

Berit Arheimer, SMHI, Changes in Hydrology and Society

Water research to support society: past, present and future



Panta Rhei: Hydro Sciences entering the Anthropocene?

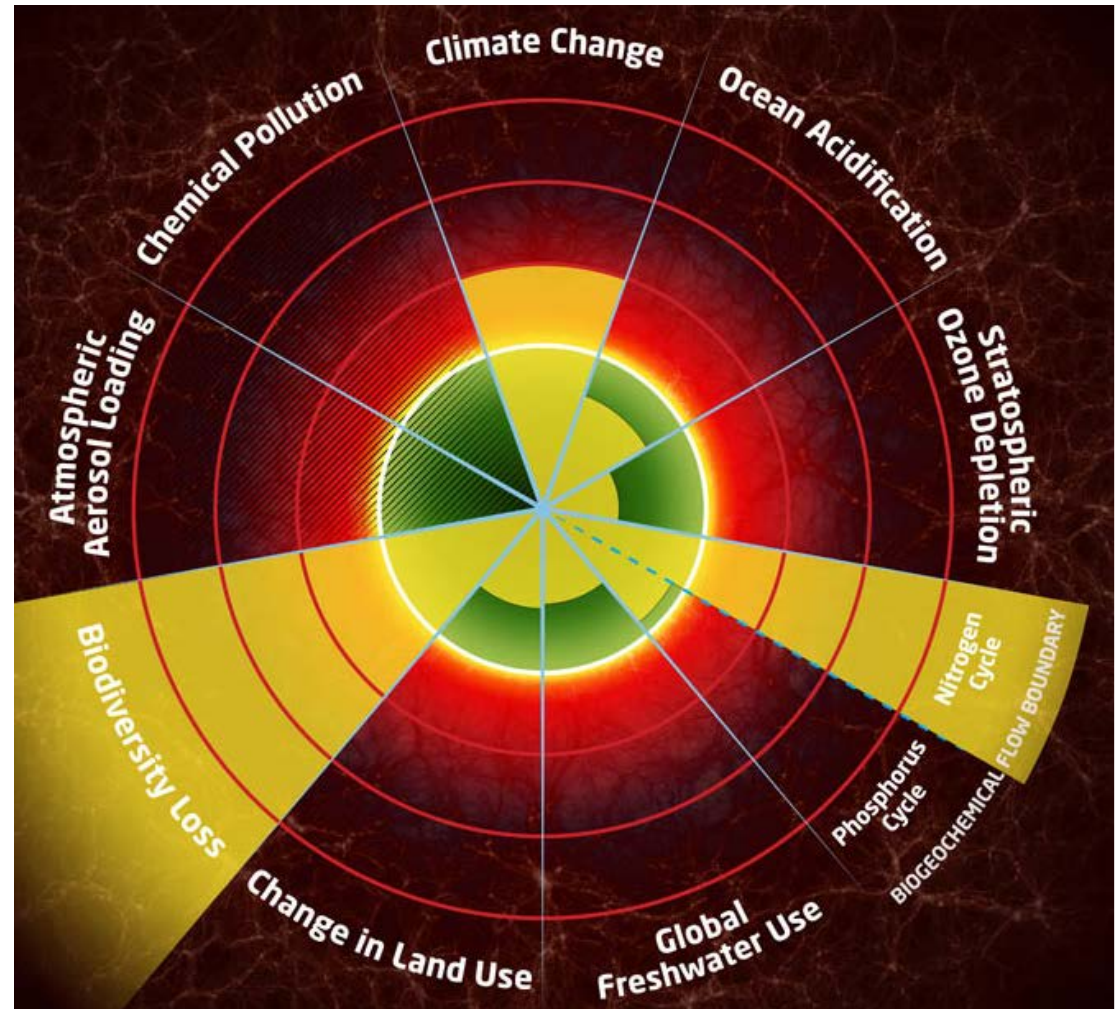
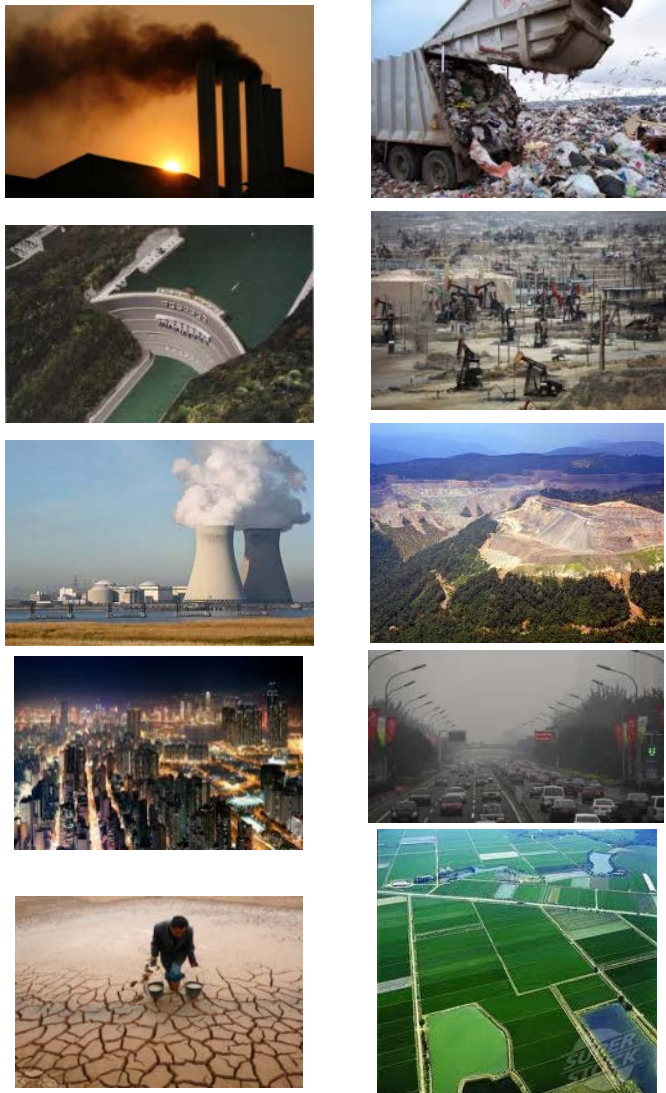


Age of Man

*Elizabeth Kolbert, 2011, on the NATIONAL GEOGRAPHIC website
Photograph by Jens Neumann/Edgar Rodtmann*

Tremendous environmental problems

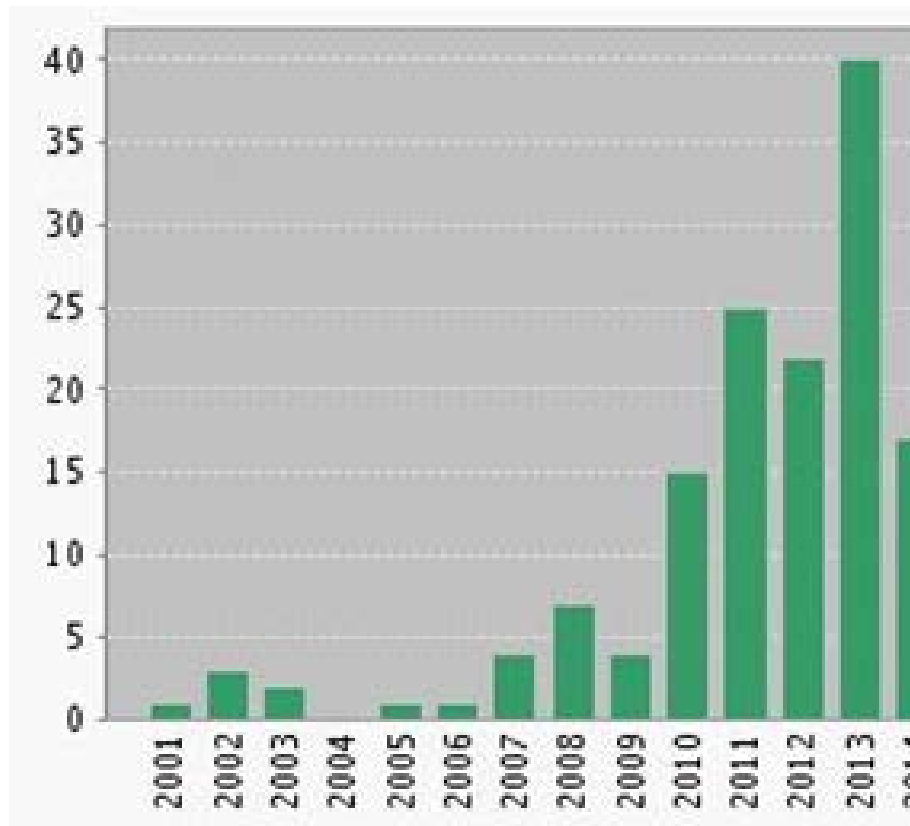
challenging hydrology and society



IGBP, 2011

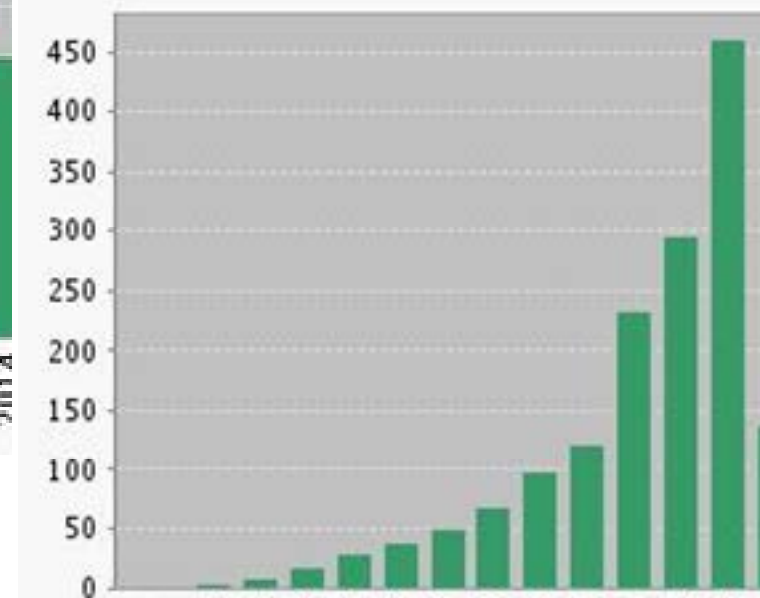
Anthropocene in Web of Science

Published Items in Each Year



The latest 20 years are displayed.

Citations in Each Year



Holocene => Anthropocene?



INTERNATIONAL CHRONOSTRATIGRAPHIC CHART

www.stratigraphy.org

International Commission on Stratigraphy

v 2013/01



Anthropocene?

Eonothem / Eon Erathem / Era System / Period	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)	
Phanerozoic	Quaternary	Holocene		present	
		Upper		0.0117	
		Middle		0.126	
	Pleistocene	Calabrian			0.781
		Gelasian			1.806
		Zanclean			2.588
		Piacenzian			3.600
		Messinian			5.333
	Pliocene	Messinian			7.246
		Tortonian			11.62
		Serravallian			13.82
		Langhian			15.97
		Burdigalian			20.44
	Neogene	Miocene	Aquitanian		23.03
			Chattian		28.1
			Rupelian		33.9
	Oligocene	Priabonian			38.0
		Bartonian			41.3
		Lutetian			47.8
		Ypresian			56.0
		Thanetian			59.2
	Paleogene	Eocene	Selandian		61.6
			Danian		66.0
			Maastrichtian		72.1 ± 0.2
	Cretaceous	Upper	Campanian		83.8 ± 0.2
			Santonian		86.3 ± 0.5
			Coniacian		89.8 ± 0.3
			Turonian		93.9
			Cenomanian		100.5
Lower		Albian		~ 113.0	
		Aptian		~ 125.0	
		Barremian		~ 129.4	
		Hauterivian		~ 132.9	
		Valanginian		~ 139.8	
Berriasian		~ 145.0			

Eonothem / Eon Erathem / Era System / Period	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)		
Phanerozoic	Jurassic	Upper	Tithonian		~ 145.0	
			Kimmeridgian		152.1 ± 0.9	
		Middle	Oxfordian			157.3 ± 1.0
			Callovian			163.5 ± 1.0
			Bathonian			166.1 ± 1.2
			Badenian			168.3 ± 1.3
			Aalenian			170.3 ± 1.4
		Lower	Toarcian			174.1 ± 1.0
			Pliensbachian			182.7 ± 0.7
			Sinemurian			190.8 ± 1.0
	Hettangian				199.3 ± 0.3	
	Triassic	Upper	Rhaetian		201.3 ± 0.2	
			Norian		~ 208.5	
			Camian		~ 227	
			Ladinian		~ 237	
			Anisian		~ 242	
		Lower	Olenekian			247.2
			Induan			251.2
			Changhsingian			252.17 ± 0.06
			Lopingian			254.14 ± 0.07
			Wuchiapingian			259.8 ± 0.4
	Permian	Guadalupian	Capitanian		265.1 ± 0.4	
			Wordian		268.8 ± 0.5	
			Roadian		272.3 ± 0.5	
			Kungurian		283.5 ± 0.6	
			Artinskian		290.1 ± 0.26	
		Cisuralian	Sakmarian			295.0 ± 0.18
			Asselian			298.9 ± 0.15
			Gzhelian			303.7 ± 0.1
Kasimovian					307.0 ± 0.1	
Moscovian					315.2 ± 0.2	
Carboniferous	Upper	Bashkirian		323.2 ± 0.4		
		Serpukhovian		330.9 ± 0.2		
	Lower	Visean			346.7 ± 0.4	
		Tournaisian			358.0 ± 0.4	

Eonothem / Eon Erathem / Era System / Period	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)		
Phanerozoic	Devonian	Upper	Famennian		372.2 ± 1.6	
			Frasnian		382.7 ± 1.6	
		Middle	Givetian			387.7 ± 0.8
			Eifelian			393.3 ± 1.2
			Emsian			407.6 ± 2.6
			Pragian			410.8 ± 2.8
		Lower	Lochkovian			419.2 ± 3.2
			Pridoli			423.0 ± 2.3
		Silurian	Ludlow	Ludfordian		425.6 ± 0.9
				Horstian		427.4 ± 0.5
	Wenlock				430.5 ± 0.7	
	Llandovery		Sheinwoodian			433.4 ± 0.8
			Telychian			438.5 ± 1.1
	Ordovician	Upper	Aeronian		440.8 ± 1.2	
			Rhuddanian		443.4 ± 1.5	
			Hirnantian		445.2 ± 1.4	
			Katian		463.0 ± 0.7	
			Sandbian		468.4 ± 0.9	
		Middle	Darriwilian			467.3 ± 1.1
			Dapingian			470.0 ± 1.4
		Lower	Floian			477.7 ± 1.4
			Tremadocian			485.4 ± 1.9
			Furongian			~ 489.5
	Cambrian	Series 3	Jiangshanian		~ 494	
			Paibian		~ 497	
		Series 2	Guzhangian			~ 500.5
			Drumian			~ 504.5
			Stage 5			~ 509
	Terreneuvian	Series 1	Stage 4		~ 514	
Stage 3				~ 521		
Stage 2		Stage 2			~ 529	
		Fortunian			541.0 ± 1.0	

Eonothem / Eon	Erathem / Era	System / Period	GSSP	numerical age (Ma)	
Proterozoic	Neo-proterozoic	Ediacaran		~ 541.0 ± 1.0	
		Cryogenian		~ 635	
		Tonian		850	
		Stenian		1000	
		Ectasian		1200	
	Meso-proterozoic	Calymmian			1400
		Statherian			1800
		Orosirian			1800
		Rhyacian			2050
		Siderian			2300
Archean	Neo-archean			2500	
				2800	
	Meso-archean			3200	
				3600	
				4000	
Hadean			~ 4800		

Units of all ranks are in the process of being defined by Global Boundary Stratotype Section and Points (GSSP) for their lower boundaries, including those of the Archean and Proterozoic, long defined by Global Standard Stratigraphic Ages (GSSA). Charts and detailed information on ratified GSSPs are available at the website <http://www.stratigraphy.org>. The URL to this chart is found below.

