

Coupling energy system modelling with hydrological modelling

Possible use of Sava River Basin Hydrological Model

**Final Workshop on
ASSESSING THE WATER-FOOD-ENERGY-ECOSYSTEMS NEXUS AND
BENEFITS OF TRANSBOUNDARY COOPERATION
IN THE DRINA RIVER BASIN**

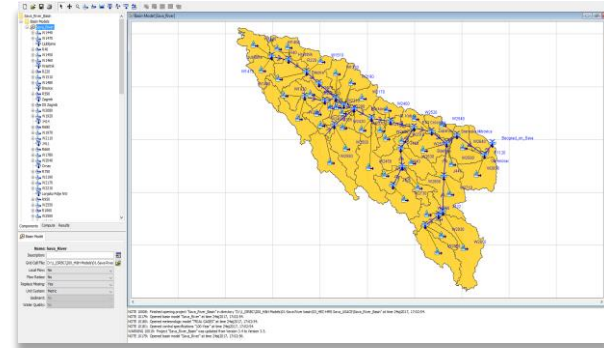
19-20 April 2017 Sarajevo

Samo Grošelj, Mirza Sarač, International Sava River Basin Commission

ISRBC activities in modeling

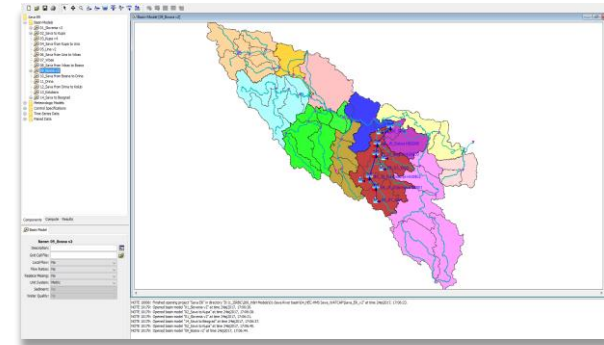
- Preliminary **hydrological and hydraulic models**

prepared by the USACE within the 1st phase of the US Government Support to the Sava countries (2009-2010)



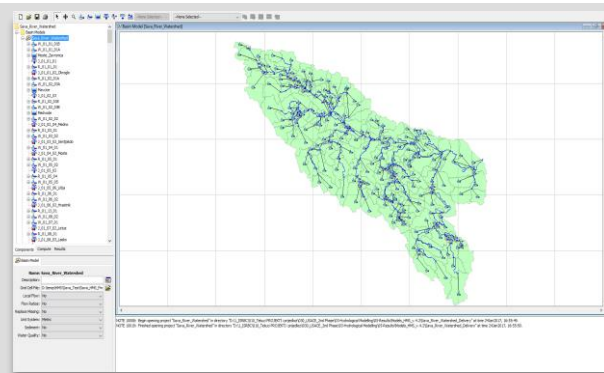
- Improved **hydrological model**

prepared by COWI within „WATCAP“ project of the World Bank (2014)



- Enhanced **hydrological model**

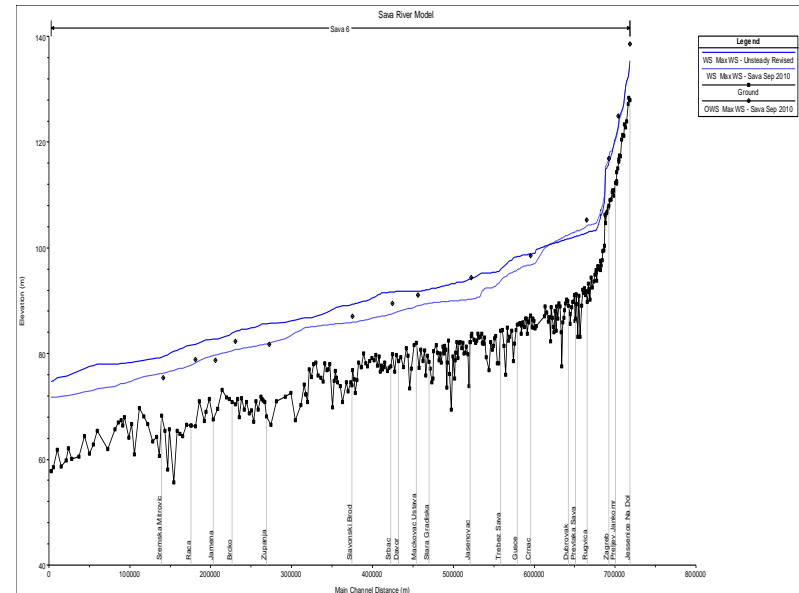
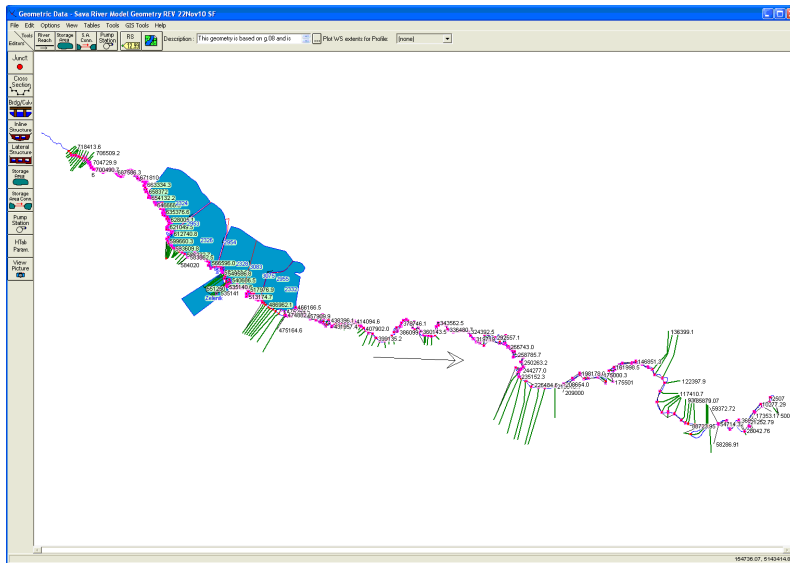
prepared by the USACE & ISRBC within the 2nd phase of the US Government Support to the Sava countries (2015-2017)



