



ITU-SUDACAD Regional Forum on Internet of Things for Development of Smart and Sustainable Cities

Khartoum, Sudan 13-14 Dec 2017

Emerging and Environmental Trends and Challenges of Water Resources in Smart Cities

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ITU expert



Outline:

The Water Cycle

Is there enough Renewable Freshwater Resources (RFWR)?

Smart Management of the Fresh Water Resources (Conventional and Non- Conventional Water Resources)

Conventional Water Resources

- **Surface water (Fresh & Saline)**
- **Groundwater**

Non-Conventional Water Resources

- **Frozen water (Icebergs)**
- **Rainwater harvesting & flood management**
- **Recycle of the residential water (black and greywater)**
- **Smart water irrigation, smart water agriculture, smart water industry**
- **Reforming water policies**

Integrated Water Resource Management (IWRM)

Case Study (South Korea)

The Water Cycle

The water on the Earth flows from the atmosphere to the ground. And then from the rivers to the sea, from where it returns to the atmosphere.

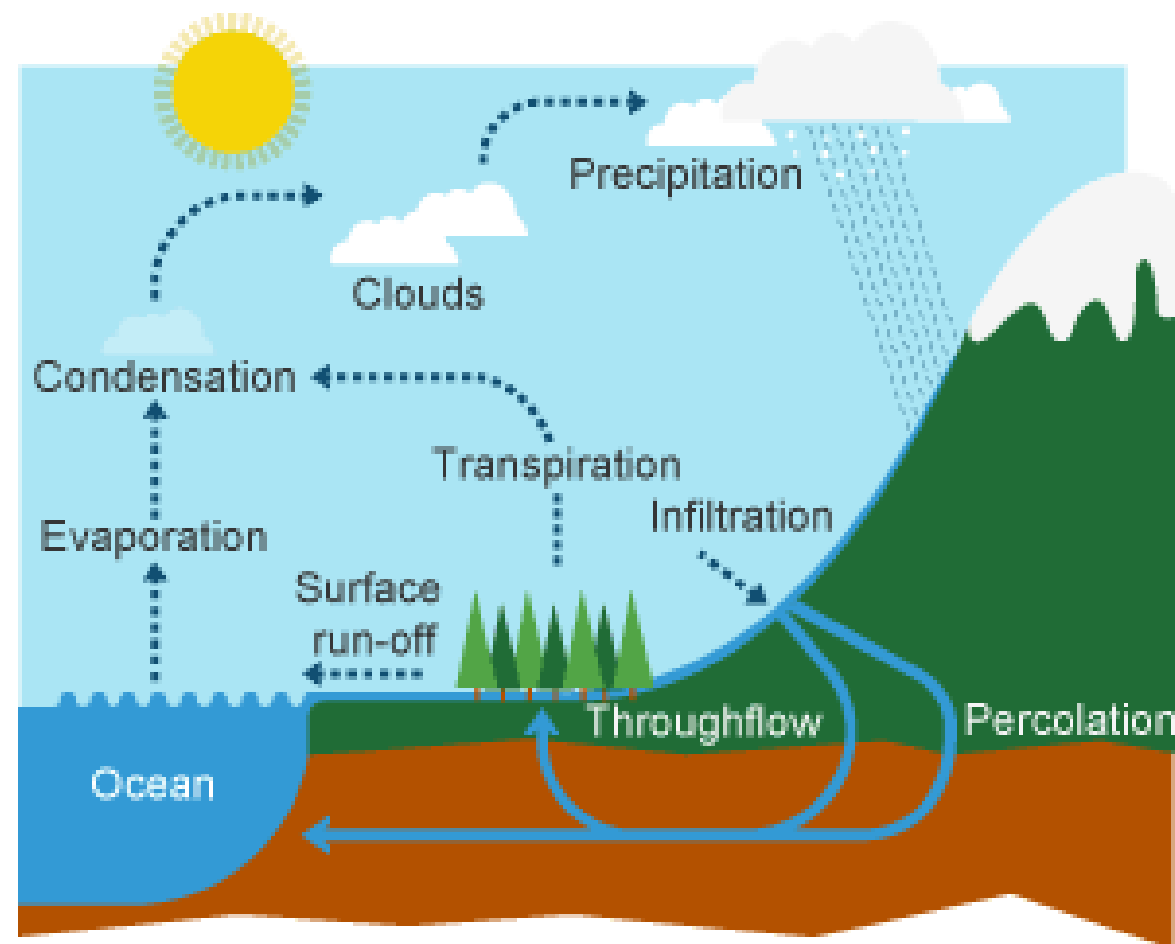
Horizontal Flows: Water runoff on the surface.

Vertical Flows: Water infiltration and evaporation.

Blue Water: Surface water and groundwater

Green Water: Soil water, available for plants

White Water: Atmospheric water





The Water Cycle

Collocation	Area covered [$10^6 km^2$]	Volume [$10^6 km^3$]	%	% of fresh water
Oceans	361.300	1.338	96.5	-
Groundwater	134.8	23.4	1.7	-
Fresh grundwater		10.530	0.76	30.1
Soil humidity	82	0.0165	0.001	0.05
Perennial ice and snow	16.2275	24.0641	1.74	68.7
Antarctic	13.980	21.600	1.56	61.7
Greenland	1.8024	2.340	0.17	6.68
Arctic islands	0.2261	0.0835	0.006	0.24
Mountain areas	0.224	0.0406	0.003	0.12
Permafrost	21	0.3	0.022	0.86
Water in lakes	2.0587	0.1764	0.013	-
Fresh water in lakes	1.2364	0.091	0.007	0.26
Salt water in lakes	0.8223	0.0854	0.006	-
Lagoons and swamps	2.682.6	0.01147	0.0002	0.006
Rivers	148.8	0.00212	0.0002	0.0006
Water in living beings	510	0.0012	0.0.0001	0.0003
Water in the atmosphere	510	0.0129	0.001	0.04
Water total	510	1385.98561	100	-
Fresh water total	148.8	35.02921	2.53	100

Data Source: Global Change in the Geosphere-Biosphere, NRC.



Looking to our neighbors

The Water Cycle

- Sustains Life on Earth
- Shapes the Surface of the Earth
- Regulates the Climate

Venus



96.5% CO₂
3.5% N₂

Earth



78 % N₂
31% O₂

Mars



93.5% CO₂
2.7% N₂

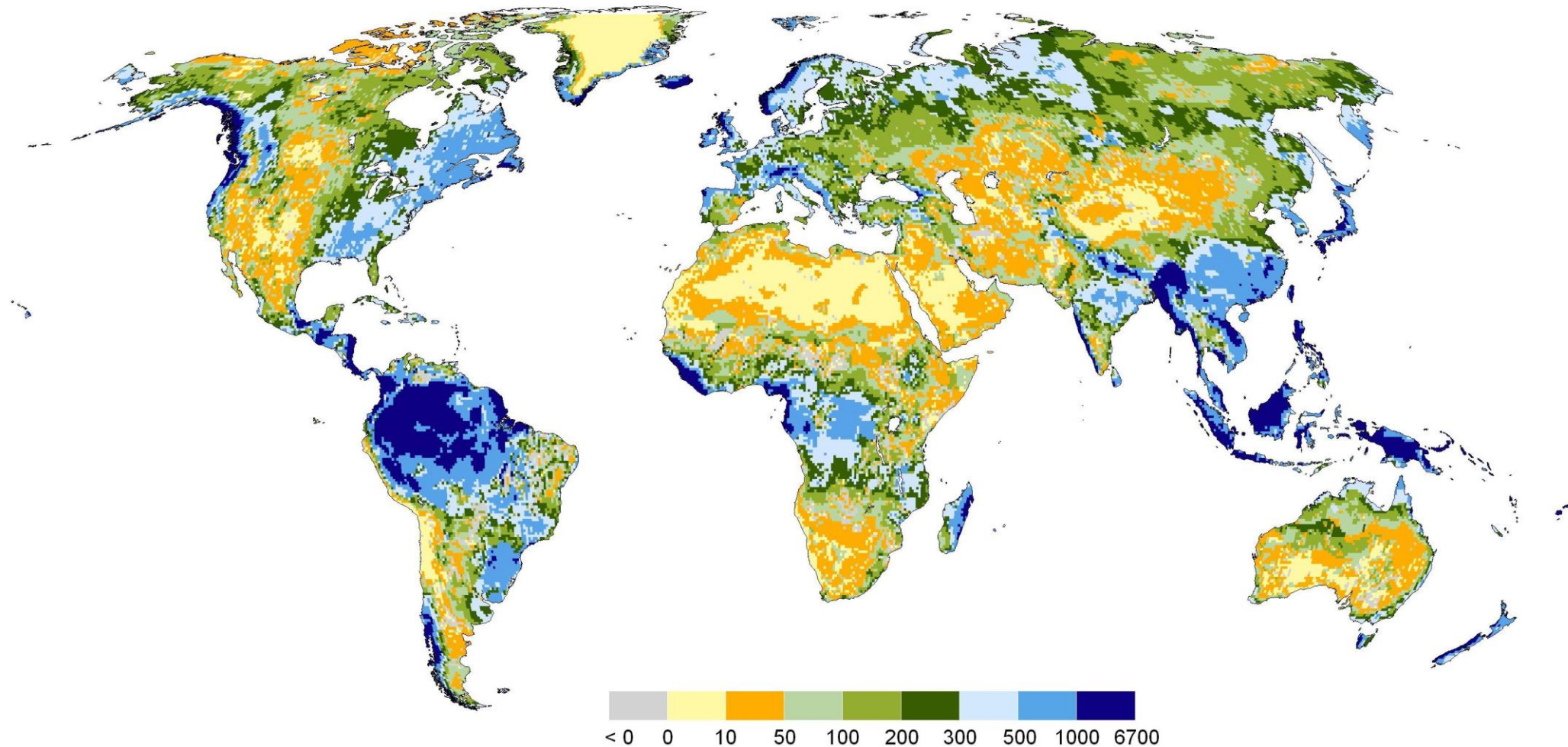
No one has very much Oxygen and Water

Is there enough Renewable Freshwater Resources (RFWR)?

- Driven by increasing populations (the world population rises by approximately 200,000 a week), growing urbanization, changing lifestyles, and economic development, the total demand for freshwater in urban areas is rising dramatically.
- According to a World Bank study (2007), the renewable fresh water availability per capita is expected to halve by 2050 (relative to 2007), due to climate change which makes many regions hotter and drier.
- Water stress and water scarcity challenges will have a severe economic and social implications. Noteworthy, the challenges for governments and water utilities are not only to increase the absolute volume of the freshwater supply but also optimizing the efficiency of water use and distribution.



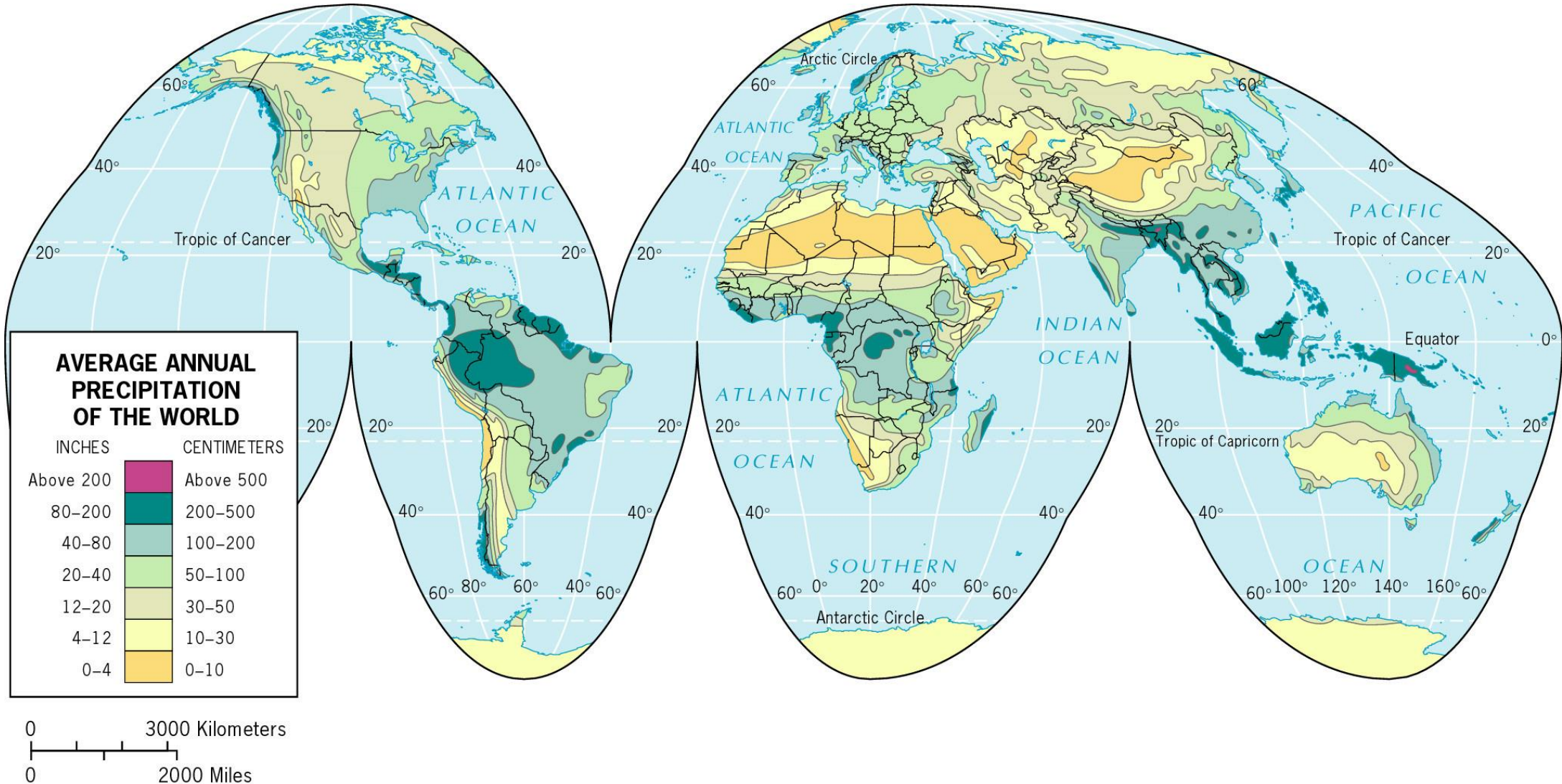
Is there enough Renewable Freshwater Resources (RFWR)?