Numerical ages are subject to revision and do not define units in the Phanerozoic and the Ediacaran; only GSSPs do. For boundaries in the Phanerozoic without ratified GSSPs or without constrained numerical ages, an approximate numerical age (~) is provided.

Numerical ages for all systems except Permian, Triassic, Cretaceous and Precambrian are taken from 'A Geologic Time Scale 2012' by Gradstein et al. (2012); those for the Permian, Triassic and Cretaceous were provided by the relevant ICS subcommissions.

Coloring follows the Commission for the Geological Map of the World. <http://www.cgmw.org>



Chart drafted by K.M. Cohen, S. Finney, P.L. Gibbard
(c) International Commission on Stratigraphy, January 2013

<http://www.stratigraphy.org/ICSChart/ChronostratChart2013-01.pdf>

Don't panic - things are improving!

4 april 2013 | Stockholm Waterfront Congress Centre

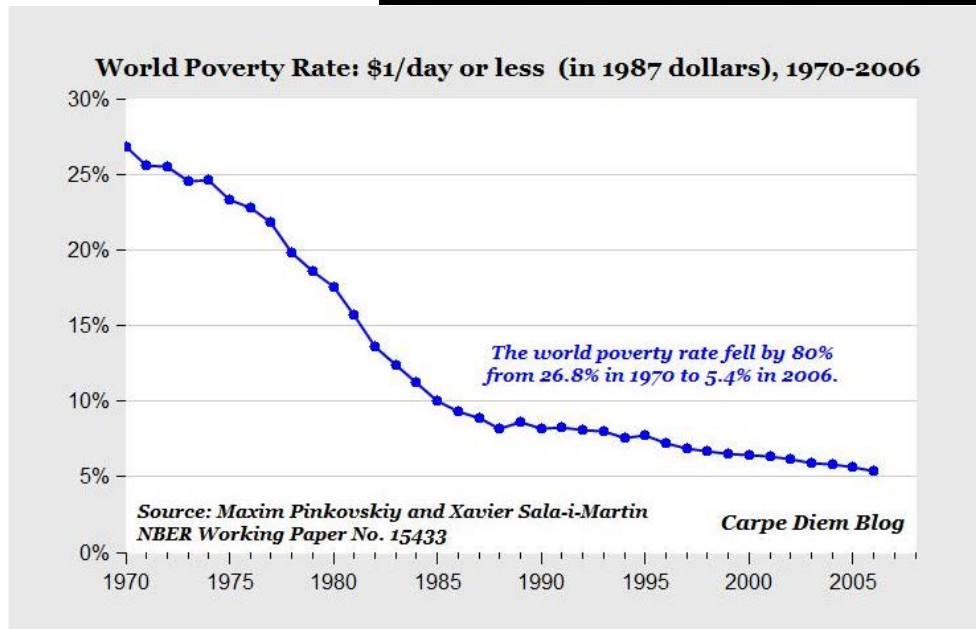


GLOBAL HEALTH
beyond 2015



Hans Rosling
Professor i internationell hälsa

Extreme poverty is the worst global health problem!



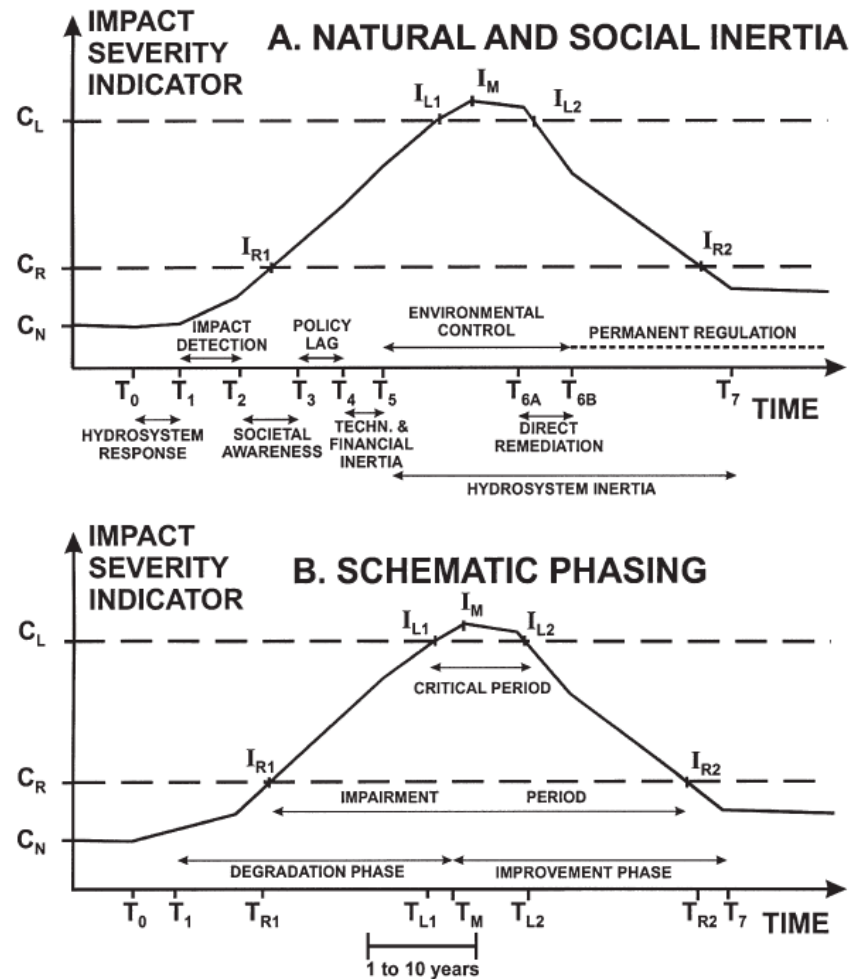
Global Ignorance in Sweden

		25 years ago	Correct
Literacy among the 20 years old in Tanzania?	20%	40%	60%
% Swedish guesses	33%	45%	4%
Babies per woman in Bangladesh?	5.5	4.5	3.5
% Swedish guesses	26%	43%	5%

Survey by Statistics Sweden 2011

<http://www.gapminder.org/>

Successful restoration of water quality



Meybeck, M. 2002. Riverine quality at the Anthropocene: Propositions for global space and time analysis, illustrated by the Seine River. *Aquatic Sciences* 64 (4):376-393

Case-study: SMHI

Hypothesis: Hydrologists are responsive to changes in hydrology and society

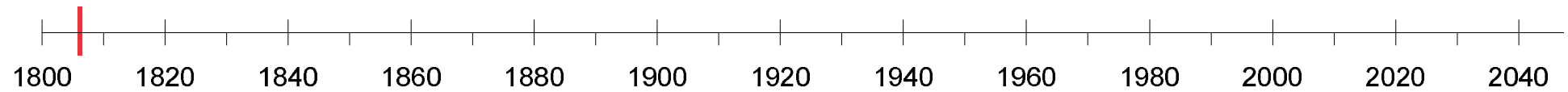


www.smhi.se



SMHI - the story of changes in hydrology and society

SOCIETY



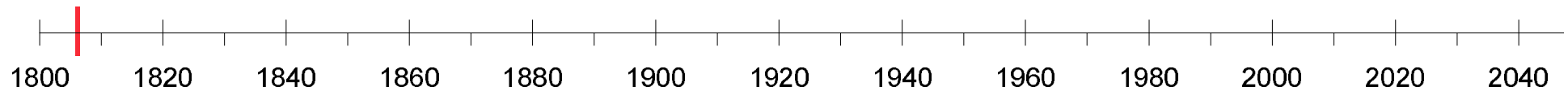
HYDROLOGY RESEARCH

SMHI - the story of changes in hydrology and society

SOCIETY

Transport, Agriculture:

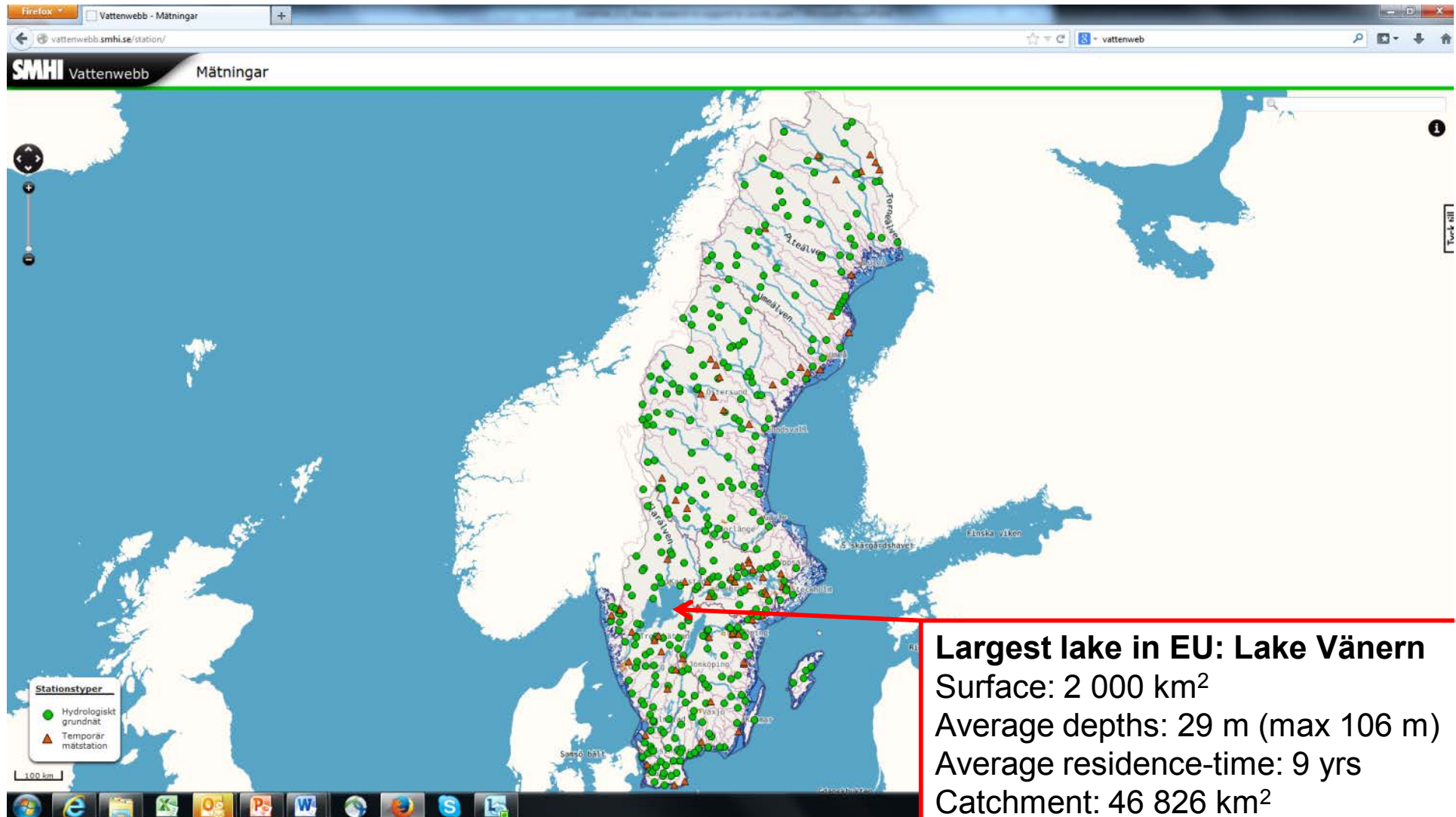
shipping, log driving,
building canals



HYDROLOGY RESEARCH

Countinous
monitoring of
River flow;
Compiling
statistics for
infrastructure

Flow observations started with the large lakes in 1808

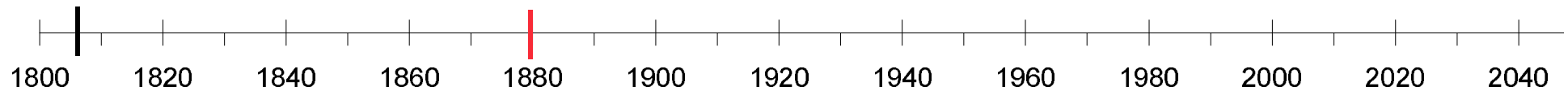


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Transport, Agriculture: shipping,
log driving, building canals

