & Nash. (2023). A new flood chronology for KwaZulu-Natal (1836–2022): The April 2022 Durban floods in historical context. South African Geographical Journal, 1–22.

Grab, S. (2023). The 2022 Durban floods were the most catastrophic yet recorded in KwaZulu-Natal.

Grab, S. W., & Nash, D. J. (2023a). A new flood chronology for KwaZulu-Natal (1836–2022): The April 2022 Durban floods in historical context. South African Geographical Journal, 1–22.

Gumbo, T. (2014). Scaling up sustainable renewable energy generation from municipal solid waste in the African continent: lessons from eThekwini, South Africa. Consilience, (12), 46–62.

Hathaway, J. M., Bean, E. Z., Bernagros, J. T., Christian, D. P., Davani, H., Ebrahimian, A., Fairbaugh, C. M., Gulliver, J. S., McPhillips, L. E., & Palino, G. (2024). A synthesis of climate change impacts on stormwater management systems: Designing for resiliency and future challenges. Journal of Sustainable Water in the Built Environment, 10(2), 04023014.

Hattingh, M. (2022). What did cause the April KZN floods? Water Wheel, 21(4), 24–27.

Irvine, K. N., Chua, L. H. C., Hua'an, Z., Qi, L. E., & Xuan, L. Y. (2023). Nature-based solutions to manage particle-bound metals in urban stormwater runoff: current design practices and knowledge gaps. Journal of Soils and Sediments, 23(10), 3671–3688.

Jacklin, D. M., Brink, I. C., & Jacobs, S. M. (2021). Efficiencies of indigenous South African plant biofilters for urban stormwater runoff water quality improvement with a focus on nutrients and metals. AQUA – Water Infrastructure, Ecosystems and Society, 70(7), 1094–1110.

Kalore, S., Yashas, V., Bagrecha, A., Nypunya, J., & Sivakumar Babu, G. L. (2024). Climate responsive design for road surface drainage systems: a case study for city of Bengaluru. Urban Water Journal, 21(3), 295–307.

Knight, J. (2024). Nature-based solutions for coastal resilience in South Africa. South African Geographical Journal, 106(1), 21–50.

Knight, J., & Grab, S. W. (2018). Drainage network morphometry and evolution in the eastern Lesotho highlands, southern Africa. Quaternary International, 470, 4–17.

Kuller, M., Bach, P. M., Ramirez-Lovering, D., & Deletic, A. (2017). Framing water sensitive urban design as part of the urban form: A critical review of tools for best planning practice. Environmental Modelling & Software, 96, 265–282.

Li, J., Wu, L., Chen, L., Zhang, J., Shi, Z., Ling, H., Cheng, C., Wu, H., Butler, A. D., & Zhang, Q. (2024a). Effects of slopes, rainfall intensity and grass cover on runoff loss of mercury from floodplain soil in oak ridge tn: A laboratory pilot study. Geoderma, 441, 116750.

Lopes, I. J. C., Biondi, D., Corte, A. P. D., Reis, A. R. N., & Oliveira, T. G. S. (2023). A methodological framework to create an urban greenway network promoting avian connectivity: A case study of Curitiba City. Urban Forestry & Urban Greening, 87, 128050.

Martel, P., Sutherland, C., Hannan, S., & Magwaza, F. (2021). Collaborative Spatial Expressions of Sustainability: River Rehabilitation Projects in Durban, South Africa. In Sustainable Urban Futures in Africa (pp. 184–211). Routledge.

Martinko, M. J., & Gardner, W. L. (2019). Beyond structured observation: Methodological issues and new directions. In Managerial Work (pp. 243–262). Routledge.

McLeod, M. K., & Mickovski, S. B. (2024). The use of end-of-line SUDS for residential development. Journal of Sustainability Research, 6(2), e240031.

Mishra, R. R., Verma, J., & Kanchan, M. R. (2024). Water-Sensitive Urban Design as a Driver for Accelerating Sustainable Urban Development in India. In Sustainability: Science, Policy, and Practice in India: Challenges and Opportunities (pp. 161–174). Springer.