US Government support to the Sava countries (1st phase)

2009 -2011

- **Main goal:** to develop a *single hydraulic model* of the Sava River and its major tributaries for the purpose of developing a comprehensive systems approach to flood risk management in the Sava River Basin

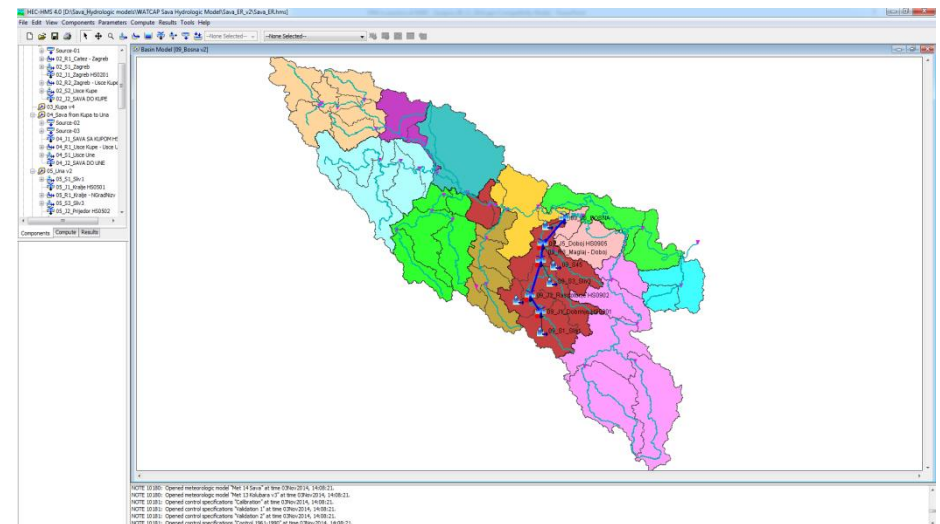
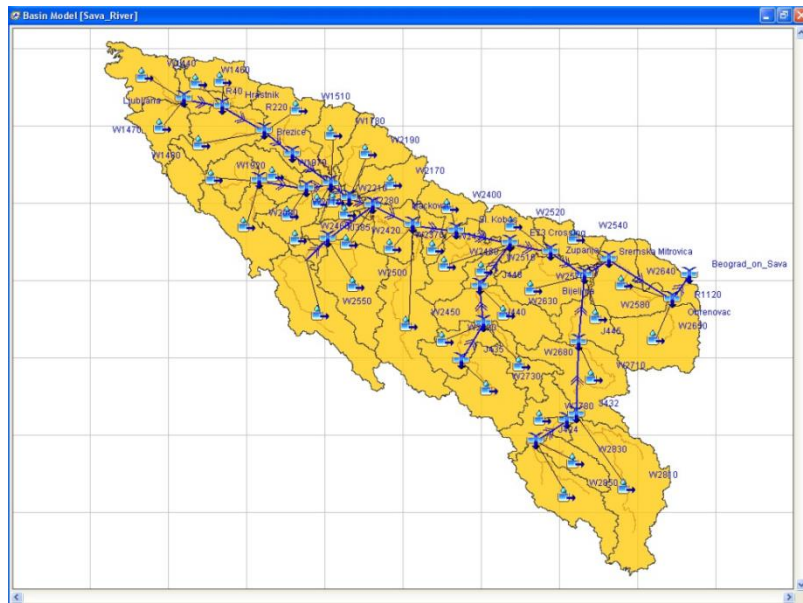


- **HEC products used** (HEC-RAS, HEC-DSS)

US Government support to the Sava countries (1st phase)

2009 -2011

- **Hydrological model (HEC-HMS):**
 - for the sole purpose of developing flow hydrographs for a representative unsteady flow hydraulic model
 - serve as a good starting point for further hydrologic analysis



