CANTHO UNIVERSITY

Co-funded by the Erasmus+ Programme of the European Union

WATERSHED MANAGEMENT COURSE PART 1 - 2

Nguyen Dinh Giang Nam, PhD CENREs, CanTho University Nguyen Hieu Trung, Prof, CanTho University

Co-funded by the Erasmus+ Programme of the European Union

Agenda

Part 1:

1. River Basin

2.Integrated Water Res. Management (IWRM)

3. Surface water / Groundwater Interaction

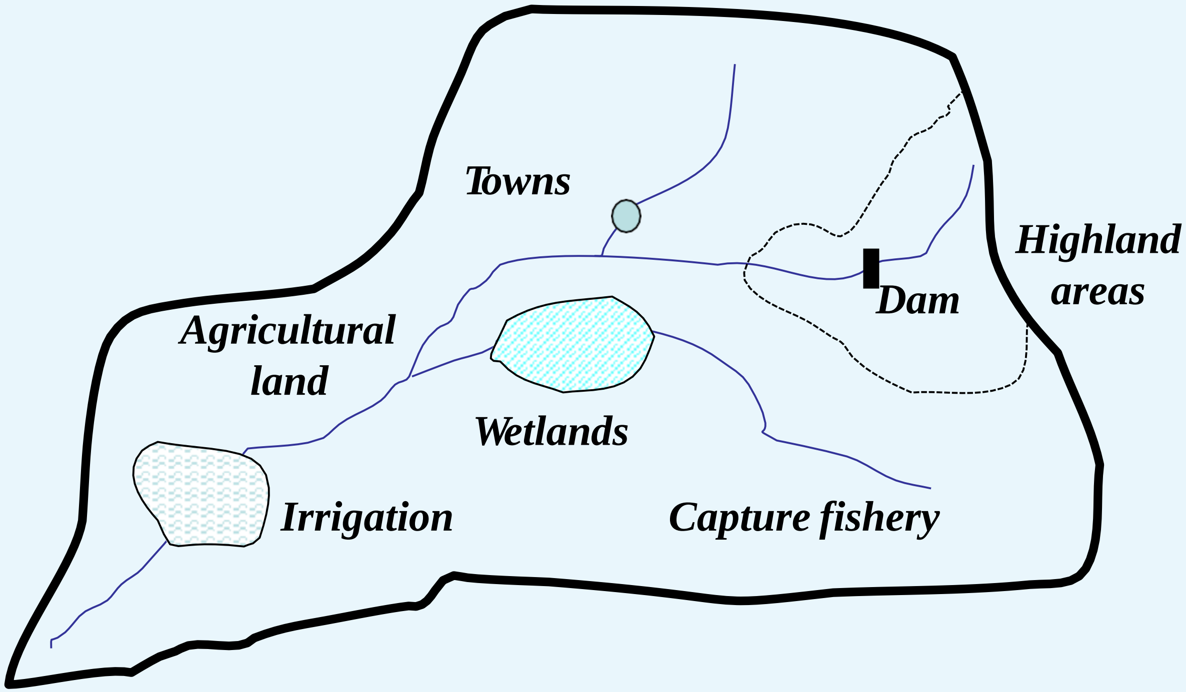
4. Model for IWRM

5. Simple IWRM model practice

Part 2: Discussion

River Basin

What is a River Basin?



Catchments are:

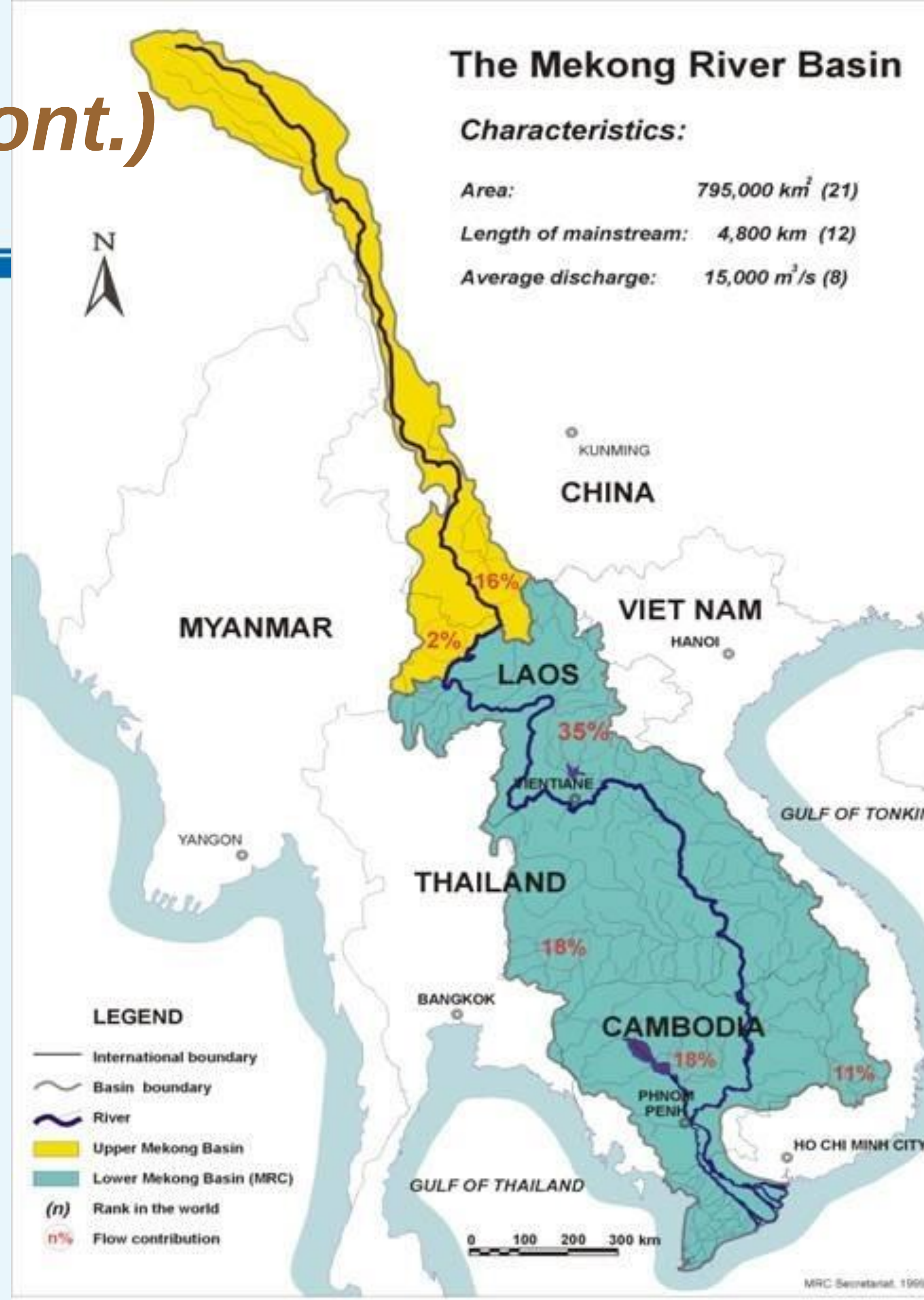
- the land area which collects the rainfall,
- the main stem of the river, the tributaries and groundwater systems that carry the water;
- the floodplain and the wetlands which receive the water

River Basin *(cont.)*

The Mekong Basin is an International River Basin

Each nation makes a contribution to water flow in the Mekong River:

China	16%
Myanmar	2%
Laos	35%
Thailand	18%
Cambodia	18%
Viet Nam	11%



CANTHO UNIVERSITY

River Basin Management (RBM)

- It deals with the management of water resources in the basin
- Purpose of RBM: To ensure the use of water and other resources in the basin in a sustainable manner
- Most of the basins have multi-objectives and limited resources
- It is necessary to assign priorities to different needs
- Need for RBM arises from the non-coordinated usage or even overexploitation of resources
- RBM can be divided into six activities:
    - Planning
    - Construction
    - Operation
    - Monitoring
    - Analysis and
    - Decision making

Integrated Water Resources Management (IWRM)

River basin can be divided into three components:

- According to the Technical Advisory Committee (TAC) Global partnership 2000

  IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.

Integrated Water Resources Management (IWRM) *(cont.)*

In order to understand better "integrated" approach

- **Traditional approach**
  - One sector
  - Limited institutions involved
  - Decision making at one sector
  - Specific issues addressed
  - Specific interests solved
  - Sectoral allocation of funds

- **Integrated approach**
  - Multi sectors
  - Various institutions involved
  - "collective" decision making
  - Complex issues addressed
  - Overriding interests solved
  - National allocation of funds

Integrated Water Resources Management (IWRM) *(cont.)*

<u>In order to understand better "integrated" approach</u>

Traditional approach:

- Hydrological/hydraulic
  - What is expected yield of the catchment?
- Engineering
  - How much water leaks from the system?
  - How can leakage be reduced?
- Management
  - What is the economic level of leakage?