Famine:
More arable land



HYDROLOGY RESEARCH

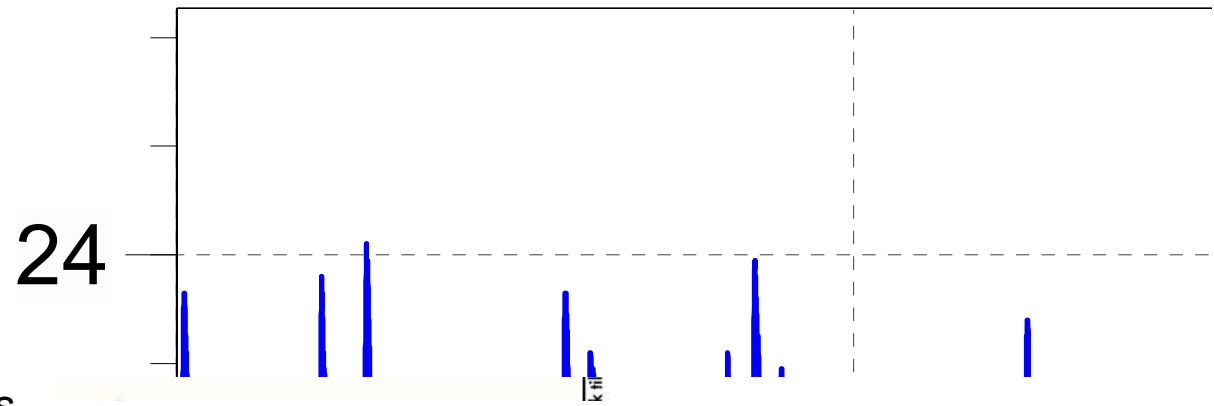
Countinous
monitoring of
River flow;
Compiling
statistics for
infrastructure

Observing
effects of
lake drainage

Lake Hjälmaren m

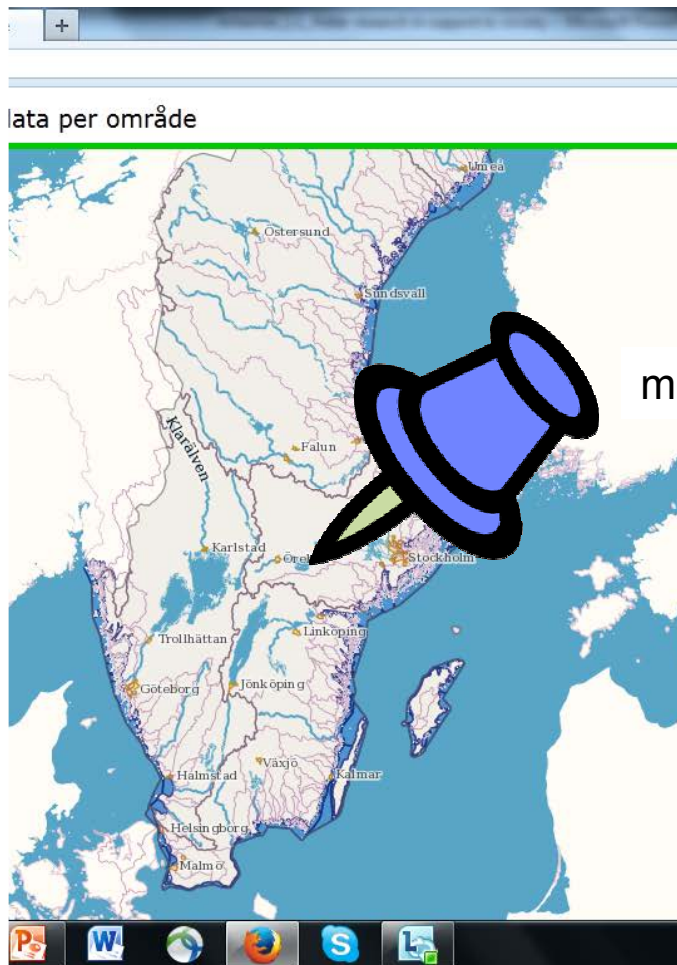
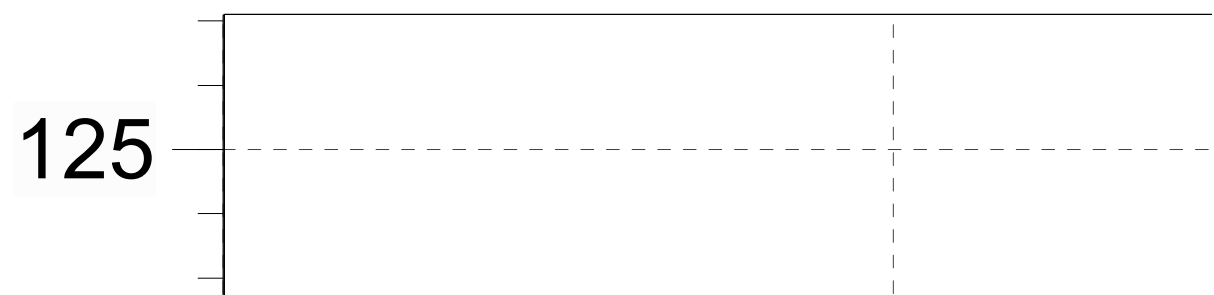
190 km² drained during 1880's

Water level



m³/s

Water flow



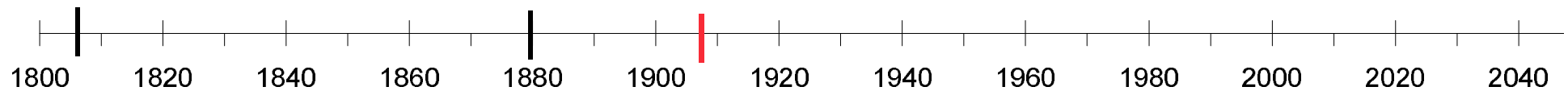
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SOCIETY

