Water Treatment Engineering: Fundamental Concepts and Definitions

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INTRODUCTION

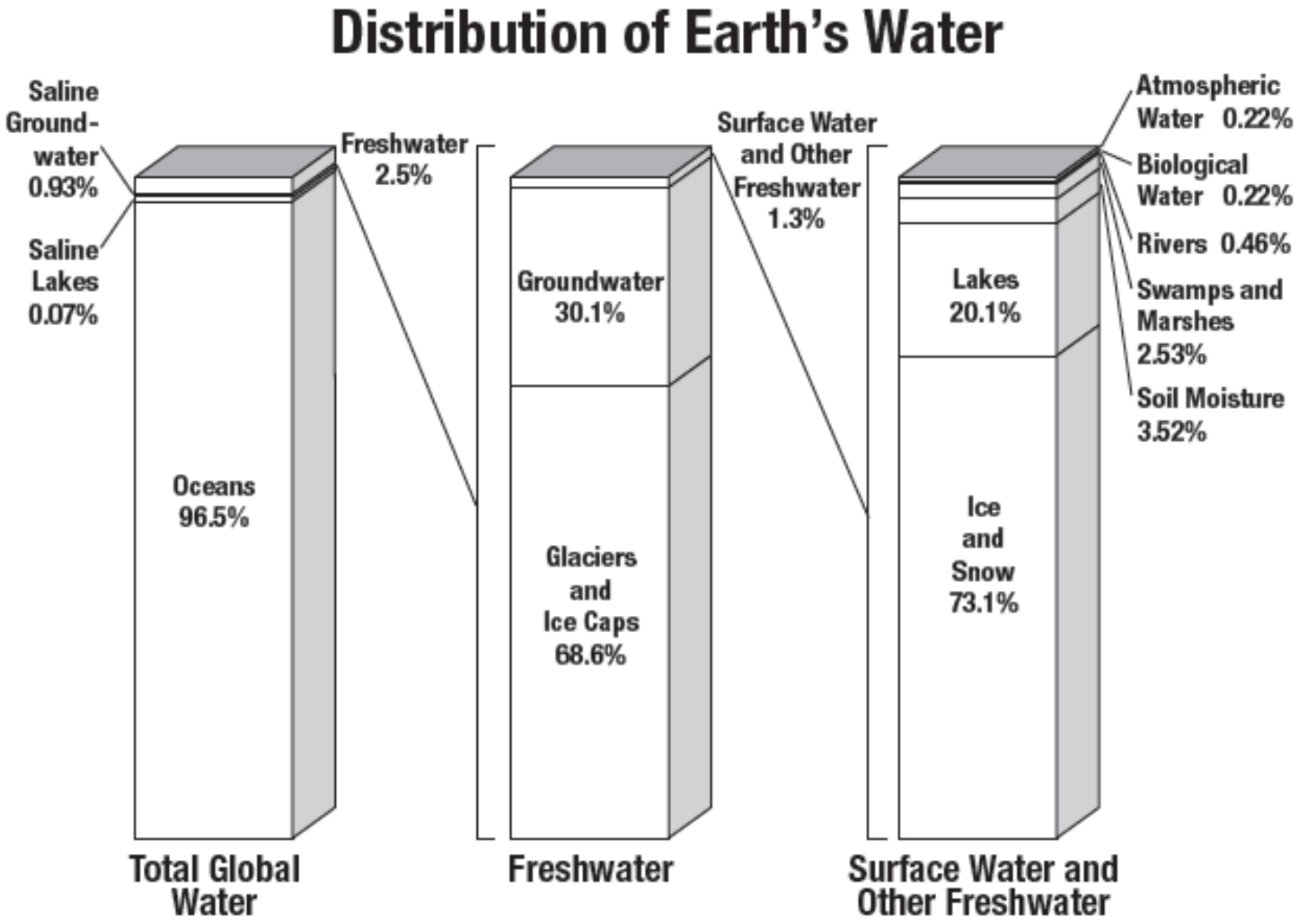
- The hydrologic cycle describes the movement of water in nature
- The total available water resources in the world are estimated in the order of 43,750 km^3/year
  - The majority is locked up in the Antarctic ice sheet
  - Americas have 45 %, Asia 28 %, Europe 15.5 % and Africa 9 % of the world's total freshwater resources
- Freshwater is about 2.5% of the total water on Earth
- Humans intervene in the hydrologic cycle (Fig. 1-1)

INTRODUCTION

Water source	Water volume, in cubic miles	Water volume, in cubic kilometers	Percent of fresh water	Percent of total water
Oceans, Seas, & Bays	321,000,000	1,338,000,000	--	96.5
Ice caps, Glaciers, & Permanent Snow	5,773,000	24,064,000	68.7	1.74
Groundwater	5,614,000	23,400,000	--	1.7
Fresh	2,526,000	10,530,000	30.1	0.76
Saline	3,088,000	12,870,000	--	0.94
Soil Moisture	3,959	16,500	0.05	0.001
Ground Ice & Permafrost	71,970	300,000	0.86	0.022
Lakes	42,320	176,400	--	0.013
Fresh	21,830	91,000	0.26	0.007
Saline	20,490	85,400	--	0.006
Atmosphere	3,095	12,900	0.04	0.001
Swamp Water	2,752	11,470	0.03	0.0008
Rivers	509	2,120	0.006	0.0002
Biological Water	269	1,120	0.003	0.0001
Total	332,500,000	1,386,000,000	-	100