Integrated approach:

- How will new investment be agreed upon?
- How can local management structures balance competing uses?
- How will stakeholders negotiate water rights in different conditions of water availability (scarcity)?
- How will consumers respond to periodic water shortages or to increasing environmental concerns?

Integrated Water Resources Management (IWRM) *(cont.)*

- Water resources management that takes full account of:
  - All natural aspects of watershed
  - Interests of water users
  - National objectives and constraints
  - Institutional framework and stakeholders

Dimension 1 (water resources) → **Include all forms of water occurrence (surface water, groundwater water…)**

Blue water: water in rivers, lakes, shallow aquifer

Green Water : water in unsaturated zone

Integrated Water Resources Management (IWRM) *(cont.)*

Dimension 2 (water users)

Household (domestic)

Industrial , agriculture, fishers, ecosystems, hydropower, recreation…etc.

Quantity and Quality of Water

Dimension 3 (Spatial Scale(

Large Scale
- International level
- National level
- Province and district level
- Local level

Hydrological System Boundaries
- River basin
- Sub-catchment
- Watersheds

Surface water / Groundwater Interaction

Key Issues for GW-SW Interaction

- Physical / Chemical Interaction – water balance / quality implications
- System Dimensions: time / flow rate factors
- River basin / aquifer boundaries
- Allocation issues
- Institutional interactions
- Legislation concordance
- Practical management / monitoring issues

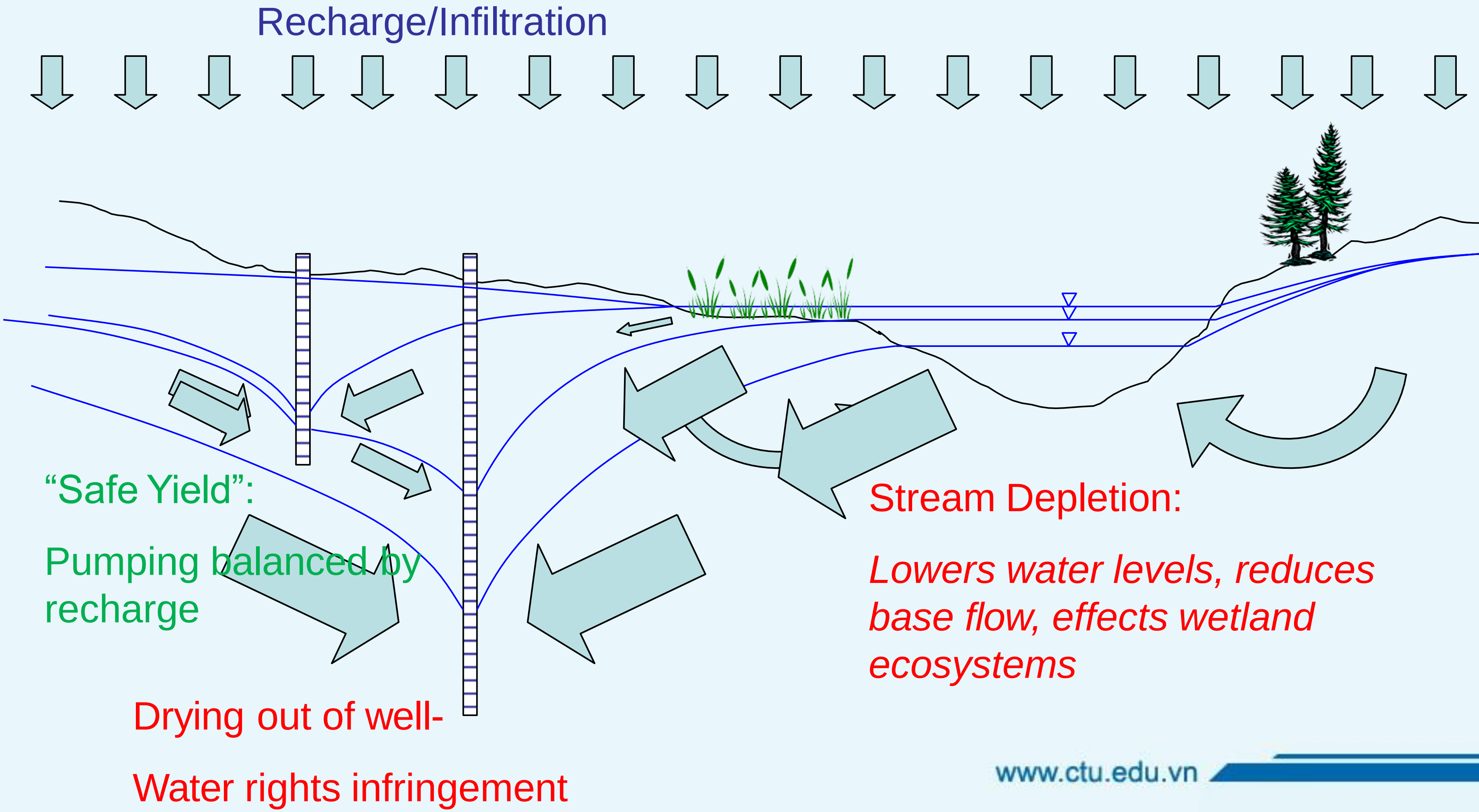
Surface water / Groundwater Interaction *(cont.)*

Physical / Chemical Interaction

- All abstraction will have an impact on the total water balance and water quality.
- Groundwater dependant ecosystems as discharge zones are often the first to register the impact of abstraction.
- These impacts may be immediate and relatively simple in small local systems, long term and complex as in large regional systems.
- The processes and their duration / time scale need to be understood for effective management.

Surface water / Groundwater Interaction *(cont.)*

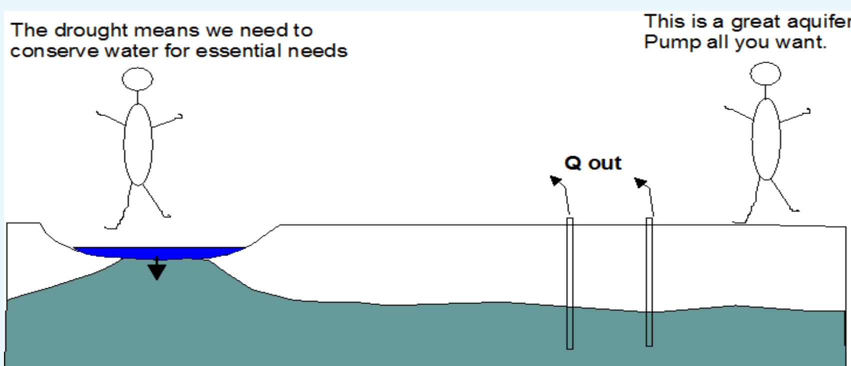
Physical / Chemical Interaction (*cont.*)



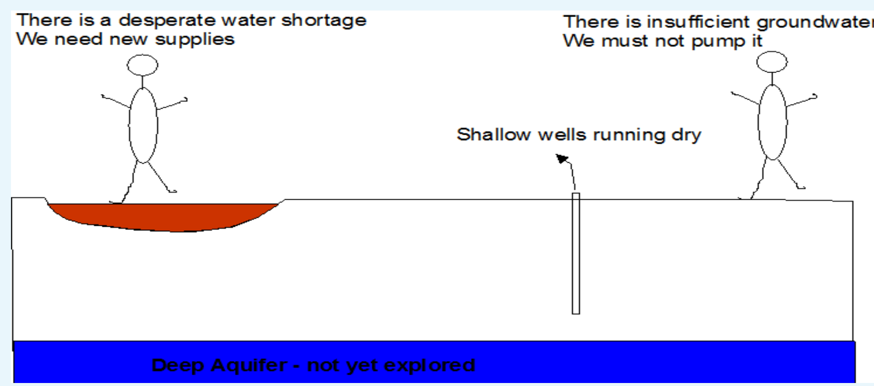
Surface water / Groundwater Interaction (cont.)

Water Allocation Issues

- Effective water allocation requires not only a good working knowledge of the basin / aquifer water balances, but also good communication between the different managers.
- Institutional and regulatory issues often impede effective scientific management of the water resource.
- Surface water allocations tend to take precedence especially if the groundwater condition is not well known or understood.



Adequate knowledge of surface and groundwater resources needed for allocation decisions.

