# Natural Systems for Water and Wastewater Treatment and Reuse

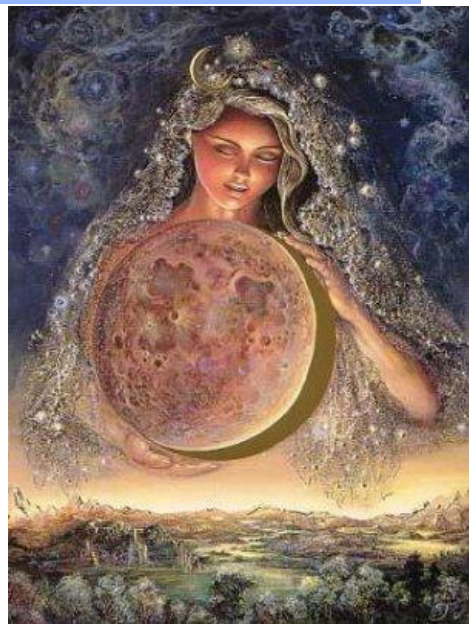
**Saroj Sharma and Diederik Rousseau**

**UNESCO-IHE, Delft, The Netherlands**

**SWITCH Scientific Conference**

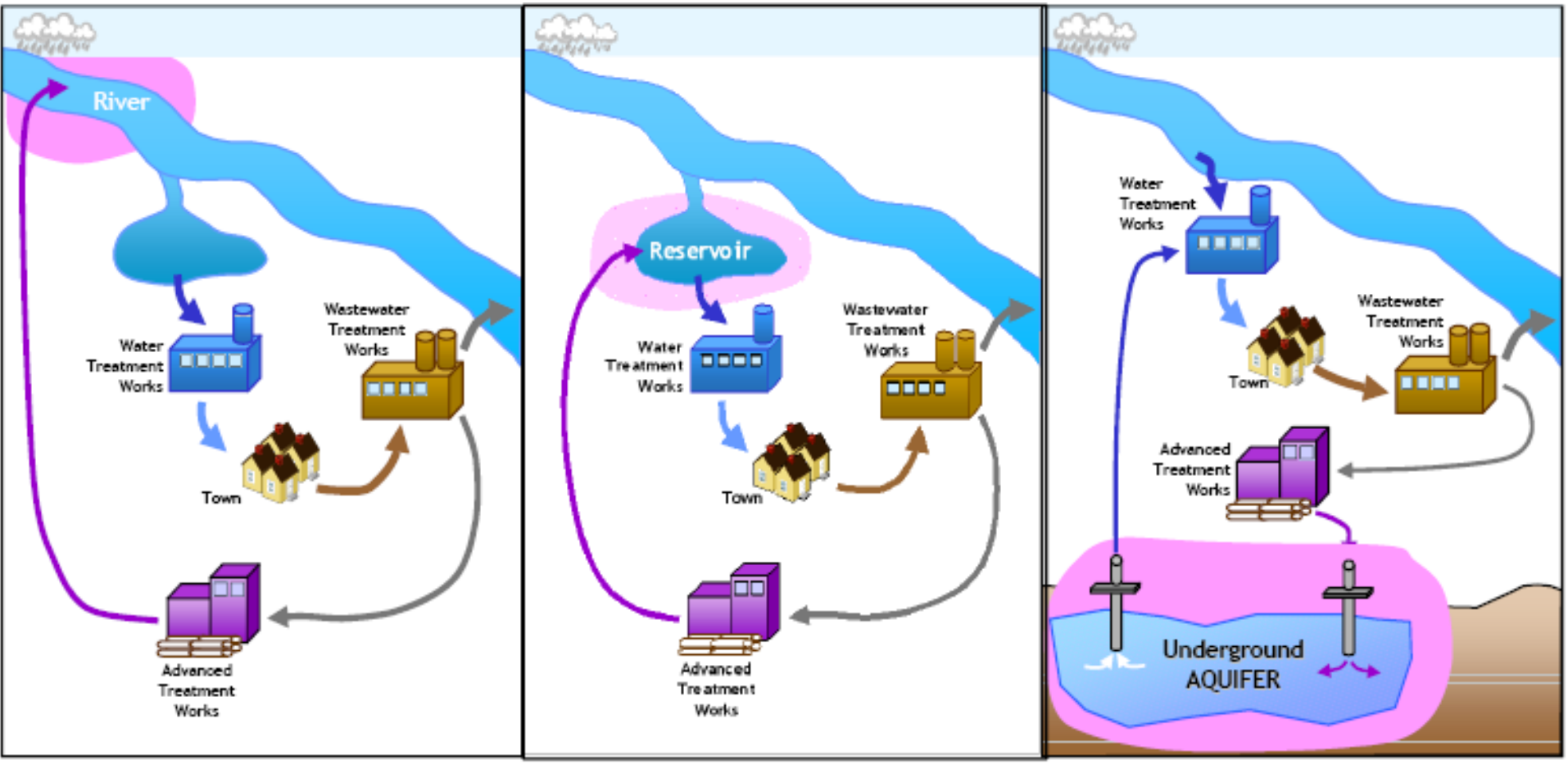
**24-26 January 2011, Paris (France)**

# Natural Treatment Systems



- **Doing it Gaia's way**
- Utilizing natural elements, features and processes (soil, vegetations, micro-organisms, water courses …)
- Integrating treatment and environmental functions (Multi-functional)
- Robust and flexible (adaptive)
- Mutiple-contaminant removal
- Minimising the use of chemicals and energy

