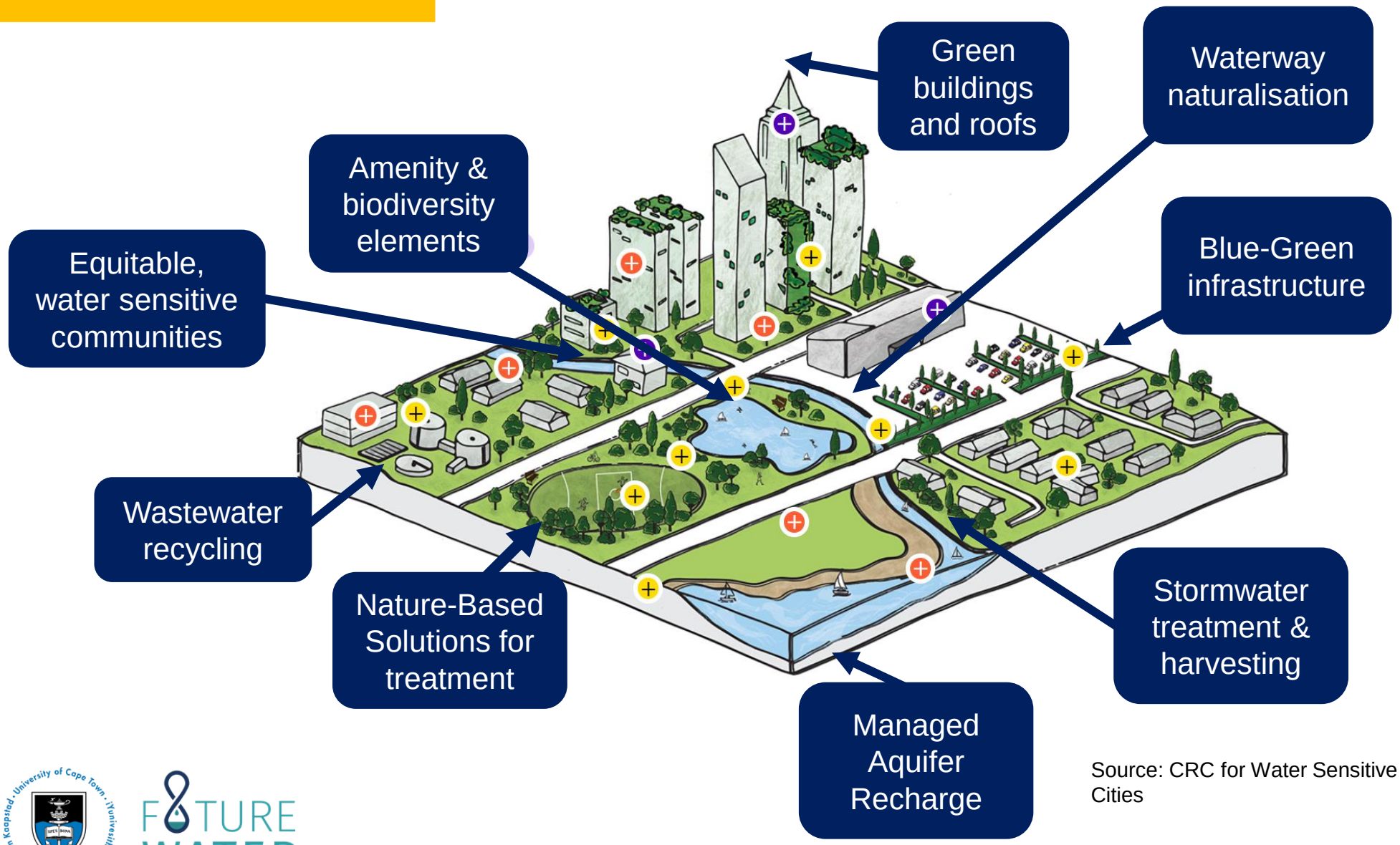
Evaluating the potential for Blue-Green Infrastructure benefits using the case study of stormwater ponds in Cape Town, South Africa

Planning support for a Water Sensitive City transition

Jessica Fell

Background



Source: CRC for Water Sensitive Cities

"Water Sensitive Cities are **sustainable**, **resilient** and **liveable** through a combination of physical infrastructure, governance arrangements and social engagement."

Blue-green Infrastructure is… “an interconnected network of landscape components, both natural and designed, that includes open, green spaces and water bodies (ephemeral, intermittent and perennial) which provide **multiple functions**” (O’Donnell et al., 2021).

Multifunctionality is explicitly and strategically planned for, rather than being a product of chance

Why WSCs and BGI?

Water resource shortages, urbanisation, deteriorating water infrastructure, declining water quality, climate change, resource and capacity constraints

Current conventional approaches ≠ liveable, sustainable and resilient water sensitive cities
(Wong & Brown, 2009; Savenije et al., 2014; Capps et al., 2016; Hoekstra et al., 2018)

Manifestation

Joburg water supply & infrastructure crisis

Nelson Mandela Bay Metro
Cape Town Day Zero crisis

Example

Current stormwater systems (Chocat et al., 2007)

Strategy & SDG alignment

CITY OF CAPE TOWN
ISIXEKO SASEKAPA
STAD KAAPSTAD

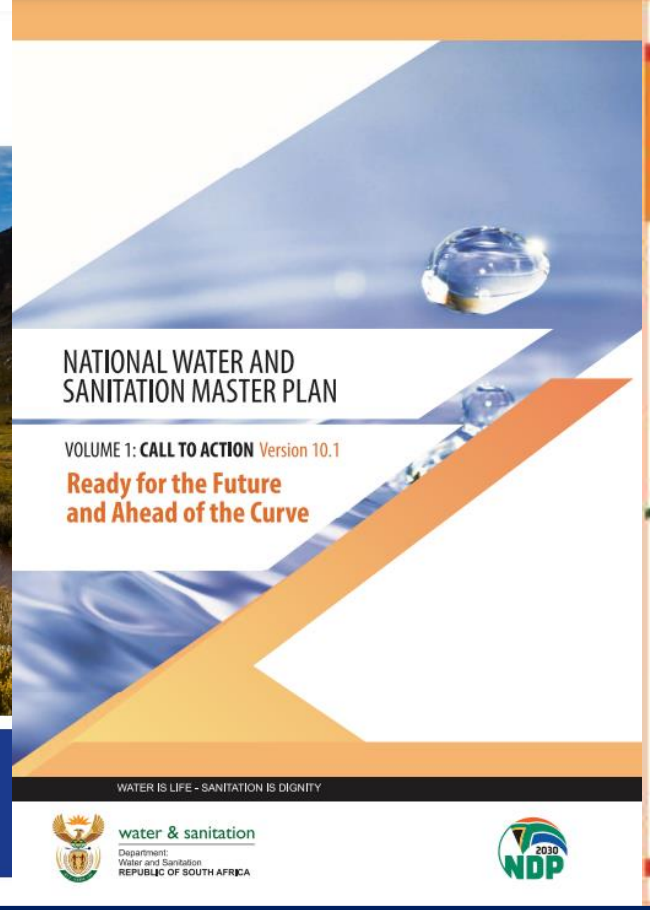
Making progress possible. To

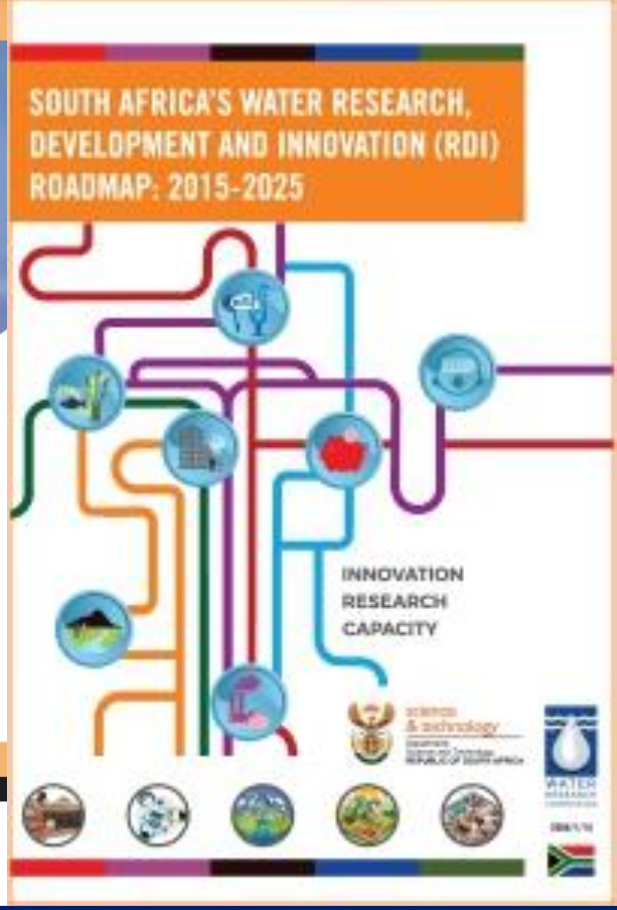
Western Cape Government
Environmental Affairs & Development Planning

