ASSESSMENT OF MODELS' PERFORMANCE IN DETERMINING FLOOD HAZARD FROM ICE JAMS

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XL International School of Hydraulics, 23-26 May 2023, Kąty Rybackie, Poland

PRESENTATION OUTLINE:

1. Introduction
2. Aim of the study
3. Study area
4. Materials and methods
5. Results
6. Conclusions

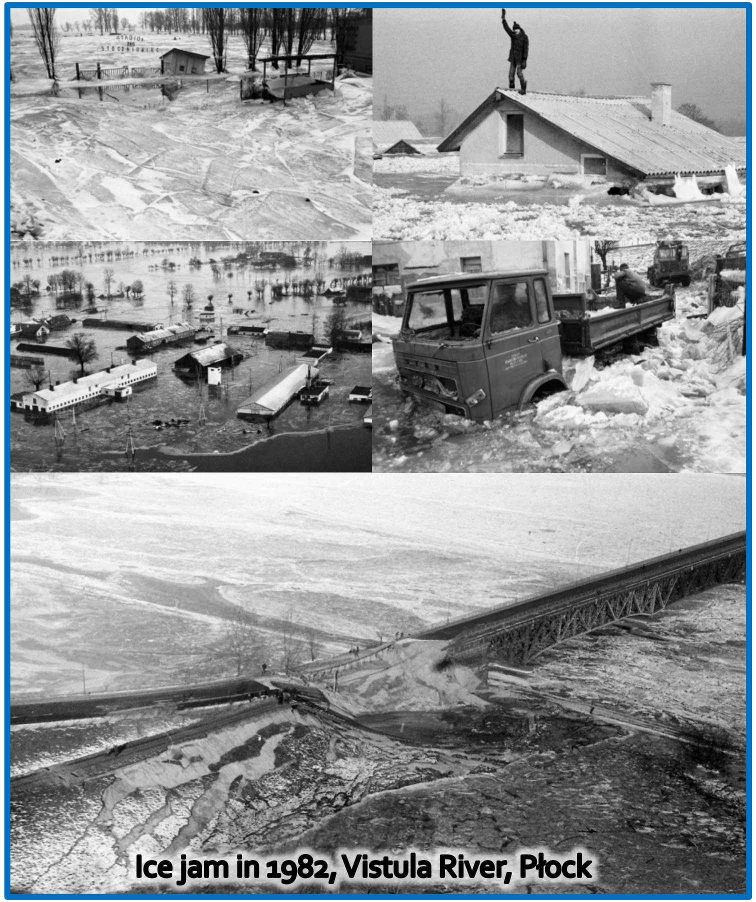
ICE-JAM AND ICE COVER PHENOMENA

- *they regularly appear on the Oder and the Vistula Rivers causing occasionally a significant increase in flood hazard and difficulties for inland navigation*

- *in European countries affected by ice phenomena, flood hazard from ice jams is still rarely analyzed*

- *lack of guidelines for the determination of flood hazard from ice jams in the European context*

Ice jam in 2021, Vistula River, Płock



Ice jam in 1982, Vistula River, Płock

FLOOD HAZARD DELINEATION – CURRENT APPROACHES

a broad literature review points to guidelines developed in Canada and US

- **Initial modeling guidelines – groups identifed based on availability of input data**

<table>
<tr><th colspan="3">Hydrotechnical approach</th><th rowspan="3">Morphological approach
(no information on ice phenomena, potential location of the ice jams indicated based on morphological parameters)</th></tr>
<tr><td rowspan="2">Direct stage-frequency method
(a long and stationary data series of water states during ice jams is available)</td><td colspan="2">Indirect stage-frequency method
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<tr><td>Deterministic approach</td><td>Stochastic approach</td></tr>
<tr><td colspan="2">Flood hazard determined based on exceedance probability curves of the water states; water gauge data/observed data are used to develop the curves</td><td colspan="2">Monte Carlo method applied - the level of flood risk determined based on the frequency of water states, which are the results of hundreds of simulations</td></tr>
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AIM OF THE STUDY

Assessment of models' performance in determining flood hazard from ice jams

SPECIFIC GOALS

G1

Comparison of two popular models in their ability to analyse ice jams and ice cover

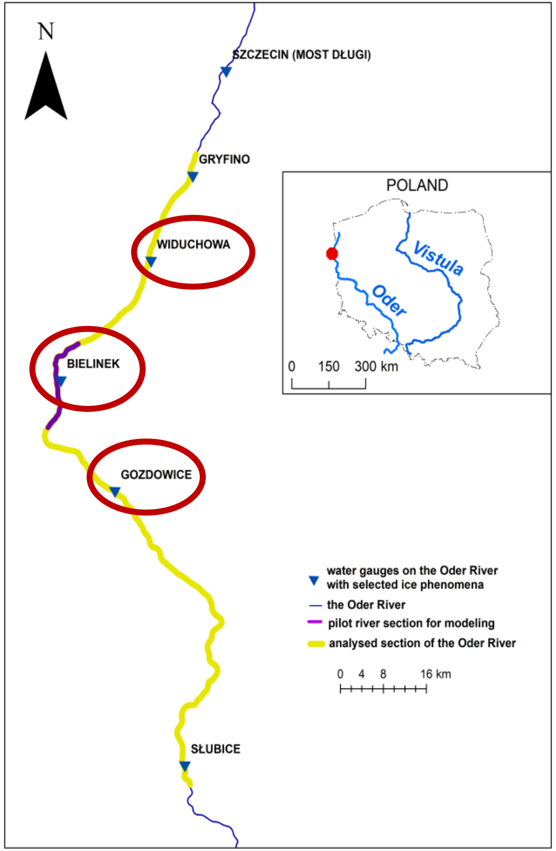
G2

Determination of flood hazard for the flood scenario from ice jams and ice cover (for H1%)

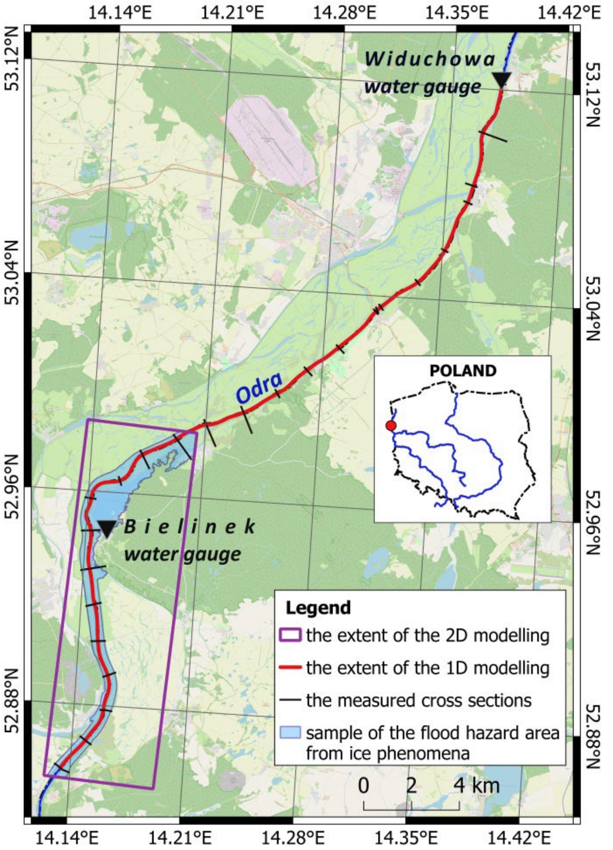
G3

Verification of direct stage-frequency method when combined with hydraulic modelling