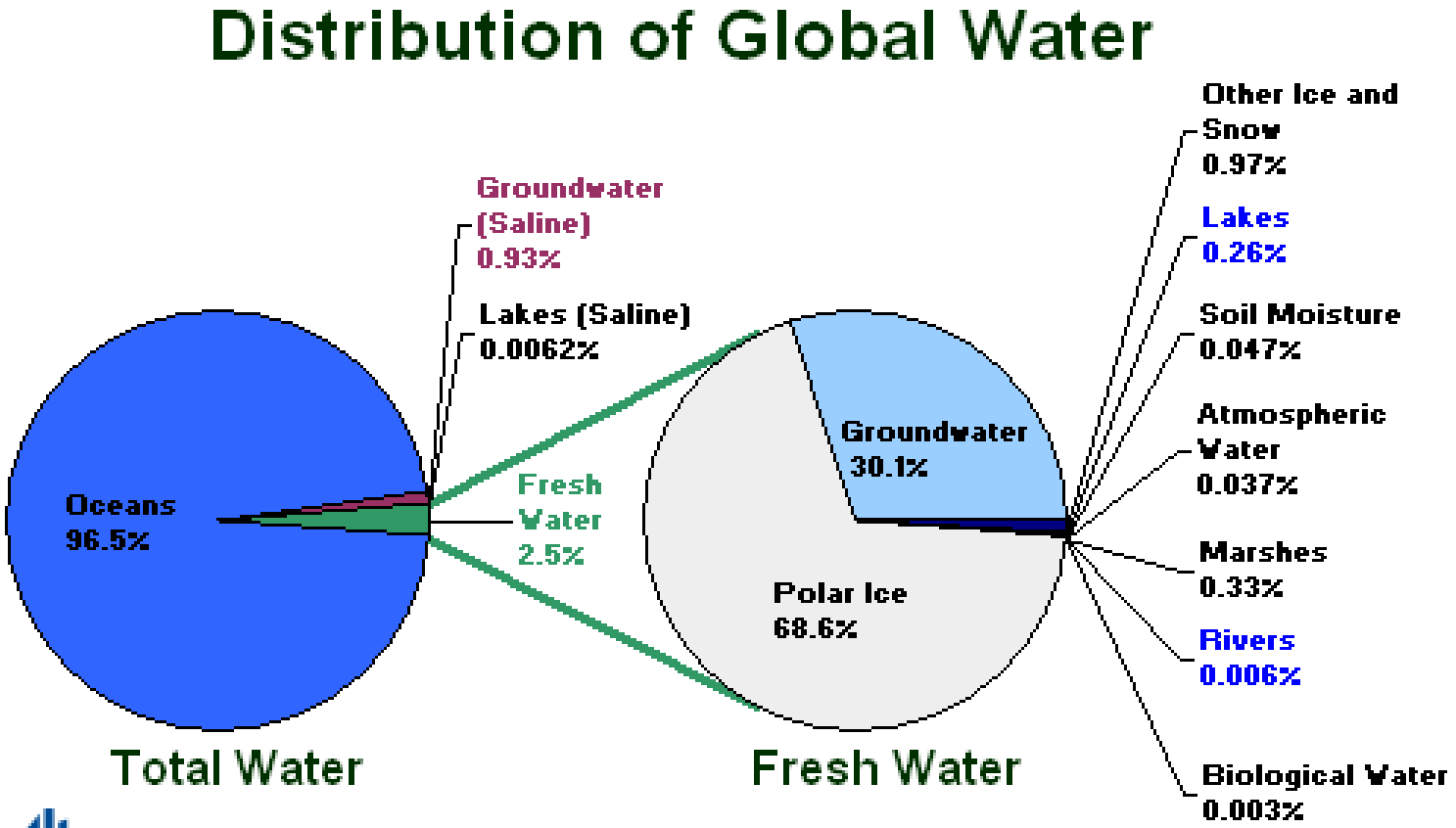
Source: Gleick, P. H., 1996: Water resources. In Encyclopedia of Climate and Weather, ed. by S. H. Schneider, Oxford University Press, New York, vol. 2, pp.817-823.

INTRODUCTION



Source: Igor Shiklomanov's Chapter, "World Fresh Water Resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources.

INTRODUCTION



Alberta Environment

Source:

Water Vs WasteWater

- "Water" used to describe pure (or close to pure) water
- WasteWater consist of waste (or pollutants or contaminants) + Water
- Closest to pure water available naturally is water vapor (not water runoff)
- The presence of pollutants (also referred to as contaminants, impurities or waste) limits the use of water

Water Vs WasteWater

- Impurities can be
  - Disssolved solids
  - Suspended solids
    - Settleable
    - Non-settleable
  - Colloidal solids
- Impurities can also be divided into organic and inorganic
- The aim of water treatment is to remove sufficient quantities of impurities to meet intended usage

Water Vs WasteWater

- Recall from slide 5 and 6 that out of the 2.5% of water that represent fresh water, only surface and ground water are practical choices for water supplies (less than 1 % of total water on earth)
- **Surface water** is exposed to pollution (natural and human activities) and usually contaminated and can not be used directly.
- **Groundwater** is naturally protected by geological formation. Occasionally further treatment is needed due to accidental contamination

INTRODUCTION

- 70% of public water supplies use surface-water
  - 30% withdraw groundwater for public supply
- In some areas, water is not metered at homes (customers are charged a flat rate for water use)
  - This can promote water waste, as consumption is not correlated to cost
- Use of various water sources requires an understanding of :
  - Water-supply choices
  - Degree of treatment required prior to recharge
  - Water-quality issues for the surface water and groundwater

Water Vs WasteWater

- Groundwater is a unique resource dependent on:
  1. Precipitation
  2. Recharge
  3. Evaporation
  4. and hydraulic connection with rivers, springs, and wetlands
- Recharge is increased by enhancing connectivity between surface-water to groundwater recharge and by direct injection