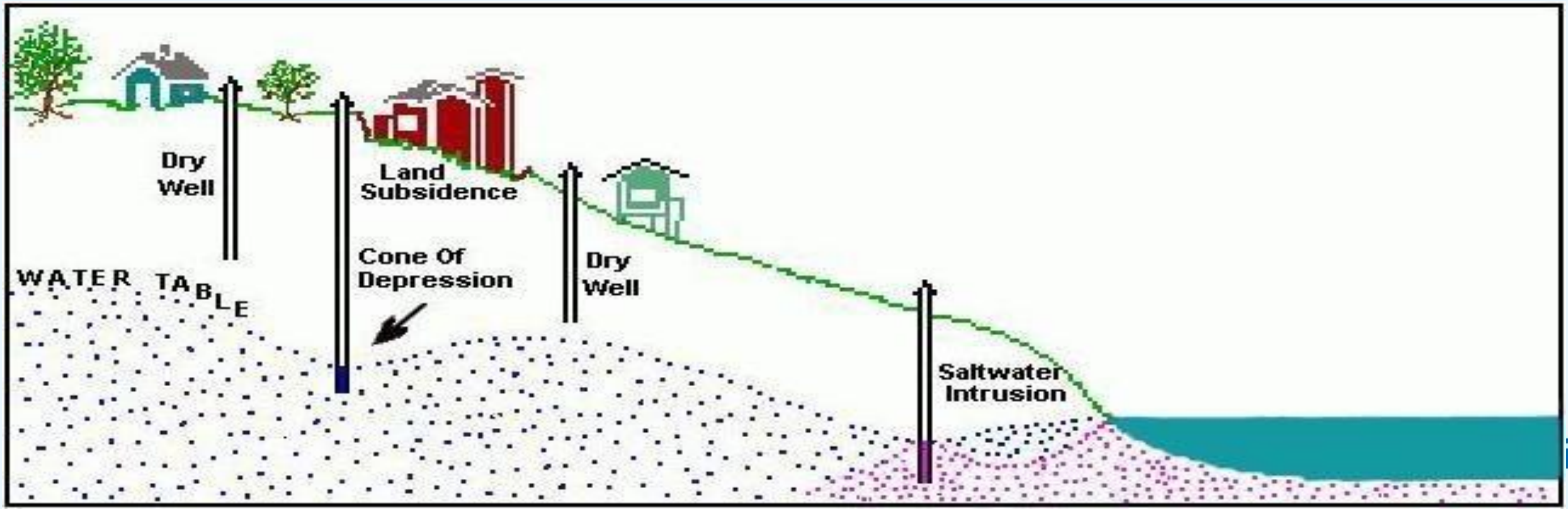


Communication and shared knowledge are essential for effective water allocation

Surface water / Groundwater Interaction (cont.)

Abstraction Impacts

- The impact of surface water abstractions on groundwater flows => reduced recharge => declining heads => reduced discharges; reduced aquifer yields; increased pumping heads; etc...
- Impacts of groundwater abstractions on surface water flows => reduced base-flows and drying out of streams; delay in start of river flow during rainy season; amelioration of floods



Surface water / Groundwater Interaction *(cont.)*

CANTHO UNIVERSITY

Institutional Interactions and legistration

- Many provinces manage their water by means of River Basin. The role of groundwater in such organizations is often minimal.
- Groundwater Managements often operate as independent organizations without reference to surface flows.
- Groundwater and Surface water are often managed by different departments.
- The actual interactions between surface and groundwater are complex, and adequate data and advanced modelling are needed to understand these interactions.
- Groundwater may not be mentioned at all in the water act.
- Often regulation of groundwater is implied in the legislation rather than specified.
- Interpretation and application of the legislation may require significant human resources and technical capacity to achieve compliance

Model for IWRM

- Groundwater and surface water resources are intimately connected
- Management of either resource requires knowledge of the impact of management decisions on both
- Due to the complexity of these systems, predictive models should be used to facilitate decision making

    - Management problem posed as a *"simulation-optimization"* exercise

Water Management

- Water managers are tasked with determining how best to obtain and allocate our water resources – who gets water, how much they get, and where they can get it from.
- In the case of groundwater allocation, the selection of well locations and pumping schedules can

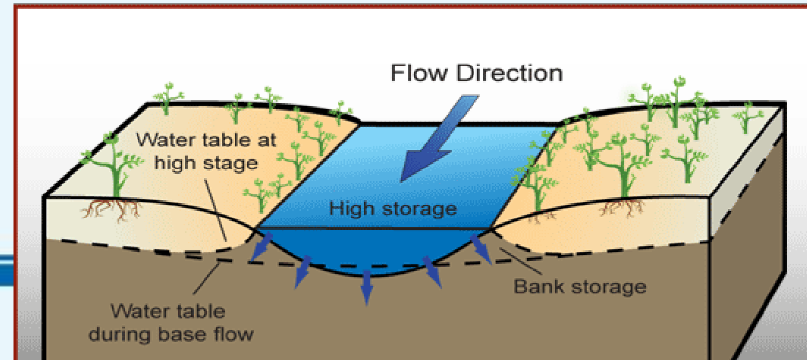
    -impact the *quantity* and *distribution* of water present in streams, wetlands, or aquifers and

    - determine the *quality* of both the pumped water and affected areas

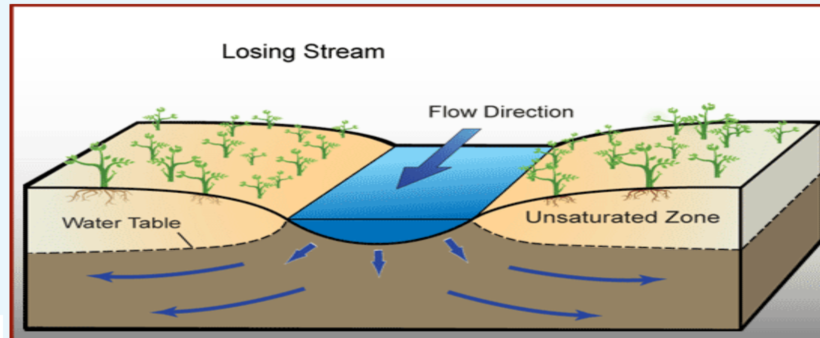
Model for IWRM (cont.)

Conceptual Models

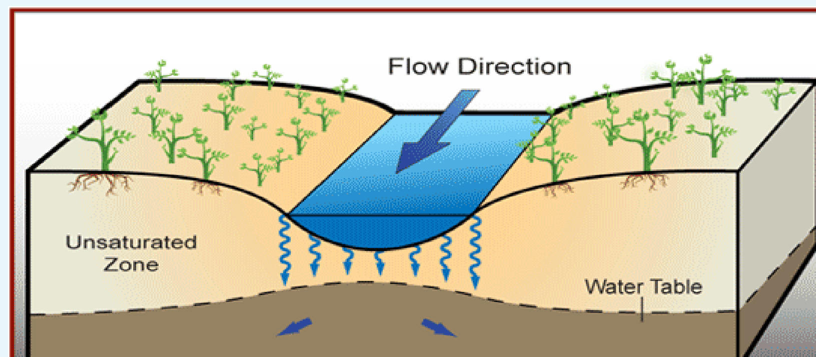
- Groundwater and surface water exchanges occur in both directions
- Behavior is generally transient and can rarely be predicted in a purely deterministic manner



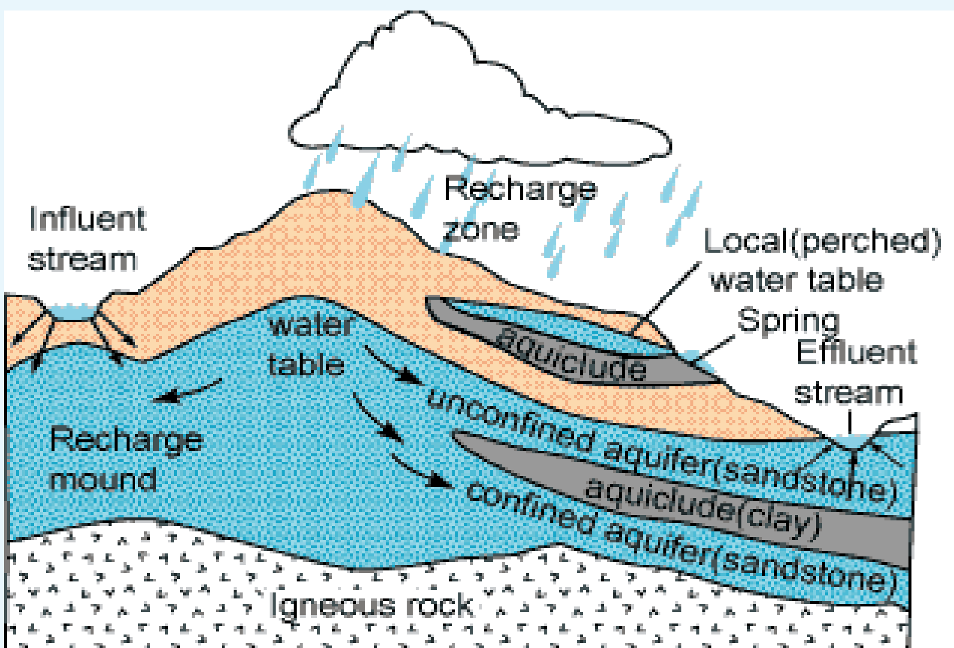
Gaining during low flow, losing during high flow.



