Changes in Flow-Regime of River Rhine
Änderungen im Abflussregime des Rheins

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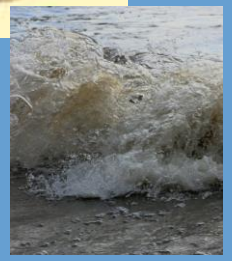

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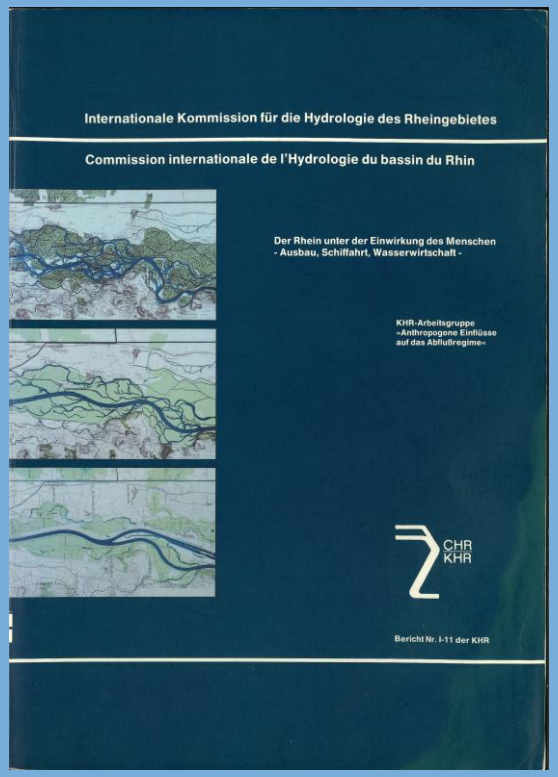
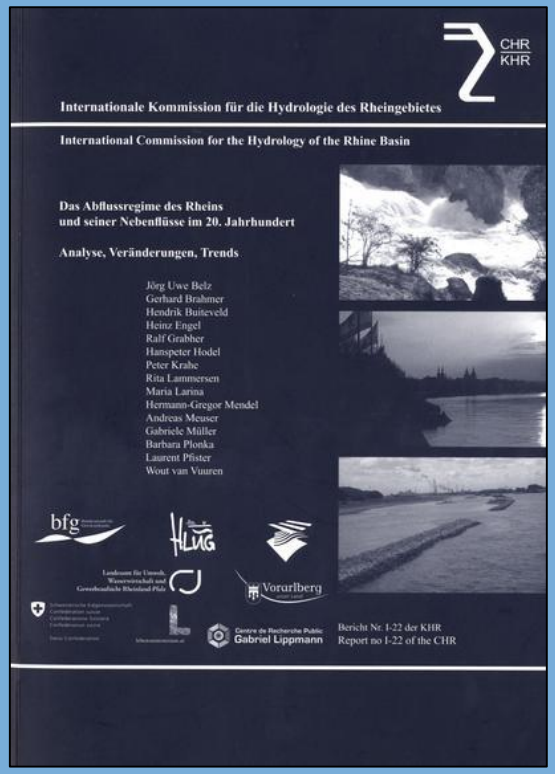
Der Rhein unter der Einwirkung des Menschen



CHR report I-11
Kalweit et al. (1994)
Anthropogenic measures on hydrology and morphology of River Rhine and its catchment

Das Abflussregime des Rheins und seiner Nebenflüsse im 20. Jahrhundert



CHR report I-22
Belz et al. (2007)
Analysis of changes of the flow regime in the Rhine catchment in the 20th century

Flow regime of river Rhine and its tributaries :
Main goals of the project

Are there changes in streamflow-characteristics in the Rhine-basin during the 20th century?

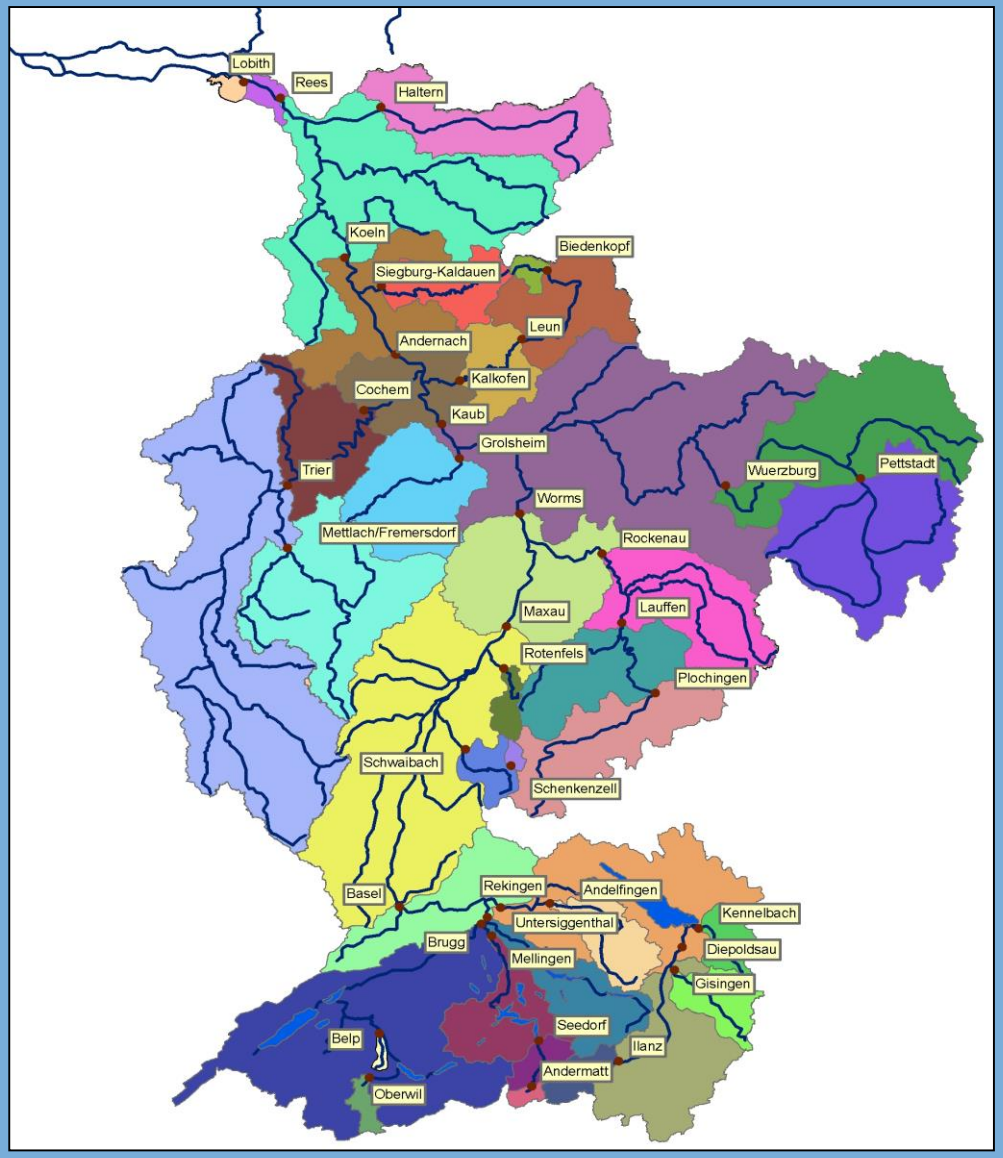
If so: What kind of changes are to be detected?

