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Regenerating Stormwater Infrastructure into Biophilic Urban Assets. Case Studies of a Sump Garden and a Sump Park in Western Australia

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Abstract: The main purpose of this paper is to demonstrate how the old modernist engineering technologies, such as single purpose stormwater infiltration basins, can be transformed into quality environments that integrate ecological and social functions and promote multiple sets of outcomes, including biodiversity restoration, water management, and cultural and recreational purposes, among other urban roles. Using the principles and theories of biophilic urbanism, regenerative design, and qualitative inquiry, this article analyzes and discusses the actors, drivers, strategies, constraints, and values motivating the stakeholders to reinvent Perth's stormwater infrastructure through two local case studies. The "WGV sump park" was developed through a public-private partnership, including professional consultants with community input, and the "Green Swing sump garden" was an owner-builder community-driven project involving volunteers, who maintain it. The results of this research suggest that both projects are successful at managing stormwater in a way that creates multiple community and biodiversity benefits. Communities could gain improved access to nature, social interaction, health, and well-being if local governments support these alternative approaches to regenerate underutilized stormwater infrastructure by promoting biophilic interventions. Mainstreaming this design approach identified some issues that may arise during the implementation of this biophilic urban approach, and the paper suggests ways to enhance the wider delivery of regenerative and biophilic design into urban planning, involving volunteer delivery and maintenance for small scale projects and fully professional assessments for large scale projects.

Keywords: biodiversity; biophilic design; regenerative design; stormwater management

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1. Introduction

Urban life is being increasingly affected by rising temperatures, variances in rainfall rates, and more frequent natural disasters, such as floods, droughts, and fires [1,2]. These issues impact not only human populations but also natural environments, resulting in loss of biodiversity. There is an urgent need to develop strategies that enhance urban livability while promoting ecological restoration and preservation. Integrating nature into cities is not only beneficial to maintain biodiversity but also ensures the multiple health benefits that nature provides to humans. Quality green spaces and biophilic places are known to enhance human health and well-being, provide ecosystem services [3,4] and show positive, measurable effects of human interaction with biota in urban environments [5–8].

Such an approach to natural systems in urban areas is applied in this paper to the practice of urban stormwater management. Stormwater management, like other aspects of urban planning and infrastructure provision from the 1940s, is subject to modernist ideals of uniform engineering that have little concern for the local place history, heritage, and biodiversity [9,10]. In Perth, the result was an approach that created uniform sumps that were fenced off and served only a simple function of stormwater management. Two such sumps that have been through a regenerative process are examined to see whether their goals have been achieved of biodiversity regeneration and local community benefit, as well as enabling good stormwater management. As such, it aims to make a comment about the benefits of regenerative design over modernist design.

The city of Perth, with around 2 million people, is a low-density modern city based on a coastal sand plain, where stormwater is often managed using Stormwater Infiltration Basins (SIBs). Metropolitan Perth has a high number of SIBs, including one type locally called "a sump" (for example, Figure 1). A sump is a local name for an infiltration-retention basin where the stormwater is retained and allowed to infiltrate into an unconfined superficial aquifer. Sumps are typically designed as a 'steeply graded rectangle with an inflow at their base' [11] and differ from more contemporary infiltration basins, which may be more thoughtfully integrated into an amenity landscape and can even include a bio-filtration function [12]. Sumps are a common landscape feature across metropolitan Perth and are often required to be fenced because of the potential for rapid stormwater inflow during heavy rainfall events [13]. Although sumps efficiently perform their function in urban stormwater infrastructure, they have not been valued for their potential social-ecological role. This paper seeks to examine two sumps that have been upgraded in Perth to facilitate their roles in urban biodiversity and local livability, as well as being suitable for stormwater management. The examples become model interventions for how creative biophilic initiatives in cities may contribute to the aforementioned goals.

The WGV sump prior to redevelopment, showing typical arrangement, including fencing, weeds, and stormwater flow during a rain event. Source: JBA

The WGV sump park after completion, with succuessfully established native vegitation. Source: Rob Frith

Figure 1. WGV sump prior and after redevelopment. Credit: JBA.

Using the principles and theories of biophilic urbanism and regenerative design, this article analyzes and discusses two local case studies: the "WGV sump park" in White Gum Valley and the "Green Swing sump garden" in Lathlain, Western Australia. A framework was then developed to help understand the actors, drivers, strategies, constraints, and values motivating the stakeholders to reinvent Perth's stormwater infrastructure. The analysis of the case studies aims to identify issues that may arise during the implementation of biophilic urbanism initiatives and suggest ways to enhance the potential benefit of integrating concepts of regenerative and biophilic design to urban planning and design.