- **1st Sava River Basin Modelling Workshop – September 2010**

2012 -2015

• Hydrologic model (HEC-HMS): WATCAP

- Purpose of this project was to assess the potential impacts of climate change on various water sectors such as navigation, hydropower, flood control, and irrigation
- Long-term continuous simulation model run at a daily time interval
- 14 models of main river basins separately analyzed
- Total delination: 44 sub-basins

| No. | Sub-basin name | Area (km ²) |
|-----|------------------|-------------------------|
| 01 | Sava to HS Čatež | 10186 |
| 02 | Sava to Kupa | 2584 |
| 03 | Kupa | 10032 |
| 04 | Sava to Una | 6627 |
| 05 | Una | 9524 |
| 06 | Sava to Vrbas | 1840 |
| 07 | Vrbas | 6386 |
| 08 | Sava to Bosna | 4491 |
| 09 | Bosna | 10457 |
| 10 | Sava to Drina | 2866 |
| 11 | Drina | 19946 |
| 12 | Sava to Kolubara | 6818 |
| 13 | Kolubara | 3636 |
| 14 | Sava to Beograd | 1007 |

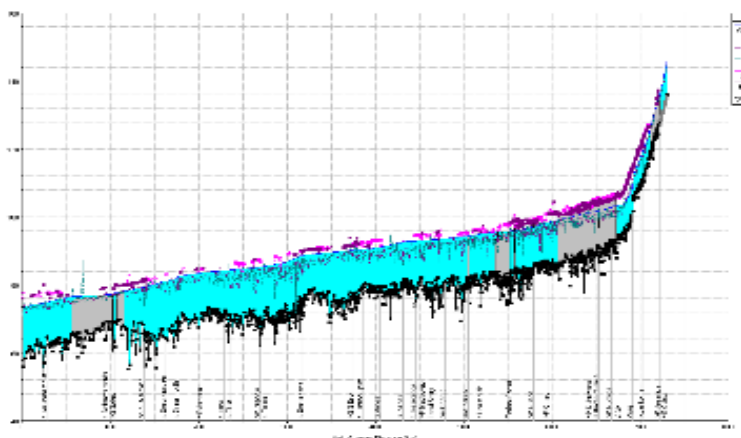
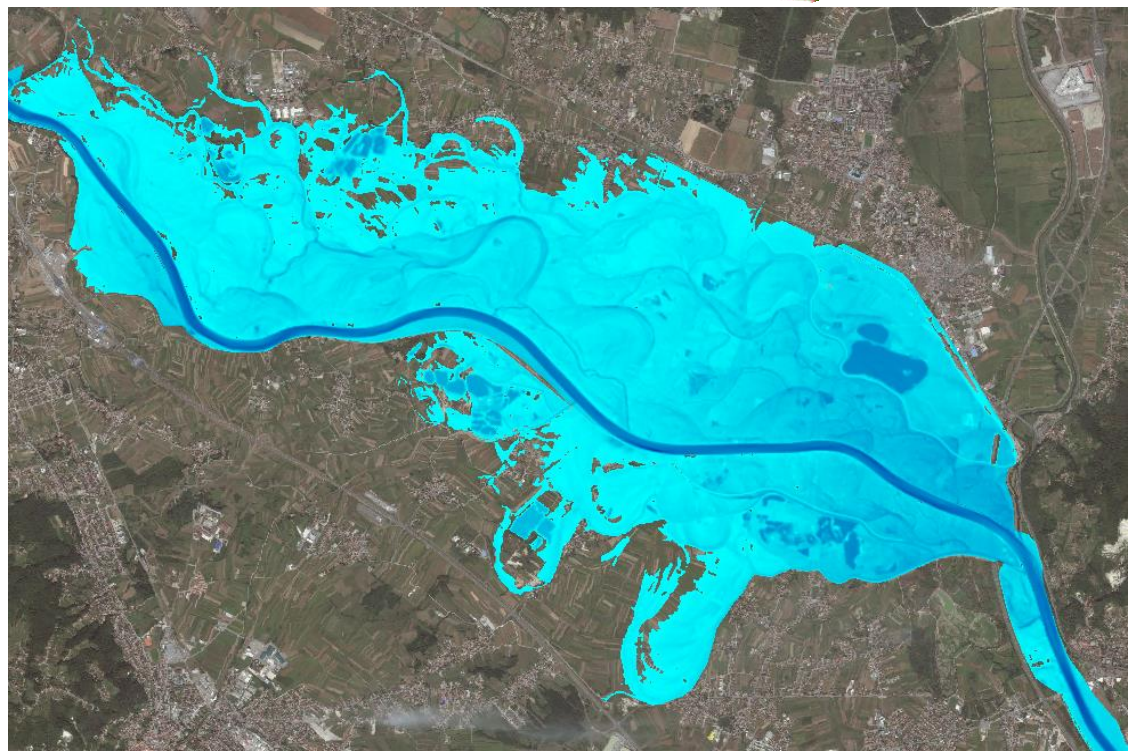
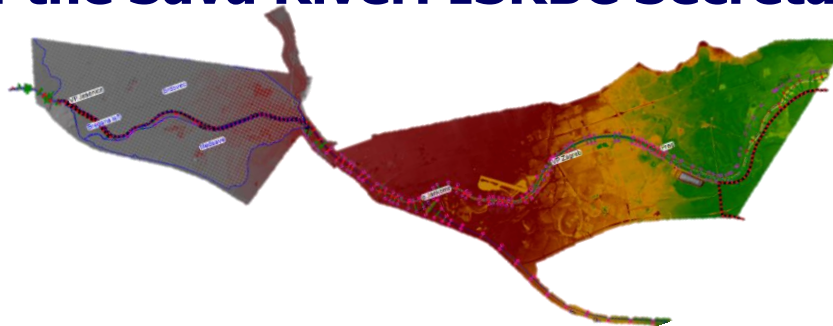
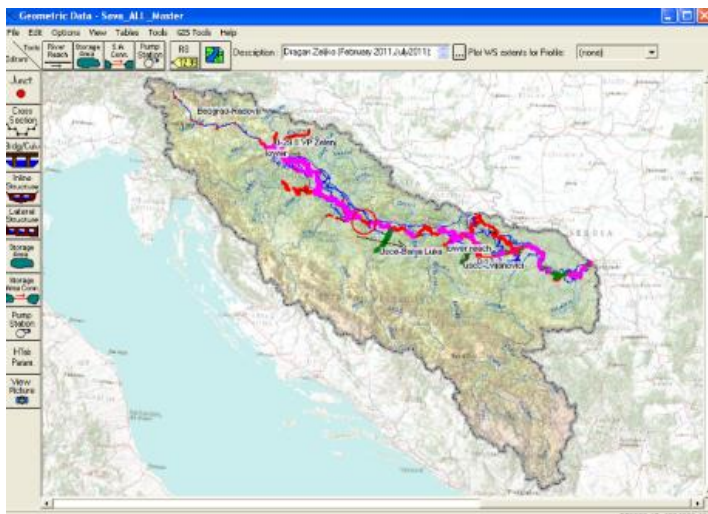