If so: Where do we find these changes?

If so: What are the reasons for the detected changes, what is the antropogenic impact, what about the climatic change?

River Rhine/flow regime:

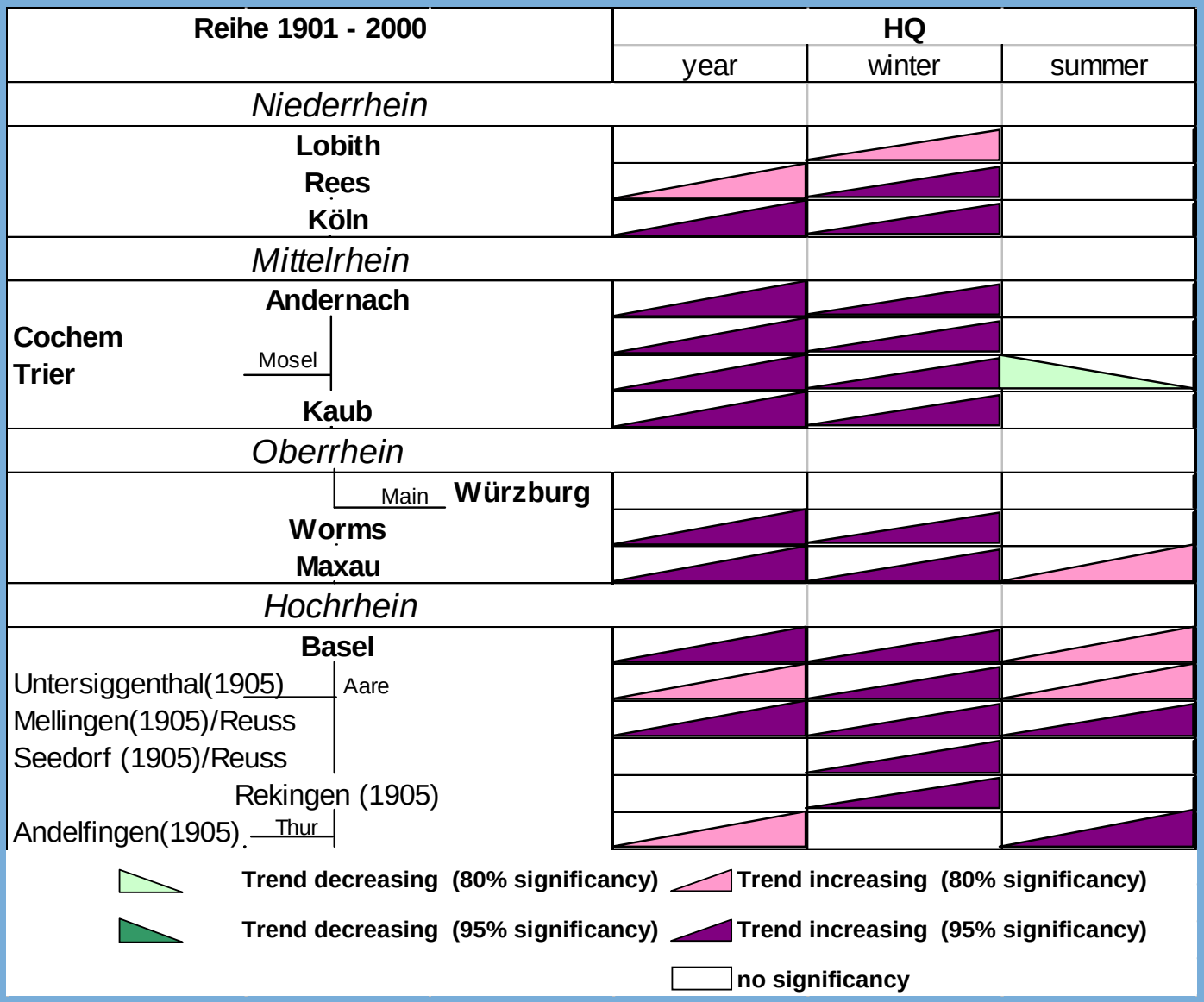
Spatial structure of the study: 38 sub-catchments



Flow regime („discharge pattern“):

…the intra-annual runoff of a stream to be regularly expected
(including the long-term characteristics of extremes (low flows and floods)

Rhine basin, period 1901-2000: Changes and trends of flood discharge (HQ)



Rhine basin, period 1901-2000: Changes and trends of low-flow extremes (NM7Q)

