

Module Hydrology

> Umwelt-Vollzug | > Gewässerschutz

> Methoden zur Untersuchung und Beurteilung der Fließgewässer

*Hydrologie – Abflussregime
Stufe F (flächendeckend)*

Entwurf vom Oktober 2007

Herausgegeben vom Bundesamt für Umwelt BAFU
Bern, 2007

> L'environnement pratique | > Protection des eaux

> Méthodes d'analyse et d'appréciation des cours d'eau

*Hydrologie – régime d'écoulement
Niveau R (région)*

Projet d'octobre 2007

Publié par l'Office fédéral de l'environnement OFEV
Berne, 2007



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Umwelt BAFU

Martin Pfaundler
*Federal Office
for the environment*



Repubblica e
Cantone Ticino

Dipartimento del Territorio
Ufficio dei corsi d'acqua

Andrea Salvetti
Cantone Ticino

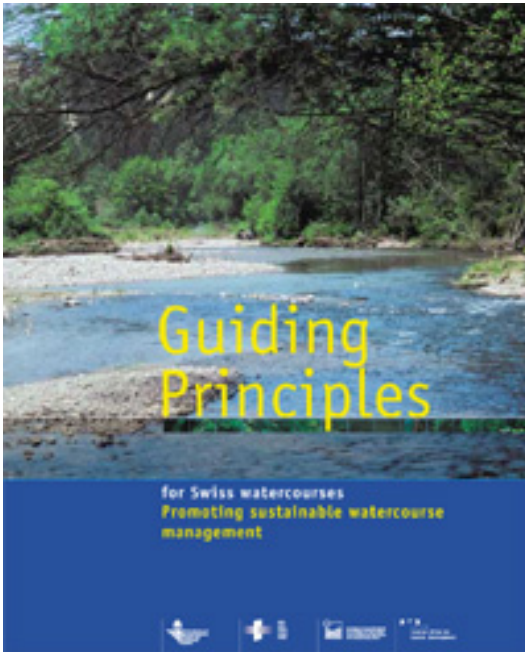
Overview

- Motivation and frame
- A rush through the methodology
- Case study Brenno

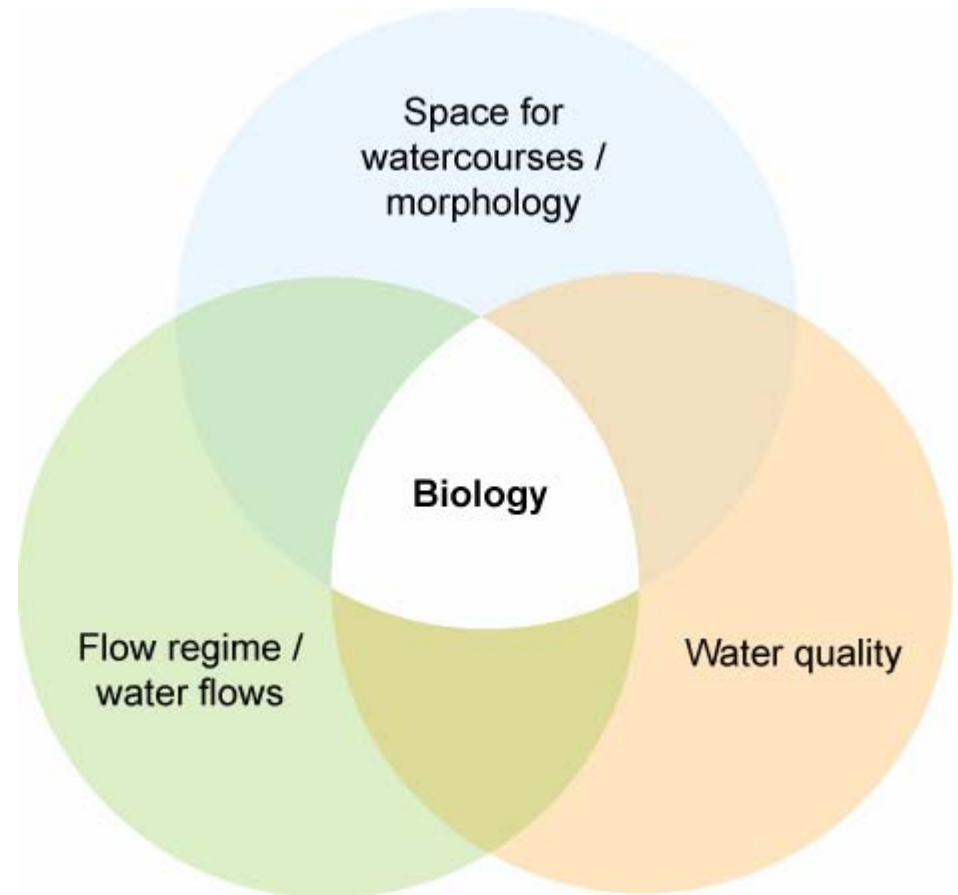
Integrated water status assessment

Guiding principles for Swiss watercourses

Promoting sustainable watercourse management



Abiotic determinants and biologic status



- 1 Water quality
- 2 Space for rivers & ecomorphology
- 3 Flow regime



developed by EAWAG,
federal and
cantonal offices

Standardized methods for the analysis and assessment
of the ecological status of water courses in Switzerland

Hydrodynamics
and morphology

Biology

Chemical and
toxic effects

R

S

-

Hydrology

Morphology

General Aspect

Higher water
and marsh plants

Makrozoobenthos

Algae

Fish

Water chemistry

Ecotoxicology

Federal Act on Water Conservation (1991)
requires ecological goals for water bodies

For surface water bodies the related ordinance (1998) specifies
– inter alia – that the hydrodynamics (sediment transport,
water-level and flow-regime) and morphology should be as
close as possible to its natural characteristic

Development of pertinent assessment methods to support the
cantons in the implementation of legal requirements

HYDMOD is not a pure
research project but rather
developped for application



HYDMOD in a nutshell



**a method to assess the impacts of
man-made interventions
on the flow-regime**

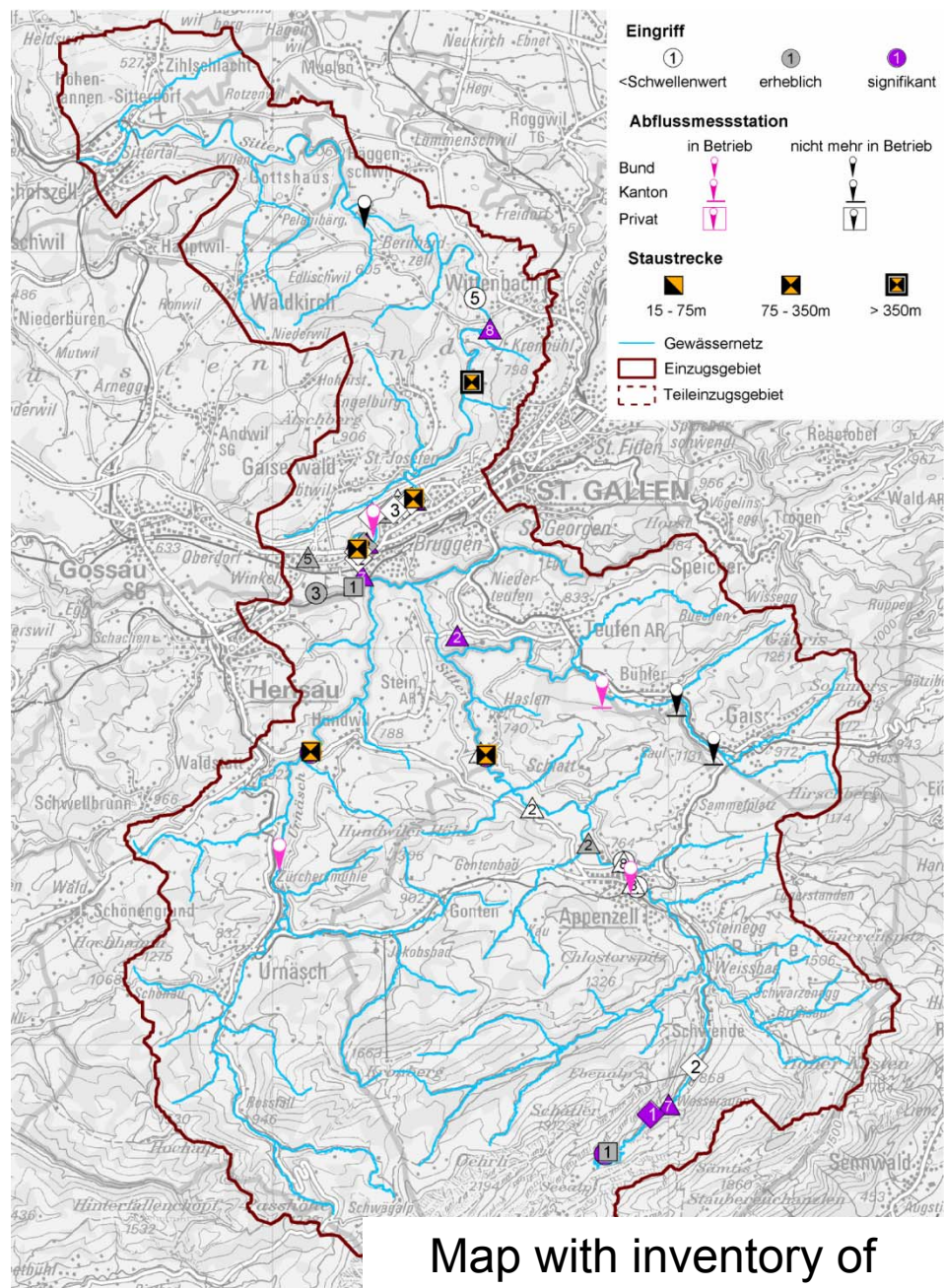
**Classification of the
flow regime's natural status**