# Preferences for Natural Systems Barrier (Environmental Returns)

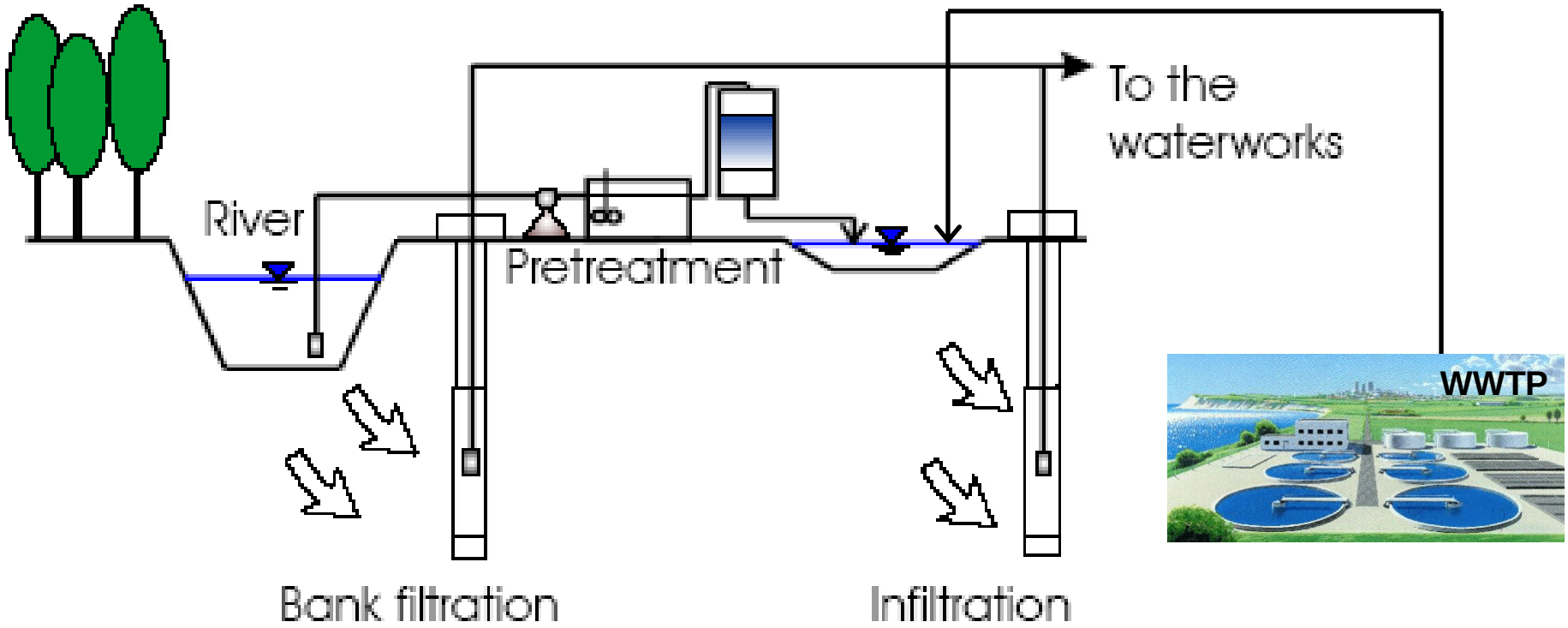


# Natural Systems for Treatment

| | | Water Treatment | Wastewater Treatment and Reuse |
|---|---|---|---|
| **Terrestrial System (Soil/Aquifer-based)** ***Managed Aquifer Recharge (MAR)*** | | 1. Bank Filtration<br>2. Artificial Recharge<br>3. Sub-surface GW Treatment | 1. Slow Rate Irrigation<br>2. Overland Flow<br>3. Soil Aquifer Treatment |
| **Aquatic System** | **Vegetation-based** (macrophytes) | | 1. Constructed Wetlands<br>2. Water Hyacinths |
| | **Pond-based** | (Storage Reservoirs) | 1. Anaerobic<br>2. Facultative (Algal ponds)<br>3. Aerobic<br>4. Maturation |

- **Hybrids** : Different combinations of natural systems and conventional systems
- **Commercial systems**: “Living Machines”, “Eco Restorers”
- From **decentralised** (household level) **to centralised** (city level) systems