• 2nd Sava River Basin Modelling Workshop – December 2014

Further development of the models

2012 -2015

- **Hydraulic model (HEC-RAS) of the Sava River: ISRBC Secretariat**

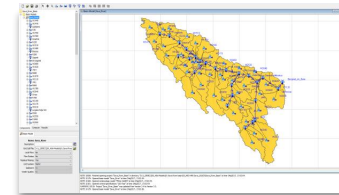
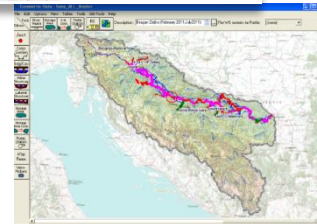
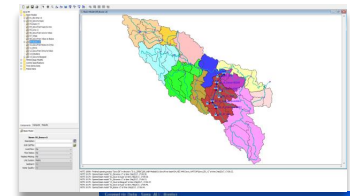


Activities within the U.S. Government support to the Sava countries (2nd phase)

2015 -2017

1. To support the **development of hydrological and hydraulic models** of the Sava River Basin, tools that will strengthen multilateral cooperation in the basin, primarily in the area of flood protection
2. To support activities leading to the preparation of a flood risk management plan as well as the **development of the system for flood forecasting**
3. To establish the models that could be used for other purposes in future (modeling sediment transport, water quality, climate change analysis, etc.)

- Develop and Calibrate a flood event-based **hydrologic model**
- Improve upon the latest mainstem Sava River **hydraulic model**



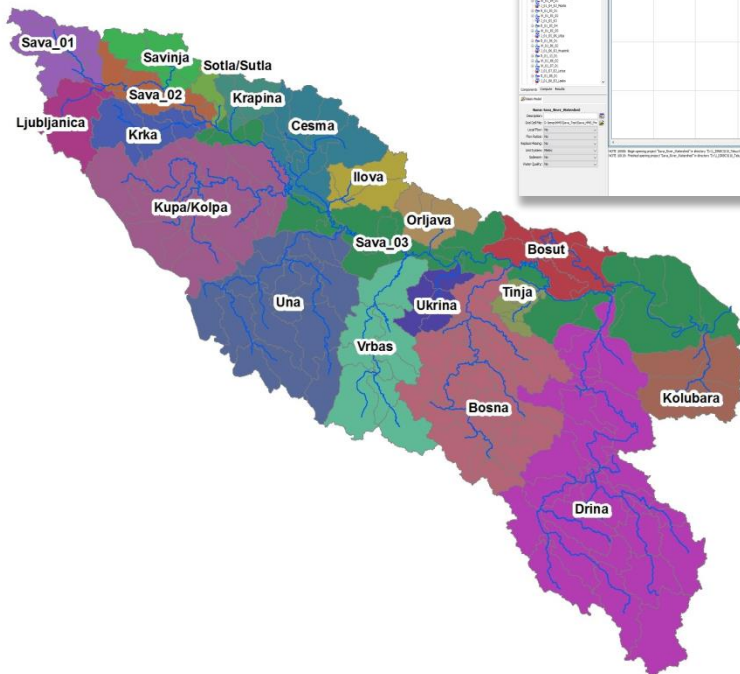
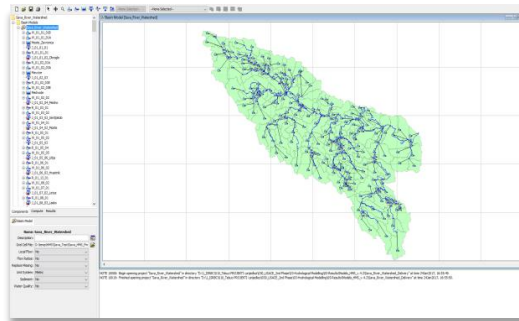
Sava HMS hydrological model