Testing the method for the Sitter river

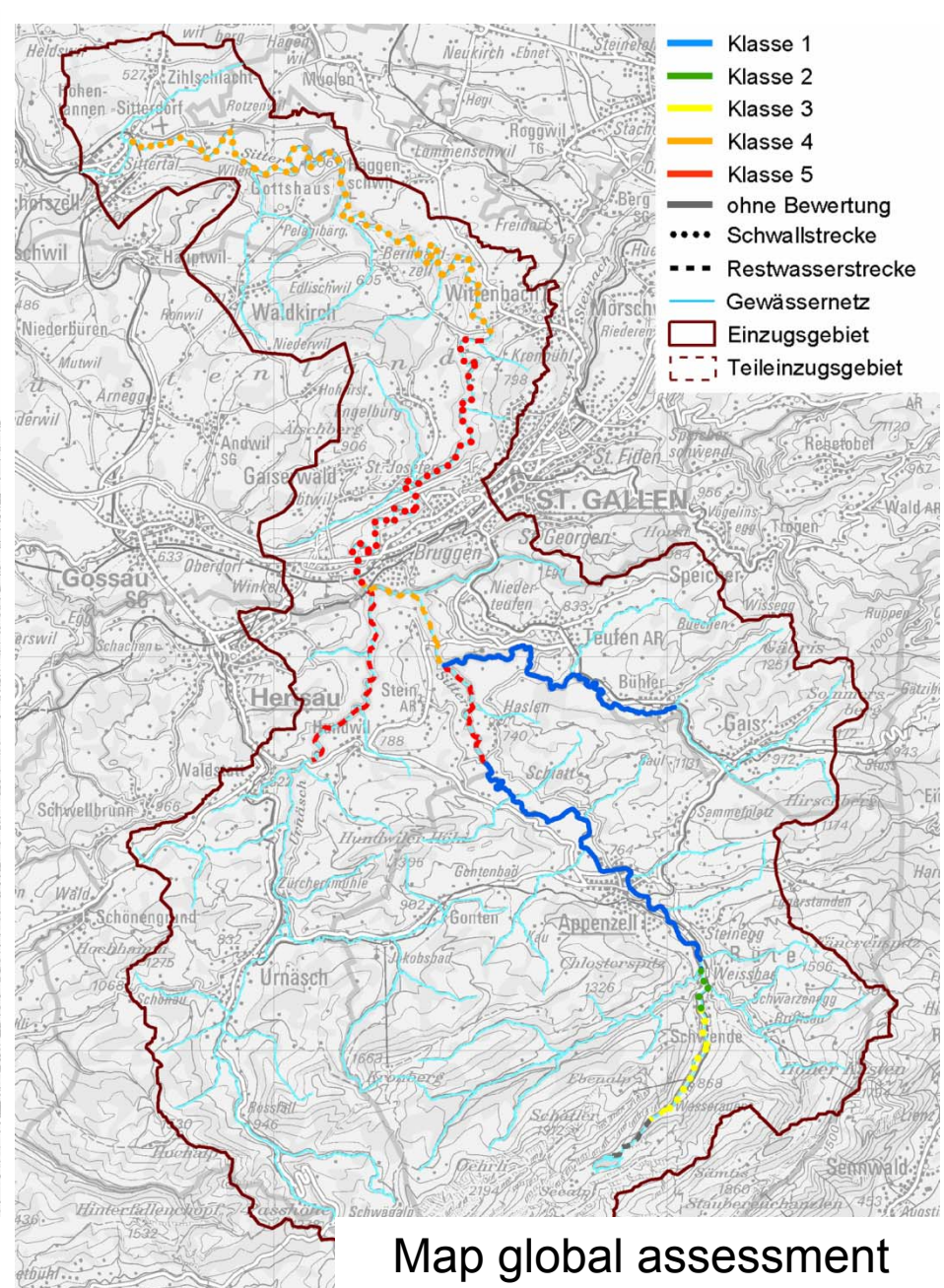


Testing the draft method jointly
with the
environmental offices from
St.Gallen and both Appenzell





Map with inventory of significant interventions

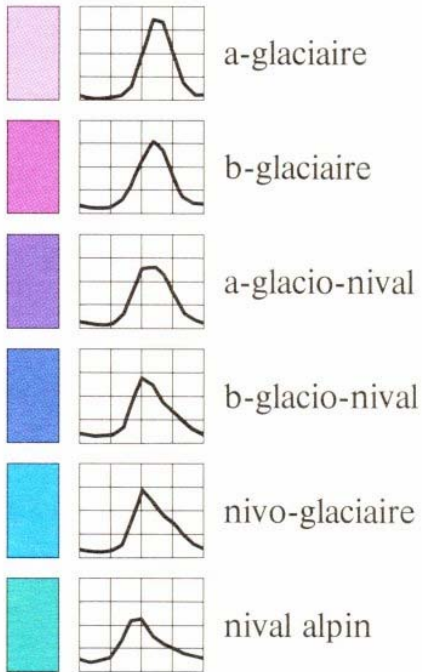


Map global assessment

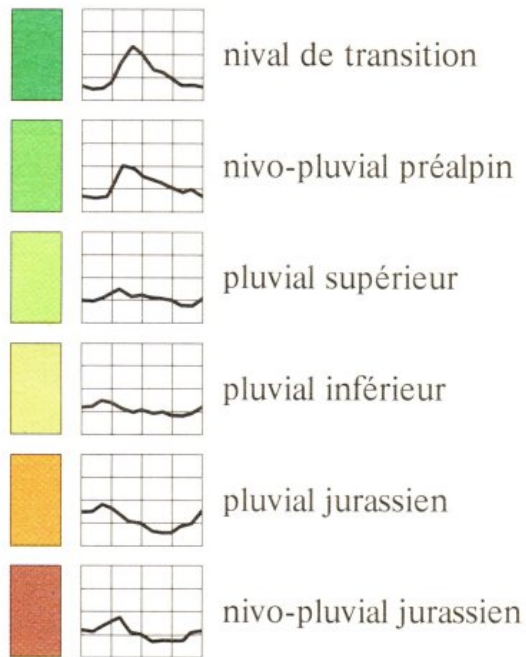
The flow regime

First association => the Swiss flow regime types ??

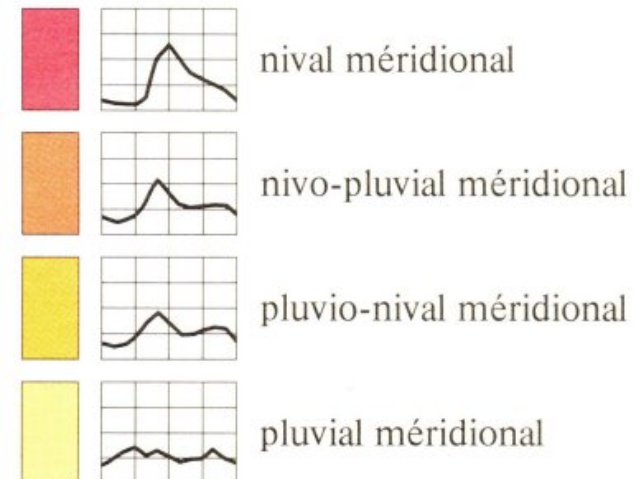
Alpine Regimes Régimes alpins



Mittelländische und jurassische Regimes Régimes du Plateau et du Jura



Südalpine Regimes Régimes du sud des Alpes



What is the "flow-regime" ?

Based on the flow-regime

flow-regime

low flow-regime

mean flow-regime

high flow-regime

- magnitude

- timing (seasonality)

- frequency

- variability

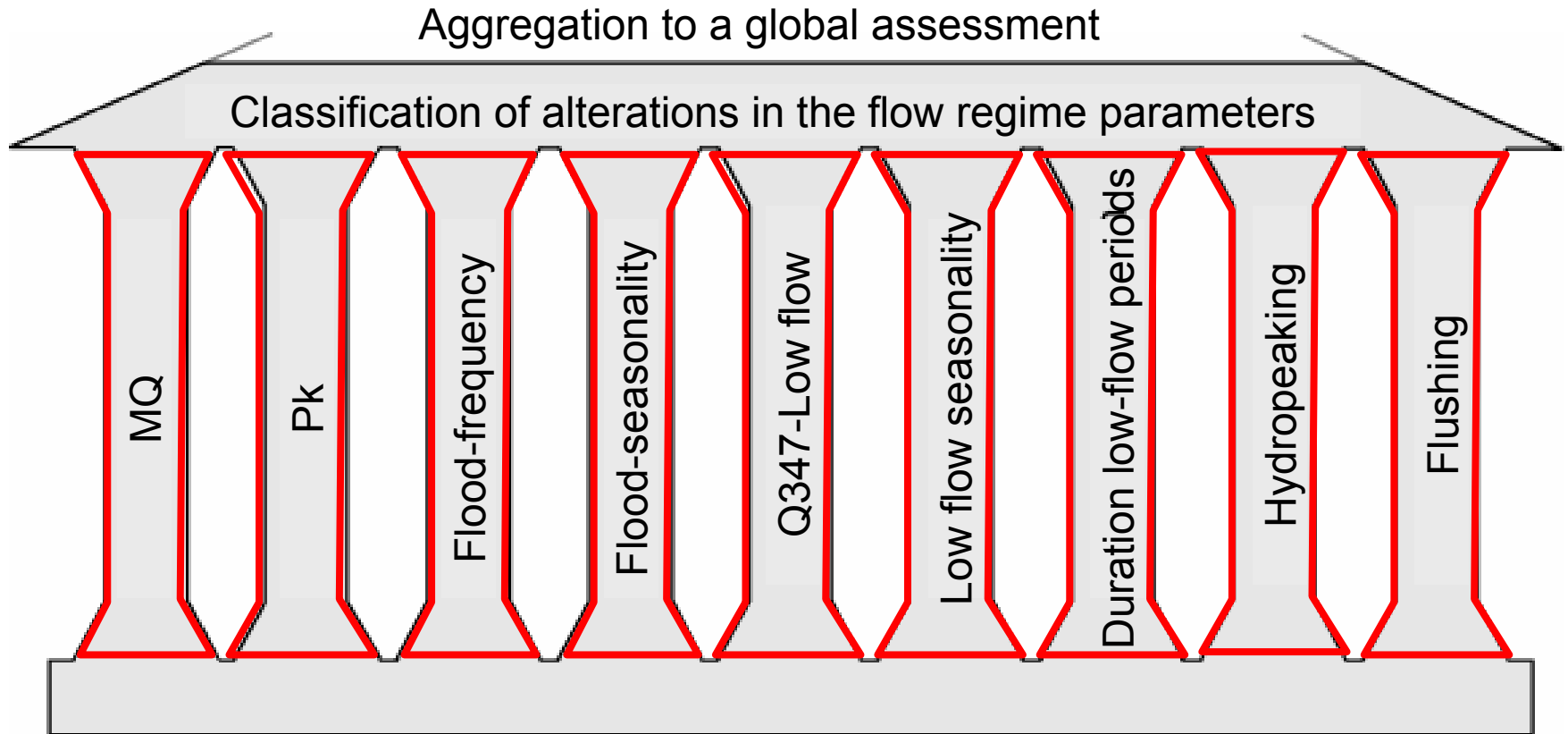
- rate of change

- duration

set of characteristics

Selection of hydrologic indicators / parameters for HYDMOD

Within HYDMOD, assessment of flow regime alterations and the status classification is based on the following indicators