# Bank Filtration, Infiltration and Soil Aquifer Treatment

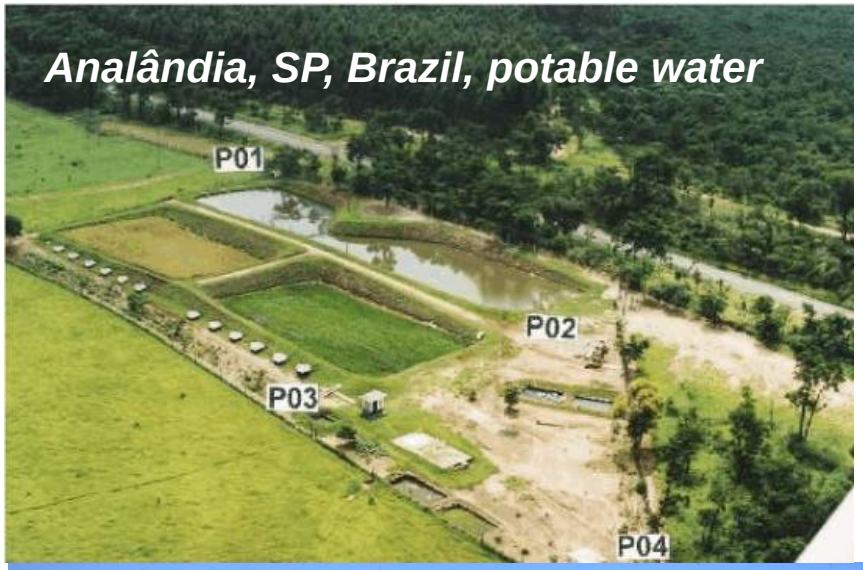



**River bank filtration (RBF)**
**Lake bank filtration (LBF)**

**Aquifer Recharge and Recovery (ARR)**
**Soil Aquifer Treatment (SAT)**

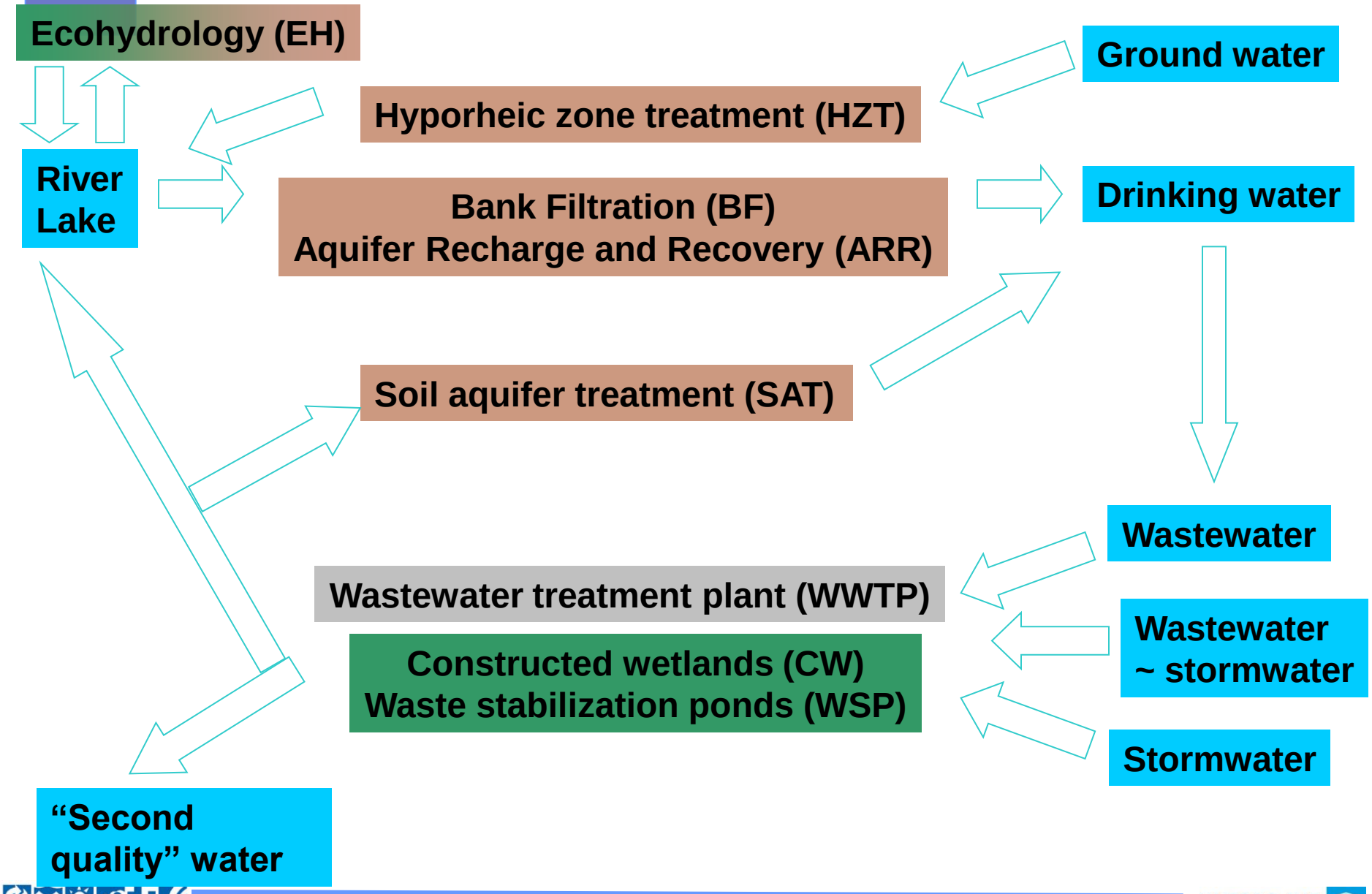
**(Source: Kuehn, 2003)**

# Constructed Wetlands and Waste Stabilization Ponds

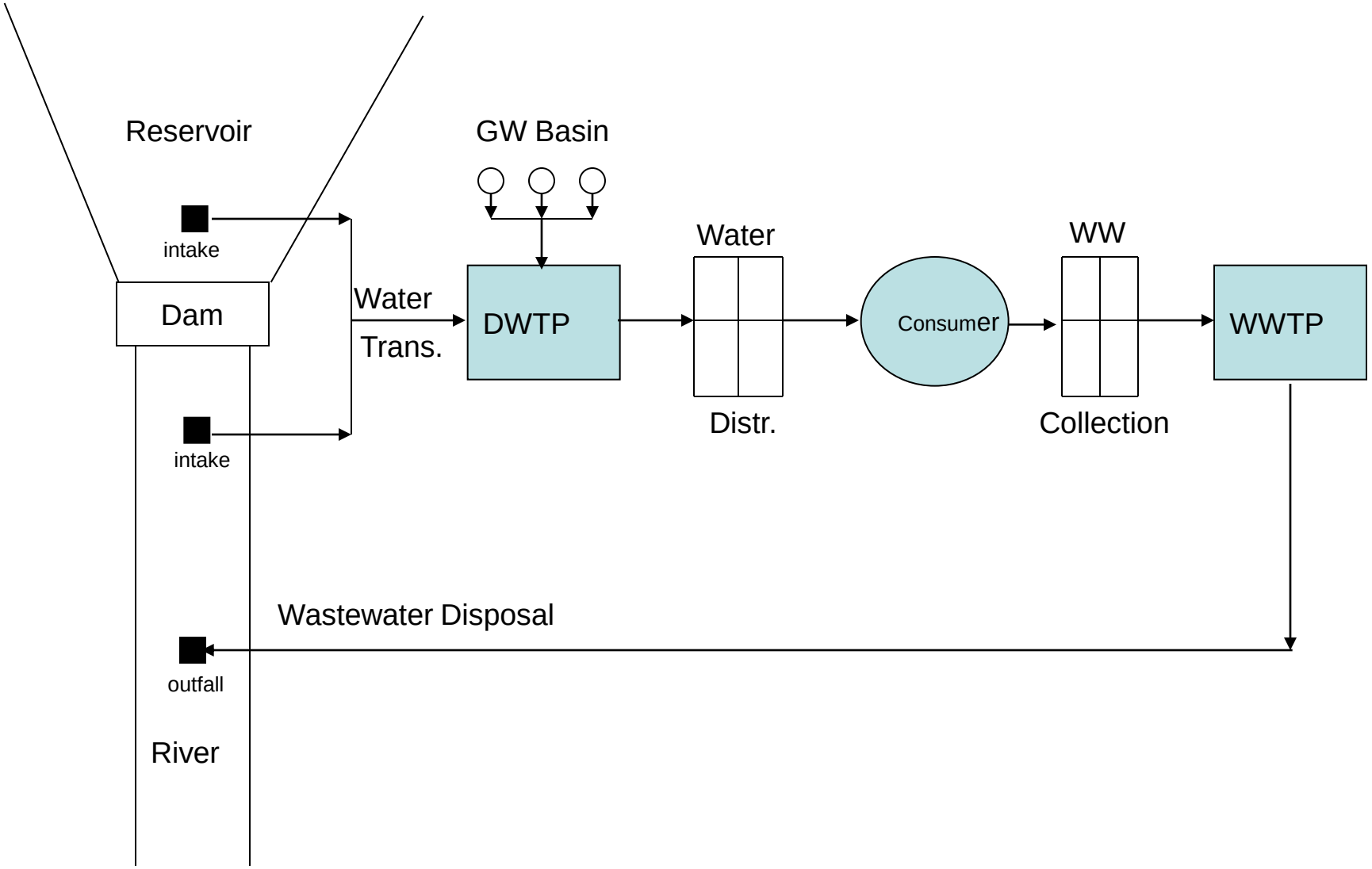





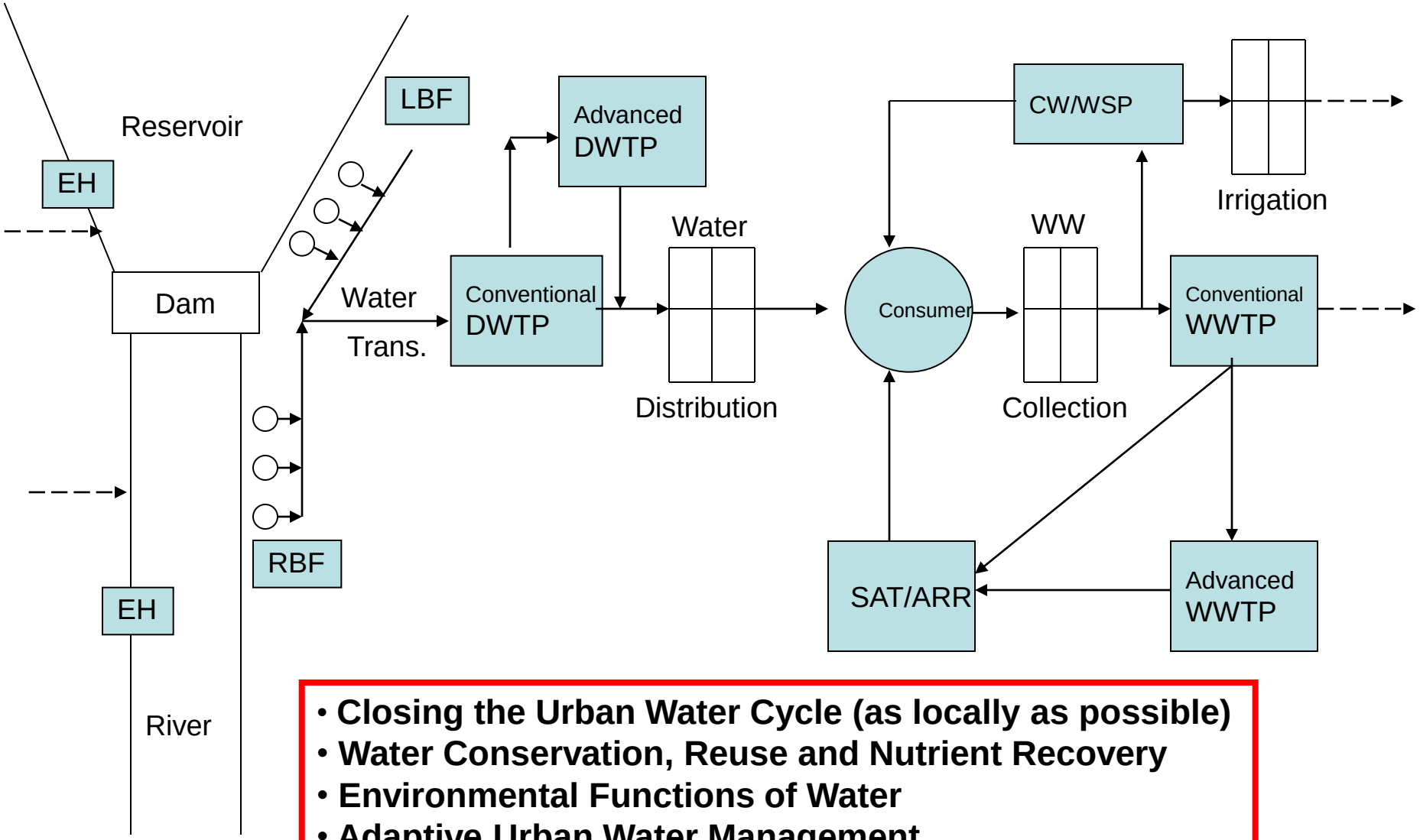
# Natural Systems for Treatment



# Traditional Urban Water Management : A *Linear* Approach



# Integrated Urban Water Management - *Cyclic* Approach




- **Closing the Urban Water Cycle (as locally as possible)**
- **Water Conservation, Reuse and Nutrient Recovery**
- **Environmental Functions of Water**
- **Adaptive Urban Water Management**

# Natural Systems Research in SWITCH Project

- **Analysis of robustness** of these natural systems for treatment of water/wastewater in the cities of the future

  - meeting water quality guidelines, emerging contaminants, water scarcity, climate change, energy crisis

- **Determination pre-treatment and post-treatment** required for a natural system for particular water use/reuse

- **Development of tools for selection** of appropriate natural treatment systems under given conditions

- **Disseminate the knowledge** on the benefits of and for the planning, design and O&M of natural systems for water and wastewater treatment

# Natural Systems Research in SWITCH Project

- **11 PhD and 36 MSc Studies involving Lab-, Pilot- and full-scale systems**
- **Key Outputs**
  - Prediction Tool of removal of organic micro-pollutants during bank filtration (SOMA)
  - Guidelines/DSS for selection of natural WWT systems
  - Guidelines for design, operation and maintenance of SAT and hybrid SAT systems
  - Manual for design, operation and maintenance of CW-EF hybrid system
  - Framework for ecohydrological (stimulation of self-purification) approach in cities (BOOK)