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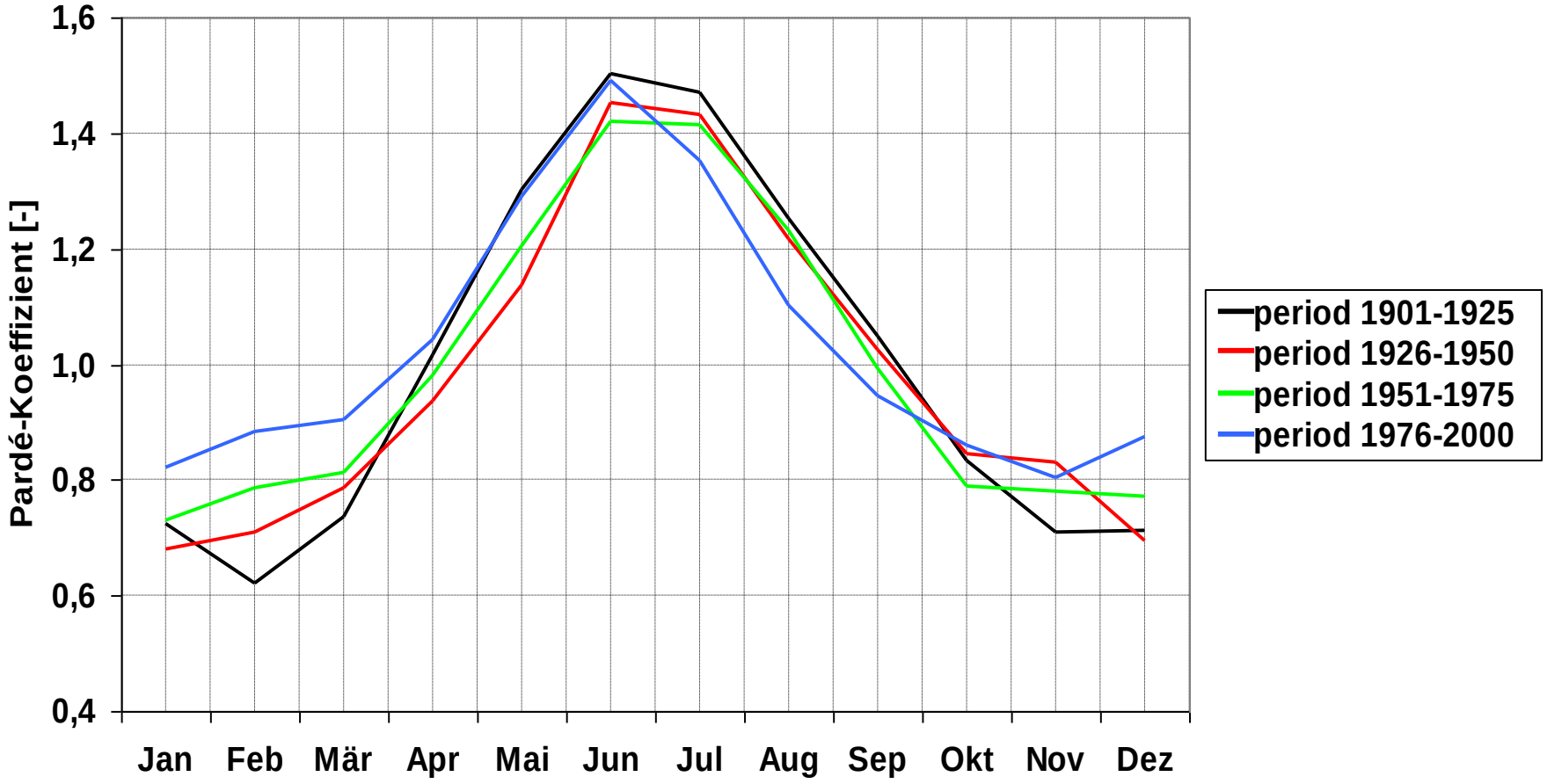
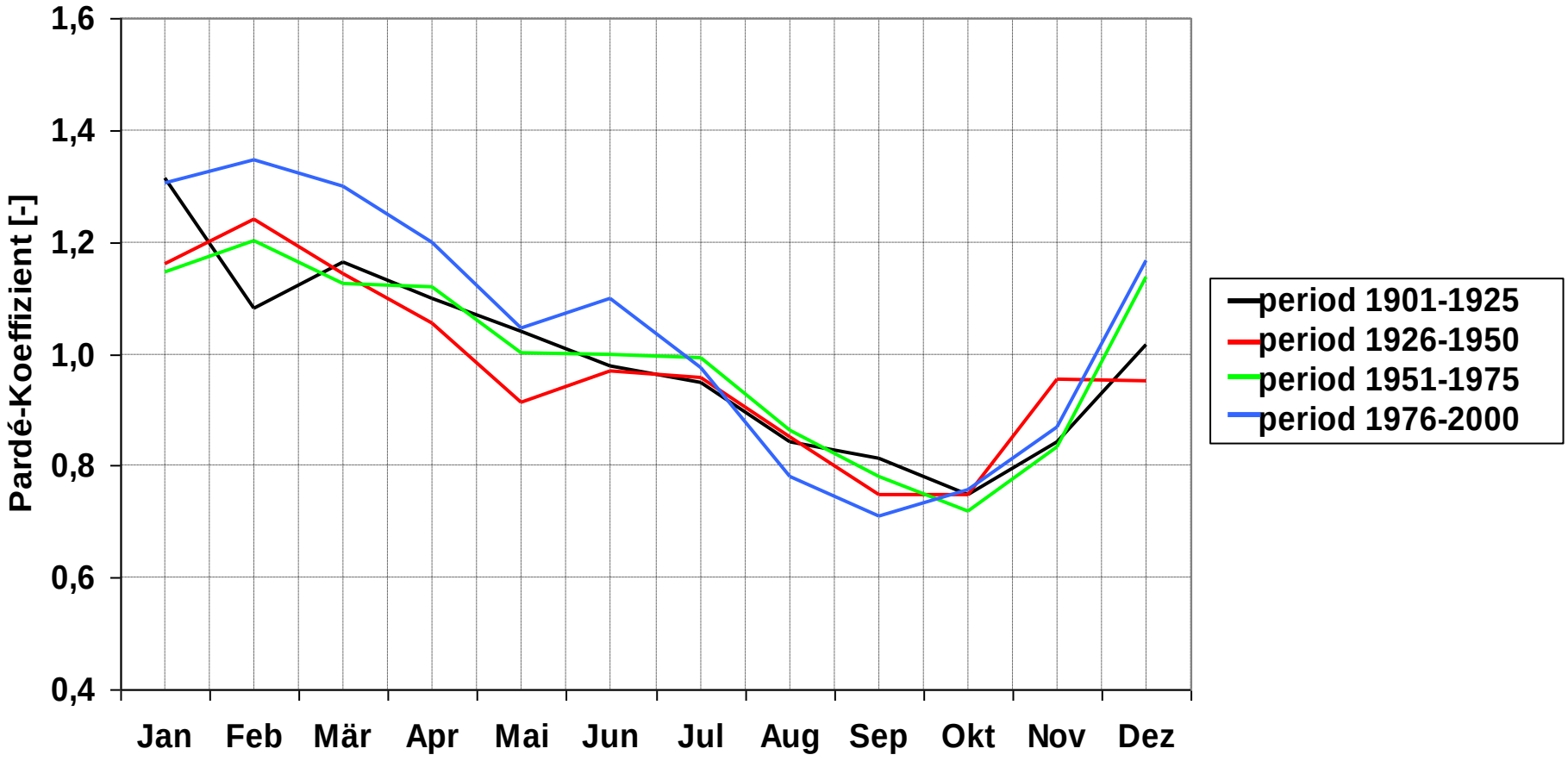
Period 1901 - 2000	NM7Q Year	Winter	Summer
Lower Rhine			
Lobith	(-)	(+)	(-)
Rees	(+)	(+)	(-)
Köln	(+)		(-)
Middle Rhine			
Andernach			(-)
Cochem	(+)	(+)	(+)
Mosel / **Trier**			
Kaub			(-)
Upper Rhine			
Main **Würzburg**		(+)	
Worms			(-)
Maxau			(-)
High Rhine			
Basel			(-)
Untersiggenthal(1905) Aare			
Mellingen(1905)/Reuss			(+)
Seedorf (1905)/Reuss			
Rekingen (1905)			
Andelfingen(1905) Thur	(-)	(+)	(-)

	decreasing trend	80% significance	increasing trend
	decreasing trend	95% significance	increasing trend
(-)	decreas. tendency	no significance	(+) increasing tendency