High flow regime

Mean flow regime

Low flow regime

Hydro-peaking

Flushing



Classification of the flow regime's natural status => assessment classes

I	natural / close to natural
II	slightly altered
III	considerably altered
IV	heavily altered
V	artificial

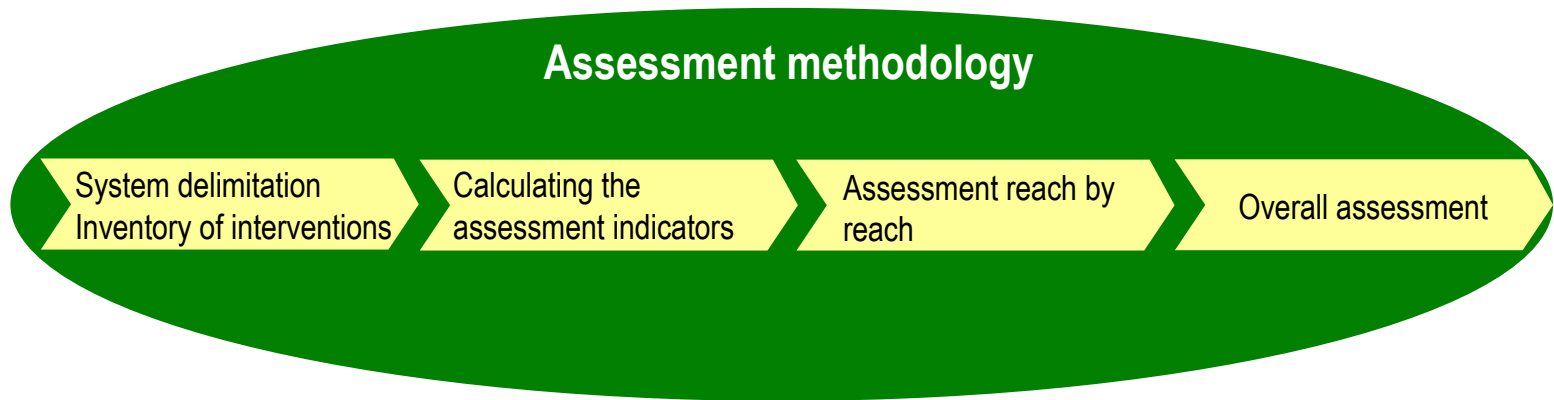
without assessment

but labelling the kind of alteration
=> phenomenon

— residual flow effects
— hydro-peaking effects

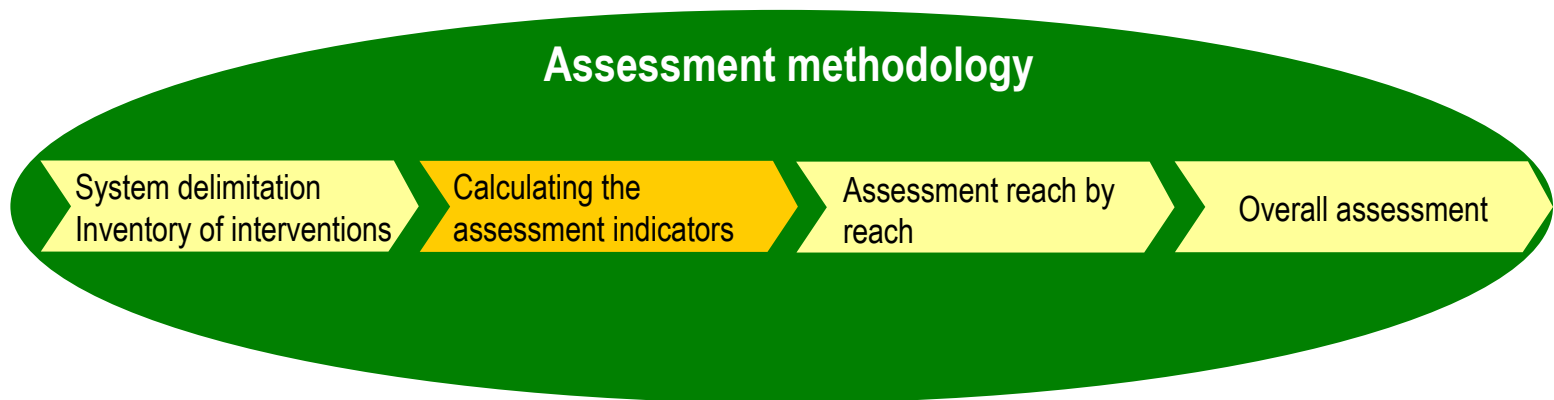
..... Assessment objects are the individual river reaches

The methodology's procedure



typology of man-made interventions relevance thresholds and significance criteria

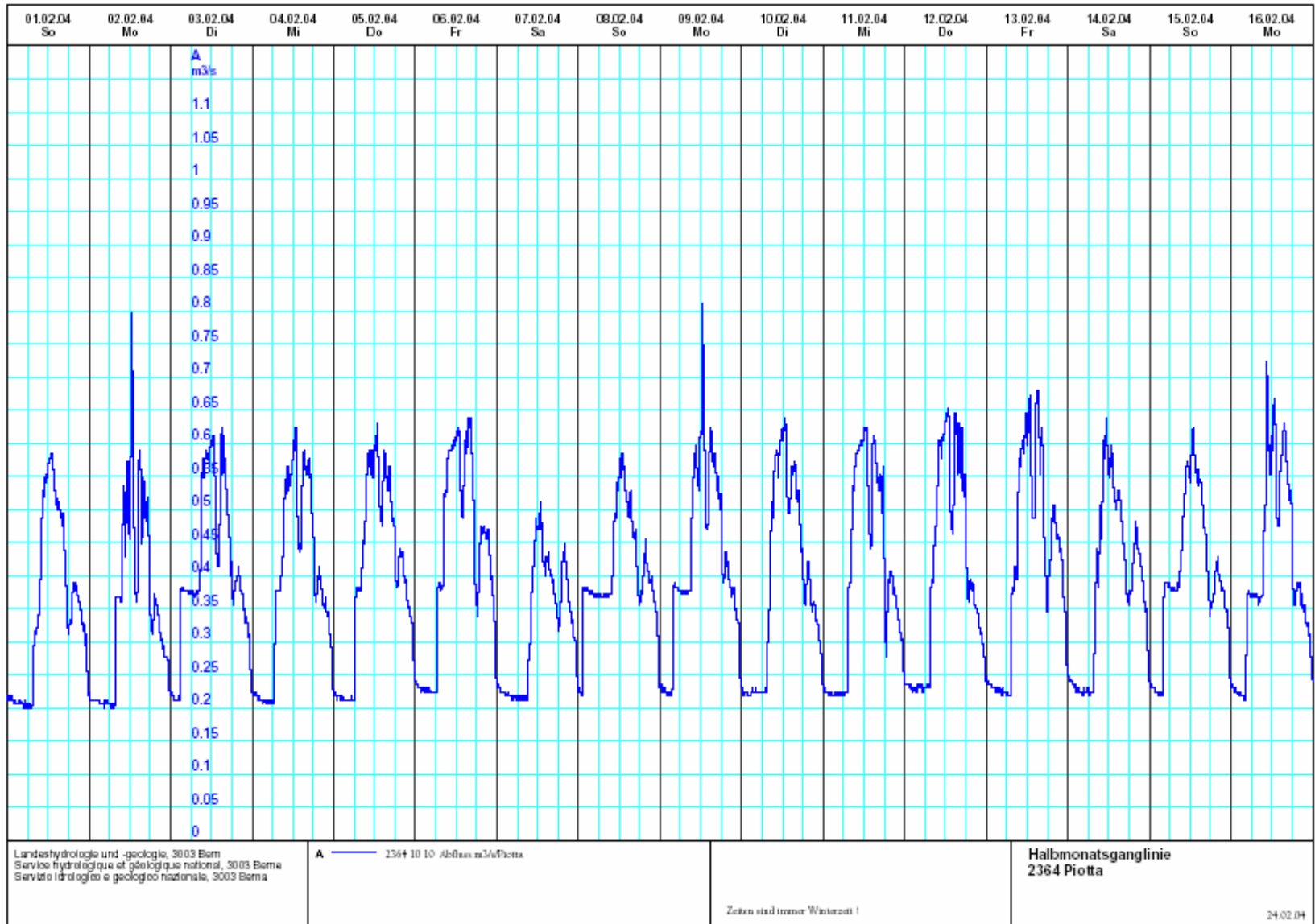
A	B	C	D	E
Code	Bezeichnung	Grössen-Schwellenwert	Signifikanzkriterium	Bemerkung
A) Wasserentnahme (aus Oberflächengewässern)				
A1	Ab-/Über-/Umleitung zur Wasserkrafterzeugung	$Q_A \geq 20 \text{ l/s}$	$Q_A : Q_{347} > 20\%$	$Q_A = \text{bewilligte bzw.}$ Entnahmer
A2	Trinkwasser-/Brauchwasserentnahme (kommunale, industrielle Nutzung)			
A3	Kühlwasserausleitung			
A4	Beschneidun			
A5	landwirtschaftlich			
A6	für fischereiwirtsch			
B) Wasserzufuhr / -einleitung (direkt in Gewässer)				
B1	Strassenentwässerung	A water withdrawals	B water discharges	C water reservoirs and regulation
B2	ARA-Auflösung			
B3	Regenwasserkanalisation Regenrückhaltebecken			
B4	Regenüberlaufbecken (Mischwasser)			
B5	Kühlwasserentnahme			
B6	Überleitung aus anderen Gewässern			
B7	Schwallbetrieb bei Wasserkraftwerken			
B8	Triebwassereinleitung aus Wasserkraftwerken			
C) Wasserspeicherung und -regulierung (Änderung des zeitlichen Ablaufes)				
C1	Speicherseen für die Wasserkraft (Tages-/Wochen-/Jahresspeicher)	$\text{Vol}_{\text{Speicher}} \geq 15'000 \text{ m}^3$	$\text{Vol}_{\text{Speicher}} > 12\text{h} * \text{MQ}_{\text{Speicherzuflüsse}}$	$\text{Vol}_{\text{Speicher}} = \text{Speichervolumen}$
C2	Mehrzweck- und andere Speicherseen (Bewässerung, Erholung, Beschneidung,...)			
C3	Ausflussregelungen von natürlichen Seen (Seeausflussregulierungen)	$\text{Regulierte Seen} \geq 10 \text{ ha oder} \geq 25'000 \text{ m}^3 \text{ Volumen}$	$\text{Vol}_{\text{Regulierung}} > 12\text{h} * \text{MQ}_{\text{Seezuflüsse}}$	$\text{Vol}_{\text{Regulierung}} = \text{regulierbares Speichervolumen}$
C4	Hochwasser-Rückhaltebecken			
		$\geq 10'000 \text{ m}^3$	$\text{Vol}_{\text{Retention}} > 1.5\text{h} * \text{MQ}$	$\text{Vol}_{\text{Retention}} = \text{Retention}$ Rückhaltebecken
D) Grundwasserbezogene Massnahmen				
D1	Entnahmen aus Quellen	$Q_A \geq 15 \text{ l/s}$	$Q_A : Q_{347} > 20\%$ Auf Stufe F nur inventarisiert, aber nicht für Bewertung berücksichtigt	$Q_A = \text{konzessionierte maximale Entnahmer}$
D2	Entnahmen von gepumpten GW	$\geq 40 \text{ l/s}$		
D3	GW-Anreicherung	$\geq 50 \text{ l/s}$		
E) Spülungen (Sedimentbewirtschaftung)				