Total renewable freshwater resources of the world, in mm/yr (1 mm is equivalent to 1 l of water per m²)

Source: Döll, P., Fiedler, K. (2008): [Global-scale modeling of groundwater recharge](#). Hydrol. Earth Syst. Sci., 12, 863-885.

Is there enough Renewable Freshwater Resources (RFWR)?

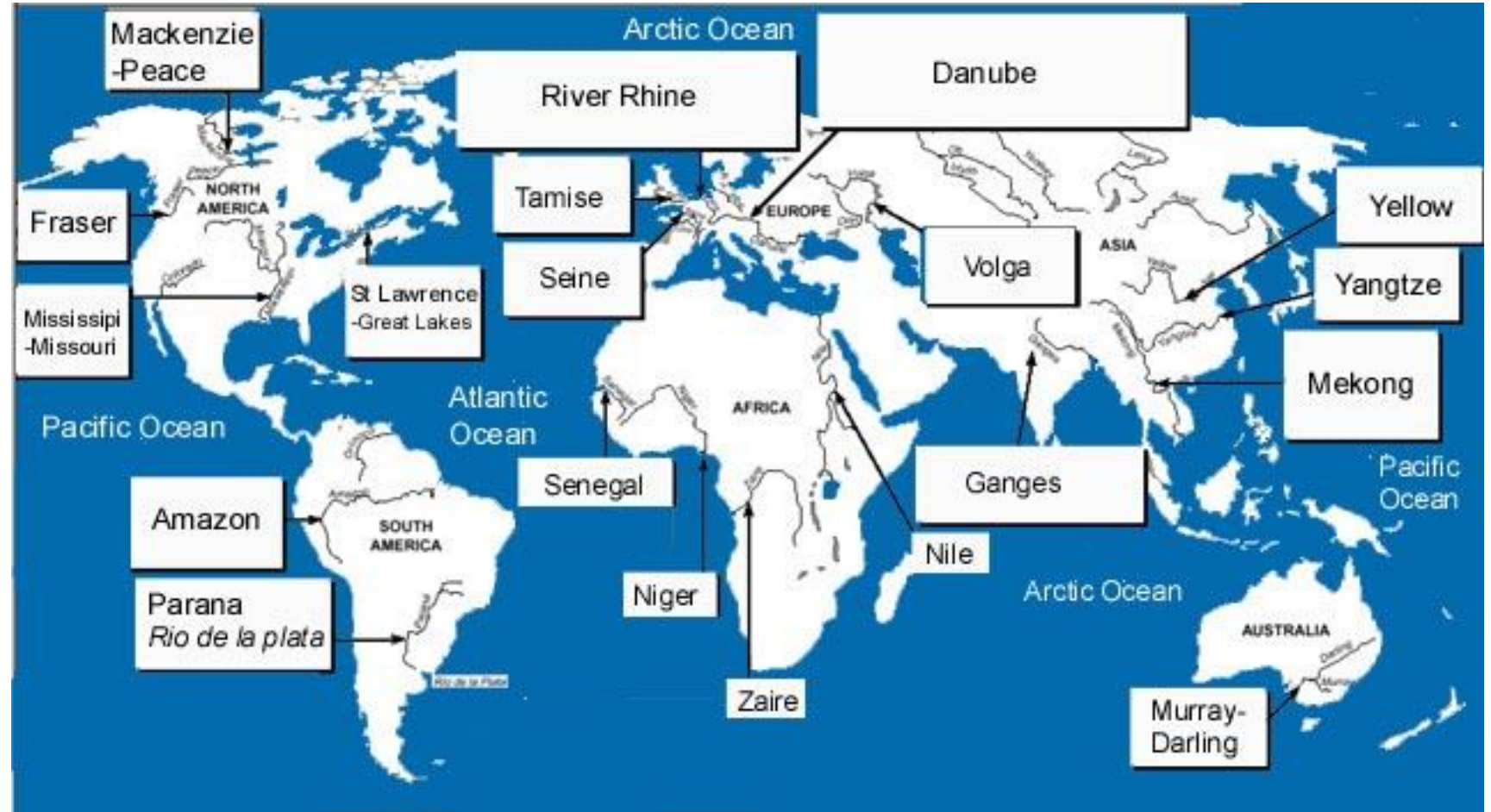


Distribution of Mean Annual Precipitation

Is there enough Renewable Freshwater Resources (RFWR)?

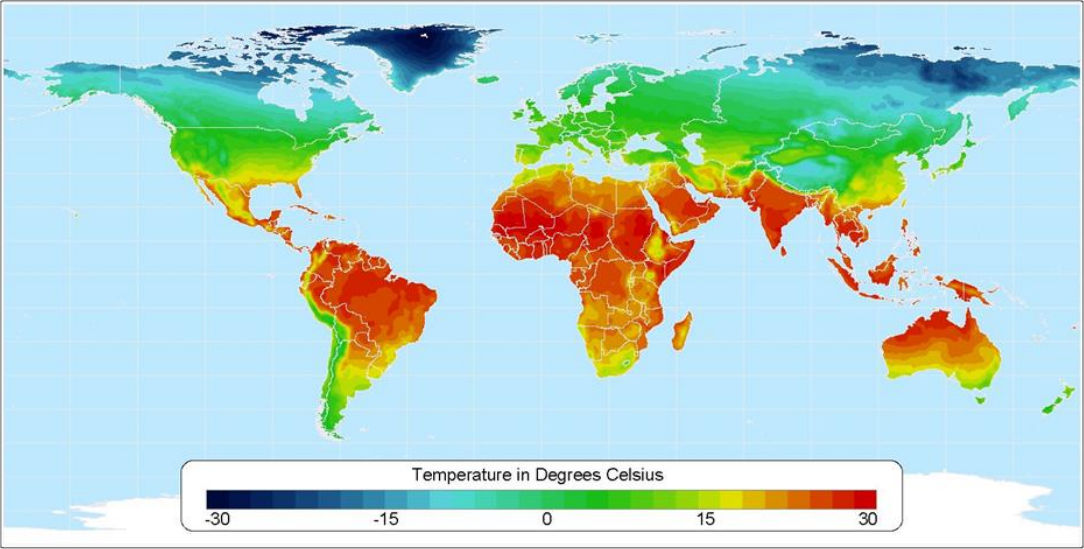


Rivers have been, and remain, our most vital water infrastructure.



The Largest Rivers on Earth

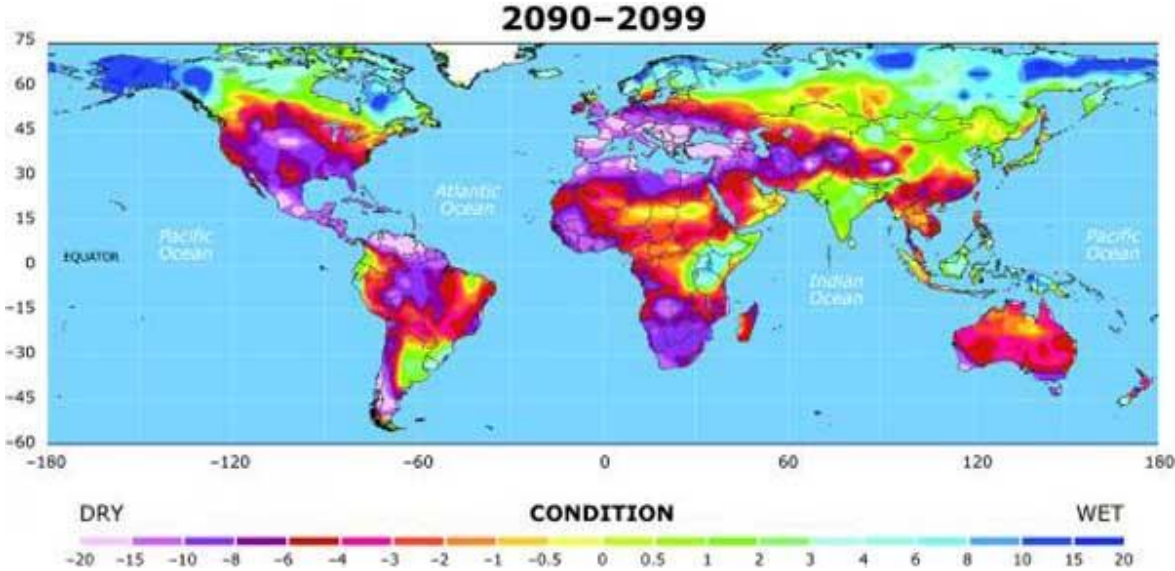
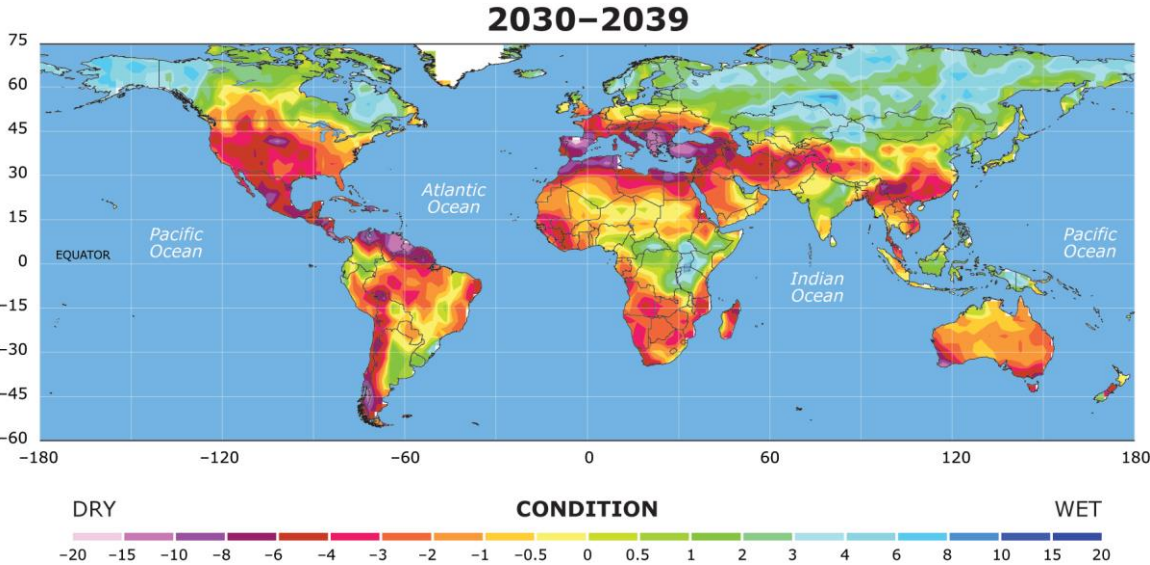
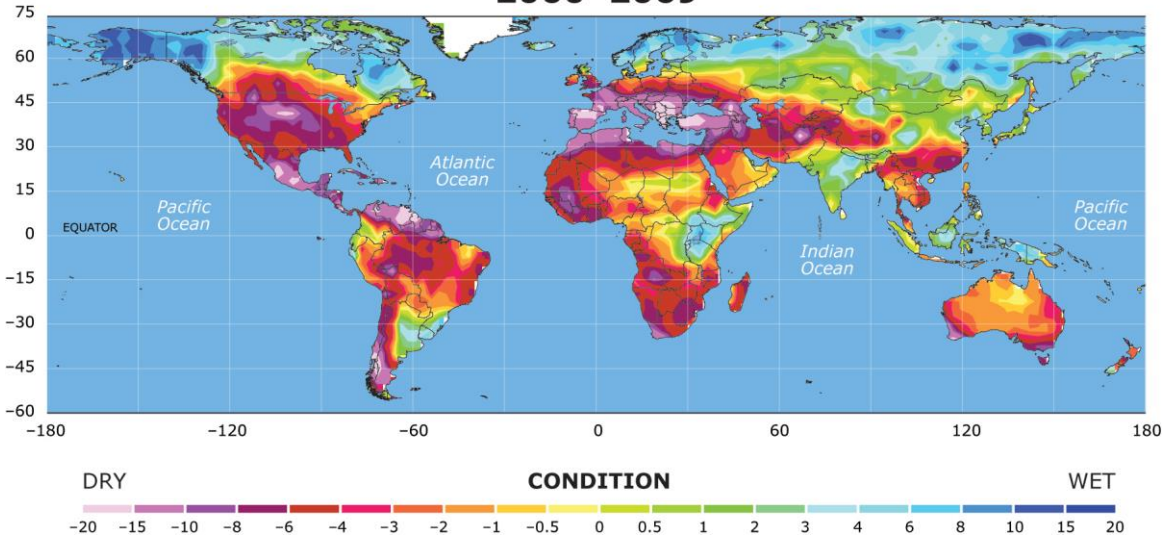
2016 Average Annual Temperature



Data taken from: CRU 0.5 Degree Dataset (New, et al.)