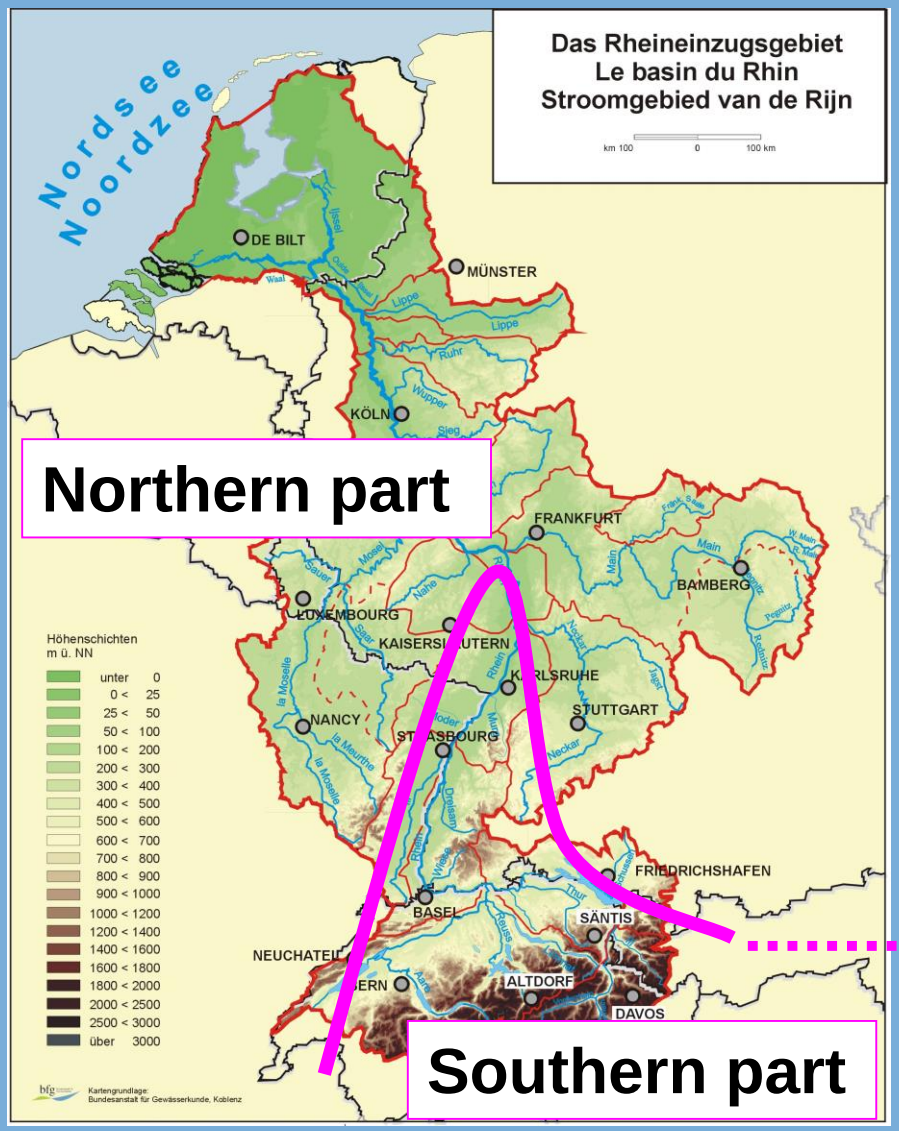
Southern Rhine Basin (gauge Basel/Rhein):
Changes in flow-regime during the 20th century
(4 sub-periods)



Northern Rhine Basin (gauge Lobith/Rhein):
Changes in flow-regime during the 20th century
(4 sub-periods)



Rhine basin: Differenciation by flow regime



Southern part:

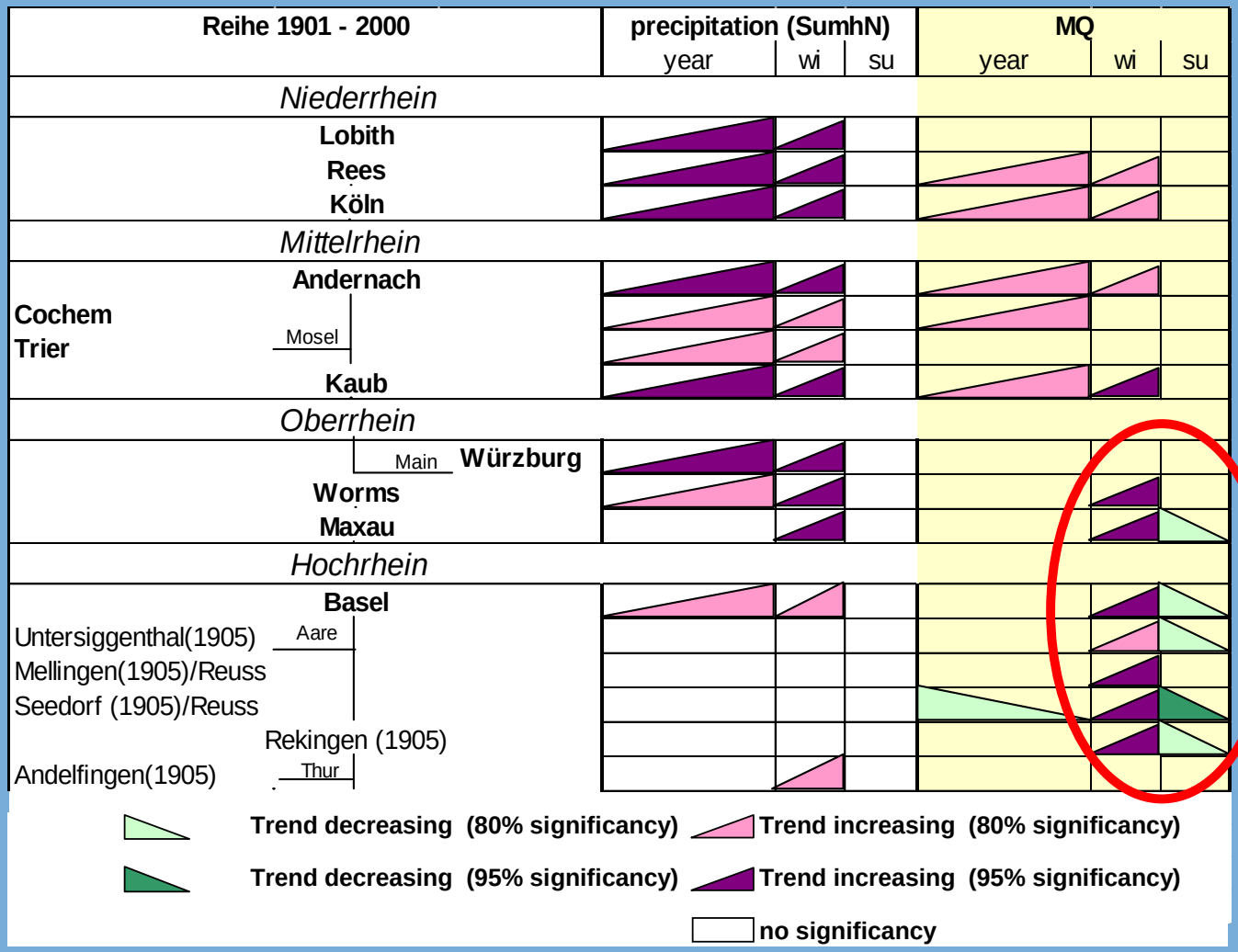
- Pluvial elements gain in importance,
- thus weakening the nival main component of the flow regime of the River Rhine,
- all-in-all seasonal redistributing of runoff,
- no increase in runoff in general.