Examples of assessment approaches
for 2 of the 9 indicators

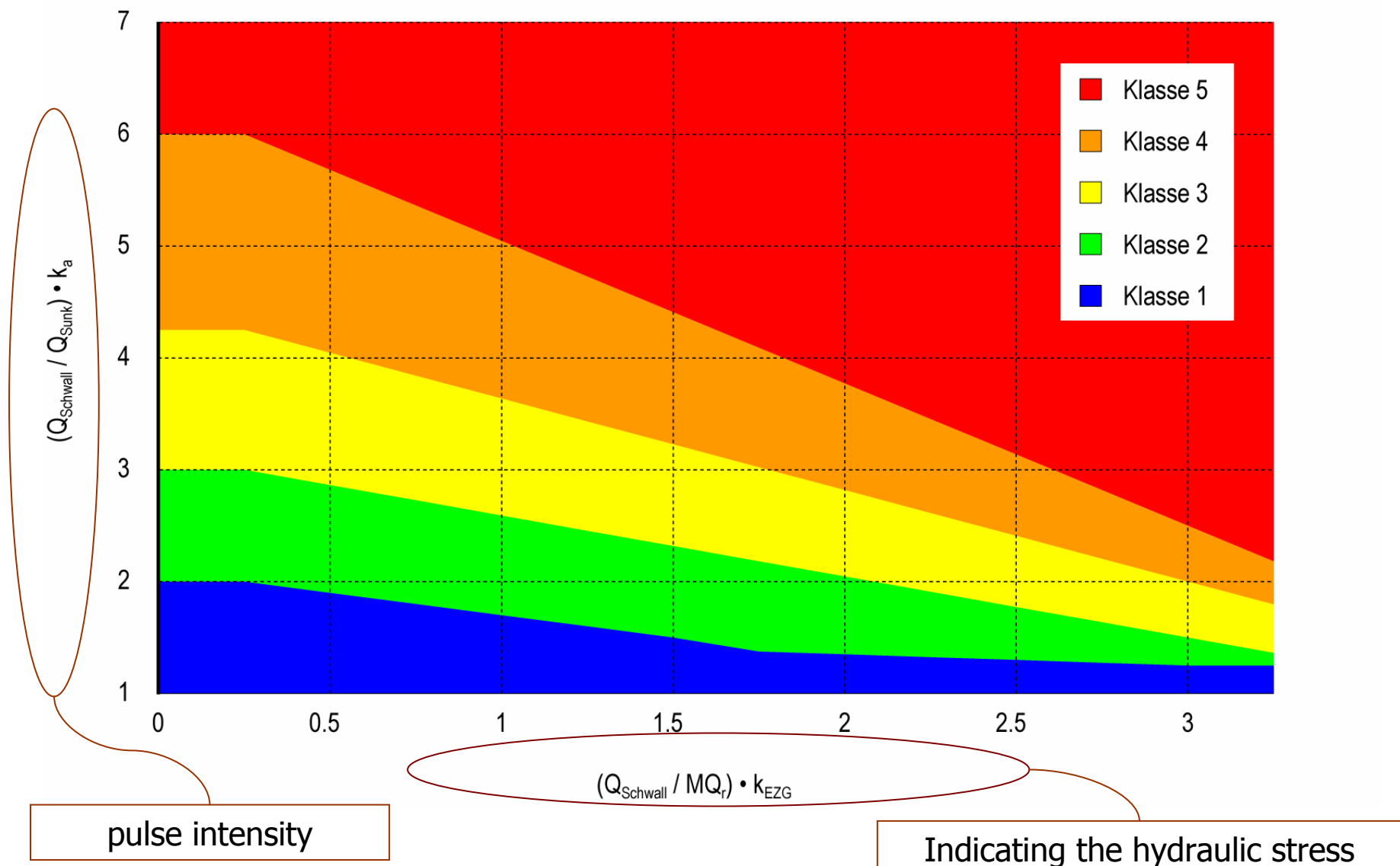
- hydropeaking
- low-flow and high-flow seasonality

Hydropeaking

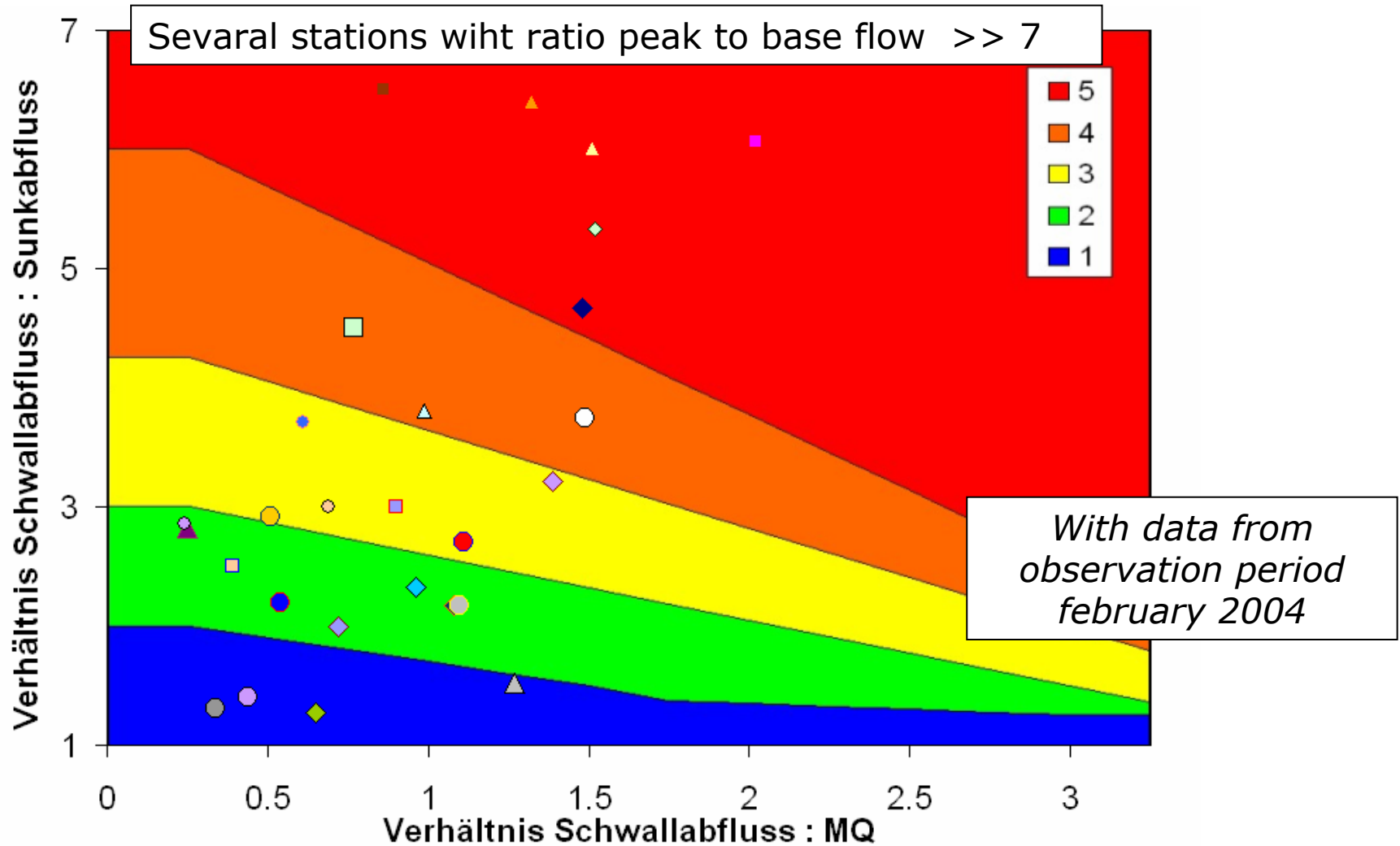


Hydrograph for the river [Ticino@Piotta](#) (period 1-16 February 2004)

