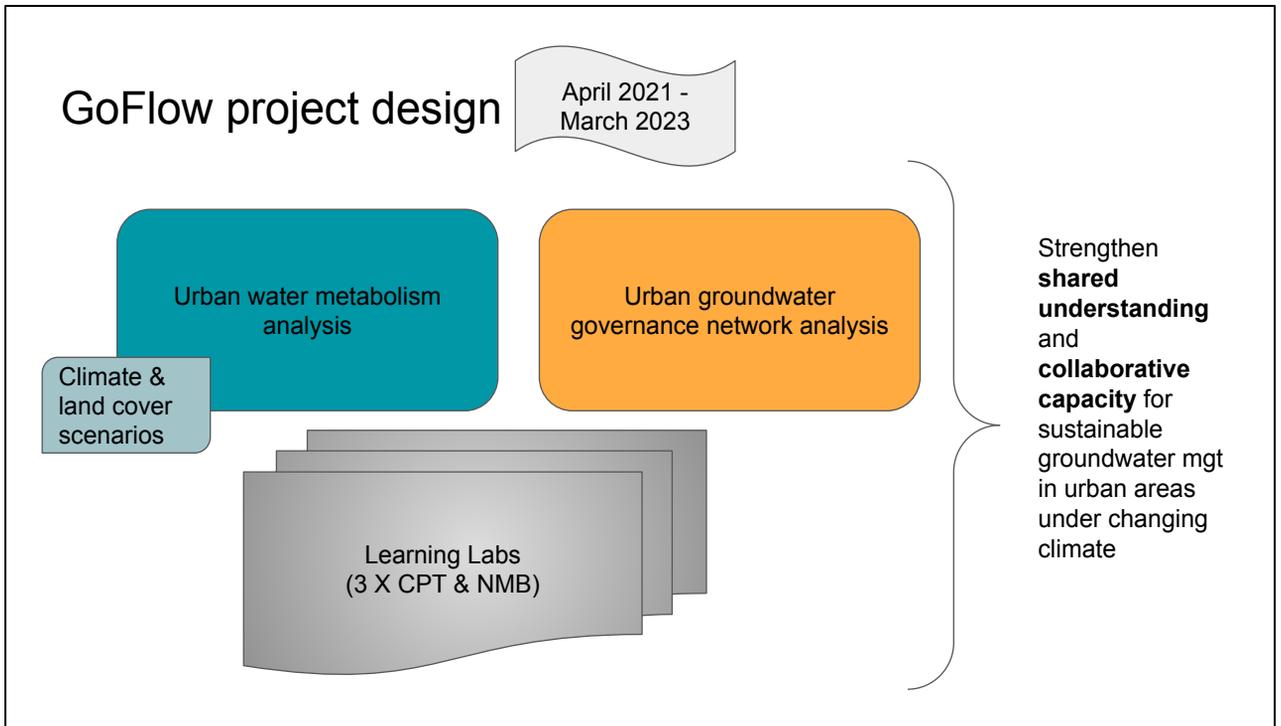# Governing groundwater flows for growing cities facing drought risks (GoFlow)

Report from NMB Learning Lab 2 Held on 2 December 2022

The Learning Lab 2 was hosted at Art-on Target in Gqeberha on 2 December 2022, and was attended by Anna Taylor, Chris Jack, Naadiya Hoosen, David Raymer, Leizel Williams Bruinders, SanMari Woithe, and Matthew Hills (with apologies for early departure).

GoFlow project design — April 2021 - March 2023

Urban water metabolism analysis

Urban groundwater governance network analysis

Climate & land cover scenarios

Learning Labs (3 X CPT & NMB)

Strengthen **shared understanding** and **collaborative capacity** for sustainable groundwater mgt in urban areas under changing climate
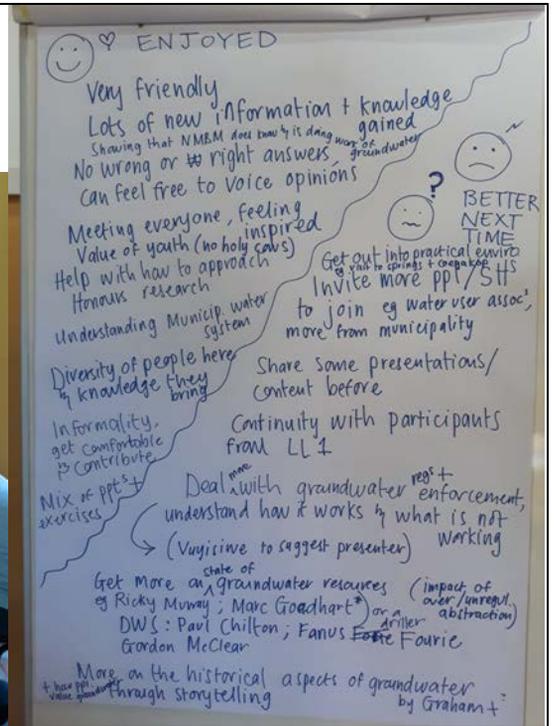
The Learning Lab began with Anna Taylor giving a brief overview of the GoFlow project for participants who did not attend the first NMB Learning Lab held in March 2022. She mentioned that WRC commissioned the project to centre the role of groundwater in growing South African cities. There is growing interest in groundwater as an alternative and diversified source for water users in cities, however it is an area of work dominated by highly specialized technical experts, mainly in the fields of hydrogeology and engineering. The knowledge and roles played by these technical experts is of course essential, but it is also important to broaden the understanding of groundwater stocks and flows amongst various public and private decision makers. It is important to break down conceptual and management silos to gain a holistic view of groundwater within urban water systems more broadly. The project is designed to bring together various sources of data and diverse stakeholders to develop an understanding the physical and social systems shaping groundwater utilisation and aquifer health. We are exploring the potential value of comparing and contrasting Cape Town and Nelson Mandela Bay water and governance systems, focussing on the role groundwater plays in it.

Programme for Learning Lab 2

Timing	Session
8.45-9.00	Arrival & coffee
9.00-9.20	Welcome, intro to GoFlow project, recap of LL1 & aim of LL2
9.20-09.45	Round of introductions
09.45-10.30	Revisiting the Urban Water Metabolism analysis for NMB
10.30-11.00	Tea / coffee break
11.00-12.00	Characterising the NMB groundwater governance network
12.00-12.45	Exploring 2 scenarios of future urban water metabolism for NMB
12.45-13.30	Lunch
13.30-14.00	Strengthening (ground)water governance network for sustainability & climate resilience
14.00-16.00	Art of changing water relations
16.00-16.30	Reflections, thanks & closing

Recognising that everyone is stretched thin as a busy year draws to an end, this Learning Lab was kept to one day. The structure of the day was to briefly recap what was covered in Learning Lab 1, revisit the urban water metabolism analysis approach, look at the scenarios of potential future metabolism in various conditions, consider the climate patterns driving drought risk, and revisit the actors, their functions and connections that make up the NMB groundwater governance network. Time was set aside in the afternoon to do a creative exercise, crafting a tree of life, to give participants and the project team time to informally discuss questions and issues that emerged during the day, while getting to know each other better.

What we did in LL1
(10-11 March 2022)

♡ ENJOYED

Very friendly
Lots of new information + knowledge gained
Showing that NMBM does know & is doing work on groundwater
No wrong or wrong right answers,
Can feel free to voice opinions

Meeting everyone, feeling inspired
Value of youth (no holy cows)
Help with how to approach Honours research

Understanding Municip. water system

Diversity of people here & knowledge they bring

Informality, get comfortable & contribute

Mix of ppts & exercises

BETTER NEXT TIME

Get out into practical enviro eg visits to springs + coega kop
Invite more ppt/SH's to join eg water user assoc, more from municipality

Share some presentations/content before

Continuity with participants from LL1

Deal more with groundwater regs + enforcement, understand how it works & what is not working
→ (Vuyisive to suggest presenter)

Get more on state of groundwater resources (impact of over/unregul. abstraction)
eg Ricky Murray; Marc Goodhart*) on a driller
DWS: Paul Chilton; Fanus Fottie Fourie
Gordon McClear

More on the historical aspects of groundwater through storytelling by Graham+
+ how ppl understand / value groundwater

Anna recapped the previous Learning Lab by revisiting what participants mentioned that they enjoyed, what could have been done better and what progress was made. It was suggested that another important participant to include in the next lab would be Andrew Lucas who is a point-person for groundwater regulation and enforcement in DWS Eastern Cape. Participants noted that DWS has restructured multiple times which has hindered progress towards operating an integrated regulatory, licencing and monitoring system. Various people at DWS do licence applications, water quality testing, monitoring, etc, but there is not one coherent system.
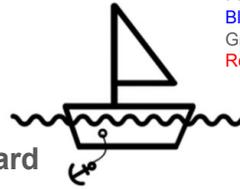
Naming & framing NMB (ground)water situation

Wind in our sails = what is moving us forward

- Stress on local water resources
- Necessity to find solutions to ongoing water crisis
- Restrictions on surface flows galvanising an interest in groundwater
- Large groundwater resources / stores (particularly the TMG aquifers)
- Groundwater is an underutilised resource and naturally recharged
- Good examples of conjunctive use
- Strong technical expertise
- Guidance and unity of senior director, engineers and technologists
- Development in SCADA and reporting systems

Anna went on to recap what participants in the first Learning Lab had identified as factors helping to move towards more effective and sustainable groundwater use in NMB.

Comparing NMB & CPT

Wind in our sails = what is moving us forward

- Stress on local water resources
- Necessity to find solutions to water crisis
- Restrictions on surface flows galvanising interest in groundwater
- Large groundwater stores (particularly TMG)
- Good examples of conjunctive use
- Strong technical expertise
- Guidance and unity of senior director, engineers and technologists
- Development in SCADA and reporting systems

- Managed Aquifer Recharge
- CCT policy goal to becoming a water sensitive city
- Greater & growing visibility of groundwater & its importance
- Groundwater monitoring
- Open data portals
- Training provided by academic institutions
- NWA, (NGS), NWRS-3

Anna highlighted the commonalities and differences between what had been raised in the NMB and Cape Town contexts. The blue bullets show factors mentioned in both city contexts, the grey points were mentioned in relation to NMB but not in CPT, and the red factors were raised in the cPT context, but not in NMB. While these are not exhaustive lists, and reflect the perspectives of those who attended the first Learning Labs, they do surface interesting similarities and differences between the two cities. A policy goal of becoming a Water Sensitive City (with a focus on diversifying, internalising and reusing supplies, as well as managing water demands), expanding practices of Manager Aquifer Recharge, establishing multi-stakeholder aquifer monitoring committees and creating open data portals to make groundwater data publicly available were all developments being made in Cape Town that were yet to be realised in NMB. Having multiple hydrogeology consultancies and four universities in the greater Cape Town area, all with water expertise for training and research, also is an advantage. Anna briefly mentioned that at a national level, the NWA, together with the NWRS-3 and revised National Groundwater Strategy, offer clear principles, rules, direction and guidance. However, these are not yet translating in a coherent way into decision-making and action in the metros, where there are many competing pressures.

Anchor = what is holding us back in NMB

Usage	High per capita consumption level
Lock-in	Historical investment into surface water
Legacy	Retarded development of groundwater resource due to legacy of Orange-Fish-Sundays transfer scheme
Awareness	Low public awareness, communication & education about groundwater
Monitoring	Lack of monitoring of groundwater usage and consumption
Data	Insufficient accurate data and information on groundwater resources
Expertise	Insufficient amount of technical knowledge, skills and expertise in groundwater sector

When looking back at what was suggested during Learning Lab 1 as key constraints on efficient, equitable and sustainable groundwater usage, a number of factors were mentioned, including insufficient monitoring, data, expertise and low public awareness of groundwater systems.

Anchor = what is holding us back in NMB

Finances	Funding available for capital expenditure on infrastructure but not sufficient funding for operations and maintenance
Politics	Politicians not engaging with departments to understand the system and instead pushing own agenda / misaligned political interests
Vision	Lack of a long-term holistic vision at the collective level
Mgt	Lack of coordinated planning and transversal management
Enforcement	Unregulated drilling and groundwater abstraction in domestic and commercial sectors

Insufficient maintenance and operations budgets and a lack of a politically supported long-term vision for NMB's water system (hydrological, infrastructural, ecological and behavioural aspects) were all raised as serious concerns, together with limited effective enforcement capacity to manage drilling and abstraction.
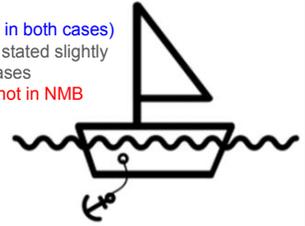
Comparing NMB & CPT

Anchor = what is holding us back

- Water losses, leaks & unlawful use
- Lack of consensus between public & private sector professionals & scientists
- Mgt, technical & operational functions operating in silos
- Unclear mandates & roles
- Limited collaboration across spheres of govt & departments
- Lack of regulatory capacity
- Poor integration of science into decision-making & mgt
- Lack of data sharing
- Various proprietary water computational models held by consultants & researchers
- Insufficient budgets for implementing vision
- Approach for reserve determination needs revising, linking surface & g/w

Again, a comparison was drawn between what was highlighted by Learning Lab participants in NMB and those in CPT. Grey points were raised in both cities, albeit in slightly different ways, blue points were shared in both cities, and red points were mentioned in the Cape Town context but were not raised in NMB. That is not to say that some of the issues highlighted in red are not experienced in NMB, but rather that they were not front of mind for those participating in the Lab. Participants mentioned that the breakdown in trust between the public and municipal government, and government in general, means that people avoid registering their boreholes. The inaccessibility of groundwater monitoring data was raised as key constraint on good governance, as is the difficulty of retaining those with technical expertise in the NMB municipality (i.e. the difficult organisational environment to work in drives many qualified staff to leave). The unstable politics in NMB, hurdles and delays in public procurement, and the focus on short-term, visible, popular projects (like building sidewalks) rather than long-term planning and investments in expanding supplies, increasing efficiencies and maintaining the infrastructure network, were all mentioned as real difficulties and serious constraints for effective water management in NMB.