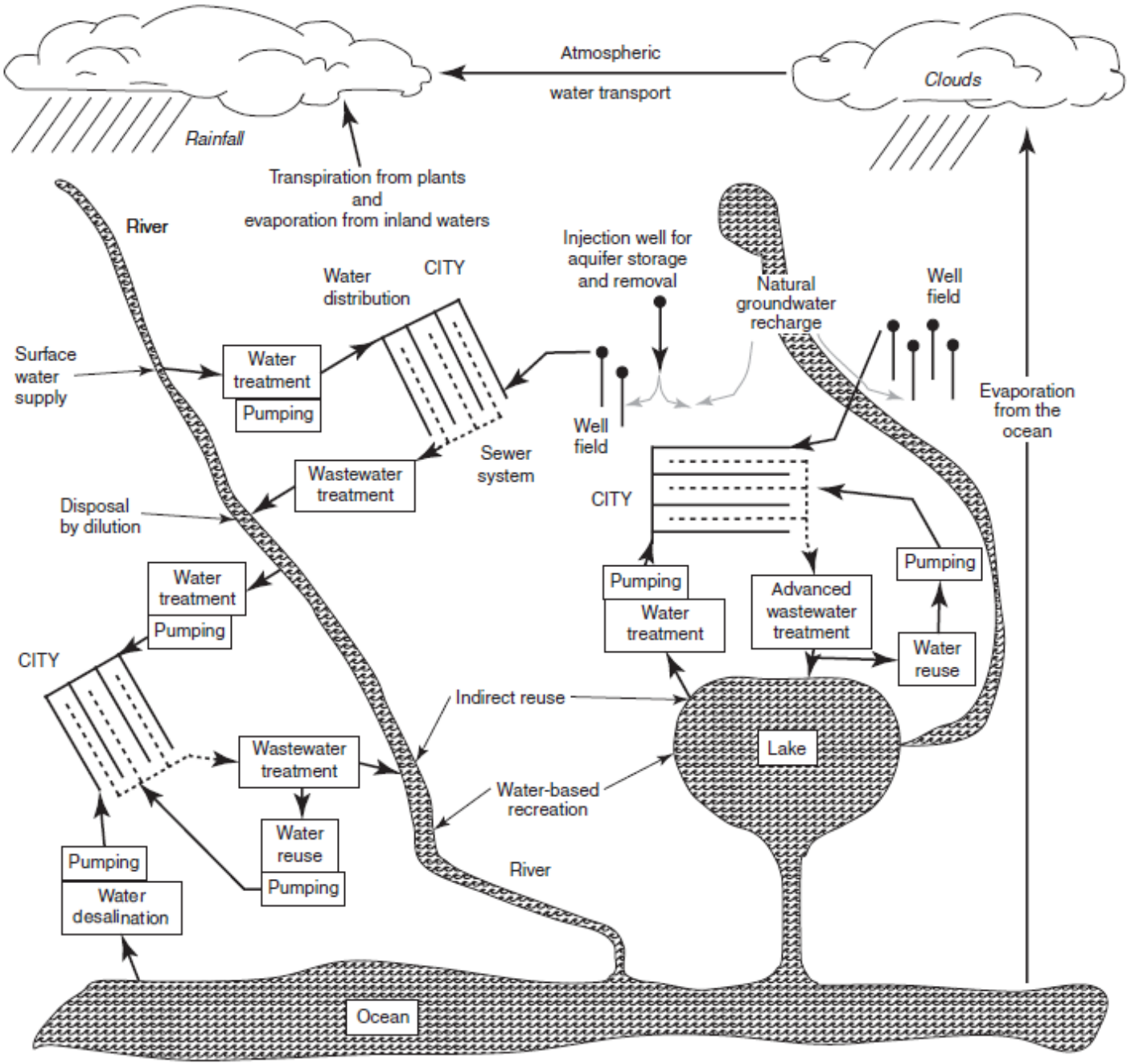


FIGURE 1–3 Integration of natural and human-generated water cycles.

INTRODUCTION

- Advanced water and wastewater treatment by mechanical plants has been introduced into the artificial water cycle
- **Water treatment** is any process that improves the quality of water to make it more acceptable for a specific end-use.
- The end use may be drinking, industrial water supply, irrigation, river flow maintenance, water recreation or many other uses, including being safely returned to the environment.
- Water treatment ***removes*** contaminants and undesirable components, or ***reduces*** their concentration so that the water becomes fit for its desired end-use (Wiki definition)