Assessment approach for hydro-peaking

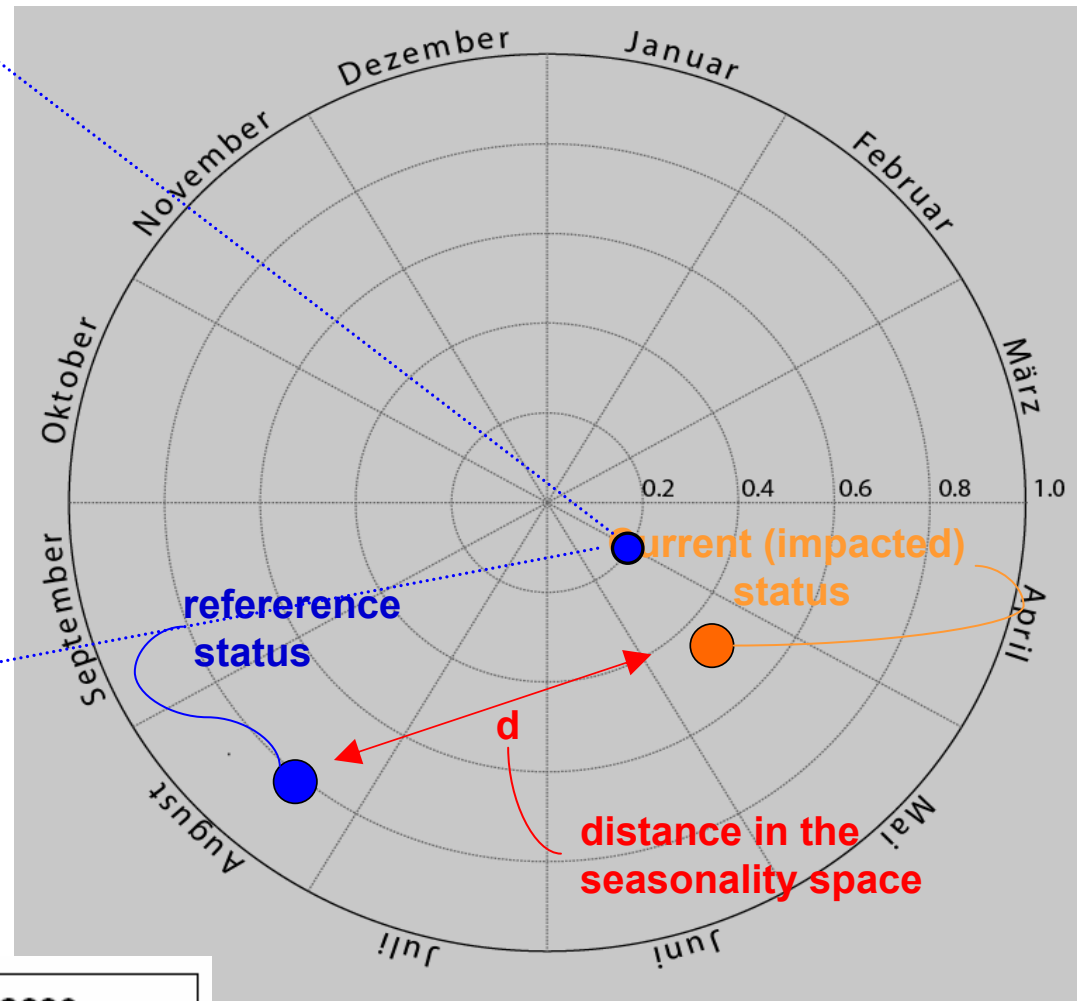
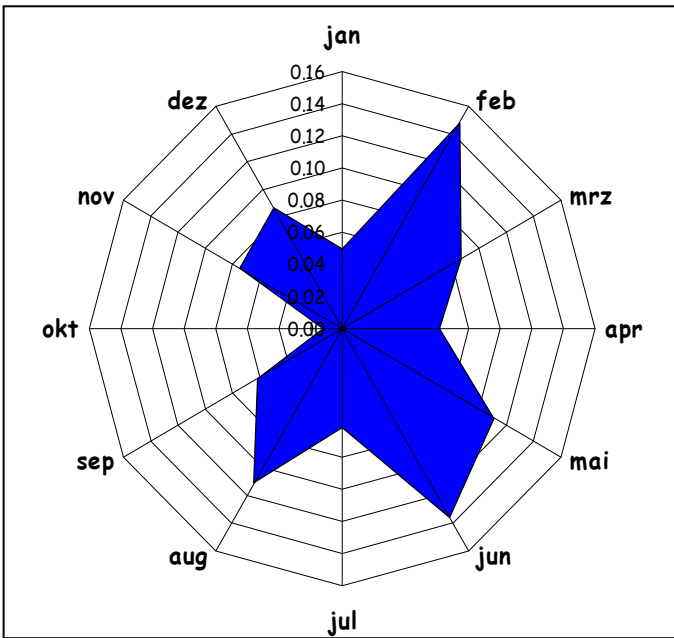


discharge gauging stations in the hydropeaking assessment scheme



- | | | | | |
|-----------------------|---------------------|-------------------------|------------------------|-----------------------|
| ◆ Sarine-Broc | ◆ Sarine Fribourg | △ Saane Laupen | □ Vorderrhein Ilanz | ◆ Rhein Diepoldsau |
| ▲ Ticino Piotta | ◆ Ticino Pollegio | ◆ Ticino Bellinzona | ◆ Rhone Porte du Scex | ◆ Albula Tiefencastel |
| □ Engelberg Aa Buochs | ▲ Linth Linthal | ◆ Linth Mollis | ◆ Vispa Visp | ◆ Rhone Brig |
| ▲ Aare Brienzwiler | □ Reuss Seedorf | △ Muota Ingenbohl | ◆ Drance Martigny | □ Rhone Branson |
| ▲ Orbe Orbe | ◆ Doubs Le Noirmont | ◆ Doubs St.Gallen | ◆ Landquart Felsenbach | ◆ Moesa Lumino |
| ◆ Inn S-Chanf | ■ Inn Martinsbruck | ◆ Hinterrhein Fürstenau | ■ Alpenrhein Domat-Ems | △ Lorze Zug |
| ◆ Aubonne Allaman | ◆ Rhone Chancy | ○ Rhone Genève | ◆ Grande Eau Aigle | ◆ Rhone Sion |

Approach for assessing the alteration in the low and high flow-seasonality

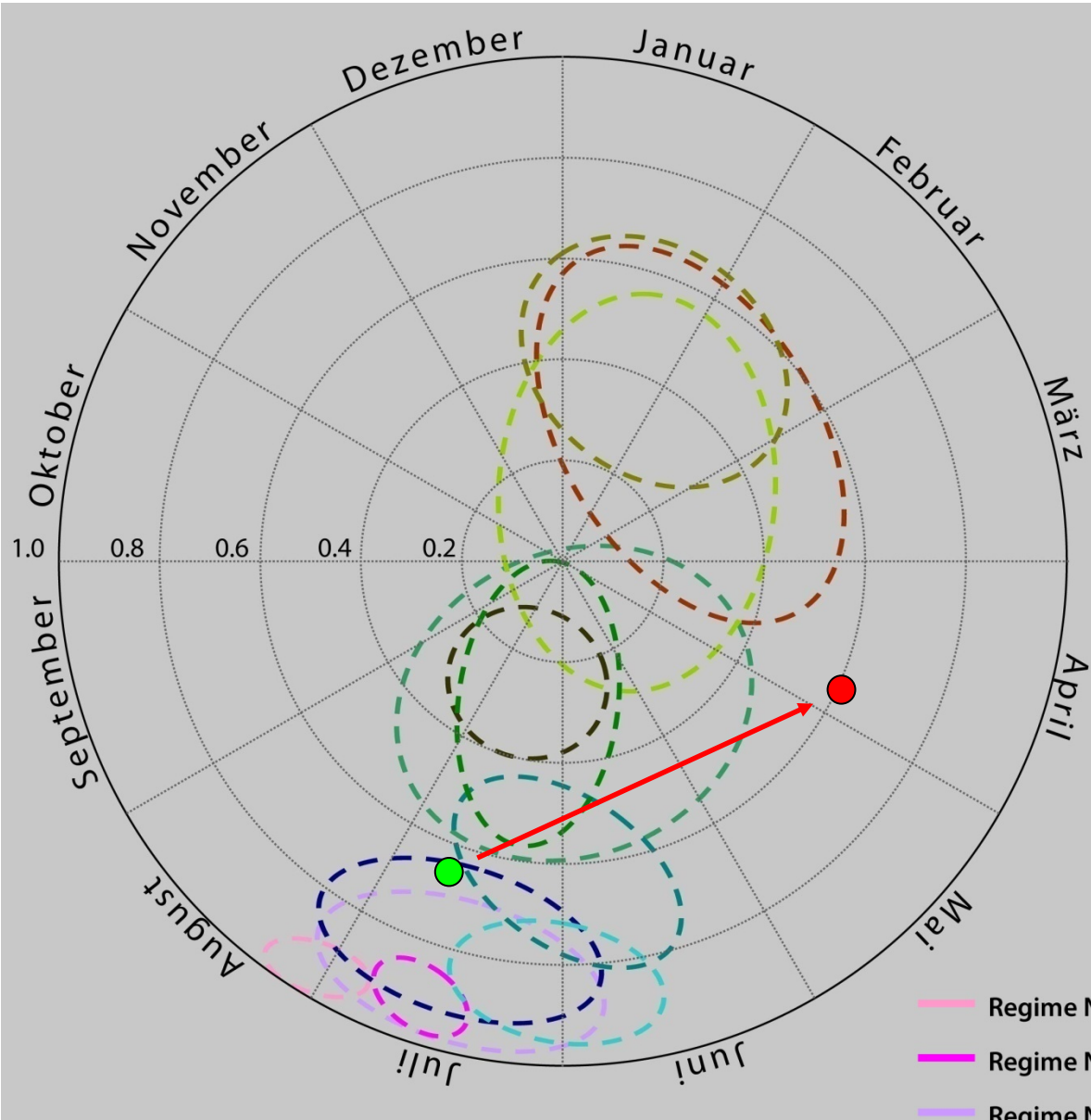


assessment depends on the shift d in the seasonality space

assessment class = $f(d)$

Distanzmass im Saisonalitätsraum	Klasse
$Dist_{i,j} \leq 0.3 (0.25)$	1
$0.3 (0.25) < Dist_{i,j} \leq 0.6 (0.5)$	2
$0.6 (0.5) < Dist_{i,j} \leq 0.9 (0.75)$	3
$0.9 (0.75) < Dist_{i,j} \leq 1.2 (1.0)$	4
$Dist_{i,j} > 1.2 (1.0)$	5

