

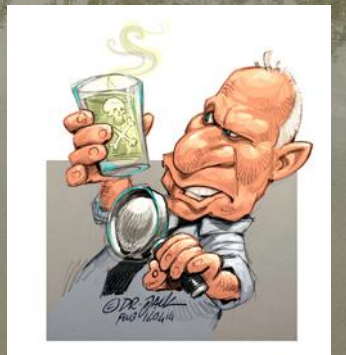
Water in Agriculture

Anthony Turton

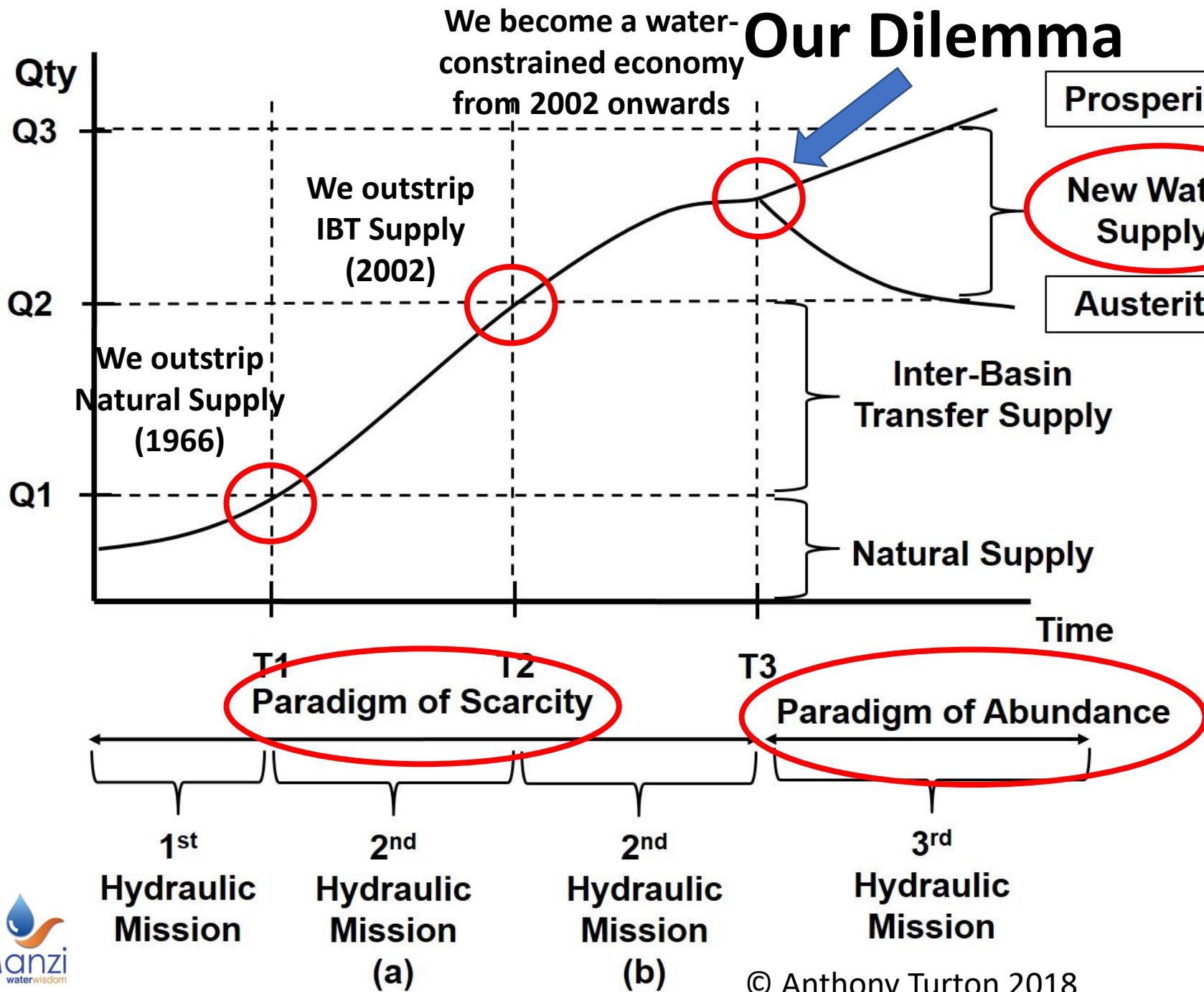
tony@anthonyturton.com

Constructed Wetland
at the Johannesburg
Zoo

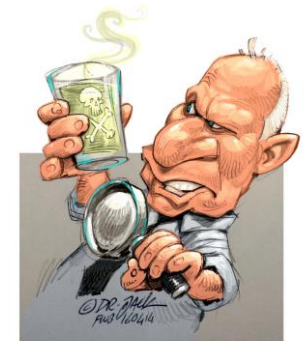
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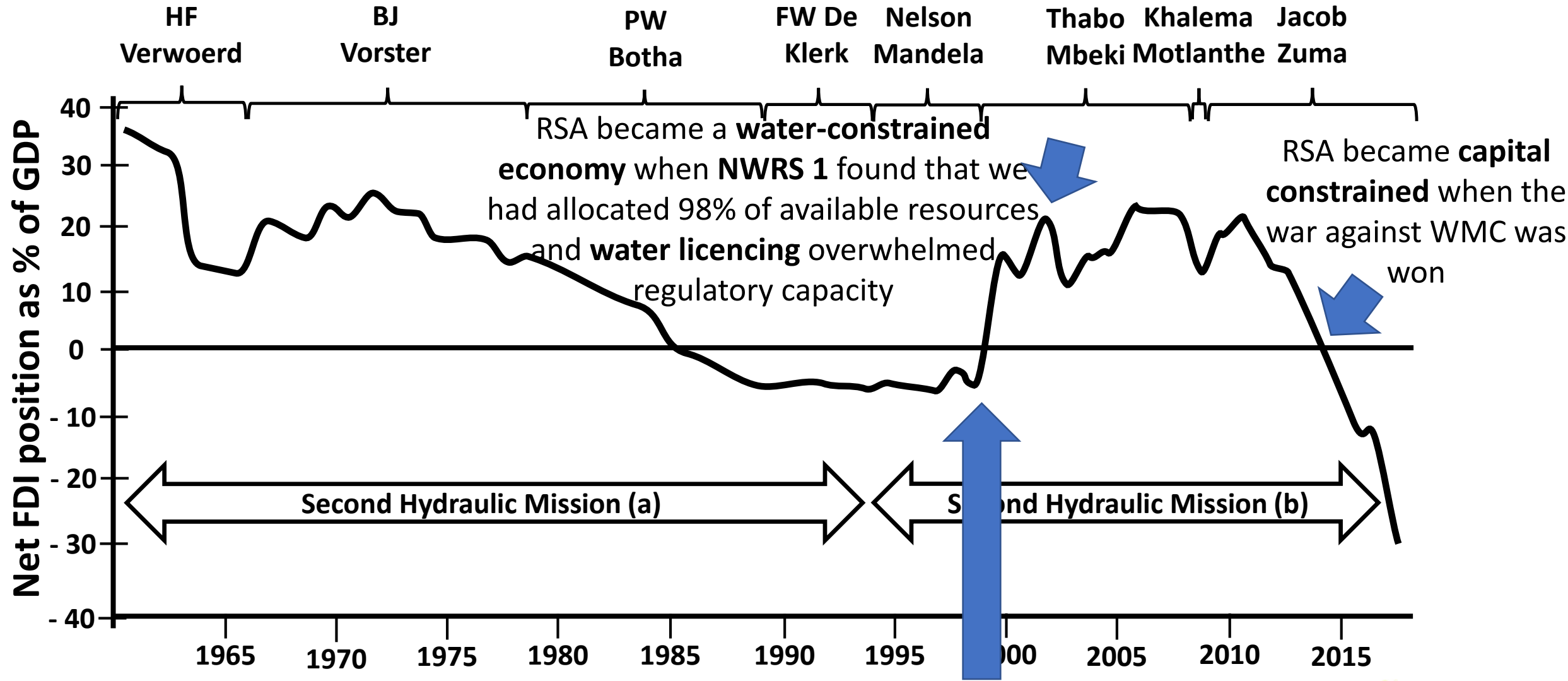
Our Dilemma