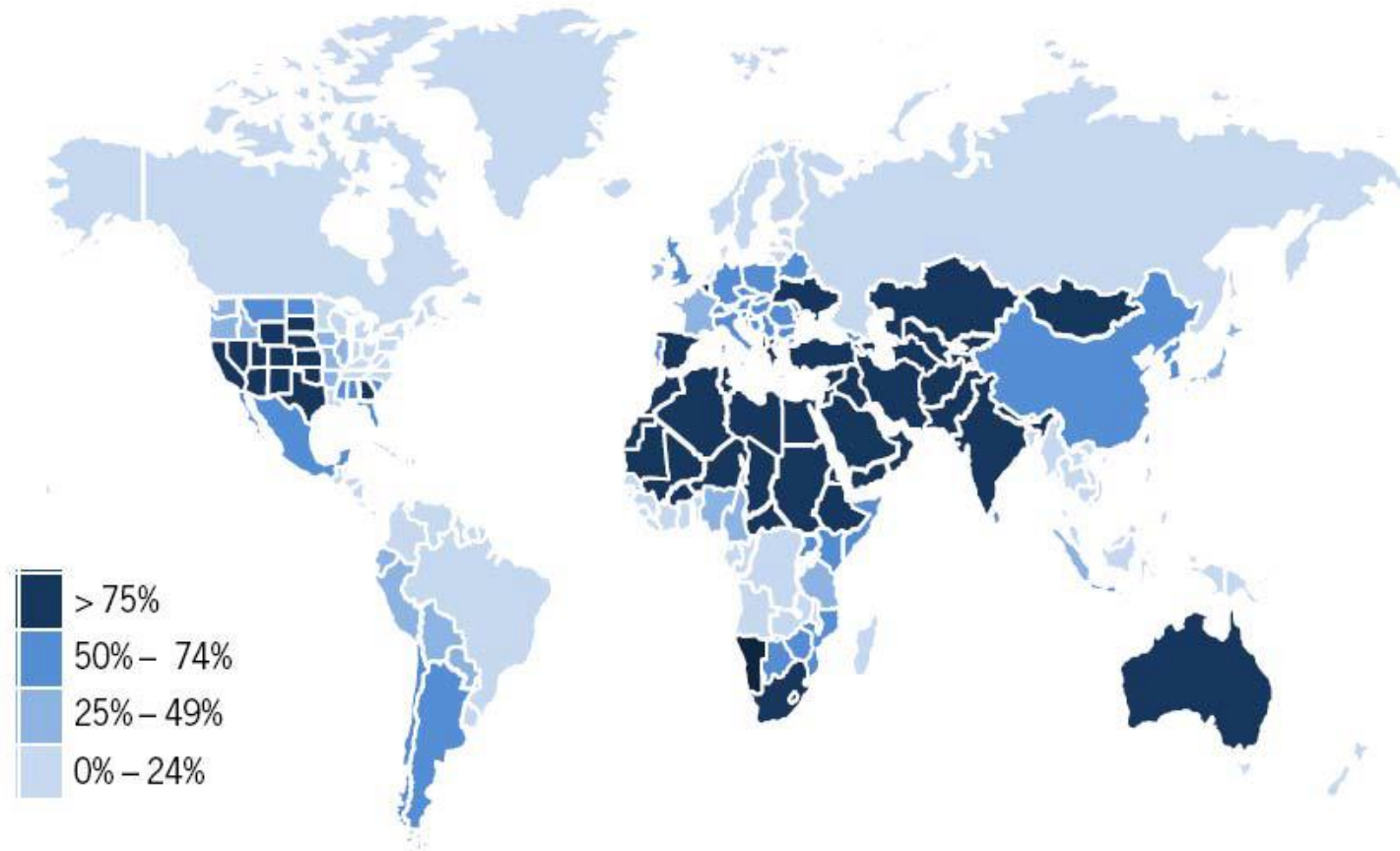
Atlas of the Biosphere
Center for Sustainability and the Global Environment
University of Wisconsin - Madison

2060-2069

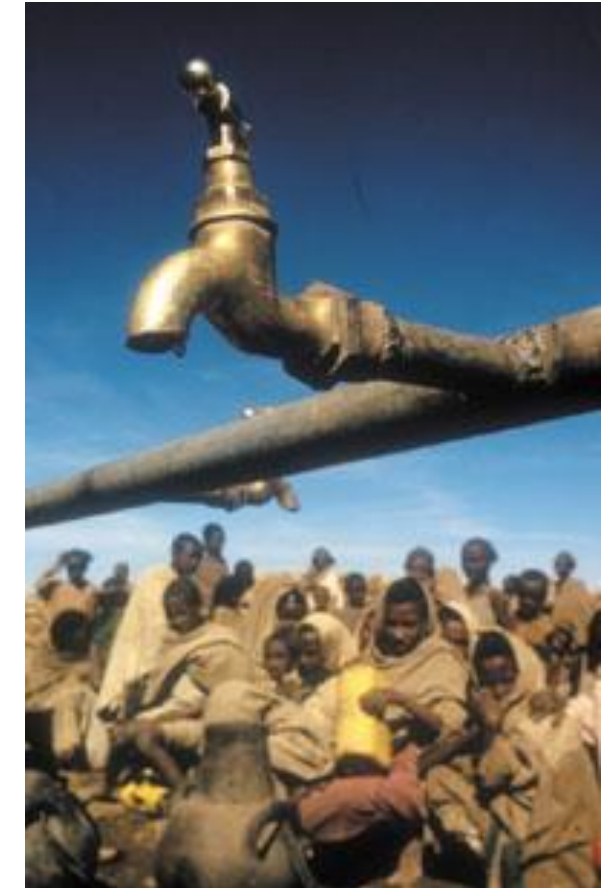




Percent of Population Facing Severe Water Stress, 2030

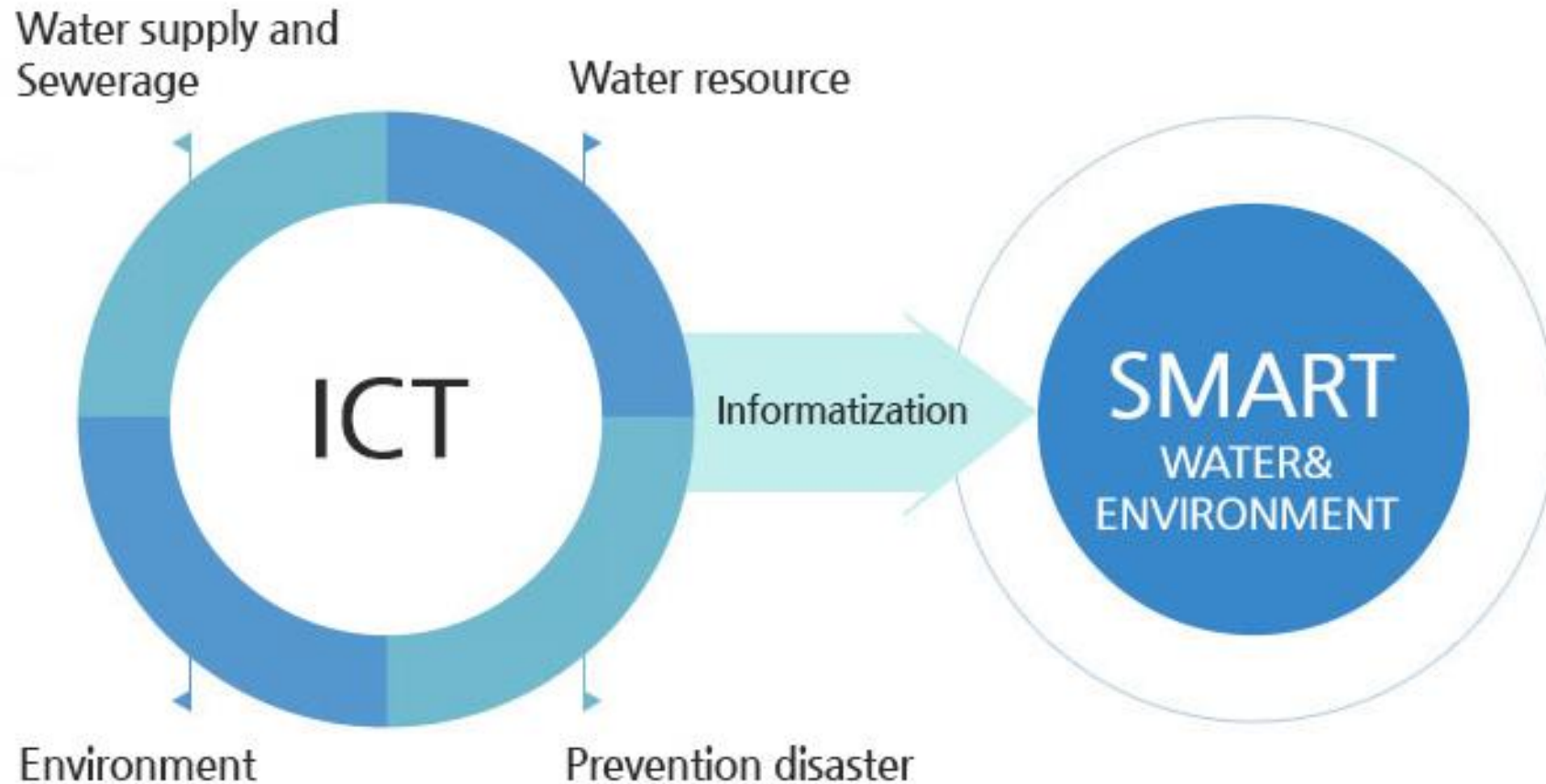


Source: OECD.



2017 Publications; 41% of the world population is in drought or water stressed regions. International Water Management Institute predicts that by 2025, all of Africa and Middle East, as well as most of South and Central America and Asia, will run out of water or not be able to afford it.

Therefore, ICT smart management of the water resources is a MUST.....

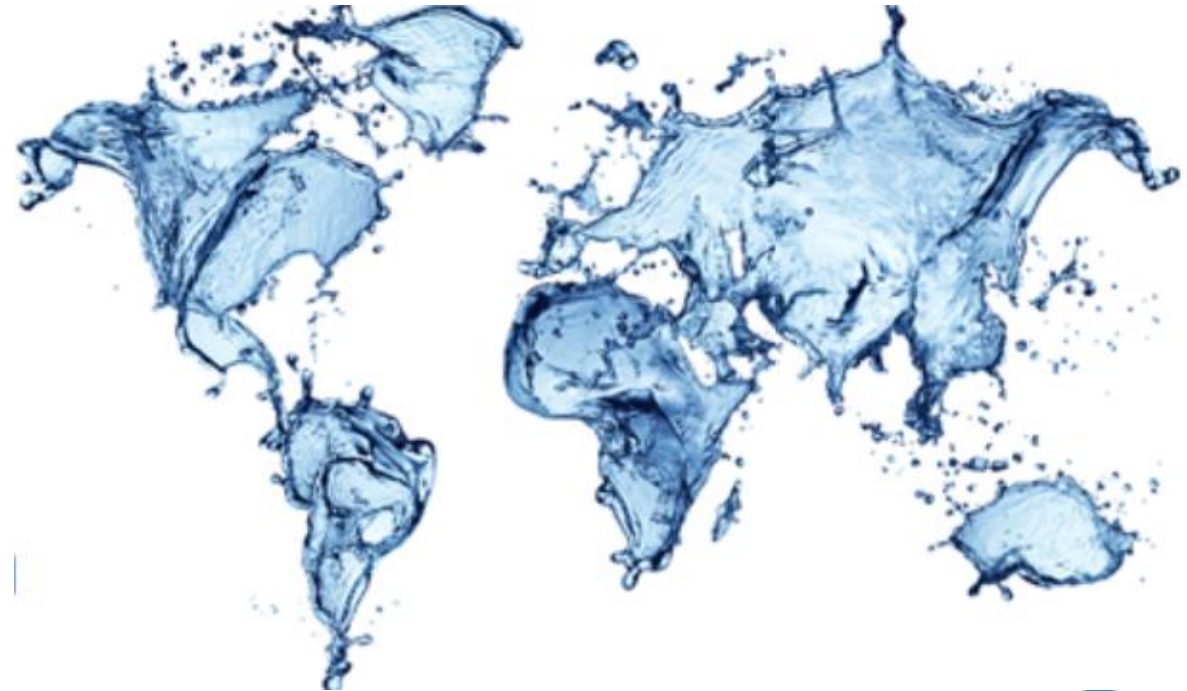


Smart Management of the Fresh Water Resources

Conventional water resources	Non- Conventional water resources
<ul style="list-style-type: none">• Surface water (Fresh & Saline)• Groundwater	<ul style="list-style-type: none">• Frozen water (Icebergs)• Rainwater harvesting & flood management• Recycle of the residential water (black and greywater)• Smart Irrigation, smart agriculture, smart industry• Reforming water policies

Conventional water resources

- **Surface water (Fresh & Saline)**
- **Groundwater**





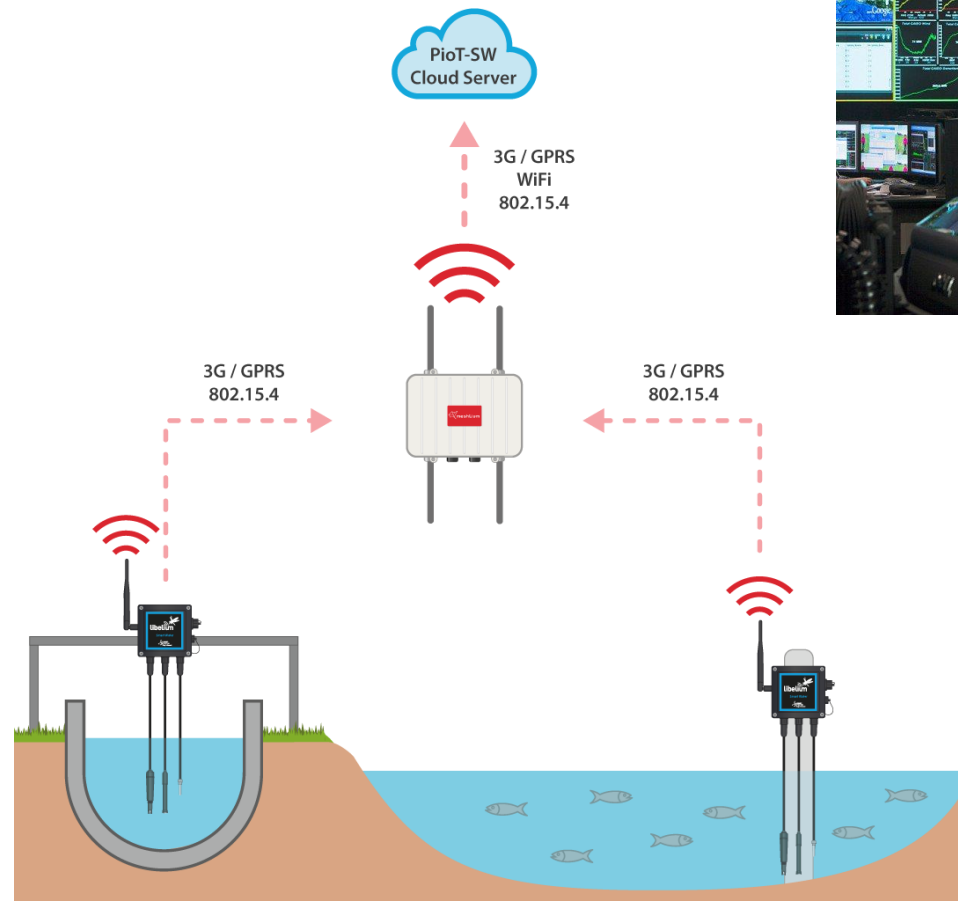
- **Surface water (Fresh)**

Which comprises rivers, streams, lakes, lagoons,....etc.