River Julia@Tiefencastel Shift in high-flow seasonality



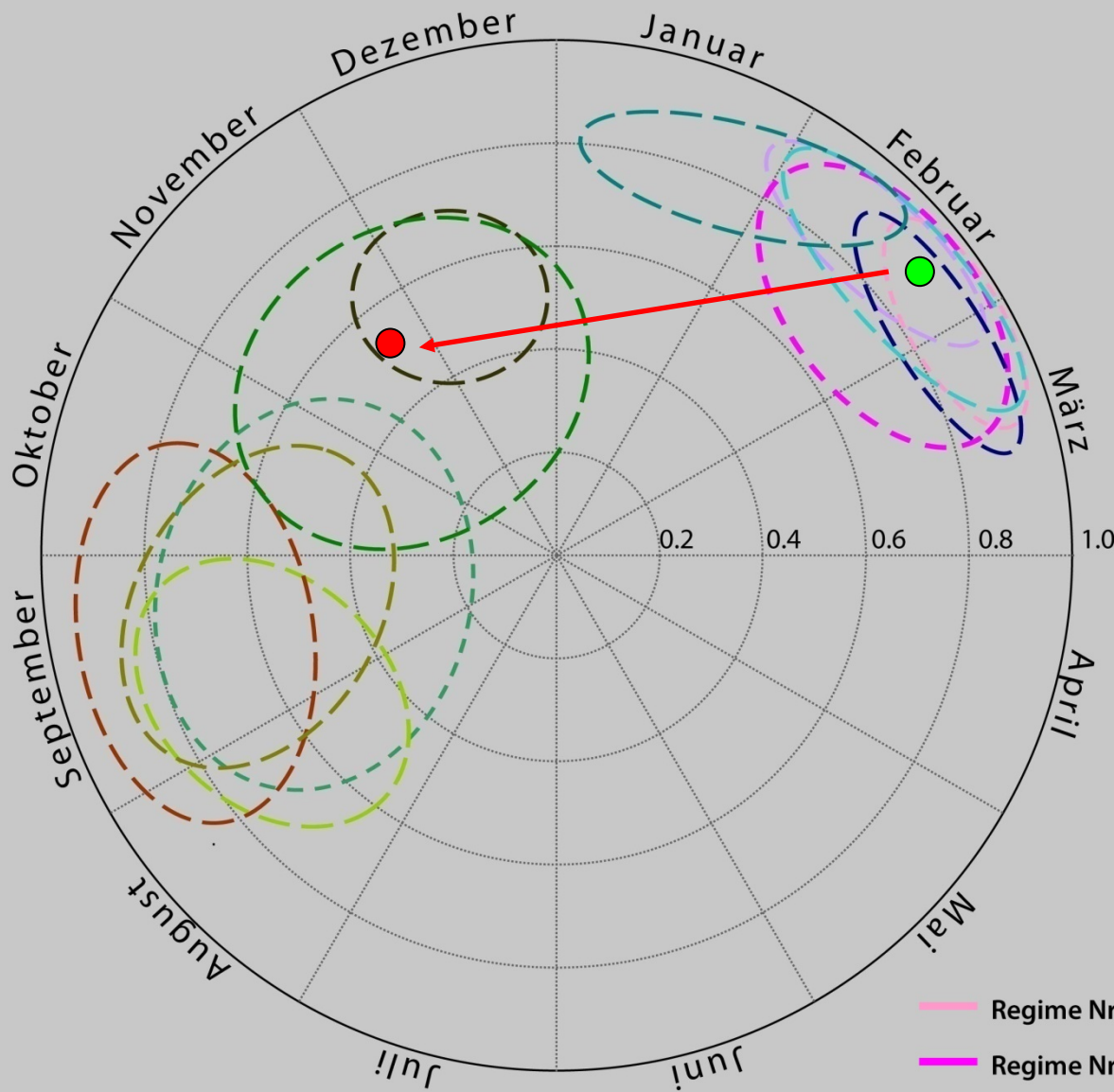
*shift of the Q_h -seasonality
caused by the Marmorera
reservoir (in operation since
1954)
comparing the periods 1919-
1948 and 1976-2002;
distance=0.84 => class 3*

- | | | |
|--------------|---------------|---------------|
| Regime Nr. 1 | Regime Nr. 7 | Regime Nr. 13 |
| Regime Nr. 2 | Regime Nr. 8 | Regime Nr. 14 |
| Regime Nr. 3 | Regime Nr. 9 | Regime Nr. 15 |
| Regime Nr. 4 | Regime Nr. 10 | Regime Nr. 16 |
| Regime Nr. 5 | Regime Nr. 11 | Einheitskreis |
| Regime Nr. 6 | Regime Nr. 12 | |



River Julia@Tiefencastel Shift in low-flow seasonality

River Julia@Tiefencastel
 shift of the QI-seasonality
 caused by the Marmorera
 reservoir (in operation since
 1954)
 comparing the periods 1919-
 1948 and 1976-2002
 distance = 1.0 => class 4



- | | | |
|--------------|---------------|---------------|
| Regime Nr. 1 | Regime Nr. 7 | Regime Nr. 13 |
| Regime Nr. 2 | Regime Nr. 8 | Regime Nr. 14 |
| Regime Nr. 3 | Regime Nr. 9 | Regime Nr. 15 |
| Regime Nr. 4 | Regime Nr. 10 | Regime Nr. 16 |
| Regime Nr. 5 | Regime Nr. 11 | Einheitskreis |
| Regime Nr. 6 | Regime Nr. 12 | |