Reuse, recovery and recycling will be the foundation of an invigorated economy

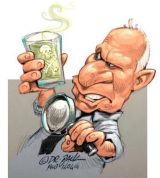


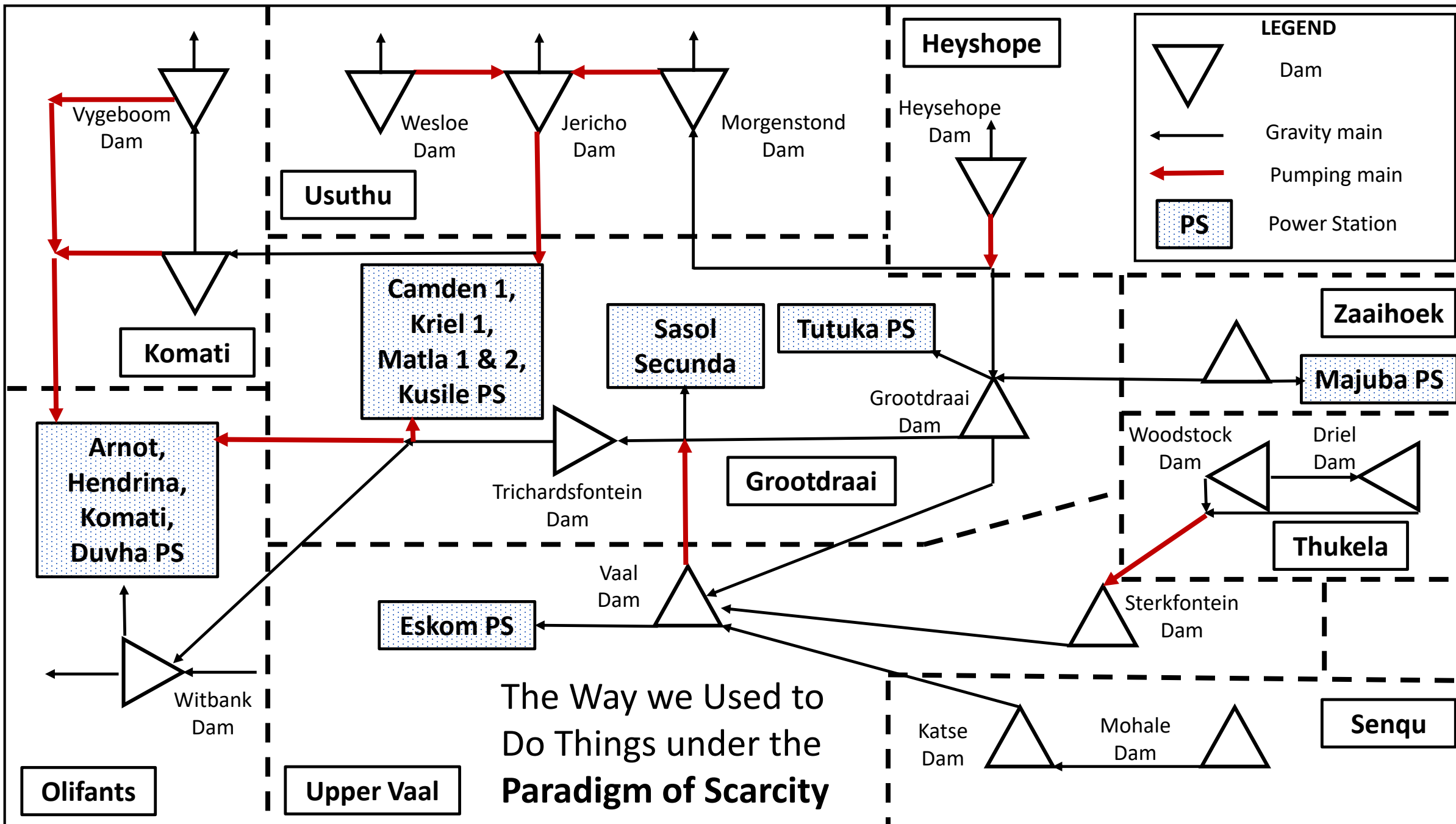
RSA Dilemma – A Water and Capital Constrained Economy



Redrawn from Economists.co.za

The **National Water Act** (1998) nationalized water and mandated the National Water Resource Strategy