Industrialisation:
Energy problem

Transport, Agriculture: shipping,
log driving, building canals

Famine:
More arable land



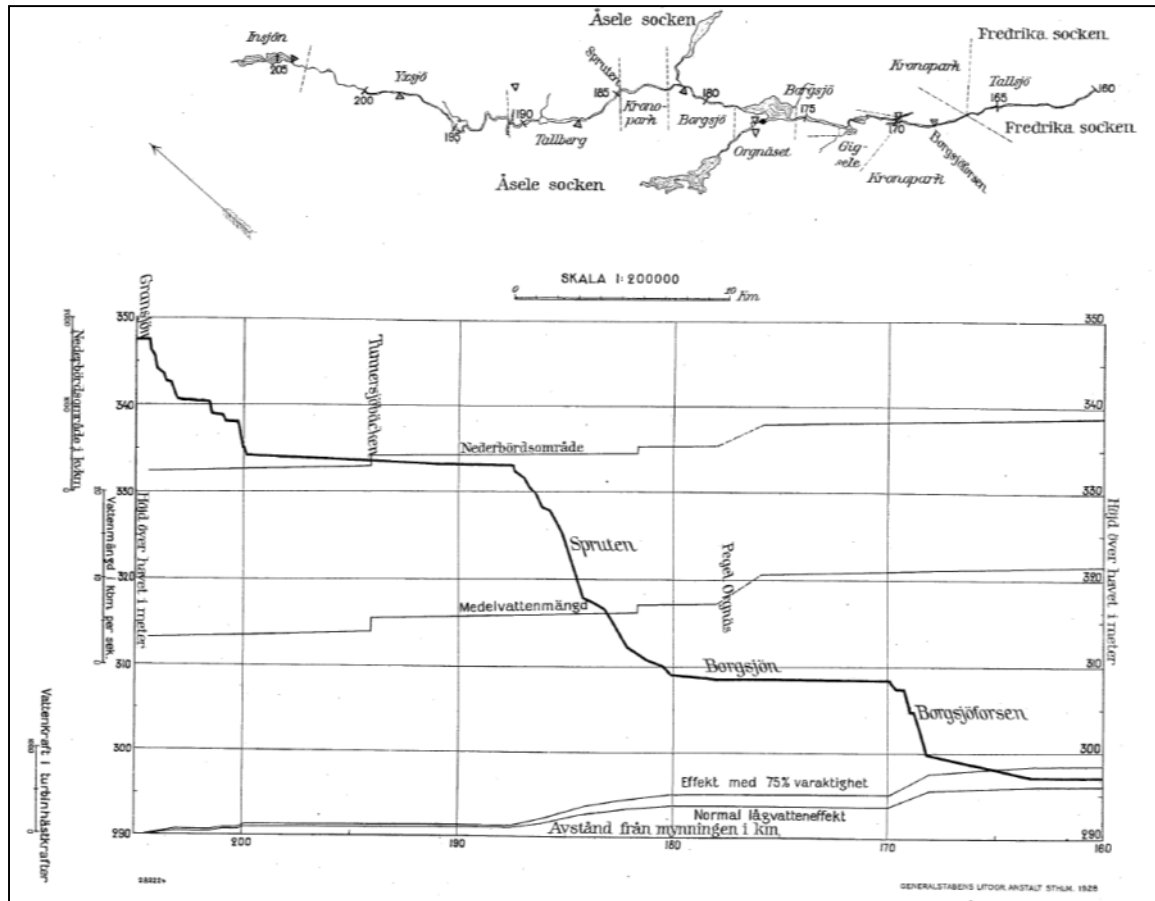
HYDROLOGY RESEARCH

Countinous
monitoring of
River flow;
Compiling
statistics for
infrastructure

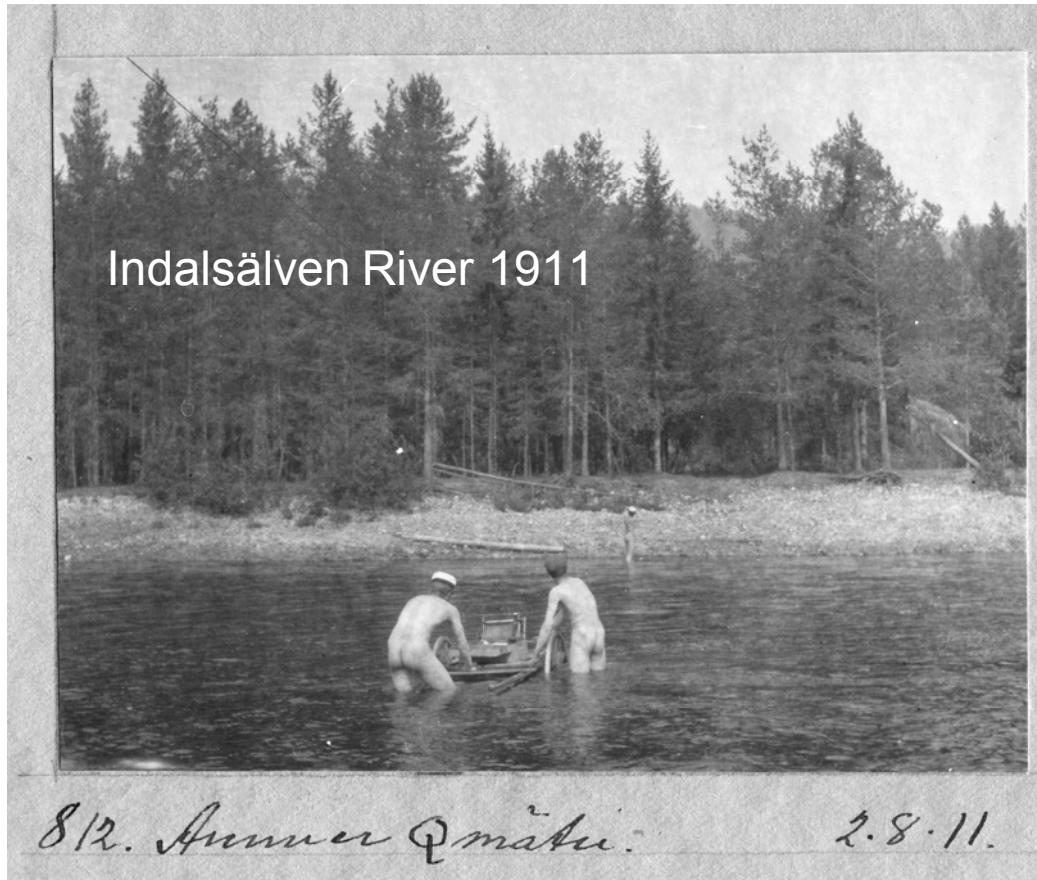
Observing effects
of lake drainage

**Mapping
hydropower
potential
(water divides,
falls, flow)**

Mapping water divides and falls

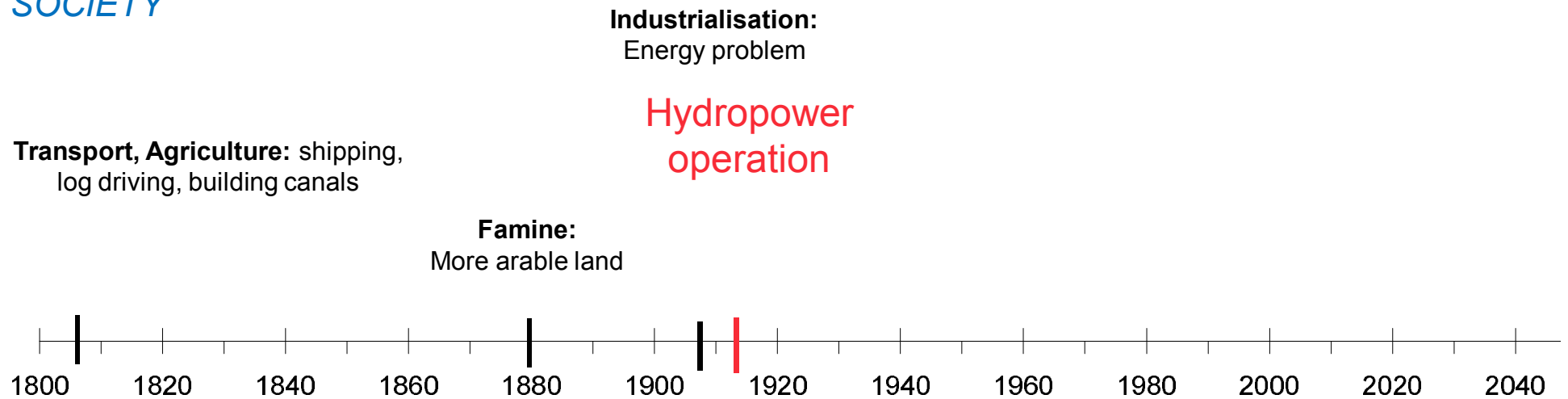


Monitoring of river flow in the North

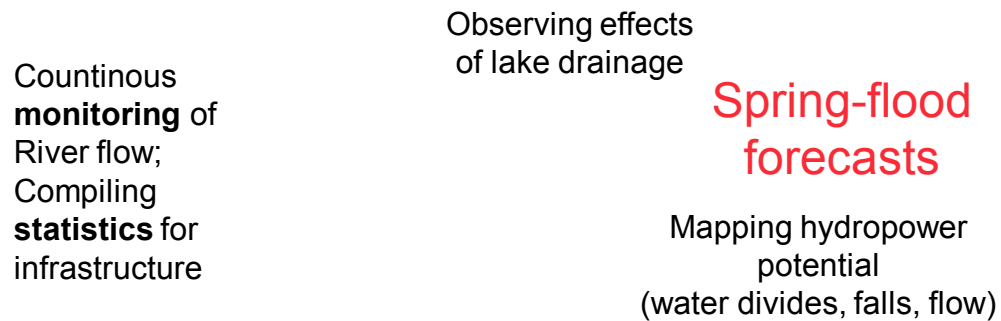


SMHI - the story of changes in hydrology and society

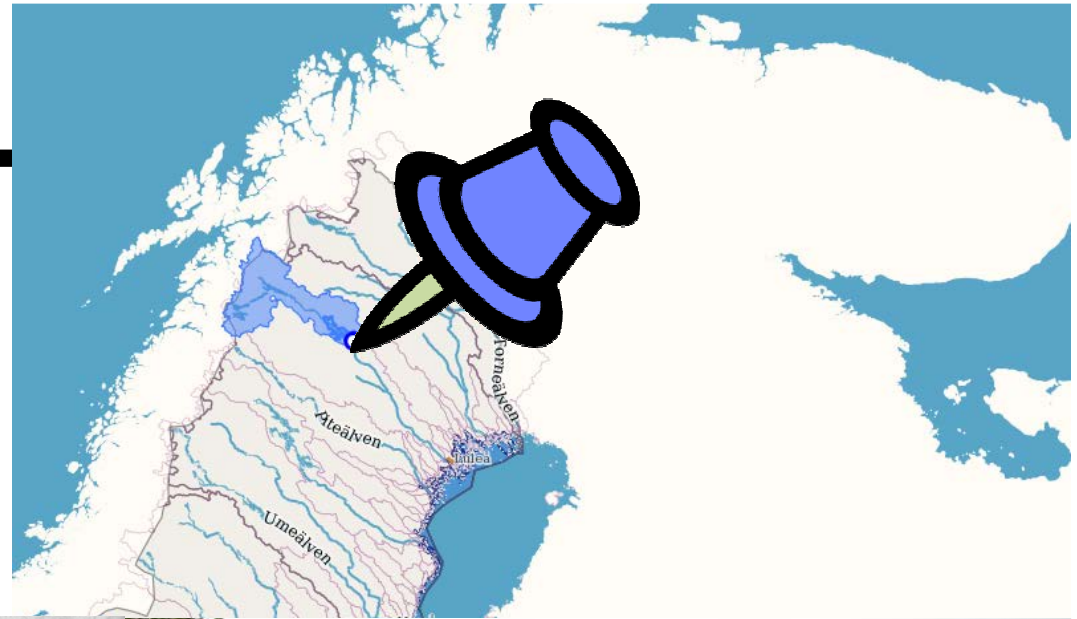
SOCIETY



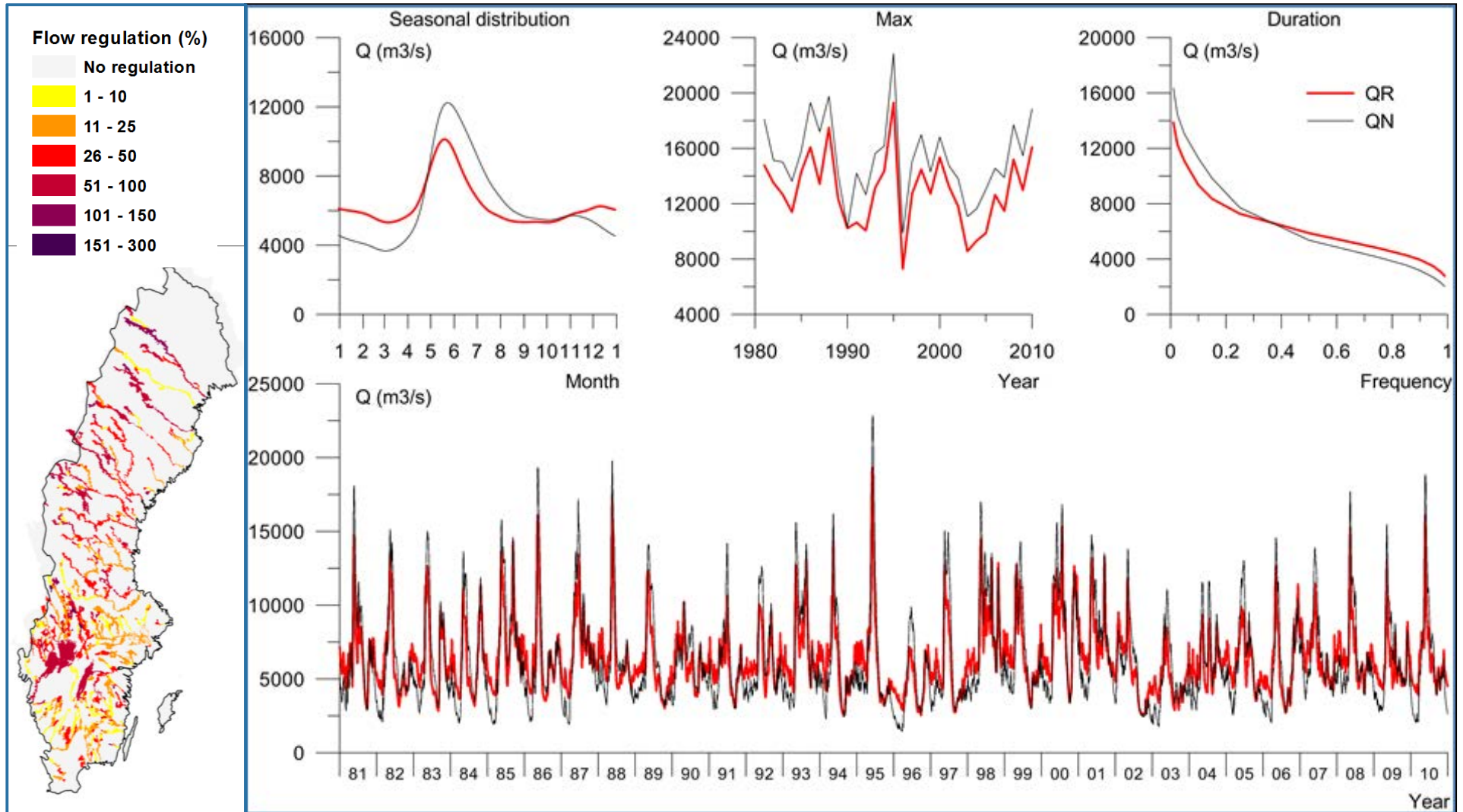
HYDROLOGY RESEARCH



Porjus: 1910 vs 2010



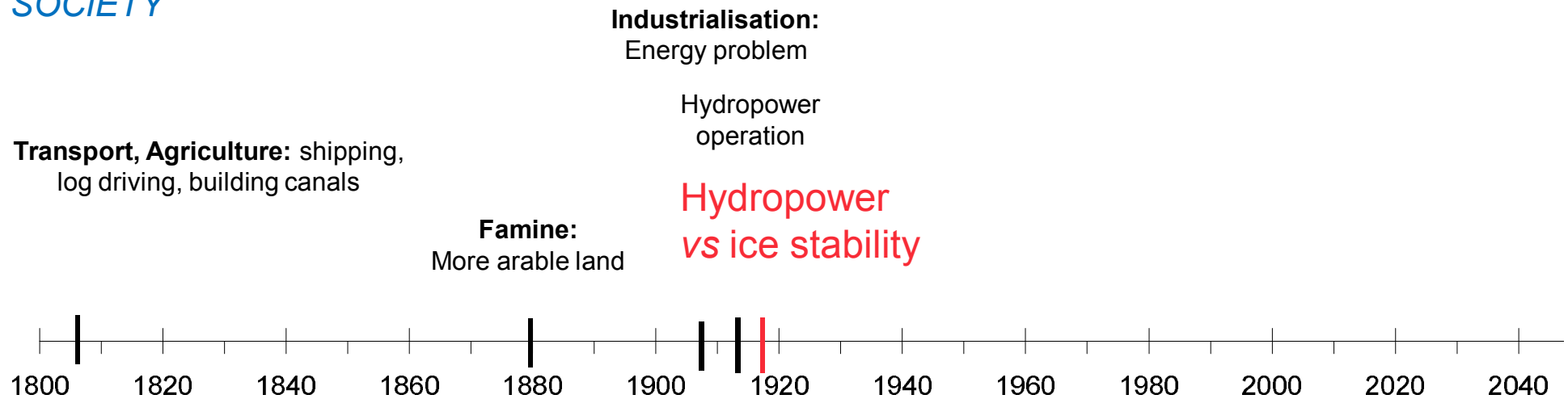
Estimated hydropower-effect on river flow to the sea



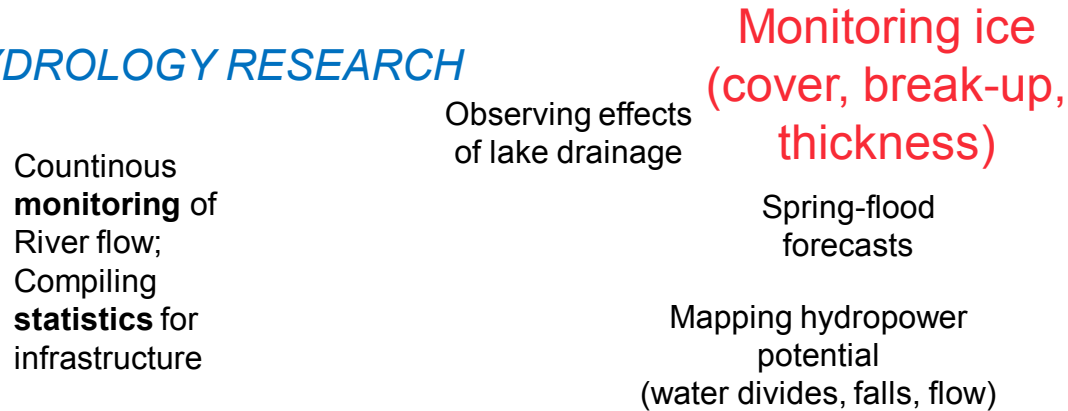
Arheimer, B. and Lindström, G. 2014. *Electricity vs Ecosystems – understanding and predicting hydropower impact on Swedish river flow*. IAHS Publ. 364

SMHI - the story of changes in hydrology and society

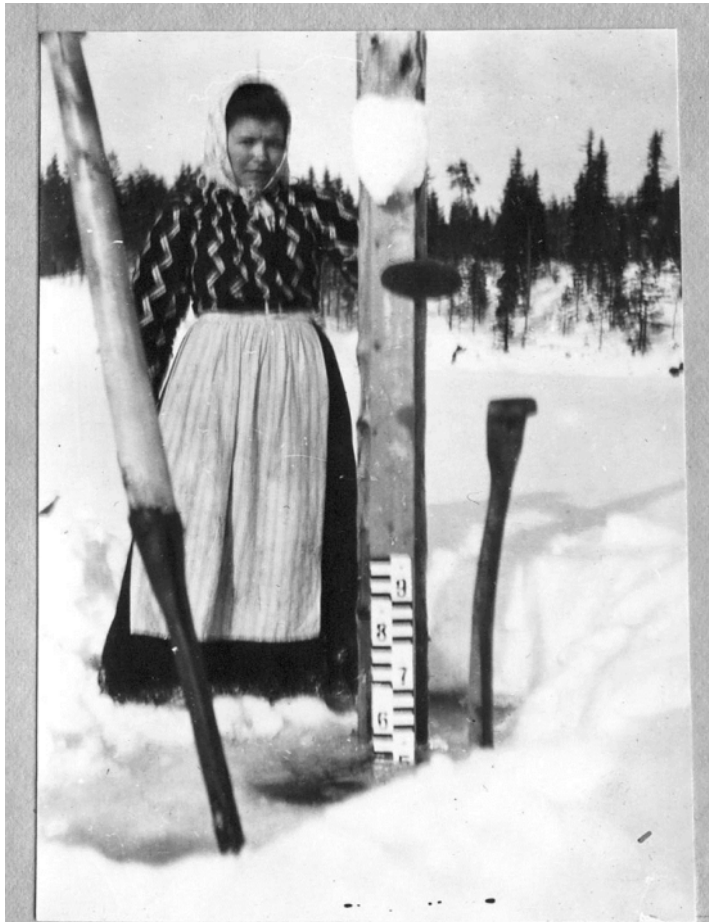
SOCIETY



HYDROLOGY RESEARCH



SMHI ice service



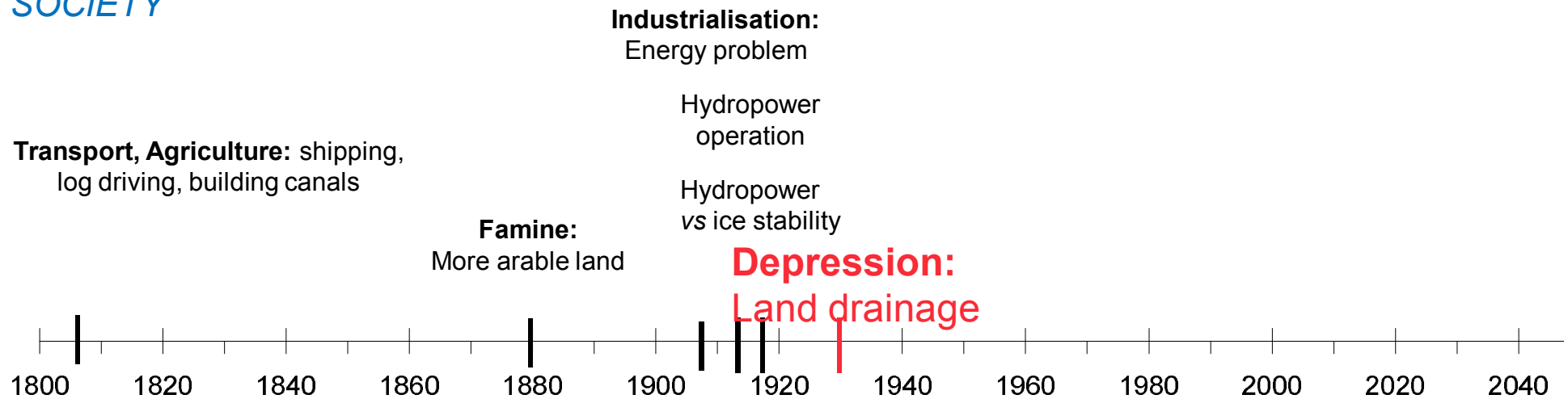
213. Ligga, vint. peg. 22.3.09.