The Oder River



The Oder River close to the water gauge Bielinek, February 2021

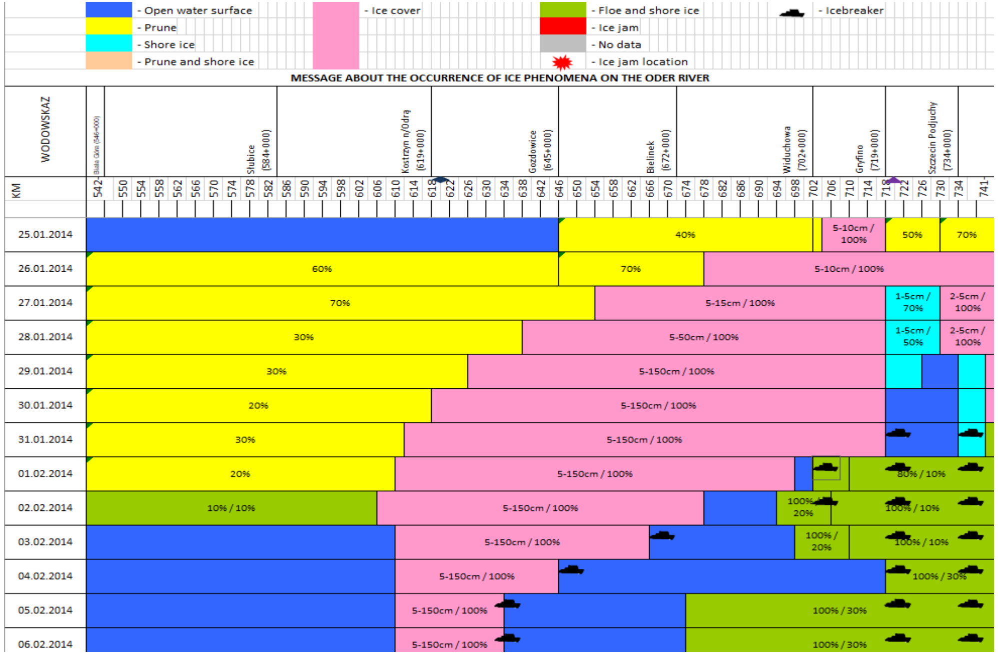


MATERIALS

– Field observations of ice phenomena

ice phenomena description in the IMGW-PIB database
historical annual hydrological books
icebreaking action raports
other documents and papers

Icebreaking action report



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water state hydrographs for the multi-year period 1972-2021 (to develope probability of exceedance curves)

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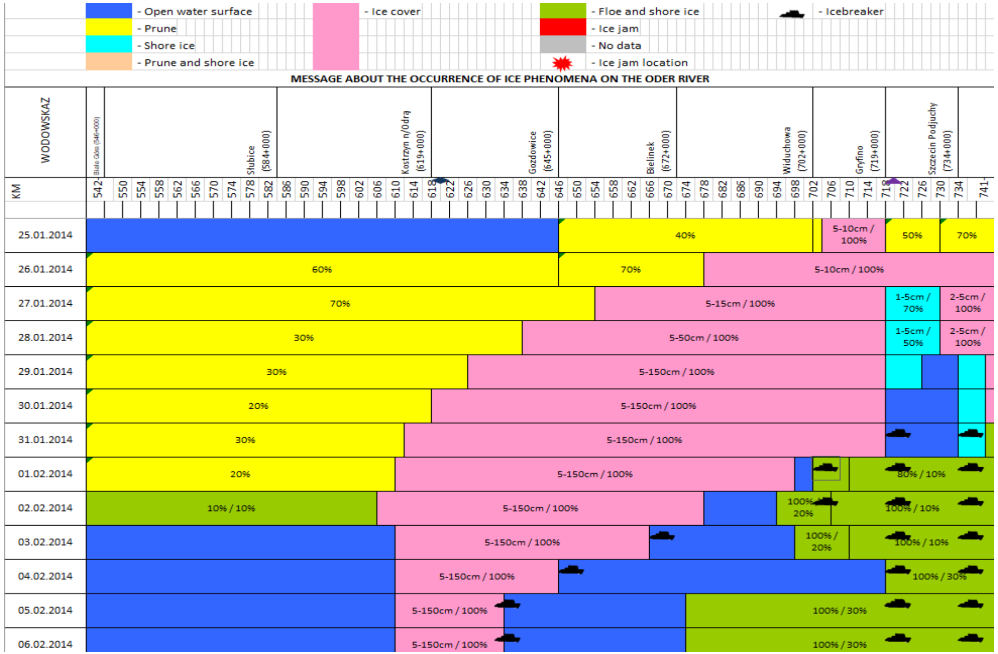
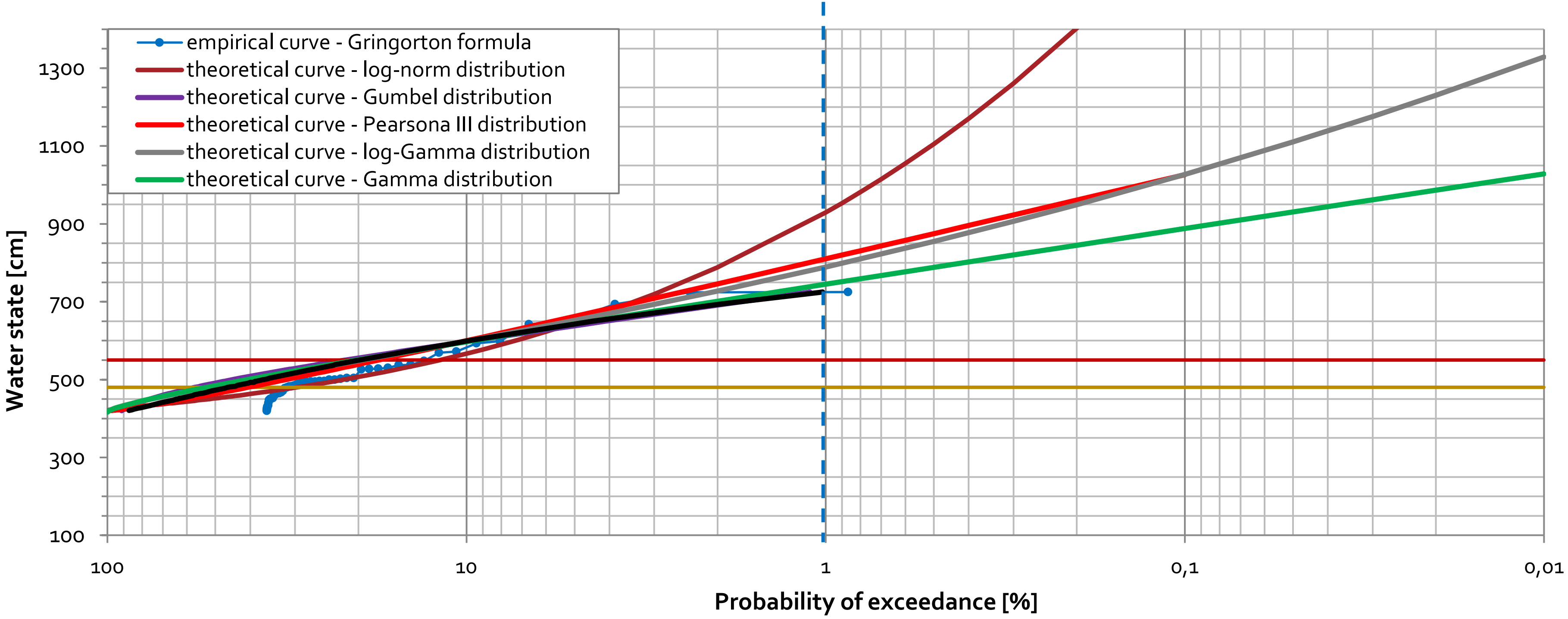