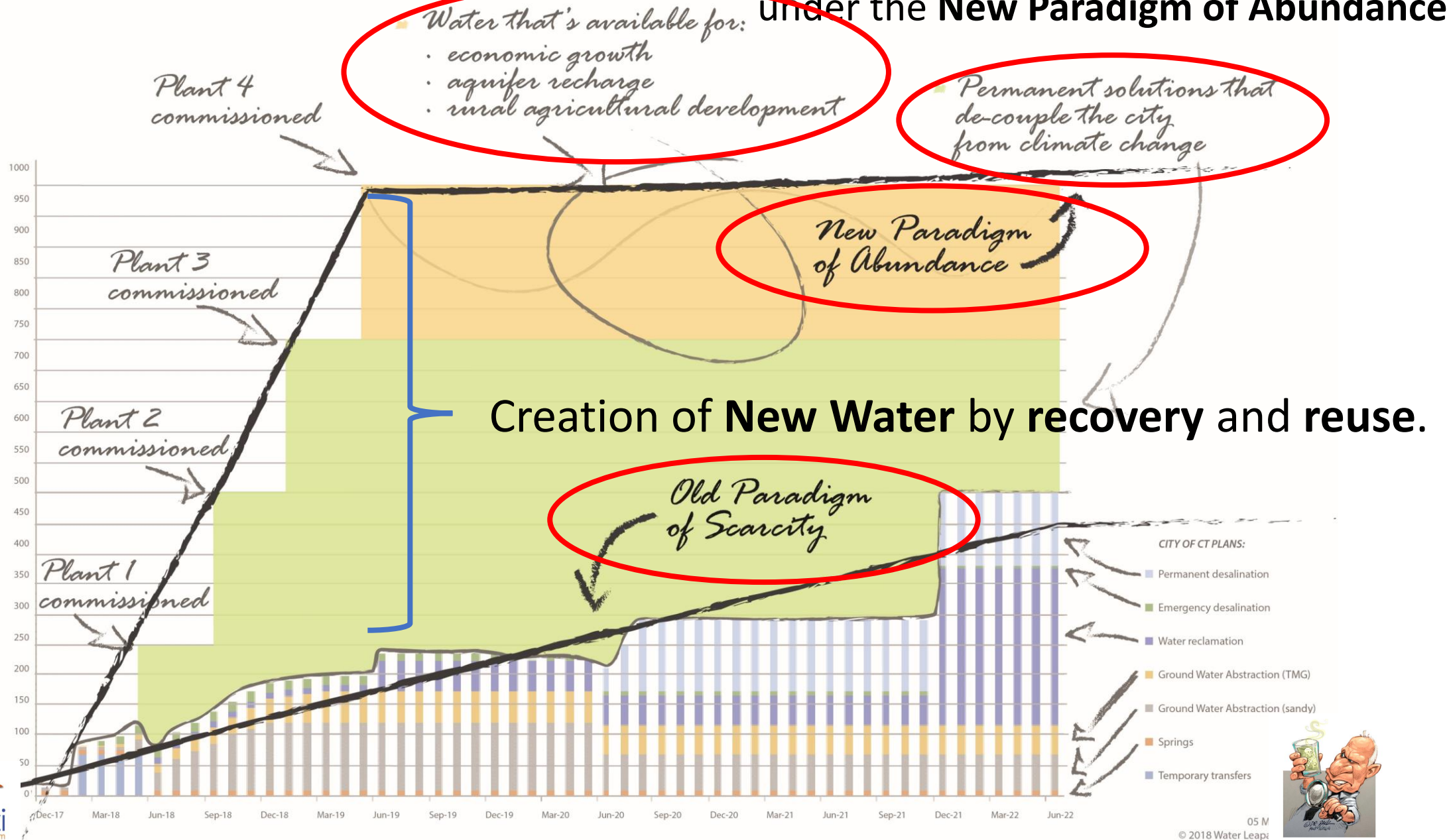




CITY OF CAPE TOWN: WATER AUGMENTATION PLANS

What the plans *should* look like

The Way we are Going to Do Things
under the **New Paradigm of Abundance**



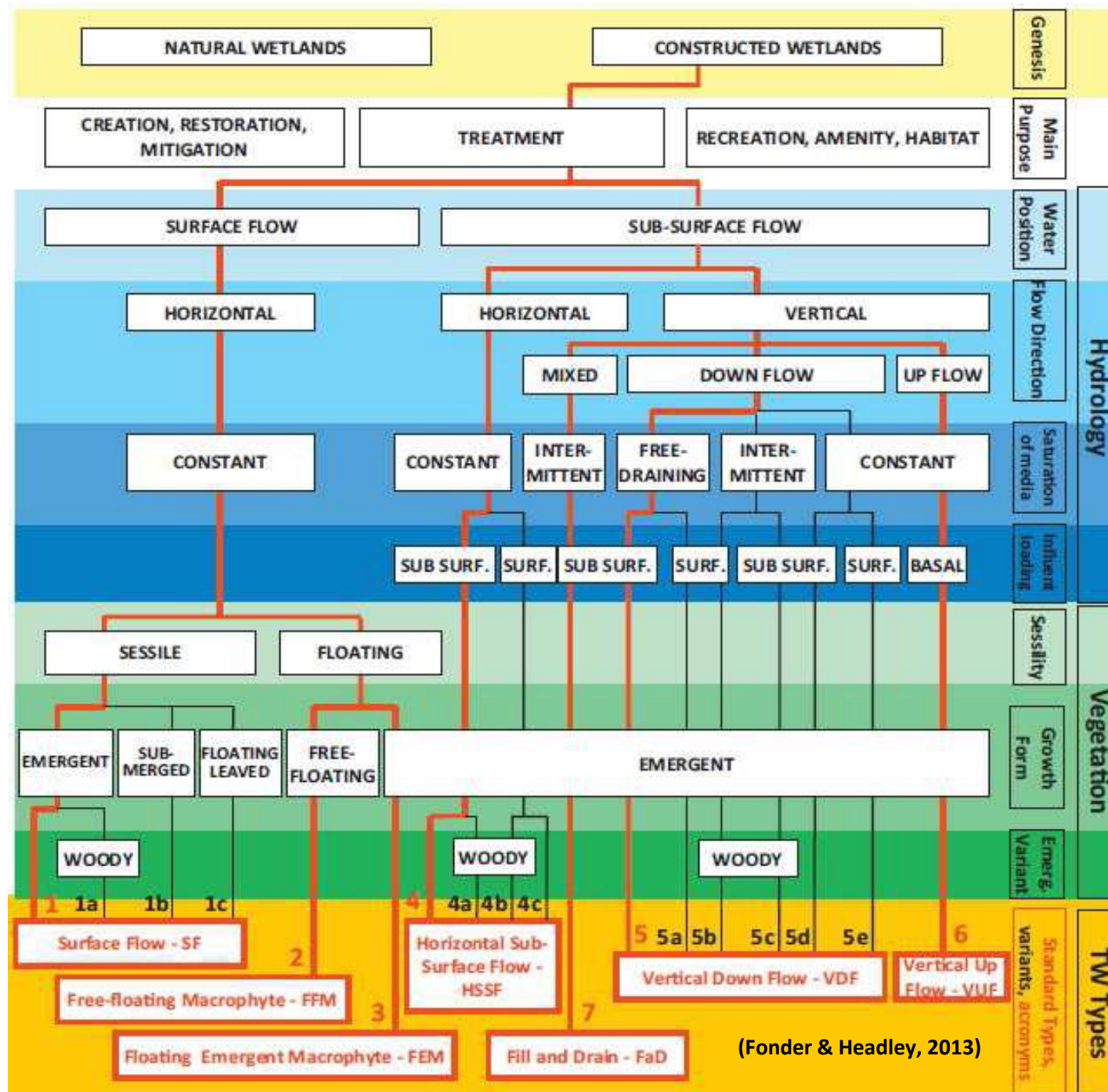
	Old Paradigm of Scarcity	New Paradigm of Abundance
Perception of Water	<ul style="list-style-type: none"> * Stock * Finite therefore scarce and limited 	<ul style="list-style-type: none"> * Flux * Infinite because it's a renewable resource
Economy	Linear	Circular
Technology	<ul style="list-style-type: none"> * Dams as principle elements * Master and Owners of Nature through hard engineering and control * Centralization under the state * Single use water at lowest cost * Groundwater managed separately * Desalination avoided as costly 	<ul style="list-style-type: none"> * Recovery plant as principle elements * Nature-Based Solutions (NBS) through softer engineering and partnerships * Decentralization increasingly under private control * Dual Stream Reticulation at variable cost * Aquifer Storage & Recovery (ASR) as key element * Desalination embraced as source of New Water
Capital	<ul style="list-style-type: none"> * Cost to be avoided as much as possible * Limited multipliers because of linear configuration of the economy * Fiscus is the sole source 	<ul style="list-style-type: none"> * Investment to be encouraged as an economic enabler * Many multipliers because of networked nature of the circular economy * PPP's with private capital as new source
Management Structures	<ul style="list-style-type: none"> * Highly centralized under State control * State Owned Enterprises only 	<ul style="list-style-type: none"> * Increasingly decentralized under <u>both</u> private and state control (new markets for solutions e.g. Residential Estates and Facilities Managers) * Special Purpose Vehicles contracted to SOE's but meeting capital risk mitigation requirements



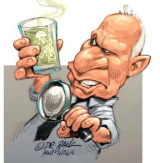
Typology of Engineered Wetlands

Major design distinction is **surface / sub-surface** flow further sub-divided into **horizontal** or **vertical** flow systems