WESTERN CAPE SUSTAINABLE WATER MANAGEMENT PLAN 2017 — 2022

Towards a new norm for water resilience

March 2018





6 CLEAN WATER AND SANITATION

11 SUSTAINABLE CITIES AND COMMUNITIES

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

13 CLIMATE ACTION

15 LIFE ON LAND

The water insensitive city: large scale centralised infrastructure and institutions

Flexible, integrated, complex, resilient infrastructure and institutions

Current state

Transition pathway

Drainage services are MONOFUNCTIONAL, with the sole function of flood protection

Cumulative Socio-Political Drivers

Water supply access and security

Public health protection

Flood protection

Social amenity, environmental protection

Limits on natural resources

Intergenerational equity, resilience to climate change

Water Supply City

Sewered City

Drained City

Waterways City

Water Cycle City

Water Sensitive City

Supply hydraulics

Separate sewerage schemes

Drainage channelisation

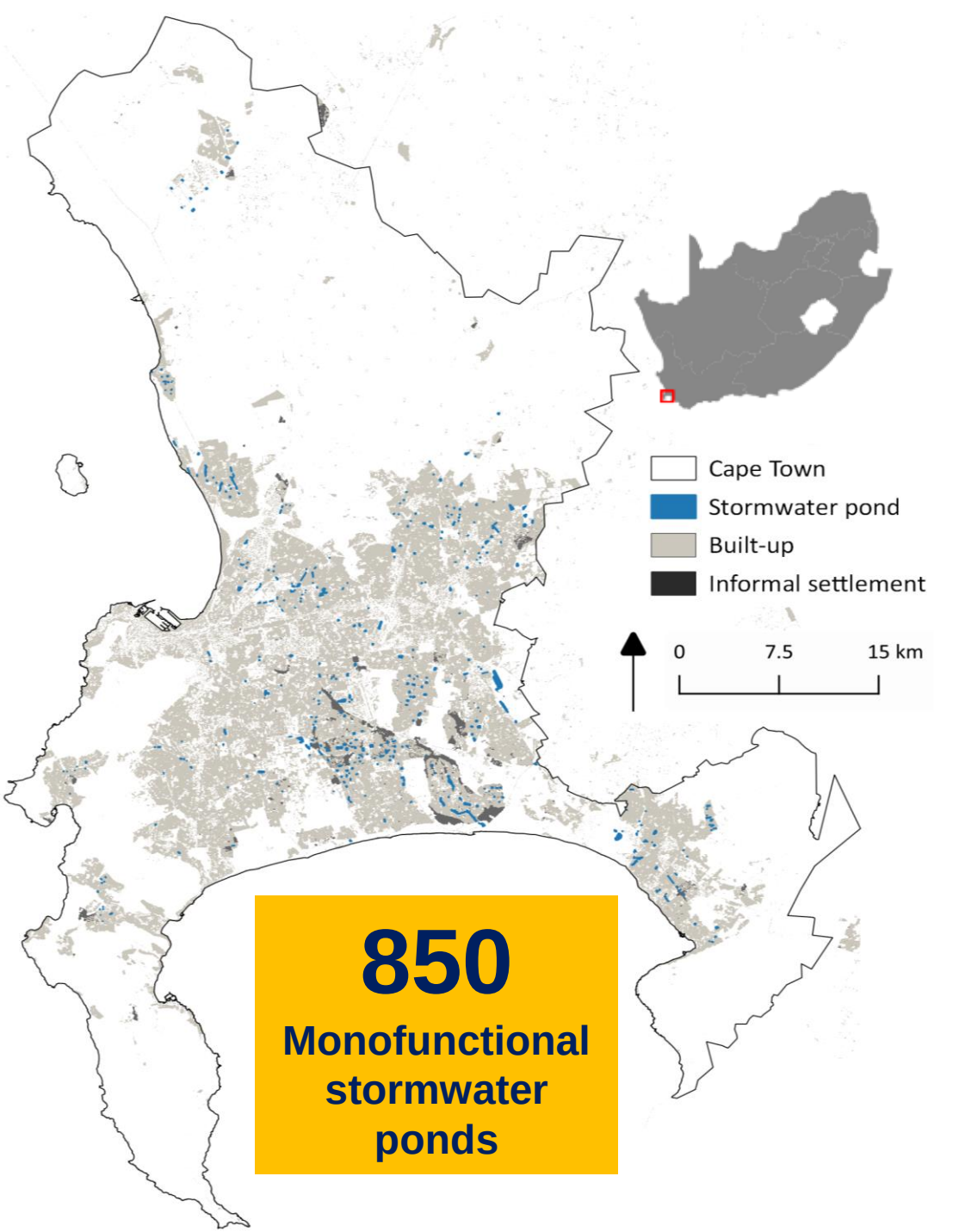
Point & diffuse source pollution management

Diverse, fit-for-purpose sources & end-use efficiency, waterway health restoration

Adaptive, multi-functional infrastructure & urban design reinforcing water, sensitive values & behaviour

Essential services: water supply, sanitation and flood protection

Service Delivery Functions



Cape Town has 850 monofunctional stormwater ponds which offer a way to achieve a Water Sensitive City through being repurposed to provide multi-functional benefits such as managed aquifer recharge, amenity and biodiversity.

When planning for multi-functional infrastructure, it is important to determine which benefits are most important and to try maximize different benefits given the spatial context and local needs.

Pathways to water resilient South African cities

FUTURE WATER

UNIVERSITY OF COPENHAGEN

MINISTRY OF FOREIGN AFFAIRS OF DENMARK DANIDA INTERNATIONAL DEVELOPMENT COOPERATION

Source: Craig Tanyanyiwa

Aims & method

"Develop an **Multi-Criteria Analysis methodology** to evaluate the potential for existing Blue Infrastructure to provide **multiple benefits** as Blue Green Infrastructure. This is done through the case study of the existing stormwater ponds in Cape Town, RSA as part of its commitment to become a WSC"

An MCA ‘establishes preferences between options by reference to an explicit set of objectives that the decision making body has identified, and for which it has established measurable criteria to assess the extent to which the objectives have been achieved’.

01 | Identification of objectives and associated criteria against which to test options

02 | Development of the options to be assessed

03 | Scoring to assess the performance of each option against the criteria

04 | Weighting of criteria

05 | Combination of scores and weights and ranking

Alternative-focused approaches and Value-focused approaches

Alternative-focused approaches begin with the development of alternatives (also referred to as options) and then proceed with defining values, objectives and criteria for evaluation.

Value-focused approaches start with an articulation of values (also referred to as principles, goals or aims) as the fundamental component of planning – putting focus first on what is desired rather than on the set of alternatives. Once values are defined, the options are identified as a means to achieve the values.

Values improve planning by articulating upfront what is important.

(1) Identification of objectives and associated criteria against which to test options,