MATERIALS

$H_{1\%} \approx 730$ cm = 6.16 m a.s.l.



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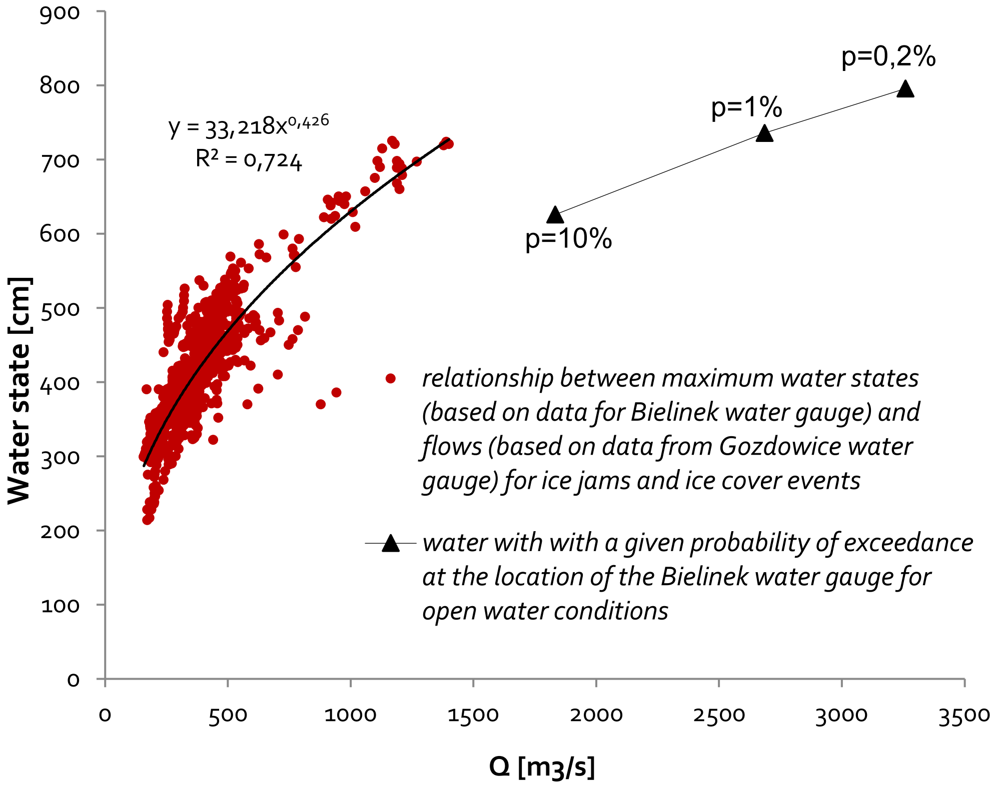
$H_{1\%}$ = 730 cm = 6.16 m a.s.l.

$Q_{H1\%}$ = 1400 m³/s

Relationship between maximum water states during ice jams and ice cover for the multi-year period 1951-2014.