ICTs play a crucial role in;

- ❑ **Telemetry and telecontrol systems**

Real time monitoring and diagnosis, as well as automatic controls improve the supervision and optimize of water resources management.



❑ Big Data Analytics:

Smart monitoring and metering at scales from basins to households will enable robust management of big data



Grand River, Ontario, Canada

Making the Grand River Watershed “Smarter”

Why the Grand River?

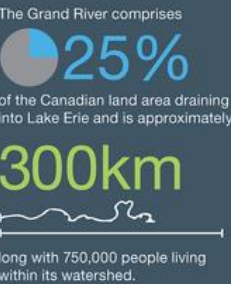
Why the Grand River? It's an urbanizing watershed with a unique mix of pristine, urbanizing, urban and agricultural land uses making it a perfect place for research and development.

In collaboration with IBM, the Southern Ontario Water Consortium has built a system that allows them to collect, store and analyze data from sensors in the Grand River Watershed in Southern Ontario.



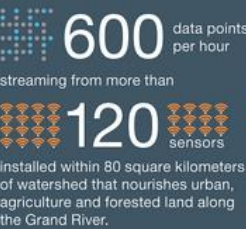
Grand River Facts

The Grand River is the largest inland river system in southern Ontario, supplying water to the Region of Waterloo, Brantford and Six Nations.



Platform Facts

The platform analyzes data collected every 15 minutes from meteorological, surface, subsurface and groundwater sensors, which monitor everything from rain- and snowfall, soil moisture, water turbidity, flow rates, temperature, to ground- and well-water quality.



Applying the Data

Using IBM hardware and software, the platform allows users to collect, store and analyze data unlike ever before, with the ability to react to environmental events to capture information that could otherwise have gone unrecorded.

This, in turn, will help researchers and others develop more sophisticated tools to predict floods, safeguard the drinking water supply and forecast the impact of growth and urbanization on vital ecosystems.



Modeling

Project Objectives

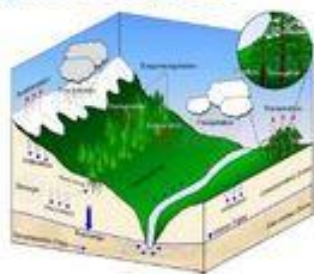
- Integrated Hydrologic Model development for South Saskatchewan River Basin (SSRB) and its major sub-basins
- Spatially distributed assessment of water-related risks to agriculture
- Overland flood mitigation strategy evaluation
- Assist with new insurance product development

Objectives of Hydrologic Simulation



- Understanding the (future) impacts of manmade changes or natural events helps informed decision making
- Improve emergency response planning
- Performance simulation and optimization of mitigation concepts even before implementation
- Assist water resources management by a Smart Watershed Computer Model

HydroGeoSphere



HGS Simulation

- Class leading hydrologic simulation software
- Simulation of the entire terrestrial water cycle
- Utilizes state-of-the-art high performance computing (HPC)

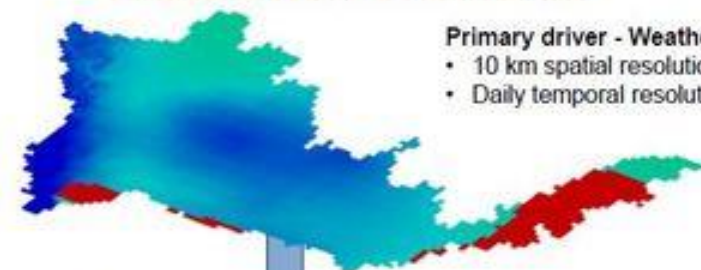
The South Saskatchewan River Basin

- Experiences climate extremes ranging from drought to flood
- Large and productive agricultural land base
- Highly regulated, e.g. dams, irrigation, diversions
- Winter processes are key to the annual water budget



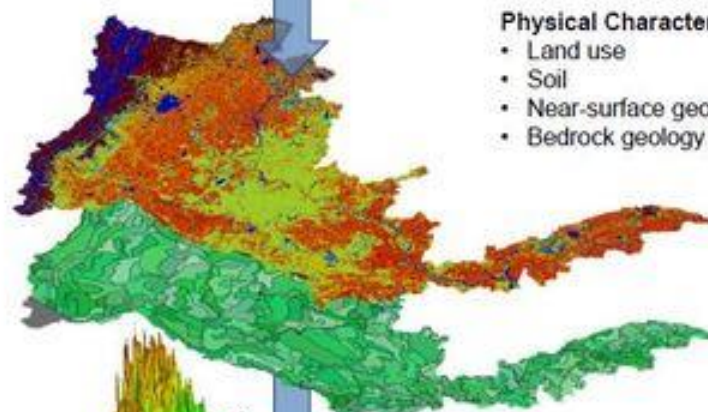
South Saskatchewan River Basin (SSRB) location map.

Basin Scale Model Construction



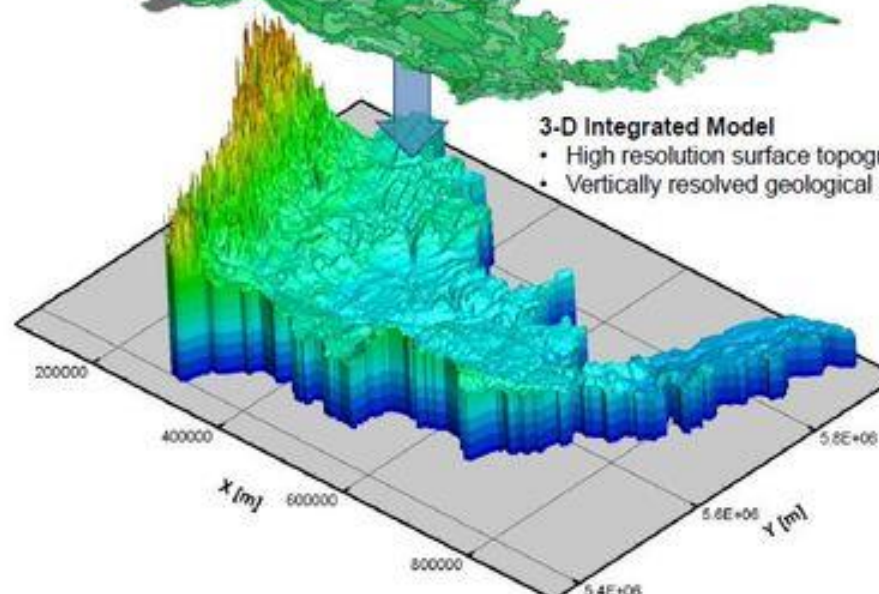
Primary driver - Weather / Climate

- 10 km spatial resolution
- Daily temporal resolution



Physical Characterization

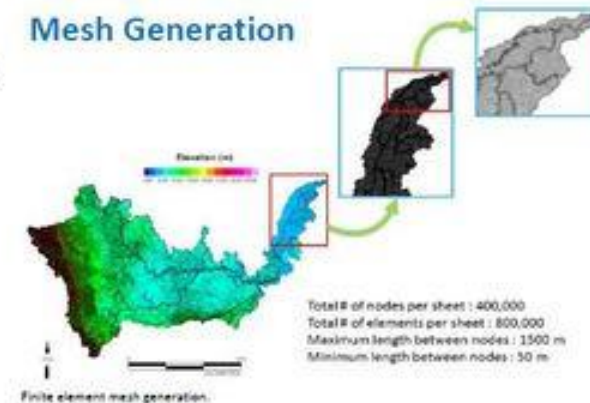
- Land use
- Soil
- Near-surface geology
- Bedrock geology



3-D Integrated Model

- High resolution surface topography
- Vertically resolved geological layers

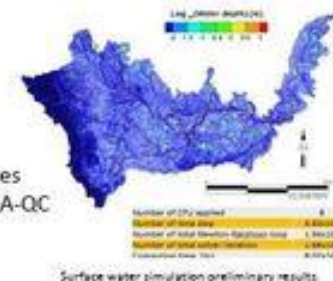
Mesh Generation



Total # of nodes per sheet : 400,000
Total # of elements per sheet : 800,000
Maximum length between nodes : 1500 m
Minimum length between nodes : 50 m

Surface Water Simulation

- Preliminary calibration
- Evapotranspiration processes
- Model domain geometry QA-QC



Surface water simulation preliminary results.

Anthropogenic Influences

- Reservoir operations
- Irrigation diversion



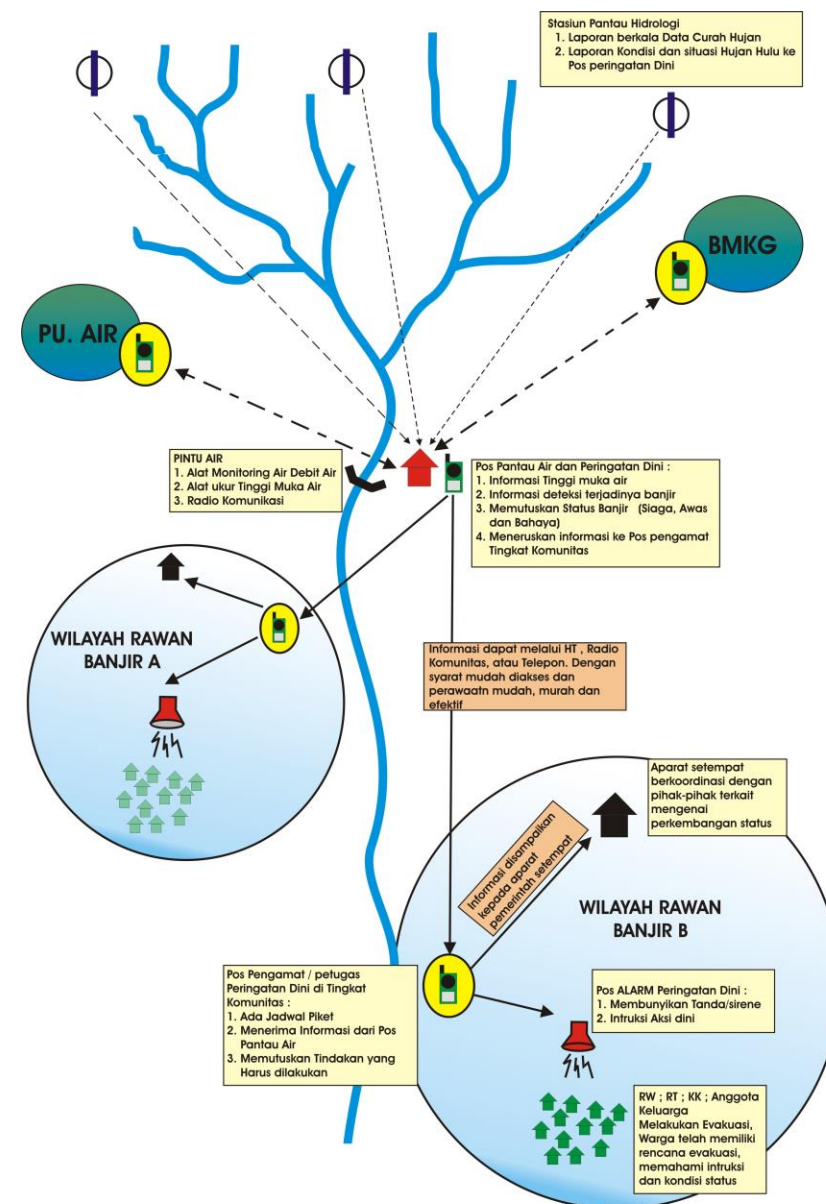
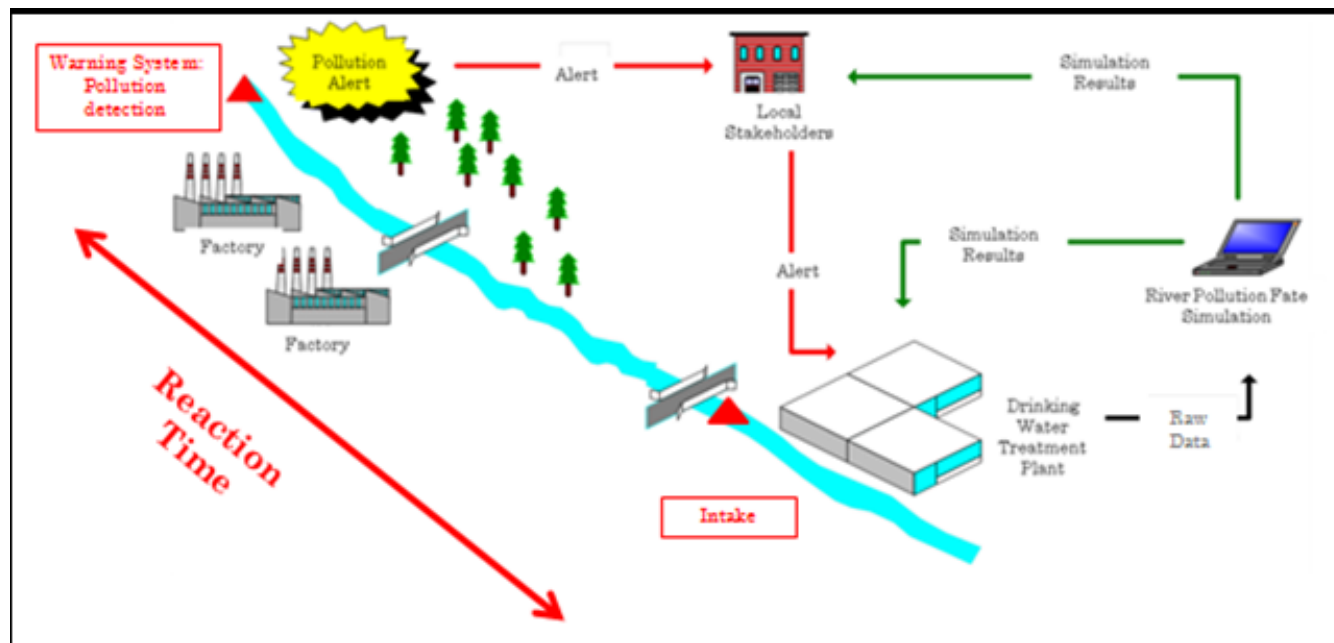
Reservoir simulation testing, e.g. Lake Minnewanka, AB.