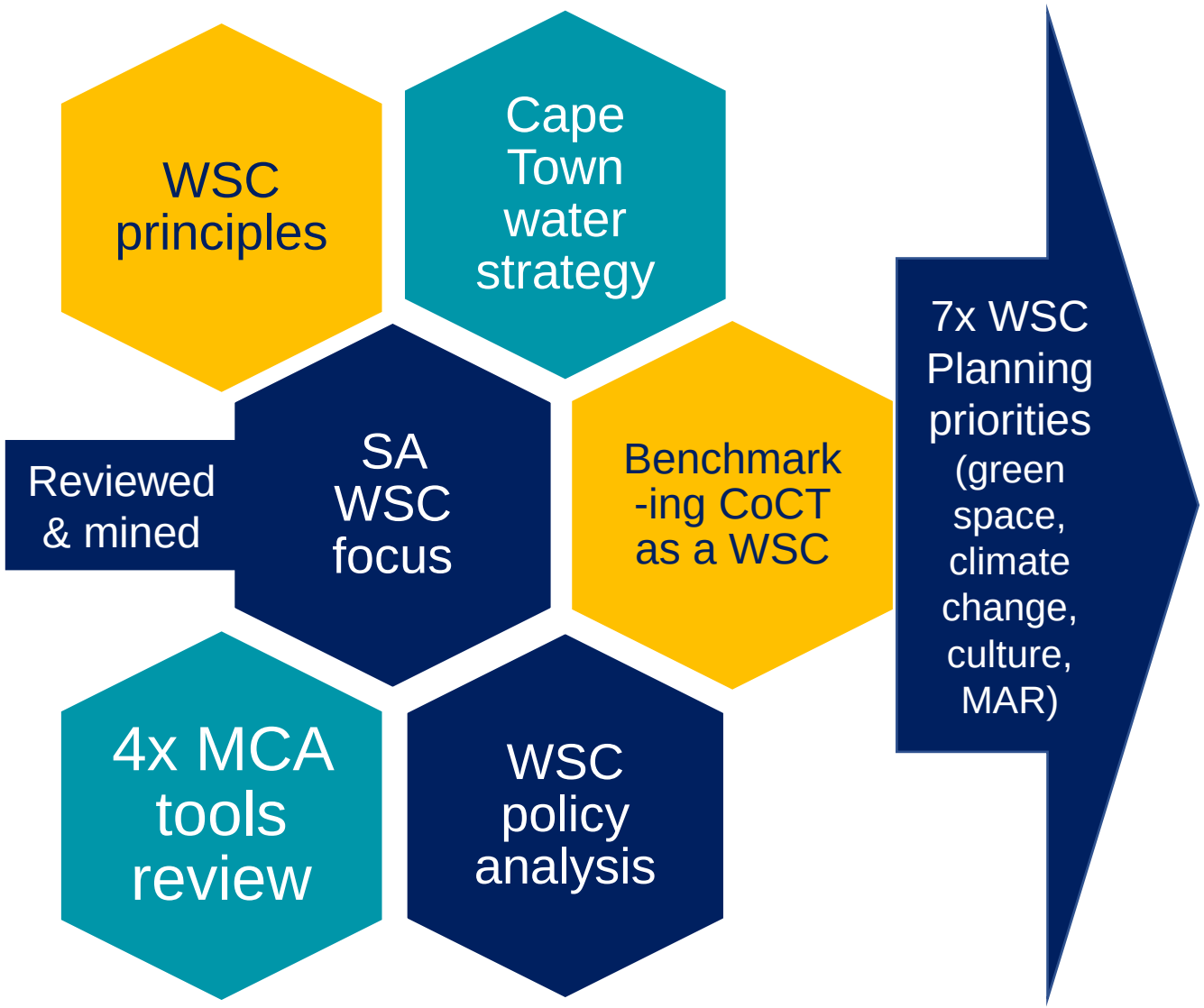
Objectives are high level aims or goals that qualitatively define what is important. They are statements of something being aspired to. Objectives are informed by values and are a means to make values explicit.

This process is guided by the decision context and questions such as '**what is to be achieved or provided for in this situation**'.

Five W's of a WSC (Meerow & Newell, 2019)

		TRADE-OFFS	Questions to consider
Identifying and structuring objectives for WSC benefits	**Why?**		What are the goals of transitioning to a WSC – why a WSC? What are the underlying reasons for transitioning to a WSC? Is the focus on process or outcome?
	What?		What is wanted and valued in a WSC? What WSC objectives should be included? What are the aspirations for and limitations to providing benefits in a WSC? What features and sectors (social, ecological, technical) are included in the city?
Selecting criteria for benefits provided by BGI in a WSC	**Who?**		Who benefits from the WSC and BGI functions? Whose benefits are prioritised?
	Where?		Where are the spatial boundaries of the city? Are some areas prioritised over others for benefits? Does providing benefits in some areas affect others?
	When?		Is the focus on achieving benefits for the short- or long-term? Is the focus on rapid onset shocks or gradual changes?

(1) Identification of objectives and associated criteria against which to test options,



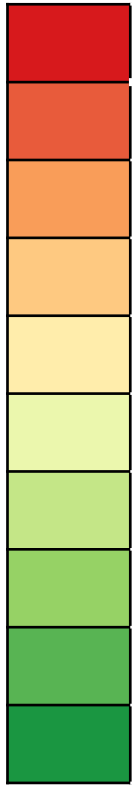
Criteria provide a way to measure the extent that options meet the objectives through measurable indicators of performance

WSC planning priority	Stakeholder						
	1	2	3	4	5	6	7
Enhancing cultural and heritage associations with water systems		x			x	x	x
Increasing water re-use			x	x	x		
Reducing climate change impacts		x	x	x	x	x	
Utilising education services potential		x		x	x	x	x
Increasing access to blue-green space	x	x	x	x	x	x	x
Incorporating stormwater quality limitations	x	x	x	x	x	x	x
Enhancing biodiversity	x	x		x	x	x	

Category	Questions
Reducing climate change impacts	• For reducing climate change impacts, is UHI reduction or carbon sequestration a higher priority? • Do retention versus detention ponds impact this criterion? • Are there any available datasets for this criterion?
Incorporating stormwater quality limitations	• The next priority is managing stormwater quality, so how can stormwater quality concerns that would limit other functions like amenity and MAR be considered? • In the example, the research has looked at the land cover type in the form of distance to informal settlements; darker green ponds (with higher criterion scores) are those with relatively longer distances to informal settlements – which indicate more potential for multifunctionality (MAR, biodiversity and amenity) as they would be less constrained by stormwater quality impacts. • The research is considering other potentially polluting land covers such as WWTWs, what others would you include?
Enhancing biodiversity	• Can stormwater ponds enhance biodiversity in the city? Any relevant datasets? • For biodiversity, is habitat size or using ponds to enhance landscape connectivity more important? • How do retention versus detention ponds impact on biodiversity? • Does the pond size impact which ponds should be prioritised?

Water Sensitive City planning priority	Criterion and attributes
Enhancing cultural and heritage associations with water systems	Culture and heritage sites (City of Cape Town, 2019h, 2019k).
Increasing water re-use	MAR potential (Surficial geology (mask layer), Aquifer, Soil permeability and Transmissivity (Bailey & Pitman, 2012; Wright & Jacobs, 2016; World Agroforestry Centre Landscape Portal, 2021; City of Cape Town, n.d.-c).
Reducing the Urban Heat Island effect	UHI intensity risk (land cover classes, daily normalised, irradiation and windspeed) (Petrie *et al*., 2019).
Community services connection with water systems	Proximity to schools, community centres and religious institutions (City of Cape Town, 2019e, 2019j; Department of Basic Education, 2021).
Increasing access to blue-green space	Recreation potential (two indicators of park presence and mean population density in 500 m pond radius (City of Cape Town, 2019i; Statistics South Africa, 2011)).
Incorporating water quality limitations	Proximity to Potential Contaminating Activities (PCA) (informal settlement, industrial, roads, landfill, wastewater treatment works,) (City of Cape Town, 2019g, 2019m; Department of Forestry Fisheries and the Environment, 2021).
Enhancing biodiversity	Aquatic biodiversity category (Snaddon & Day, 2009).

3. Scoring to assess the performance of each option against the criteria



0 – 0.1 Low priority/potential

0.1-0.2

0.2-0.3

0.3-0.4

0.4-0.5

0.5-0.6

0.6-0.7

0.7-0.8

0.8-0.9

0.9-1 High priority/potential

Water Sensitive City planning priority	Explanation
Enhancing cultural and heritage associations with water systems	Intersection with national, provincial and local heritage resources indicates potential for the pond to contribute to conserving the heritage resource
Increasing water re-use	The ponds require suitable conditions for MAR via surface infiltration
Reducing the Urban Heat Island effect	The higher the UHI risk, the greater the need for cooling from Blue-Green Infrastructure
Community services connection with water systems	The closer the ponds are to schools, community centres and religious institutions, the more education services reach and pond ownership
Increasing access to blue-green space	The higher the population density, the higher the level of potential recreational use by people living withing walking distance
Incorporating water quality limitations	The further away the pond is from a PCA, the lower the likelihood for poor water quality impacts to limit other potential functionalities
Enhancing biodiversity	Alignment to the Cape Town Biodiversity strategy