Connected losing stream



Disconnected stream



Model for IWRM *(cont.)*

<u>"Typical" GW-SW optimization problem</u>

- Maximize groundwater withdrawal with minimal impact to surface water resources
- By changing:
  - *Pumping rates, schedules, & locations*
  - *Surface irrigation and storage measures*
- Subject to multiple constraints:
  - *Groundwater quantity & quality*
  - *Surface water quantity & quality*
  - *Cost*

CANTHO UNIVERSITY

Model for IWRM *(cont.)*

<u>Quantity constrains</u>

- Groundwater quantity / distribution
  - Sustainable pumping rates (or close enough)
  - No water rights infringements (penalty function)

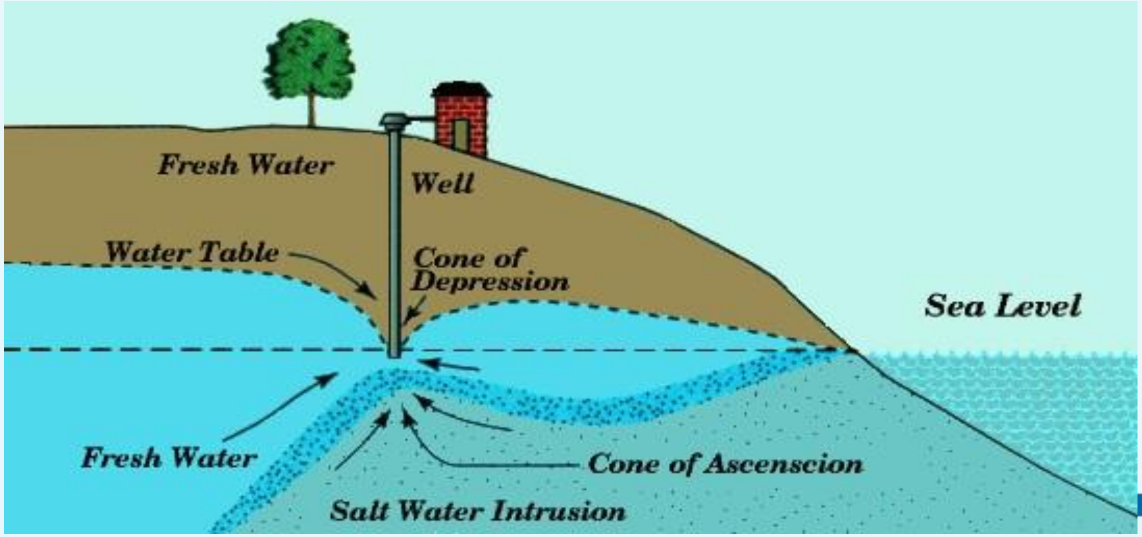
- Surface water quantity / distribution
  - Water levels must typically be maintained high enough to sustain fish and bird habitats, recreation
  - Flow rates have to be within desirable limits for
    - » Hydropower
    - » Dilution of agricultural & industrial waste
    - » Sediment transport
  - All impacts propagate downstream – watershed-scale management is common

Model for IWRM *(cont.)*

Quality constrains

- May wish to minimize or disallow amount of surface water allowed to reach pumping wells
  - Reduces/removes presence of surface water contaminants

- Seawater intrusion



Model for IWRM *(cont.)*

First Generation Models:

- Concentrated in hydraulic and hydrologic aspects such as flood routing, reservoir operation etc.
- Models for sediment transportation and water quality simulation were developed side by side.
- **Streamflow Synthesis and Reservoir Regulation (SSARR)** from USACE
- **SIMLYD –II** from Texas water development board
- **HEC-5** model is also widely used to simulate operation of reservoir systems.

Model for IWRM *(cont.)*

Second generation models:

- Able to consider both hydrologic and water quality aspects
- These are able to perform interactive analysis and display of results
- **Interactive River – Aquifer Simulation (IRAS)** by Loucks et al. (1994) extensively uses graphics in system simulation
- **European Hydrological System (SHE)** is a distributed and physically modeled system and describes the major land flow processes of the hydrologic cycle
- **MIKE SHE** is a advanced version of SHE with add-ons for water quality, soil erosion, irrigation etc
- Water quality simulation models are a standard feature of river basin models
- Widely applied one is the **Enhanced Stream Water Quality Model (QUAL2E)** which simulates temperature, dissolved oxygen, biochemical oxygen demands etc.
- Another one is the **Water Quality for River Reservoir Systems (WQRSS)** by Hydrologic Engineering Center.

Model for IWRM *(cont.)*

CANTHO UNIVERSITY

Third generation models:

- Interactive models with graphical user interfaces, GIS inputs and screen display of results

Tennessee river valley authority Environment and River resource Aid (TERRA):

- Reservoir and power generation management tool linked to a local area network for real time functioning

River Basin Simulation Model (RIBASIM):

- Simulates river basins for various hydrological conditions
- Links hydrological inputs at various locations with specific water uses in the basin
- Evaluates alternatives of infrastructure, operational and demand management through a decision support system (explained in the previous module).

MIKE BASIN:

- Represents rivers and tributaries as network with branches and nodes.
- Has a graphical interface which is linked to ArcView GIS
- Gives information on individual reservoir outputs and irrigation scheme with frequency and magnitude of water shortages.

Model for IWRM *(cont.)*

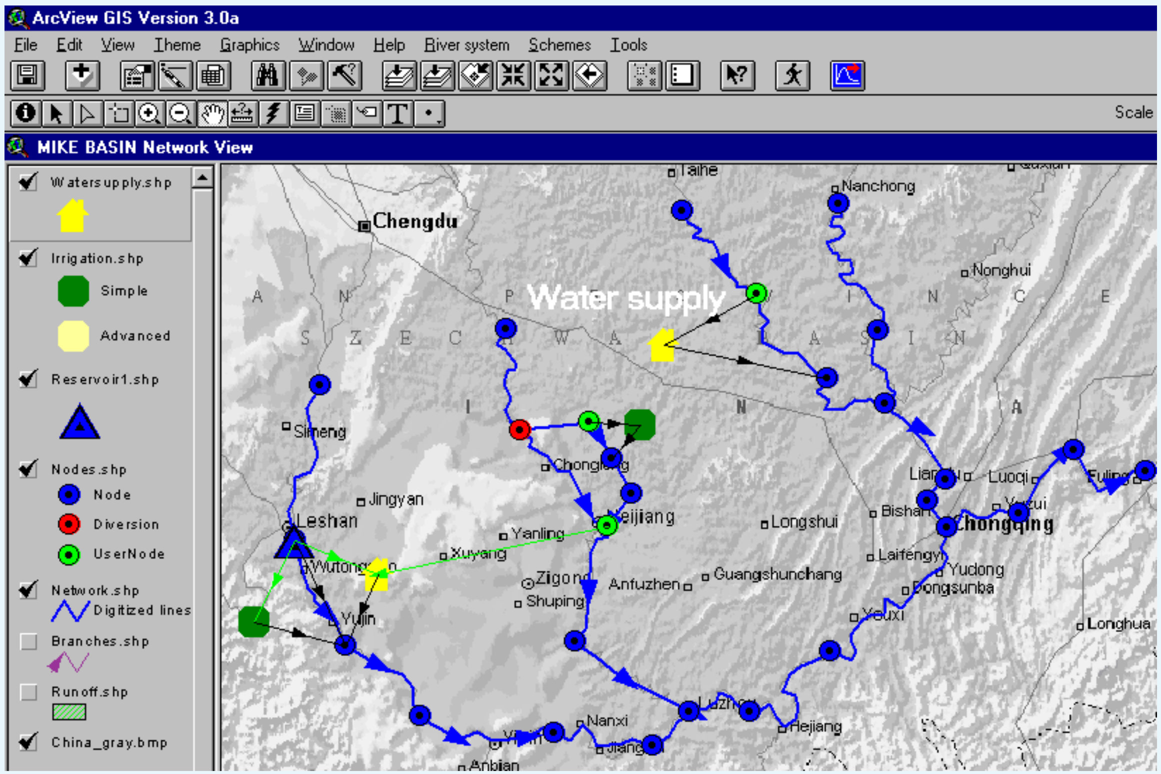
MIKE BASIN

- Modeling tool for integrated river basin planning and management
- Developed by DHI in Denmark (**http://www.dhisoftware.com/mikebasin**)
- Addresses water allocation, conjunctive use, reservoir operation, and water quality issues.
- Couples ArcGIS with hydrologic modeling to provide basin-scale solutions
- Provides a mathematical representation of the river basin encompassing the main rivers and their tributaries, the hydrology of the basin in space and time, existing as well as potential major schemes and their various demands of water.
- River systems are represented by a network consisting of branches and nodes.
- Branches represent individual stream sections
- Nodes represent confluences, locations where certain water activities may occur, or important locations where model results are required.