1.1. Theoretical Background

Biophilic urbanism and regenerative design approaches serve to reconnect urban citizens with nature [5,14]. Biophilic interventions facilitate access to nature through the creation of abundant green environments in cities, between and on buildings, providing health and wellbeing to their users and residents [5,8,9]. Regenerative design promotes positive contributions that can heal and improve place conditions, both in their social and biophysical aspects, keeping the system thriving [15–17]. The regenerative design approach sees the integration of humans and their activities with other forms of life in a harmonious and mutually beneficial manner as the core principle in mitigating the threats to sustainability and as a leading pathway to 'restoring the inherent regenerative capacity of natural and social living systems' [18]. Regenerating open spaces is an appropriate pathway to making cities and neighborhoods more livable, not only in the physical aspect but psychologically, as well. It can be achieved by creating biophilic environments that improve livability through the access to nature in attractive open spaces in local areas of cities. The biophilic environments can be created by deploying a variety of urban nature-based solutions, such as pocket parks, community gardens, rainwater gardens, living streams, and green streets [6,19,20].

The benefits from contact with nature are crucial for human well-being but also depend on repeated experiences because, to be functional, it has to be nurtured and developed [7,21,22]. Beatley [6] (p. 154) calls this frequent contact with natural environments 'a daily dose of nature'. He explains that biophilic urbanism interventions provide opportunities for fulfilling experiences of nature, creating green urban spaces for easy and frequent access to nature, and consequently bolstering the reconnection of a city and nature. Besides the human-centered benefits, biophilic urbanism can contribute to the urban and regional regeneration of the ecosystems and biodiversity by restoring or creating new habitats for natural systems [23,24]. As Kellert and Calabrese [19] (p. 11) put it:

> *'Multisensory encounters with nature in the built environment can greatly contribute to comfort, satisfaction, enjoyment, and cognitive performance, and when feasible, should be encouraged'.*

Both biophilic and regenerative design promote an emotional attachment to particular settings and places, encouraging positive interactions between people, nature, and their places that enable a sense of belonging to and responsibility for human and natural communities and their health and wellbeing [25].

Regenerative design seeks to promote conditions that are conducive to life, helping living systems to recover their capacities of re-organizing and regenerating themselves, leading to the wider regeneration of built environments and communities [15,26,27]. These social-ecological approaches to the design of built environments are part of the concept of regenerative sustainability [16,28,29]. The built environment is seen as feasible to be restored and regenerated through the implementation of 'localised ecological design and engineering practices rooted in the context and its social-ecological narratives' [28].

The regeneration and repurposing of storm-water infiltration basins or sumps appear to fit within these social-ecological approaches.

1.2. Location of the Case Studies

Perth is the capital city of Western Australia, with a Mediterranean climate type along the coast. It is set within an ancient landscape and it is considered a biodiversity hotspot [30], which is threatened by urban sprawl [9]. Perth is situated on the Swan Coastal Plain with a groundwater system comprised of two principal aquifers, namely, Gnangara and Jandakot. Those two mounds provide Perth with potable water and also support a vast network of lakes and wetlands. The sandy soils of the Coastal Plain are highly permeable and allow for rapid stormwater infiltration and recharge of the underground aquifers. A system of soak wells and open drainage sumps enables on-site stormwater infiltration in metropolitan Perth [12,31] and provides favorable conditions supporting natural habitats in the urban environment.

The importance of natural habitats within the urban fabric and nearby regional spaces has been recognized for most of the city's history [32,33]. The growing global awareness of biodiversity issues, for example, the Convention on Biological Diversity (CBD) and the associated Aichi Target 15, have alerted Perth's responsible agencies to the implications that unplanned urban growth poses the ecosystem services' provision and ecosystem resilience [34]. However, there has been little or no awareness of the value that is being lost by neglecting stormwater sumps as opportunities for multifunctional urban green infrastructure and urban habitat.

1.3. The Sumps—An Overview

Although most of Perth's sumps are typically under a maintenance program (usually by local governments), many of them remain an eye-sore to the public and create significant wasteland, attracting weeds and litter. Local governments can be reluctant to upgrade the sumps to public green spaces due to their inability to ensure the stormwater function is maintained and the resulting perception that these sumps are for engineering purposes rather than local biodiversity and livability [35]. This paper tries to help resolve this perception by showing that they can be both.

In order to enable a local sump to be upgraded for biodiversity and livability functions, there is a need for system modification that can enable water infiltration to rapidly occur during large storms. The typical sump in Figure 1 needs to be upgraded first by ensuring it has sufficient capacity to handle stormwater. Figure 2 shows what was done in the WGV sump, but such system modifications depend on the specific hydrological capacity of a particular sump.