Technical support was provided by

US Army Corps of Engineers

Final HEC-HMS Model contains a separate basin models for each tributary basin and mainstem reach (**22 models in total**):

- 1 for the complete Sava River basin (**SavaFFWS**)
- 4 for the Sava River mainstem (Sava hydraulic model)
- 17 for the main tributaries



- On **16 Jan 2017, model(s) have been distributed** to:
 - ministries of the Parties to FASRB
 - agencies/institutions responsible for water management of the Parties
 - hydro-meteorological services of the Parties,
 - relevant ministry of Montenegro
 - in addition, models for specific sub-basins (Drina, Vrbas) have been delivered to hydro-power companies which provided data for the related sub-models
- On **02-03 Mar 2017, workshop have been held**
 - attended by more than 40 participants representatives of the Parties, Montenegro and HPP companies



Sava RAS hydraulic model

- **Sava LiDAR project**

- Areas (around 3.315 km²)

- Sava River course "levee to levee with the buffer zone" from SI-HR border to Belgrade
- Main retention areas along the Sava River
- Flooded areas due to levee breach 2014
- Bosutsko-Morovicka lowland forest area
- Cities Zagreb and Belgrade

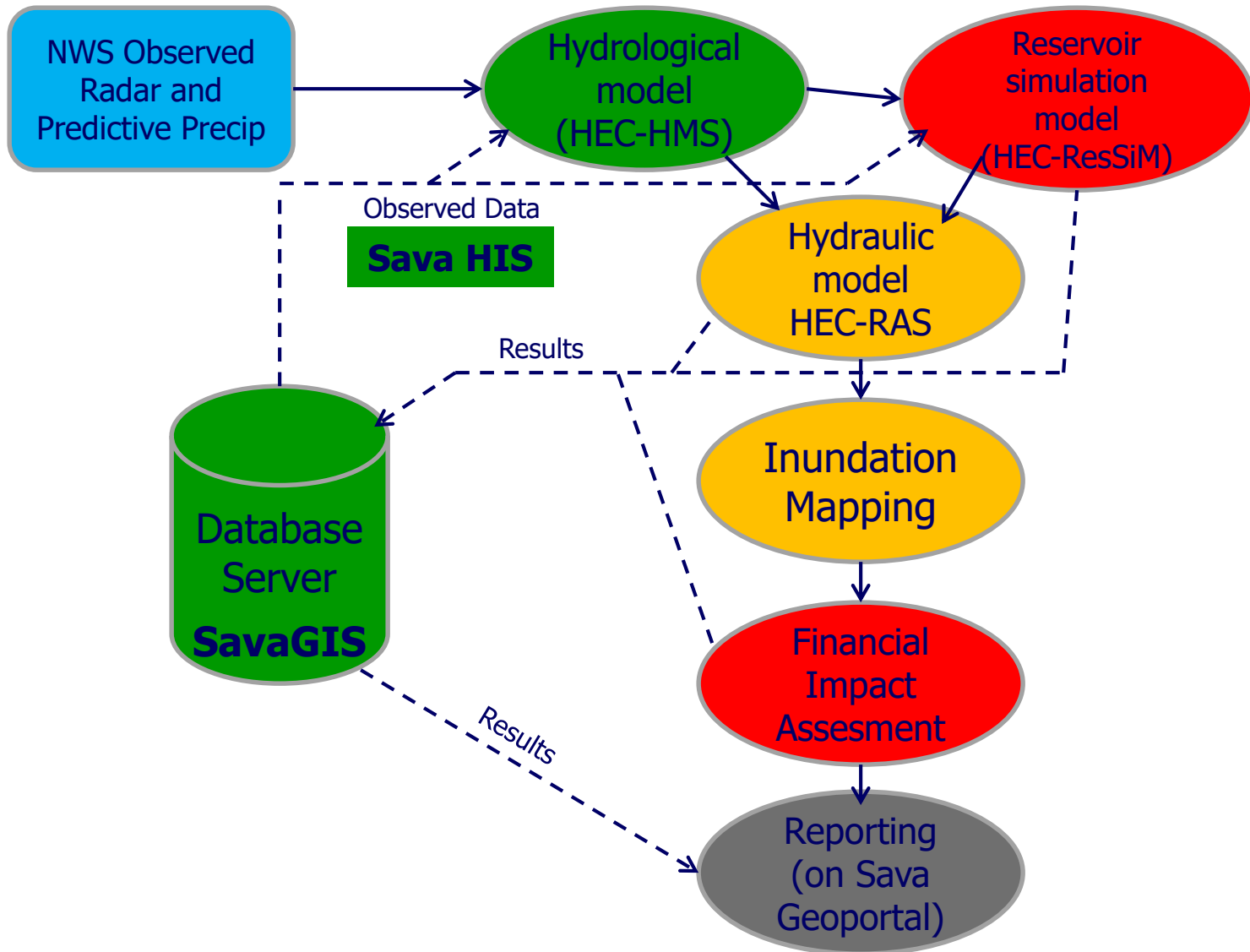


- The Consultant has contracted with the deadline end of May, 2017 for the final submission of products