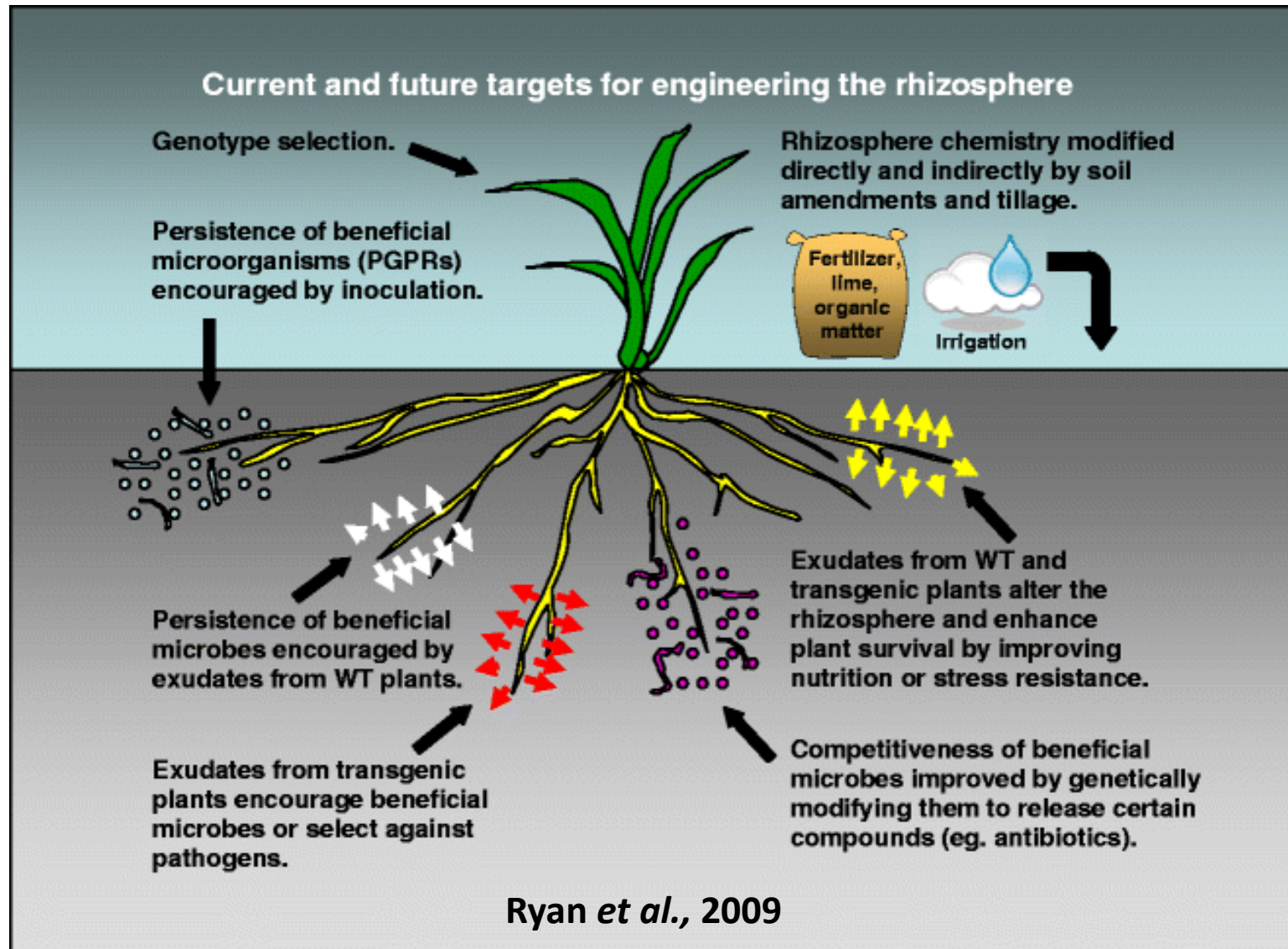
Fundamental problem is the propensity for a **preferential flow-path** that limits contact time with the **rhizosphere**



(Fonder & Headley, 2013)



Its All About the Optimization of the Rhizosphere



The **Rhizosphere** provides **habitat** to the communities of **bacteria, fungi** and **archaea** needed to metabolize waste.

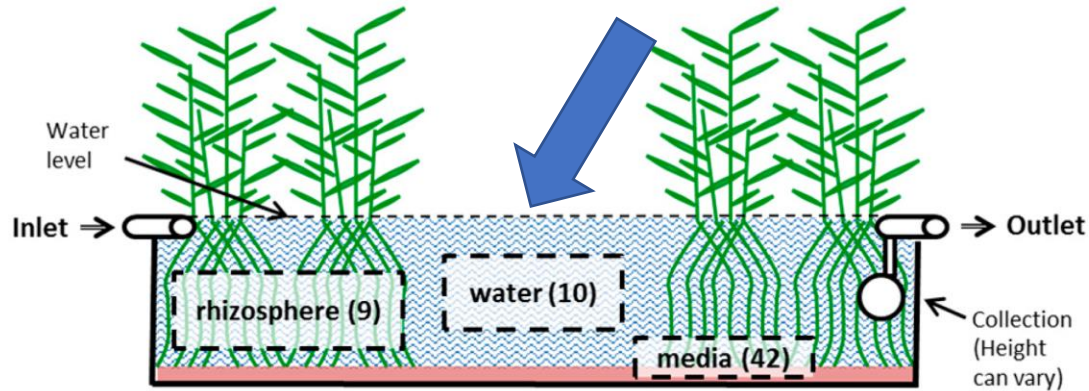
In the context of an **engineered wetland** the **rhizosphere** is where the work is done so **contact** and **retention** has to be optimized.



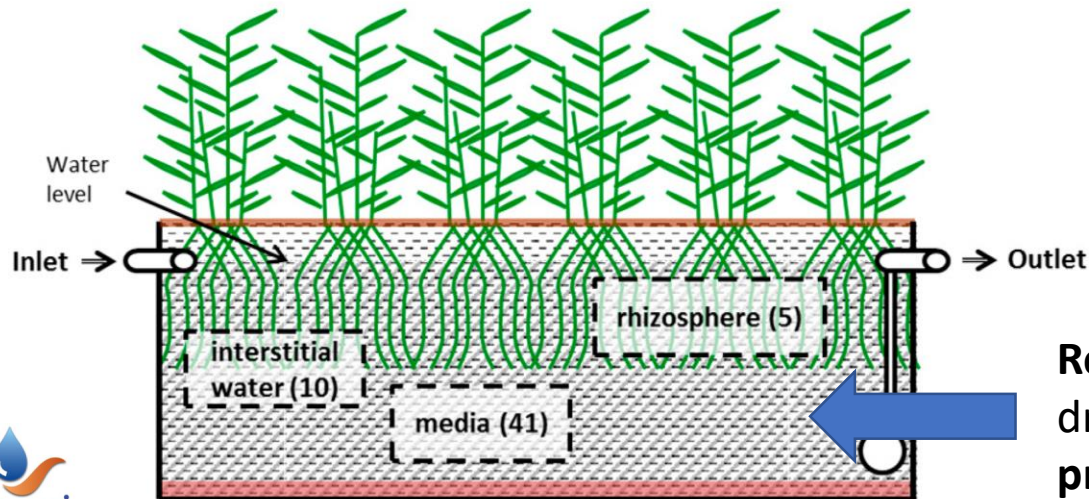
Design Limitations

Anoxic conditions and the emergence of **preferential flow-paths** over time **BUT rhizospheric communities are 10X more active** when degrading organics than general media (Weber & Legge, 2013).