# Alternative Hybrid SAT Treatment – (MEKOROT)

## SAT+ NF for sustainable water reuse

Secondary effluent

**Sand Filter**

**SAT fields**

Reclamation well

**reservoir**

**NF**

filtrate

brine

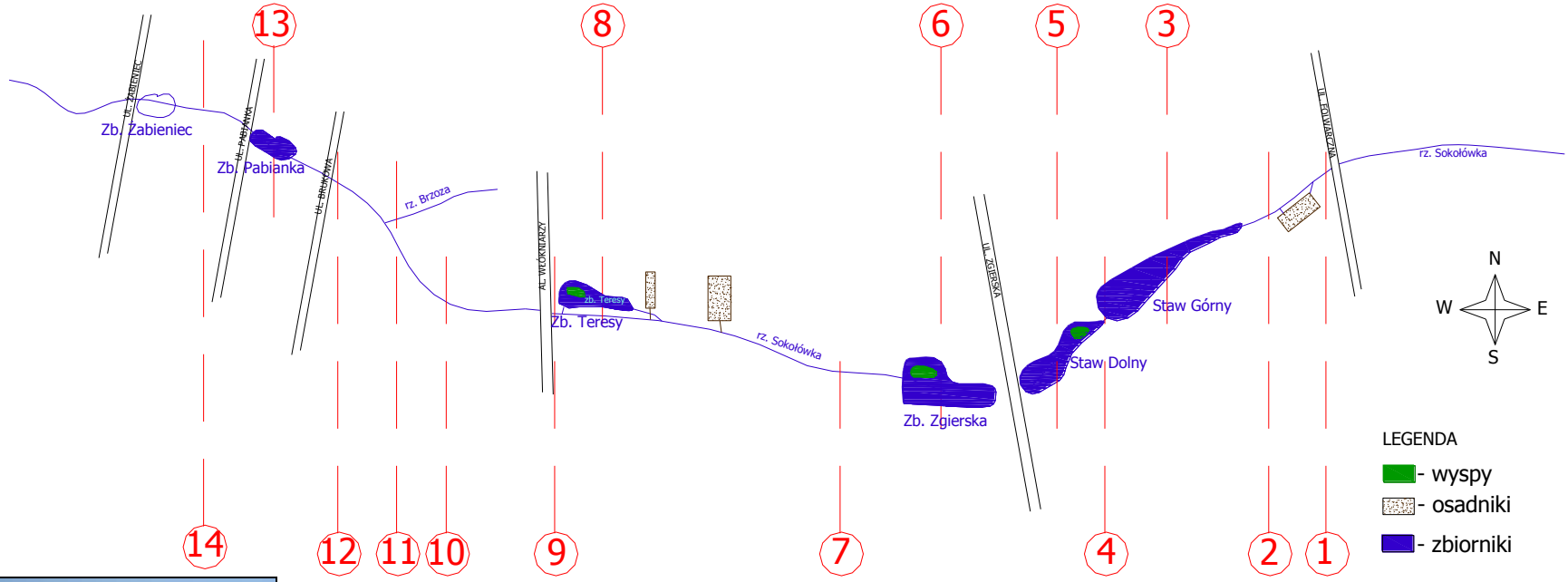
# Electroflocculation–Constructed Wetland Hybridization – Hebrew University of Jerusalem, Israel