Overview of bulk supply system & drought mitigation measures provided by Matthew Hills (NMBM) in LL1

Reviewing the main groundwater sources (existing / operational and planned) in and around NMB presented by Matthew Hills from NMBM in the first LL, participants highlighted the importance of the Uitenhage Artesian Basin for bulk withdrawals. According to Mr Raymer, 6ML are currently being abstracted from the Uitenhage Springs but that this will drop considerably when the Coega Kop site comes online (i.e. it hadn't yet as of Dec 2022). There was discussion about the varying quality of water, with very high quality water withdrawn from the Springs, whereas the water at Coega Kop is high in manganese. David Raymer provided an update on other developments, notably that Bushy Park is currently being connected to the pipeline, and that the Fort Nottingham reservoir is active. The metro has done drilling at the Churchill dam, as well as close to Jeffery's Bay where there was some possible exploitation. But the NMB metro decided that the the Kouga Local municipality can develop this. Churchill is supplying Kouga currently. The Churchill water is being treated at the dam. There was mention of a 1956 Act that regulated how much farmers could abstract from the Uitenhage Basin and the the municipality of the time even went in to seal some unpermitted boreholes.
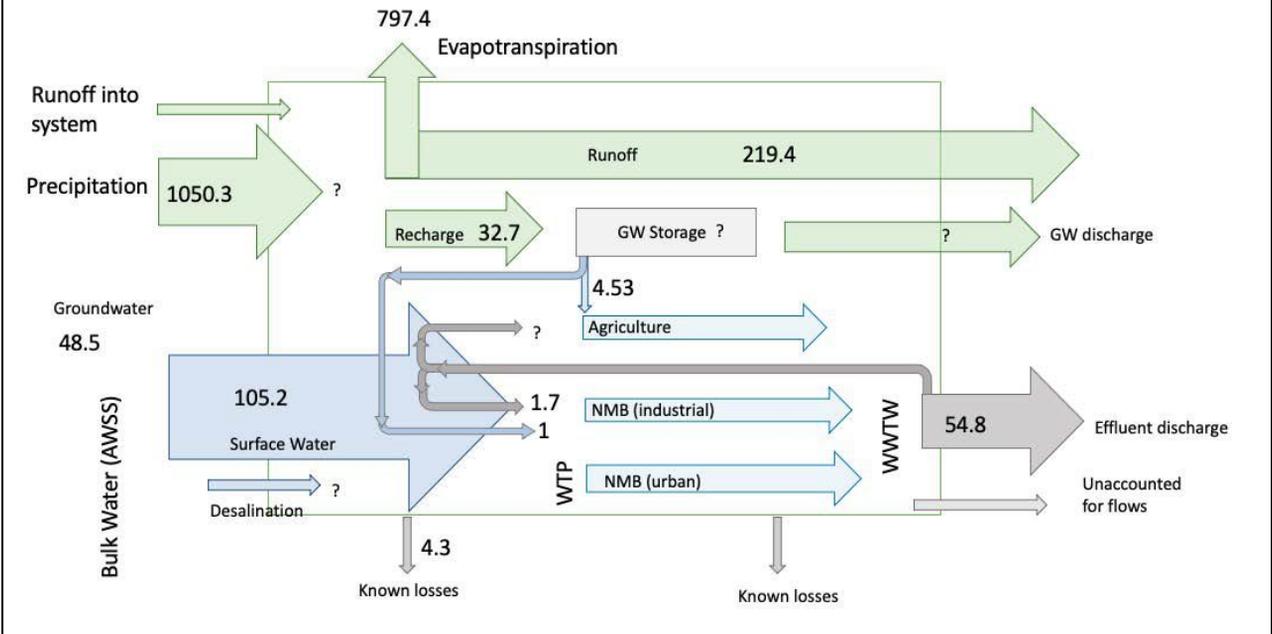
Explained Urban Water Metabolism Framework
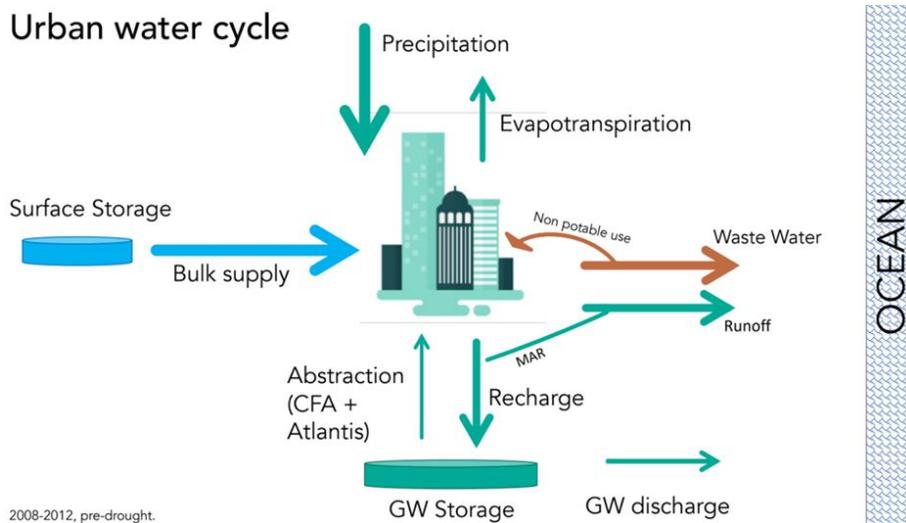
We revisited the Urban Water Metabolism framework, developed primarily in Australia to calculate various indicators used to benchmark cities against the principles of a Water Sensitive City, but increasingly applied elsewhere in the world. For an explanation provided by Ffion Atkins, see this video:
https://drive.google.com/file/d/146mXupqu5SrklOBUtkYQNDBP5JTHoZqP/view?usp=sharing

Nelson Mandela Water Budget (Mm³/year)

This schematic provides an overview of the volumes of various hydrological and anthropogenic flows into and out of the NMB municipal system, as per the metabolism analysis. Data constraints mean that the volumes are estimates, but still help to see the big picture and the orders of magnitude of the various flows and how they compare. It also helps to highlight were key data gaps exist.
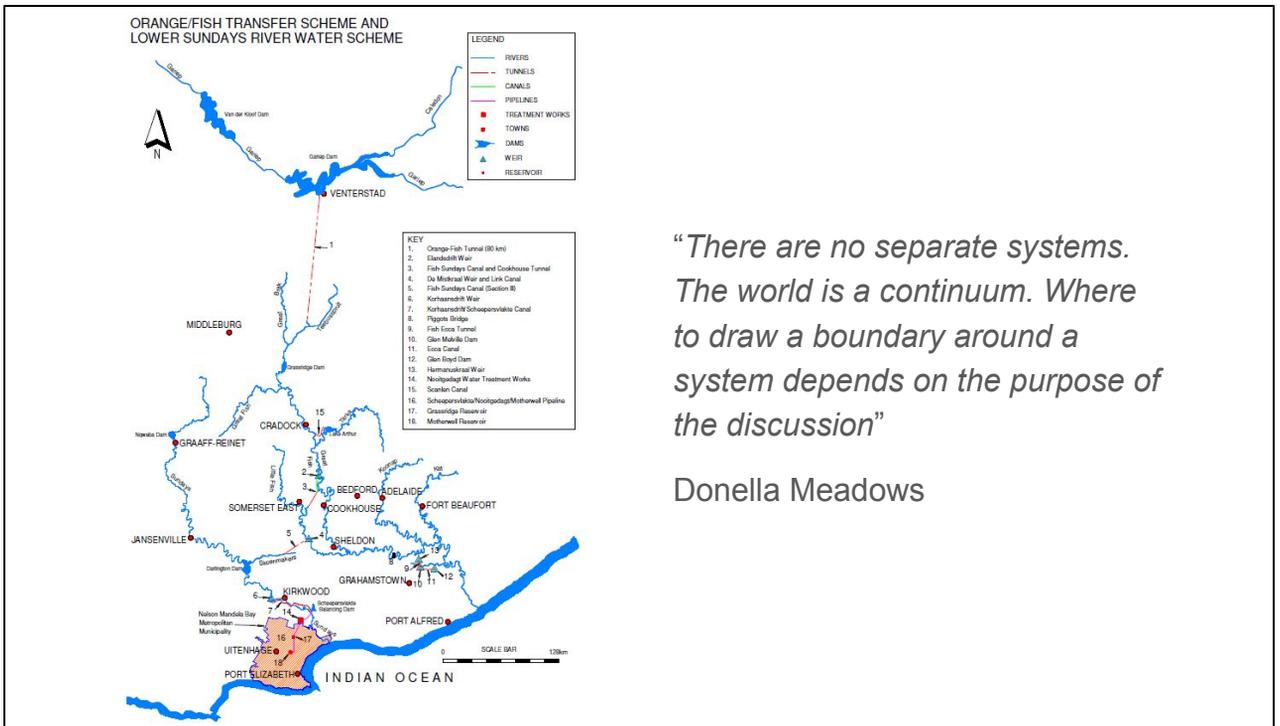
Initial influence mapping

Group 1 = enforcing groundwater laws and usage
Group 2 = protecting or conserving aquifers and/or recharge

In the first Learning Lab participants began discussing the level influence that different actors have over particular aspects of groundwater management. It highlighted the important role of the Algoa Supply System Steering Committee, and the clear need for but lack of cooperative governance between the metro, neighbouring municipalities, provincial government and DWS. It also suggested that drilling contractors and pump test contractors potentially have a key role to play in ensuring the registration of all boreholes, but they do not fulfil this role currently as they report only to their clients and not to any authorities or oversight bodies.

Explored city regional hydro-social boundaries
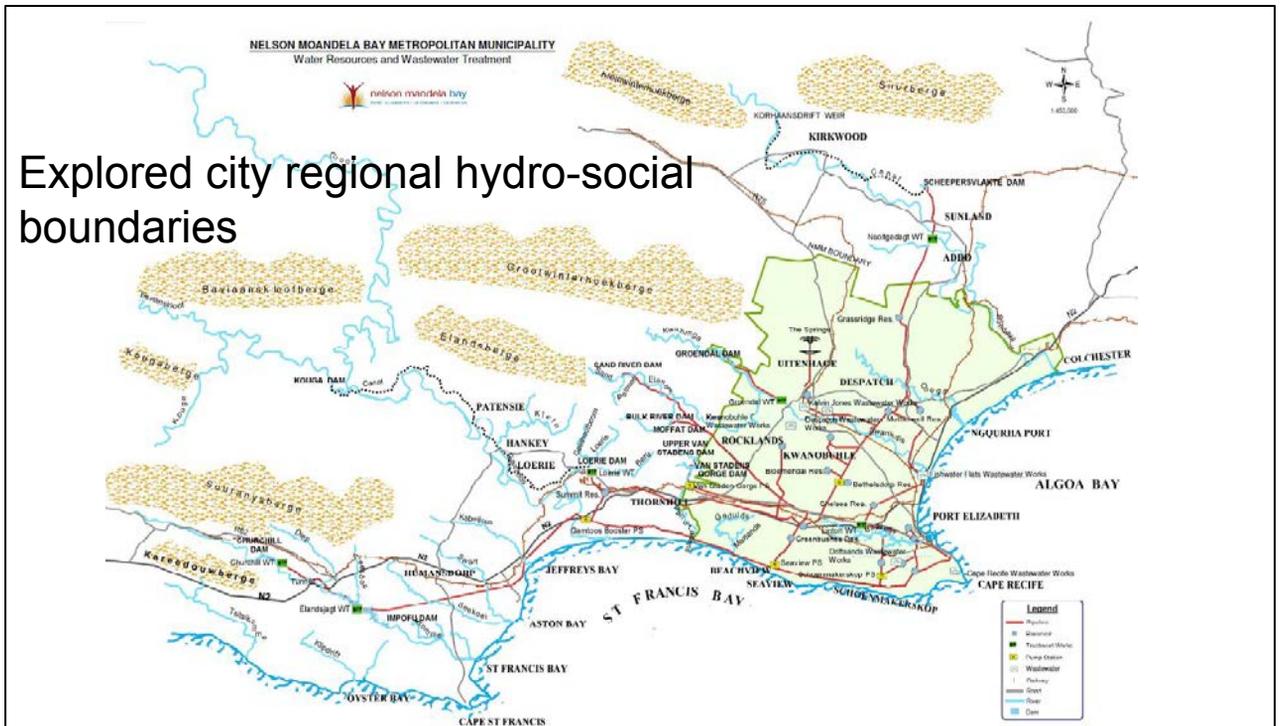
Discussed that applying an urban water mass balance to operationalise the metabolism framework requires determining a system boundary. While we had intentions of conducting a city regional analysis, it proved too difficult in both the NMB and Cape Town cases to get the required data from neighbouring municipalities. Therefore the municipal boundary was used as the boundary of the urban system in the analysis.