Raw water supply

Coagulant

Auxiliary chemicals

Rapid mix

Flocculation

Settling tank

Filter

Chlorine

Rapid mix

Chlorination basin

Potable water

Water Distribution

Water Treatment

Surfacewater Discharge

Secondary Treatment

Preliminary and Primary Treatment

Final settling

Biological treatment

Primary settling

Grit chamber

Pumping station

Return activated sludge or recycle flow

Sewage Collection

Wastewater Treatment

Primary Effluent

Anaerobic Zone

N_2 gas

Organic P → P

Mechanically mixed anaerobic chambers

Anoxic Zone

N_2 gas

$NO_3^- \rightarrow N_2$

Mechanically mixed anoxic chambers

Aerobic Zone

$NH_3 \rightarrow NO_3^-$

P → Cell Mass

Air mixed aerobic chambers

Final Settling

N_2 gas

$NO_3^- \rightarrow N_2$

Effluent

Lake

NO_3^-

Recirculation of NO_3, $Q_S = Q$

Sludge

Return Activated Sludge, $Q_R = 0.3Q$

Advanced Wastewater Treatment

Secondary effluent

Coagulant

Auxiliary chemicals

Rapid mix

Flocculation

Settling tank

Chlorine

Filter

Chlorine

Rapid mix

Chlorination basin

Tertiary effluent

Irrigation

Recycled Water

Secondary effluent

Cartridge filters

Compressed air

MicroFilters

Break tank

Cartridge filters

High-pressure pumps

Chlorine

Sulfuric acid

Threshold inhibitor

Reverse Osmosis Units

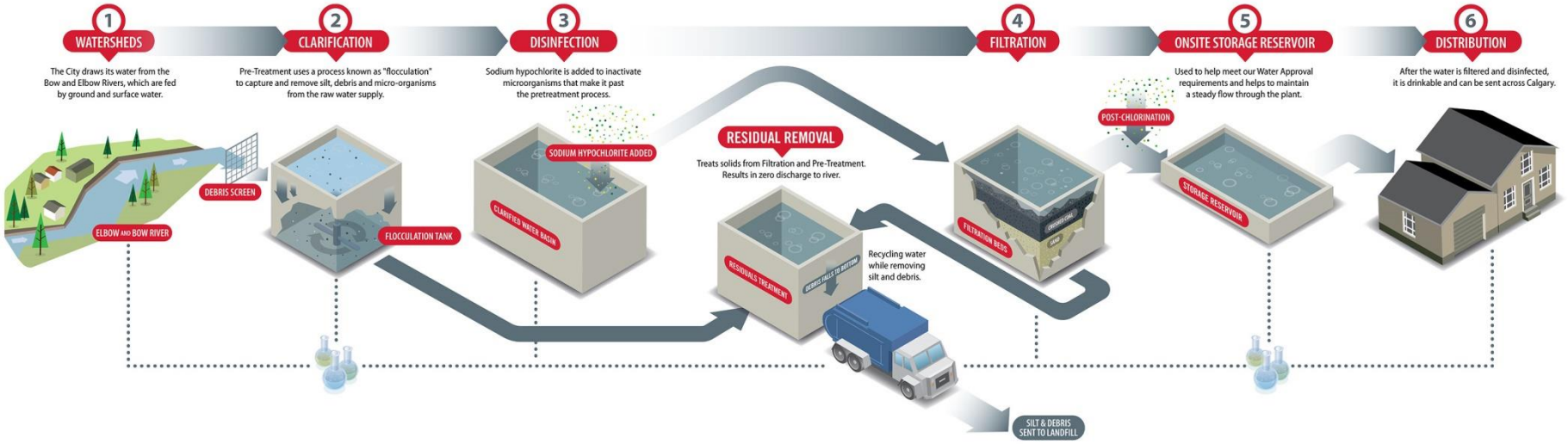
Ultraviolet Disinfection

Packed-tower decarbonator

Injection well

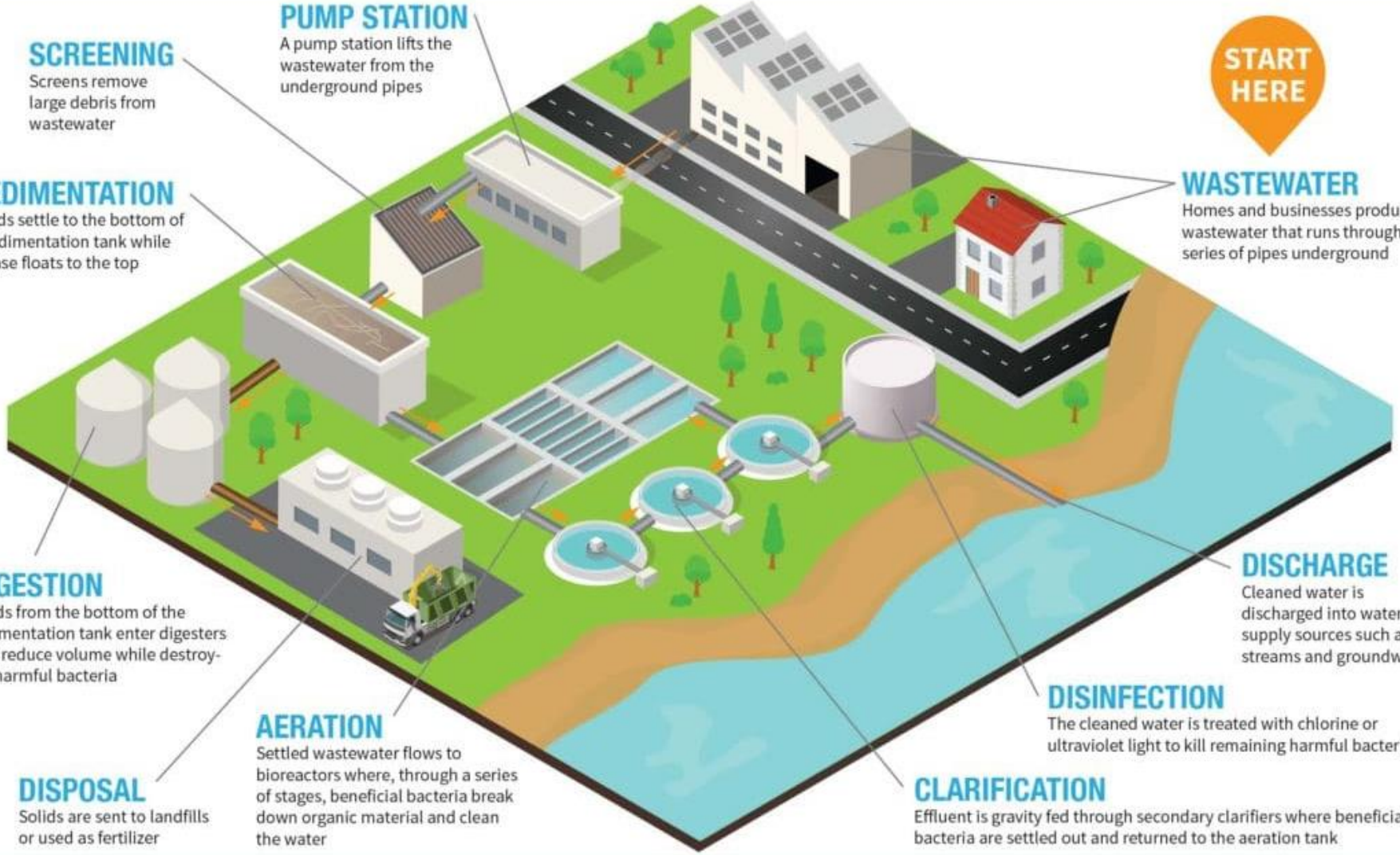
Water Reclamation

The Water Treatment Process



Source: http://www.calgary.ca/UEP/Water/Scripts/Water-tour/Images/Water-treatment-process-3085px.jpg

WASTEWATER TREATMENT



PUMP STATION
A pump station lifts the wastewater from the underground pipes

SCREENING
Screens remove large debris from wastewater

SEDIMENTATION
Solids settle to the bottom of a sedimentation tank while grease floats to the top

WASTEWATER
Homes and businesses produce wastewater that runs through a series of pipes underground

DIGESTION
Solids from the bottom of the sedimentation tank enter digesters that reduce volume while destroying harmful bacteria

DISCHARGE
Cleaned water is discharged into water supply sources such as streams and groundwater

DISINFECTION
The cleaned water is treated with chlorine or ultraviolet light to kill remaining harmful bacteria

AERATION
Settled wastewater flows to bioreactors where, through a series of stages, beneficial bacteria break down organic material and clean the water

DISPOSAL
Solids are sent to landfills or used as fertilizer

CLARIFICATION
Effluent is gravity fed through secondary clarifiers where beneficial bacteria are settled out and returned to the aeration tank

www.tataandhoward.com

INTRODUCTION

- Groundwater systems throughout the U.S. have been permanently lowered by withdrawals that exceed recharge
- The role of engineering has changed with the evolving demands for water
- Increased water use has created environmental consequences resulting in the need to engineer

INTRODUCTION

- In industrialized regions of the world, wastewater is treated before being discharged
- In non-industrialized regions, concentrated pollution is often discharged into freshwater supplies
  - Much of the world does not have access to clean, safe water
- About 35% of U.S. water use is unsustainable
- Humans intervene in the hydrologic cycle, generating artificial water cycles (Fig. 1-3)

INTRODUCTION

- Focus has shifted to sustainability and the need to sustainably create new supplies…
  - Through water reuse and desalination
  - Balancing demand/supply, and human/ecosystem needs
- Surface water, climate change & groundwater are connected
  - Managed with appropriate understanding & analytical tools

Sustainability is the ability to balance natural, physical, social, and economic environments to meet the needs of the present without compromising future generations

INTRODUCTION

- People must learn to live within the capacity of the earth to treat wastes and provide for life's resources
  - The earth has a limited capacity to absorb wastes
- Carbon footprint is the total greenhouse gas emissions caused by individuals, organizations, production and waste treatment
  - Typically reported in equivalent units of CO_2

INTRODUCTION

- The Kyoto Protocol defines legally binding limits and timetables for reducing GHG emissions
  - Federal/state mandates & initiatives to be more sustainable will increase over the next several years

- Western U.S. states and Canadian provinces are developing a regional cap-and-trade program
  - An overall limit on GHG emissions will be established and facilities will be able to trade permits (allowances) to emit