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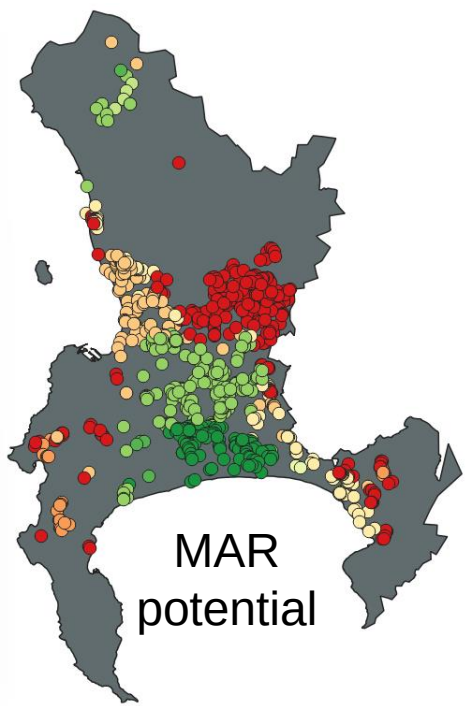
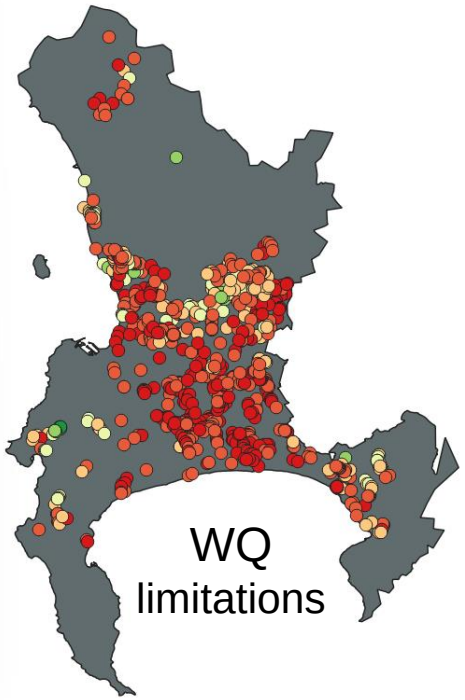
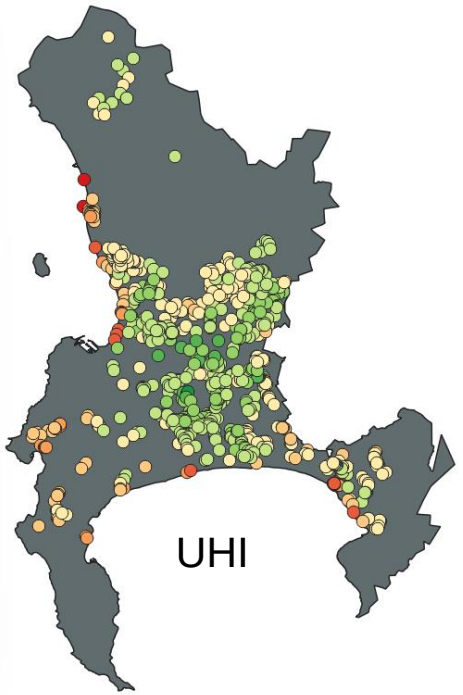
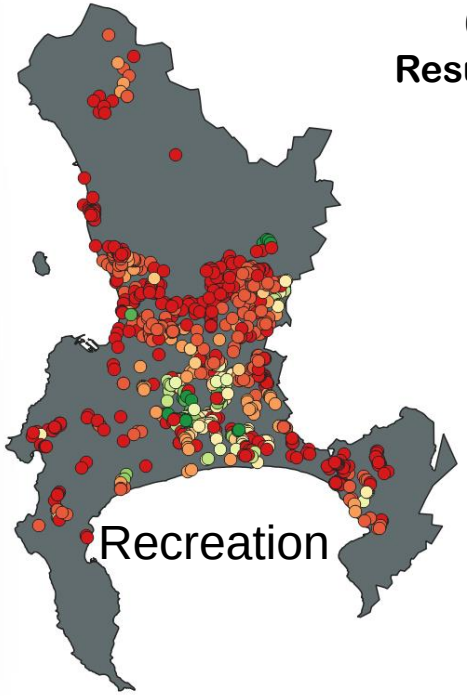
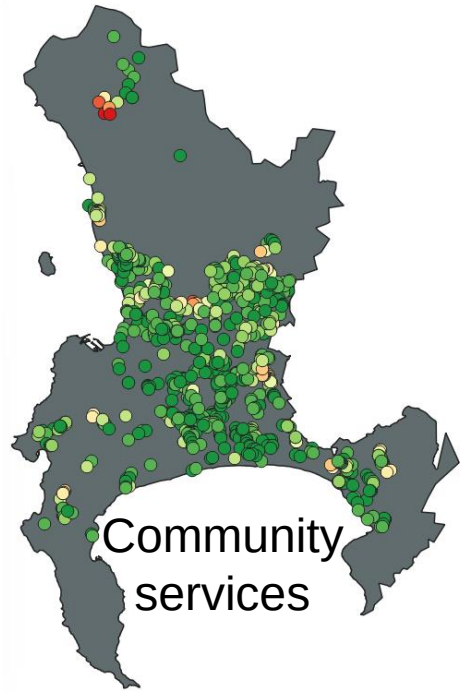
FUTURE WATER