ORANGE/FISH TRANSFER SCHEME AND
LOWER SUNDAYS RIVER WATER SCHEME

LEGEND

RIVERS
TUNNELS
CANALS
PIPELINES
■ TREATMENT WORKS
● TOWNS
DAMS
▲ WEIR
● RESERVOIR

N

Gariep

Van der Kloof Dam

Gariep Dam

VENTERSTAD

1

MIDDLEBURG

Grassridge Dam

Ngwaba Dam

GRAAFF-REINET

CRADOCK

15

BEDFORD ADELAIDE

SOMERSET EAST COOKHOUSE

FORT BEAUFORT

JANSENVILLE

SHELDON

5

13

Darlington Dam

GRAHAMSTOWN

9
10 11 12

KIRKWOOD

6

Scheepersvlakte
Balancing Dam

PORT ALFRED

Nelson Mandela Bay
Metropolitan
Municipality

7 14

16 17

UITENHAGE

18

PORT ELIZABETH

INDIAN OCEAN

SCALE BAR

0   120km

KEY
1.   Orange-Fish Tunnel (80 km)
2.   Elandsdrift Weir
3.   Fish Sundays Canal and Cookhouse Tunnel
4.   De Mistkraal Weir and Link Canal
5.   Fish Sundays Canal (Section II)
6.   Korhaansdrift Weir
7.   Korhaansdrift/Schoeporsvlakte Canal
8.   Piggots Bridge
9.   Fish Ecca Tunnel
10. Glen Melville Dam
11. Ecca Canal
12. Glen Boyd Dam
13. Hermanuskraal Weir
14. Nooitgedagt Water Treatment Works
15. Scanlan Canal
16. Schoeporsvlakte/Nooitgedagt/Motherwell Pipeline
17. Grassridge Reservoir
18. Motherwell Reservoir

"*There are no separate systems.
The world is a continuum. Where
to draw a boundary around a
system depends on the purpose of
the discussion*"

Donella Meadows

It was pointed out that the Gariep Dam is in a different rainfall regime to NMBM and is
drawn on by many other users. Access to the Orange-Fish-Sundays scheme helps to
stave off a Day Zero situation in NMBM but exposes the city to other vulnerabilities,
such as risks associated with the transfer tunnels.

Using UWMF / water mass balance to test scenarios

- What time horizon (5-10 years; 10-20 years)
- What scenarios to prioritise for testing:
  - maximum reuse;
  - weighted land cover change with change of porous aquifers weighted higher;
  - spatially selective rewilding to maximise natural recharge;
  - the conversion of all detention ponds into maximised infiltration ponds
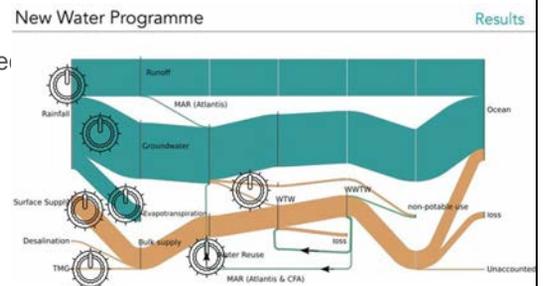
In the first Learning Lab we started discussing what scenarios might be useful to test to see how various changes play out across the urban water cycle. Two fairly simplistic scenarios have been prepared to present at this Lab, to discuss the potential value of such exercises to decision-making processes. The NMB water mix as of 2022, before any major new drought-response interventions have come online, is compared against the planned future water mix and a hypothetical water mix according to the principles of a water sensitive city.

WRI, Zutari, SACN, NMBM Urban Water Resilience

COMPONENT 2: *City Water Resilience Approach*

1 UNDERSTAND THE SYSTEM

The city's unique context is appraised to understand shocks and stresses, identify important system interdependencies, convene key local stakeholders and map key infrastructural assets and governance processes.

Output
- City Characterization Report

2 ASSESS URBAN WATER RESILIENCE

The city's current practices are assessed according to the City Water Resilience Framework to identify areas of existing strength and weaknesses that will be addressed by future actions and establish a baseline against which progress is measured.

Output
- Multi-stakeholder consultations

3 DEVELOP AN ACTION PLAN

Based on the city assessment, an action plan is developed for realizing interventions that build water resilience. The action plan is based on holistic evaluation of anticipated benefits and costs and prioritization of key projects.

Output
- Action Plan

CWRA scope of work for Africa

4 IMPLEMENT THE ACTION PLAN

5 EVALUATE, LEARN AND ADAPT

OurWater Governance Tool

The OurWater tool used in developing the City Characterization Report. It is an online resource that maps infrastructure and the organizations that manage that infrastructure.

We reminded participants that the World Resource Institute (WRI), together with the South African Cities Network (SACN), are driving an urban water resilience programme across Africa. Gqeberha is one of the participating cities in which the work is being undertaken in partnership with NMBM. It involves doing a baseline assessment of the water system, developing a vision for what a resilient water system for NMBM might look like, and then identifying priority actions to invest in towards unlocking that vision. This work is taking place in parallel. Representatives from WRI and Zutari participated in the first Learning Lab. And we participated in their online workshops to establish the NMBM baseline, as well as a recent in-person stakeholder workshop (held on 20 October 2022) to explore what the vision for a water resilient Gqeberha. As was the case in Cape Town, the water crisis has sparked a focus on these issues and encouraged international actors to support local efforts, by providing additional expertise, using their convening power to pull together various stakeholders, and push for more integrated planning and action to build water resilience.
For an update on WRI's work (including link to download the Gqeberha City Characterization Report) see here:
https://thecityfix.com/blog/south-african-cities-show-commitment-to-accelerate-water-resilience-at-2023-un-water-conference/

Aim of GoFlow Learning Lab 2

Extend and deepen discussion & knowledge sharing on:

- Seeing the system in terms of the flows that make up the water metabolism of NMB - how it is now, how it could be in future
- Recognising the actors impacting groundwater, what ties exist between them, and what capacities they have to implement
- What new / different actors, relations & capacities are needed to navigate the system towards / away from certain scenarios

Build relations & shared understanding between (ground)water actors

Anna reiterated the aim of this second Learning Lab event, building on the first. The intent was to feed back progress made on developing the urban water metabolism analysis for NMB and running some scenarios to see how things change under various conditions. And show where we have got to with building an understanding of the actors involved in making groundwater-related decisions - who they are, how they are connected, and what capacities they have to fulfil their functions. As always, the aim is also to create a conducive environment for participants to connect, share their insights, as questions of the research being done, and suggest ideas for future directions.

Introductions

Please share with us:

1. Your name
2. Organisation / group you work for / with
3. What brought you here today
4. 1 groundwater-related thing you WONDER about

We did a round of introductions to hear from everyone in the room.

Urban Water Metabolism Framework
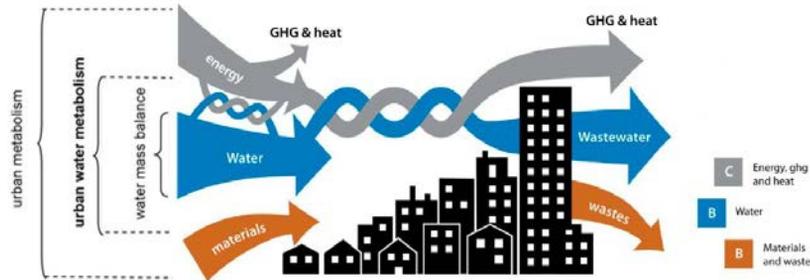
GoFlow Learning Lab II, Gqeberha
November, 2022

Ffion Atkins, UCT

The metabolism analysis has been undertaken by Ffion Atkins, but she was on maternity leave, so Dr Chris Jack presented the information on her behalf. Dr Atkins had also prepared a set of videos explaining the material, which can be viewed here for further details:

UWMF intro:
https://drive.google.com/file/d/146mXupqu5SrklOBUtkYQNDBP5JTHoZqP/view?usp=sharing

NMB Scenarios Analysis:
https://drive.google.com/file/d/1-7W_cWrIIn842ZiEuw3wPQohL0rizOzy/view?usp=sharing

Decision relevance on UWM analysis:
https://drive.google.com/file/d/1Hv8T7FJ_BThH-A3erWNaPdA7VrpcrT0W/view?usp=sharing

Urban Metabolism

- Considers a city as a system

- Conceptual framework that describes and quantifies the flows that enter a city, which are used or stored, and then that leave the city.

- A tool that is key to understanding the performance of a city in relation to it's water management goals/objectives.

- Can bridge diverse understandings of complex systems

Urban metabolism is a metaphor for conceptualizing resource flows through urban systems as analogous with ecosystems. With an inferred intent of emulating the higher resource efficiencies of natural systems.
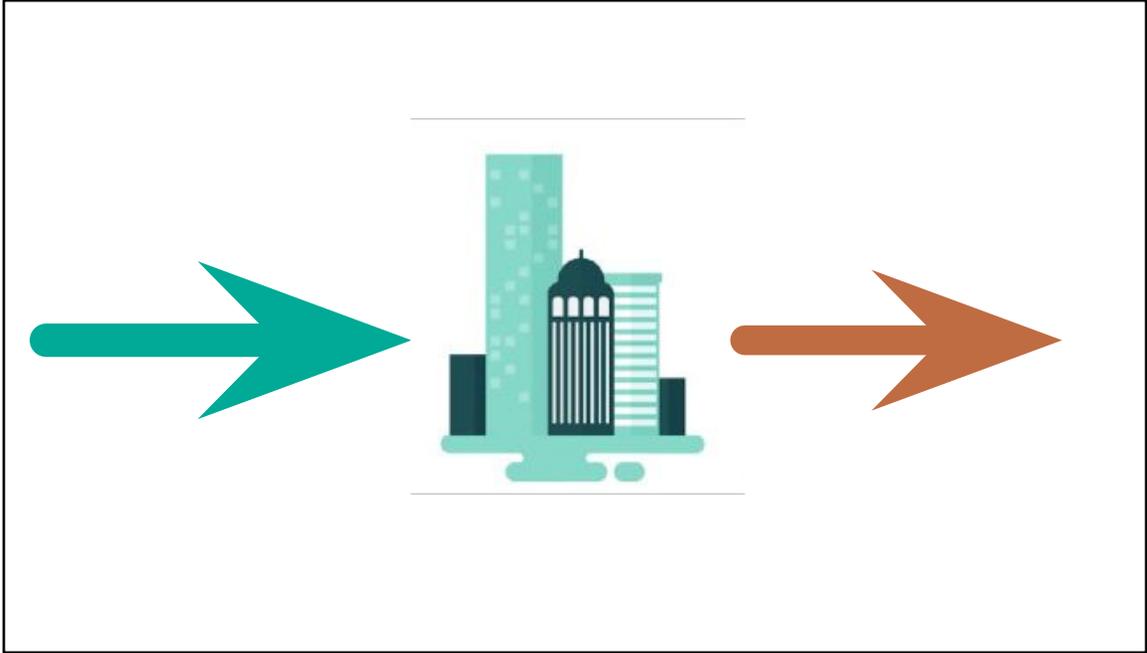
This is current dominant trend in resource consumption…. Its linear. What goes in, largely goes out… Incredibly wasteful in comparison to how its done at a cellular level and underpins many environmental problems, as well problems of inequality.

The thinking and intention behind the urban metabolism approach is to redesign a city's resource flows into something more circular and thereby more efficient and less wasteful. Defining and delineating the boundary of the urban system is one of the challenging aspects of applying this approach. The municipal boundary is a political and administrative boundary rather than a physical one. But it does have a strong bearing on data collection and accessibility.

The applications of Urban Metabolism

- Understanding resource cycles/dynamics, and the role of social/ecological/technological drivers.

- Scenario planning/decision support tool for resource management
  - How do we best manage our urban water water cycles? Toward what end?

- Transition to circular economy
  - Where can we reduce our waste? At what point of the value chain can we reuse/recycle?

- Benchmarking
  - Measure progress towards resource management objectives.

Helpful tool to test our understanding of a system and how it works. Building an integrated view and quantified representation of a system helps bring multiple and diverse understandings and perspectives together. Also important in setting baselines, against which goals can be set and changes can be measured through the use of indicators. Applying the metabolism approach to water involves conceptualising and visualising how much water of various kinds moves through the city. It enables high-level scenario planning and benchmarking against an aim of becoming a water sensitive city.

Cape Town Water Strategy

1

SAFE ACCESS TO WATER AND SANITATION

The City of Cape Town metropolitan municipality[2] will work hard to provide and facilitate safe access to water and sanitation for all of its residents in terms of well-defined minimum standards. In particular, the City will work with communities in informal settlements and with other stakeholders to improve the daily experience of access to water and sanitation, with an emphasis on building trust and increasing safety within these communities through this process.

2

WISE USE

The City will promote the wise use of water by all water users. This will include promoting water conservation behaviour through (a) pricing water with reference to the cost of providing additional supply, while retaining the commitment to provide a basic amount of water for free for those not able to afford this; (b) revising by-laws and planning requirements, and using other incentives to support water efficiency and the treatment and reuse of water; (c) supporting active citizenship by substantially improving customer management and engagement; and (d) managing the water network effectively to reduce losses and non-revenue water.

3

SUFFICIENT, RELIABLE WATER FROM DIVERSE SOURCES

The City will develop new, diverse supplies of water including groundwater, water reuse and desalinated water, cost effectively and timeously to increase resilience[3] and substantially reduce the likelihood of severe water restrictions in future. The City is committed to increasing supply by building affordable new capacity of approximately 300 million litres per day over the next ten years, and in suitable increments thereafter, in a way that is adaptable and robust to changes in circumstances.