INTRODUCTION

- Climate change has the potential of reducing available water supplies in many areas
  - As a result, it will be necessary to reduce water demands
    and/or develop new supplies.
- Wastewater treatment presents opportunities to reduce the carbon footprint with a goal of becoming carbon neutral
- Water conservation & energy efficiency have always been part of the water and wastewater industry

INTRODUCTION

- While reducing energy demand, wastewater treatment plants can also be a source of energy production
  - Methane produced by anaerobic digestion is a source of renewable energy created during wastewater treatment
- There are also sustainable options for management of the solids at a wastewater treatment plant.
  - Biosolids can be composted and used on agricultural land or bagged and sold to the public

INTRODUCTION

- Advanced systems that reclaim wastewater to nearly original quality have encouraged direct reuse of water
- Direct return for potable water is not encouraged due to hazards from viruses & traces of toxic substances
  - Another problem is buildup of dissolved salts that can be removed only by costly demineralization processes
- With the increase in demand for freshwater, direct water reuse by some metropolitan areas may be realistic in the future

INTRODUCTION

- The basic sciences of chemistry, biology, hydraulics, and hydrology are the foundation for understanding water supply, wastewater treatment & sustainability
- Advanced wastewater treatment incorporates both biological unit operations and chemical processes that are similar to those applied in water treatment

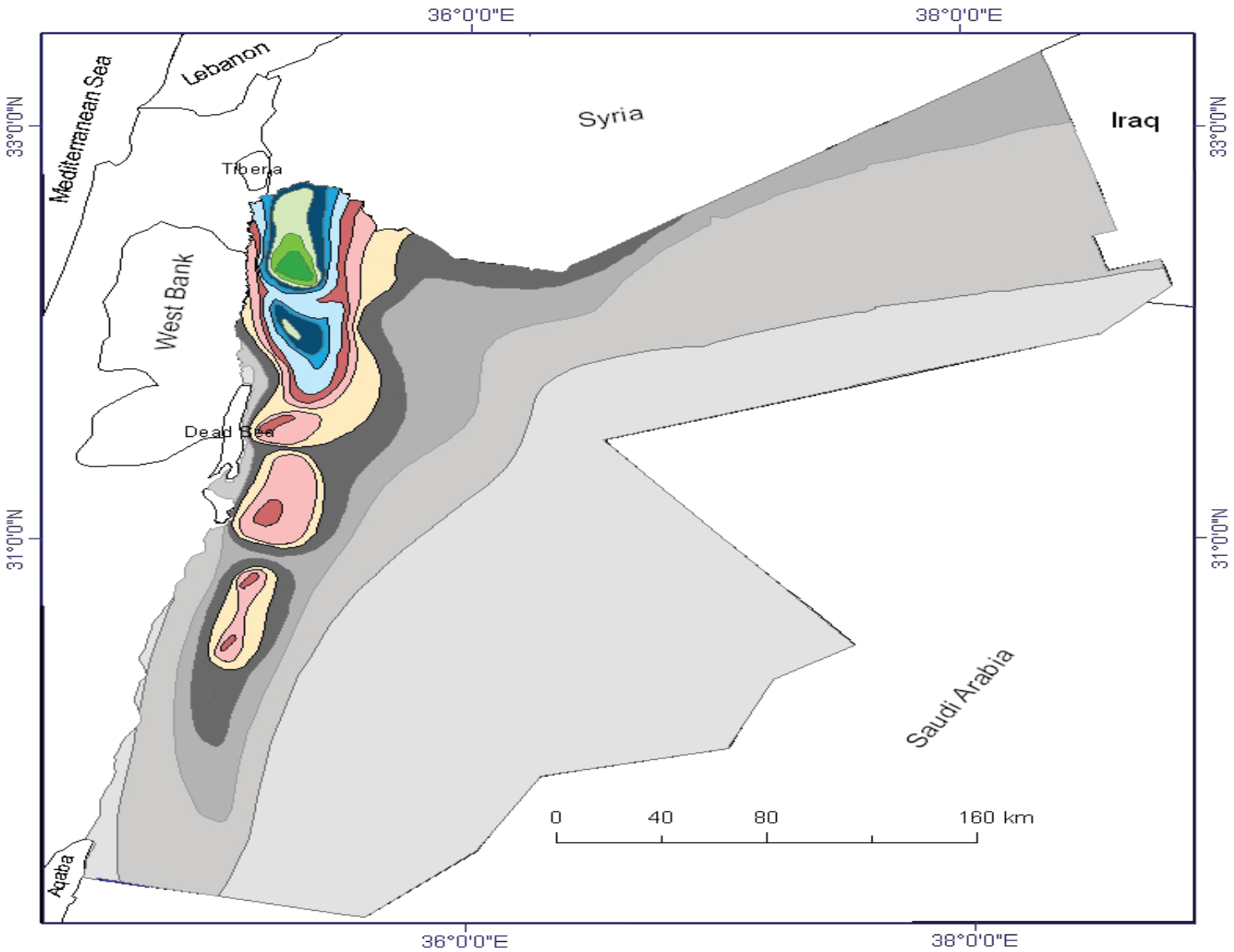
INTRODUCTION
Water & Jordan
Few facts

INTRODUCTION

- In simple words
  - We DO NOT have lots of water
  - We DO have problem
  - **BIG ONE**
- International standard (int. health organization)
  - Water poverty line is 1000 cubic meter /capita/yr
  - In Jordan 120 cubic meter /capita/yr
  - Used to be 3600 cubic meter /capita/yr (1946)
  - As of March 7th, 2015:
    - Irbid, 85 cubic meter /capita/yr
    - Jerash, 77 cubic meter /capita/yr
    - Mafraq, 144 cubic meter /capita/yr
    - Ajlun 67 cubic meter /capita/yr