Model for IWRM *(cont.)*

MIKE BASIN

Graphical User Interfaces (GUI) for different applications



Representation of river network in a basin

Model for IWRM *(cont.)*

MIKE BASIN

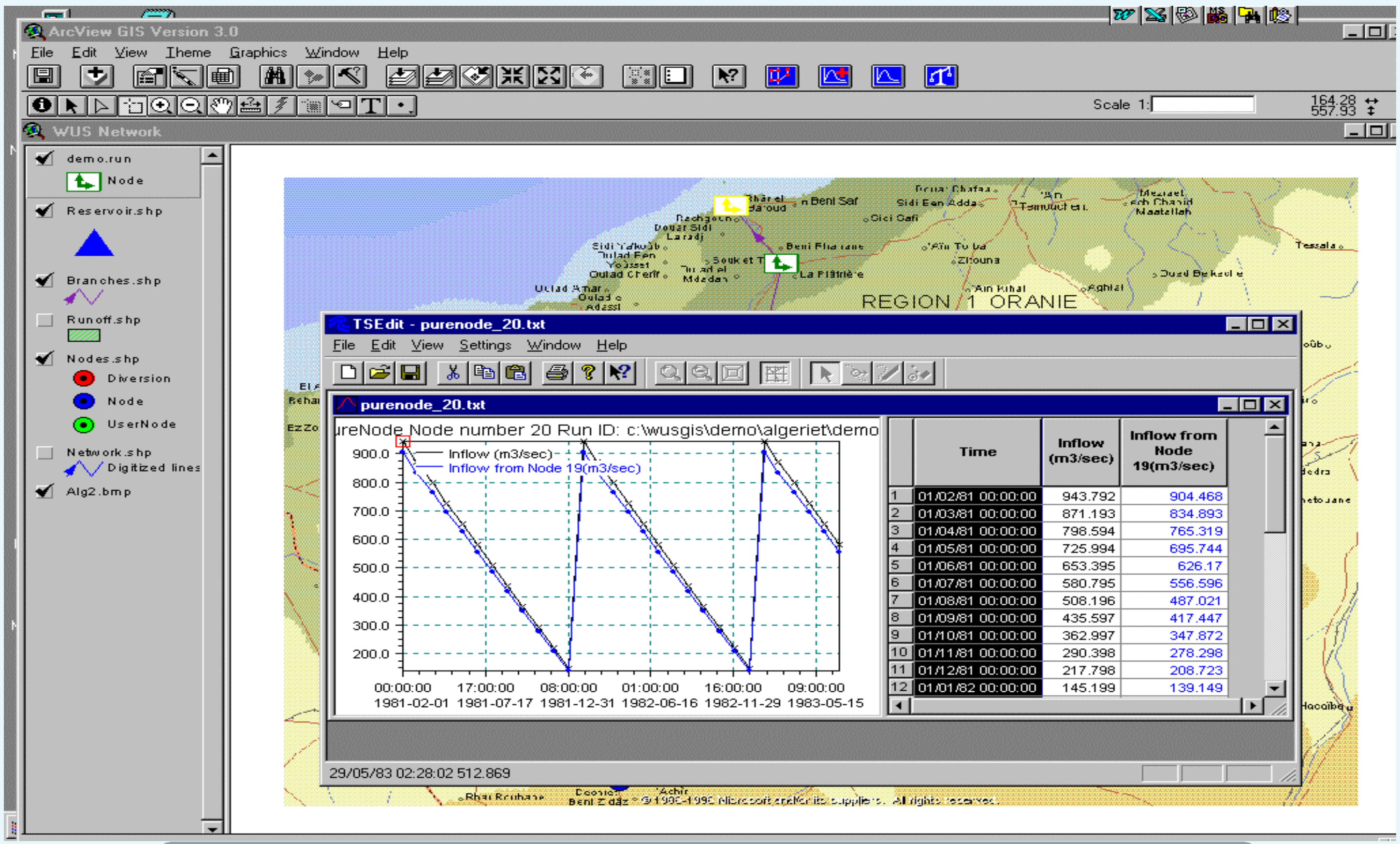
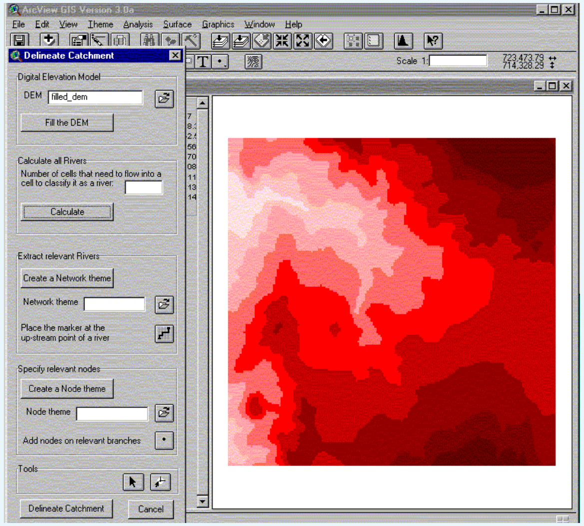


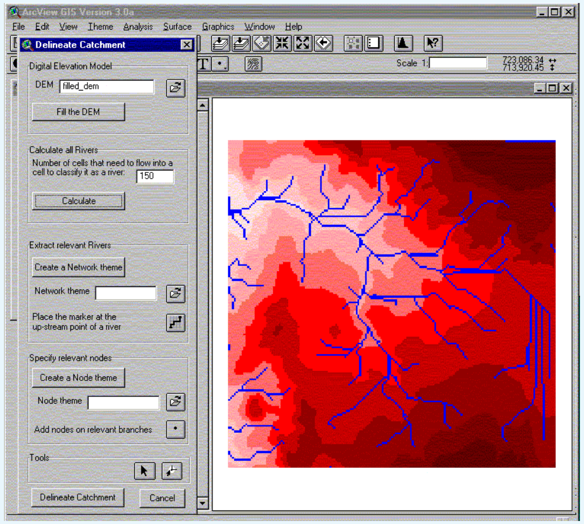
Illustration of results – Flow at a node

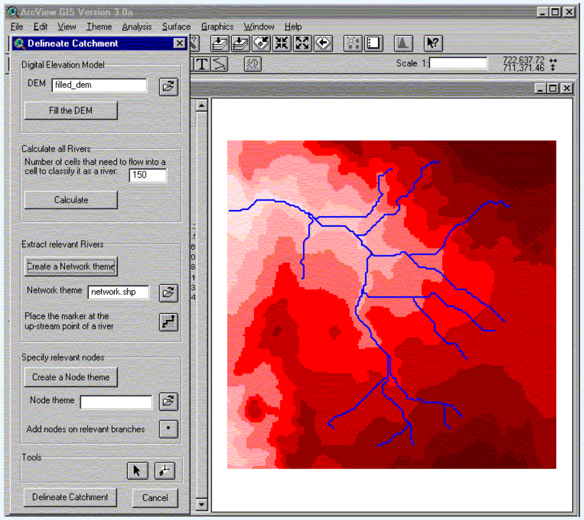
CANTHO UNIVERSITY

Model for IWRM

MIKE BASIN







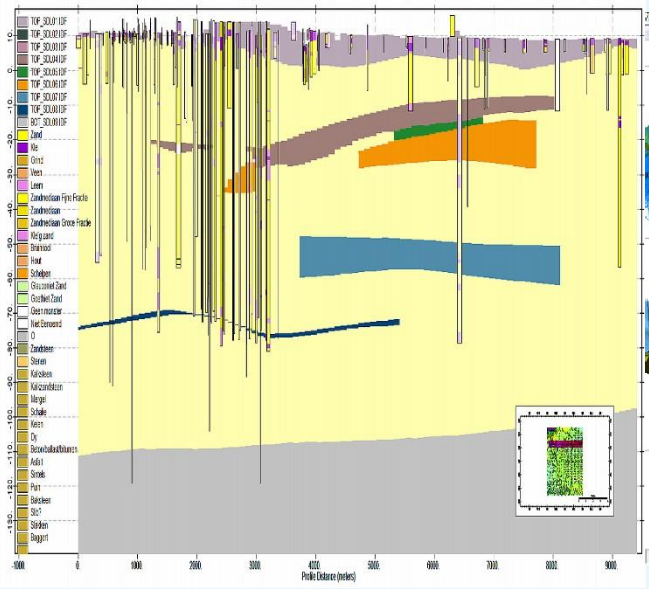
Delineation of catchment and river networks from digital elevation models (DEMs)