4

SHARED BENEFITS FROM REGIONAL WATER RESOURCES

The City will work with key stakeholders and partners, including other urban and agriculture water users and other spheres of government, to make the most of the opportunities to optimise the economic, social and ecological benefits of regional[4] water resources, and to reduce the risks. The City will do this through collaborative processes.

5

A WATER-SENSITIVE CITY[5]

The City will actively facilitate the transition of Cape Town over time into a water-sensitive city with diverse water resources, diversified infrastructure and one that makes optimal use of stormwater and urban waterways for the purposes of flood control, aquifer recharge, water reuse and recreation, and is based on sound ecological principles. This will be done through new incentives and regulatory mechanisms as well as through the way the City invests in new infrastructure.

The goal of becoming a water sensitive city is articulated in Cape Town's new Water Strategy.
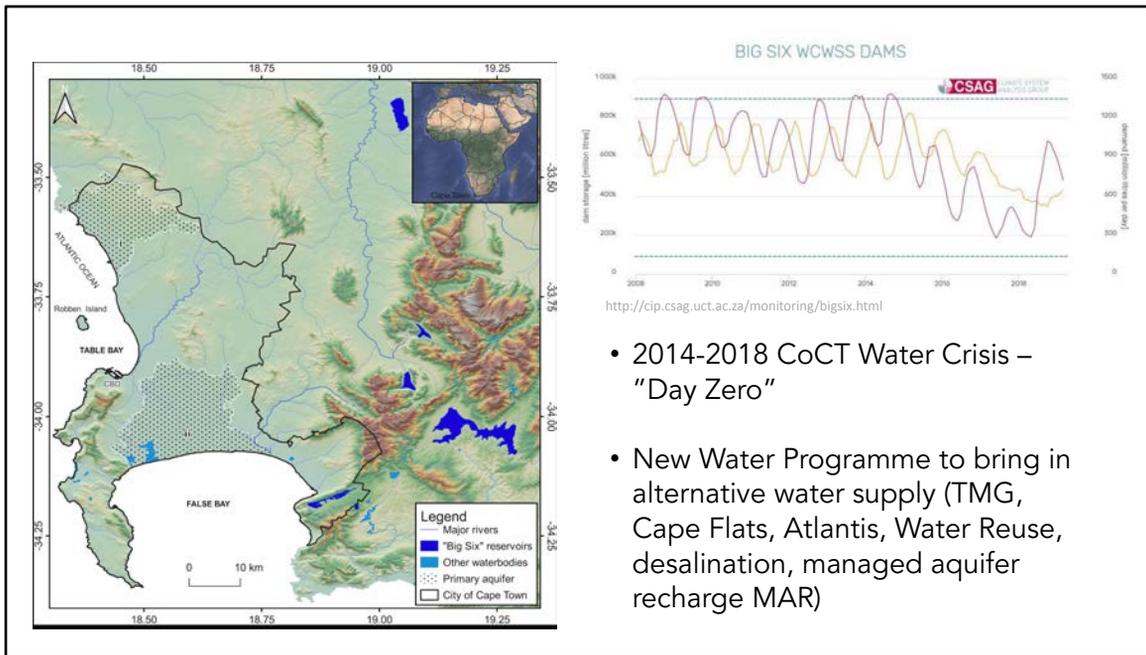
A Water Sensitive City is

Liveable + Resilient + Sustainable + Productive

- Serves as a potential water supply catchment, providing a range of different water sources at different scales and for different uses
- Provides ecosystem services and a healthy natural environment, offering a range of social, ecological and economic benefits
- Consists of water sensitive communities where citizens have knowledge and desire to make wise choices about water, are actively engaged in decision making, demonstrate positive behaviour (e.g. conserving water at home).

This is the definition of a water sensitive city being used and promoted internationally. How do we know if a city is water sensitive or not?

http://cip.csag.uct.ac.za/monitoring/bigsix.html

- 2014-2018 CoCT Water Crisis – "Day Zero"

- New Water Programme to bring in alternative water supply (TMG, Cape Flats, Atlantis, Water Reuse, desalination, managed aquifer recharge MAR)

In response to the experience of the Day Zero water crisis in Cape Town (2014-2018) a programme of bringing new water sources into the supply mix is being implemented. This includes groundwater exploitation from the Table Mountain Group and Cape Flats aquifers, as well as water reuse, managed aquifer recharge, and desalination.

Participants raised the following points:
- NMB geology does not support MAR in the way that it's done in Atlantis.
- Water losses in NMB are extremely high.
- Is there potential for making use of the North End Lake and the fountains at the airport? Groundwater spontaneously appeared at airport and they pump out 800KL a day of water. Good quality groundwater came out of nowhere, but the municipality didn't investigate where it came from, where the source is, and it just gets lost.
- North End Lake is a natural lake but is polluted by sewage effluent from failing sewer system. Could be fixed by fixing sewers. There was a program to collect rubbish in the stormwater inlet which helped. Microbiological process to aerate water was also being used, but funds dried up. Storm water is just flowing out.
- In the old days, PE was full of little streams running out to sea. But over time the streams were seen as a nuisance and were paved over.
- What happens to the water from natural springs found in the Uitenhage Artisan Basin? Some take the water and sell or give it away illegally. They say

- they don't sell the water, the just make people pay for the transport. They are often not licenced. There are regulations against using spring water for swimming pools.
- There is general confusion about using spring / fountain water, if it can be used uncapped, for what purposes. If someone needs to get info from DWS regarding groundwater, where is the contact point?
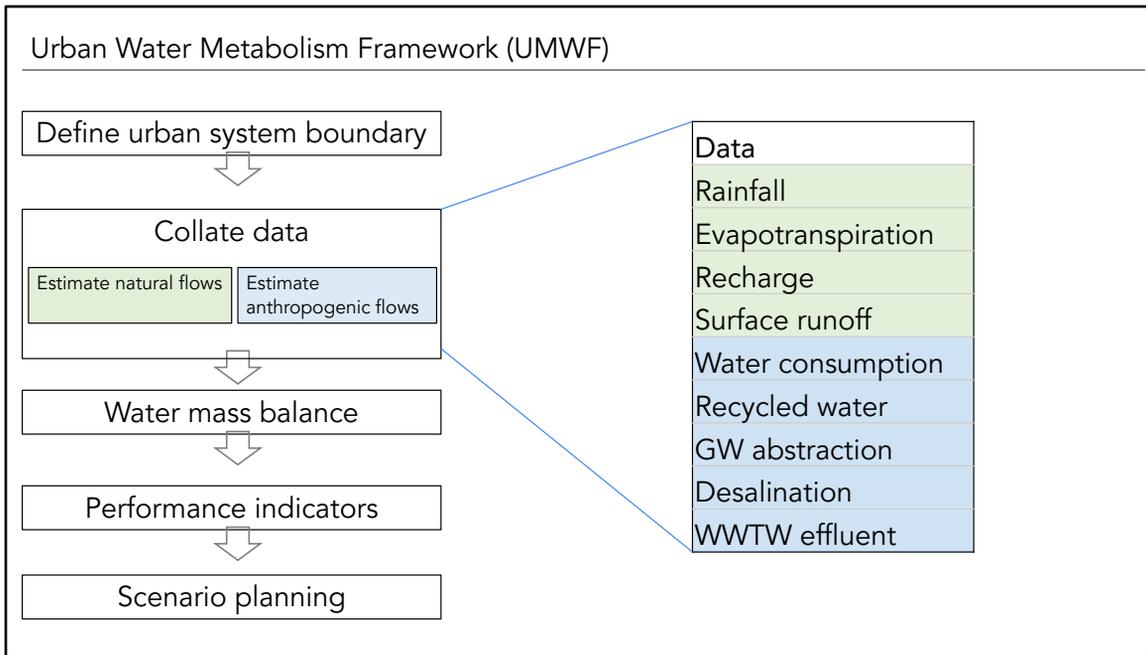- Water use license applications take years.

Are we water sensitive?

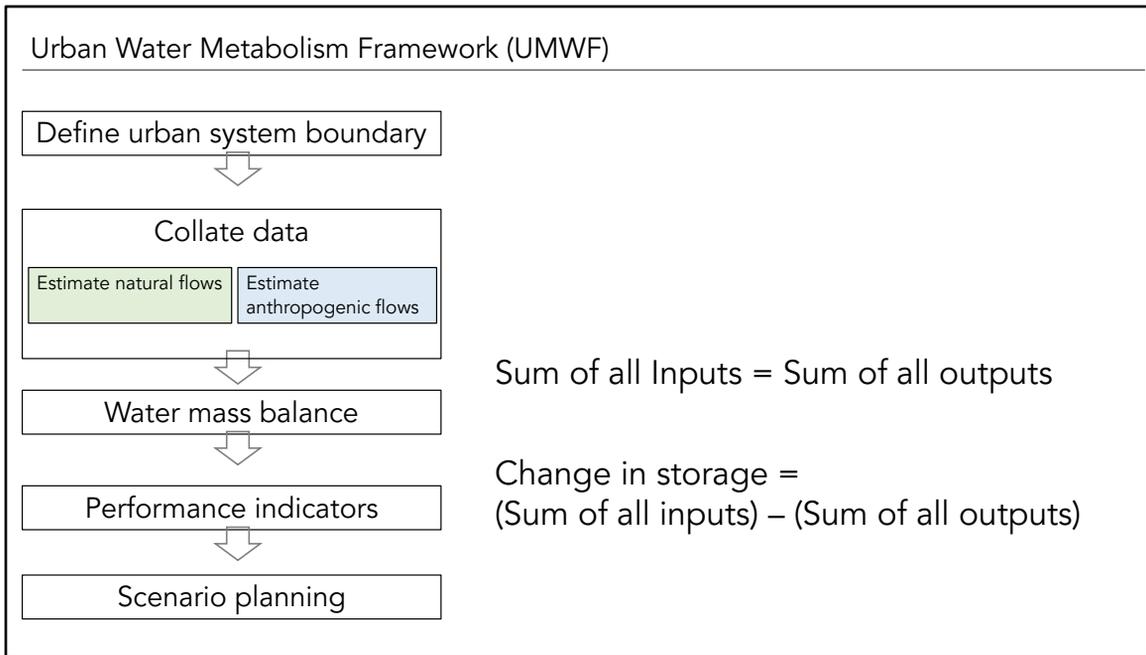Are the decisions we are making moving us in that direction?

Conducting water metabolism analyses can assist in addressing these questions.

UWMF

Define urban system boundary
↓
Collate data

| Estimate natural flows | Estimate anthropogenic flows |

↓
Water mass balance
↓
Performance indicators
↓
Scenario planning
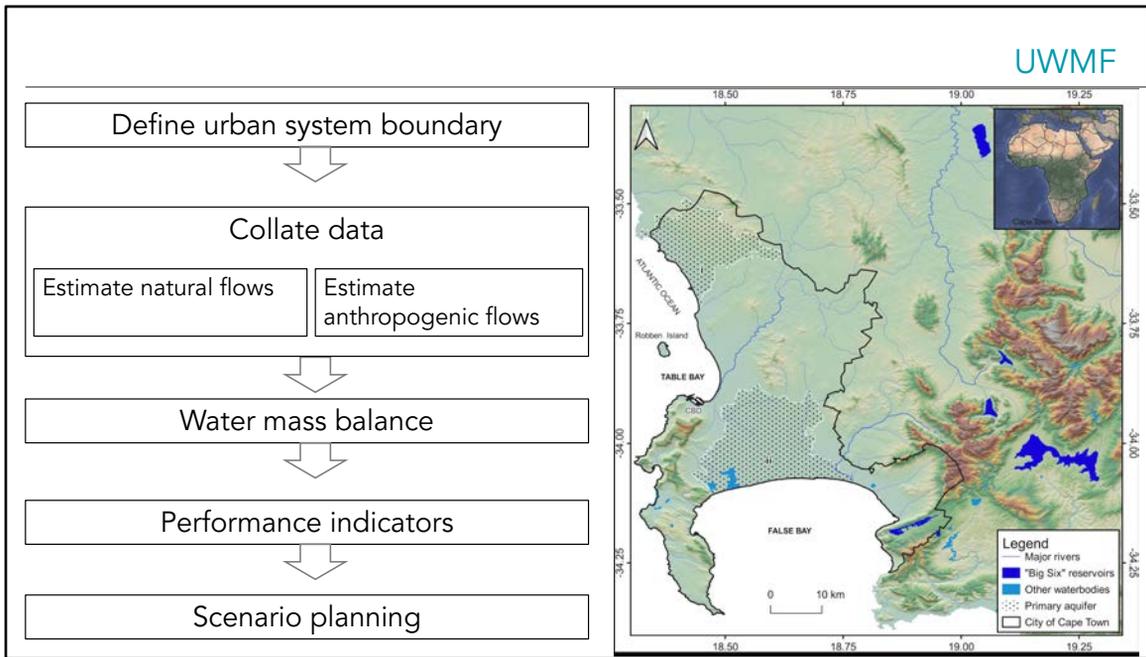
Conducting an urban water metabolism analysis comprises several steps.

Urban Water Metabolism Framework (UMWF)

Define urban system boundary

Collate data

Estimate natural flows | Estimate anthropogenic flows

Water mass balance

Performance indicators

Scenario planning

Data
Rainfall
Evapotranspiration
Recharge
Surface runoff
Water consumption
Recycled water
GW abstraction
Desalination
WWTW effluent

The data requirements are considerable. Getting hold of suitable data is difficult and time consuming. For some variables the available estimates are not very robust. But bringing these different datasets together is a key value add of the approach. Numbers can be refined as better data becomes available.