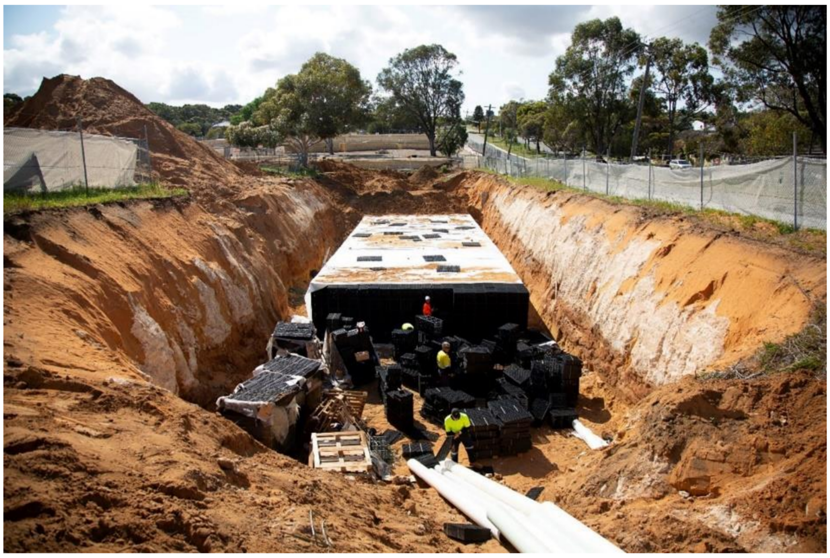

Figure 2. Drainage cells being installed at WGV to ensure adequate drainage function are maintained prior to landscaping. Credit: DevelopmentWA.

2. Materials and Methods

The case study methodology of qualitative inquiry [36] was used to define an emerging framework for mainstreaming; it aims to pursue how the actors, drivers, constraints, strategies, and values motivating stakeholders could reinvent the stormwater basins.

This paper is based on primary and secondary data, collected using a number of techniques and approaches developed by Francis [37] for landscape architecture case study research. It is based on document analysis (reports, audio-visual recordings, drawings), site visits, photographic documentation, an interview with a project leader, and the first-hand report from a co-author involved in the design of both projects. Using the principles and theories of biophilic urbanism and regenerative design, the article uncovers the designs behind these successful biophilic initiatives and their ability to bring nature into modernist urban engineering.

The rationale behind this research methodology was that explanatory case studies can be used to develop a strategic approach to mainstreaming the regeneration of the sumps within the Perth stormwater system. Both cases presented certain conditions, factors, and processes that can provide a more in-depth understanding of the issues affecting a broader intake of biophilic urbanism.

The case studies involved diverse factors in the development of their projects, comprising social, environmental, and technological aspects in the strategies that oriented their processes. However, the effectiveness of the strategies implemented in both case studies, the WGV sump park and the Green Swing sump garden, needed to be assessed to consider mainstreaming possibilities that could arise from their work, integrating concepts of regenerative and biophilic design into urban planning and design.

The diagram in Figure 3 presents the analytical framework components:

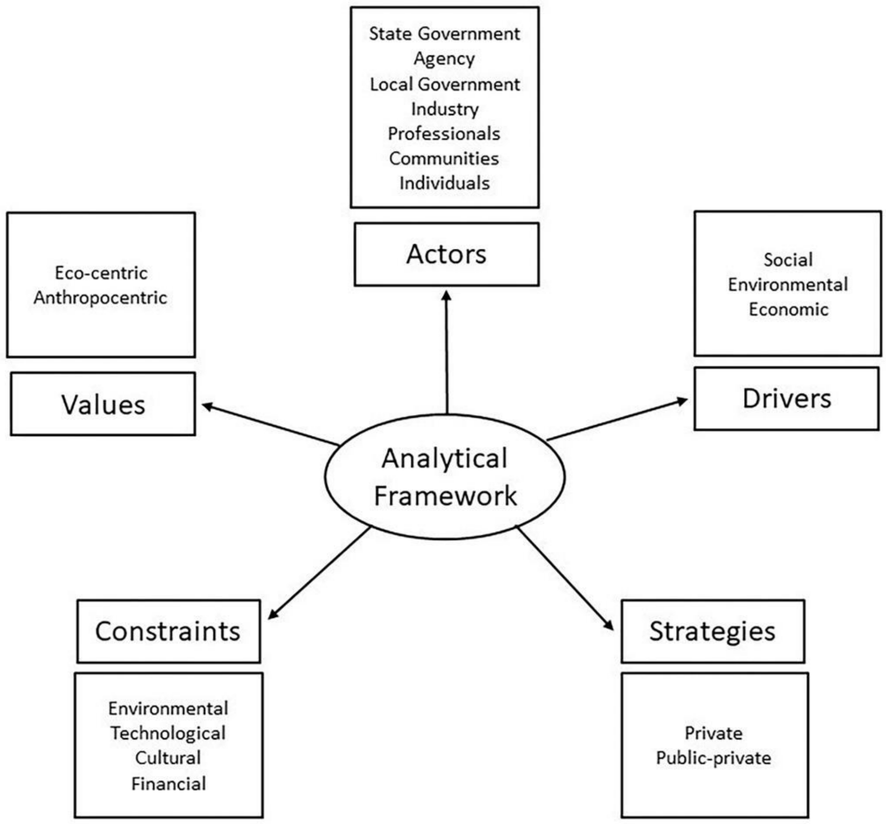

Figure 3. Analytical framework using qualitative inquiry. Credit: Authors.

The results for each case study will be presented first to show their ability to reach both stormwater goals and biodiversity/livability goals at the same time, then they will be analyzed to see how they could be mainstreamed.

2.1. Actors

Actors refer to the stakeholders, or all parties involved in the development of ideas, design, development, and implementation of a social-ecological project, in this case. Actors may be individuals, communities, institutions, local, state of federal governments, government agencies, professionals and consultants, industries, and other parties participating in the project [38,39].

2.2. Drivers

Social, economic, and environmental tenets are drivers supporting the strategies and actions behind the case studies, according to their scale, budget, and scope of intervention. In this context, biophilic urbanism and regenerative design are social-ecological tenets that are part of the concept of regenerative sustainability [29]. The built environment is seen as feasible to be restored and regenerated through the implementation of ecological design and engineering practices that are drivers in this project [16,28,29].

Social drivers involve the need to reconnect humans and nature through encouraging and facilitating human relational approaches between humans and other living organisms in urban settings, in this case. Regarding design application, this can be implemented in three main ways: (a) literal connection through direct relation to natural features, such as outdoors spaces, use of natural materials, vegetation, and water; (b) facsimile connection, by using nature imagery in forms, shapes, and materials; and (c) evocative connections using qualities and attributes of nature in design [5,7,21].

Economic drivers entail short- and long-term cost-benefit aspects, according to the complexity of needs and resources, budgetary availability, stakeholders' interests, and benefits expected from the mainstreaming of biophilic regeneration of sumps at neighborhood and future city scales. Another way for economic drivers to be considered is through the value uplift of property shown to be associated with biophilic urbanism, which brings economic value to a whole region of the city [40].

Environmental drivers relate to the restoration and re-establishing of the capacity of living systems to regenerate themselves, e.g., the restoration of damaged ecosystem services. Humans play a significant role in regenerating the healthy conditions of an ecosystem by creating an integral interconnection that promotes a mutually beneficial relationship between cities and their bioregions [16,23,26]. There are multiple other ways that local biophilic urbanism, such as the sumps, which are examined in this paper, contribute to urban improvements: greening public spaces, increasing local biodiversity, improving circular economy outcomes, and reduction of the urban heat island effect.

2.3. Strategies

Social-ecological approaches to the built environment promote design and development strategies to enable actions aiming to restore and enhance existing and potential conditions of a place, in both its biophysical and cultural aspects. Human activities have to be planned in a way that provides for and are provided by the systems where they take place by aligning human communities and economic activities with a place's capacity to support life [16,26].

This perspective implies a new role for designers and a design process that reflects the understanding of how life support systems and their subsystems work in the sites where interventions will take place [15]. This includes psychological and cultural literacy [16,26].

2.4. Constraints

In-depth knowledge of a place is crucial to the effective design and implementation process of regenerative biophilic interventions and their mainstreaming. Stakeholders need to consider hindrances and obstacles that may occur related to physical, environmental, institutional, technological, cultural, and other aspects [39].

2.5. Values

Values are understood as a set of beliefs, qualities, or behaviors that frame our goals and attitudes, providing standards against which individual or societal behaviors can be benchmarked. Hes and du Plessis [31] identified 10 appropriate values based on how nature works to ensure the healthy and continued functioning of the whole system, founded on the idea of an interconnected, interdependent, and integrated world. According to the focus or the main beneficiaries of a project's goals and actions, the approaches utilized may be anthropocentric when the focus are human beings or eco-centric when all forms of life are the target.

Anthropocentric and eco-centric values can be balanced by implementing the strategies of biophilic and regenerative design into urban environments. Biophilic design tends to seek human health and wellbeing, while regenerative design principles tend to look at creating conditions for all living systems [26,29].