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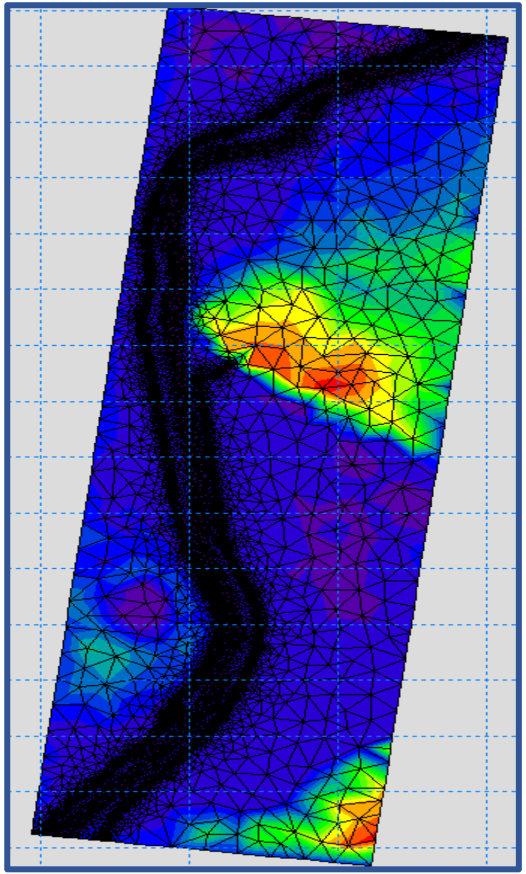
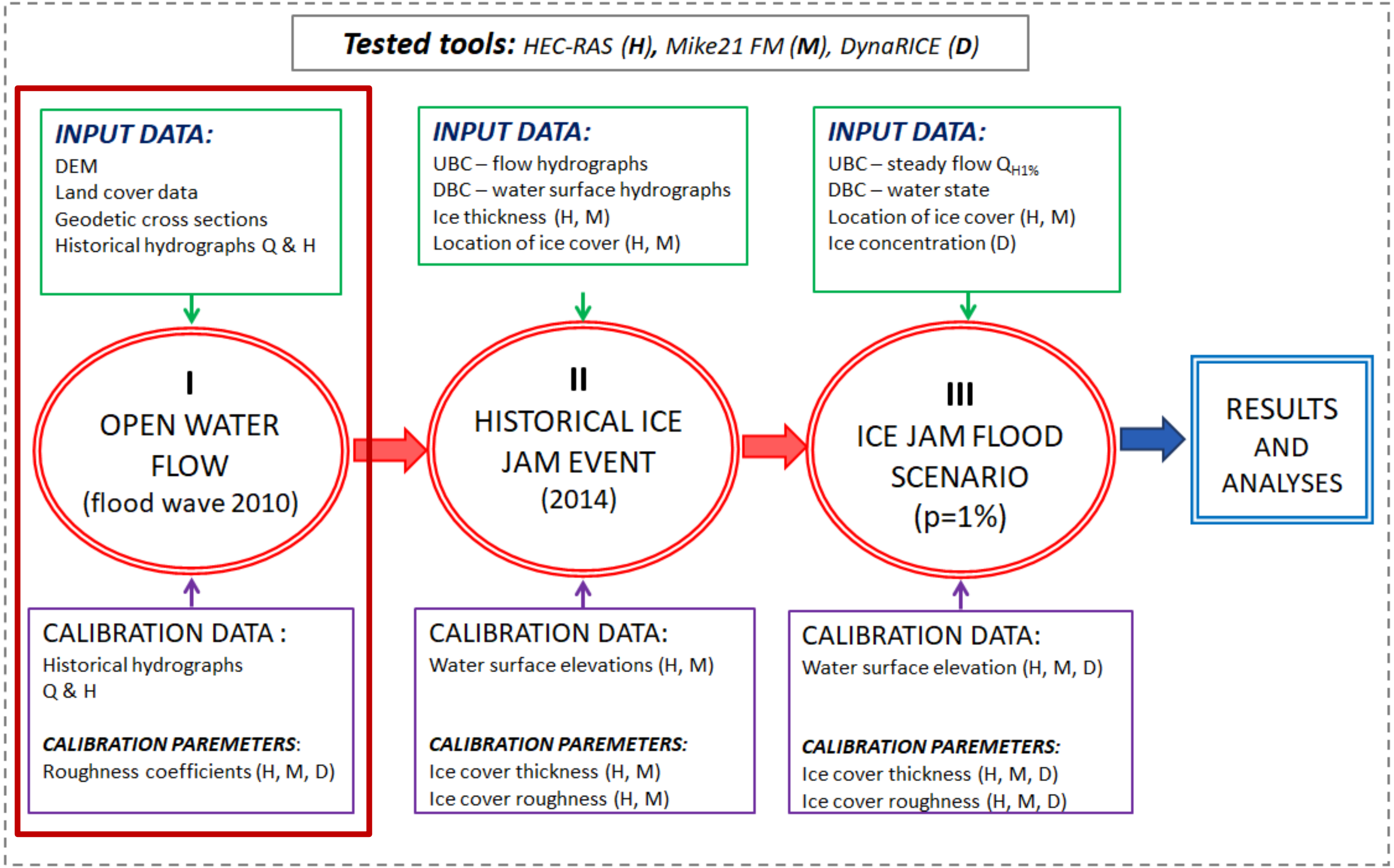
- Spatial data (GUGiK, PGW WP)

  DEM, land cover from BDOT10k, geodetic cross sections

Bathymetry in Mike21 FM



METHODS


Tested tools: HEC-RAS (H), Mike21 FM (M), DynaRICE (D)
INPUT DATA:
DEM
Land cover data
Geodetic cross sections
Historical hydrographs Q & H
I
OPEN WATER FLOW
(flood wave 2010)
CALIBRATION DATA :
Historical hydrographs Q & H
CALIBRATION PAREMETERS:
Roughness coefficients (H, M, D)
INPUT DATA:
UBC – flow hydrographs
DBC – water surface hydrographs
Ice thickness (H, M)
Location of ice cover (H, M)
II
HISTORICAL ICE JAM EVENT
(2014)
CALIBRATION DATA:
Water surface elevations (H, M)
CALIBRATION PAREMETERS:
Ice cover thickness (H, M)
Ice cover roughness (H, M)
INPUT DATA:
UBC – steady flow $Q_{H1\%}$
DBC – water state
Location of ice cover (H, M)
Ice concentration (D)
III
ICE JAM FLOOD SCENARIO
(p=1%)
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CALIBRATION PAREMETERS:
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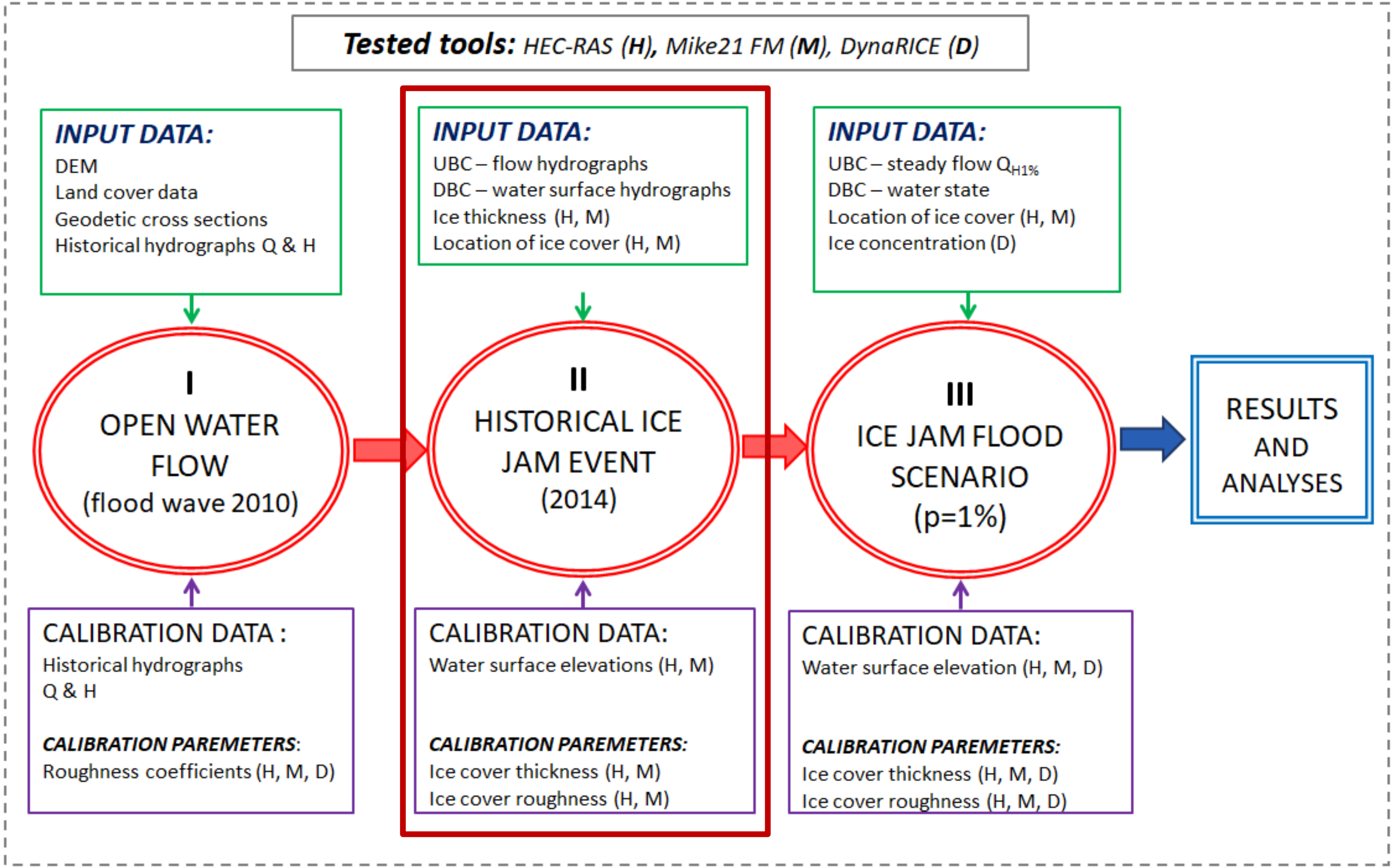
Ice cover roughness (H, M, D)
RESULTS AND ANALYSES