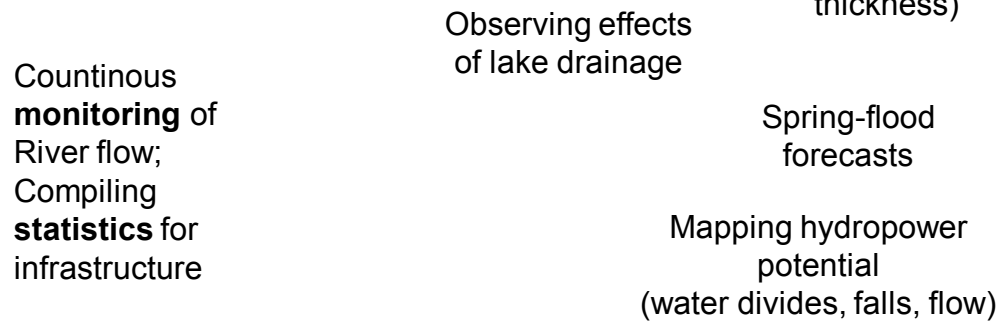
781. Björkvattnet, isbornning 19.1.11.

SMHI - the story of changes in hydrology and society

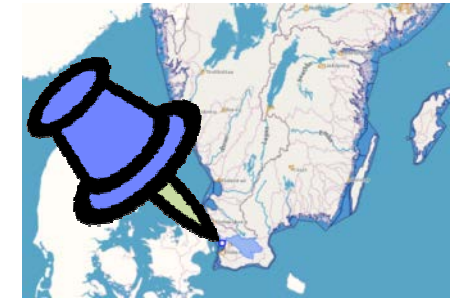
SOCIETY



HYDROLOGY RESEARCH



Land drainage in the Kävlingeån River



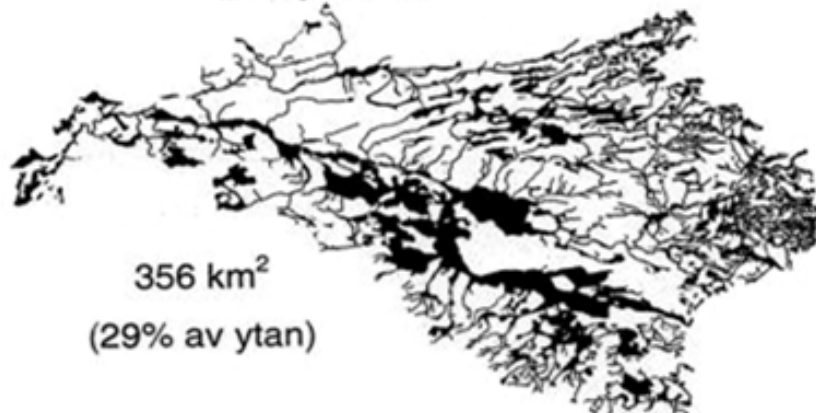
1812-1820

Wetlands = 29% of the catchment

1950-1953

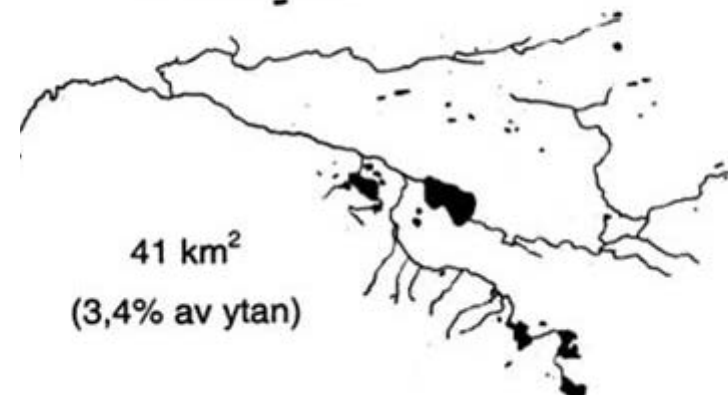
Wetlands = 3% of the catchment

FÖRR ... Åren 1812 - 1820
Kävlingeåns vatten system innan undikningar
och dräneringar verkställdes ...



NU ... Åren 1950 - 1953
Kävlingeåns vatten system efter hollits verkställda
undikningar och dräneringar ...

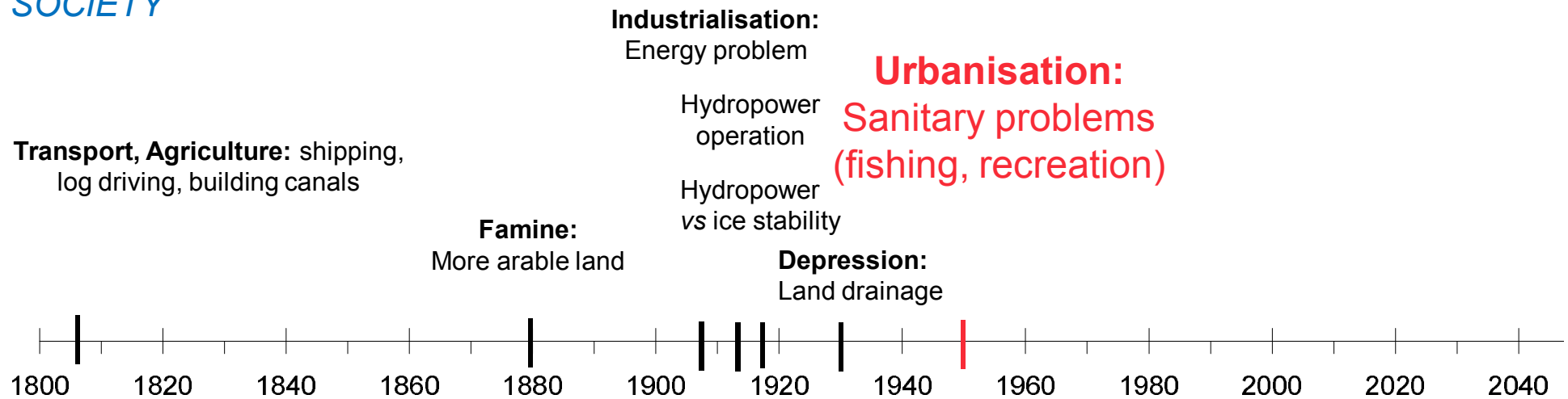
-88%



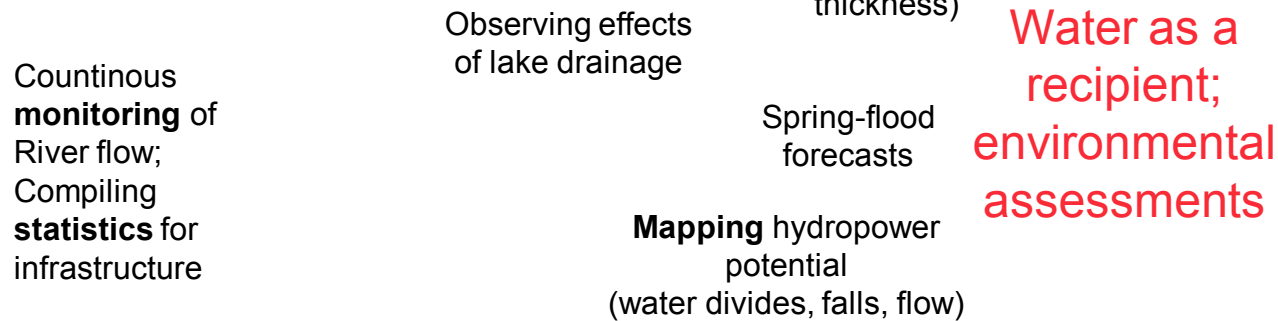
Source: Ph Wolf, Utdikad civilisation (1956)

SMHI - the story of changes in hydrology and society

SOCIETY

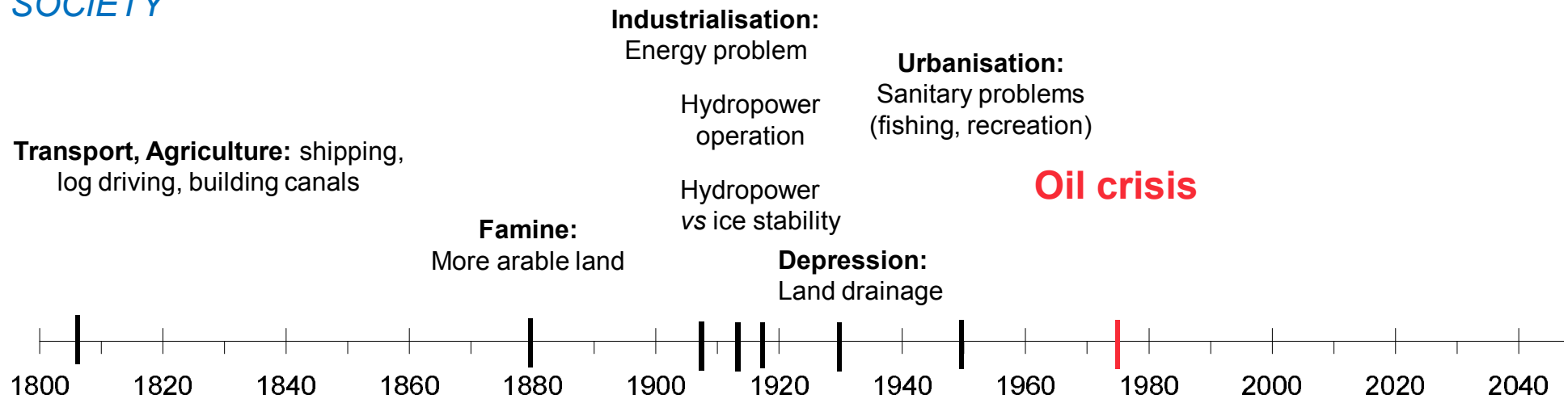


HYDROLOGY RESEARCH

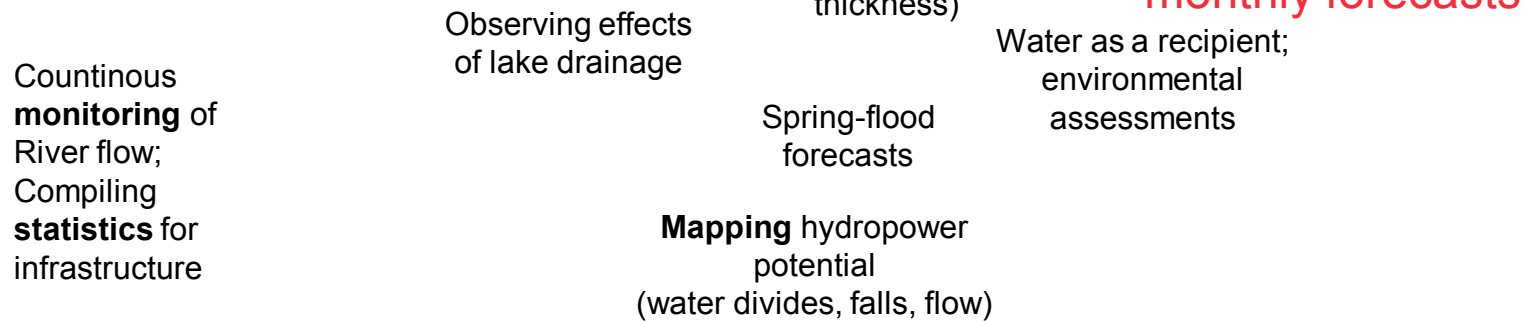


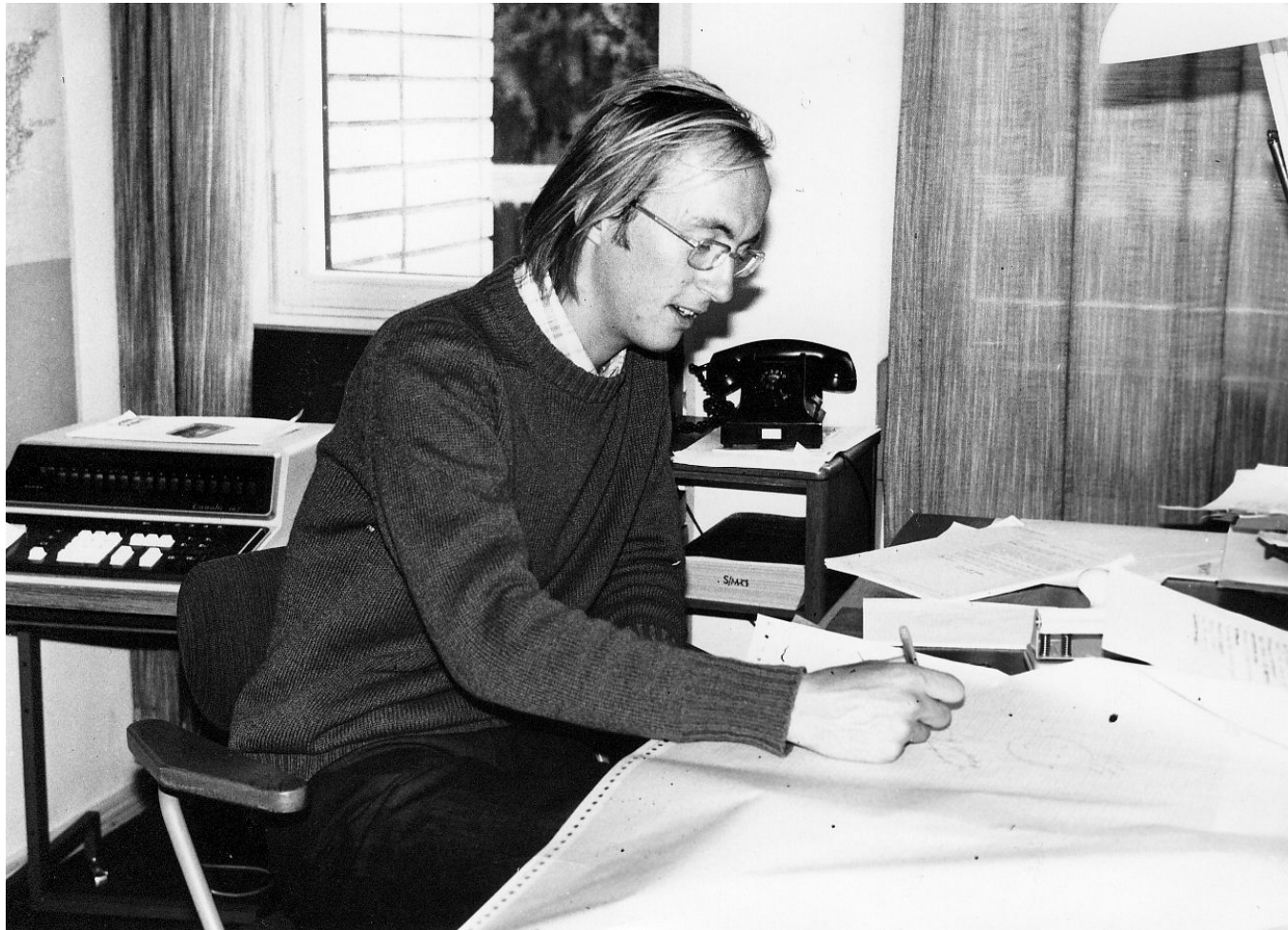
SMHI - the story of changes in hydrology and society