Northern part:

- Strenghtening of the winterly runoff-component,
- in the whole, discharge increases

Changes of flow-regime in the Rhine basin during 20th century

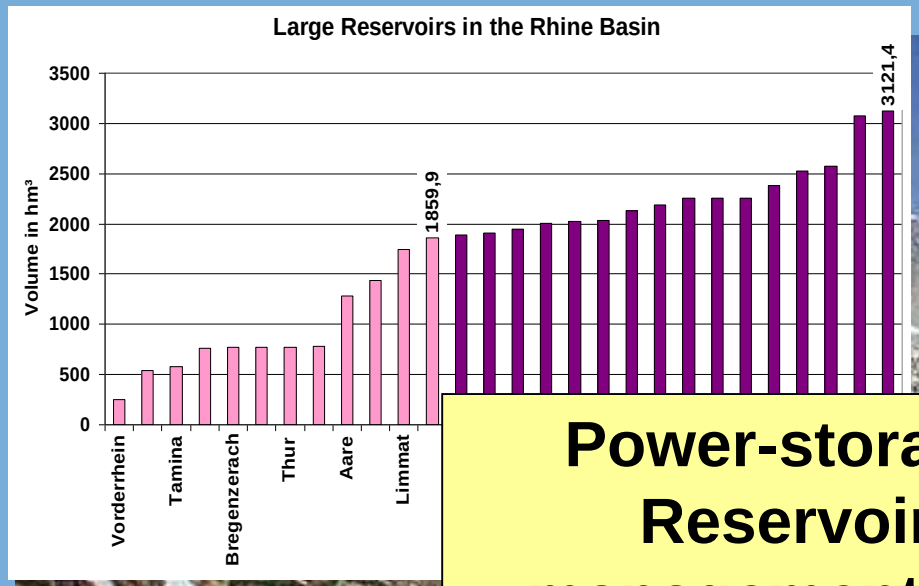
Important process: Precipitation



Seasonal redistribution

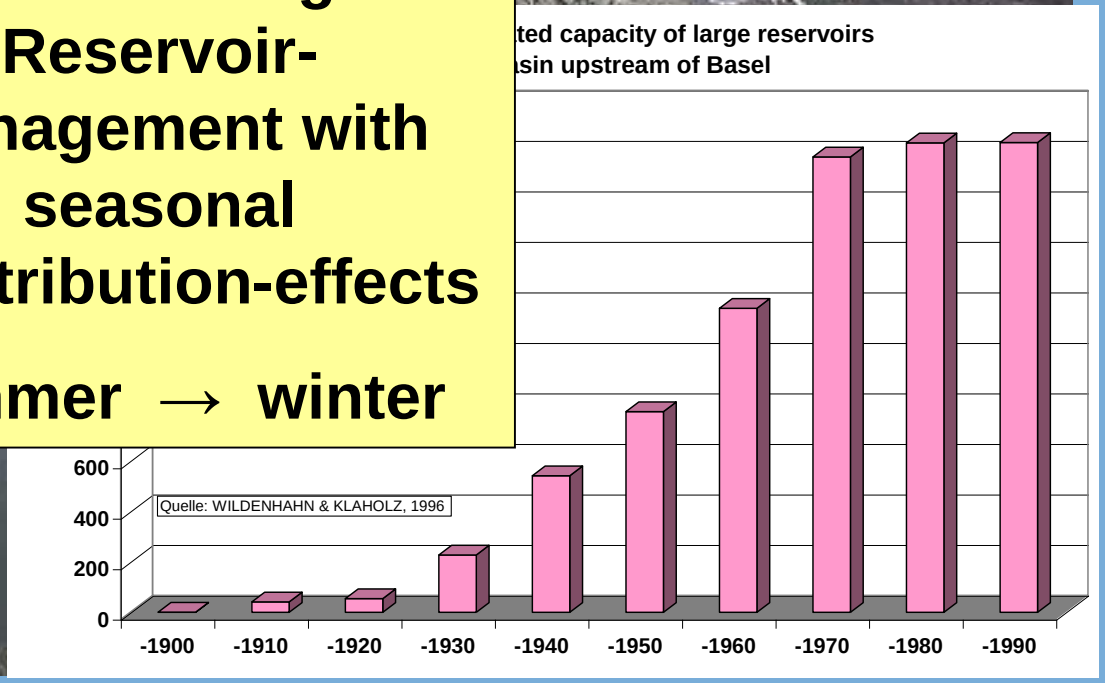
Changes of flow-regime in the Rhine basin during 20th century