3. Case Studies

3.1. WGV Sump Park

Situated in the City of Fremantle's local government area, the WGV residential development was described as 'a carbon positive living laboratory', as it was designed to demonstrate an innovative approach—"Innovation Through Demonstration"—to urban infill, which included all the One Planet Living goals and, in particular, the goal to achieve zero carbon outcomes [41,42]. This approach aimed to introduce higher densities, diversity of housing types and sizes, responding to changing demographic cohorts and climate conditions, including an award-winning social housing initiative called Sustainable Housing for Artists and Creatives (SHAC), amenities, and a range of sustainability initiatives, such as energy, water, and landscaping strategies. This new residential estate, comprising more than 80 residential units, was developed on a 2.29-hectare former school site, owned by the Western Australian State Government, by DevelopmentWA (the WA state government land development agency). Adjacent to this area was a fenced sump owned and managed by the local government. The sump was integrated into the development's planning [31,43,44] and became, what is called in this paper, the WGV sump park.

The City of Fremantle and DevelopmentWA were the key supporters of the project. Together with Curtin University, the community of White Gum Valley, private sector investors, engineering, and environmental design consultants were involved in generating sustainable solutions to increase the quality of life, address the environmental and social challenges, and create a sustainable community [31,42]. To help achieve these objectives, the One Planet Living framework was used [41].

The structure plan for the WGV development subdivided the area into 28 development lots and open public spaces. The revitalization of the adjacent 0.16-hectare sump aimed to convert the underutilized space into a publicly accessible landscape, which would add social, economic, and environmental value to the residential estate while still performing its function as a drainage overflow area with a capacity of 2000 cubic meters. The revitalization project encompassed engineering and earthworks to deal with stormwater effectively and a landscape design to ensure that local biodiversity and canopy increase and provide recreational green space to the community [31,45].

On the engineering side, the project team conducted an assessment of the sump capacity and modelled the expected performance. The results indicated that the existing conditions at the time (2015) complied with the 5-year ARI (average recurrence interval) event but not with the 100-year ARI event. Considering the landscape project to be developed on site, a consultant's recommendation was to install water storage cells underground to maximize the stormwater storage, a simple and effective sustainable urban drainage approach to manage stormwater on-site [46]. To protect the drainage system, urban stormwater debris from the surrounding catchment is captured by gross pollutant traps, which are cleared out regularly [45].

The design incorporated water-sensitive urban design principles and water efficiency measures. The landscape concept was based on a winter wet depression feature, where plants that prefer seasonally wet conditions occur at the bottom of the sump and those that prefer drier conditions grow at the top. The plant palette included a diverse range of trees, shrubs, grasses, and groundcovers that are native to the area for biodiversity benefits. Large boulders of locally occurring limestone were chosen for retaining the embankment of the sump in an informal way [45]. The result of this landscaped public space was expected to strongly contribute to creating sense of place, health, and wellbeing for users and residents

(Figure 4) and was formally assessed by the Fremantle Council after close discussions with the local community, who also agreed to help with providing local history narratives that could be used in the park.

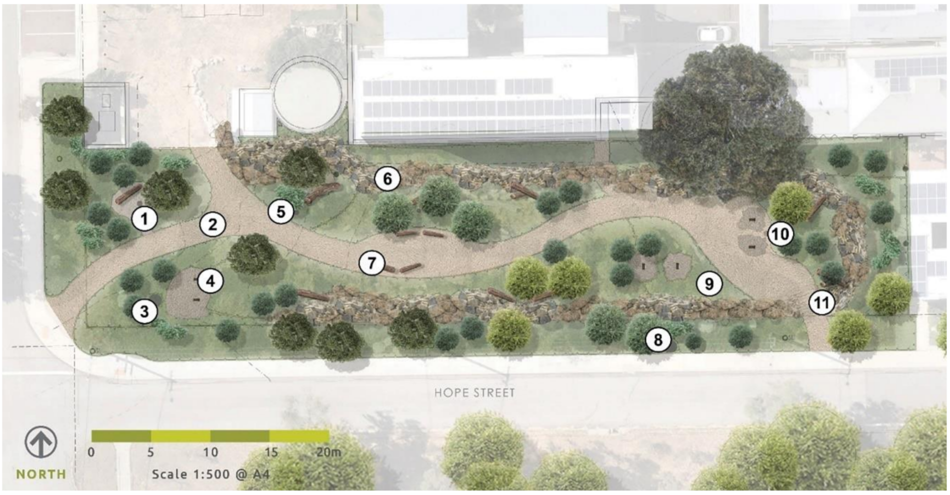

Figure 4. WGV sump park landscape plan. (Key: 1. Informal nature play with climbing logs; 2. Pathways made from crushed recycled rubble; 3. Gross pollutant traps; 4, 9, & 10. Bubble-up pits from underground cells; 5. Air-vent for underground cells; 6. Limestone boulders; 7. Log seats; 8. Planted street verge; 11. Steps.) Credit: JBA.