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HYDROLOGY RESEARCH

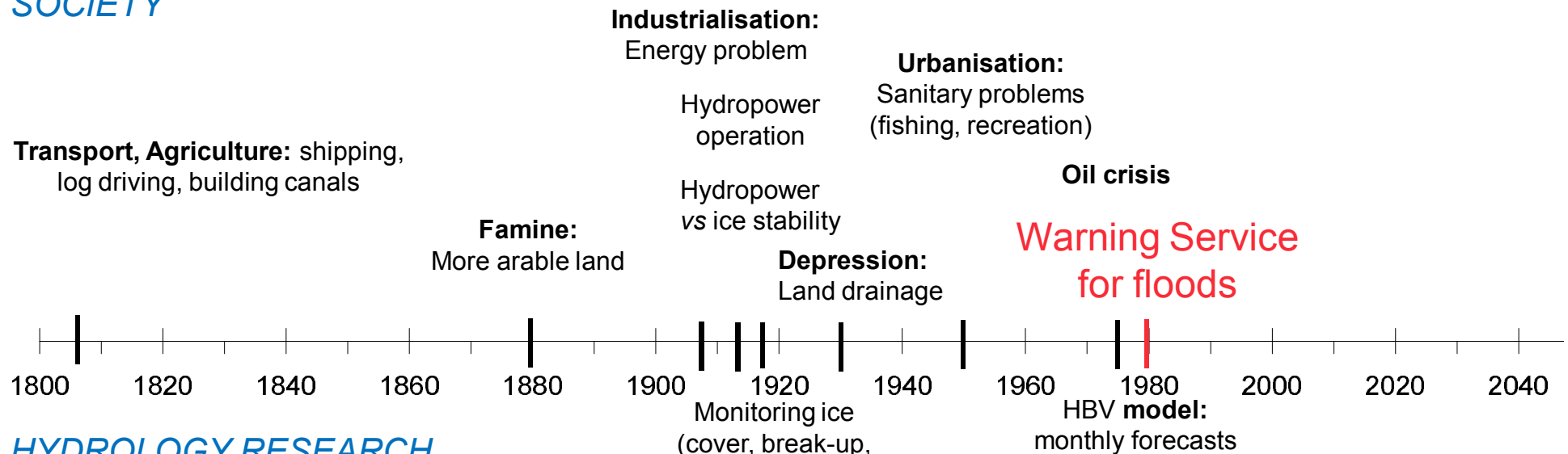


Sten Bergström, 27 yrs

Bergström, S., 1976. Development and application of a conceptual runoff model for Scandinavian catchments. Norrköping: SMHI Reports RHO, no. 7.

SMHI - the story of changes in hydrology and society

SOCIETY



HYDROLOGY RESEARCH

Countinuous monitoring of River flow; Compiling statistics for infrastructure

Observing effects of lake drainage

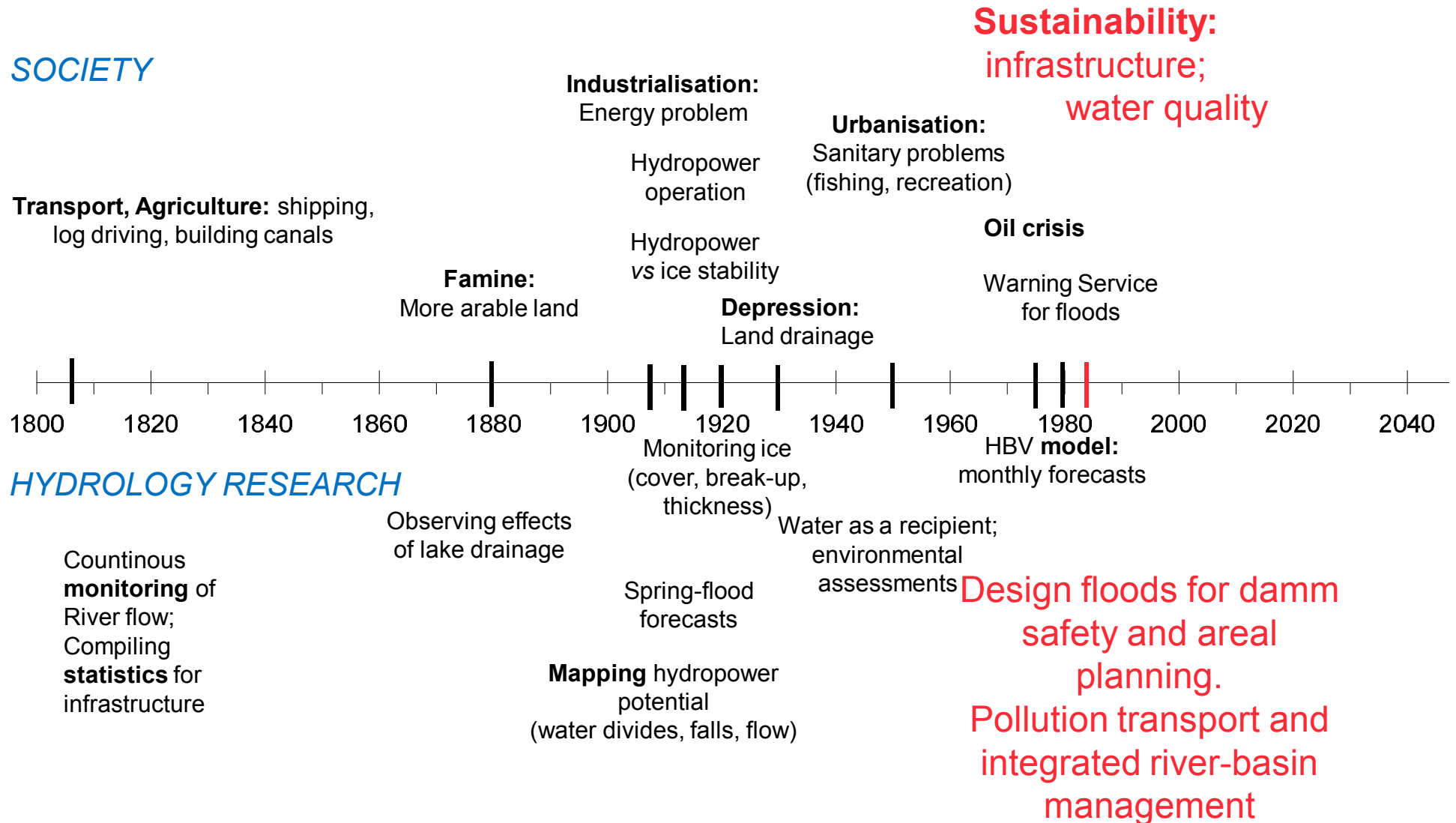
Spring-flood forecasts

Mapping hydropower potential (water divides, falls, flow)

Water as a recipient; environmental assessments

HBV model: monthly forecasts

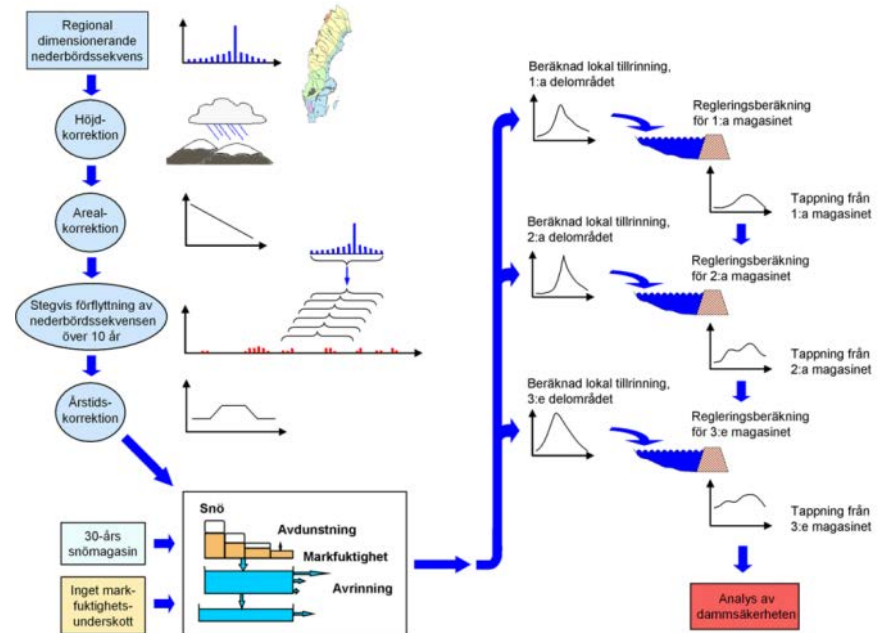
SMHI - the story of changes in hydrology and society