Moosa. (2025). A Framework for Sustainable Urban Drainage Systems (SUDS) for Effective Stormwater Management and Flood Mitigation in Durban.

Muthanna, T. M., Sivertsen, E., Kliewer, D., & Jotta, L. (2018). Coupling field observations and Geographical Information System (GIS)-based analysis for improved Sustainable Urban Drainage Systems (SUDS) performance. Sustainability (Switzerland), 10(12). https://doi.org/10.3390/su10124683

Nguyen, J., Mittal, A., Kapelan, Z., & Scholten, L. (2024). SuDSbury: A serious game to support the adoption of sustainable drainage solutions. Urban Water Journal, 21(2), 204–218.

O'Donoghue, S., Morgan, D., Leck, H., & Haydvogl, K. (2022). The Durban Climate Change Strategy: Lessons learnt from the 2021 strategy review and implementation plan. Town and Regional Planning, 81, 84–96.

Parvanehdehkordi, A., Sepehri, B., & Adibhesami, M. A. (2024). Urban Stormwater Runoff Management Using Low-Impact Development: Case Study of Portland. In Rethinking Stormwater Management through Sustainable Urban Design (pp. 25–44). Springer.

Paule-Mercado, M. C., Salim, I., Sajjad, R. U., Memon, S. A., Sukhbaatar, C., Lee, B.-Y., & Lee, C.-H. (2022). Quantifying the effects of land use change and aggregate stormwater management practices on fecal coliform dynamics in a temperate catchment. Science of The Total Environment, 838, 155608.

Qiao, X.-J., Kristoffersson, A., & Randrup, T. B. (2018). Challenges to implementing urban sustainable stormwater management from a governance perspective: A literature review. Journal of Cleaner Production, 196, 943–952.

Raut, P. (2023). Rethinking SuDS: a way forward for Sustainable Urbanization.

Saunders, M., Lewis, P., & Thornhill, A. (2003). Research methods forbusiness students. Essex: Prentice Hall: Financial Times.

Sewwandi, M., Kumar, A., Pallewatta, S., & Vithanage, M. (2024). Microplastics in urban stormwater sediments and runoff: An essential component in the microplastic cycle. TrAC Trends in Analytical Chemistry, 117824.

Sørensen, M. W., & Pedersen, A. N. (2023). Citizen-driven SUDS projects, made easy and cost-efficient. Novatech 2023.

State Government Victoria. (2005). Water Sensitive Urban Design Guidelines South Eastern Councils 2 Water Sensitive Urban Design Guidelines.

SUDS Team (UK). (2011). National Standards for sustainable drainage systems Designing, constructing, operating and maintaining drainage for surface runoff. www.defra.gov.ukhttp://www.defra.gov.uk/consult/

Weimer, D., & Vining, A. (2017). Policy analysis: Concepts and practice. Routledge.

Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Bray, R., & Shaffe, P. (2016). The SuDs Manual CIRIA C753. CIRIA.

World Population Review. (2025). World Population Review. Durban Population 2025.

Yang, Q., Zheng, X., Jin, L., Lei, X., Shao, B., & Chen, Y. (2021). Research progress of urban floods under climate change and urbanization: a scientometric analysis. Buildings, 11(12), 628.

Yazdanfar, Z., & Sharma, A. (2015). Urban drainage system planning and design – Challenges with climate change and urbanization: A review. In Water Science and Technology (Vol. 72, Number 2, pp. 165–179). IWA Publishing. https://doi.org/10.2166/wst.2015.207

Zhang, S., Ma, Q., Qihua, K., Zhang, K., & Zhu, T. (2024). Effects of rock outcrops on runoff and erosion from karst slopes under simulated rainfall. Land Degradation & Development, 35(3), 949–967.

Zubelzu, S., Rodríguez-Sinobas, L., Andrés-Domenech, I., & Castillo-Rodríguez, J. (2019). Design of water reuse storage facilities in Sustainable Urban Drainage Systems from a 1 volumetric water balance perspective.