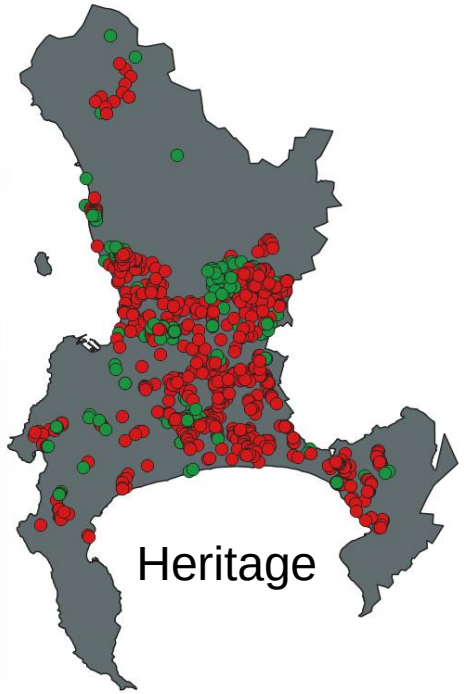

MAR
potential

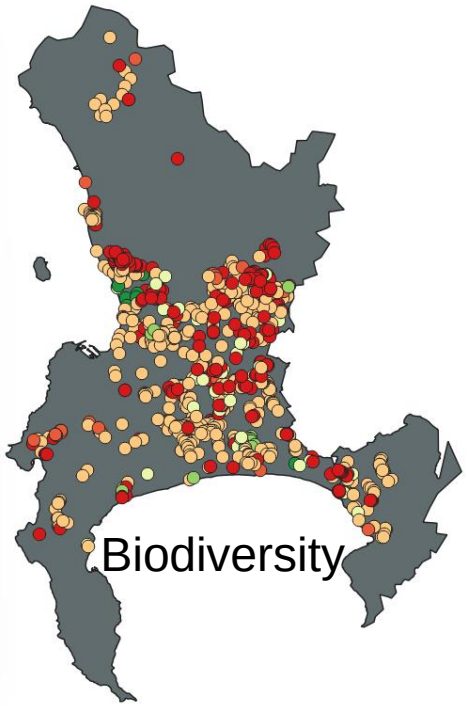

WQ
limitations

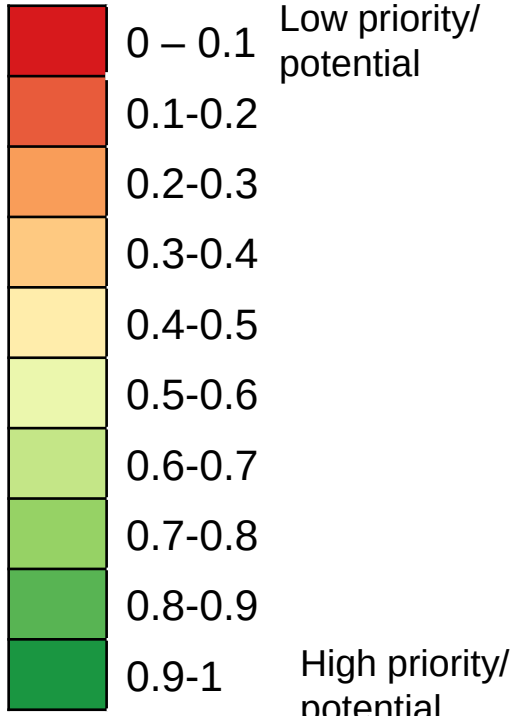

UHI


Recreation


Community
services

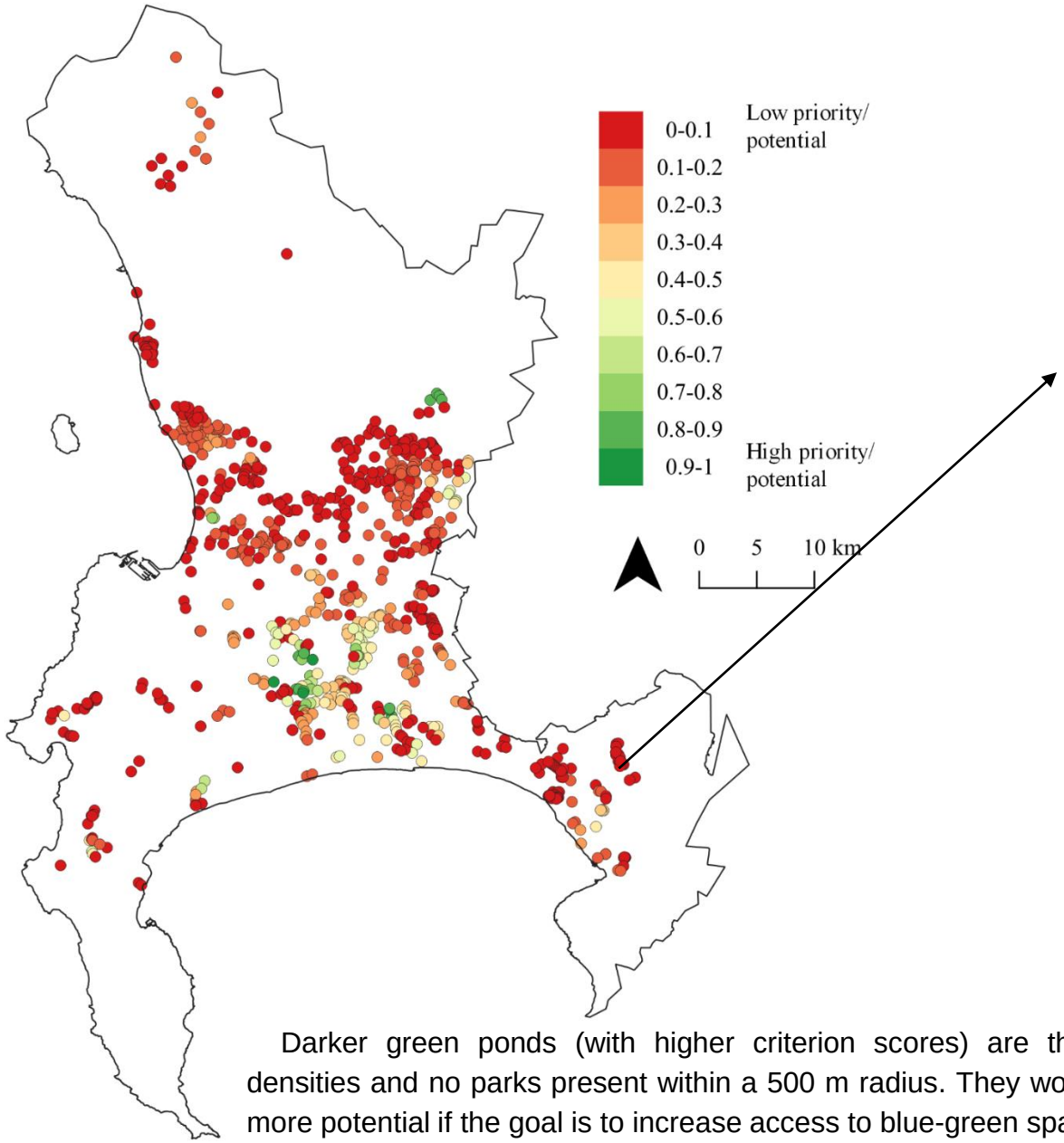

Heritage


Biodiversity


0 – 0.1
0.1-0.2
0.2-0.3
0.3-0.4
0.4-0.5
0.5-0.6
0.6-0.7
0.7-0.8
0.8-0.9
0.9-1
Low priority/
potential
High priority/
potential

Increasing access to blue-green space

Recreation potential (two indicators of park presence and mean population density in 500 m pond radius (City of Cape Town, 2019i; Statistics South Africa, 2011)).

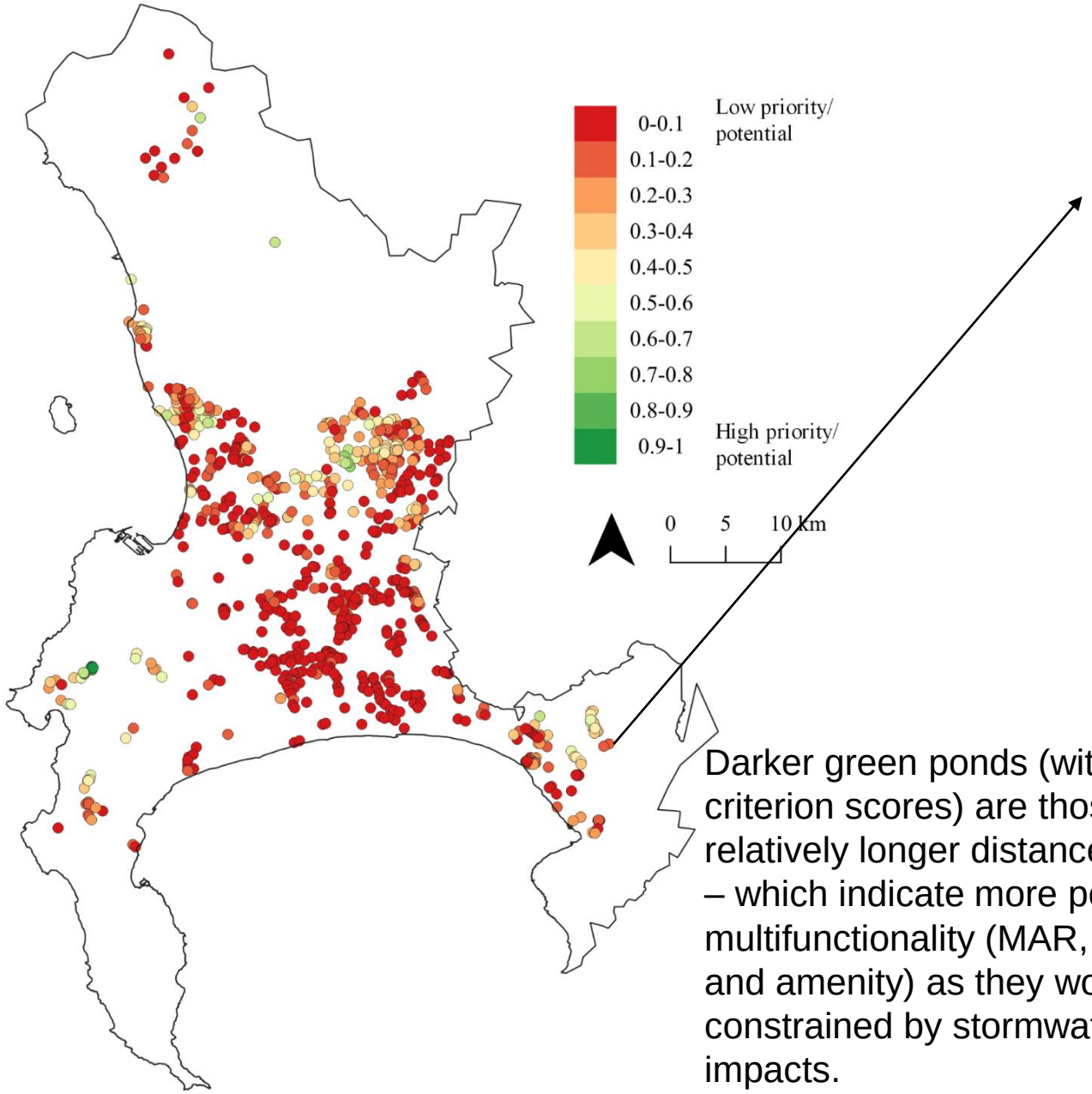


Mean population density (per hectare) and park presence within 500 m of pond	Performance scale (mean)	Pond percentage
Park present	0	10.5%
0–22	0.0	36.6%
22–44	0.1	27.0%
44–66	0.2	8.0%
66–88	0.3	4.7%
88–110	0.4	4.5%
110–132	0.5	2.8%
132–154	0.6	2.5%
154–176	0.7	1.1%
176–198	0.8	1.3%
198–220	0.9	0.7%
220–242	1.0	0.4%

Darker green ponds (with higher criterion scores) are those with higher population densities and no parks present within a 500 m radius. They would be higher priority or offer more potential if the goal is to increase access to blue-green spaces for recreation.