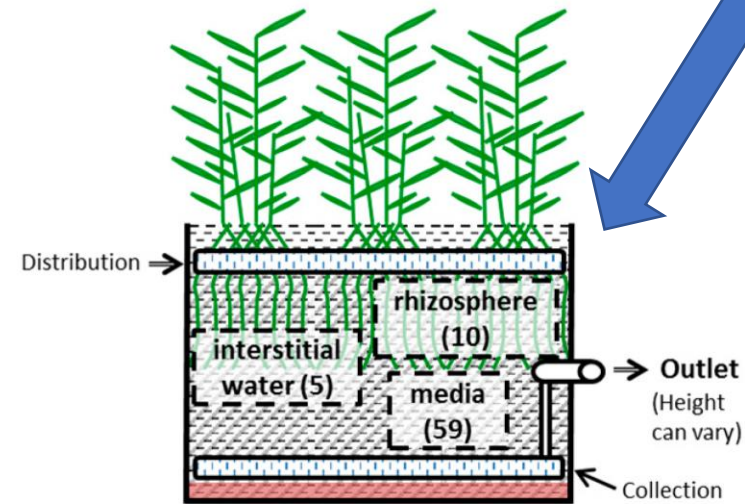
A: Free Water Surface Flow (SF)



B: Horizontal Subsurface Flow (HF)



C: Vertical Flow (VF)

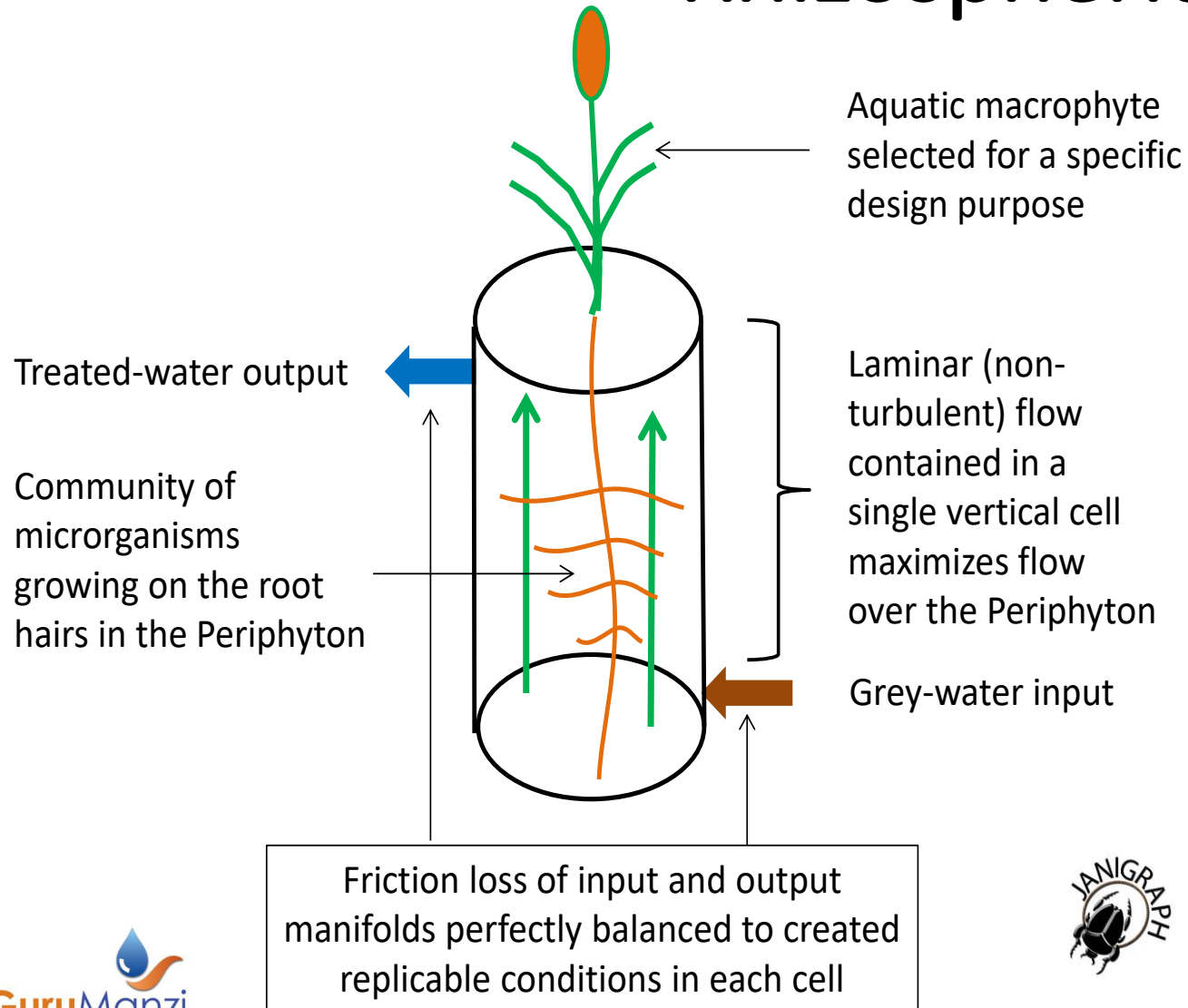


Reduced rhizosphere contact driven by the emergence of preferential flow-paths over time

(Weber, 2016)



Optimizing Vertical Flow for Contact Time with Rhizospheric Biota



Engineered wetland is reduced to a **series of cells** with isotropic flow conditions as per **SA Patent Application 2015/03442**.

Up-flow creates a **parachute effect** of the root hairs that optimizes **periphyton biota and biofilm growth**.

Preferential flow-paths are eliminated optimizing the **efficiency** of the footprint.

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SA Patent 2015/03442

Vertical Up-Flow Periphyton Optimization



Mesh bag suspended in the cell.

Healthy and rapid **root development**.

Root hairs stimulated by the **parachute effect** of the **up-flow** creates the **largest possible area of contact** with the water being treated.

Peat plug created over time that can be removed and **safely disposed** if **hazardous metals** are being metabolized by **specific microbial colonies**.

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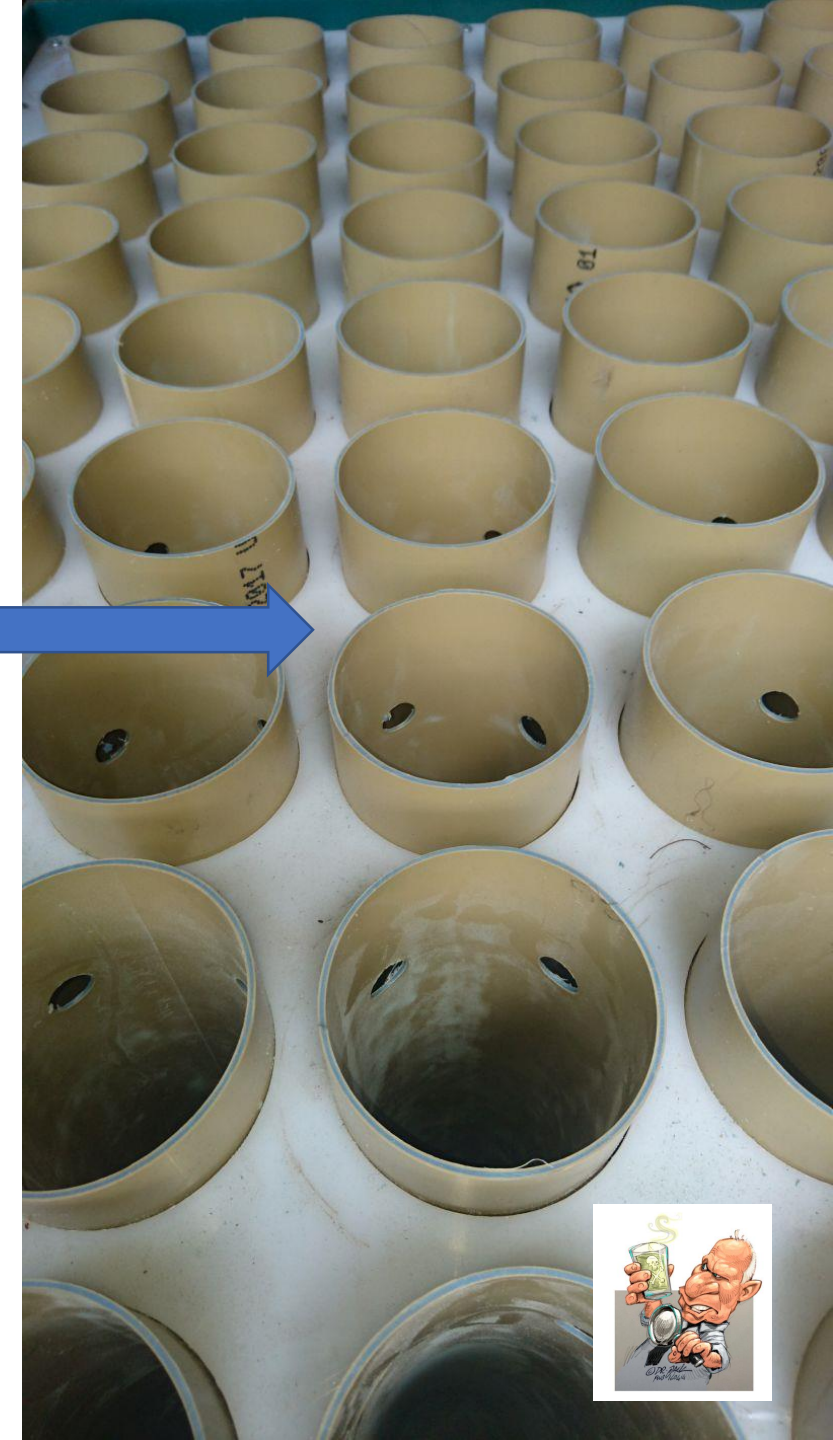