Reasons



Power-storage: Reservoir-management with seasonal redistribution-effects

summer → winter



KHR/CHR:
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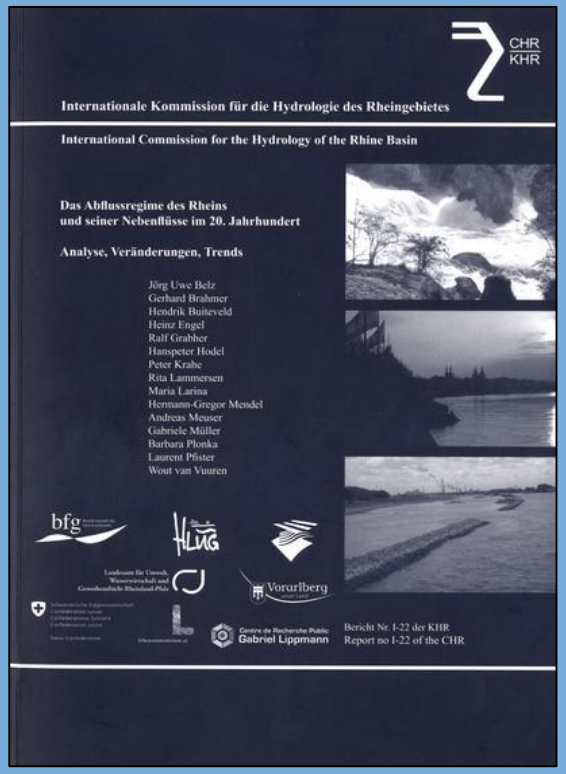
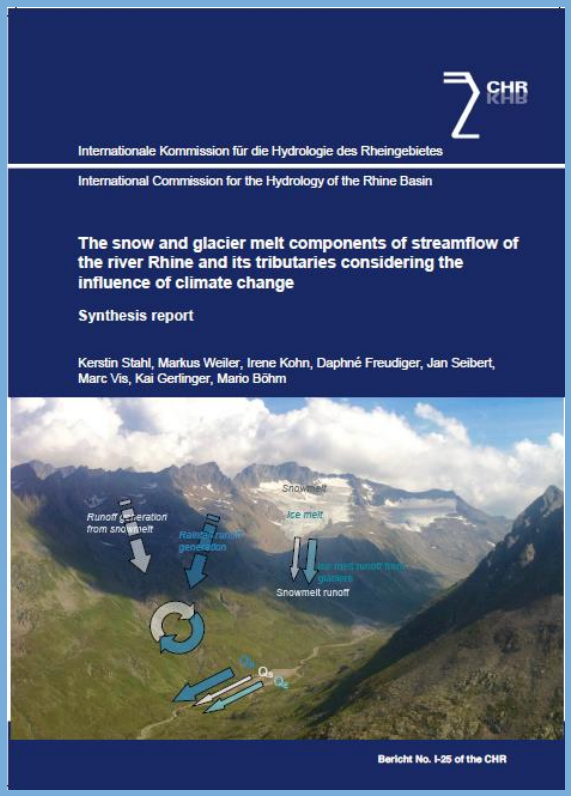
Das Abflussregime des Rheins und seiner Nebenflüsse im 20. Jahrhundert



CHR report I-22
Belz et al. (2007)
Analysis of changes of the flow regime in the Rhine catchment in the 20th century

CHR report I-23
Görgen et al. (2010)

The snow and glacier melt components of streamflow of the river Rhine and its tributaries



CHR report I-25
Stahl et al. (2016)
The amount of snow and glacier melt components in streamflow considering the influence of climate change (ASG 1 + 2)