Work in Progress

- Full 3D simulations
- Irrigation data assembly
- Higher resolution sub-basin modeling

The Saskatchewan River is a major river in Canada, about 550 kilometres long,

❑ Risk assessment and early warning system (EWS)



Benefits:

ICTs smart technology (intelligent sensors, wireless communications, code-division multiple access (CDMA), satellite images, and GIS) will enable;

- ✓ Real-time efficient management of reliable water demand and supply,
- ✓ Disaster prevention,
- ✓ Water quantity & quality,
- ✓ Optimized distribution, and
- ✓ Optimized ecosystem.





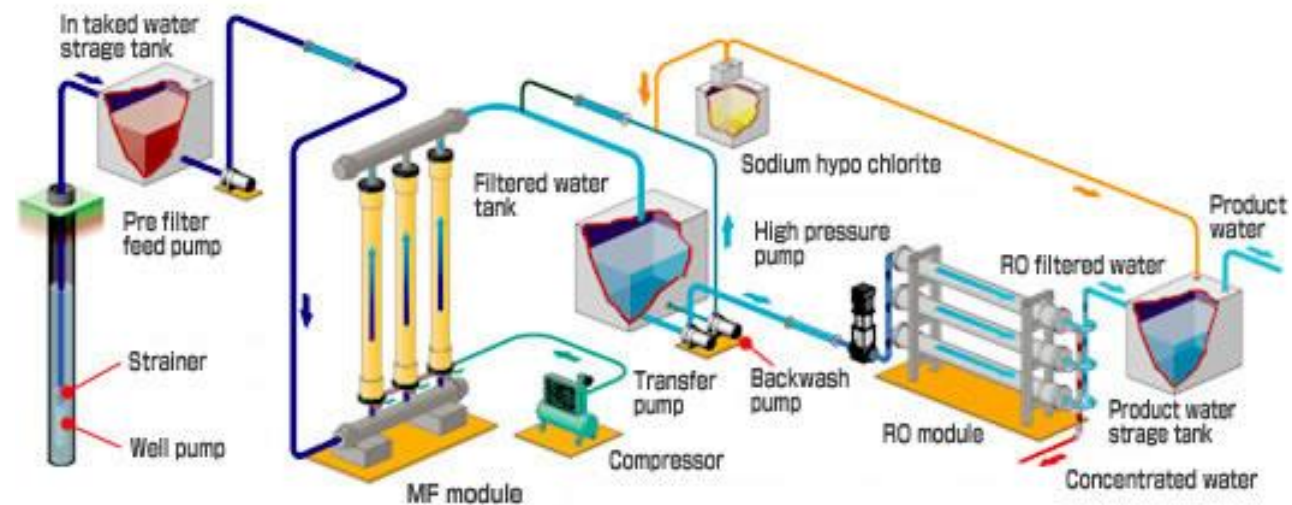
- **Surface water (Saline)**

Which comprises seawater & salt lakes,.....etc.

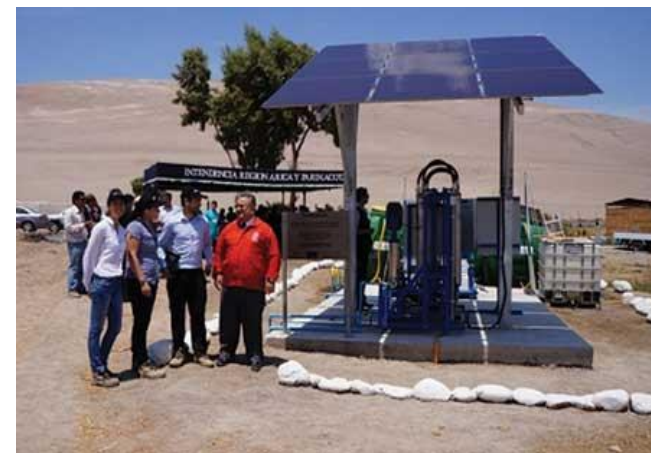
Saline water represents 97% of water on the earth

ICTs play a crucial role in;

☐ **Desalination technologies**



Membrane Filtration, Reverse-Osmosis
Seawater Desalination System



Solar Powered Water Desalination



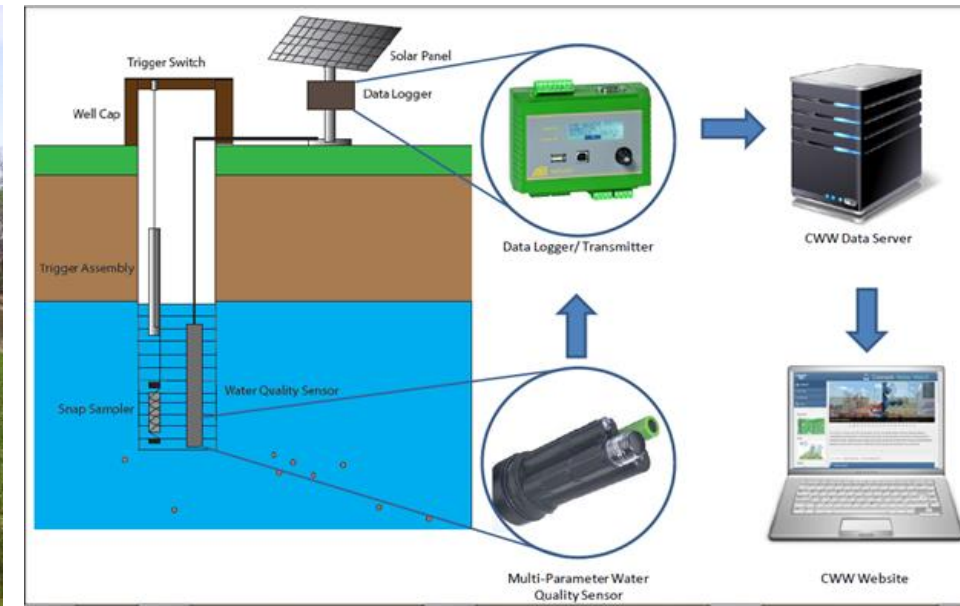
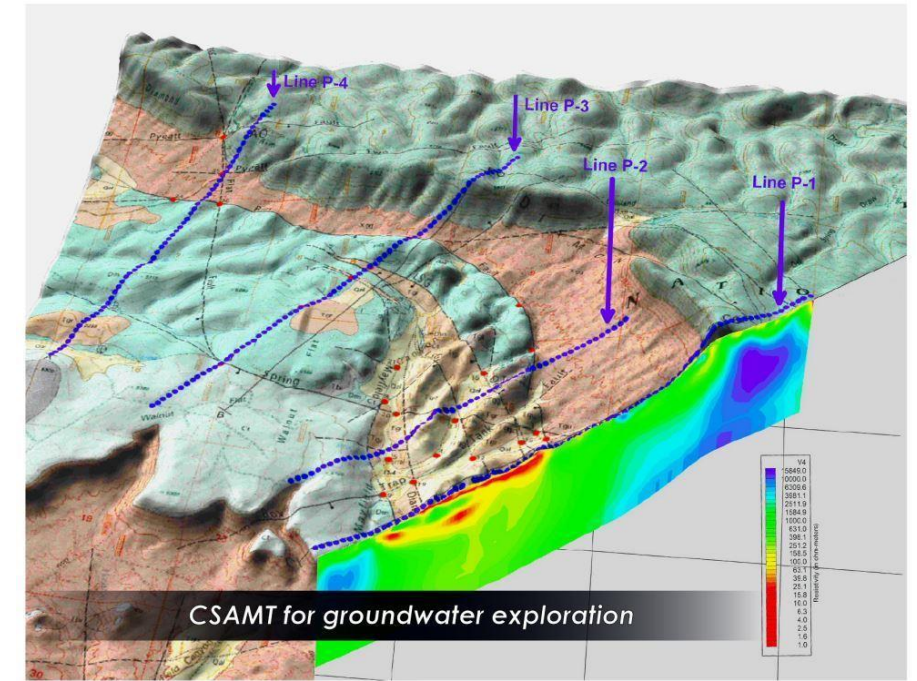
- **Groundwater**

Represents 30% of freshwater on the earth

ICTs play a crucial role in;

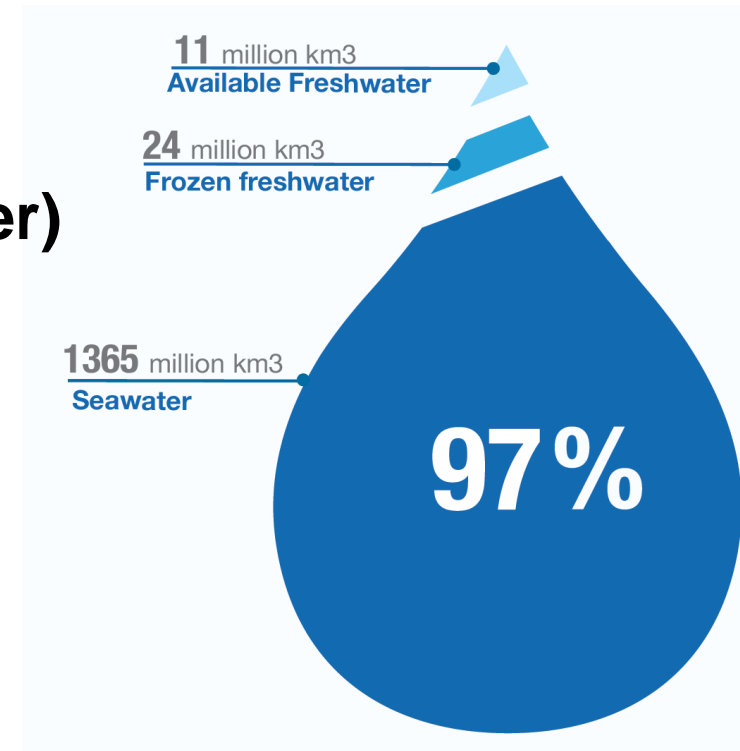
☐ **Groundwater exploration**

☐ **Regular and real time monitoring, diagnosis, modeling, automatic controls for surface water resources**



Non-Conventional water resources

- Frozen water (Icebergs)
- Rainwater harvesting & flood management
- Recycle of the residential water (black and greywater)
- Smart irrigation, smart agriculture, smart industry
- Reforming water policies