METHODS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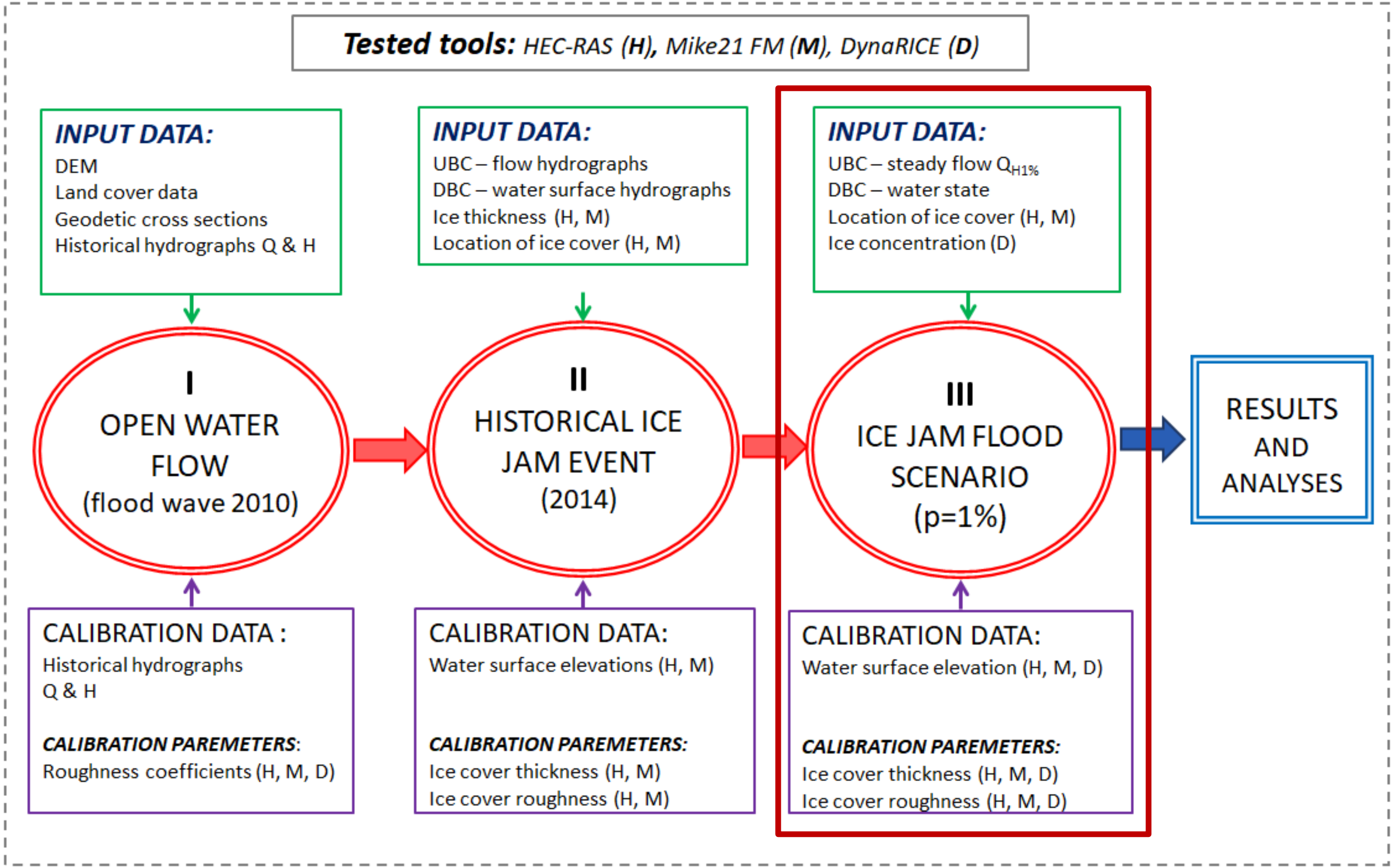
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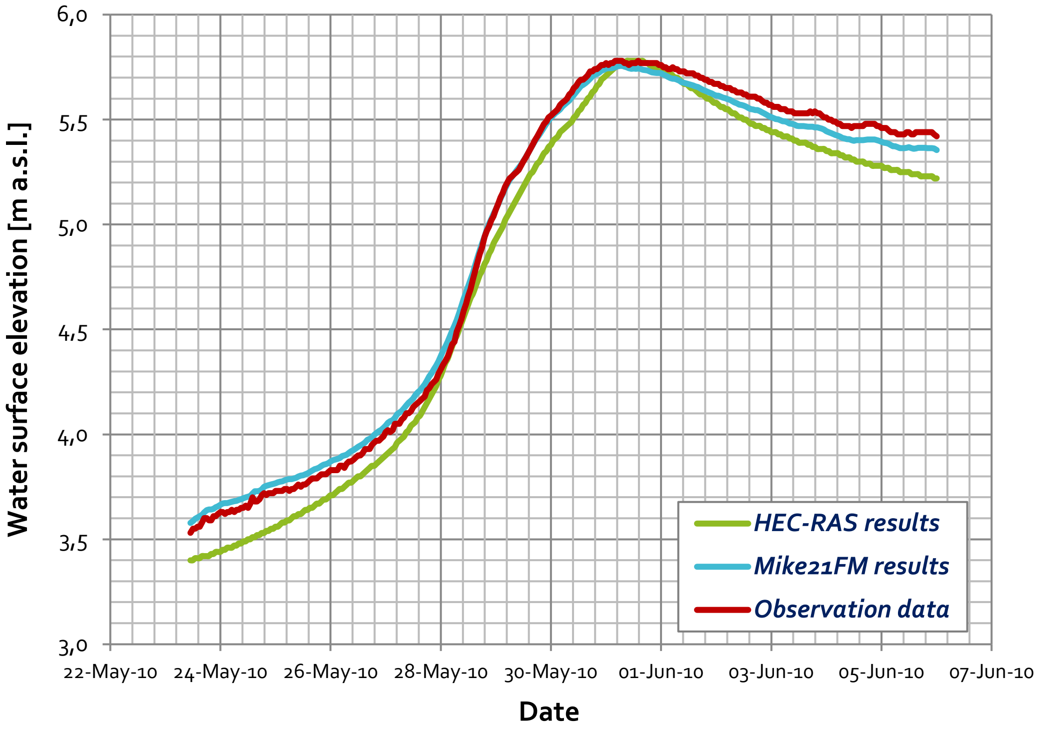
RESULTS AND ANALYSES