- Improve upon the latest mainstem Sava River **hydraulic model**

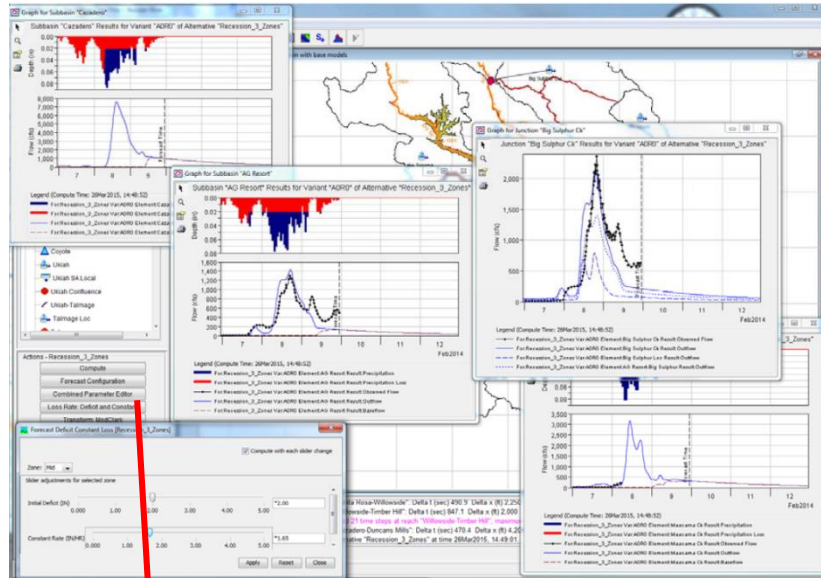
- Once the LiDAR derived products are completed, setting up of a new geometry of the model will start
- The results from the calibrated hydrological HEC-HMS model (already completed as a first activity), will be used in hydraulic modelling