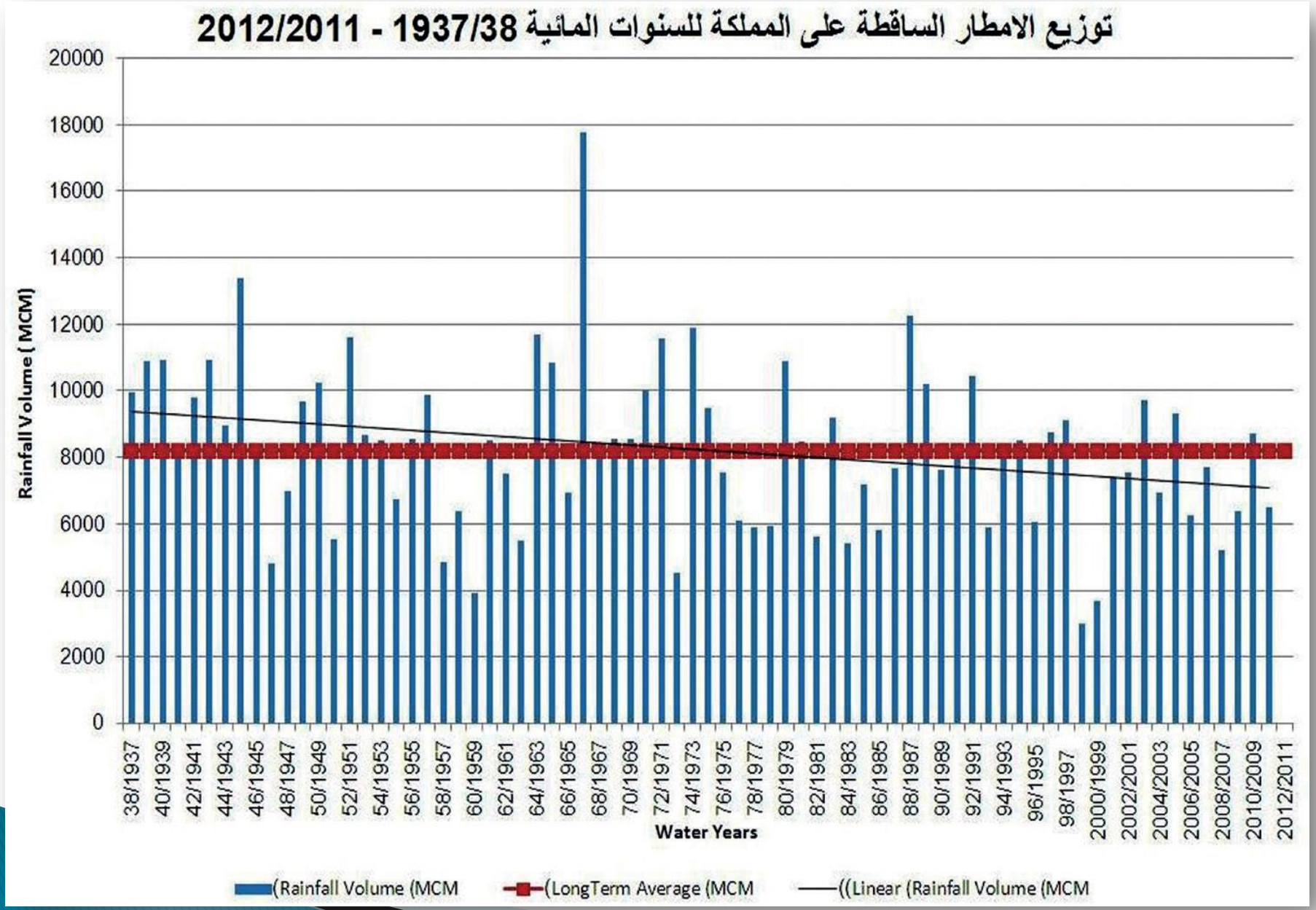
INTRODUCTION

- The Second poorest country in the world in water
- Combine with energy problem, Jordan is the poorest in the world when it comes to water
- 91% of Jordan is either dry or semi-dry (less than 200 mm)
- 5.7% semi dry (201-300 mm/yr)


36°0'0"E
38°0'0"E
33°0'0"N
31°0'0"N
Mediterranean Sea
Lebanon
Syria
Iraq
Tiberia
West Bank
Dead Sea
Saudi Arabia
Aqaba
0
40
80
160 km
Rainfall (mm)
50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
501 - 550
551 - 600
601 - 650
N
W
E
S

INTRODUCTION

- Rainfall rate in Jordan (5.8-11) billion cubic meter / yr
- Long term average 8.522 billion cubic meter/yr
- About 90 % evaporates
- 240 - 290 million cubic meter / yr charge groundwater sources