Non-Conventional water resources

- **Frozen water (Icebergs)**

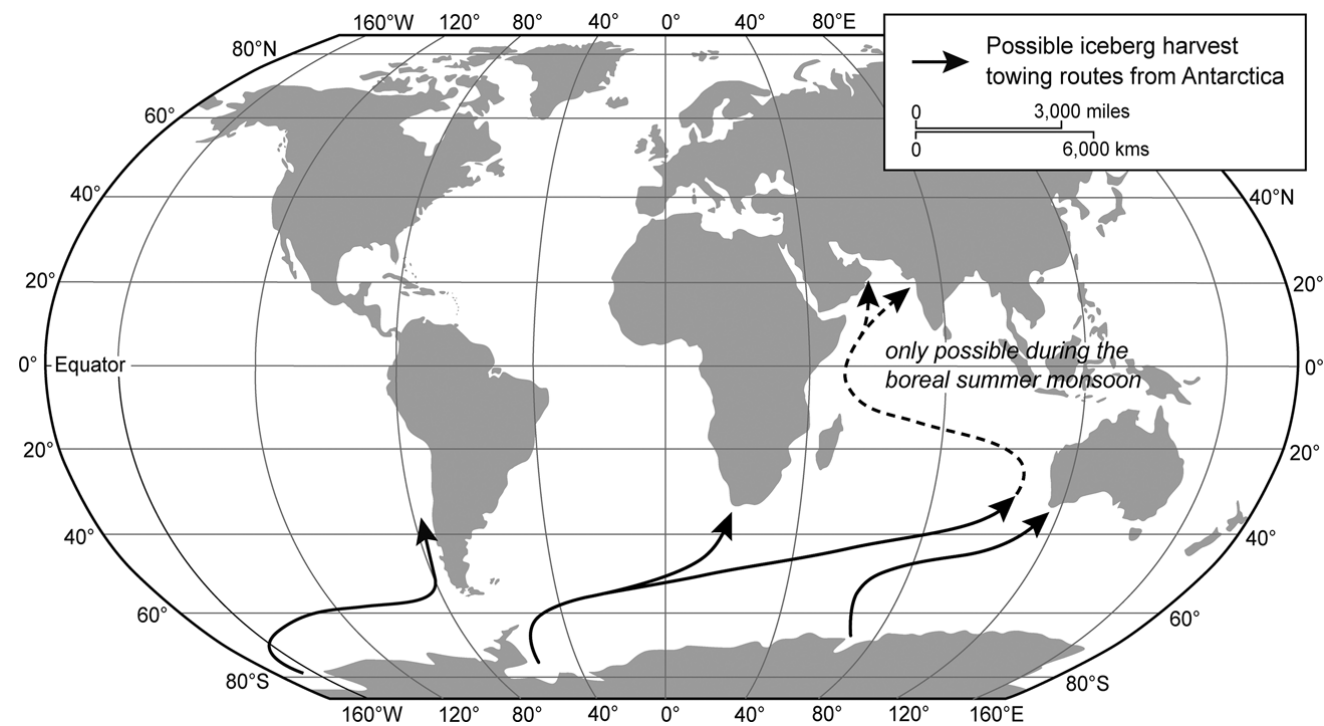
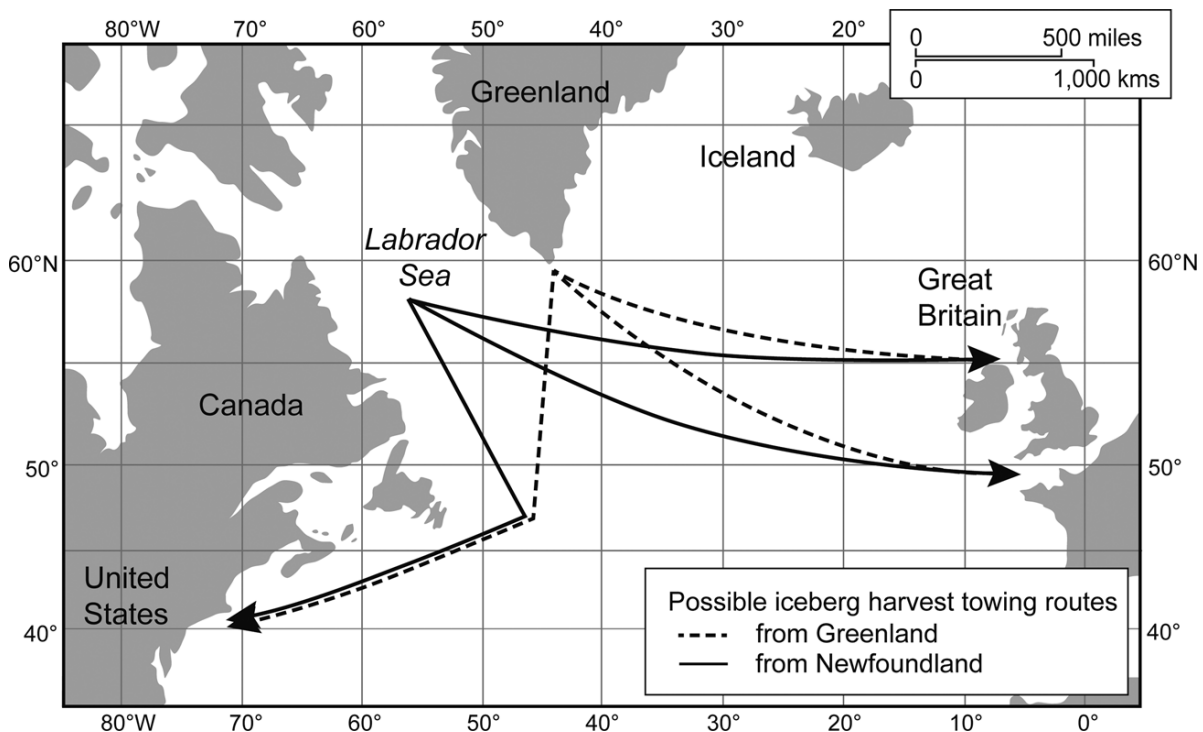
Represents 68.7% of freshwater on the earth



Frozen water

Several schemes have been proposed to make use of icebergs as a water source, however to date this has only been done for novelty purposes. The Himalayas, which are often called "The Roof of the World", contain some of the most extensive and rough high altitude areas on Earth as well as the greatest area of glaciers and permafrost outside of the poles



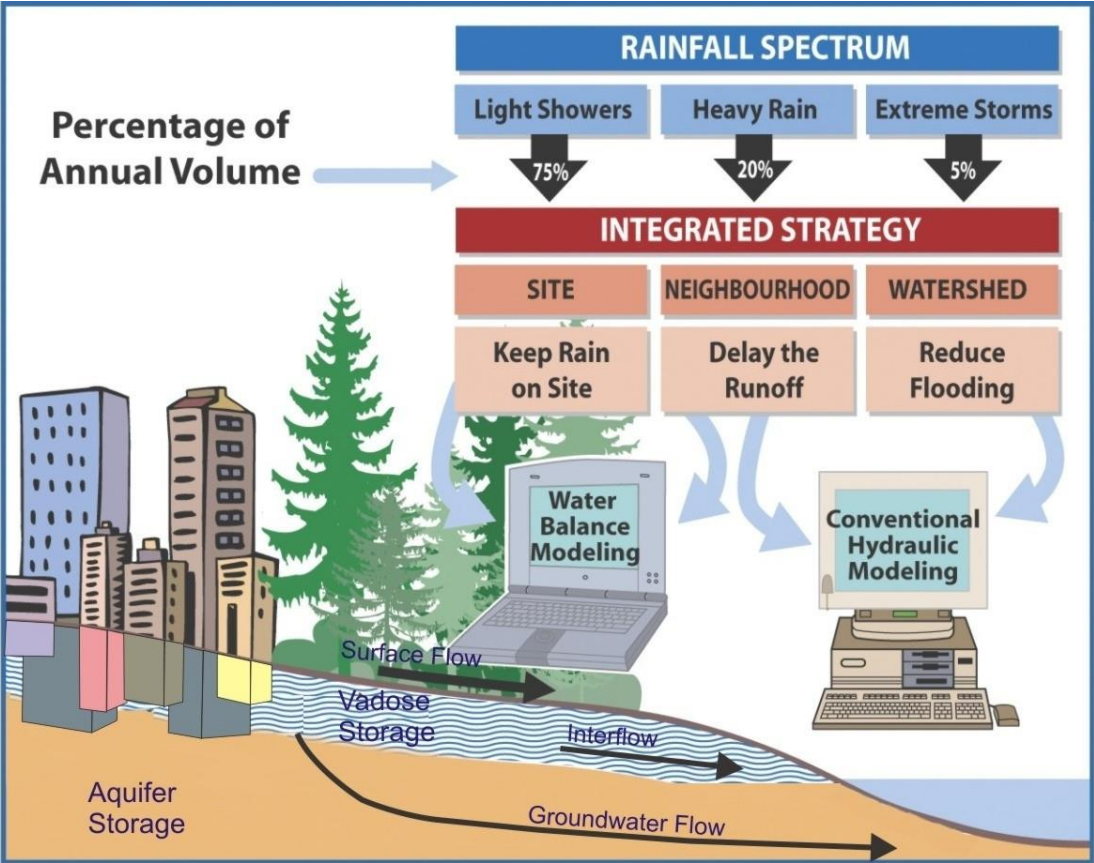
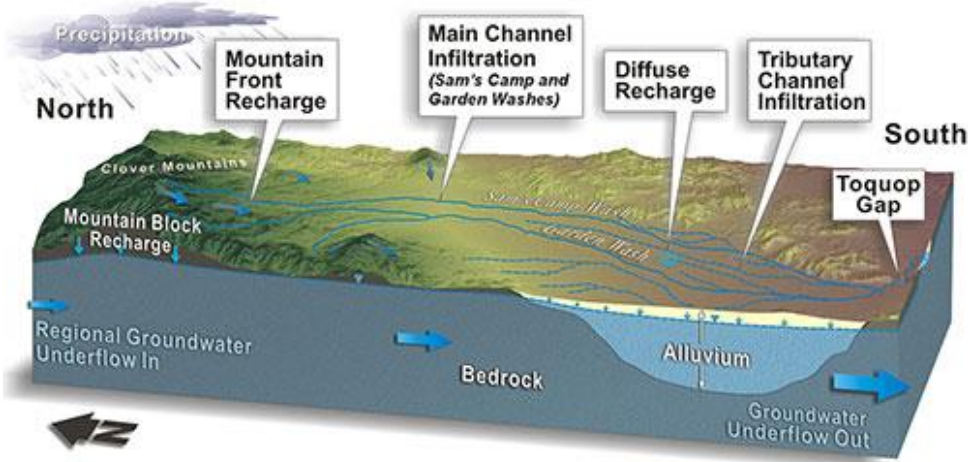
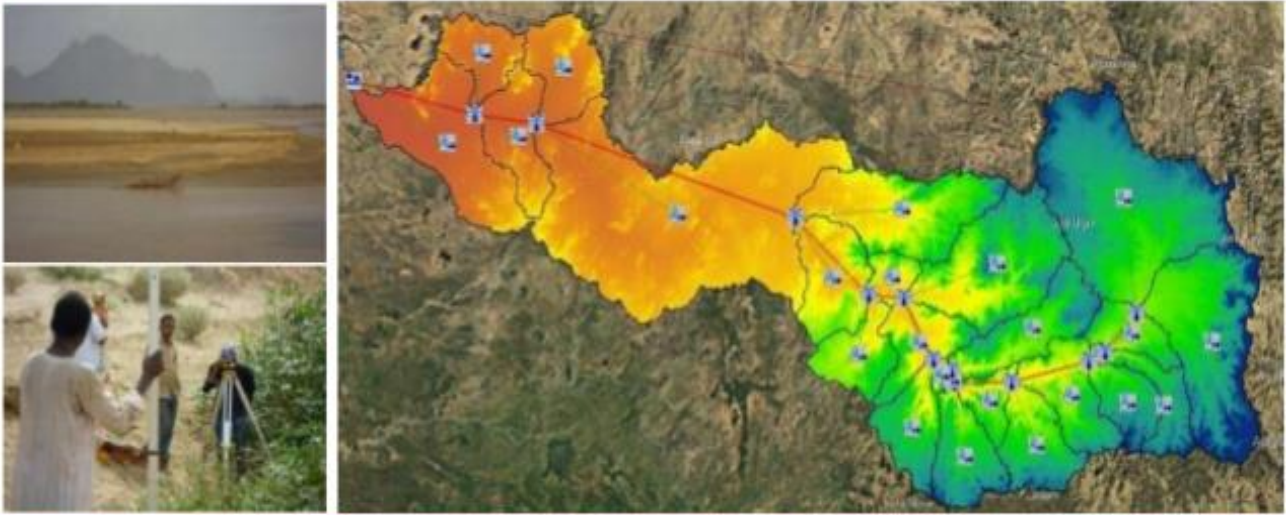


Non-Conventional water resources

- Rainwater harvesting & flood management

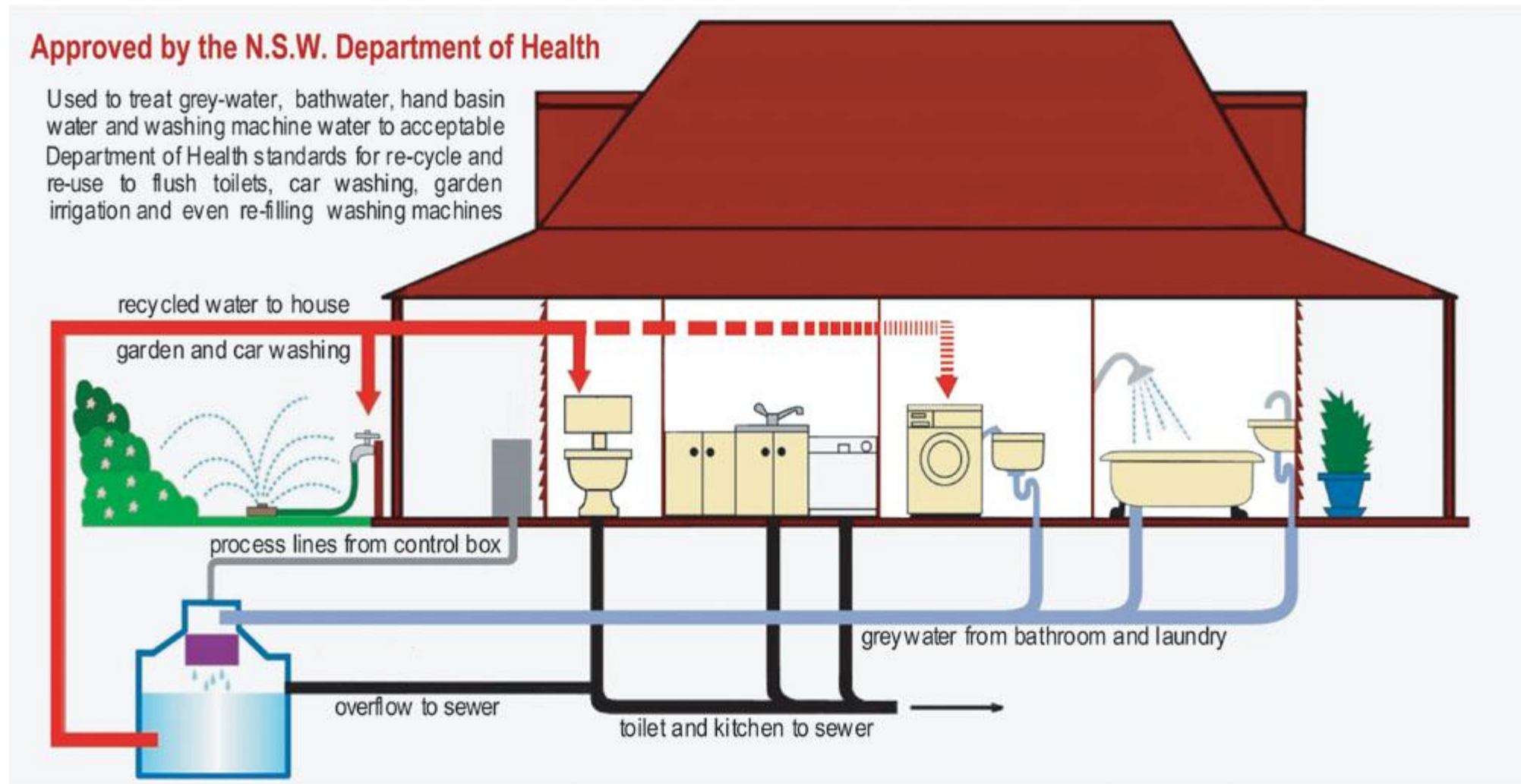
DEVELOPMENT OF FLOOD FORECASTING SYSTEM HEC HMS+RAS

Basin Characteristics	Model Inputs	HMS Parameters
25 sub-basin	5 raingauges (Ethiopia)	Loss (SCS Curve Number)
Watershed ~20,000km ²	El Gera flow data (GRTU)	Transform (SCS Unit Hydrograph)
12 river segments	TRMM, RFE, CMORPH SRE Data	Baseflow (Constant Monthly)
	DEM, LULC, FAO Soil Data	Routing (Muskingum)



Non-Conventional water resources

- Recycle of the residential water (black and greywater)





Non-Conventional water

- Smart Irrigation

SMART IRRIGATION

IRRIGATING IN HARMONY WITH THE WEATHER[®]

You water your plants, but where does that water go?