Sava models coupling - HEC structure

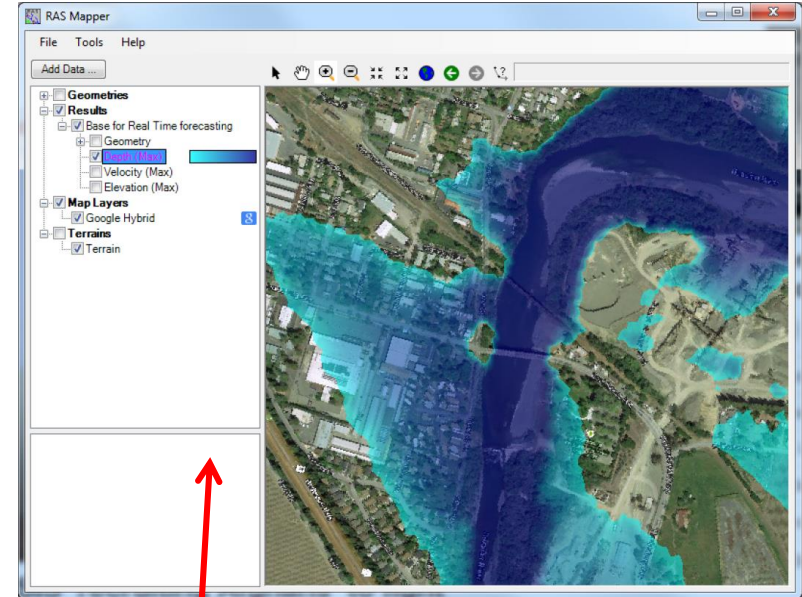


Sava models coupling

Hydrological (HEC-HMS) Calibration



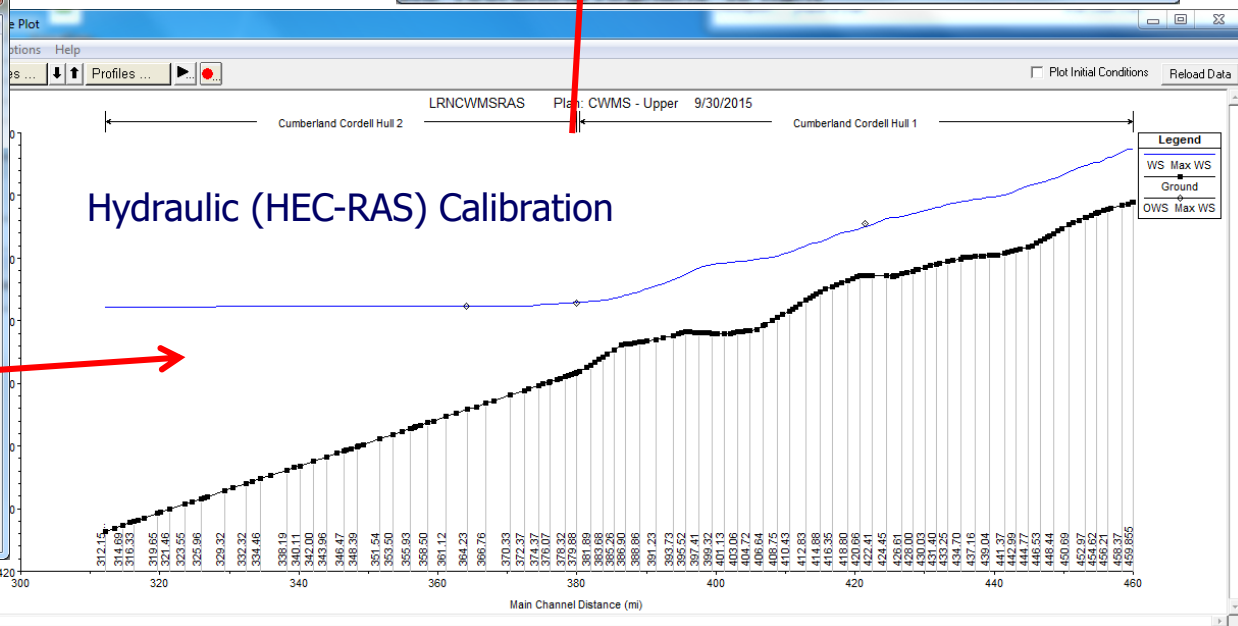
Inundation and Depth Mapping



Unsteady Flow Data - Sava River Unsteady Flow Rev 1

Boundary Condition Types

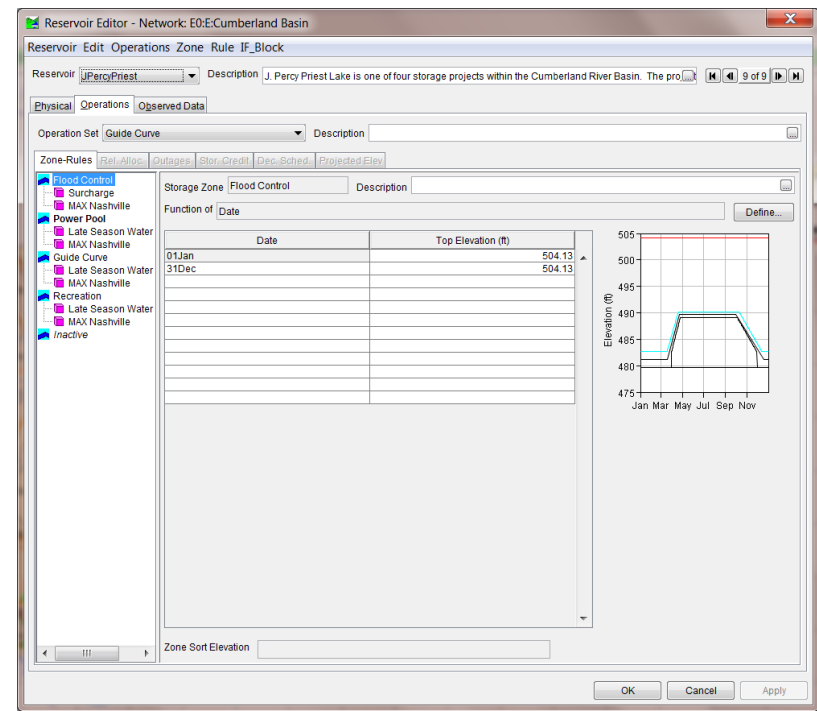
| River | Reach | RS | Boundary Condition |
|-------|-------|----|-------------------------------|
| 1 | Sava | 6 | 718413.6 Flow Hydrograph |
| 2 | Sava | 6 | 602285.6 Lateral Inflow Hydr. |
| 3 | Sava | 6 | 575817.8 Lateral Inflow Hydr. |
| 4 | Sava | 6 | 519403.1 Lateral Inflow Hydr. |
| 5 | Sava | 6 | 429605.1 Lateral Inflow Hydr. |
| 6 | Sava | 6 | 410859.8 Lateral Inflow Hydr. |
| 7 | Sava | 6 | 315356.6 Lateral Inflow Hydr. |
| 8 | Sava | 6 | 263364 Lateral Inflow Hydr. |
| 9 | Sava | 6 | 170279.3 Lateral Inflow Hydr. |
| 10 | Sava | 6 | 154436.4 Lateral Inflow Hydr. |
| 11 | Sava | 6 | 2506780 Normal Depth |