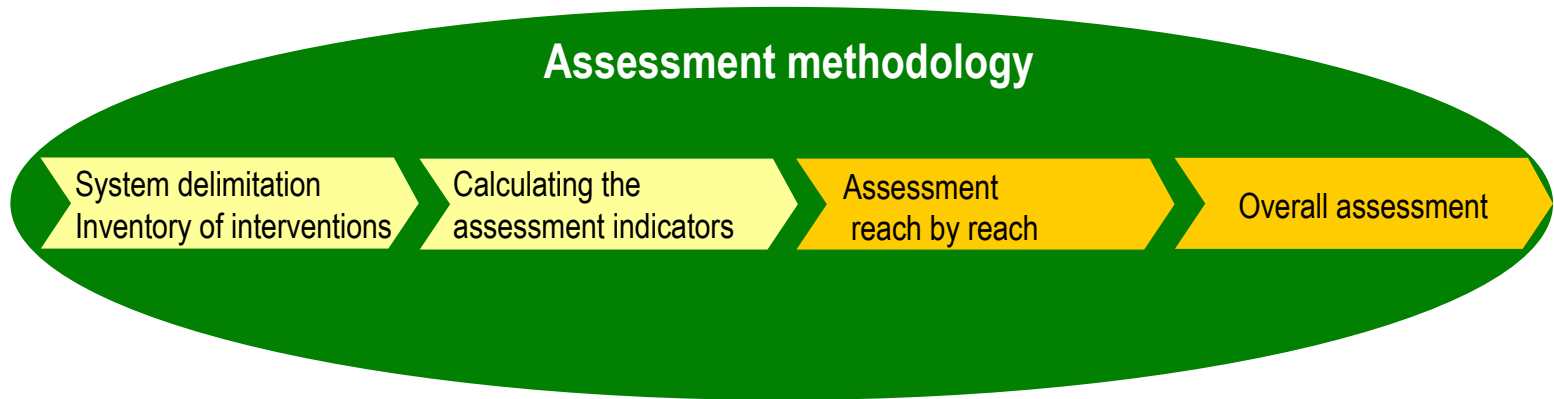
Assessment methodology

System delimitation
Inventory of interventions

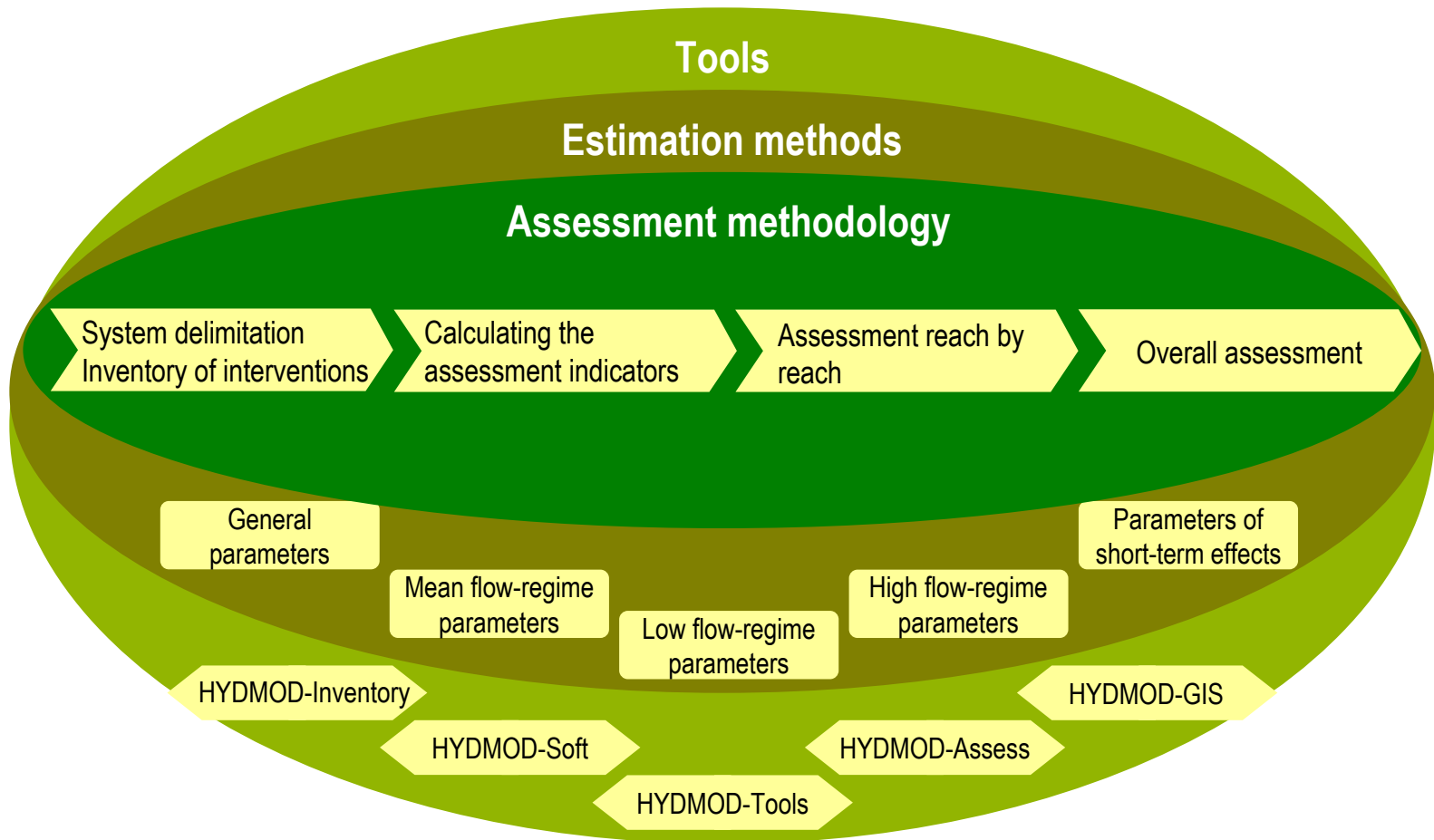
Calculating the
assessment indicators

Assessment
reach by reach

Overall assessment



HYDMOD..... the „package“



Blenio Valley

Testing HYDMOD in the Blenio valley (Brenno river)



Repubblica e
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Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Umwelt BAFU

Dipartimento del Territorio
Ufficio dei corsi d'acqua

- Basin Area: 400 km²
- Mean altitude: 1820 m a.s.l.
- Glacier Area: 1.1 %
- Mean Yearly Runoff:
 - Today: 4.6 m³/s
 - Bef. Dam Constr.: 17.9 m³/s
- Q347:
 - Today: 1.24 m³/s
 - Bef. Dam Constr.: 4.70 m³/s



Rationale and Objectives

Evaluation of:

- Meaningfulness and Practicability of the whole Procedure
- Meaningfulness of the Assessment Indicators and of the Significance Criteria for the Interventions
- Meaningfulness of the Assessment Approach
- Graphic Representation of Results
- Effort (in Terms of Time and Data Requirements) for the Application of the Method

Blenio Valley – Interventions and Problems

- The Brenno River is highly influenced from Water Management Activities (Water Withdrawal and Diversion, Hydropower-plants, ...).
- Nature Protection Areas of National Importance
- Different Projects carried out in the catchment (Ökostrom, Ct. Ticino, ...)



Identification and inventory of man-made interventions

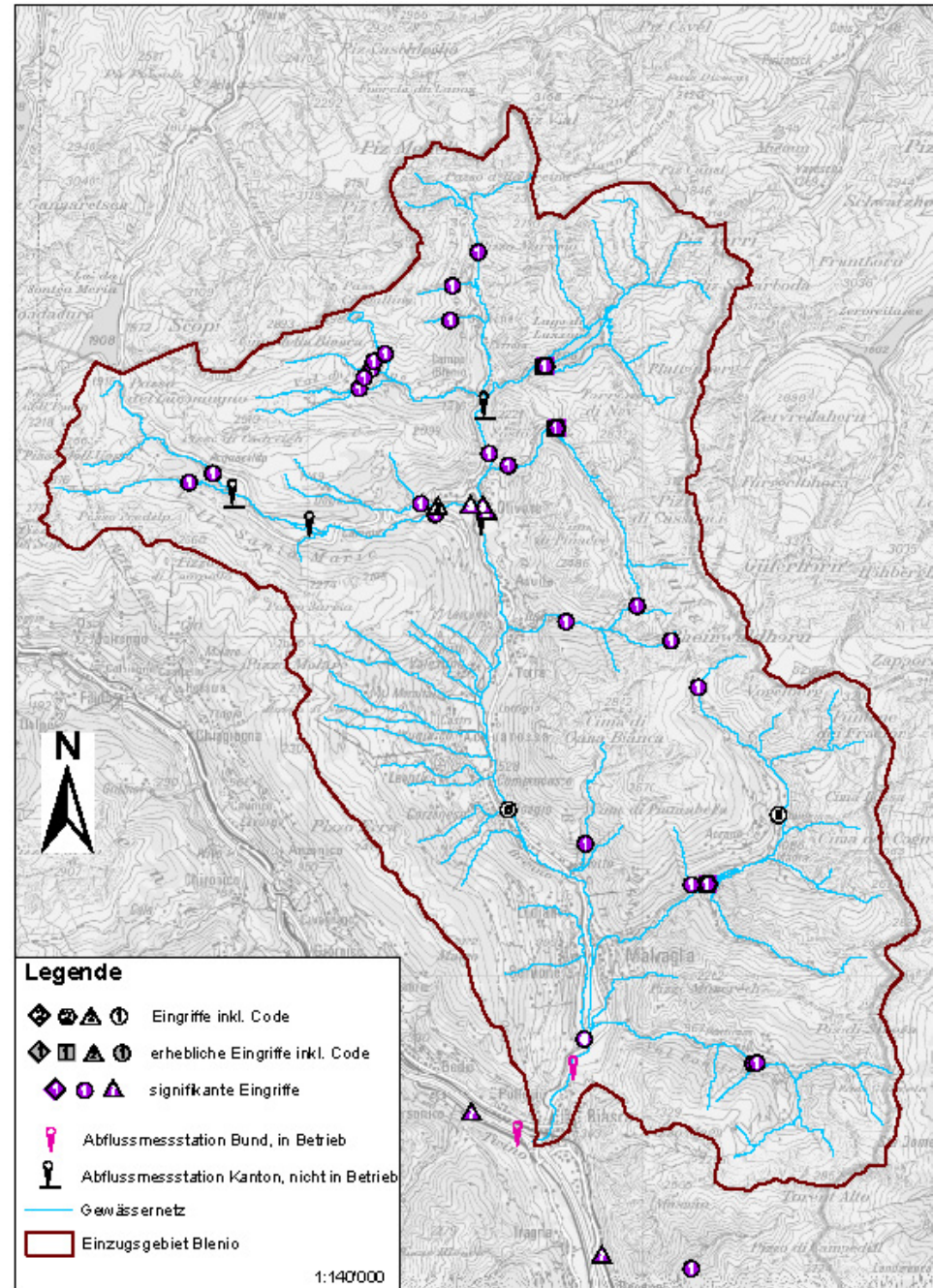
- | | | | |
|---|-------------------|--|---------|
| A | Water withdrawals | A1: for Hydropower production
A6: for Fishery Activities: | 24
3 |
| B | Water discharges | B2: Olivone Water Treatment Plant
B6: Storm Sewer System | 1
3 |
| C | Reservoirs | C1: for Hydropower | 3 |

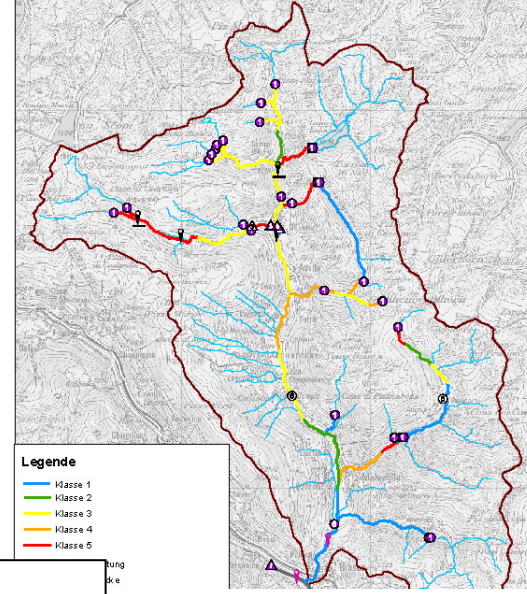
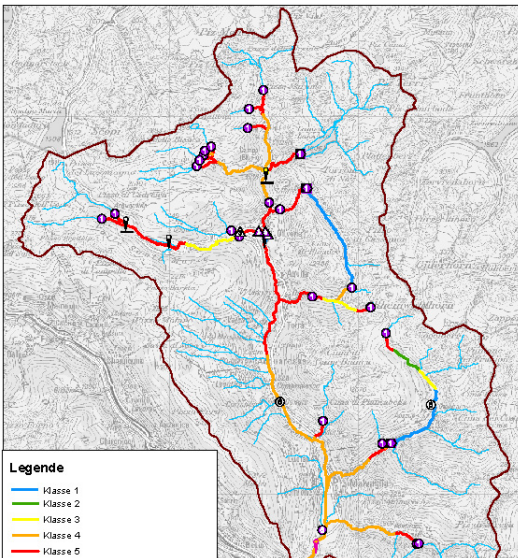
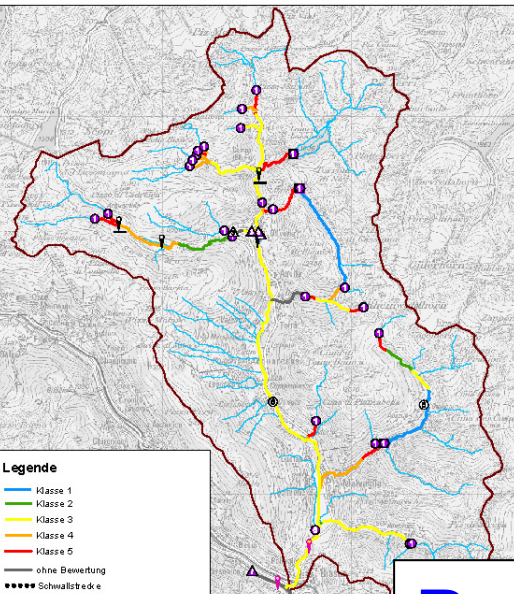
ID	Kt. Tessin	Name / Bezeichnung des Eingriffs	Koordinaten Entnahme		Höhe Entnahme m ü.M.	QA Ausbau l/s	Kraftwerk	Speicher- volumen [m ³]
			Ost-West	Nord-Süd				
		46	Lareccio - Ri di Lareccio	706420	154577	1729		1200
		47	Acquacalda - Brenno	707127	154840	1729		2300
		48	Bovarina - Ri di Stabbio Nuovo	711455	157355	1723		1500
		49	Inferno I und II - Affluenti fiume d'Orsaira	711811	157934	1731		750
		50	Fontanascia - affluente del fiume d'Orsaria	711880	158160	1739		100
		51	Clasca - Vall'Agrasina	672204	159334	1720		350
		52	Clasca - Vall'Agrasina	672204	159334	1720		350
		53	Presciedo - Ri di Pralognan	160382	160382	250		250
		54	Camadira - Brenno	715200	157376	1739		3200
		55	Quarnaio - Orino	721458	148502	2043		1000
		56	Brenno - Riale della Valsoi	720646	150030	2037		700
		57	Adula - Affluente riale della Valsoi (Ina)	713286	150035	2156	07	Luzzone - Olivone 190000
		58	Lucomagno - Brenno del Lucomagno	713286	150035	1025	90	Luzzone - Olivone 106944000
		59	Sommascona - Rr di Piera	713286	150035	1029		1100
		60	Sesto - Brenno della Greina	715240	163035	1042	90	Biasca 2719000
		61	Marzano - Ri di Corzoeso	715246	144634	1032		600
		62	Val Soja - Riale della Valsoi	717560	150460	1117		1600
		63	Simano - Affluente di sx. Brenno	718119	143891	1005		900
		64	Rasoira - Affluente di dx. Orino	721252	142687	995		300
		65	Albeglia e Legiuna - Riale di Boveta e Riale di Lesgiuna	723068	137396	1030		3500
		66	Boggera - Boggera	723186	137414	998		2000
		67	Nala - Nala	721260	131331	1015		2000
		UE4	Riale di Corzoeso - Corzoeso	715246	144634			50
		UE6	Brenno della Greina	715240	163035			35