The sump regeneration project achieved notable results. The multiple outcomes of the site have been documented [42] to show that it met many targets. In terms of hydraulic performance, the sump successfully manages stormwater events. Residents and passersby enjoy the new park, and the vegetation is establishing well (Figures 1 and 5).

In terms of the One Planet Living principles that used to inform the design of WGV, the sump park supports the "Land use and wildlife" principle through creating new habitats and contributing to an increase in biodiversity. It also addresses "Sustainable water" through reduction of flood risks and reducing potable water use, as well as "Sustainable materials" and "Zero waste" [41,44]. The livability elements of the WGV sump park are less defined in goals and outcomes, but it is clearly popular, with many public events being held in the space. It is an innovative communal green space, featuring local heritage stories and public space infrastructure, which is now a major part of a local community.

3.2. Green Swing Sump Garden

The Green Swing is the name of the group of "citizen developers" who collaboratively developed an innovative residential cluster called Genesis in Lathlain, Victoria Park. The group initiated the project in 2009 as a sustainable living venture by purchasing an 840 m^2 lot, located 5 km from Perth CBD, close to a train station and adjacent to a fenced stormwater sump (Figure 6). The project resulted in the construction of two townhouses and two apartments on the one block. The buildings were designed to be solar passive for thermal comfort and incorporated renewable energy systems, rainwater harvesting, and greywater reuse. An energy monitoring system was installed to monitor energy usage [47,48].

The decision to develop on the site at 96 Rutland Avenue was influenced by the proximity to the sump, which is one of the 130 such sumps owned and managed by the Town of Victoria Park as the local government authority [49]. The group proposed to transform the underutilized space around the sump into a productive and recreational space, and to that purpose received advice from a design consultant for the early stages of the planning process.

Figure 5. The WGV sump park shortly after completion being used by the public for educational purposes. Credit: JBA.

The majority of the implementation and management of the sump garden was driven by the proponents, in collaboration with a local community garden association, with the aim of setting a precedent that could become a model of biophilic regeneration of underutilized urban green assets in Victoria Park and beyond to other parts of Perth.

A landscaping plan for the 175 m^2 site prepared for the sump by the design consultant included revegetation with plant species, as well as some fruit-bearing plants. The plan featured footpaths, garden furniture, and space for community gardening. The lowest part was retained for stormwater infiltration. No additional engineering or earthworks were undertaken because the sump was adequately sized (Figure 7) and unaltered in its function by any of the other landscaping. Its capacity is much smaller than the WGV sump park and was considered more than sufficient to meet the stormwater infiltration requirements.

Figure 6. The sump in Lathlain before and after revitalization. Credit: JBA.

Figure 7. Green Swing sump garden landscape plan. (Key: 1. Vehicle access pathway to council requirements; 2. Native verge plantings; 3. Access gate; 4. New fence alignment; 5. Food forest; 6. Original fence alignment; 7. Pedestrian paths; 8. Controlled access and sight lines from adjacent property; 9. and 11. Stormwater outlets; 10. Base of sump; 12. Native grasses and groundcovers to stabilize sump banks; 13. Layered native shrubs and trees for habitat.) Credit: JBA.

The proposal to convert the sump into a community garden was submitted to the Town of Victoria Park and was endorsed by the council. The Green Swing sump garden became the first satellite community garden for the Victoria Park Community Garden Association, who agreed to manage it. The proponents also anticipated that the innovative sump project would become an inspiration for others to undertake a similar challenge.

The project was privately funded by the proponents, and all the landscaping work was performed by the residents of Genesis, who also purchased and planted the seedlings [48].

The sump garden upholds its original function as a stormwater basin. The conversion of this formerly underutilized area into a community garden incorporated native plant species, fruit trees, and vegetable garden beds, bee keeping, and chickens (Figures 7 and 8). According to the residents, the Town of Victoria Park was very supportive since the beginning of the project, and every 6 months, they carry out inspections in the sump gardens [47]. So far, the governance approach afforded by the local Victoria Park Community Garden Association has been successful.

Figure 8. The sump garden is used for a range of urban agriculture activities, including bee keeping. Credit: Rob Frith.

The sump garden is a productive green space and a place of relaxation for the residents of the Genesis and the local community. As the project leaders explained, 'the Green Swing was about the journey towards a more sustainable community, getting to know your neighbors and looking after the environment we live in' [47,48].

4. Comparative Analysis Using the Framework for Mainstreaming

The results from applying the framework to the case study analysis are presented in Table 1. The analysis sets out commonalities and disparities between both cases, WGV and the Green Swing. The following aspects and elements of the projects have been compared: project's size, time of design and construction, scope and scale, actors involved, drivers that motivated actions, available budgets, strategies and processes used, constraints, and values. Through this comparative analysis, the authors attempt to see if the regeneration of old modernist sumps into regenerative biophilic urban assets can contribute to creating sustainable communities and inform policies for replication in other locations looking for healthy communities and ecosystems to thrive together.