Noppikoski dam break 1985



Workflow for calculating design floods for hydropower dam safety



Diffuse pollution

1980's: Acidification

=> PULSE model



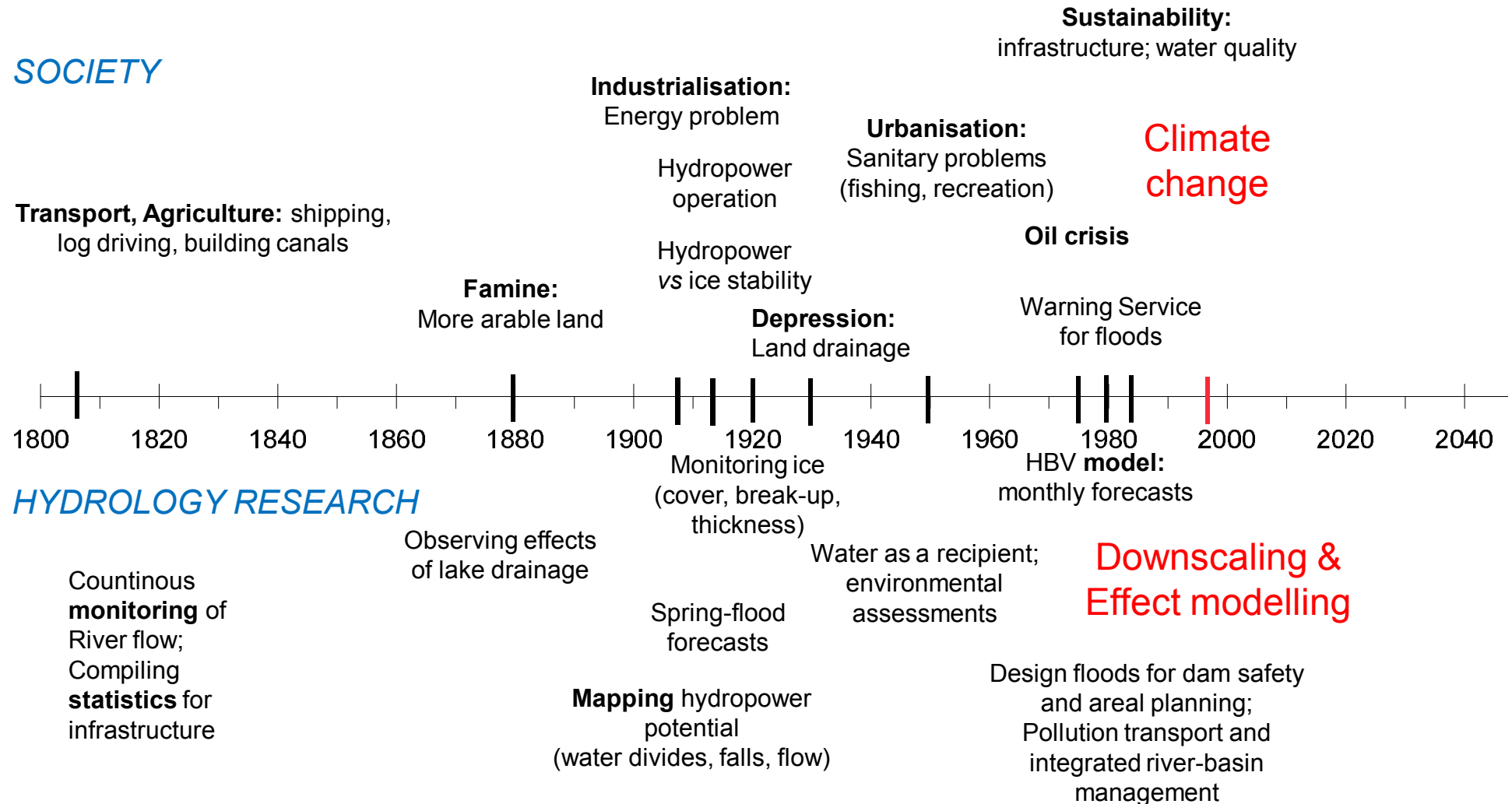
1990's: Eutrophication of Baltic Sea

=> HBV-NP model

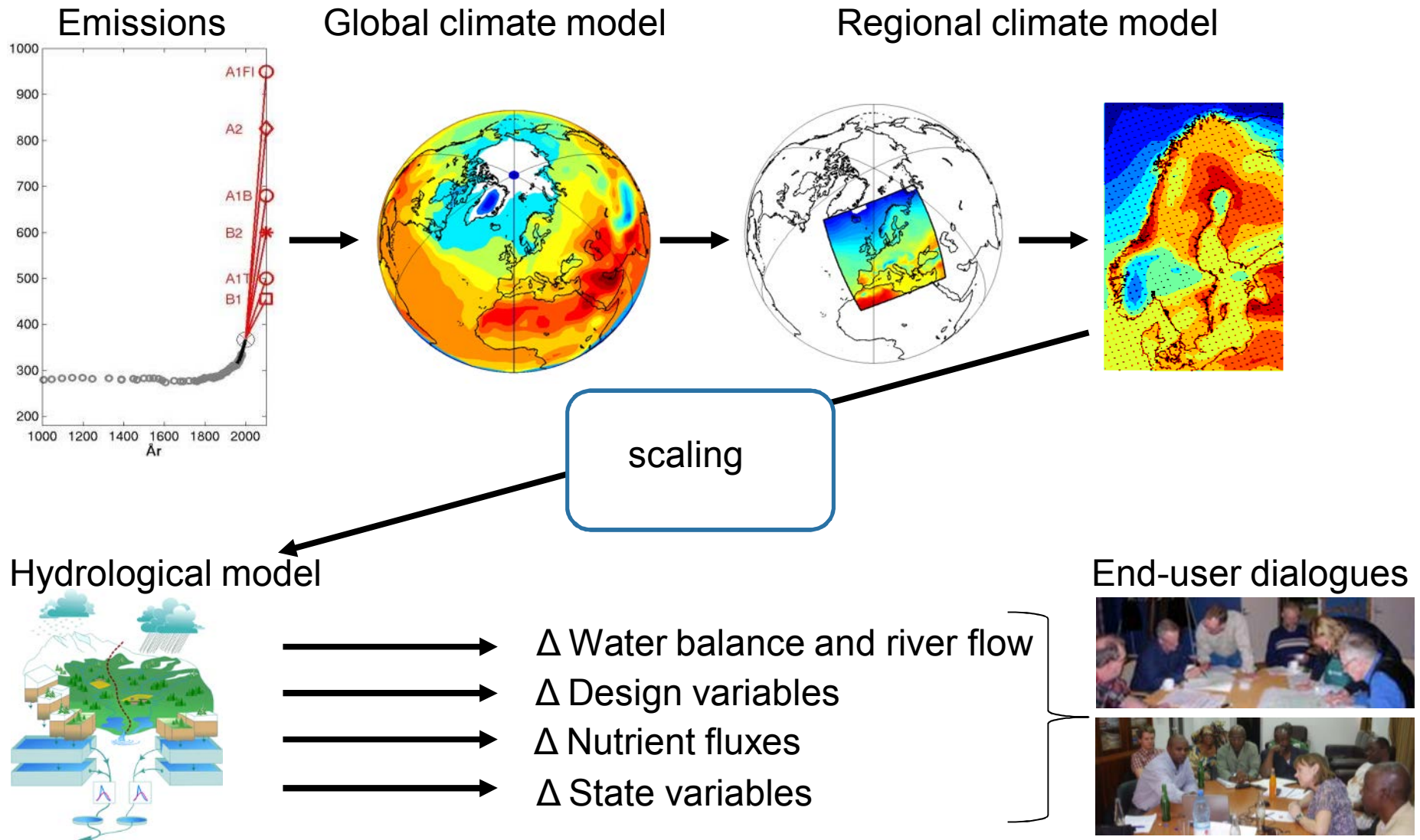


Arheimer, B. and Brandt, M., 1998. Modelling nitrogen transport and retention in the catchments of southern Sweden. Ambio 27(6):471-480.

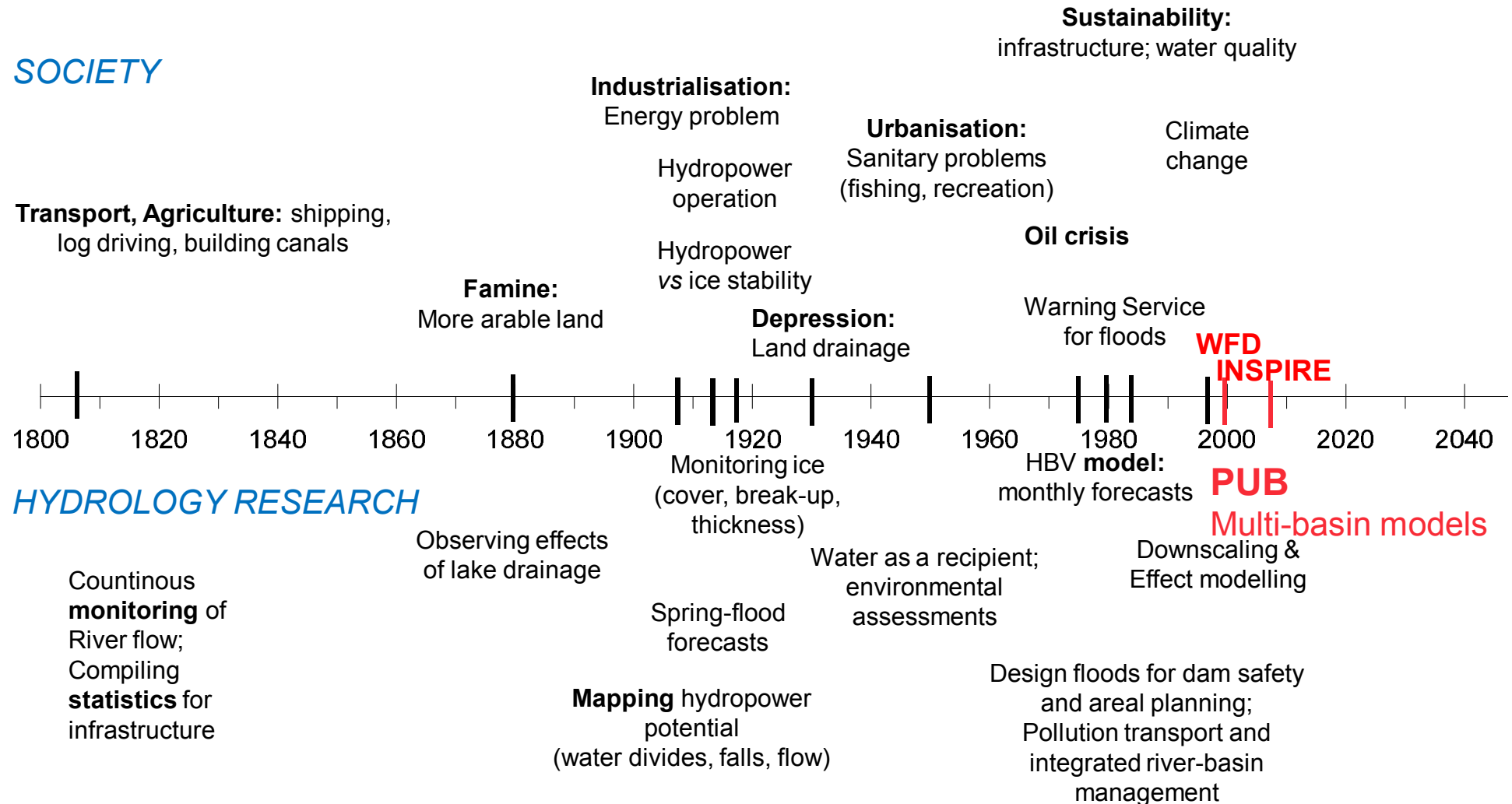
SMHI - the story of changes in hydrology and society



Workflow for climate change impact studies



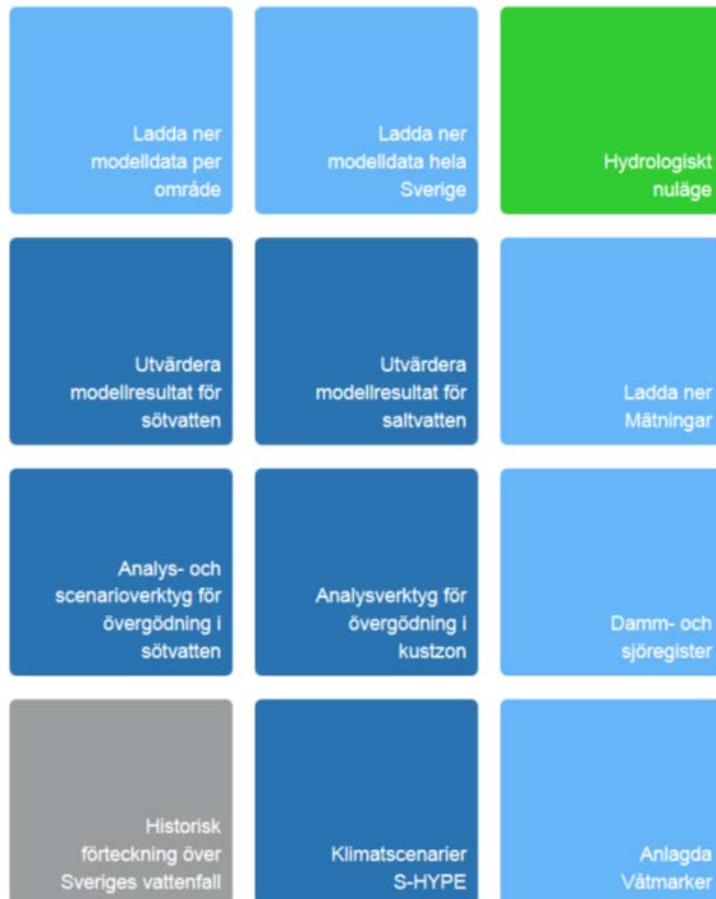
SMHI - the story of changes in hydrology and society



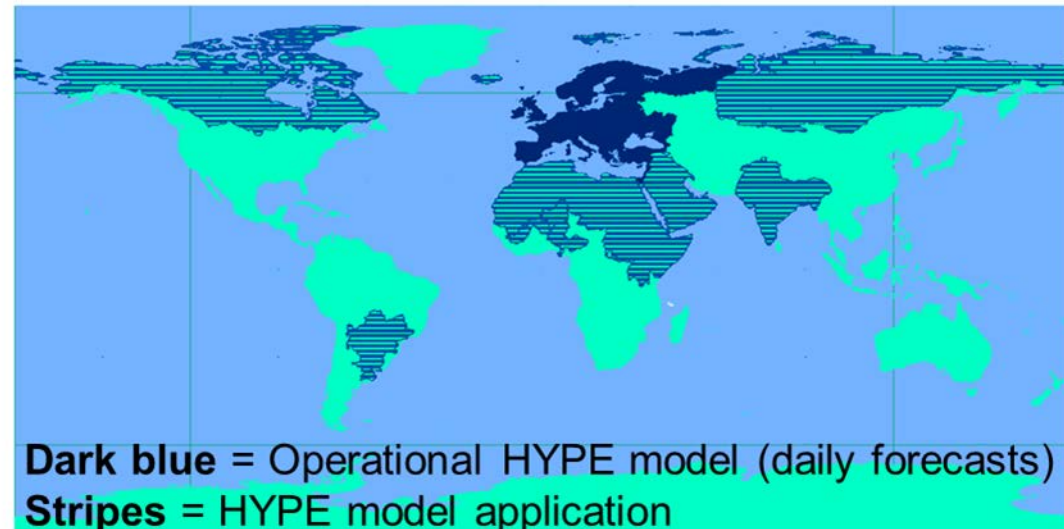
EU directives WFD + INSPIRE =

Predictions in Ungauged Basins *through* Large scale multi-basin modelling

<http://vattenwebb.smhi.se/>

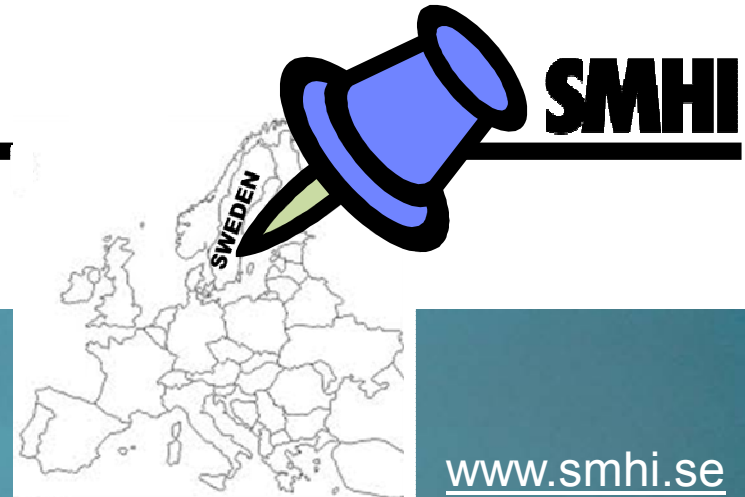


<http://hypeweb.smhi.se/>



Case-study: SMHI

Result: I cannot reject the hypothesis that hydrologists are responsive to changes in hydrology and society