Incorporating water quality limitations

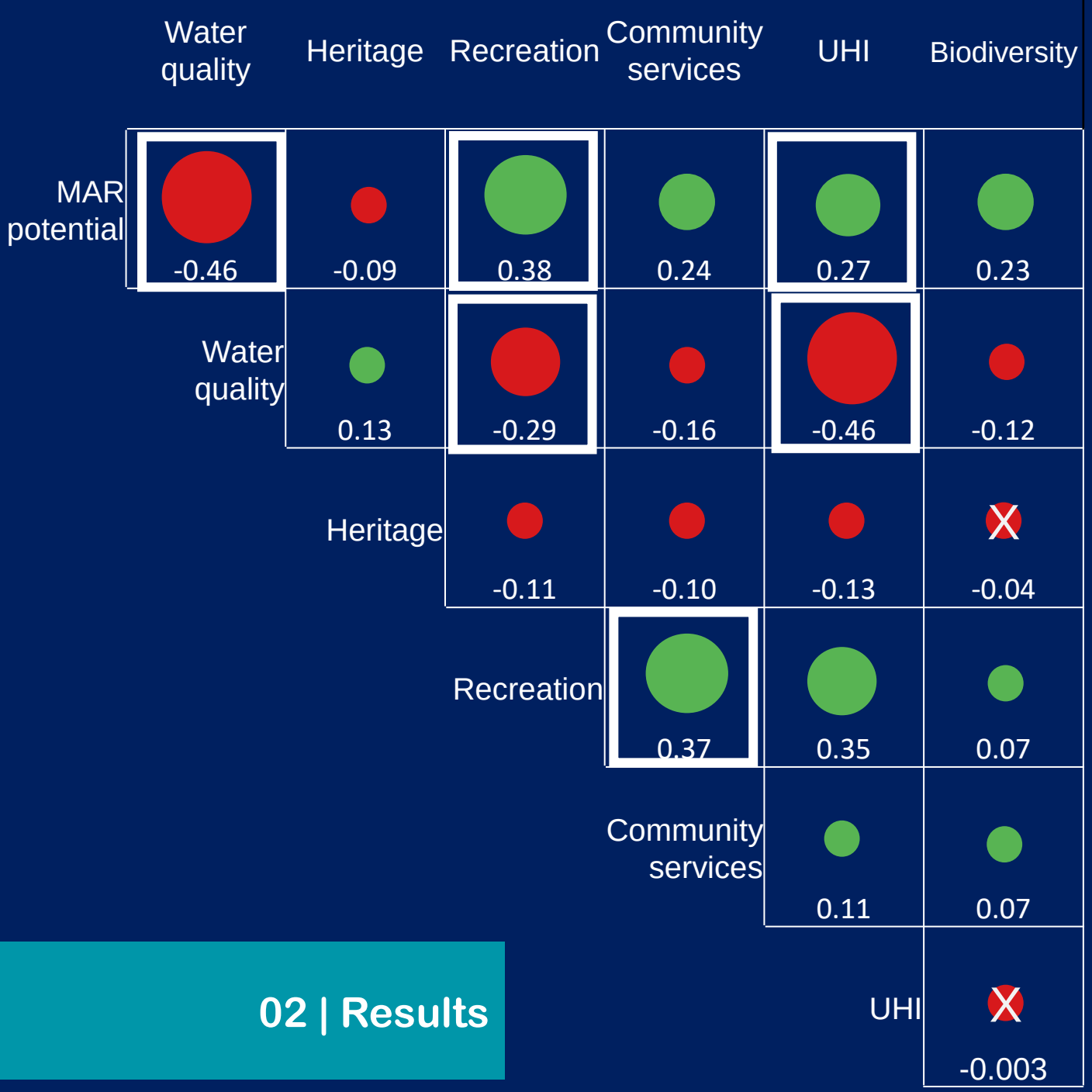
Proximity to Potential Contaminating Activities (PCA) (informal settlement, industrial, roads, landfill, wastewater treatment works,) (City of Cape Town, 2019g, 2019m; Department of Forestry Fisheries and the Environment, 2021).



Distance to PCAs (m)	Performance scale (mean)	Pond percentage
0–200	0	46.2%
200–400	0.1	15.6%
400–600	0.2	11.2%
600–800	0.3	8.8%
800–1000	0.4	6.7%
1000–1200	0.5	5.8%
1200–1400	0.6	3.3%
1400–1600	0.7	0.9%
1600–1800	0.8	0.7%
1800–2000	0.9	0.1%
2200–2400	1	0.6%

Darker green ponds (with higher criterion scores) are those with relatively longer distances to PCAs – which indicate more potential for multifunctionality (MAR, biodiversity and amenity) as they would be less constrained by stormwater quality impacts.

PCAs	Pond percentage
Landfills	1.3%
Informal settlement Land cover	32.5%
Industrial Land cover	47.3%
Roads Land cover	17.7%
WWTW	1.2%