Both cases were created and constructed in the same decade of the 2010s. But they differ in scale and scope; while the Green Swing involves four residential units, besides the sump garden, the WGV is a residential precinct development that comprises more than 80 units, amenities, and green open space. Due to the differences in scale and scope, they present a diversity of actors involved. The Green Swing vision was conceived by a small group of citizen developers, who attracted others with a similar mindset and interests. The WGV vision originated from conversations among the local government, state agencies, and local community about the need to innovate residential precincts' design [43]. This suggests that small to medium local biophilic regeneration projects can be initiated and led by community members and may only require minor input from professional consultants if technological involvements are not requested. Both cases have been designed and developed as innovative responses to sustainable urban living expectations, boosted by social, environmental, and economic drivers. It is interesting to note that many social and environmental drivers overlap.

Table 1. Comparative analysis of the WGV Sump Park and the Green Swing Sump Garden. Credit: Authors.

	Green Swing	WGV
Actors	Group of owner-builders and individuals with common interests and values Professional consultant	Community Professional consultants (engineering, environmental, and landscape design) Local Government: City of Fremantle State Government Agencies: DevelopmentWA
Drivers	Social (building a sustainable community; creating space for community collaboration and enjoyment; providing inspiration for the wider community; beautification of the area surrounding the development) Economic (self-funded; uplift property value) Environmental (increase urban green space; contribute to local biodiversity)	Social (demonstrate "Innovation through Demonstration" model; enhance attractiveness of the area surrounding the development) Economic (alignment of key stakeholders' interests; budget availability; uplift property value) Environmental (increase of urban green space; biodiversity enhancement; addressing canopy loss)
Strategies	Private initiative Developing an innovative approach to increase urban green space through the creative use of the underutilized space of the adjacent sump.	Public-private partnership Creating "Innovation by Demonstration" model One Planet Living framework Water-sensitive urban design
Constraints	Model development Concerns at community level Concerns at local government level, mainly health and safety issues Obtaining permissions and approvals Lack of clear policy guidelines	Concerns at government level-flood modeling issues, health, and safety issues Obtaining permissions and approvals

The drivers highlighted by the stakeholders of the Green Swing sump garden focus mainly on social and environmental benefits, for example, inspiring the local community to engage in the process of enhancing the urban landscape, as well as building connections between the individuals (members of the community). The sump garden provided a place for collaboration, such as food production and enjoyment of the natural space, helping to build community. For the stakeholders of the WGV sump park project, one of the main objectives was demonstrating how to effectively utilize space in a medium-density development to deliver ecological, social, and economic benefits. Hence, the sump park was highly dependent on local government and state agencies for financial support, as well as engineering and environmental technical advice and development. The sump park focus was directed towards mitigation of canopy loss and biodiversity enhancement. For all the stakeholders, the environmental issues were crucial to address.

Strategies used responded to the objectives and scale of each project. The Green Swing sump garden was a small-scale project supported by a simple and clear strategy that regarded the sump biophilic regeneration as an opportunity to increase urban green space and gain additional productive and recreational space for community building while inspiring other communities to do the same. It proceeded because the local authorities could support it without needing to increase its budget to accommodate its management. The involvement of a local gardening group was a critical step in this process. The WGV sump park was a more complex and larger-scale project that needed a stronger professional strategy. A public-private partnership was then developed that created an "Innovation through Demonstration" model and utilized the One Planet Living sustainability framework and the guidelines of water-sensitive urban design to steer their actions. Thus, strategies were to involve volunteers for the small scale and professional advice for the large-scale. Both were appropriate in creating the necessary support to deliver the projects.

In regard to the constraints affecting the progress of the projects, similar issues emerged for both cases, for example, concerns at the local government level, which had to be addressed in order to obtain relevant approvals. Health and safety issues became a priority for local governments and communities; in both cases, removing the fence and allowing public access was the main health and safety concern. In the case of the Green Swing sump garden, the local government decided to keep the existing fence, though it had an easily opened gate. To retrofit the WGV sump, a hydrological assessment was undertaken to determine the required sump capacity and the potential to use underground drainage cells and landscaping to meet drainage and social requirements. It was a costly process that could only be achieved with financial support from the City of Fremantle and DevelopmentWA. A business case for the Green Swing sump garden was deliberately avoided as it was considered another obstacle by the project proponents [48], and this confirms the importance of having a project small enough to be seen as primarily a volunteer exercise.