The water wets the soil where the plant roots can absorb it. If it would just stay there, irrigation would be simple, but it doesn't.

It evaporates from the topsoil, and seeps down into the groundwater table (or out the bottom of your plant pot). Water that the soil couldn't absorb is lost as run off, and even water that the plant does absorb is lost through its leaves, through transpiration.

The good thing is we can calculate how much goes where. We need to know the plant, the soil, and most importantly the weather.



What's the weather got to do with it?

The weather has a big impact on the rate at which water evaporates from the soil and transpires through the leaves.

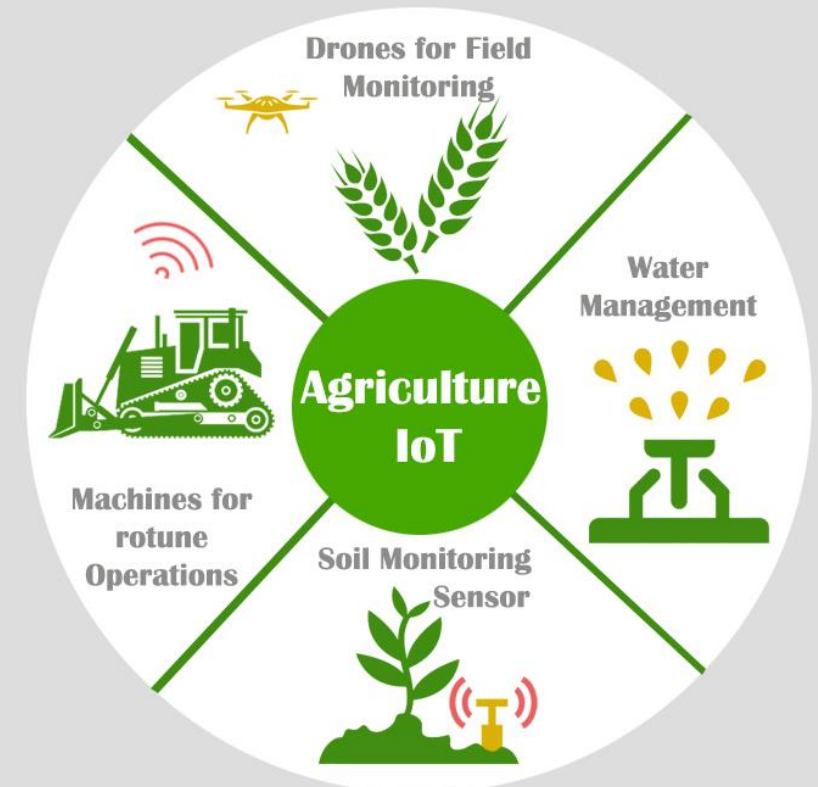
Temperature and sun exposure, as well as wind and humidity, have the biggest impact. By tracking these as well as rainfall we can precisely calculate how much water must be replenished through irrigation to maintain proper soil moisture. Your typical irrigation timer won't do this for you, but a smart irrigation controller will, which could save you as much as 50% of your landscaping water, or more.

Non-Conventional water resources

- Smart agriculture



How IoT technology is benefiting today's modern farming industry



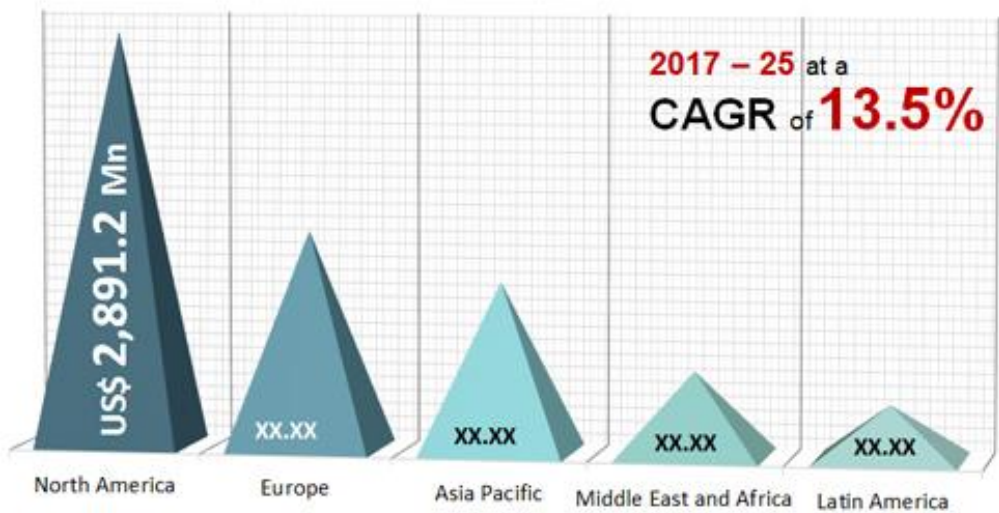


Non-Conventional water resources

- Smart agriculture

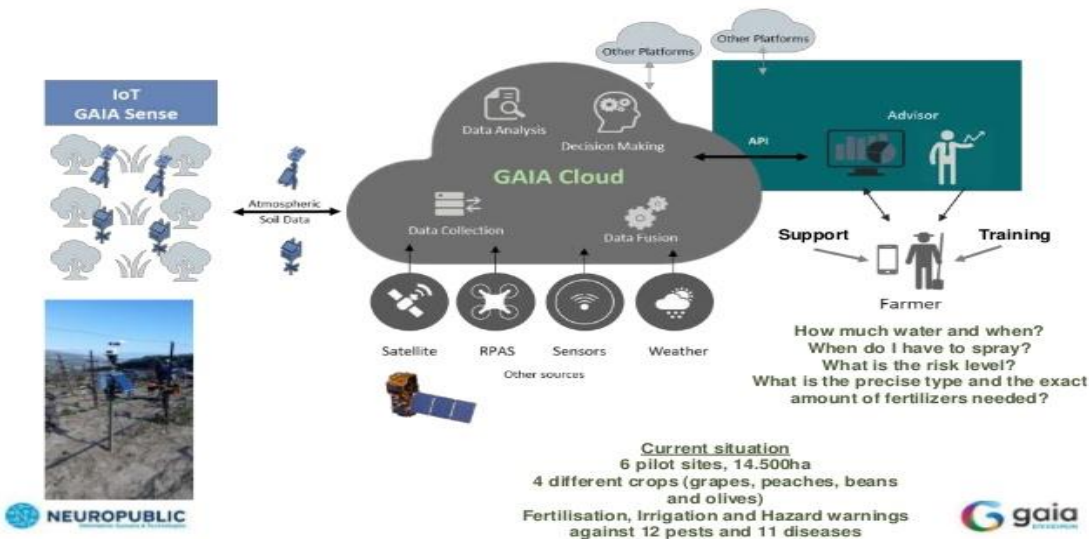
Global Smart Agriculture Market Revenue

By Geography, 2016 (US\$ Mn)



Source: TMR Analysis, 2017

IoT and Cloud Infrastructure for Smart Farming

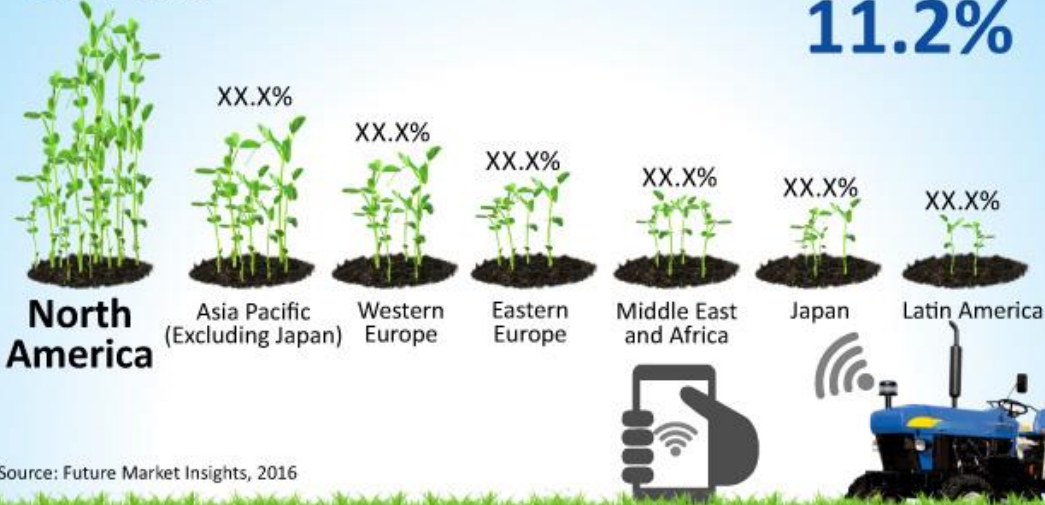


Global Smart Agricultural Solution Market Value Share (%)

By Region (2016)

53.4%

2016 – 2026 at a CAGR of 11.2%



Non-Conventional water resources

- Smart industry

The life cycle of water

ABOUT 90% OF WATER USED
IS RETURNED TO SOURCE



Non-Conventional water resources

- Reforming water policies



Should involve the society, public domain, governments, NGO, institution, academia, private sector,...etc

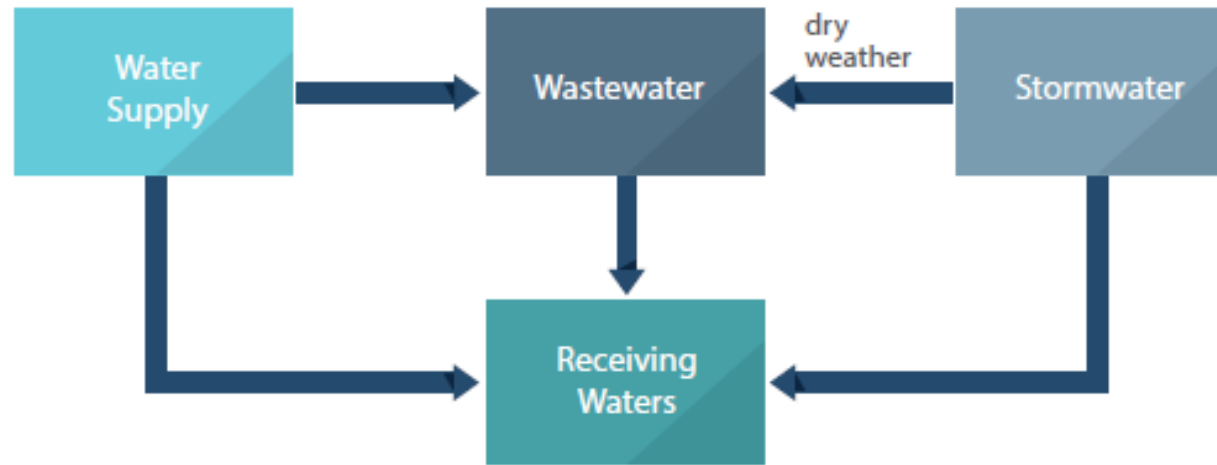




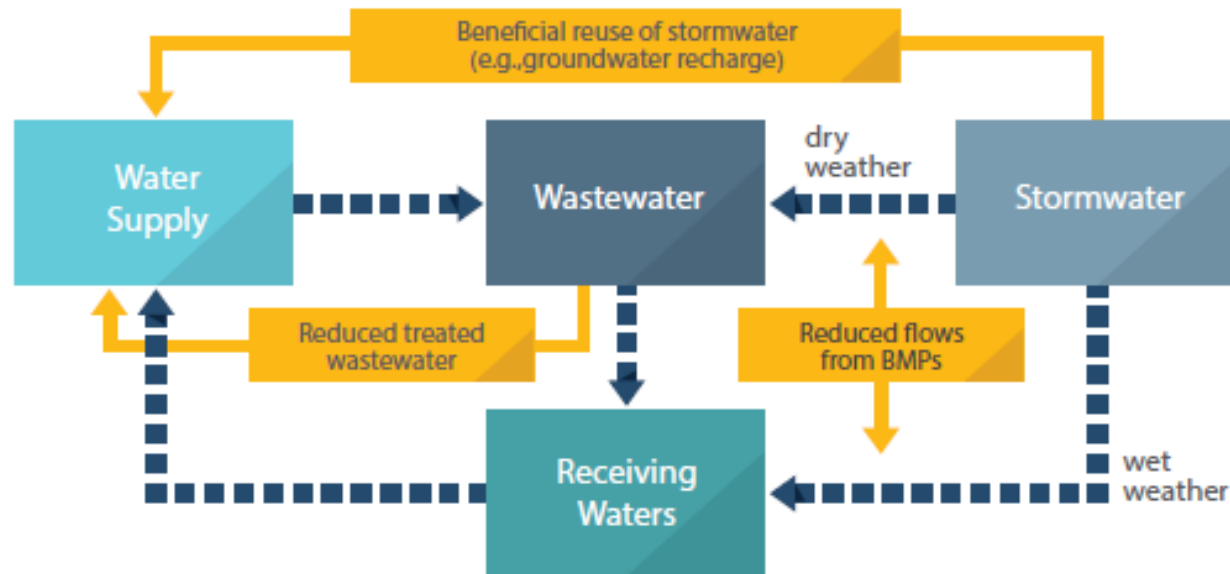
Integrated Water Resources Management (IWRM)