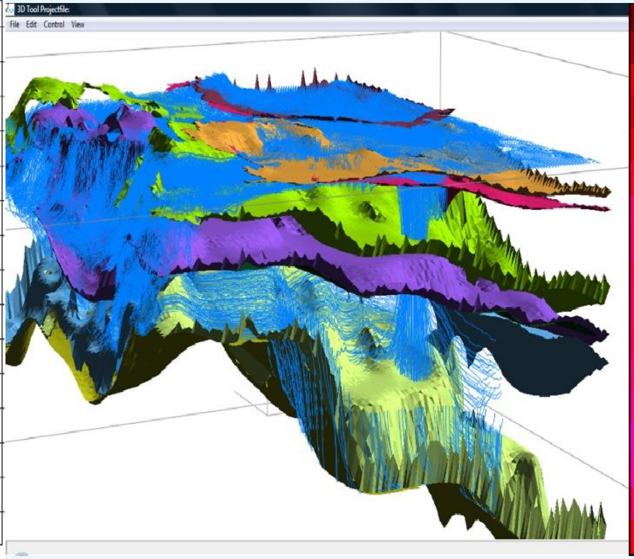
Model for IWRM *(cont.)*

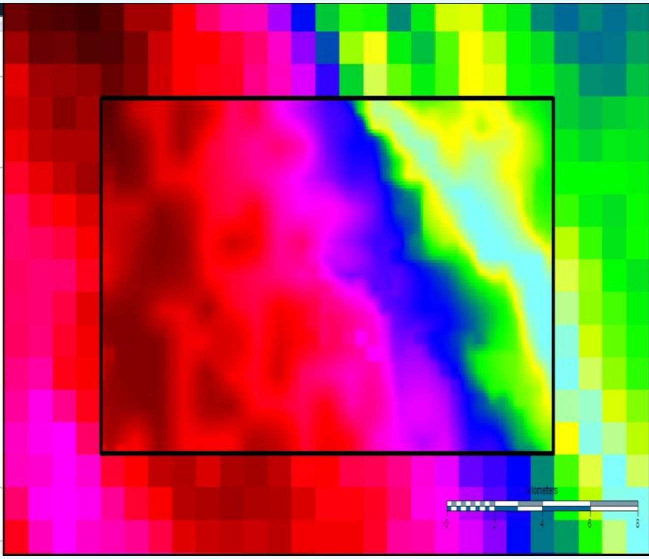
- Stands for Interactive MODeling and an developing software based upon the concept of MODFLOW (USGS), made by Deltares in 2009
- Accelerated and easy to use:

iMOD

- User-friendly interface
- Groundwater flow models in many scales.
- High-resolution 3D MODFLOW groundwater computations



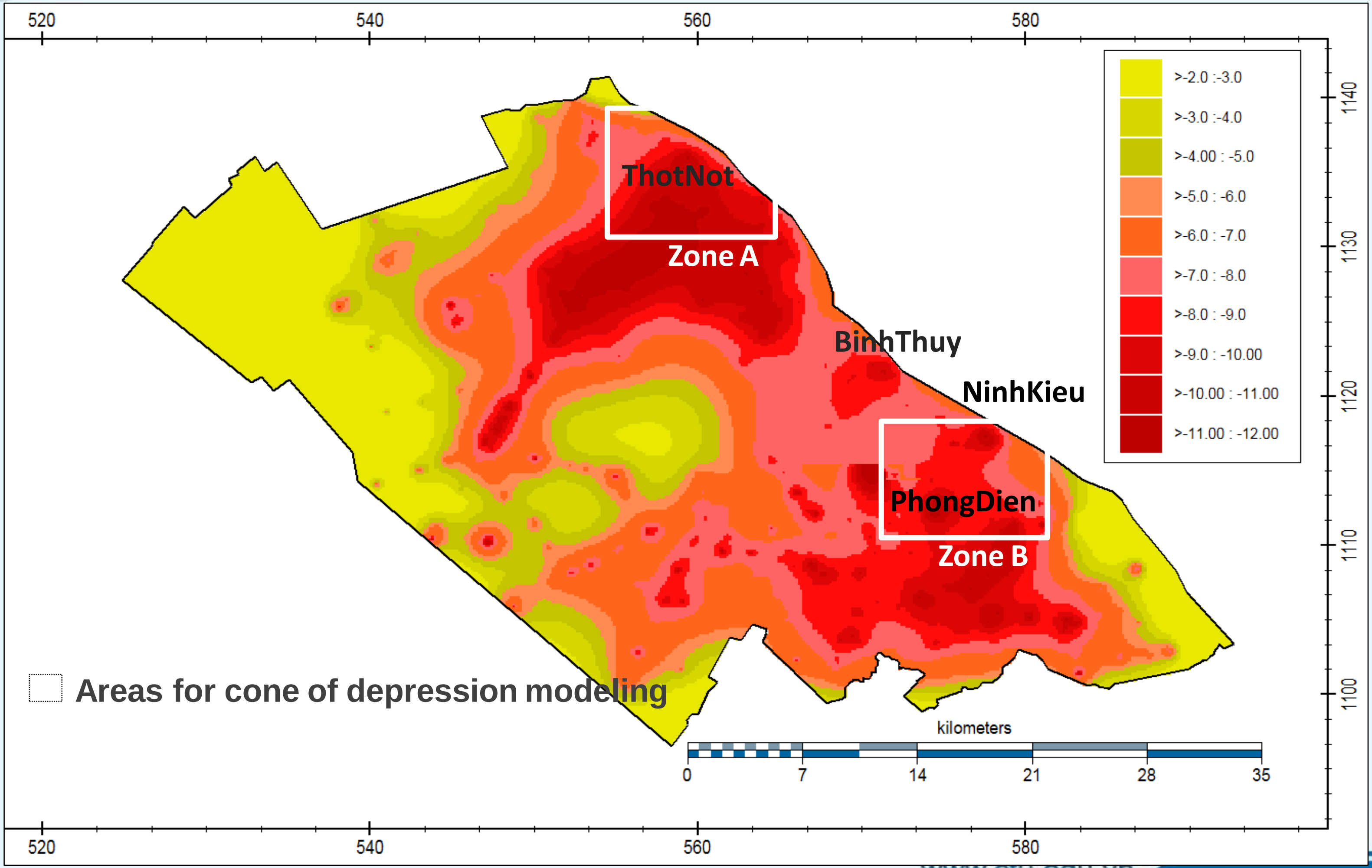




Model for IWRM *(cont.)*

CANTHO UNIVERSITY

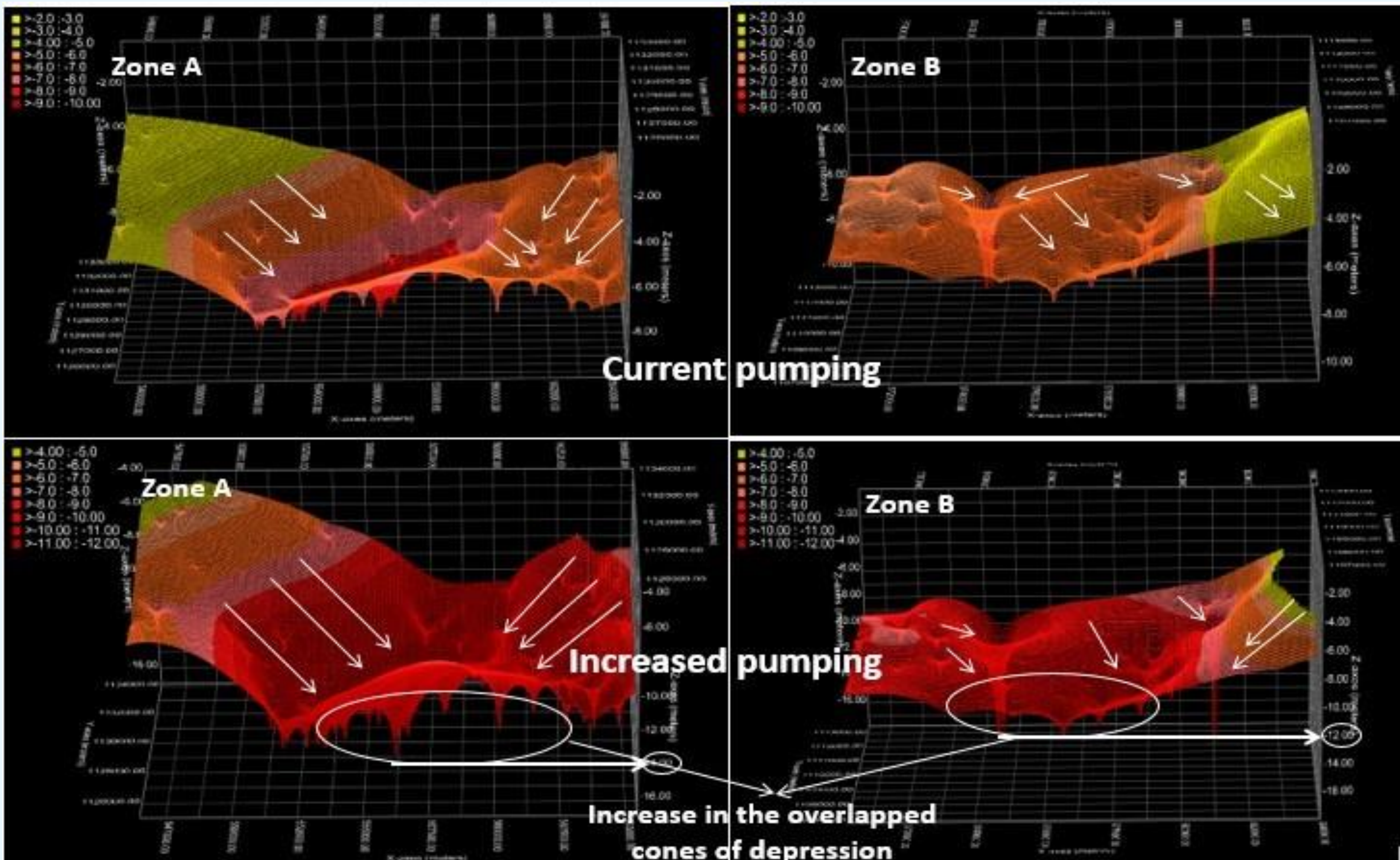
Modeling to analyze the impacts of GW Pumping using iMOD in CanTho city