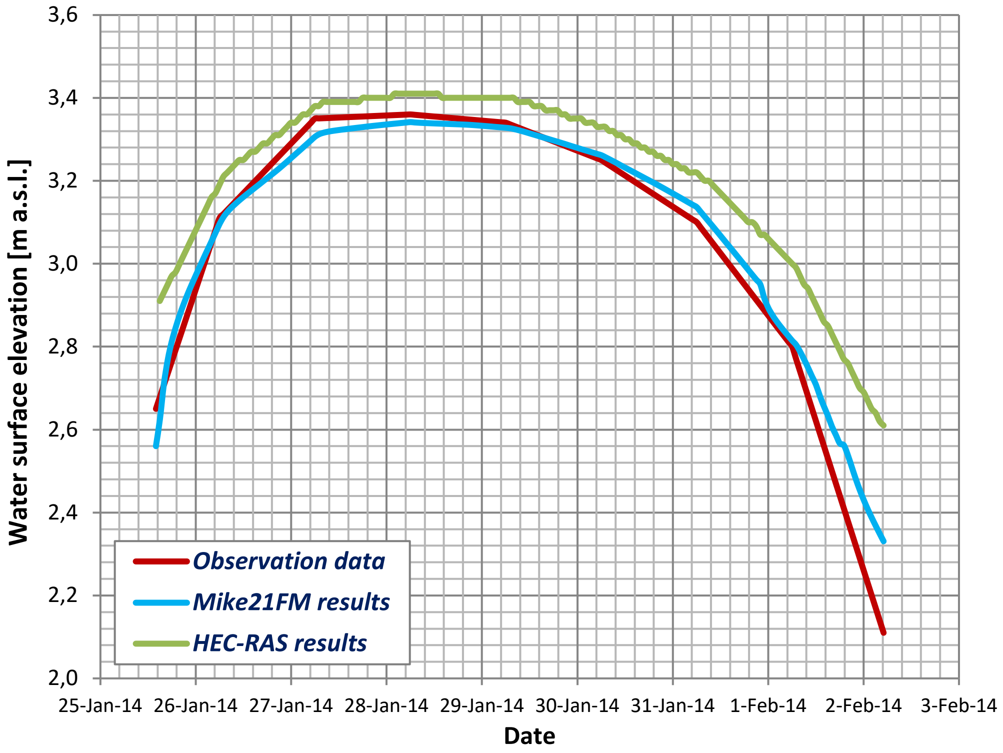
RESULTS – I OPEN WATER FLOW



Summary of calibration results for the water gauge Bielinek

No.	Assessment parameter of water surface elevation	HEC-RAS	Mike21FM
	water gauge Bielinek		
1	Correlation coefficient R^2	0.99	0.99
2	Water surface elevation absolute error at the peak of the flood wave (ΔHmax)	6 cm	4 cm
	Water surface elevation percentage error at the peak of the flood wave (% ΔHmax)	0.69%	1.03%
	Calculated maximum water surface elevation	5.78 m a.s.l.	5.76 m a.s.l.
	Observed maximum water surface elevation	5.82 m a.s.l.	5.82 m a.s.l.
3	Root mean square error (RMSE)	12 cm	5 cm