VUF-MEWS Configuration

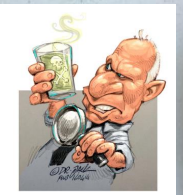
Dense root development forming a **peat plug** with large active **periphyton surface area** (First Generation Prototype).

High cell density (Second Generation Prototype) with isotropic flow in each cell.

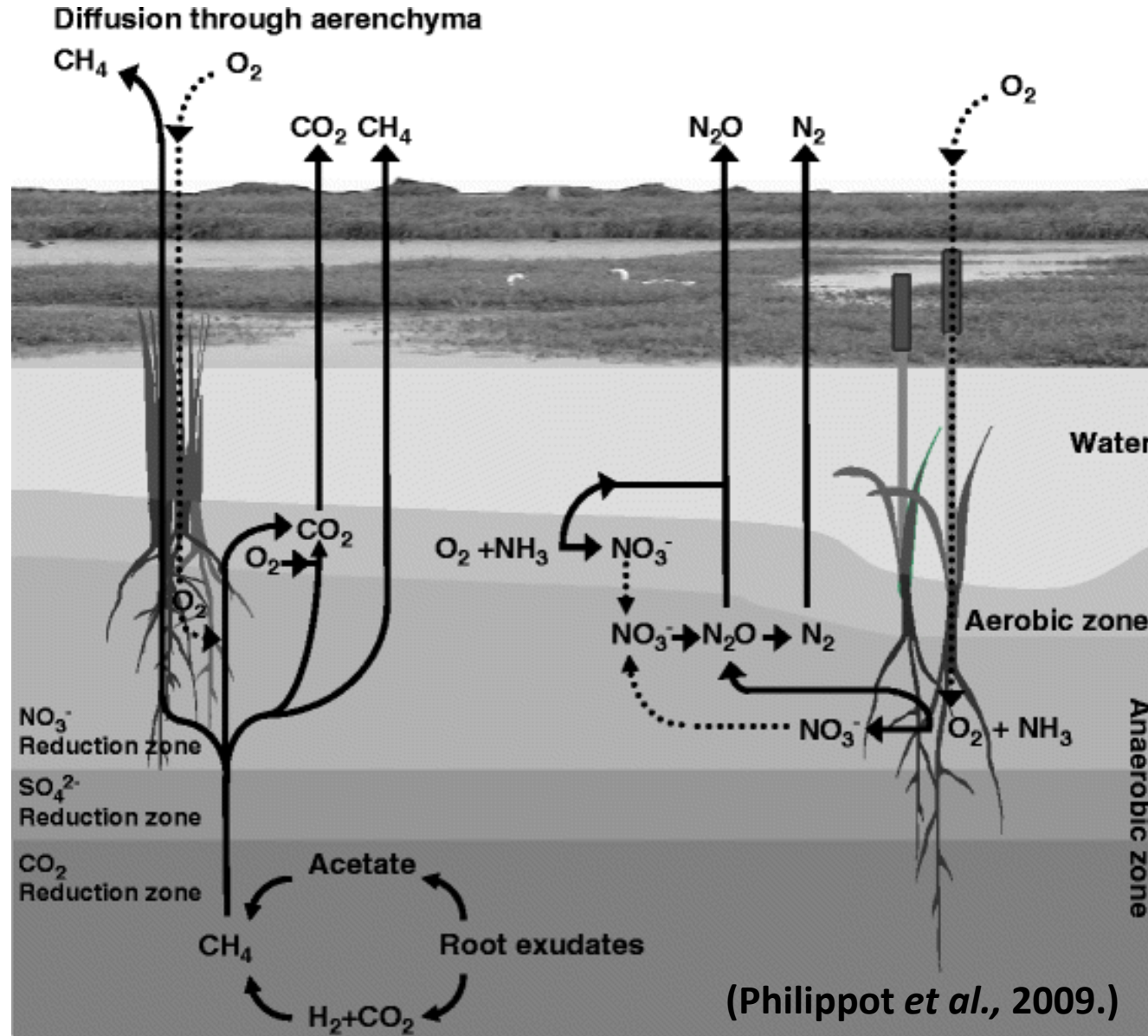
Modular design (Second Generation) means **scalability** and *integration* into **landscape** and **architectural design**.



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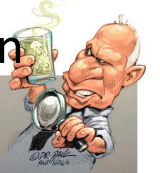
Engineering Specific Redox Conditions