Spatial distribution of GW heads under increased pumping in the future

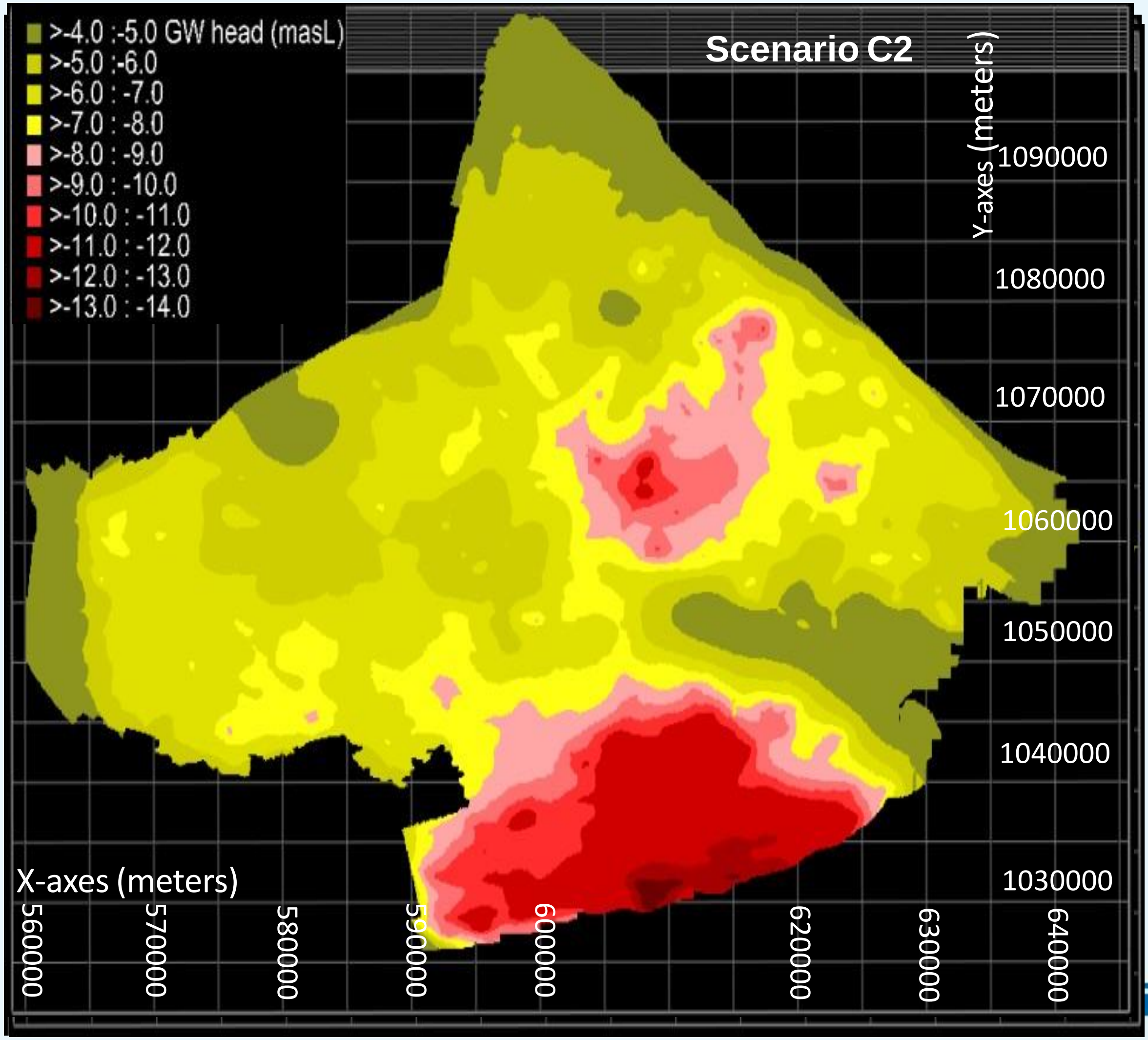
Model for IWRM *(cont.)*

Modeling to analyze the impacts of GW Pumping using iMOD in CanTho city



Model for IWRM *(cont.)*

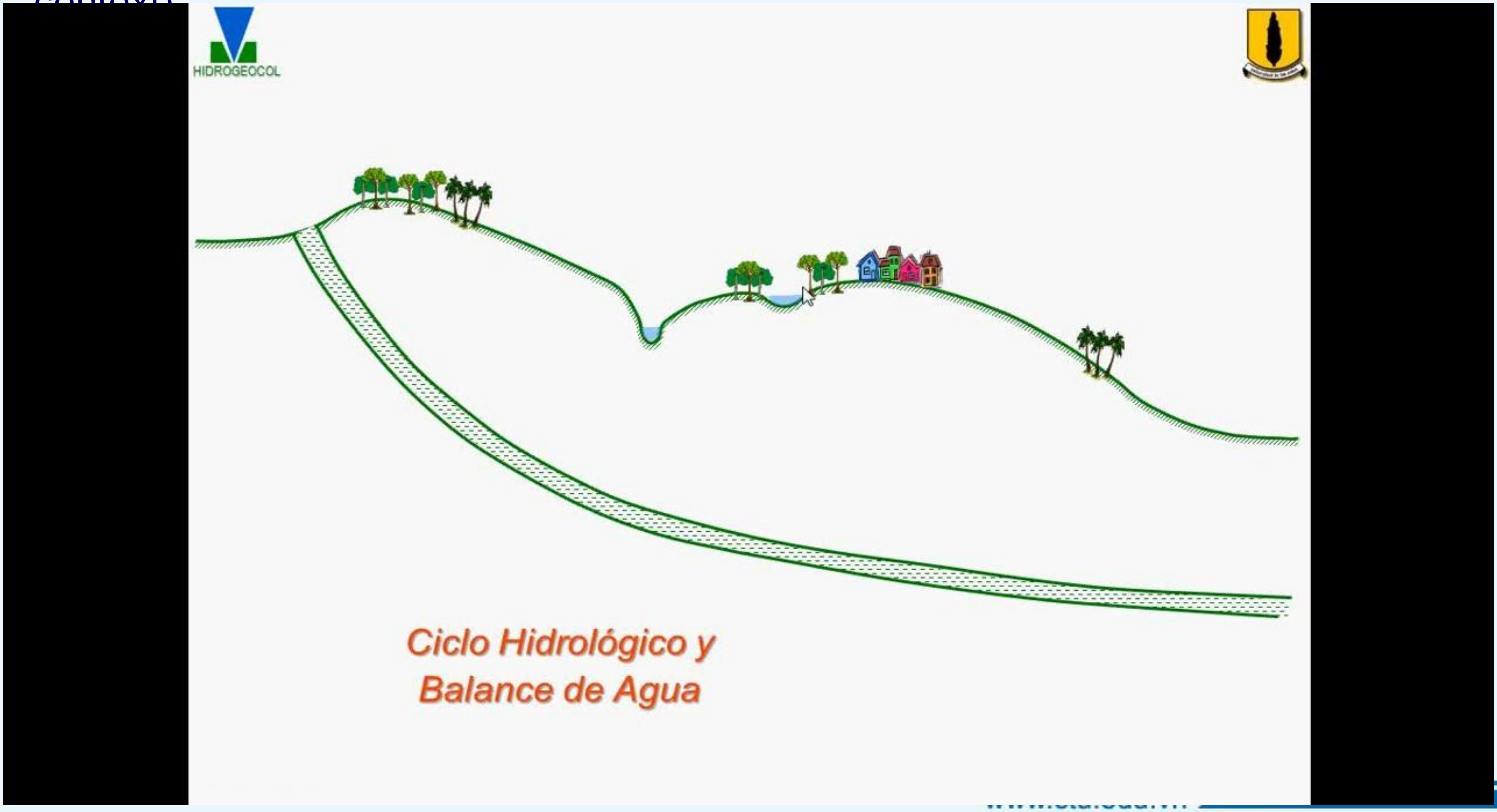
Modeling to analyze the impacts of GW Pumping using iMOD in SocTrang city



Model for IWRM *(cont.)*

Model practice

- 1D model impact (integrated surface-groundwater in term of climate change context)