Non-Integrated Water Resource management



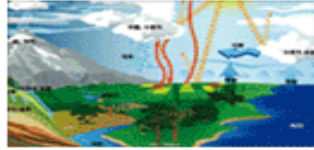
Total Water Management (Integrated Water Resources)



Traditional versus integrated water management including best management/LIDs (US EPA, 2012)

Hydrological

Integrated consideration of rainfall, run-offs, evaporation, and other processes



Topographical

Integrated management of water sources, valleys, streams, and estuaries



IWRM

Functional

Integrated consideration of water quantity, quality, ecology, disaster prevention, and other factors



Social

Governance that all water-related entities in the basin participate in



Existing water managemnet
(Water Grid)

+

Information and
communication technology
(Smart)

=

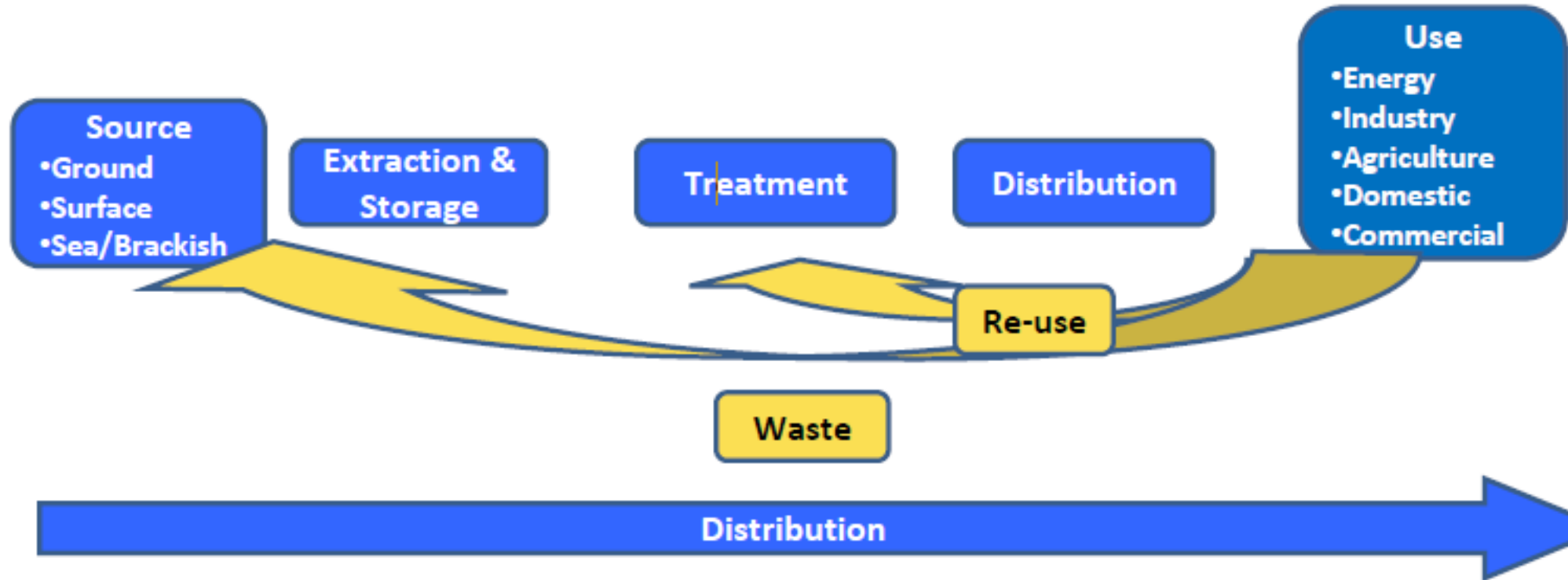
Smart Water Grid
(SWG)

- Individual supply system
- Water and energy loss
- Supply-side, and unilateral

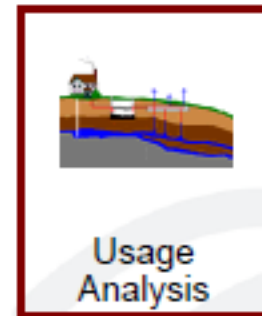
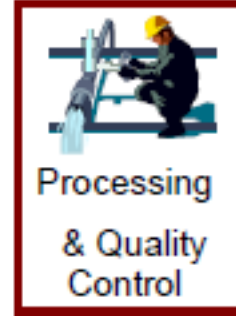
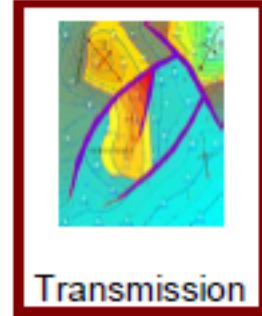
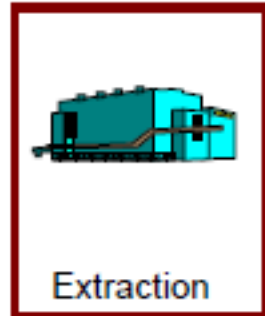
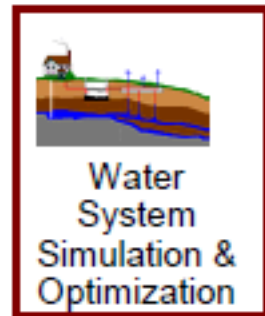
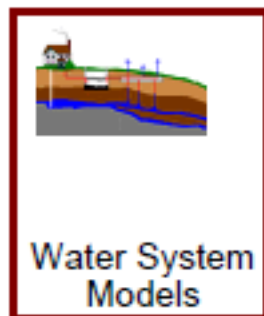
- Smart measuring devices
- Real-time information
- Transmitting and receiving

- Diversification of supply routes
- Integrated operation of infrastructure
- High efficiency, and reduction of energy
- Consumer-centered, and multi-directional

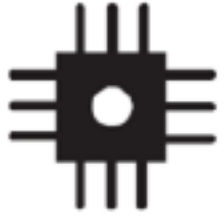
Integrated Water Resources Management



Match technical capability



Not just because “we can” but because “we must”



INSTRUMENTED

We now have the ability to measure, sense and see the exact condition of practically everything.



INTERCONNECTED

People, systems and objects can communicate and interact with each other in entirely new ways.

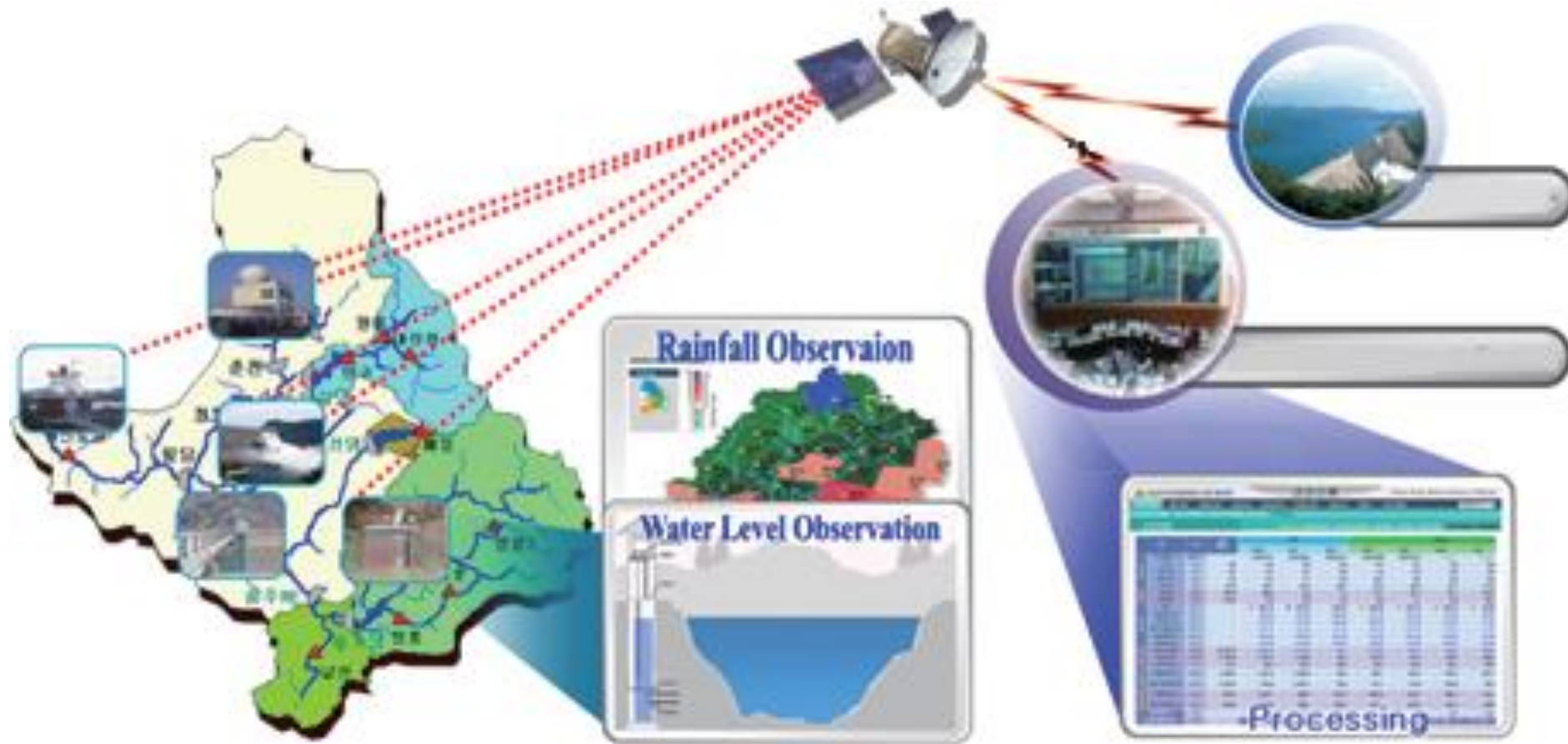


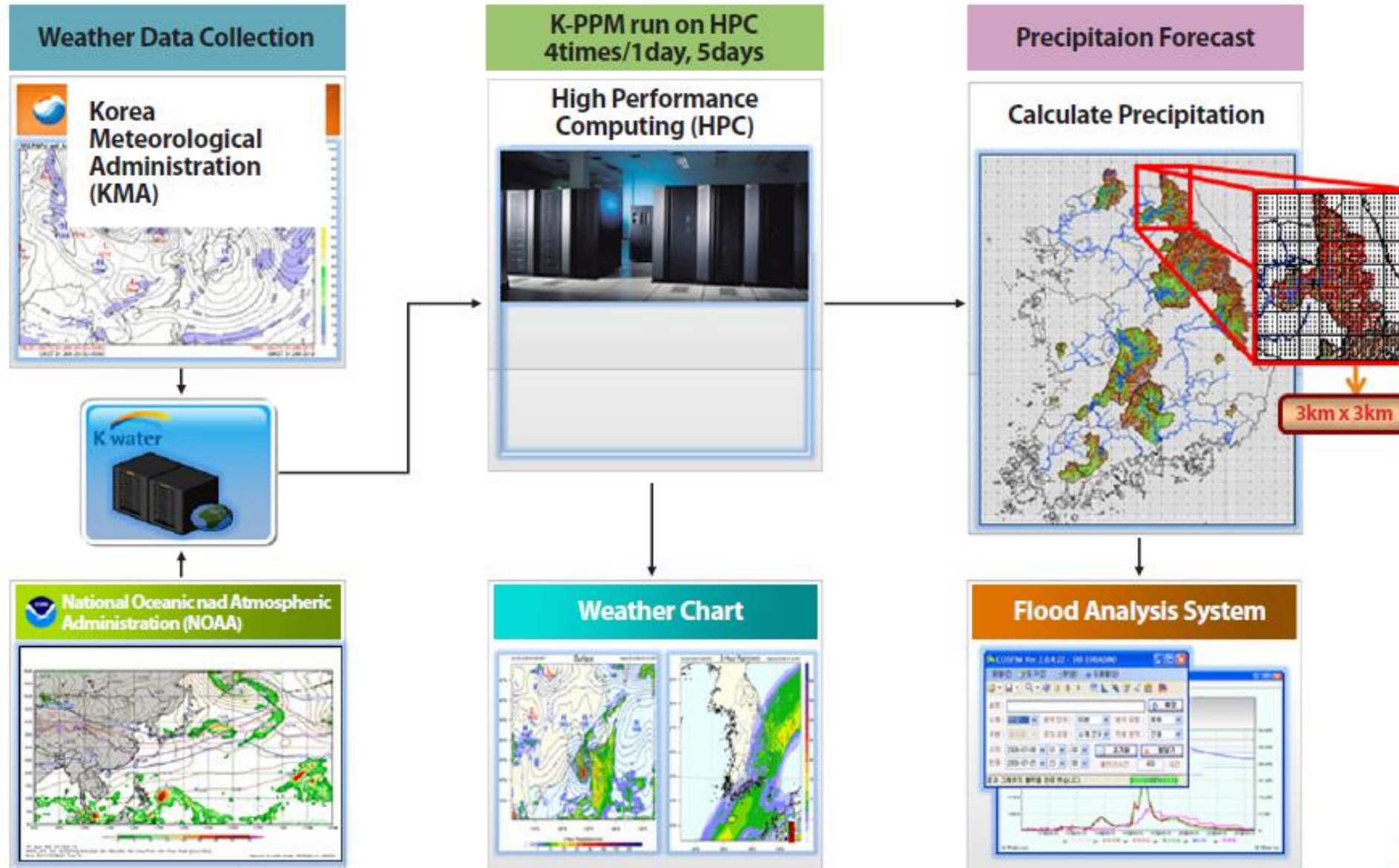
INTELLIGENT

We can respond to changes quickly and accurately, and get better results by predicting and optimizing for future events.



Case Study (South Korea): The system functions to combine real-time data (covering water level, rainfall, water quality,etc.) and video of closed-circuit televisions from major dams, river, streams in the country for 24/7 monitoring services. K-water shares the data with the Korea Meteorological Administration, the Ministry of Land, Infrastructure and Transport of Korea





Enterprise integrated water management system
between meteorological and hydrological data, South Korea



Thank You