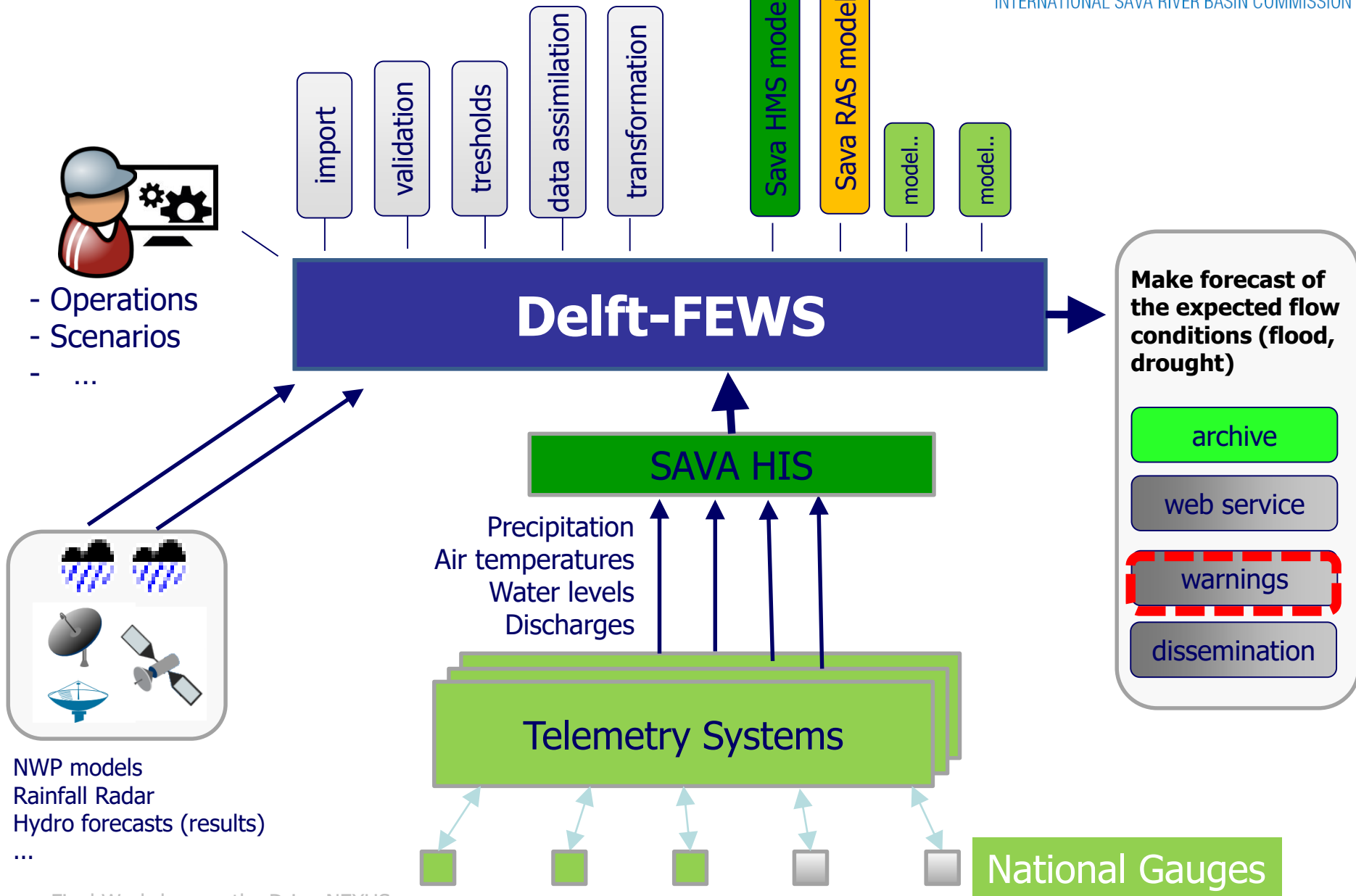
Hydraulic (HEC-RAS) Calibration

HEC-ResSIM – Further steps

- Modeling component simulates **reservoir operation**
- Allows user to input rules that **define guidelines** for reservoir operation
- Model then uses the rules to **make decisions** on how the reservoir should be operated
- User has ability to override ResSIM decisions



Sava FFWS - schematic overview



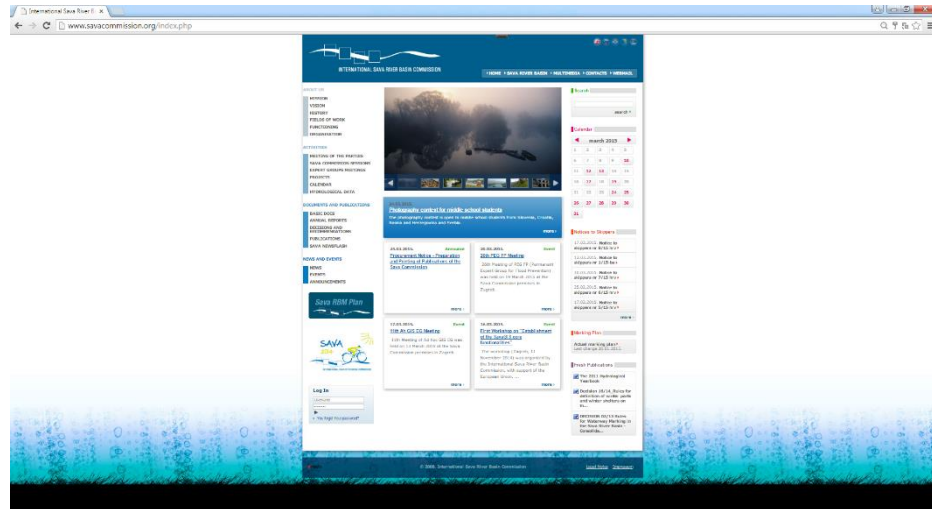
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