RESULTS – II HISTORICAL ICE JAM EVENT



Summary of calibration results for the water gauge Bielinek

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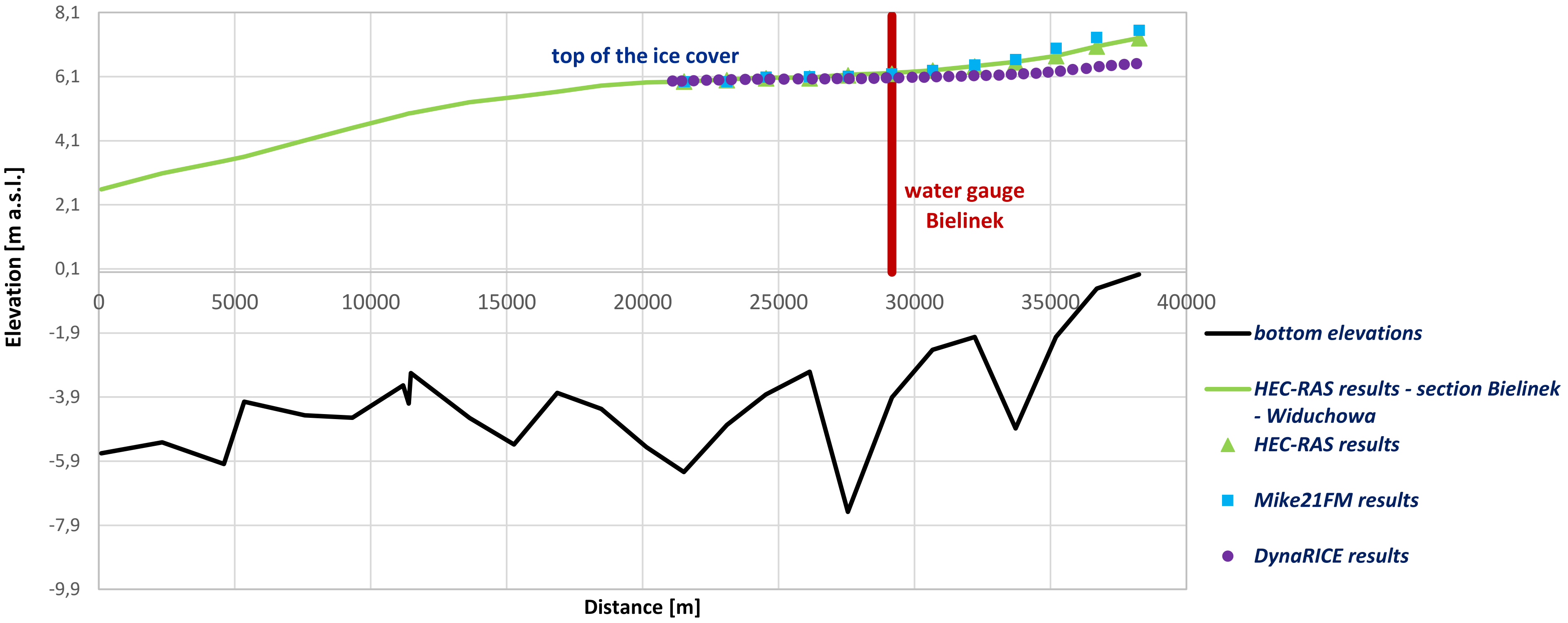
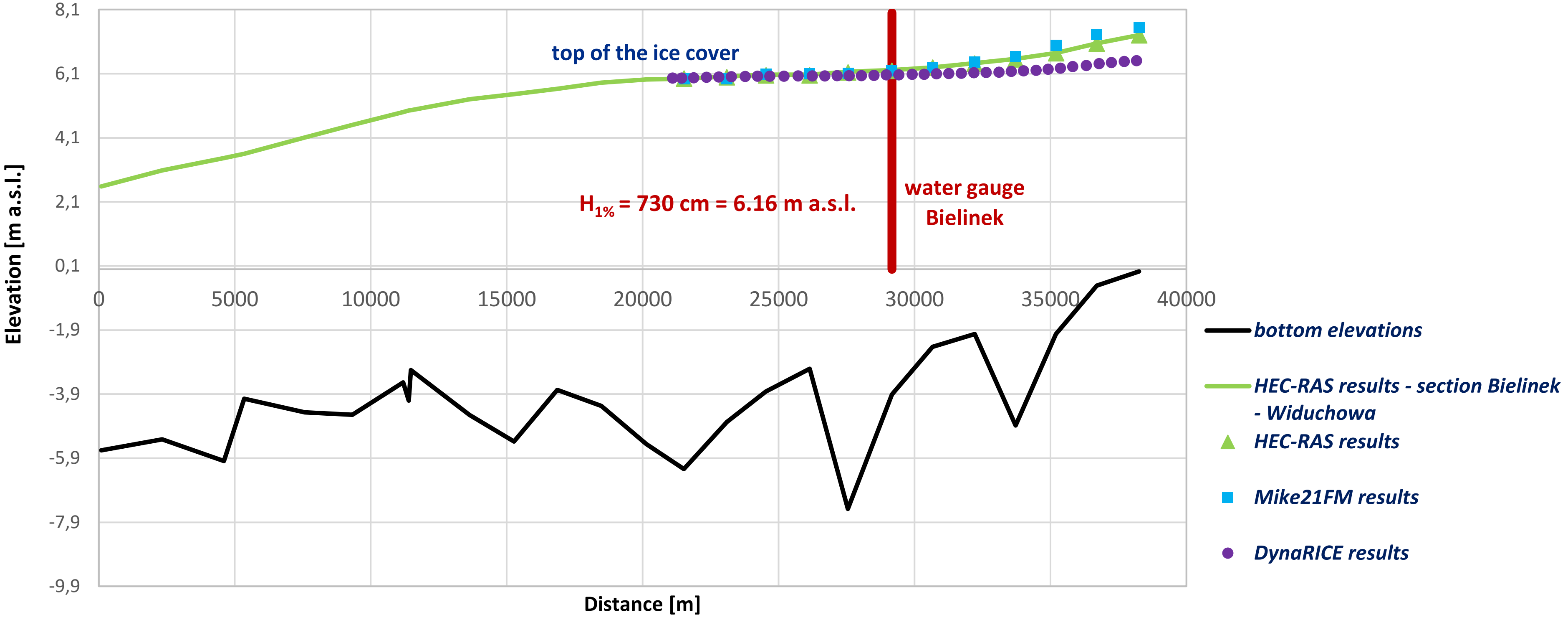
	water gauge Bielinek		
1	Correlation coefficient R^2	0.99	0.99
2	Water surface elevation absolute error at the peak of the flood wave (ΔHmax)	5 cm	2 cm
	Water surface elevation percentage error at the peak of the flood wave (% ΔHmax)	1.49%	0.54%
	Calculated maximum water surface elevation	3.41 m a.s.l	3.34 m a.s.l
	Observed maximum water surface elevation	3.36 m a.s.l.	3.36 m a.s.l.
3	Root mean square error (RMSE)	15 cm	6 cm

RESULTS – III ICE JAM FLOOD SCENARIO



RESULTS – III ICE JAM FLOOD SCENARIO

HEC-RAS = 6.14 m a.s.l.
Mike21FM = 6.19 m a.s.l.
DynaRICE = 6.07 m a.s.l.



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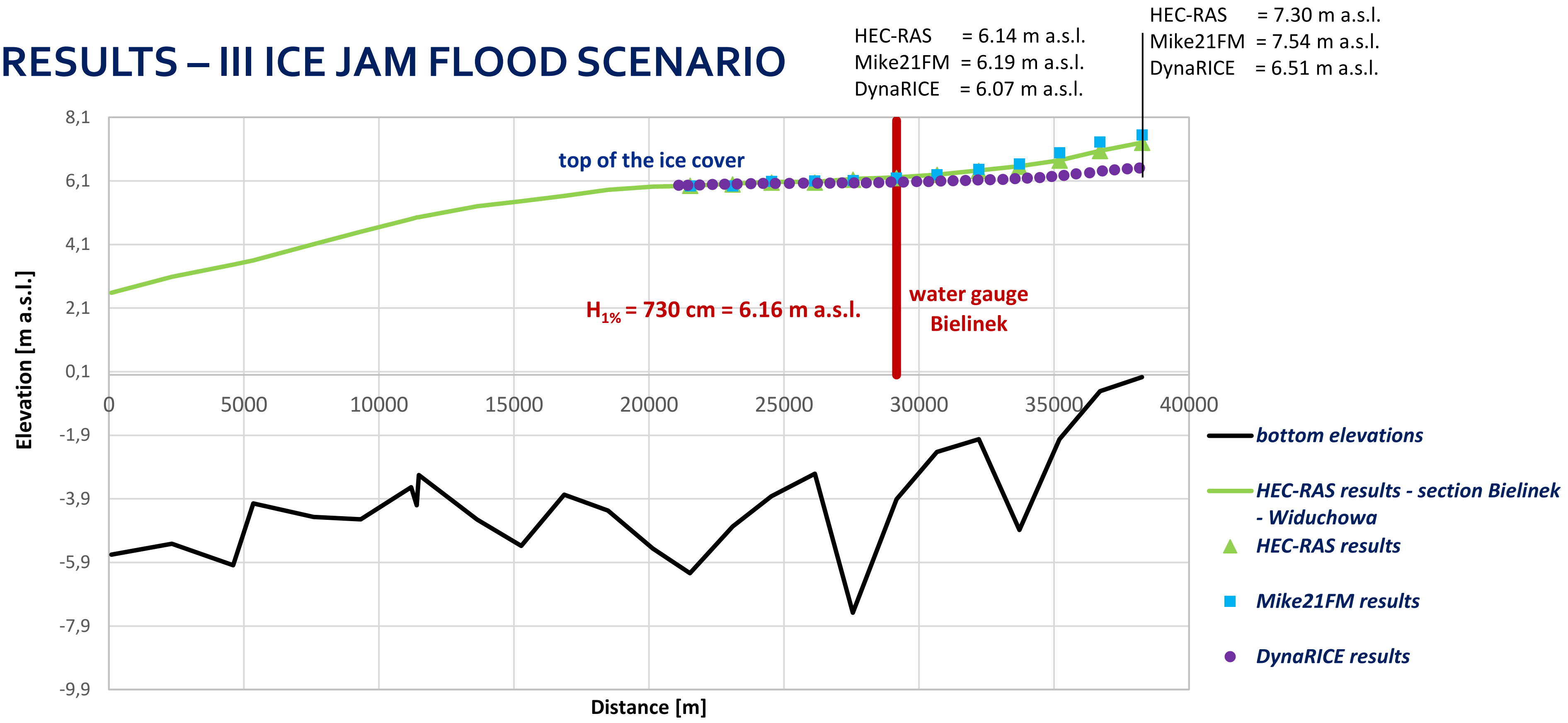