Thank you !

„Flow regime of the river Rhine and its Tributaries During the 20thCcentury - Analysis, Changes, Trends“

(=**„Das Abflussregime des Rheins und seiner Nebenflüsse im 20. Jh. - Analysen, Veränderungen, Trends“**)

Belz, J.U. (D)
Brahmer, G. (D)
Buiteveld, H. (NL)
Engel, H. (D)
Grabher, R. (A)
Hodel, H. (CH)
Krahe, P. (D)
Lammersen, R. (NL)

Larina, M. (D)
Mendel, H.-G. (D)
Meuser, A. (D)
Müller, G. (A)
Plonka, B. (D)
Pfister, L. (LUX)
van Vuuren, W. (NL)

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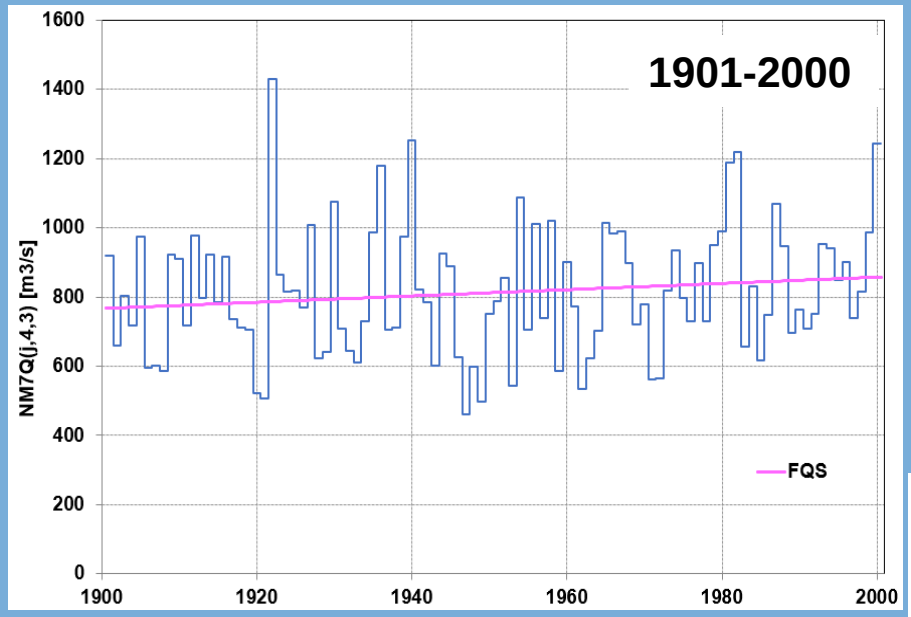
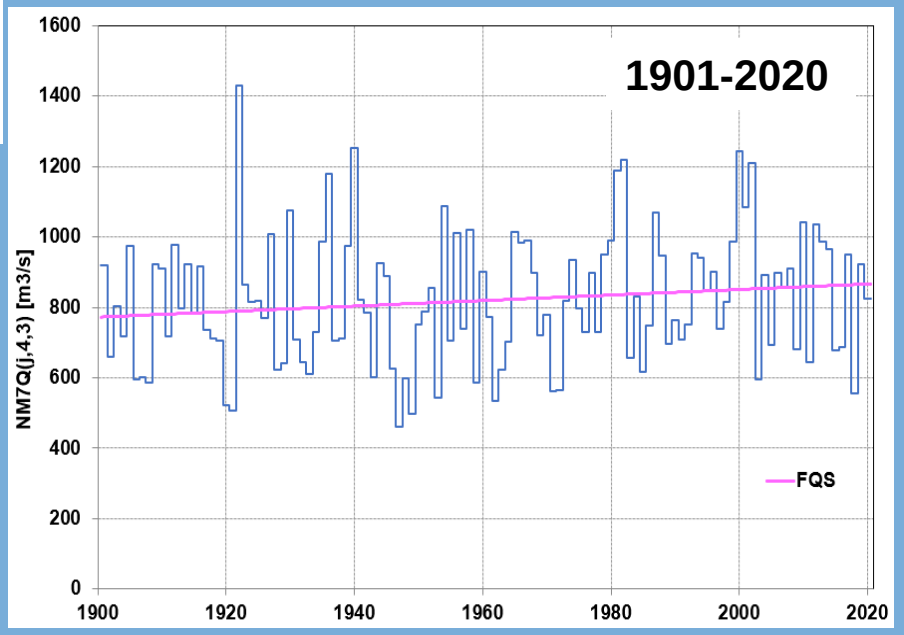
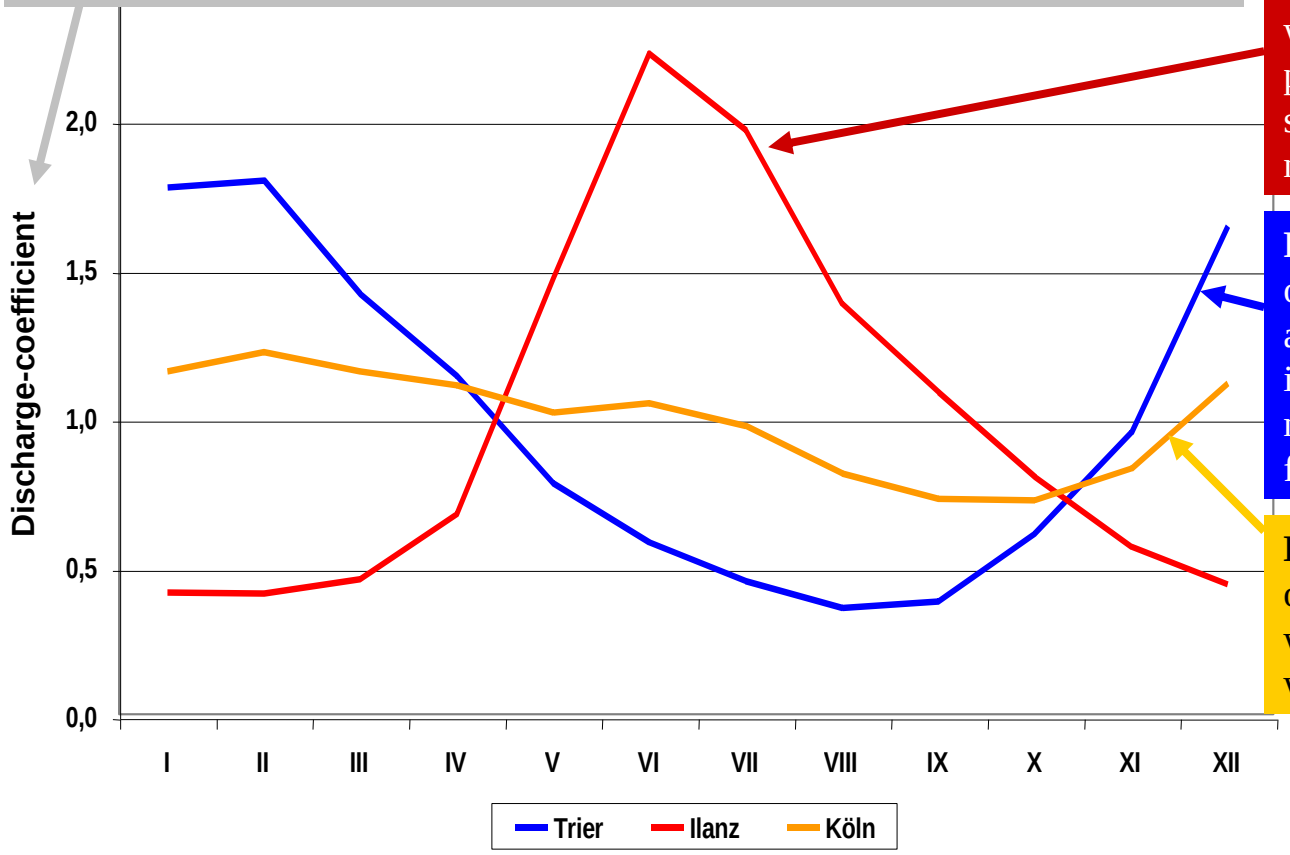
EXCURSUS: Gauge Kaub (Rhein)
Longterm Stability of Low-flow Trend (NM7Q)