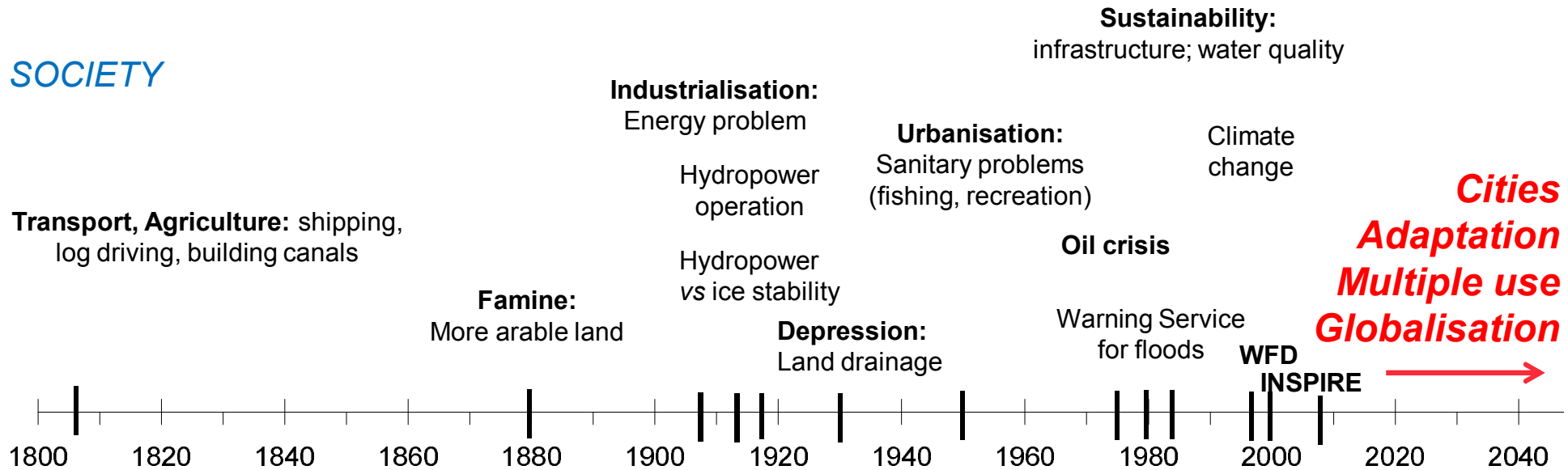


www.smhi.se

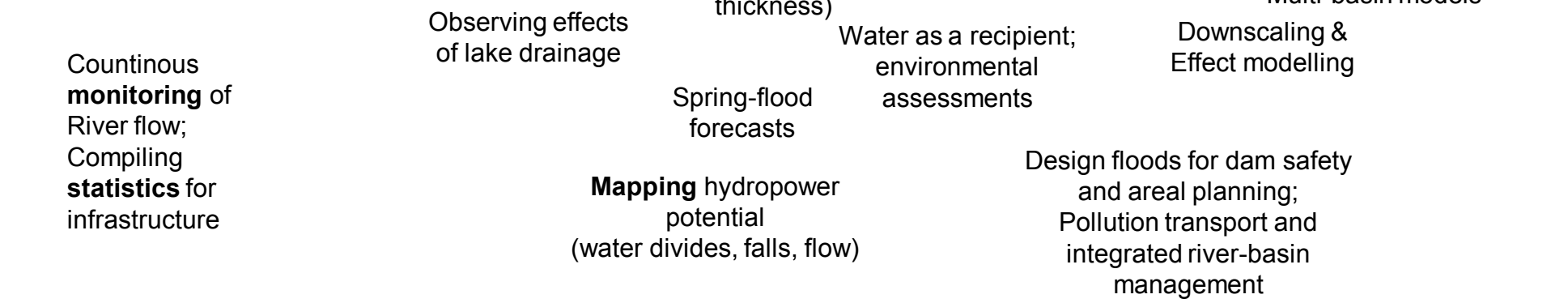


SMHI - future changes in hydrology and society?

SOCIETY

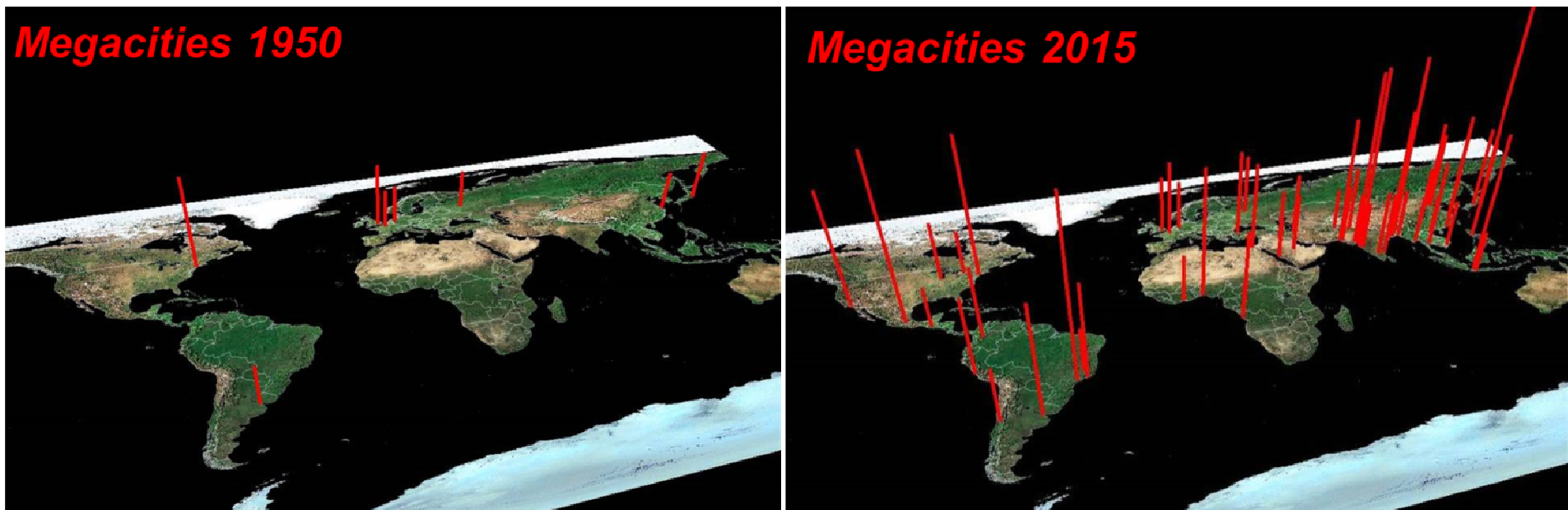


HYDROLOGY RESEARCH



Megacities (>10 million inhabitants):

Future societal needs will be linked to people's needs



Population world-wide in cities:

1950 30%

2007 50%

2030 60%

Source: U.N. Population Division

Copenhagen: 2 July 2011

150 mm of rain in 2 hrs - 1 billion Euro in insurance costs!



Adaptation – e.g. growing cities, more river flow *and* sea-level rise

Rotterdam (Maeslant barrier)



Thames Barrier



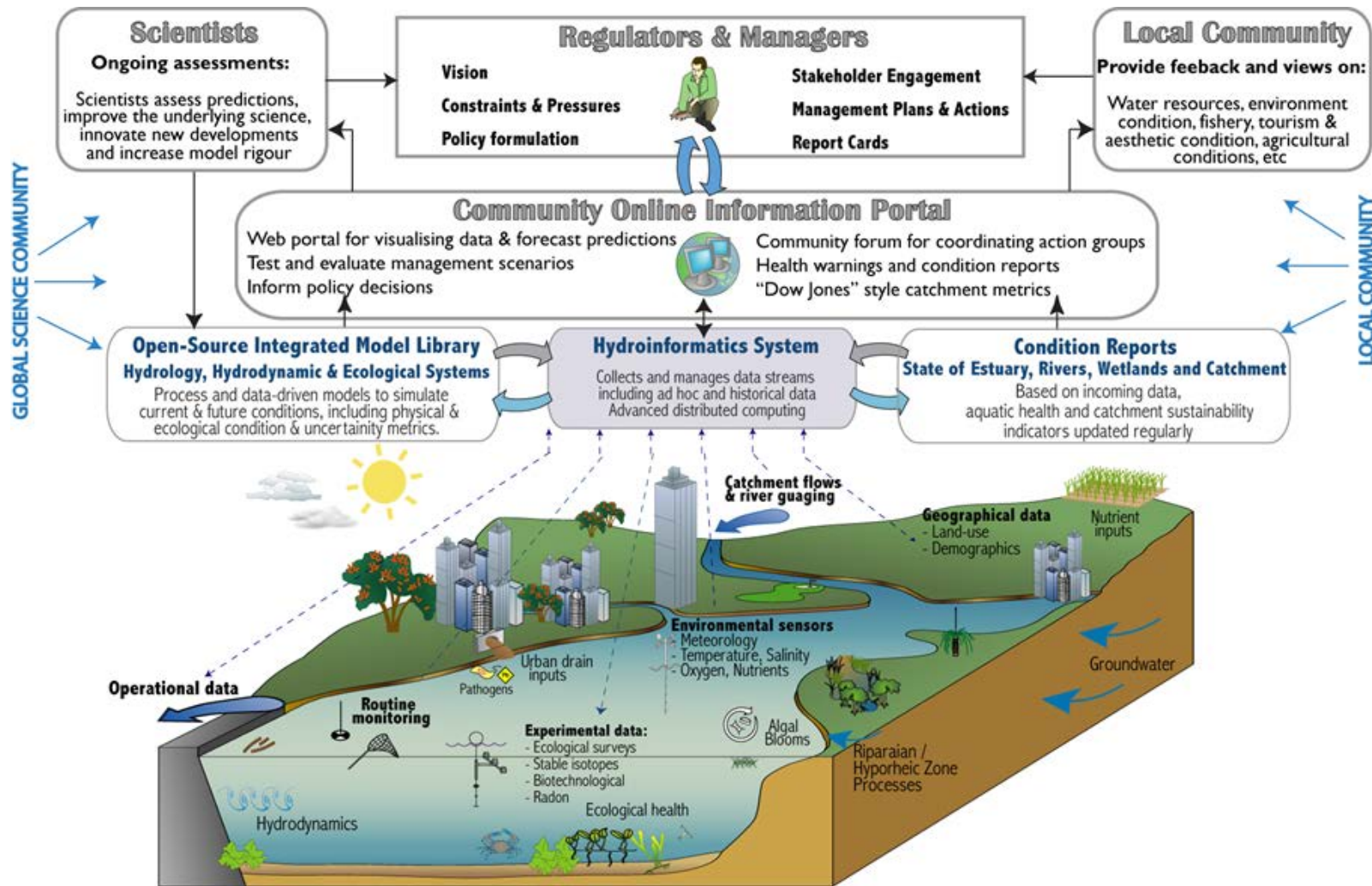
St Petersburg



Stockholm ?



Multiple use: holistic view and knowledge sharing

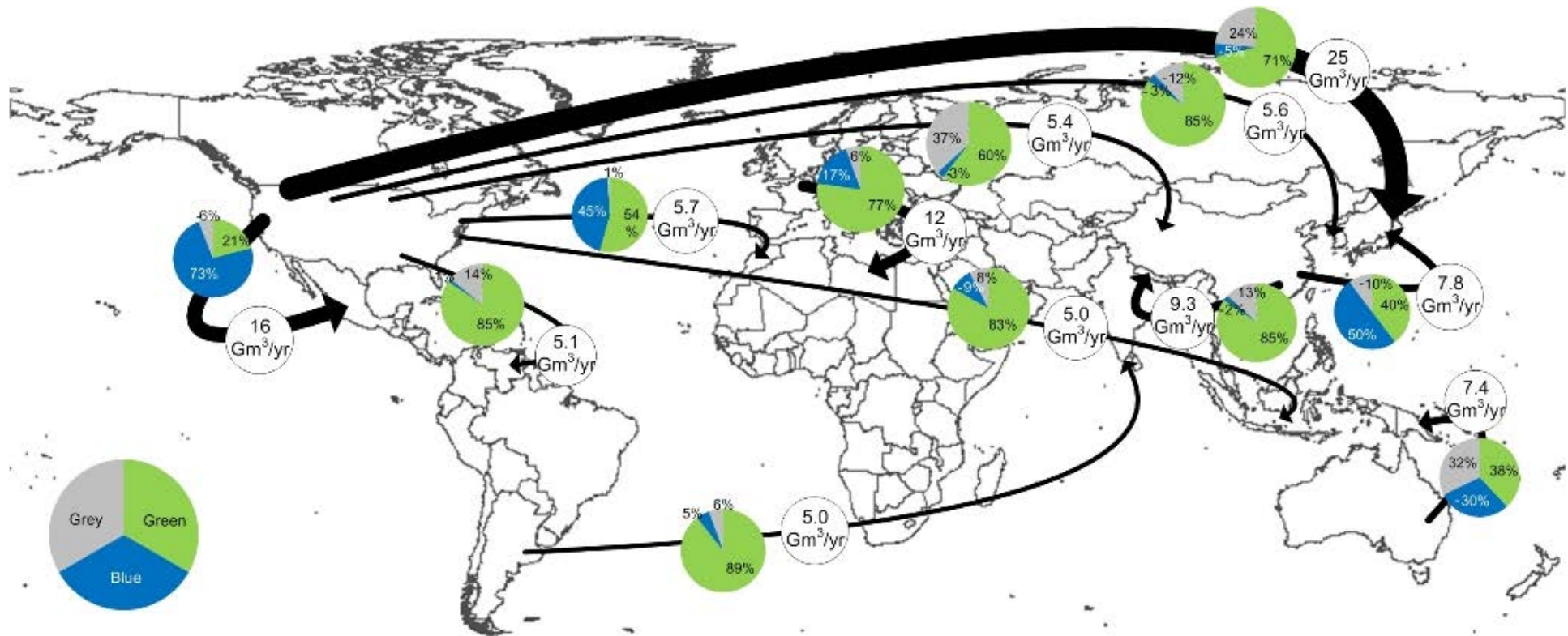


Hipsey, M.R. and Arheimer, B., 2013. Challenges for water-quality research in the new IAHS decade on hydrology under societal and environmental change. IAHS Publ. 361:17-29.

Globalisation

Water conflicts OR cooperation?

Global water savings associated with international trade in agricultural products (1996-2005).



Mekonnen, M.M. and Hoekstra, A.Y. 2011. National water footprint accounts: the green, blue and grey water footprint of production and consumption, Value of Water Research Report Series No.50, UNESCO-IHE.

Water research to support society

Scientists have choices in what role they play towards societal changes:

Pure Scientist Does research, e.g. on whale migration. Has no connection to current decision context	Issue advocate Recommends a specific decision, e.g., no more than 1,000 whales should be taken per year.
Science Arbiter Answers questions posed in decision context, that can be resolve empirically, such as, how many whales are their in the ocean? Nebulous, value-laden terms like "damage" are to be precisely specified or avoided in the process of formulating questions	Honest broker Provides a set of options and their consequences. E.g., Taking 0 whlaes has these consequences, taking 0-400 these, >400 these, and so forth. Consequences should be defined broadly, to include the set of relevant values at stake, e.g., environmental economic, political, etc

Conclusions

- 'Times they are a changing' but all changes are not necessarily all bad – ***Don't panic!***
- Hydrologists have long records of tackling changes in hydrology and society – ***We can make it again!***
- It's time to include humans in hydrological models or analysis, AND become aware of scientists' roles for decision-making – ***We can make a difference!***