Urban Water Metabolism Framework (UMWF)

Define urban system boundary

Collate data

Estimate natural flows | Estimate anthropogenic flows

Water mass balance

Performance indicators

Scenario planning

Sum of all Inputs = Sum of all outputs

Change in storage =
(Sum of all inputs) – (Sum of all outputs)

Engineers working in water resource management are very familiar with this type of mass balance. But where urban water metabolism is unique is that it integrates the hydrological flows into the system as well.
Also, the use of performance indicators and their application to scenario planning, take this approach one step further.

Cape Town Water Budget
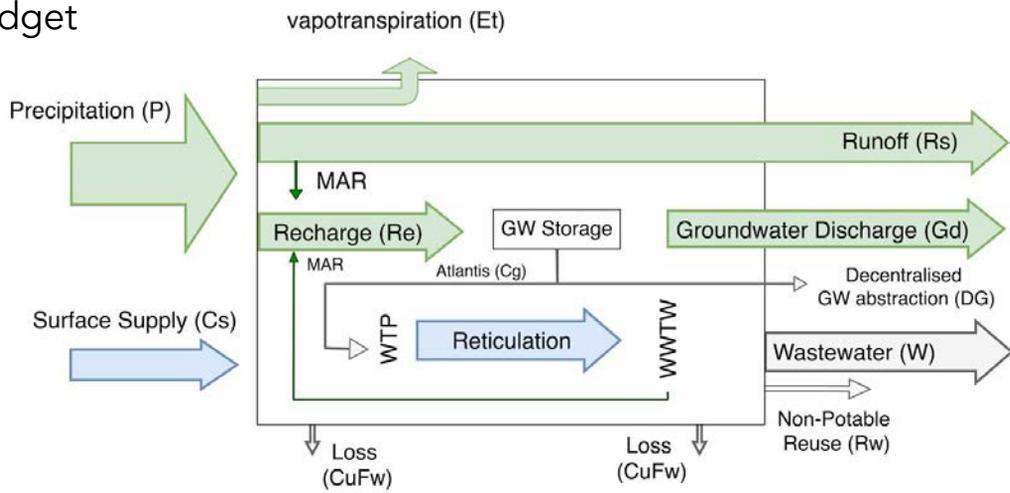
Collating the available datasets for Cape Town, this is what the water budget looks like.

Mass Balance Analysis

		Scenario 1 (GL/year)	Scenario 2 (GL/year)
	Input		
P	Precipitation	1471.4	1471.4
Csw	Bulk water supply (surface water dams)	324.9	246.0
Cg	Centralised groundwater abstraction (TMG)	0	18.3
Cd	Centralised desalination	0	18.3
Sub-total		**1796.2**	**1753.9**
	Internal flow		
Cg	Centralised groundwater abstraction (CFA+Atl)	3.3	20.1
Rw	Recycled water (potable use)	0.0	25.6
Rw(MAR)	Managed aquifer recharge	0.0	16.1
Re	Groundwater recharge	741.7	741.7
Sub-total		**745.0**	**803.4**

|		Scenario 1 (GL/year)	Scenario 2 (GL/year)
	Output		
Dr	Decentralised rainwater harvest	0.0	0.0
Dg	Decentralised groundwater abstraction	26.9	26.9
W	Wastewater effluent	234.8	157.5
Cufw	Known losses	48.6	84.7
Rw	Recycled water (non-potable use)	18.8	18.8
Rs	Surface runoff	492.3	466.8
Gd	Groundwater discharge	0.0	710.8
ET	Evapotranspiration	711.6	218.6
Sub-total		**1751.7**	**1709.6**
Water balance (total) (error)		**2%**	**2%**

These are the numbers in Cape Town's water budget. Scenarios 1 is the pre-drought situation. Scenario 2 is with the New Water Programme fully implemented.

Pre-drought
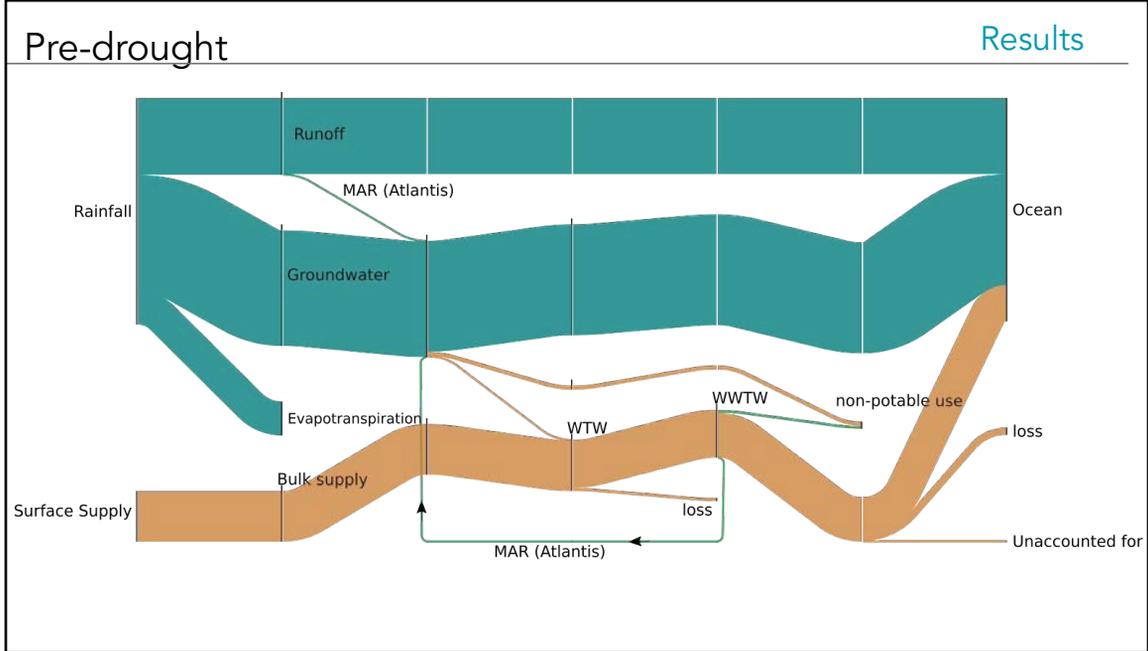
Presented in a Sankey diagram from Atkins et al (2021)

New water programme
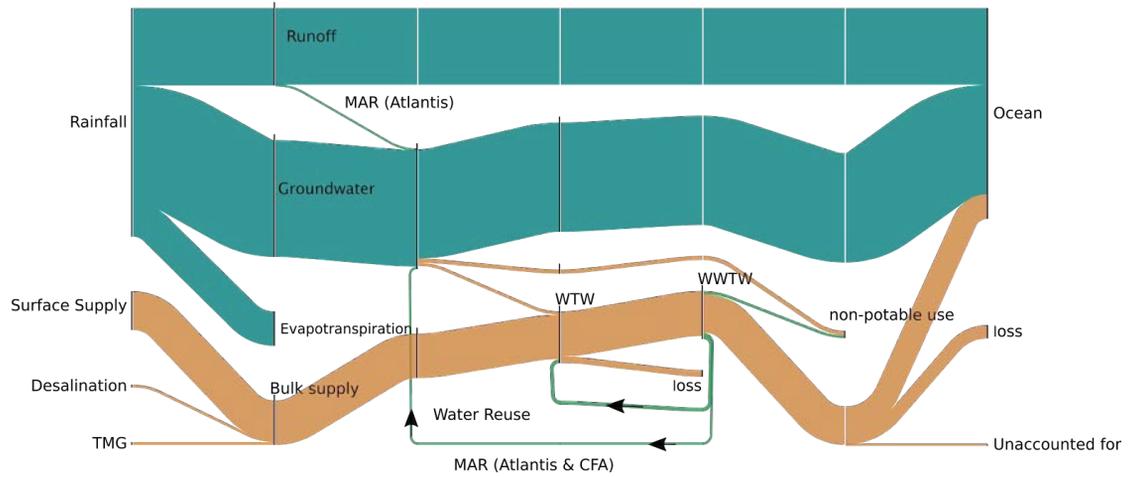
Can see diversified inflows and more reuse.

Is Cape Town water sensitive?

Are the decisions we are making moving us in that direction?

Alternative water supply under the New Water Programme

Source	Pre-drought yield (GL/year)	Effective yield (GL/year)
Groundwater (CFA and Atlantis)	3.3	20.1
Groundwater (Table Mountain Group)	0	18.3
Reuse	0	25.6
Desalination	0	18.3
Berg River Dam augmentation[a]		14.6
Alien vegetation clearing[a]	-	20.1
Demand management[a]	-	25.6
Managed aquifer recharge (CFA and Atlantis)	4.65[b]	25.5[c]

Look across these 2 scenarios of the pre-drought water mass balance and the water mass balance after the New Water Programme is implemented makes it possible to assess whether Cape Town is moving towards becoming a more water sensitive city, through diversifying water sources, increasing internalisation and circularity of water flows, increasing water efficiencies and reducing losses and waste.

Performance Indicators

Performance indicator	Description	Equation
Urban water efficiency	Total external water use per capita (kL/capita/year)	C_{ext}/Population
Water supply internalisation	Proportion of total urban water demand met by internally harvested/recycled water	$(C_{int} + D)/$ $(C_{int} + C_{ext} + D)$
Hydrological performance	Ratio of post- (i) to pre-urbanised (o) annual stormwater runoff (Rs) and groundwater recharge (Re)	Rs(i)/Rs(o), Re(i)/Re(o)

- Water-related energy efficiency

- Water-related nutrient efficiency

Renouf et al., 2019

Performance indicators are important in the implementation, assessment and communication of progress towards sustainability goals. There are several methods to benchmark the performance of water management.

Water-related energy refers to energy used to pump, treat, and dispose of water, but also in the use phase (heating, cooling etc.), the latter being more significant in scale than the former (Kenway et al. 2011b). Its quantification is important for understanding the potential energy trade-offs for water supply options, or urban energy saving opportunities. Water and energy efficiencies are usually not coupled in urban and regional planning processes.

Water-related nutrient efficiency refers to the extent to which nutrients mobilised in wastewater and stormwater runoff (nitrogen and phosphorous), are recovered and reused. An example is the utilisation of wastewater for agricultural irrigation, for which the reuse and avoided discharge of nutrients is important when considering the value of wastewater recycling.

Are we moving towards water sensitivity?

Performance Indicator	Pre-drought	New water programme
Urban water efficiency (Kl/capita/yr)	77	66
Water supply internalisation	13%	25%
Hydrological performance *Runoff*	1.4	1.4
Hydrological performance *Recharge*	0.69	0.72

Following Renouf et al., (2017)

With the New Water Programme, runoff does not change, but recharge increases marginally to 0.72, reflecting the volumes of water redirected from WWTW effluent to managed aquifer recharge (MAR).

What is clearly evident is that runoff represents an internal resource that, if cleverly managed, could reduce our reliance on external sources. This would entail increasing the use of non-potable water for non-potable uses, and making clever use of space to reduce and recharge the Cape Flats aquifer.

There are of course, inherent challenges of using these resources, notably the seasonality of runoff and poor water quality.

What about Water Equity? This is something that a student on this WRC-funded project is exploring for her Masters research project.
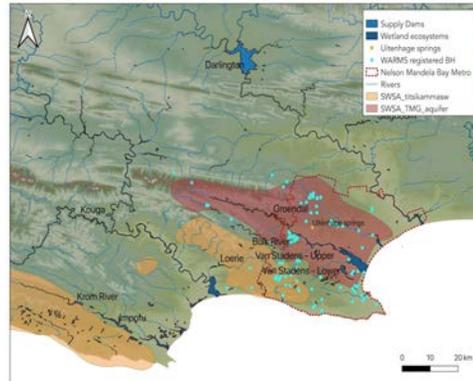
The comment was made that it can be useful to benchmark between cities. So performance indicators for NMB can be assessed against those of CPT. Data availability and access remains a big challenge though. Much of the old data is in a paper filing system that has now been archived and newer officials don't know how to use it. Also some reticulation plans are missing. Historical data from the Western