The challenges identified as the most difficult to overcome were related to legal status, path dependency, and leadership. Other common difficulties and obstacles during different stages of the project included obtaining relevant permissions to develop the sumps and reassuring the skeptical officers in government agencies about the feasibility of the projects. The approval of the drainage cells proposed for the WGV sump park was described as a lengthy process. Similar opinions came from the citizen developers of the Green Swing, which listed lengthy approval processes as one of the main obstacles.

The values supporting the actions show similarities related to social, ecological, and economic aspects and reflect the initial objectives related to livability and biodiversity. In both cases, the personal values of those involved were clear as they praised community building, innovation, sustainable urban living, and place-making, as well as sustainable food production (in the Green Swing case). In both cases, place-making manifested as a strong value to provide facilities for the local community to interact and develop ownership of the place. The principles of sustainable development highlighted in the One Planet Living program became the source of professional values that the stakeholders at the WGV would share and follow. The values required to develop place-based water-sensitive landscape design showcase conservation efforts, environmental regeneration, and biodiversity enhancement. For the developers of the Green Swing sump garden, the values oscillated around community building and sustainable urban farming. The modest design and volunteer-based governance were aimed at expressing these values and enabling the local community to be able to create the on-going maintenance of the areas as they came to live there with their families.

Environmental values were strongly indicated, especially biodiversity, ecological regeneration and conservation, and water management (in the WGV case). These values were not seen as harming the economic prospects for their developments, in particular, there was an expectation that they would uplift the property value. In the case of WGV, the precinct won a number of significant awards and the sales of the lots and units were generally more rapid than the market at that time. The sump park was also seen to provide social and educational value to the wider community of White Gum Valley. The Green Swing park was considered to have contributed to the area's improved real estate value.

Both cases aimed at demonstrating innovative approaches to increase urban green space. The old stormwater sumps became multifunctional features, serving not only as stormwater infrastructure but also enhancing recreational and educational infrastructure and biodiversity. Enhancing attractiveness and overall beautification of the developments and the adjacent surroundings became one of the leading drivers for both communities and developers. The educational, recreational, and ecological aspects of the regeneration projects appear to fulfil the objectives of biophilic urbanism and regenerative design.

The framework suggests strong reasons for mainstreaming biophilic revitalization of stormwater infrastructure at both a small and large scale.

5. Conclusions

The paper has reviewed the biophilic regeneration of two stormwater sumps in Metropolitan Perth, and the results have indicated that multiple outcomes favoring biodiversity regeneration and local community benefits can be achieved whilst enabling effective stormwater management. From the perspective of the biophilic urbanism agenda, this is a more favorable design outcome than the outcome obtained from the 1940s style of modernist engineering.

The question posed in this paper asked how such a design can be mainstreamed and whether the two sumps could shed light on whether this is possible.

Regenerating stormwater infiltration basins have drivers, dynamics, and values that can enable sustainable outcomes. The analysis of the two case studies in Metropolitan Perth reveals that the barriers to the wider implementation of the biophilic approach to the sumps' revitalization and repurposing are mainly socio-institutional but can be overcome at both small-scale and big-scale sumps.

The Green Swing sump garden is a successful design for a small-scale sump, which demonstrates how a creative use of underutilized areas can contribute to sustainable urban living and serves as a model to be adapted to other places and communities. Similarly, the WGV sump park has shown the multiple benefits for a whole community or suburb by regenerating a large-scale stormwater sump.

The results of the comparative analysis suggest that the key difference between the small- and large-scale projects is in their governance approach to delivering and maintaining the sumps. The small scale was largely a volunteer approach in delivery and maintenance, and the large scale was a fully professional approach, involving greater commitment from an on-going maintenance budget from the local government authority. The local small-scale regeneration project suggests that such small systems can be initiated and successfully led to completion by a group of charismatic community members with necessary but limited input from other professionals. The large-scale regeneration project can similarly work but requires more partnerships to be developed and a fully professional assessment process. In both cases, leadership was needed to drive the necessary changes, though this may be enough to enable the policies and strategies to be mainstreamed, as the demonstrations have shown multiple benefits with few, if any, negative side effects.

The two projects analyzed here suggest that it is necessary to develop such inspirational examples to create the kind of mainstreaming necessary for biophilic urban regeneration in general and that the two-scale approach may have benefits in many other kinds of biophilic and regenerative urbanism. Another lesson that emerged from the analysis of the results is that health and safety issues need to be addressed at the proposal stage to secure adequate approvals from local authorities. In the case of the Perth sumps, alternative health and safety design solutions need to be tested and, if successful, they need to be made publicly available in order to encourage similar regenerative projects.

These projects have helped educate communities, property owners, local councils, utilities, and developers, showing that quality green urban assets should not be viewed as "optional extras" in any urban development but as critical elements of successful, value-driven, economic developments at a small and large scale.

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