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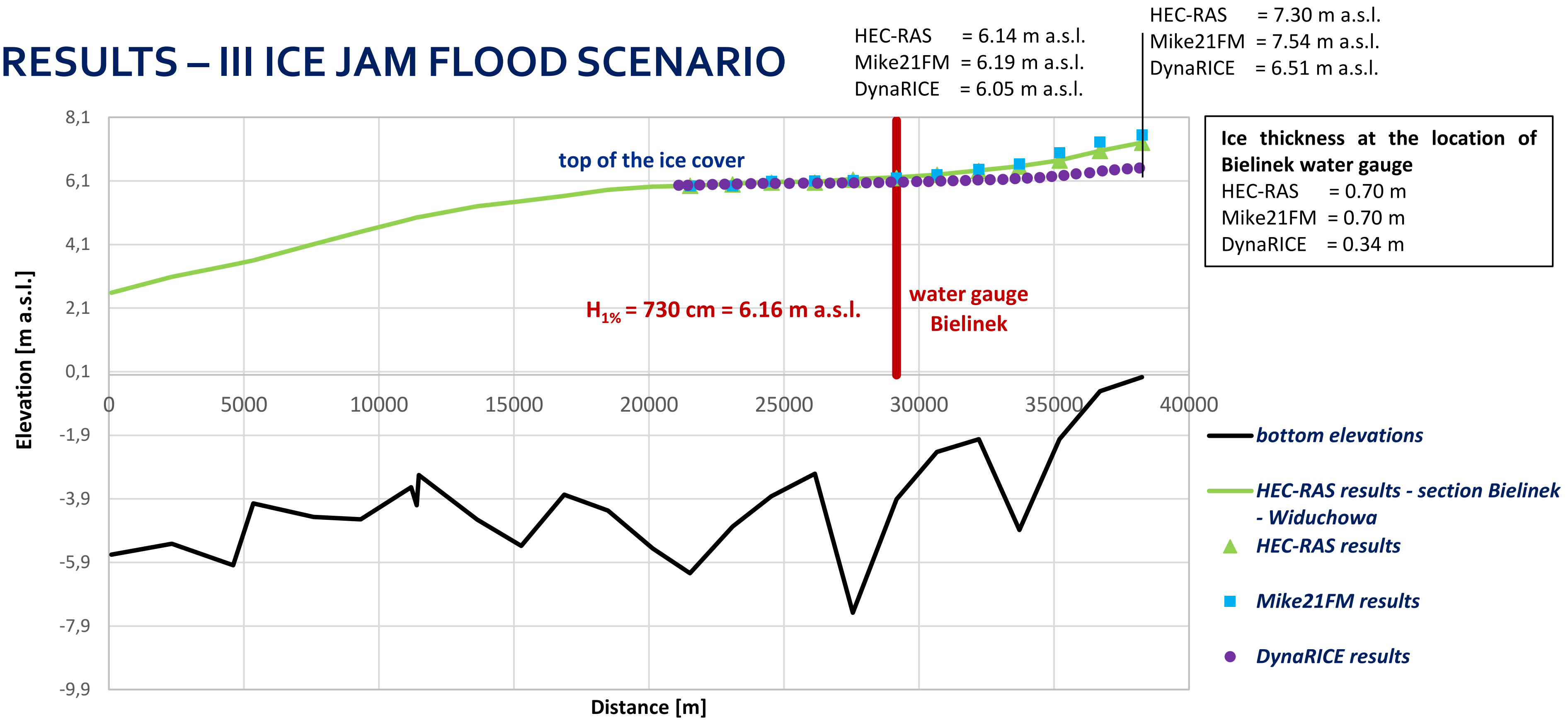

CONCLUSIONS

- Calibration results for the open water table did not differ significantly between the models tested. Similar result was observed for the test of calibration ice parameters by modeling historical ice jam event.
- All models were capable to reflect the water state during the 2014 ice jam event however, Mike21 FM was highly unstable after implementation of the ice cover and not all ice parameters worked correctly (e.g., ice concentration).
- The flood scenario tests showed that HEC-RAS and Mike21 FM were able to reflect the assumed water levels at the Bielinek water gauge (6.16 m a.s.l.) however, the ice thickness calculated in the DynaRICE was closer to historical observations (in HEC-RAS and Mike21 FM ice thickness was a model input parameter).
- The results obtained for the probable event differ significantly from historical data on ice cover thickness. Thus, it was concluded that it is necessary to extend the model and conduct further analysis to determine the value of the lower boundary condition.

CONCLUSIONS

- The direct stage-frequency method, i.e. the determination of flood hazard based on the analysis of hydrological data, poses many problems related to data interpretation, uncertainty and availability. In addition, calculations for the probabilistic scenario had to be based on information about the corresponding historical event.

- The modeling of ice jams based on the direct method, does not take into account the high randomness of ice formation. Additionally, it is important to consider the significant influence of lower boundary conditions and their consequences. The results of the work carried out enabled the development of preliminary recommendations and indicated the need for further research, including the scope of the stochastic approach.

THANK YOU