Standardised diagram of characteristic types of flow regimes in the Rhine basin, reference period 1951-2000

Discarge coefficient (PARDÉ):
ratio of long term monthly flow-average : long term annual flow-average

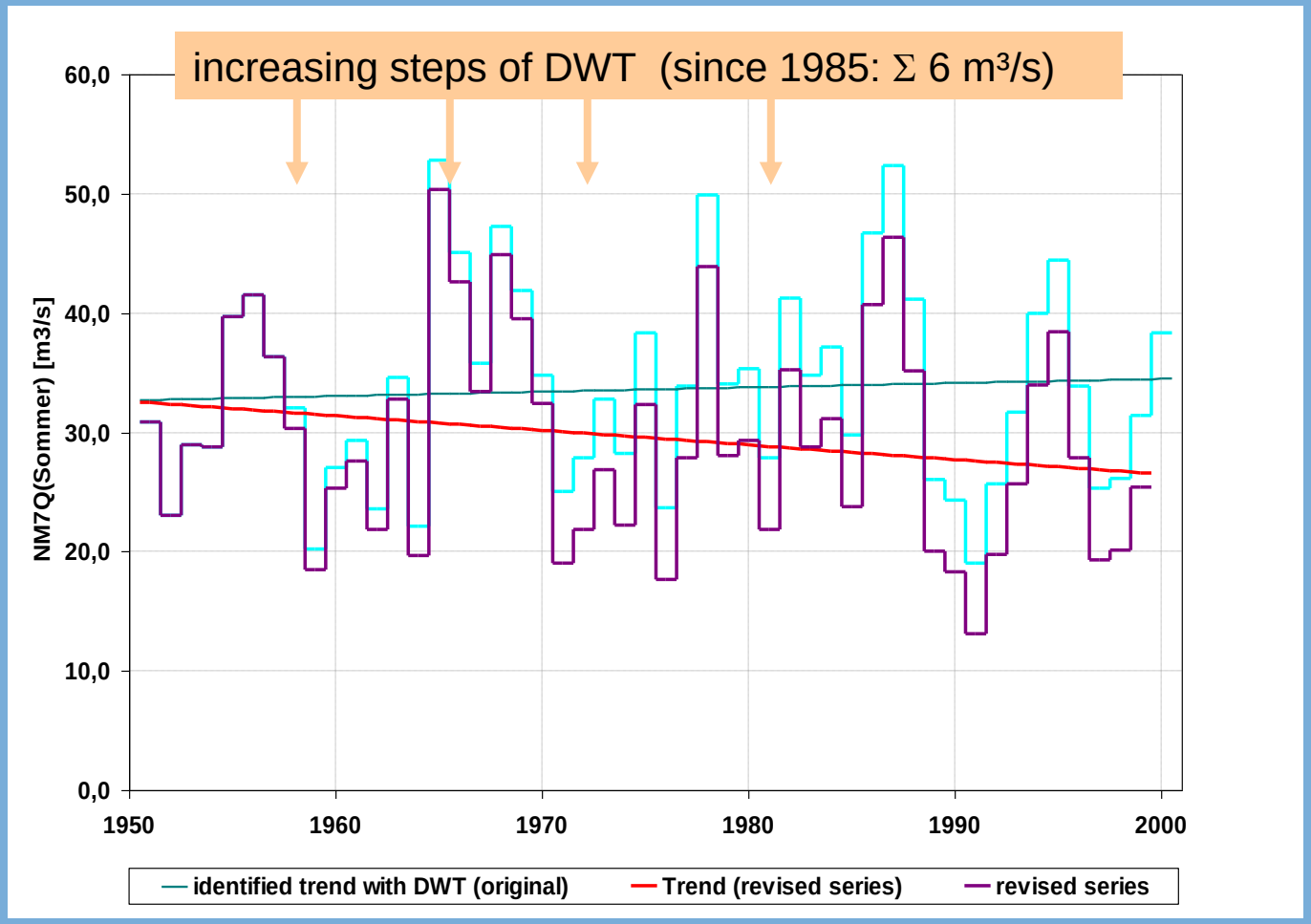


Nival (= snow-dominated)
regime of mountainous areas, very wide range of amplitude, single-peak, maximum in summer due to snowmelt, frost-inducted minimum in winter

Pluvial (= rain dominated)
oceanic regime, wide range of amplitude, single-peak, maximum in the mild rainy winter months, minimum in summer resulting from intensive evapotranspiration

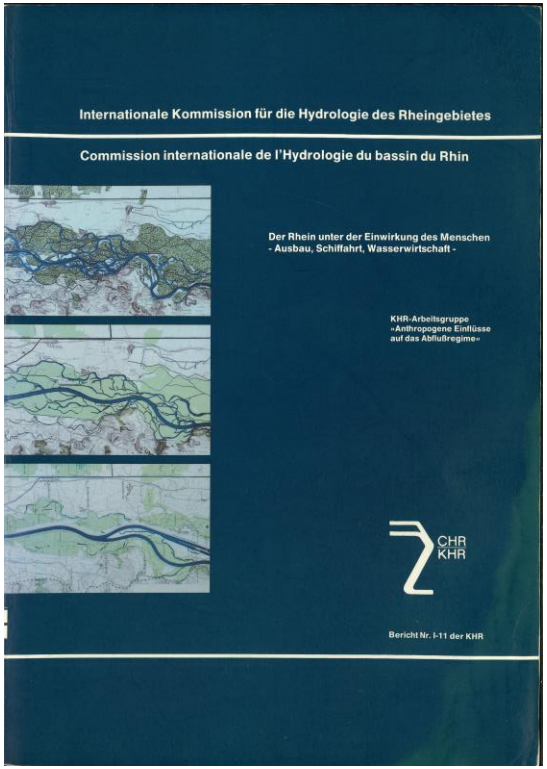
Balanced pluvial mixed regime
of the rain-snow type, two-peaks, with the main maximum in late winter and a minimum in autumn

Changes of flow-regime in the Rhine basin during 20th century:
Special anthropogenic impacts
Example River Neckar: Interbasin runoff-transfer
Trend and reversed trend in the summer half-year NM7Q series against the background of DWT (drinking-water transfer), period 1951-2000



KHR-Forschung zu Abflussregime und Klimawandel

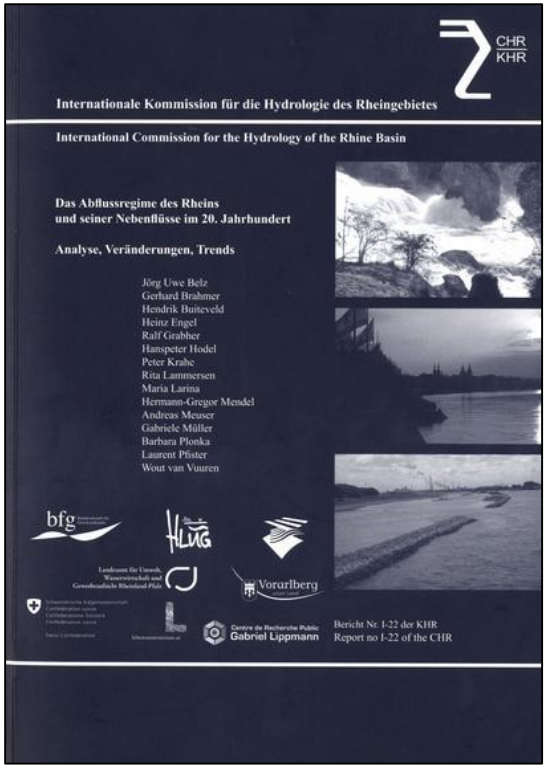
Der Rhein unter der Einwirkung des Menschen



CHR report I-11
Kalweit et al. (1994)

Impact of climate change on hydrological regimes and water resources management in the Rhine basin

Analyse der Änderungen im Abflussregime des Rheins im 20. Jh.



CHR report I-22
Belz et al. (2007)

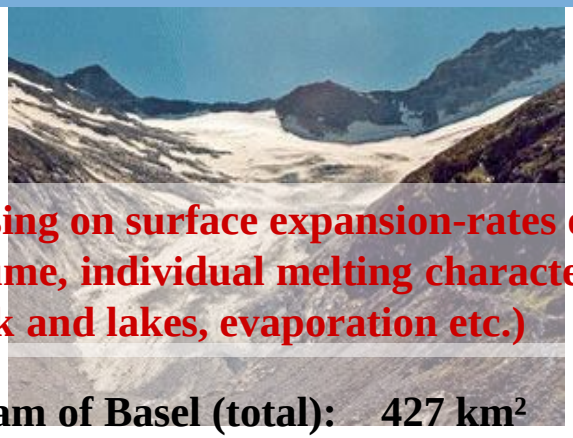
Das Abflussregime des Rheins und seiner Nebenflüsse im 20. Jahrhundert - Analyse, Veränderungen, Trends

Zukünftige Entwicklung des Abflussregimes/RheinBlick 2050

CHR report I-23
Görgen et al. (2010)

Assessment of Climate Change Impacts on Discharge in the Rhine River Basin: Results of the RheinBlick2050 project

Intensified glacier-melting (IGM) in the Rhine basin
Extrapolation to the sub-catchment BASEL
A_{Eo} 35925 km²



Simplistic extrapolation, basing on surface expansion-rates only (not considering glacier-volume, individual melting characteristics of glaciers, retention-effects of the stream-network and lakes, evaporation etc.)

Glacier-covered area upstream of Basel (total): 427 km²
Glacier-covered area upstream of Ilanz (total): 20.9 km² (i.e. 1/20)

Melting-contribution at Ilanz (year), 0.25 m³/s
if assigned to the 4 high-summer months: 0.75 m³/s

0.75 x 20 = 15 m³/s
mMQ (August): 1270 m³/s

⇓

percentage of mMQ(August) related to IGM in the Basel sub-catchment: 1.2 %