- Removal of phosphorus and humics




# Ecohydrology Demo activities - Sokolowska river, Lodz

## - Floating islands and controlled flooding





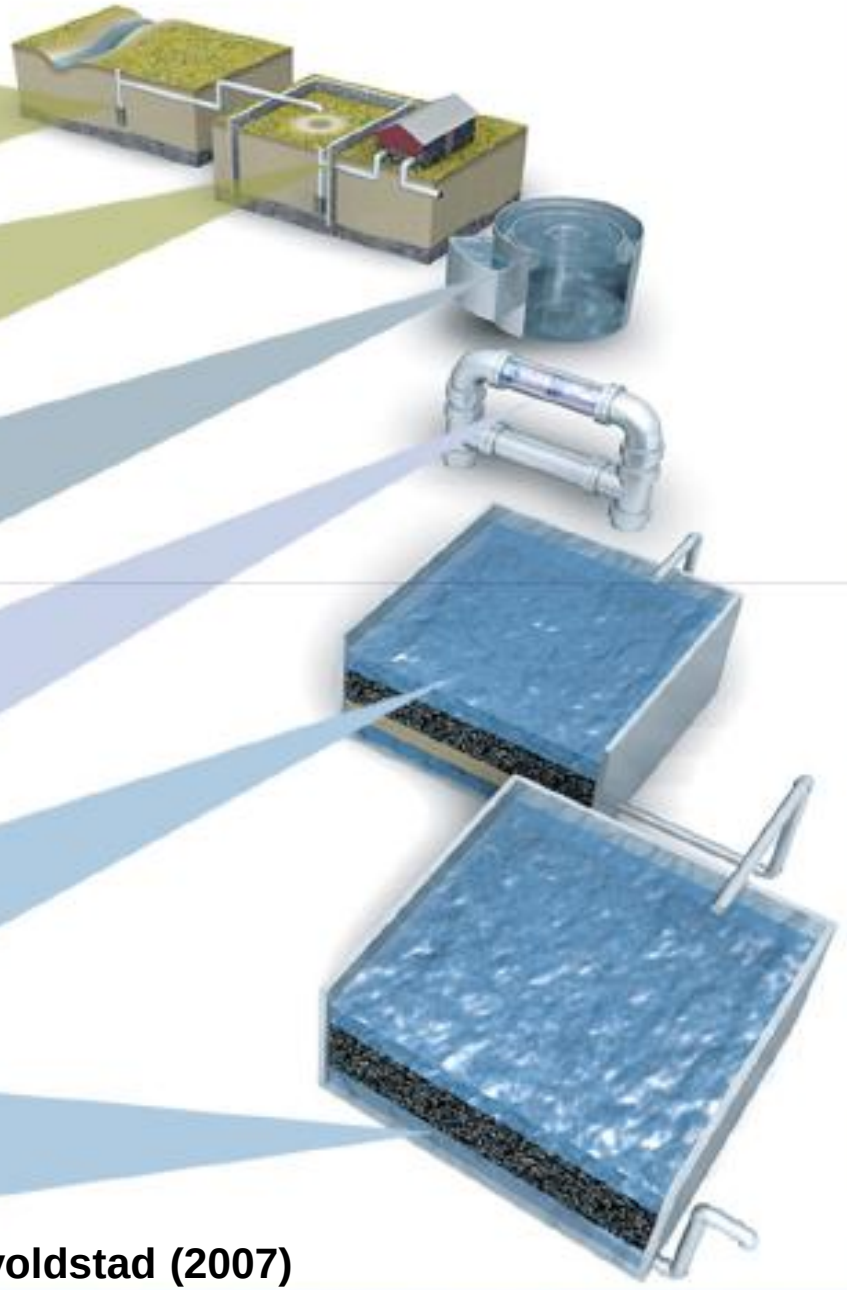



# Emerging Trends and Research Areas

- **Natural Treatment Systems for the Cities of Future**
  - closing the urban water cycle – locally
  - integration with environment; reduction of area required
  - climate change adaptations, reduction in energy use
- **Hybrid Systems for Water Treatment**
  BF/ARR as the first barrier:
  - BF + conventional treatment ($O_3$+ GAC)
  - BF + (ARR) + Membranes
  - BF + ARR + ($O_3$) + Biofiltration (GAC)
- **Hybrid Systems for Wastewater Reuse**
  - Constructed Wetlands + SAT ; WSP + SAT
  - (short term) SAT as pre-treatment for membranes
  - MF/UF + SAT + NF/RO
  - SAT + MF/UF + UV disinfection

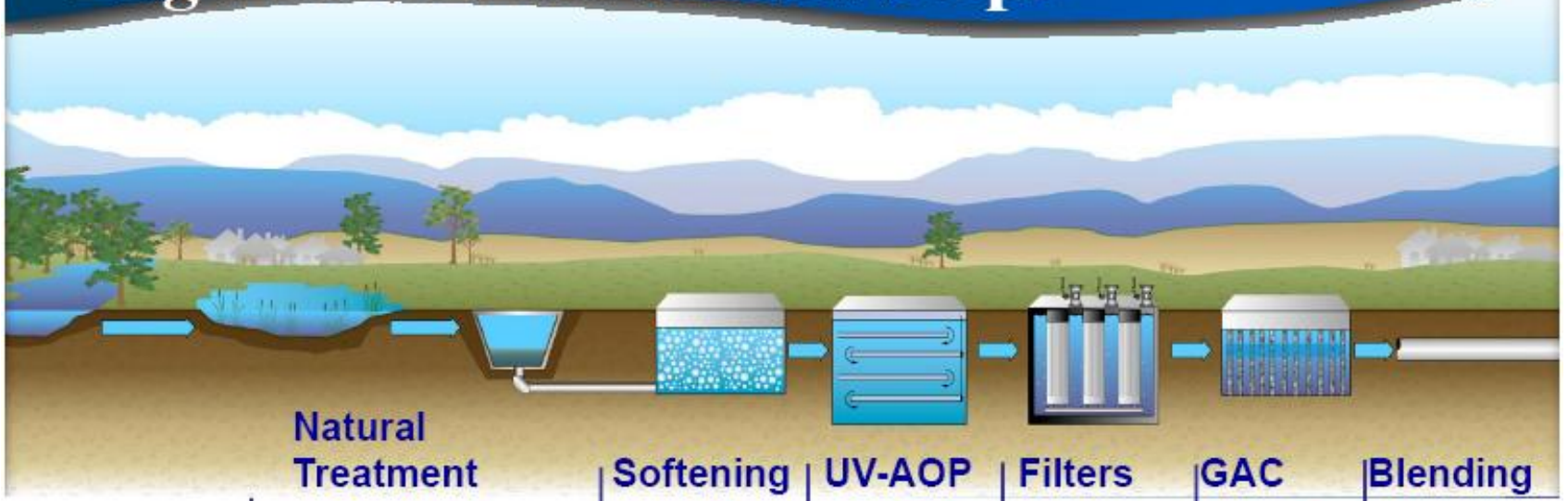
# Prairie Waters Project Multi-Barrier Purification Approach

1. Riverbank filtration extracts water from alluvium, and removes nitrate, pathogens, and trace organic chemicals in about 10 days of travel time.
2. Aquifer recharge and recovery provides additional travel time for additional removal of nutrients and trace organics.
3. Chemical softening reduces hardness, calcium, manganese, iron, and scaling potential.
4. High intensity UV light combined with hydrogen peroxide kills pahogens and oxidizes remaining trace organics.
5. Granular filters remove remaining particles and pathogens.
6. Granular activated carbon adsorbs remaining trace organics and improves taste.



Source: Ingvoldstad (2007)

# Combining the Best of Natural and Engineered Purification Steps



| | Natural Treatment | Softening | UV-AOP | Filters | GAC | Blending |
|---|---|---|---|---|---|---|
| Taste and Odor | ✓ | ✓ | ✓ | | ✓ | |
| Color | ✓ | ✓ | ✓ | | | |
| TDS | | | | | | ✓ |
| Nitrate | ✓ | | | | | |
| Pathogens | ✓ | | ✓ | ✓ | | |
| Organics | ✓ | ✓ | | | ✓ | |
| Micro-Pollutants | ✓ | | ✓ | | ✓ | |