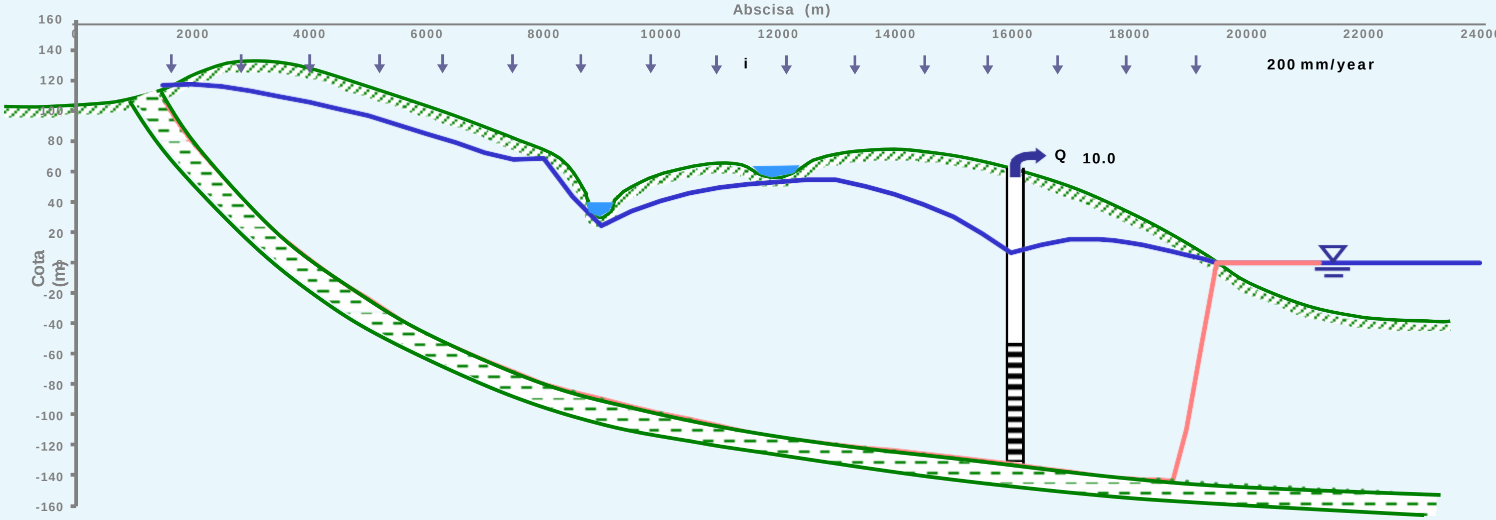


Model for IWRM *(cont.)*

Model practice

- 1D model impact (surface-groundwater in term of climate change context)

		K(m/d)= 1.8		Inf(mm/year)=		200	ρ sea=	1.05	ω(Relax.Fact)=		1.5	0.54795 =Inf(mm/d),		Δ=	20	*Badon Ghyben-Herzberg				RIVER		
Abscissa (m)	x	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000
Δx (m)	Δx	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Cell Inf. (m3/d/m)						-0.274	-0.274	-0.274	-0.274	-0.274	-0.274	-0.274	-0.274	-0.274	-0.274	-0.274	-0.274	-0.274	-0.274	-0.274	-0.274	-0.274
h river (m)																				5		
hid.resist. (d)	c																			15		
1/c river	1/c																			0.06667		
Pump.(m3/d/m)	Q																					
Bottom (m)	Bot				106	77	56	35	17	2	-12	-24.3	-36.7	-49	-56.8	-64.533	-72.267	-80	-85	-90	-95	-99.2
Sat. Thick. (m)	b				6.5	41.0606	60.0888	78.23	92.8347	103.948	113.553	120.975	127.991	134.433	135.919	136.684	137.504	140.923	148.795	122.348	134.625	144.285
Transm.(m2/d)	T			10	11.7	73.9091	108.16	140.814	167.102	187.106	204.396	217.756	230.383	241.979	244.655	246.031	247.506	253.662	267.831	220.226	242.326	259.713
BG & H*					-2333.5	-2361.2	-2321.8	-2264.6	-2196.7	-2119	-2031.1	-1933.5	-1825.8	-1708.7	-1582.4	-1443	-1304.7	-1218.5	-1275.9	-646.95	-792.51	-901.7
Interfase					106	77	56	35	17	2	-12	-24.3	-36.7	-49	-56.8	-64.533	-72.267	-80	-85	-90	-95	-99.2
Head (m)	h				116.089	117.503	115.531	112.674	109.286	105.408	101.022	96.1522	90.7754	84.925	78.6167	72.2054	67.6193	68.4737	43.3765	24.2718	33.3951	40.177

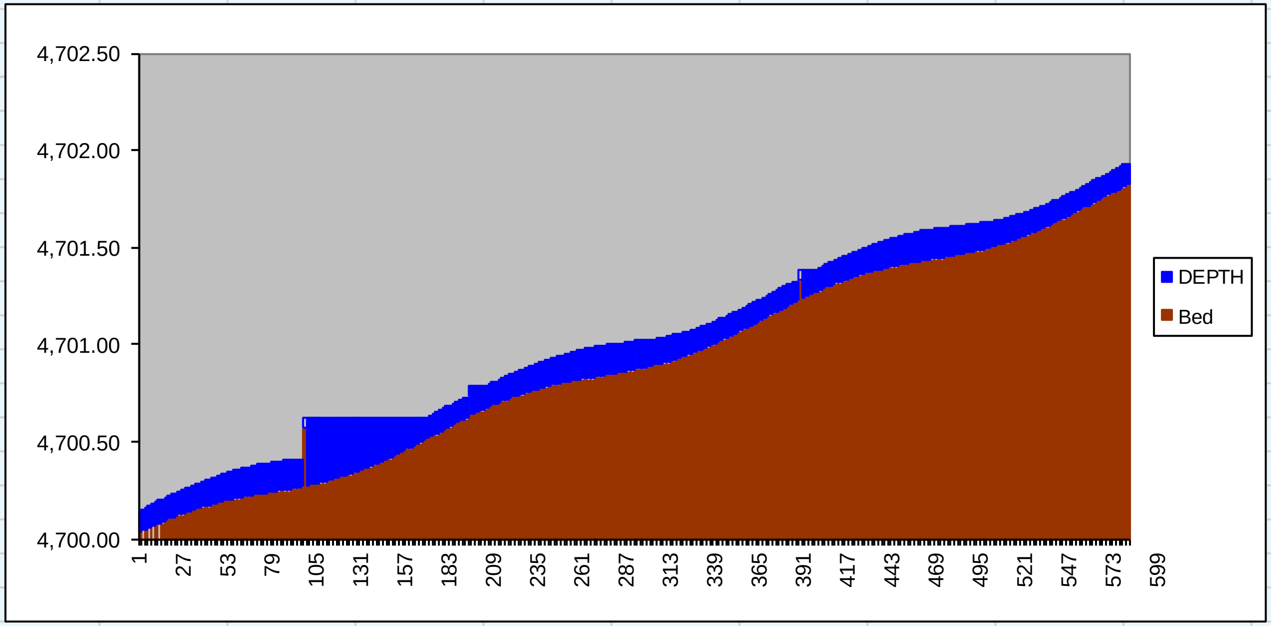


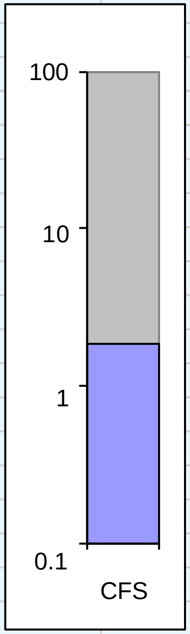
Model for IWRM *(cont.)*

Model practice

- 1D integrated model Reservoir/dam impacts on River Reach

Riffles	Distance	height		Q =	1.819701	CFS
A	100	0.3		n =	0.04	d'less
B	200	0.1				
C	300	0.1		Bed Period =	200	ft
D	400	0.1		Amplitude =	0.05	ft
				Phase Shift =	20	ft





Discussion

Group 1: IN YOUR COUNTRY, WHAT ARE THE CHALLENGES IN **IWRM** IMPLEMENTATION?PLEASE GIVE SOME EXPLANATIONS

Group 2: WHAT DO WE HAVE TO CONSIDER IN THE **IWRM** IN REGARD TO CLIMATE CHANGE IN YOUR COUNTRY?

Group 3: IN YOUR OPINION, WHICH STAKEHOLDERS SHOULD BE INVOLVED (DIMENSION 2) FOR **IWRM**?THE PRIORITY OF THEM AND WHY?

Group 4: IN YOUR COUNTRY, WHAT ARE THE MAJOR CAUSES FOR CONFLICTS OVER WATER USES? PLEASE SPECIFY AN EXAMPLE?

Please use A0 paper and select a member for sharing information from your group discussion

CANTHO UNIVERSITY

Co-funded by the Erasmus+ Programme of the European Union

Thank you!

Contact us at ngdnam@ctu.edu.vn / nhtrung@ctu.edu.vn for more information