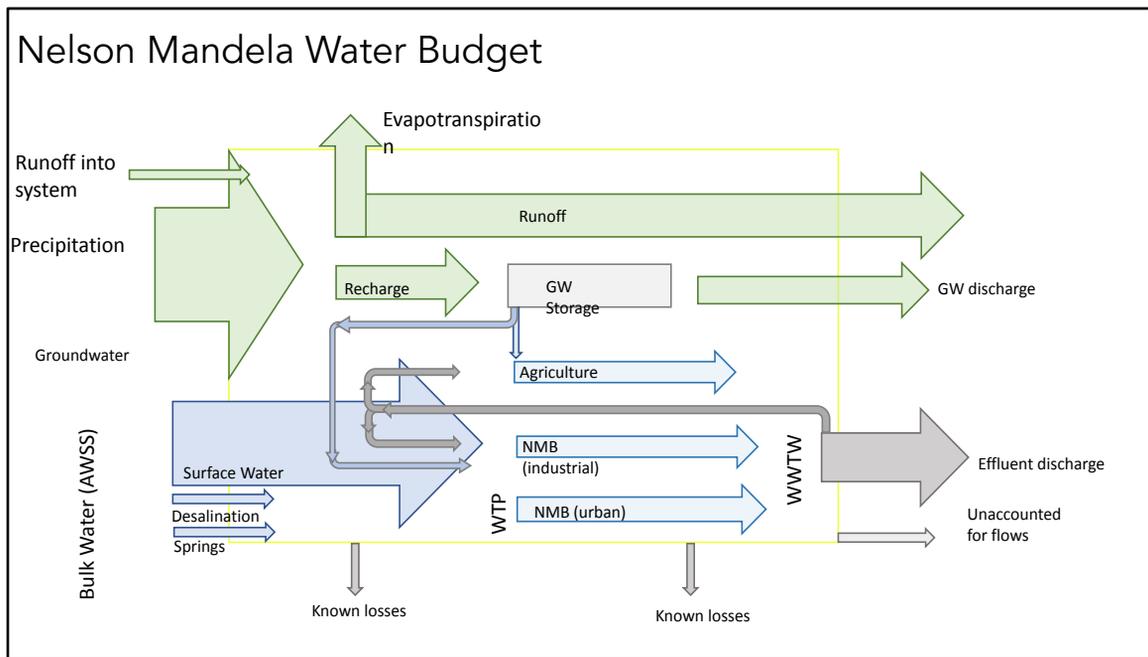District Council is missing.
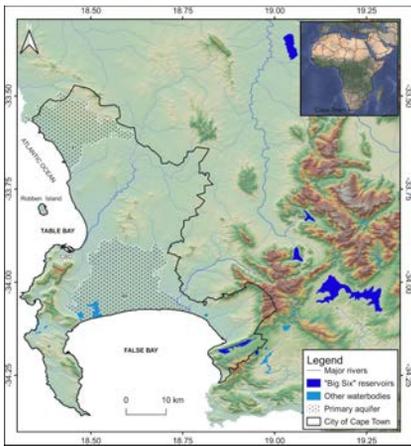
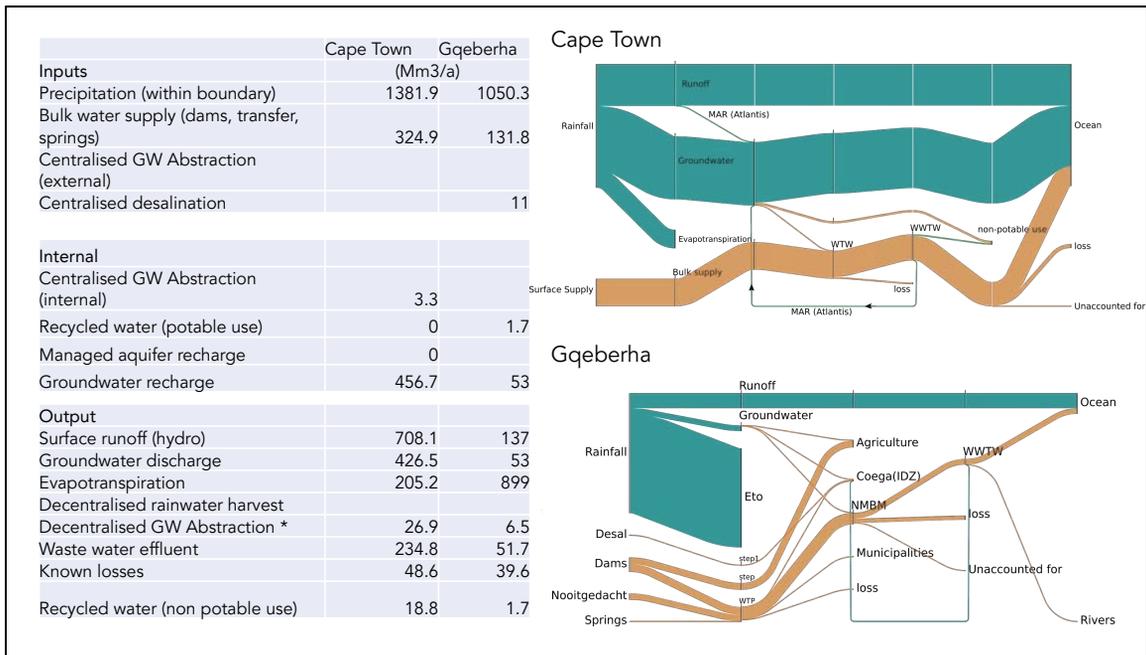| Cape Town	Gqeberha
Population: 4.23 Million Area: 2445 km2 Total Water Yield: 600 Mm3/a	Population: 1.26 Million Area: 1959 km2 Total Water Yield: 167 Mm3/a

Exploring the two cities enables insights to emerge from seeing similarities and differences.

Nelson Mandela Water Budget. Looking at this figure the following points were discussed:

- Agriculture has been difficult to unpack. Farms around Uitenhage are big water users. Comment made that government should buy the farms to get access to the water, which would be cheaper than developing new water sources as at estimated cost of 40 million per ML.
- Algoa System Reconciliation committee meet every 6 months to compare what has happened with the model projections. Jenny Pashkin might be a person of interest.
- NMB is on the edge of 3 weather systems and so can get rain at any time of the year, but typically the spring months of August to November is when runoff is highest.
- If the stormwater system in not well maintained and gets clogged with solid waste and alien invasive plants it has a huge impact on runoff.
- Wastewater is used for watering lawns and sports fields. SAPPI factory used to be a big user.
- Coega IDZ is not turning out as planned.
- Fish River is under serious strain.
- Darlington Dam wall not in good shape.
- Loadshedding severely compromising pumping and aeration of wastewater.

	Cape Town	Gqeberha
	(Mm3/a)	
Inputs		
Precipitation (within boundary)	1381.9	1050.3
Bulk water supply (dams, transfer, springs)	324.9	131.8
Centralised GW Abstraction (external)		
Centralised desalination		11
Internal		
Centralised GW Abstraction (internal)	3.3	
Recycled water (potable use)	0	1.7
Managed aquifer recharge	0	
Groundwater recharge	456.7	53
Output		
Surface runoff (hydro)	708.1	137
Groundwater discharge	426.5	53
Evapotranspiration	205.2	899
Decentralised rainwater harvest		
Decentralised GW Abstraction *	26.9	6.5
Waste water effluent	234.8	51.7
Known losses	48.6	39.6
Recycled water (non potable use)	18.8	1.7

Cape Town

Gqeberha

Comparing the estimates of input, internal and output flows between the two cities. A question was raised about why the known losses for Cape Town look high. We were reminded that these figures are not showing percentages but volumes in Mm3 per annum. So a 48.6 Mm3/a loss from a bulk supply of 324.9 Mm3/a represents a know loss factor of ~15%, which is considered quite low by South African and even international standards. The NMB loss figure of 39.6 Mm3/a of a bulk supply of 142.8 Mm3/a represents ~28%. Both cities have implemented leak fixing programmes and pressure management to bring down their losses in times of water crisis.

NMB Pre-intervention

Results

A question was raised about the potential for making use of North End Lake and the fountains at the airport as additional sources of water. Groundwater spontaneously appeared at the airport and gets pumped out at a rate of ~800KL per day. Participants discussed that North End Lake is badly polluted from sewage effluent. There was a programme to collect solid waste out of the stormwater inlet, which helped. And there was a microbiological process to aerate the water. But funds ran out.

There was discussion amongst participants about general confusion that exists regarding the use of naturally occurring springs and artesian boreholes. People are paying to have the water transported to fill up swimming pools and alike. Often unlicensed. There are apparently regulations against using spring water for swimming pools. But many don't know or choose not to find out. DWS is not forthcoming with information and it is difficult to know who to contact with enquiries. And water use license applications take so long to process. This leads to a lot of uncertainty and unregulated activity.

Urban Groundwater Governance Network Analysis

Anna Taylor then drew attention to the governance aspects of the work.

Why analyse groundwater governance arrangements in 2 SA city regions?

- Many existing groundwater governance studies have focussed on rural contexts
- Reliance on g/w in SA cities & surrounds growing
- Explore if city region is a suitable scale for such analyses
- Develop a 'meso' methodology that enables analysis beyond individuals but within organisations with a focus on shaping / influencing decisions & actions (beyond stated / formal rules to understand patterns of actions & behaviour)
- Test methods, looking to design something repeatable to enable comparison over time and between different locations / contexts
- What will it take to adapt from current arrangements to a sustainable conjunctive use set up?

Anna started by revisiting the rationale for studying urban groundwater governance in this project. Part of it is because SA cities are increasingly turning to groundwater as an alternative water source, both for municipal supply and for private self-supply by businesses and households. Part of the reason is to test out various methods for collecting governance related data and information at the city scale that reflects how things really work based on people's lived experiences, rather than rules and procedures as stated on paper in laws, policies and plans.

Analyse urban g/w governance networks how?

- Developing and testing a participatory social network analysis of g/w governance
- Social networks are a set of nodes (actors) and ties representing some relationship or lack of relationship (Brass & Krackhardt, 2012)
- A relationship (tie between nodes) involves a flow of resources between actors (nodes) that can be material or non-material
- Resources can include time, data, information, expertise, money, and shared activity (Williams & Durrance, 2004)

Drawing on social network theory and participatory mapping, the methods being tested are based on interviews and focus group discussions in the Learning Labs. These are semi-structured to find out from multiple people's perspectives: (1) who the relevant actors are that impact on the urban flows of groundwater and health of aquifers abstracted form for use in the city; (2) what relations exist between the actors; and (3) what flows through these relations (e.g. finances, data, time, expertise).

Considerable groundwork to settle on a way of structuring data collection

- **Actors** [org & org sub-units]
- **Attribute 1**: Actor type [govt; consultant; academic; funder; NGO; civic; intermed]
- **Attribute 2**: Governance level / scale of influence [local; regional; national; internat]
- **Attribute 3**: Aquifer acting on / in
- **Attribute 4**: Groundwater function / activities [select relevant categories]
- **Attribute 5**: Capacity to implement [0 = no capacity to implement; 1 = minimal capacity; 2 = moderate capacity; 3 = high capacity]
- **Attribute 6**: Strength of ties with other actors [0 = no interaction; 1 = minimal / occasional interaction > 6 months; 2 = semi-regular interaction < 6 months, > 1 month; 3 = frequent interaction < monthly]

It has been difficult to settle on how best to collect and capture the relevant groundwater governance data. Have settled on trying to capture the names of the organisational and sub-organisational actors, breaking the large, complex organisational actors, like metropolitan municipal government, down into relevant units or departments. For each actor characterise them according to 6 attributes, as listed in the slide. It has not been possible to capture all the necessary data for all attributes of all actors. The capacity to implement and the strength of ties attributes are proving particularly difficult to collect robust data on, highlighting the need for further research using different data collection methods (and possibly different metrics) for these aspects.

Attribute 4: typology of urban g/w functions / activities

Understanding ●

- Delineating & characterising aquifers
- Estimating yields
- Delineating groundwater protection zones
- Monitoring groundwater levels
- Monitoring groundwater quality

Operating ●

- Installing boreholes & well points
- Operating & maintaining wellfields
- Building / expanding WTWs
- Managing & maintaining aquifer recharge infrastructure
- Clearing alien invasive vegetation from catchments to enhance recharge
- Sand mining (reducing infiltration)

Regulating ●

- [Applying for water use licences]
- Determining raw water allocations & restrictions
- Processing water use licences & EIAs
- Enforcing water use licences & EIAs
- Preparing and revising (ground)water bylaws
- Enforcing bylaws
- Registering boreholes & well points
- Setting & enforcing usage restrictions
- Designating groundwater protection zones
- Enforcing groundwater protection zones

Capacitating ●

- Training groundwater professionals
- Training groundwater users
- Public awareness raising & education
- Advocating for changes in groundwater use, rules, access, sanctions
- Building & maintaining partnerships
- Financing / providing funding

We talked through the four clusters or types of groundwater functions that have emerged through the research: understanding; regulating; operating; capacitating. The blue items listed are ones that were added from discussions during the second Learning Lab in Cape Town. The colour dots pertain to the exercise that we did as part of the second Learning Labs in both cities, where workshop participants were asked to indicate which functions each identified actor fulfils. And add any actors they feel are missing from the current identified set. The name of each organizational actor was presented on a small card and laid out the table for all to consider and discuss.

Attribute 5: Capacity to implement (incl ops & maintenance)

i.e. to translate what strategies, plans and budgets say into action on the ground within the timeframes laid out

funds, staff, skills, facilities, and other resources to carry out the required programs to realize policy goals and fulfil plans

- Annual budget for groundwater programmes
- Number of staff working on groundwater programmes
- Level of technical expertise
- Efficiency of modalities to leverage capacity outside of org (e.g. tendering, procurement, partnership agreements)
- Formal / legitimised mandate

This is attribute of the capacity organisational actors have to implement their functions and mandates is considered very important to understand but is taking some time and effort to work out how to meaningfully characterise and assess, initially to describe but ultimately to try and measure, as a basis for monitoring changes over time. Getting multiples people's perspectives - especially those of practitioners - on how to assess this attribute is very useful. We tried in the 2nd Learning Lab in Cape Town to try and describe the various elements listed here for each actor. It raised as many questions as answers, but this is all important in trying to think through how best to do such a governance analysis in a way that yields useful information.

Attribute 5: Capacity to implement (incl ops & maintenance)

Metric	0	1	2	3
Annual budget for groundwater programmes	No dedicated budget	Less than 1 million	1 - 10 million	Over 10 million
Number of staff working on groundwater programmes	No dedicated staff	Less than 5	5 - 10	Over 10
Level of technical expertise	None	Low	Medium	High
Efficiency of modalities to leverage capacity outside of org	None	Low	Medium	High
Formal / legitimised mandate	None	Contested / unclear	Limited	Clear & widely recognized

This table is how we tried scoring the various elements for Cape Town actors operating in the groundwater space. We did not have enough time or participants at the NMB 2nd Learning Lab to get into this detail.