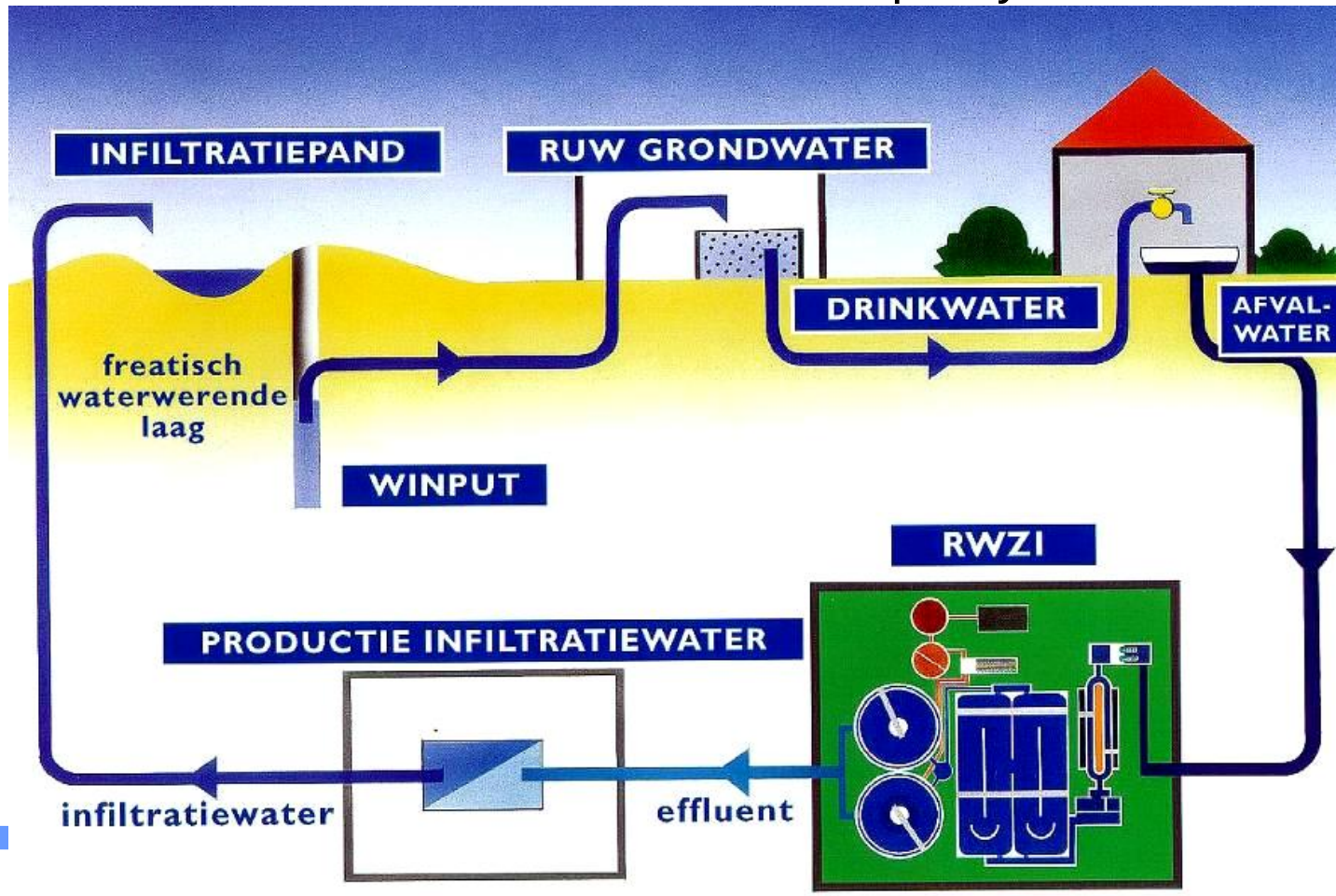
**Source: Binney (2006)**

# Water Reclamation System, Wulpen/Torreele, Belgium

Pre-treatment: Tertiary Effluent + Dual Membrane (UF/RO + UV)
MAR method: Pond infiltration
Water use: Indirect Potable (Re)Use