Trade-offs and synergies

WQ limitations - MAR potential

WQ limitations – Recreation

WQ limitations - UHI

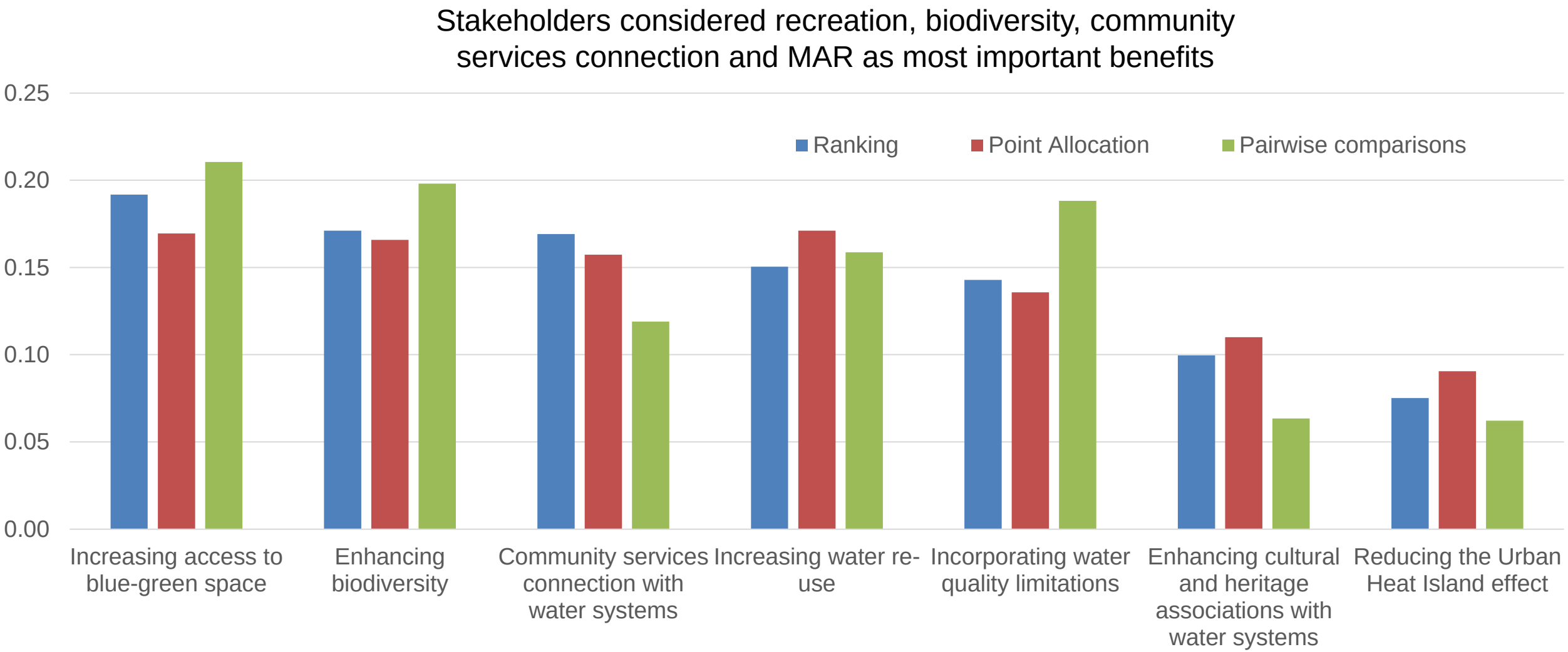
Recreation - MAR potential

Recreation – Community services

Recreation - UHI

Participatory MCA
Stakeholder derived weights

Workshop with x20 diverse stakeholders



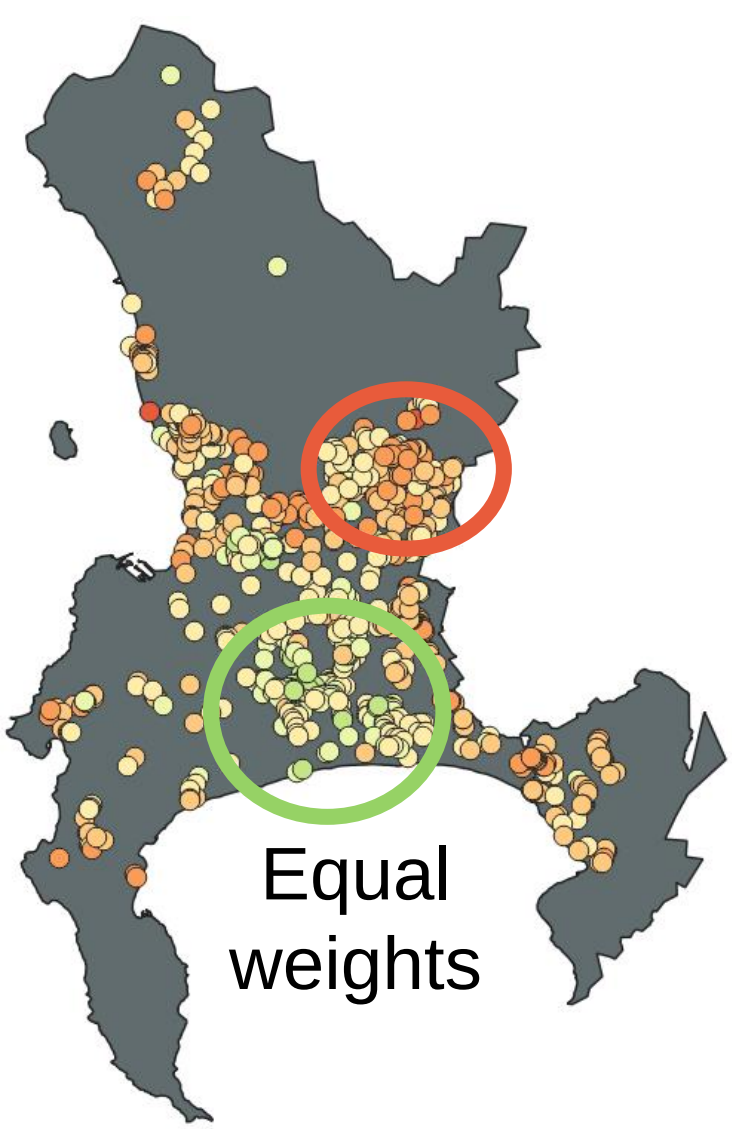
04 | Combination & ranking

Weighted linear combination

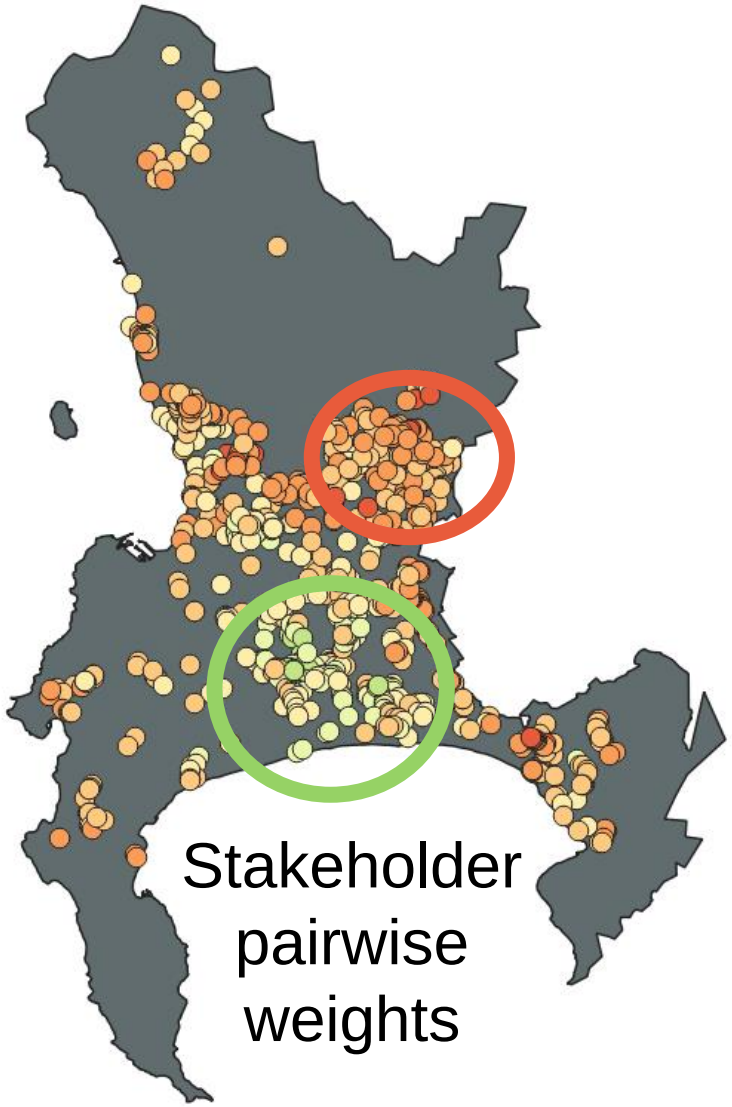
$$S_i = w_1 s_{i1} + w_2 s_{i2} + \ldots + w_n s_{in} = \sum_{j=1}^{n} w_j \, s_{ij}$$ (Dodgson *et al.*, 2009)

where the preference score for option *i* on criterion *j* is represented by s_{ij} and the weight for each criterion by w_j, with *n* criteria the overall score for each option is S_i.

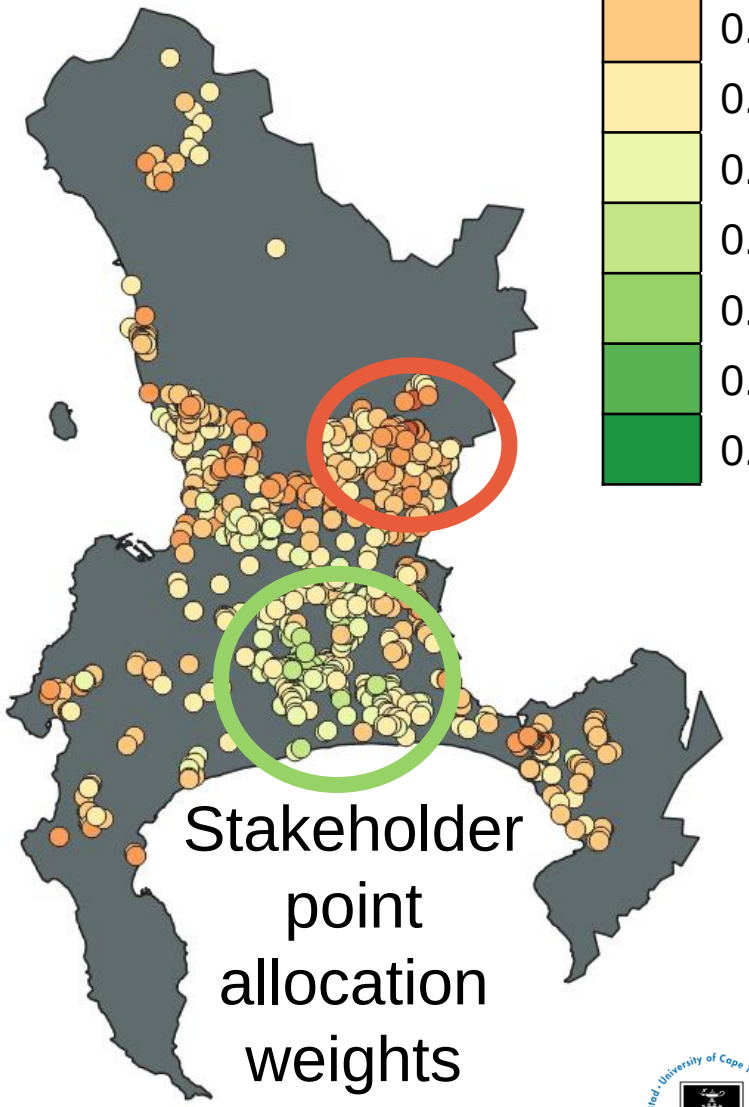
Stormwater pond priority scoring and ranking