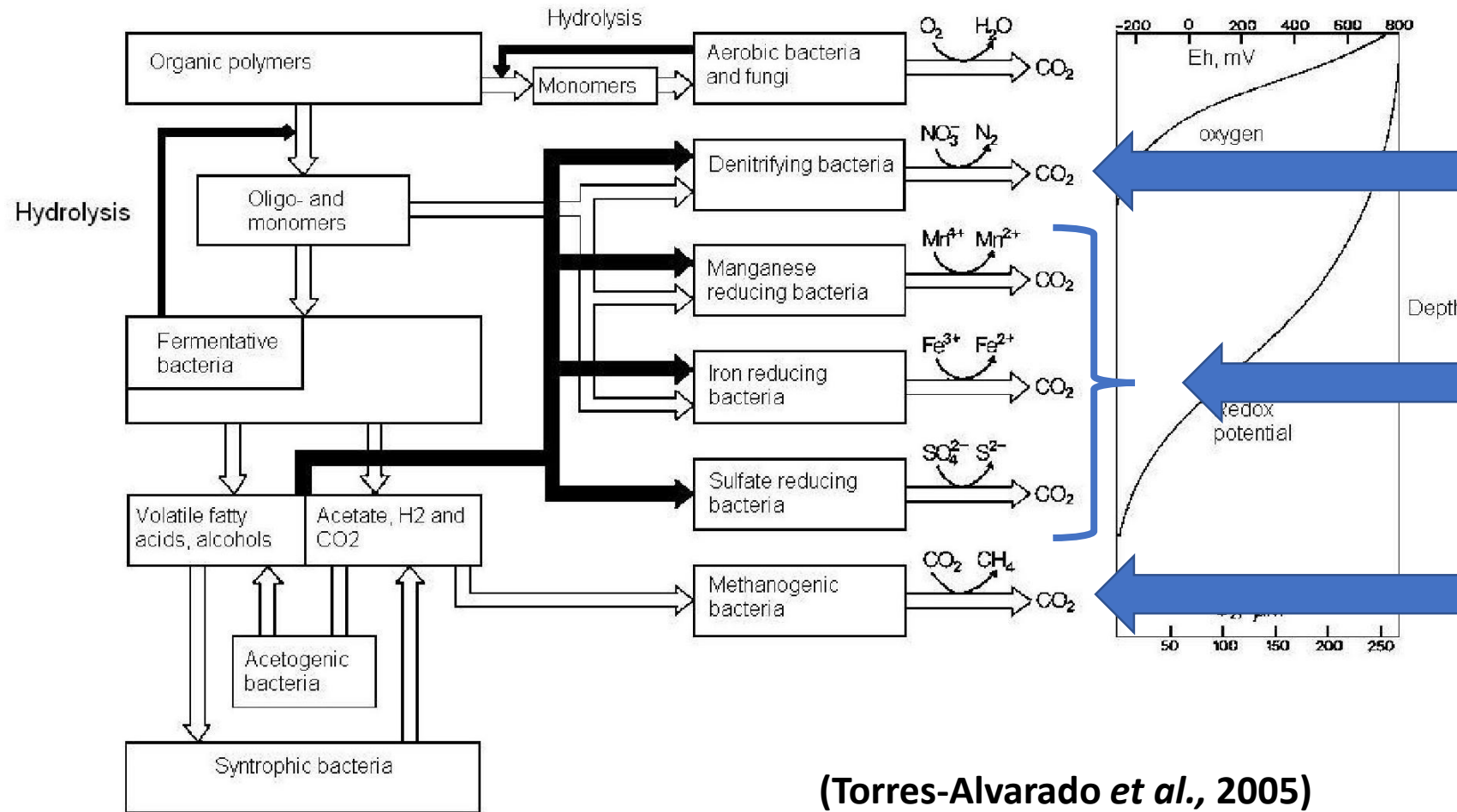
Depending on the need, **Redox conditions can be optimized** by design and the selection of specific parameters.

Aerobic conditions generally result in faster metabolization with reduced retention time, but are unable to deal with specifics like metals.

Anaerobic conditions facilitate denitrification and sustain colonies of Sulphate Reducing Bacteria (SRB) iron and manganese metabolization (Thamdrup B. 2000).



Degradation Pathways in Engineered Wetlands



For **nitrification** of nutrient-rich effluent **aerobic conditions** can be optimized.

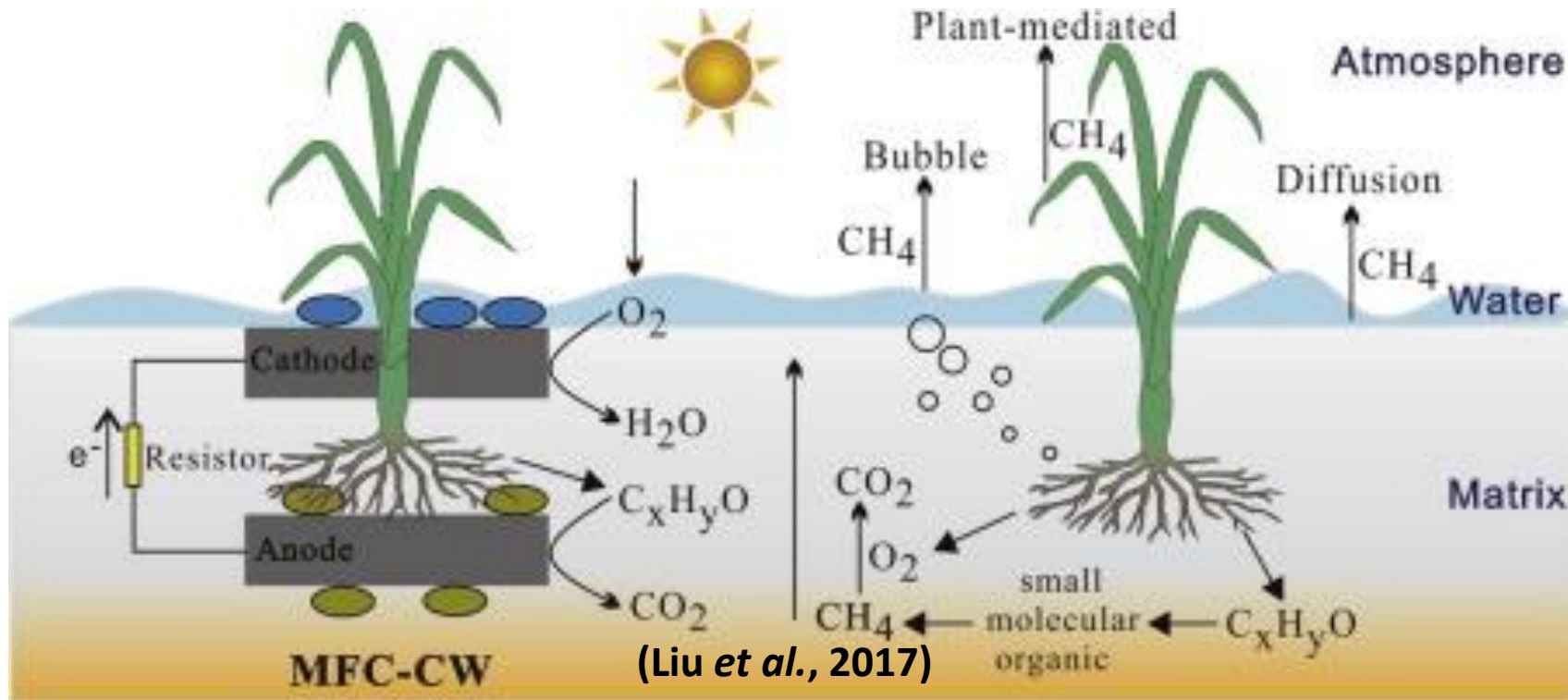
For **acidic mine waters** sulphate, iron and manganese reducing **bacteria** can be stimulated under **anoxic** conditions (Thamdrup B. 2000; Moreau *et al.*, 2013).

Methanogenic Archaea thrive under **anoxic conditions** so methane production can be reduced by changing the **redox parameters**.

Figure 1. Main pathways in the degradation of organic matter in wetlands (Westermann, 1993b).



Engineered Wetlands and Electrical Polarity



A **Microbial Fuel Cell Coupled Constructed Wetland (MFC-CW)** has shown that methane emissions can be significantly reduced (Liu *et al.*, 2017).