Attribute 6: Strength of ties with other actors

0 = no direct interaction

1 = minimal / occasional interaction, less frequently than 6 months

2 = semi-regular interaction, average frequency of between 1 and 6 months

3 = frequent interaction, more than once a month on average

Similarly, this is how we got Learning Lab participants in Cape Town to rate the strength of ties between actors, based on the frequency of their interactions. The frequency of interactions can be quite dynamic and variable, depending on what work is happening at the time, which makes this rating difficult in some cases.

Emerging insights

- Growing role(s) of metro municipal government both as bulk abstractors and as overseeing growing number of domestic & industrial/commercial users
- Tension for city govt btw allowing/encouraging decentralised diversification to increase resilience of the system and the loss of revenue from high-volume users (paying more in stepped tariff structure) substituting municipal water for alternative sources
- Role for metro police in enforcing bylaws
- Drilling companies play important role - how much oversight and regulation?
- DWS enforcement capacity severely constrained
- No urban (ground)water user associations to negotiate, set, monitor and enforce collective usage rules (envisaged devolution not happening)

Some governance related insights have emerged from the documents reviewed, interviews conducted, and 3 Learning Labs held prior to this one, as listed in this slide. Participants discussed the importance of drillers and the need for their involvement in data collection and management initiatives. But participants felt that most drillers are distrustful of government and do not register their drill sites on any database. In line with the Water Act, NMBM has a bylaw that deals with groundwater, but it is very generic. The relevant bylaws need to be tightened considerably. There was discussion about attitude within the community being a problem and a hindrance to borehole registration and groundwater data collection. People don't register their boreholes because they think it will mean additional levies. A participant highlighted that the sewage tariff is calculated based on municipal water usage, so if alternative water sources are being used to supplement municipal supply this is not reflected in the sewage tariff, which effectively means people are then under-paying for the sewage service they are using. Data that does exist is not shared or readily accessible. For example water chemistry is tested, but the data is not shared. Nobody puts their data in a central database. An open access database would be something that benefits everyone, including drillers who could easily get information on groundwater potential in an area, and the city government for monitoring purposes. If this was available in NMB it could make a difference to attitudes. Is there a commercial advantage to protecting data or making it propriety that gets in the way of such sharing and making open access? It was mentioned that there is a new open-source borehole database in Cape Town available at https://tablemountain.groundwaterinfo.africa/index.php/view/
In relation to attitudes, there are also connections between indigenous peoples and

wetlands that are part of the picture.

Next steps for data gathering & analysis

Metrics for assessing capacity to implement

Any existing actors missing

Evaluating ties

Comparing network composition and structure between NMB & CPT

Identifying missing and under-capacitated nodes and weak ties as basis for recommendations

These are the next steps for the governance aspect of this work. We were not able to cover all of these aspects in relation to NMB in the second Learning Lab, but focussed on revisiting the set of actors already identified, discussing if any in the list are not relevant, if any actors are still missing, what groundwater-related functions they fulfil, and what ties or connections are important.

Participants gathered around a table and we laid out the cards, with each card naming an organisational actor in the groundwater space in NMB. We discussed the functions each actor fulfils and gave them a colour dot to indicate the types of functions. The key points that were raised and discussed were:

- DWS keeps restructuring so it's hard to know what units within the organization are strongly working. DWS is core, has a big regulatory and monitoring function and some function in terms of communication. DWS determines allocations and restrictions.
- National Treasury plays a big part in releasing funds in an emergency, including in the water crisis, and some of these funds go to installing the groundwater schemes, including abstraction and treatment.
- NMBM Disaster Management Centre is a relevant actor because the disaster declaration has to go through them and they have a capacitating and coordinating function.
- Provincial Department of Environment and Tourism don't do much in NMB. Not equivalent to Western Cape Department of Environmental Affairs and Development Planning that play a key role in the EIA process for drilling in protected areas like around Steenbras Dam.
- Key NMBM units include water distribution and bulk water.
- For consultancies their activities are project based. They will have info, do the project, do the close out, and they are done.
- Drilling contractors fulfil the operational function. Many drilling contractors came in from outside of NMB during the crisis. Agreed with suggestion made in Cape Town LL of distinguishing between 'fly-by-nights' and registered

- drillers who are members of drilling association.
- Pump test contractors should be included as separate actors, as they establish the sustainable yield.
- Also pump installer contractors. They come in after the drillers and the pump test contractors.
- Commercial actors include Coca-Cola, Isuzu, Aspen, Netcare, VW.
- The university, NMU, is a big water user, including groundwater.
- The Lower Sundays Water Users Association is not relevant in the groundwater space as only deals with surface water.
- Similarly the Gamtoos and Sundays Irrigation Boards also only deal with surface water so not relevant in the groundwater space.
- Coega Development Corporation (CDC) is a smaller user than what people might think. Might have a borehole for irrigating plants but not a major user. The municipality supplies the Coega Development Zone in bulk then the CDC allocate, but this is mainly surface water. Poor quality water in that area so low groundwater potentials.
- The Swartkops Conservancy is not so relevant to the groundwater space. They are on the Metro's back constantly because of pollution from the Markman and Motherwell stormwater canals.
- Gift of the Givers put in a lot of boreholes in response to the water crisis. They pay for boreholes to be installed and maintained, so they play a capacitation function.
- Metro police should be enforcing borehole by-laws but they aren't. They do not have the training or capacity.
- Media potentially have an important role to play in public awareness raising and education, but currently they do not. They are just looking for stories. Local print media is poor. Radio media, e.g Algoa FM, does a better job. They are paid by the NMBM Metro government to provide content. However, their reporting can be misleading.
- Sand mining companies operating locally may well be reducing infiltration and influence level of recharge possible. They should be regulated by the national Department of Minerals Resources and Energy but they are not interested in reigning in the mining companies. They are chasing bigger problems and opportunities.
- Security companies are needed to protect the investments that are made in groundwater. Syndicates are operating that steal equipment. It is serious. Gift of the Givers boreholes are getting vandalized.
- The Business Chamber have helped the metro reduce the backlog of outstanding leaks to be fixed, cleaned the storm water drains, given tanks but not active in the groundwater space
- NBI play a capacitating function, fixing leaks at schools, helping the metro with communications and acting as a go-between for government and business, they have resourced 2 mentors for mentoring NMBM staff in operational functions
- The Algoa Water Supply System Strategy Steering Committee convene every

- 6 months to review the models, but have so many platforms that it is hard to keep up. Ilsa Chilton and Jenny Pashkin are key people. Because of the drought they are very active, between DWS EC and DWS National Office. A current focus is trying to manage the illegal irrigation in Langkloof.
- If you apply for a water use license you are supposed to monitor your borehole but it doesn't happen. From DWS side its mandated but the municipality does not. Only boreholes that have to be constantly monitored according to the municipals bylaws are near the landfills. Boreholes are there for monitoring pollution. There was a national monitoring programme, used to happen but not so much now. Sensors and electronic monitoring are expensive and therefore it doesn't get done. Many boreholes exist without meters and no monitoring.
- Another actor to add is NMBM's SRAC (Sport, Recreation, Arts & Culture) which operates 10-12 boreholes for watering parks, fields, etc.
- Suggestion made that there should be a national drilling association to enforce the drillers to comply and share their data in the same way there's a pump test association. National Groundwater Association should have an influence to get the drillers to register. A consolidated database would be a major facilitator for good groundwater governance.
- When asked about aquifer / groundwater monitoring committees, as have been set up in Cape Town linked to the City's Water Use Licence for the TMG and CFA schemes, participants indicated that these are non existent in NMB but should be encouraged. However, the lack of trust in the municipal government means that private users are reticent to share their information.
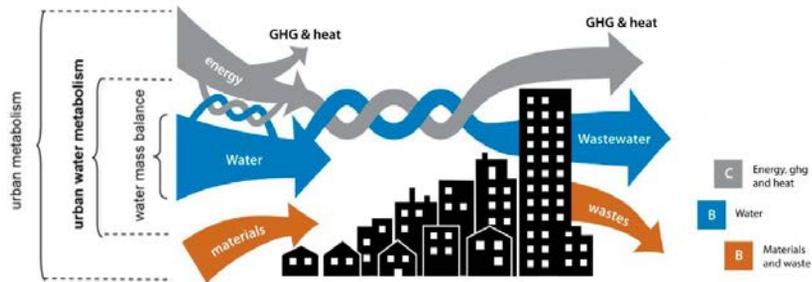
After enjoying lunch together, we discussed the relevant of the urban water metabolism analysis for decision making around urban groundwater management.

- How can the information generated from urban water metabolism analysis inform decisions for urban water management in a changing climate?

- What new insights about urban water management does UWMF provide?

- Where and when is the urban water metabolism useful for decisions, and where is it not?

How does an urban water metabolism analysis improve our understanding of the urban water cycle so that we may improve how we manage it? Part of what we are exploring in the project is whether there is potential value in the UMWF to inform policy, planning or operational decisions, beyond being a purely academic exercise.

Questions that were asked during Learning Lab 1

Clarification/misunderstanding
•Why do we have groundwater arrow not going to industries?
•Runoff and ecological reserves? How much is left for ecological reserves?
•Difference between loss and unaccounted for? Why don't we redirect this loss?

Interesting but beyond current scope
•What about untreated flow, pollution from industry and city.
•How will you ensure that GW is used efficiently by the City?
•How will you measure that recharge is not influenced negatively?
•What is affecting recharge into the groundwater resource?

Operationalising UWMF
•How would the Sankey diagram look if urban management objectives were achieved?
•Can we increase GW recharge?
•What could be done to increase recharge, to make use of runoff that ends up in the ocean
•How would this Sankey diagram look if we achieve our urban water management goals and objectives
•How does the picture change with climate change? How does it change with planned initiatives? What is the desired state?
•How will 2deg warming change the natural flows?
•How can we reduce the GW and runoff flowing to the ocean, and instead to agriculture, industry and urbans?
•Where is my potential to increase supply or reduce inefficiencies/wastage

During the 1st NMB Learning Lab when we showed and discussed a preliminary analysis of NMB water flows, we asked participants to formulate questions they had about the metabolism analysis and to position the questions on the Sankey diagram based on what aspects the question relates to. These were the questions that were asked during Learning Lab 1. We clustered them into questions of clarification, questions that are interesting but beyond the scope of this project to address, and questions that pertain to operationalising the framework.
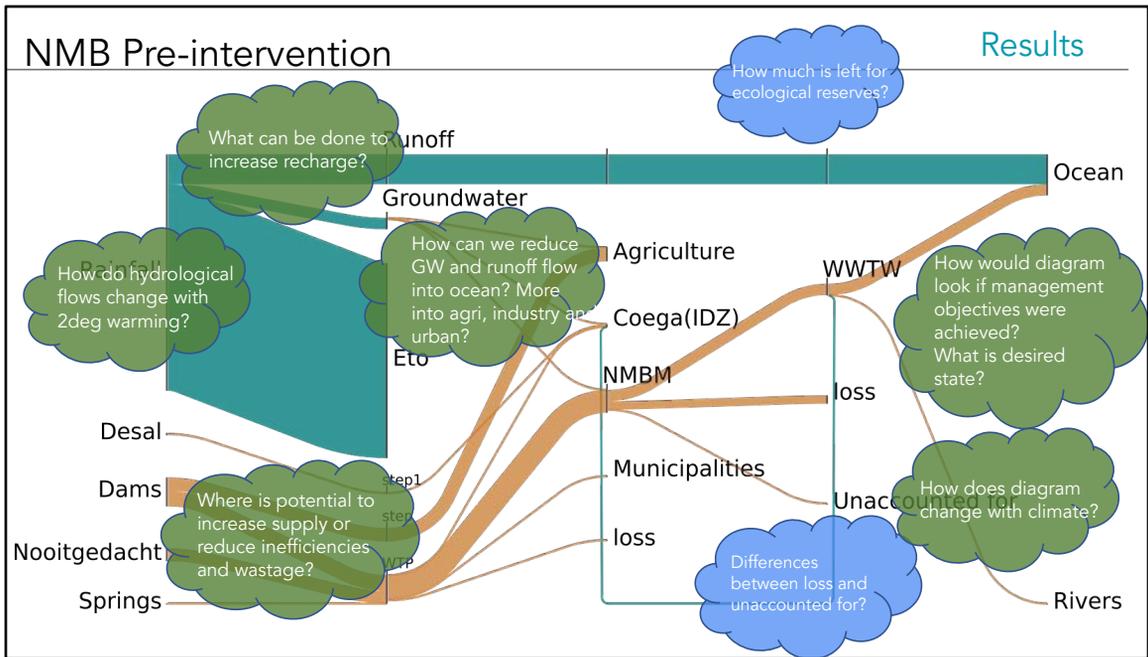
This figure shows some of the questions raised by participant in the 1st Learning Lab positioned on the revised flow diagram. Green being the questions that relate to interrogating how to operationalize a framework like this (and the information it generates). Blue being the questions that are more for clarity and improved understanding.

Performance and Scenario Analysis

Building urban resilience to drought

Drought is not only felt in balance between supply and demand. Drought impacts the entire wellbeing of the city.

How do we build resilience to drought holistically, with the whole urban system in mind?