توزيع الامطار الساقطة على المملكة للسنوات المائية 2012/2011 - 1937/38
Rainfall Volume (MCM)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
38/1937
40/1939
42/1941
44/1943
46/1945
48/1947
50/1949
52/1951
54/1953
56/1955
58/1957
60/1959
62/1961
64/1963
66/1965
68/1967
70/1969
72/1971
74/1973
76/1975
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80/1979
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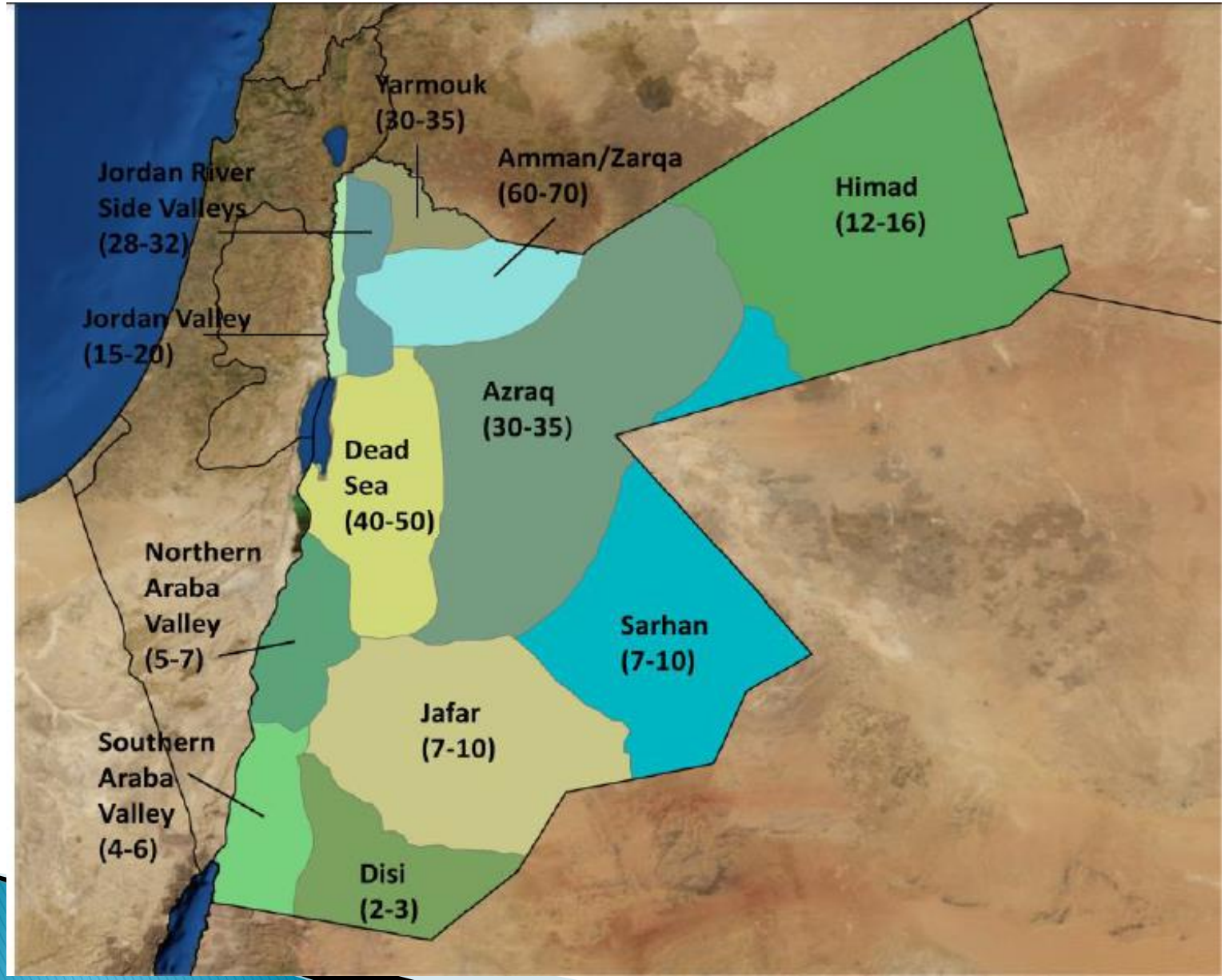
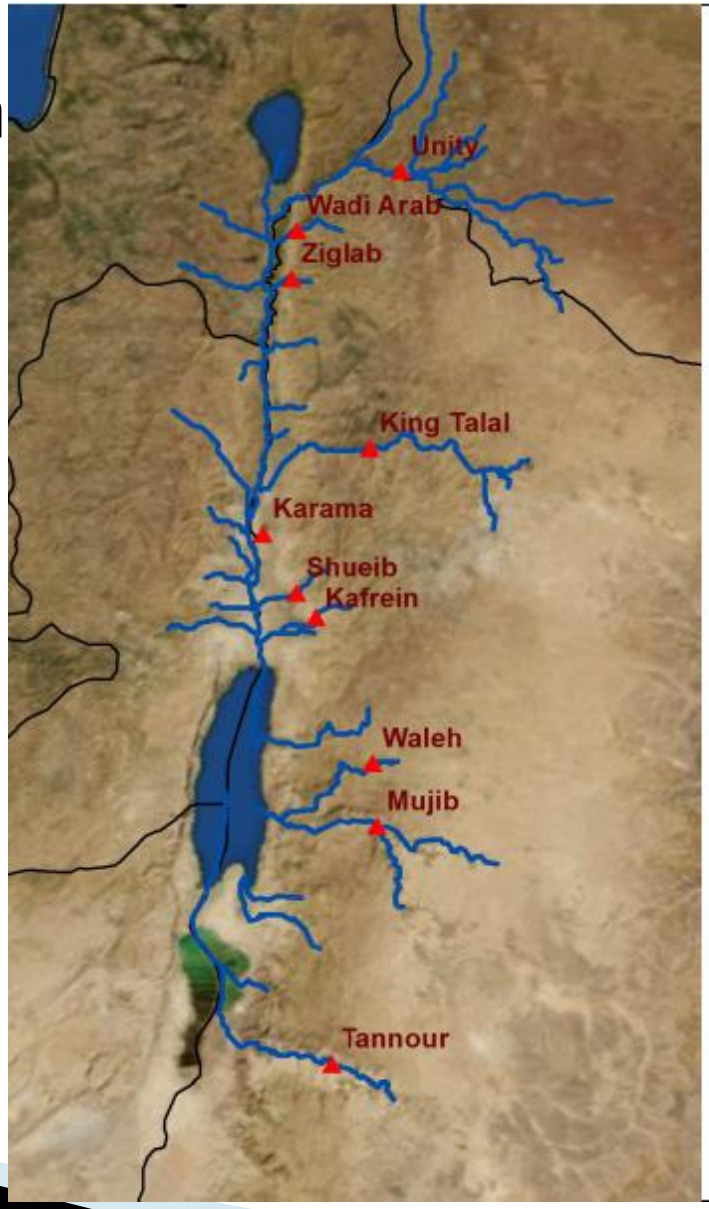
86/1985
88/1987
90/1989
92/1991
94/1993
96/1995
98/1997
2000/1999
2002/2001
2004/2003
2006/2005
2008/2007
2010/2009
2012/2011
Water Years
(Rainfall Volume (MCM
(LongTerm Average (MCM
((Linear (Rainfall Volume (MCM