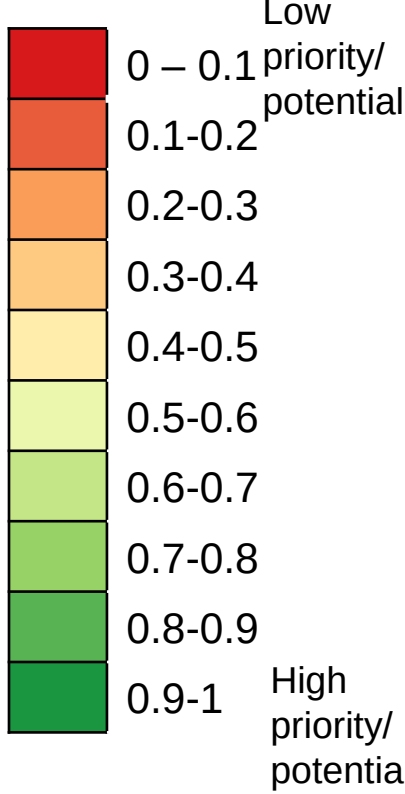
Equal weights



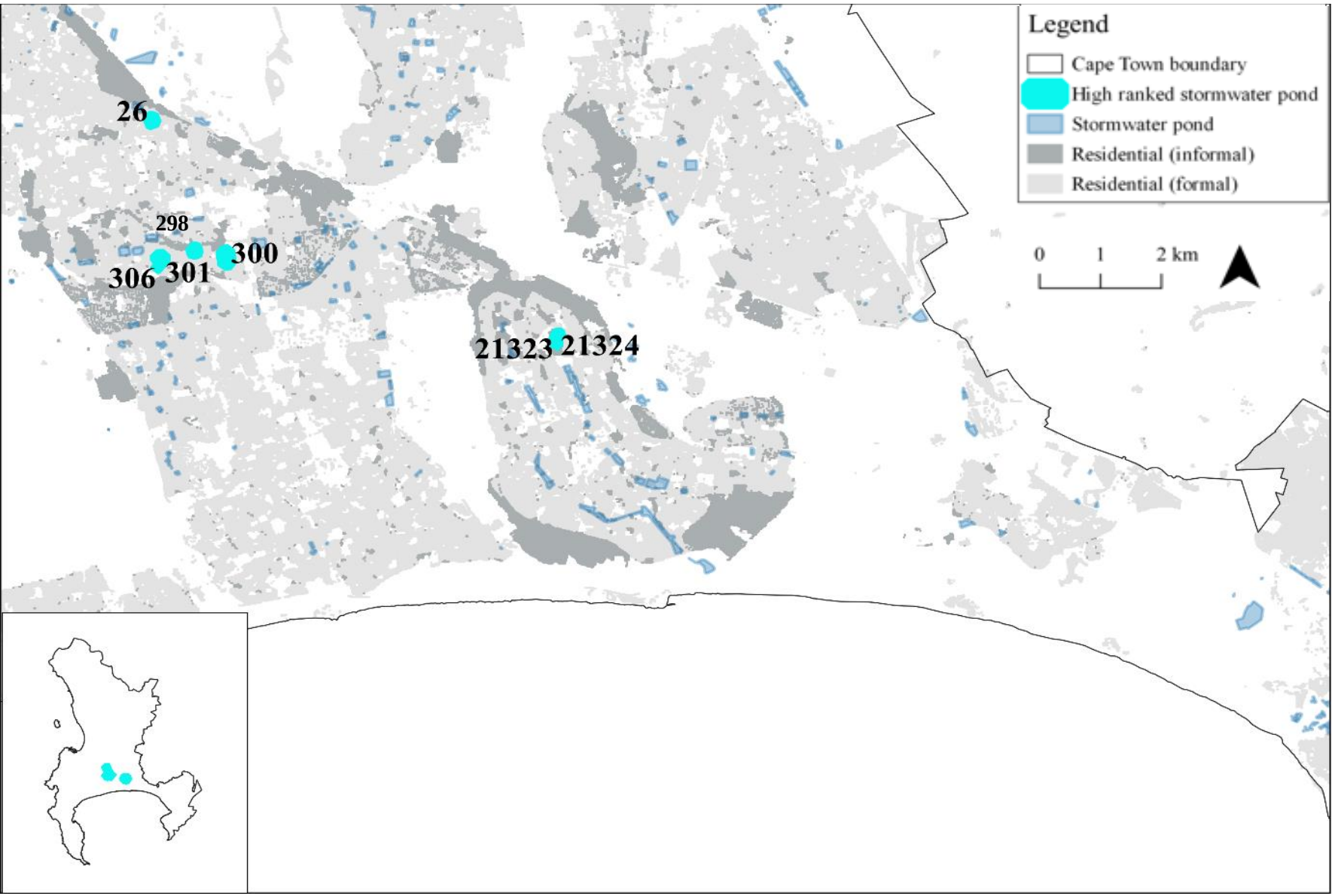
Stakeholder pairwise weights



Stakeholder point allocation weights



Scores	Potential/ priority	Pond percentage			
		Equal weights	Stakeholder ranking weights	Stakeholder point allocation weights	Stakeholder pairwise comparison weights
0–0.1	Low	0%	0%	0%	0%
0.1–0.2		1.8%	3.7%	4.0%	8.4%
0.2–0.3		30.8%	30.1%	29.7%	42.1%
0.3–0.4		37.5%	39.5%	37.1%	32.0%
0.4–0.5	Moderate	23.9%	20.9%	22.5%	14.5%
0.5–0.6	Moderate	5.0%	4.6%	5.3%	2.8%
0.6–0.7		1.1%	1.3%	1.3%	0.2%
0.7–0.8		0%	0%	0%	0%
0.8–0.9		0%	0%	0%	0%
0.9–1	High	0%	0%	0%	0%

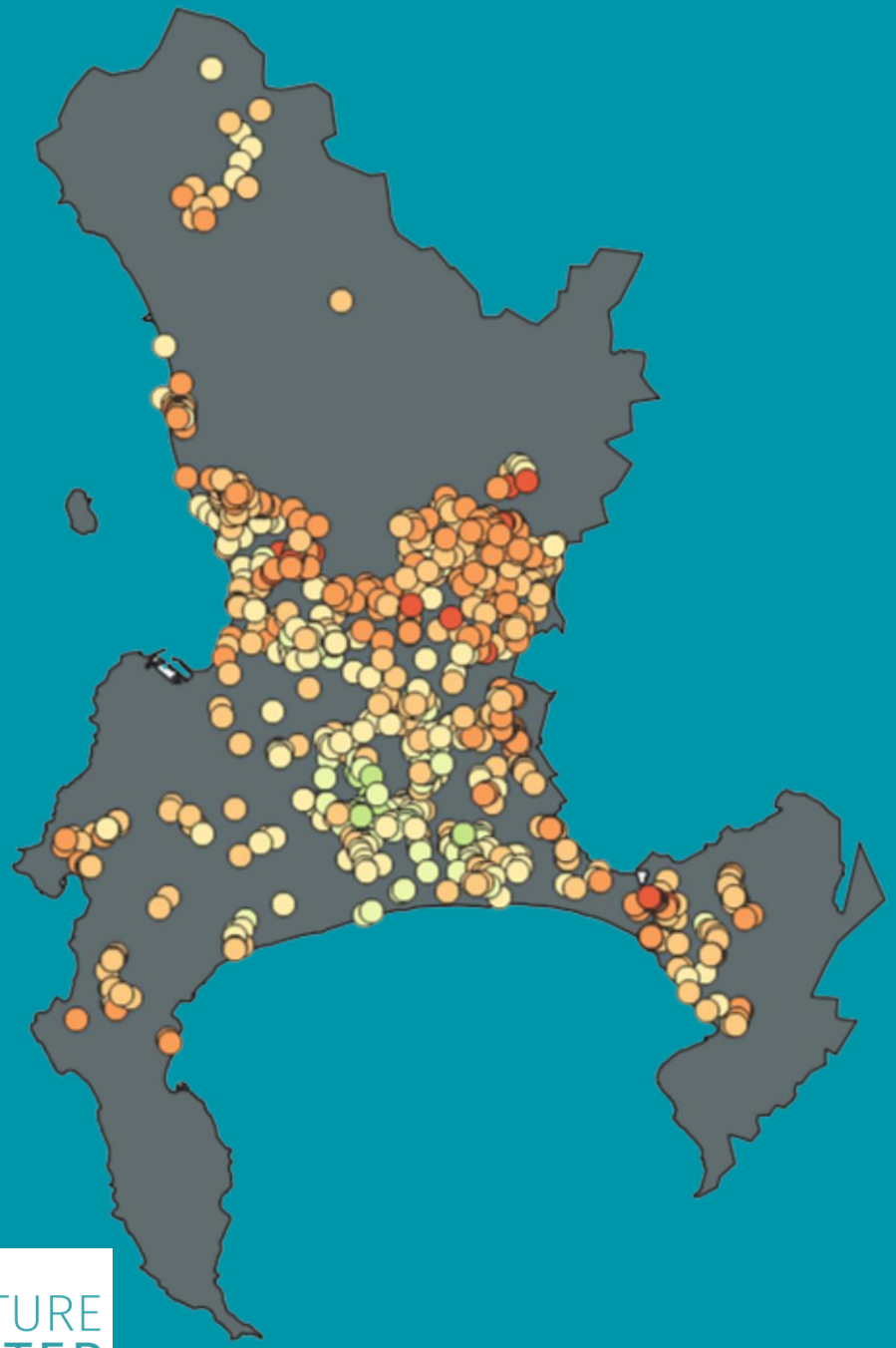


Pond ID
301

Pond ID
298

Pond ID
21323

MCA elements	Description
Strategic	Value-focused thinking is used to identify and structure objectives (Section 3.4) in accordance with the vision of a WSC (Section 2.2).
Flexible	The seven WSC planning priorities (objectives) and criteria can be adapted. Different existing BI options can be used. The steps and process of the MCA can be adapted.
Participatory	Stakeholder input is obtained through expert semi-structured interviews and stakeholder weighting.
Transferable	The MCA methodology can be used for other contexts, and particularly in the Global South.



Thank you.

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