A strong driver of this research is on the fact that many growing cities in South Africa are facing/will face increase drought risk. The impacts of droughts are not only on the balance between supply and demand, but can also have direct impacts on the well-being of the city - including public health, strained economic situations, increased water prices and an overall decrease in the quality of life of the city's population. So when we start thinking about these broad terms such resilience, drought resilience in particular, we do need to focus on more than just securing supply.

A Water Sensitive City is

Liveable + Resilient + Sustainable + Productive

- Serves as a potential water supply catchment, providing a range of different water sources at different scales and for different uses
- Provides ecosystem services and a healthy natural environment, offering a range of social, ecological and economic benefits
- Consists of water sensitive communities where citizens have knowledge and desire to make wise choices about water, are actively engaged in decision making, demonstrate positive behaviour (e.g. conserving water at home).

Bearing in mind that water sensitive cities are more than just supplying water the city, they are also liveable, resilient, sustainable and productive.

Nelson Mandela Bay Metropolitan Scenario Analysis

Source	Current (Mm3/a)	Future (Mm3/a)	Idealised (Mm3/a)
Surface Water	71.3	71.3	50.8
Natural Spring	2.2	2.2	2.2
Nooitgedacht	58.4	76.7	58.4
Groundwater		20.4	20.4
Desalination	11.0	27.4	11
Recycled water (Coega)		21.9	27.50
Recycled water (NMU)		1.3	1.3
Recycled water (Drinking)		3.7	13.7
Managed Aquifer Recharge (MAR)			85.71
Loss recovery		7.3	20
Total External Inputs	142.8	222.5	142.9
Total Internal flows	0	34.1	148.21

Idealised scenario reduces external inputs and increases internal flows:

- Assumes water consumption is the same as current consumption;
- Builds in redundancy (capacity for desal and increased transfer are there but not relied upon)
- Increases water recycling (potable and non-potable uses)
- Waste water and stormwater runoff are cleverly managed in the urban landscape for enhanced aquifer recharge.
- Losses are dramatically reduced.

We discussed the NMB water metabolism scenario analysis. The current scenarios shows figures prior to major drought interventions coming into effect. The future scenario captures all of the measures currently planned being implemented. The idealised scenario keeps in mind the water sensitive principles, reducing external water inputs and increasing internal water flows. Creating urban landscapes that maximise water availability, when it arrives. Using treated effluent for this is a good approach as it is more reliable and can be engineered with effect than infrequent stormwater runoff. Can be used for irrigating parks/urban green spaces used for recreational purposes, restoring wetlands, increasing localised infiltration rates etc.

When looking at the scenarios, there was discussion about the phases of developing the Nooitgedacht Dam. Currently in phase 3. A 4th phase is being investigated to further expand supply capacity up to 280 ML per day. A discussion ensued about the risk of over reliance on Nooitgedacht. In 2016 there was a canal failure which required 4 weeks to be fully restored. Water resilience requires infrastructural resilience as well as supply resilience. DWS manages the allocations from the Gariep Dam. Other towns and municipalities all rely on allocations from the Gariep Dam. Abstraction from Coega Kop was expected to be 27 ML/day in February 2023 and eventually get up to 36 ML/day. The discussion highlighted that ML/day is possibly a more useful and relatable measure that Mm3/annum.
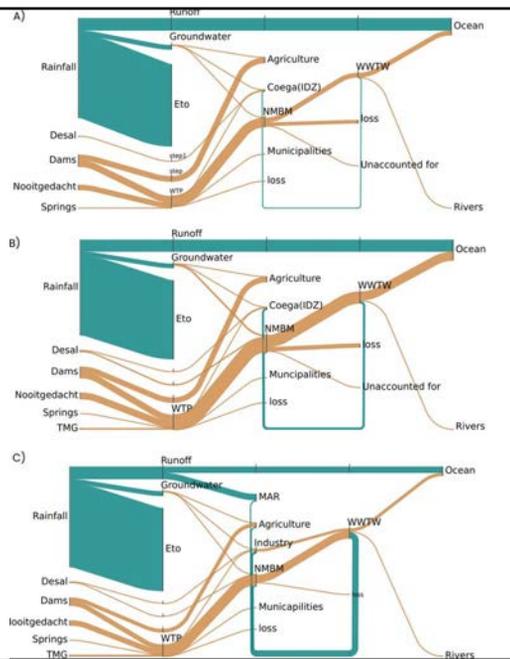
There was a discussion about the potential for managed aquifer recharge (MAR) in

and around NMB. SRK commissioned a study and found that dune sand is very shallow and undelain by bedrock, so storage is not big enough. The aquifer is fractured so its difficult to ge a good idea of how much storage there is. Stormwater retention ponds in Walmer could yield water for artificial recharge.

A question was raised about whether and if so how rainwater tanks are captured and represented in the water budget and scenarios.

Nelson Mandela Bay Metropolitan Scenario Analysis

Source	Current (Mm3/a)	Future (Mm3/a)	Idealised (Mm3/a)
Surface Water	71.3	71.3	50.8
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Details of the mass balance are available in the report. But the Sankey diagrams visualize the various mass balances. A) being Current Water Mix, B) the future Water Mix and C) the idealized scenario.

The idealised scenario shows much greater internalization resources:

Increased recharge via MAR from both runoff and WWTW

Increased recycling to industry, agriculture and NMBM in general.

Losses are reduced

Overall, increased internalization and fit-for-purpose use of all water sources from within the system.

Diversification of sources are still there – many alternative forms of water should/when a crisis occur again.

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Indicator (Renouf et al 2017)	Method	Unit	Current	Future	Idealised
Population density	Population/area	capita/km^2	643.2	643.2	643.2
Intensity of water use	Total water use/area	kL/d/km^2	208.8	290.9	228.0
Water Efficiency	Centralised supply/population	L/d/capita	310.6	430.3	310.6
Supply Internalisation		%	5	14	27
Wastewater potential for Water supply					
Centralised supply replaceability (%)	Wastewater flow/centralized water supplied	%	36	17	11
Total use replaceability (%)	Wastewater flow/total water use	%	35	16	10
Stormwater Potential for Water Supply					
Centralised supply replaceability (%)	Stormwater flow/centralized water supplied	%	96	68	26
Total use replaceability (%)	Stormwater flow/total water supplied	%	92	66	25
Wastewater and Stormwater Combined					
Potential of total water use replaceability (%)	(Wastewater + stormwater)/total water use	%	126	82	36
Loss recovery for Water Supply					
Water loss recovery potential of total water use replaceability	Water loss/total water use	%	26	16	1

We briefly looked at how the performance of the system changes according to each scenario. Overall the future water mix improves the performance of the urban water cycle and does indeed bring the city closer towards a more water sensitive objective. With the idealised scenario, further progress towards water sensitivity is achieved. Supply internalisation greatly improves with the Future Water mix, reflective of the increased water recycling capacities currently being planned. With the Idealised scenario – even more internalisation is achieved, reflective of greater efforts for water recycling as well using stormwater resources for enhance recharge and other fit-for purpose uses.

A note on the Stormwater and Wastewater potential for Water Supply, the greater the number the more of that resource is available. The smaller the number, the less of that resource is available – and in this case the reduced % replaceability reflects the water being used or recycled in the system. For Wastewater – this improves with both Future and Idealised scenarios. For stormwater, in the case of the idealised scenario, this is also the case as stormwater is redirected for enhance aquifer recharge. But the future water mix doesn't stipulate any use of stormwater, and so this reduced potential reflects rather the greater water supply to the system.
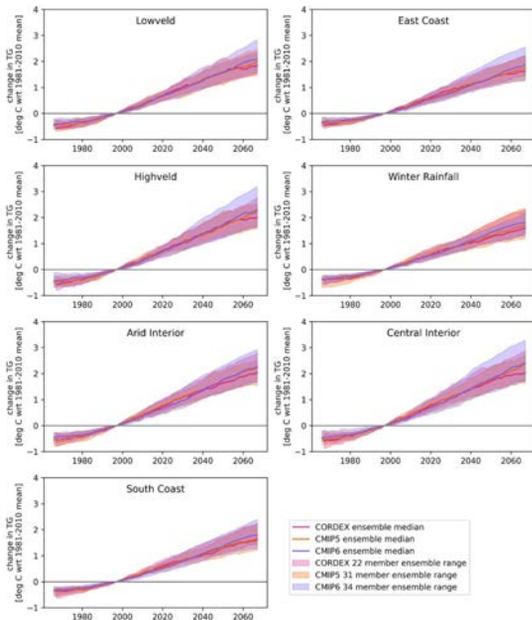
Climate trends/projections

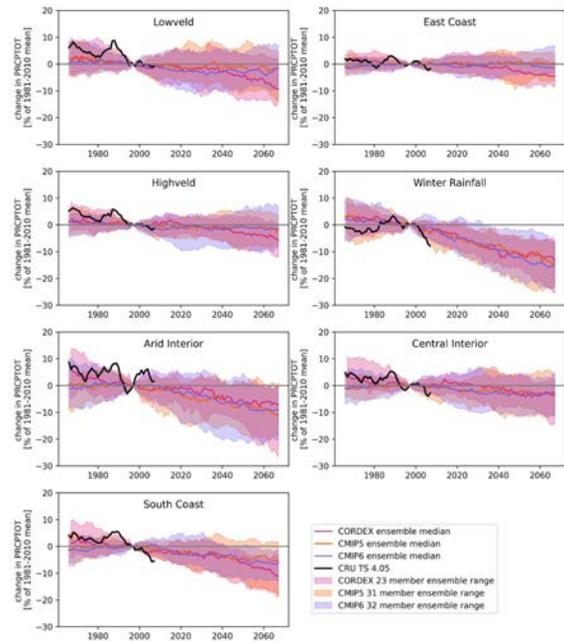Approximately homogeneous
hydro-climate zones
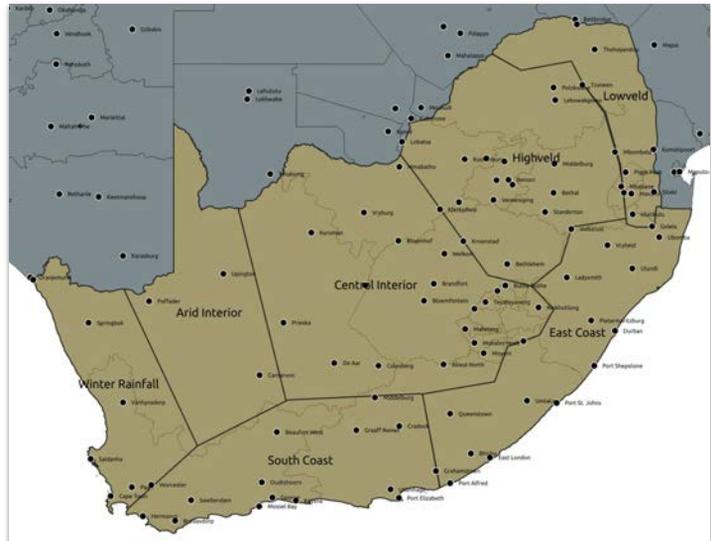
We spent the last session looking briefly at climate trends affecting the availability of water in NMB. Dr Chris Jack showed the hydro-climatic zones and then zoomed into results for the South Coast.

Climate trends/projections

The temperature trend in all regions shows clear warming. The rainfall patterns vary between regions and on the whole are less clear with some models suggesting likely drying and others possible wetting. However, the South Coast region shows a drying trend. In light of reliance on the transfer scheme from the Gariep, the rainfall and evaporation trends in the central interior are important for NMB. For this region, the rainfall signal is less clear. Participants indicated that climate change is not really part of the dominant NMB drought and water scarcity narrative.

Ended off the day with a creative exercise

We concluded the day with a creative exercise, each decorating a tree of life. This provided time to use a different part of our brain, chat further, express our creativity, laugh and have fun trying something very different from our regular work. Part of what we are experimenting with in the Learning Labs is how to build connections between different people working on various aspects of urban water issues. In addition to talking through content, we find that having time to reflect and be in each others company in more relaxed and creative ways can spark different conversations and connections… especially when it means all going outside of our professional comfort zones.

List of Learning Lab invitees

Organization	Name
NMBM	Laure Pieterse
NMBM	Barry Martin
NMBM	Matthew Hills
NMBM	Amanda Magugwana
NMB Business Chamber	Prince Matonsi
Coega Development Corp	Graham Taylor
DWS EC	Fhatuwani Aron Magonono
DWS EC	Vhuthu Tshishonge
DWS EC	Lufuno Munzhelele
DWS EC	Sivuyisiwe Mbange
DWS EC	Vuyiseka Jack
DWS EC	Andrew Lucas
DWS EC	Ilse Chilton

Organization	Name
NMU	Andre Hefer
NMU	Gaathier Mahed
NMU	Leizel Williams-Bruinders
NMU	Alex Lenferna
NMU	Tristin O'Connell
NMU	Carla Dodd
NMU	Bamanye Takashi
Zutari	Dan Abraham
Umhabiso Consult	David Raymer
Independent hydrogeologist	SanMari Woithe
Kainos SA	Marc Goedhart
Independent hydrogeologist	Donovan Samuels
Zwartkops Conservancy	Dale Clayton
WRI	Amanda Gcanga
SACN	Rebecca Gatangí

This shows the list of people invited to join the Learning Lab event. We are still working to expand the network based on suggestions and referrals. Suggestions for who else might be interested and relevant include:

- Anton de Wit, NMU
- Representative from the Borehole Drillers Association (Christo Steyn a possible contact point)
- Gary Koekemoer, Chair of the WESSA Algoa Branch
- Dr Belinda Clark, Coastal and Enviro Network
- Garth Sampson, SAWS