Capacity: 6,850 m³/d

**Source: Wintgens (2008)**
**RECLAIM WATER**

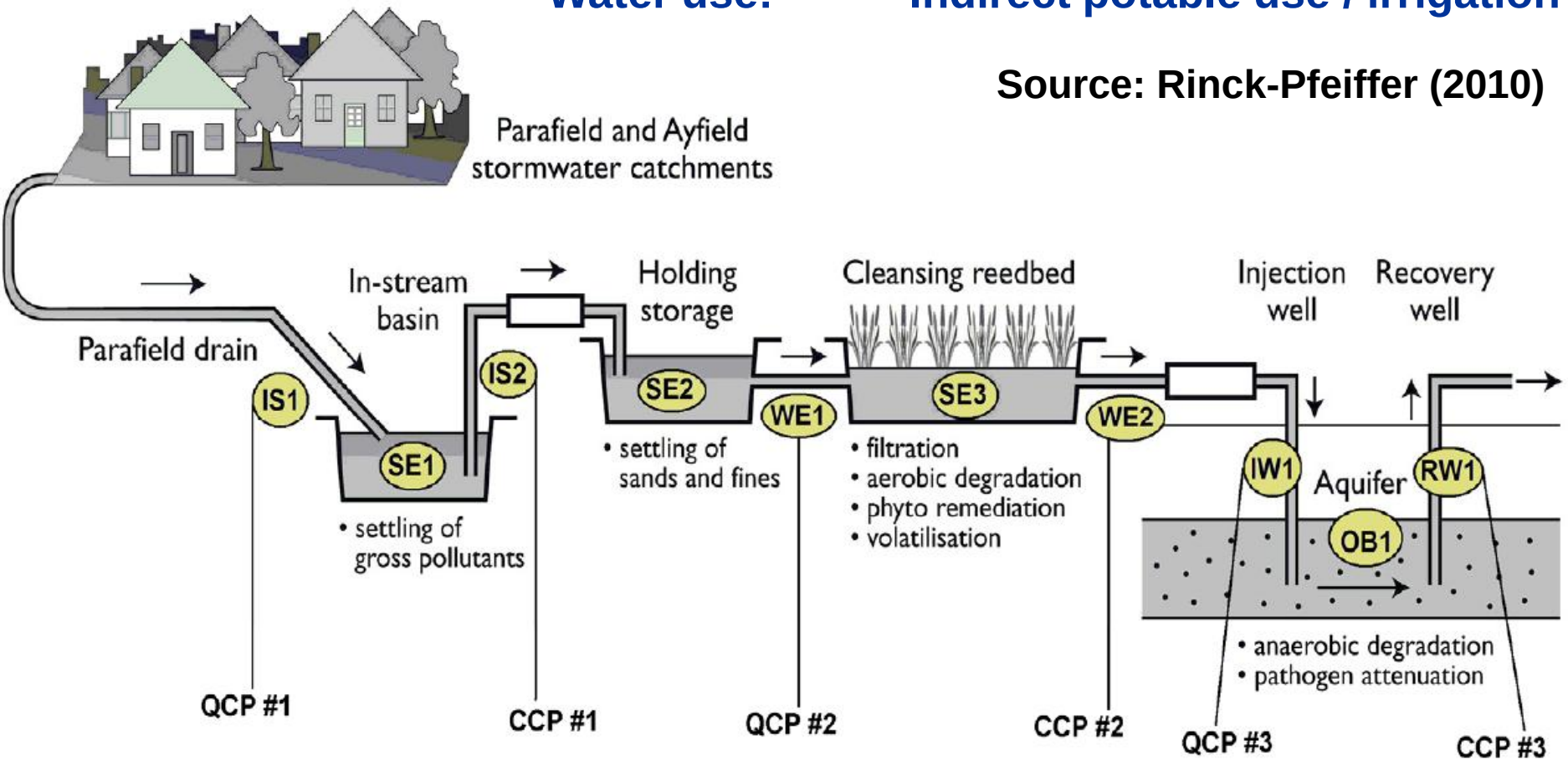



SWITCH

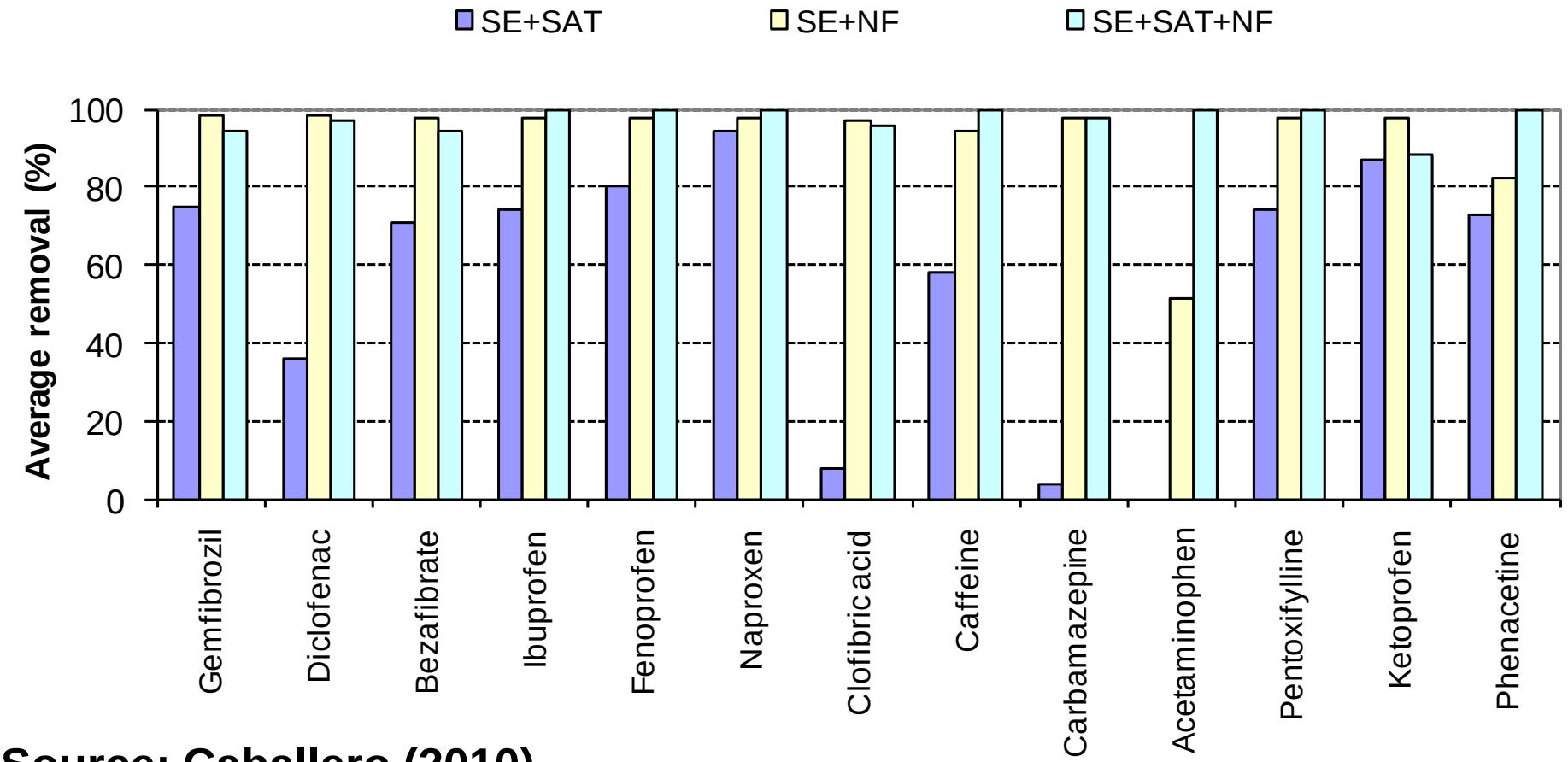
# Stormwater Reuse System - City of Salisbury (Australia)

**Pre-treatment:** Stormwater storage + wetlands
**MAR method:** Direct injection for ASTR
**Water use:** Indirect potable use / irrigation

**Source: Rinck-Pfeiffer (2010)**



# Comparison of the Removal of the Selected Pharmaceuticals from Secondary Effluent in Different Treatment




**Source: Caballero (2010)**

# What should be done to Promote Natural Treatment Systems?

- **Development of Design Guidelines, Nomographs, Software, Decision Support Systems for Application**
- **Including, and Officially Recognizing Natural System Technologies for Water and Wastewater Treatment**
- **Information Dissemination: Making Design Engineers, Planners and Educators aware of the Potentials of Natural System Technologies (training and capacity building; demonstration)**
- **Networking among professionals involved in Natural System Technologies (at different levels) for information sharing and collaborative research**

# Conclusions

- **Natural Systems have high potential for application in water and wastewater treatment as wells in improvement of water quality of urban rivers in cities of future.**

- **Natural Systems are robust, flexible and can be used in different scale as pre-treatment, main treatment (without or in combination of conventional treatment systems) or for post treatment.**

- **Natural Systems can remove multiple contaminants, use minimum energy and chemicals, and promote water reuse and nutrient recovery.**

- **Selection of appropriate types of natural systems and adaption of their design and O&M is required to suit the local conditions and intended use of the treated water.**

# Acknowledgement


- EU SWITCH Project no 018530-2 under the Sixth Framework Programme


- For further information please visit:

  www.switchurbanwater.eu

  www.unesco-ihe.org

- THANK YOU FOR YOUR ATTENTION!