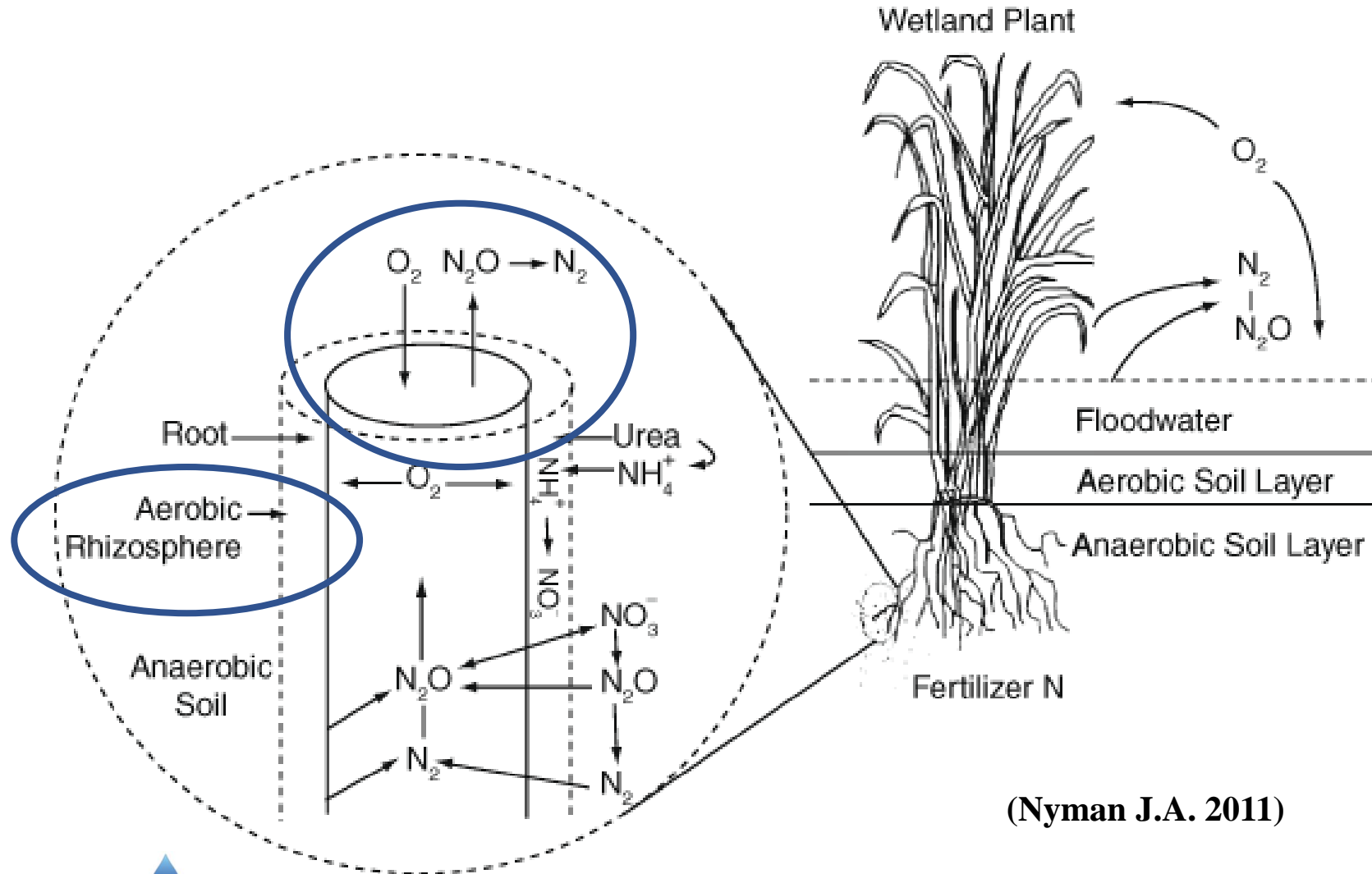
Electrogenesis and **methanogenesis** can co-exist in harmony (Liu *et al.*, 2017).

By exposing influent to an **electromagnetic field (EMF)** is it possible to alter **methanogenesis** (Enigma)?

The bioanode is an inexhaustible source of electron acceptors that reduces methane emissions owing to electricigens outcompeting methanogens for carbon and electrons when substrate is deficient (Liu *et al.*, 2017).



Aerobic Conditions in an Anoxic Environment



(Nyman J.A. 2011)

Roots create a **pathway for oxygen and nitrogen transport** into the water being treated in an engineered wetland.

This creates **aerobic conditions in the rhizosphere**.

It is possible to **preselect specific Archaea, Bacteria and Fungal combinations** for specific treatment conditions.

In advanced applications it is possible to **genetically engineer the microbiota** to metabolize complex toxins (Saleem *et al.* 2017).

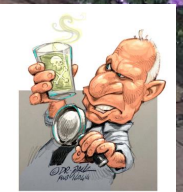
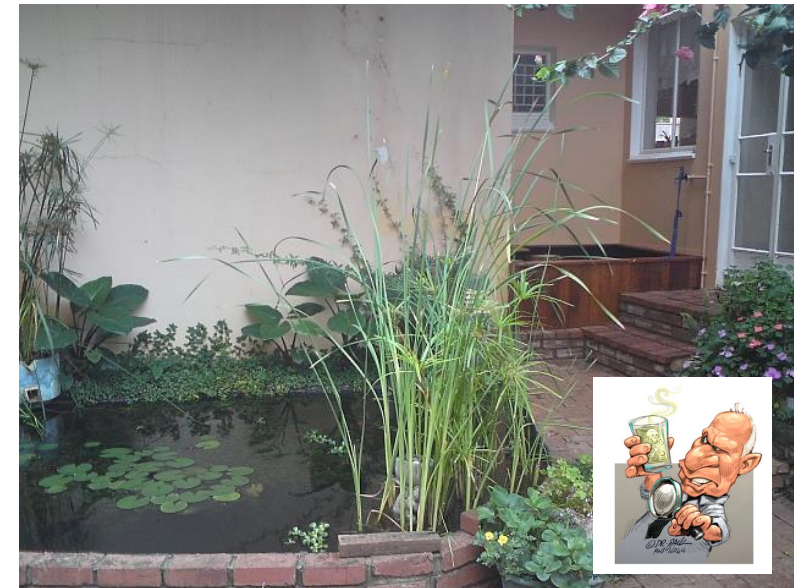


Pulsed Wetland Design

Interstitial spaces in **substrate** are forced to “**breathe**” creating large contact area.

Highly reliable (this unit has worked without stoppage for almost 10 years) **with minimal maintenance.**

Suited for **architectural and landscape application** but scalable to industrial use.



Commercial Applications

- Useful **component** in a **recycling system** treating grey water to safe non-potable standards for **discharge to the environment** or **re-use for flushing**.
- Ideal for inclusion in **architectural or landscape applications** opening **new markets with clients other than the state (real estate developers)**.
- **Scalable** to **industrial applications** with **modular design** enabling a range of **macrophytes** and **microbiota** to be used for **targeted treatment**.
- Major value is in **real estate development** where **optimization of natural wetland use can be offset** by providing appropriate **ecosystem services** in a **quantifiable manner**.
- **Remediation of passive mine water flows** using specific archaea and Redox conditions.
- Septic tank or **package plant effluent management** where cumulative impact is a limiting factor on license conditions.



Advantages and Disadvantages

- **Modular design** allows for **scalability** from small to large installations.
- Ease of **incorporation** into commercial and residential real estate as a key **element of architectural and/or landscape design**.
- **Mosquito-free** habitat for avifauna.
- **Small footprint** due to **high cell density** and large **rhizosphere contact** area.
- **Low maintenance** requirements over time.
- **Peat plug disposal of hazardous contaminants** if the need arises.
- Can become **part of urban design** with urine separation toilets.
- **Quantifiable offset benefits** for ecosystem services as part of **business case**.
- Can be **inoculated** with genetically engineered or **pre-selected microbiota**.
- Disadvantage is **the seasonality of performance (site selection is critical)**



The Vertical Up Flow - Modular Engineered Wetland System (VUF-MEWS) is a solution to specific water treatment problems where **modular flexibility enhances architectural and landscape design objectives with a range of commercial applications**

Thank You



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