Ground water in Jordan



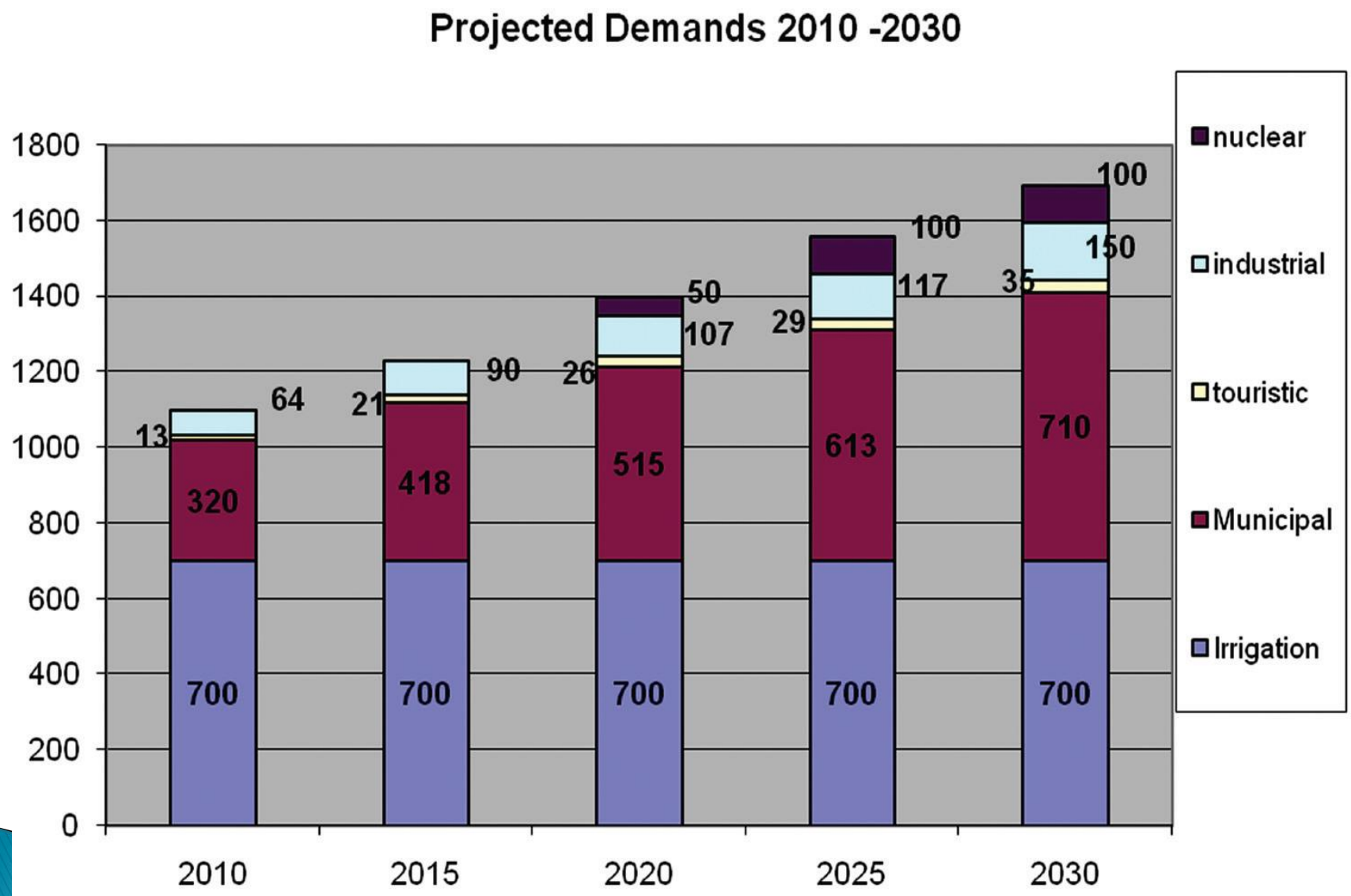
INTRODUCTION

- 713 million cubic meter/yr turn into surface water (mainly Yarmouk river, some valleys, seasonal flows

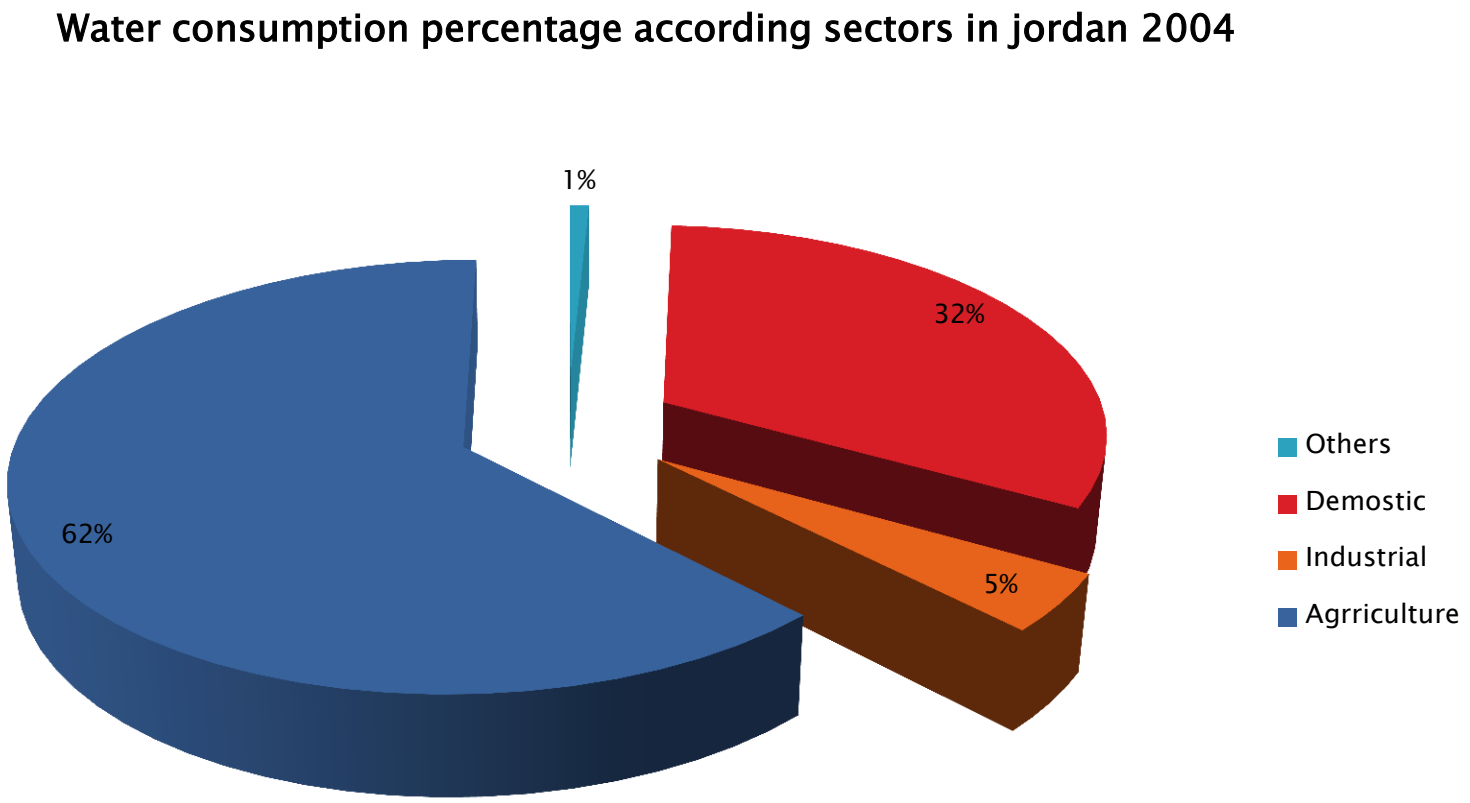


Dam	Storage (MCM/year)
Unity Dam	110.0
Wadi Arab	17.0
Ziglab	3.8
King Talal	75.0
Karama	55.0
Shueib	1.4
Kafrein	8.4
Waleh	9.3
Mujib	35.0
Tannour	16.8
Total	**331.7**

Water demand in Jordan



Water demand in Jordan



2004

Most of previous material has been taken from

Water and Wastewater Technology

Seventh Edition

Mark J. Hammer

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Thank You