Identification of interventions

- Identification of all Interventions
- Significant Interventions (Relevance Thresholds and Significance Criteria)

HYDMOD Test : Significant Interventions

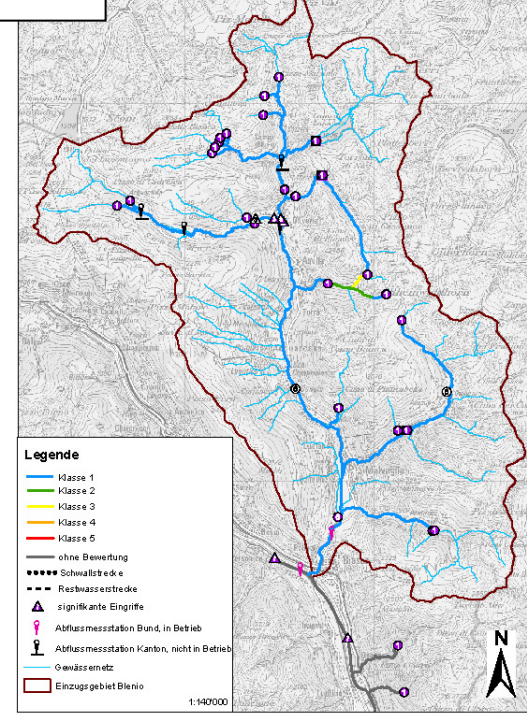
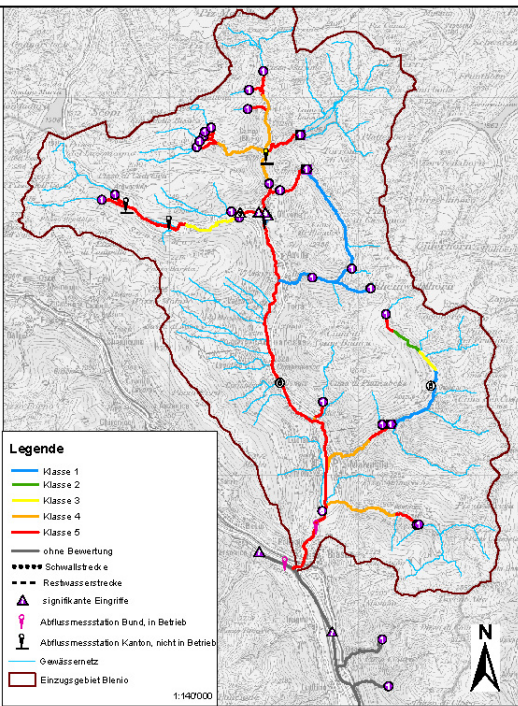
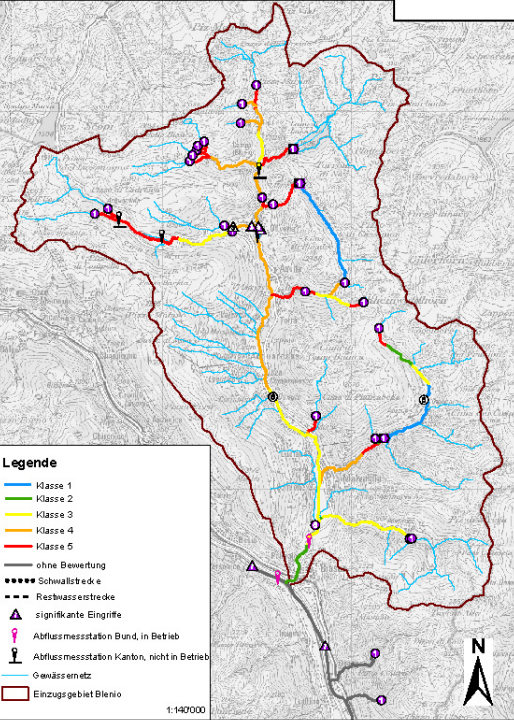




Results for each Indicator

Anhang 10: Hydromod - Erprobung Blenio - Karte Bewertung HQ-Saisonalität

Anhang 7: Hydromod - Erprobung Blenio - Karte Bewertung HQ-Saisonalität

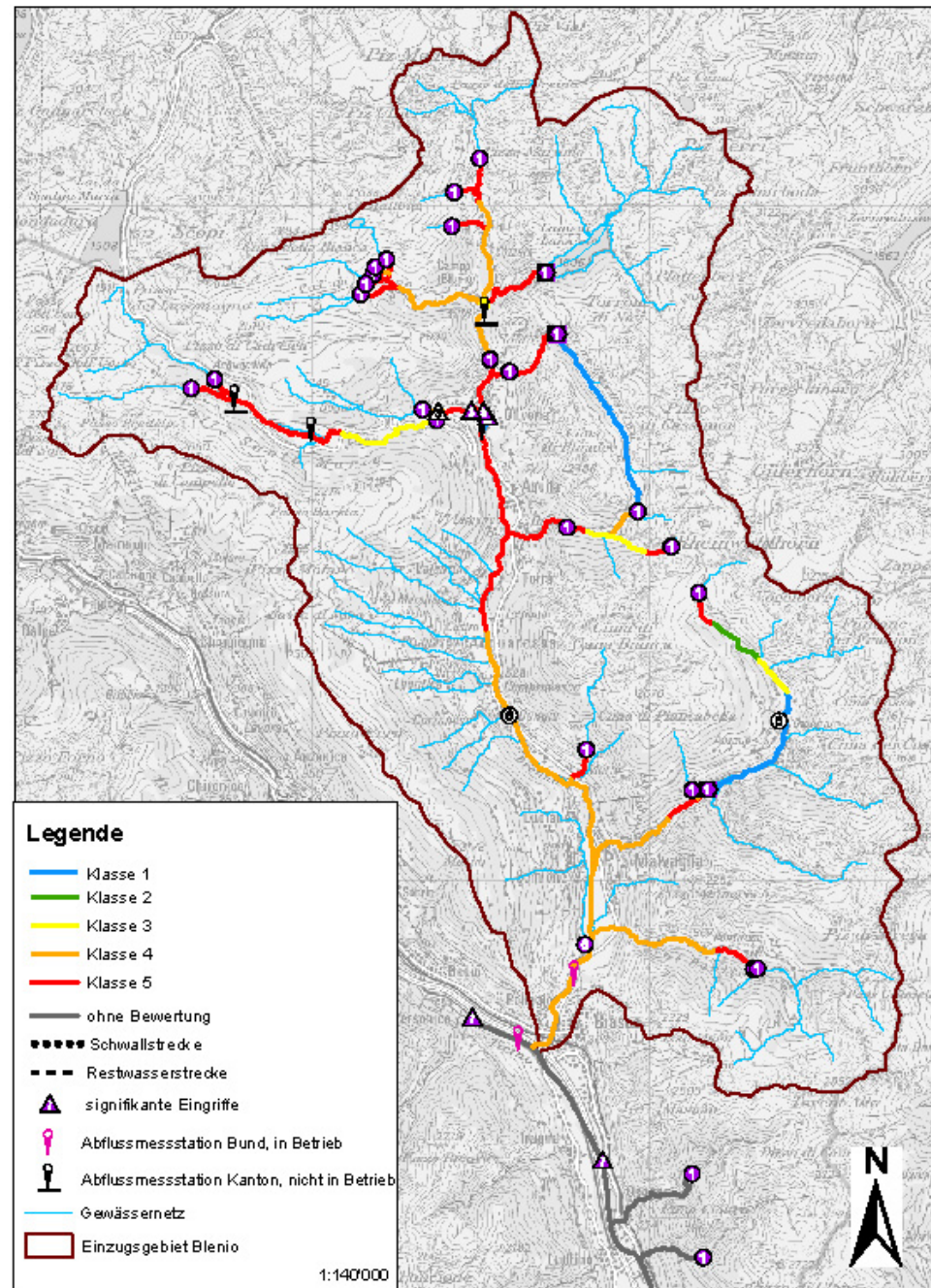


Results for Mean Flow (MQ) and Seasonal Pattern (PK)

- Huge modification of the mean runoff regime as a consequence of Water Management activities
- Quite long „red reaches“: the „Dilution Capacity“ of the river is limited.

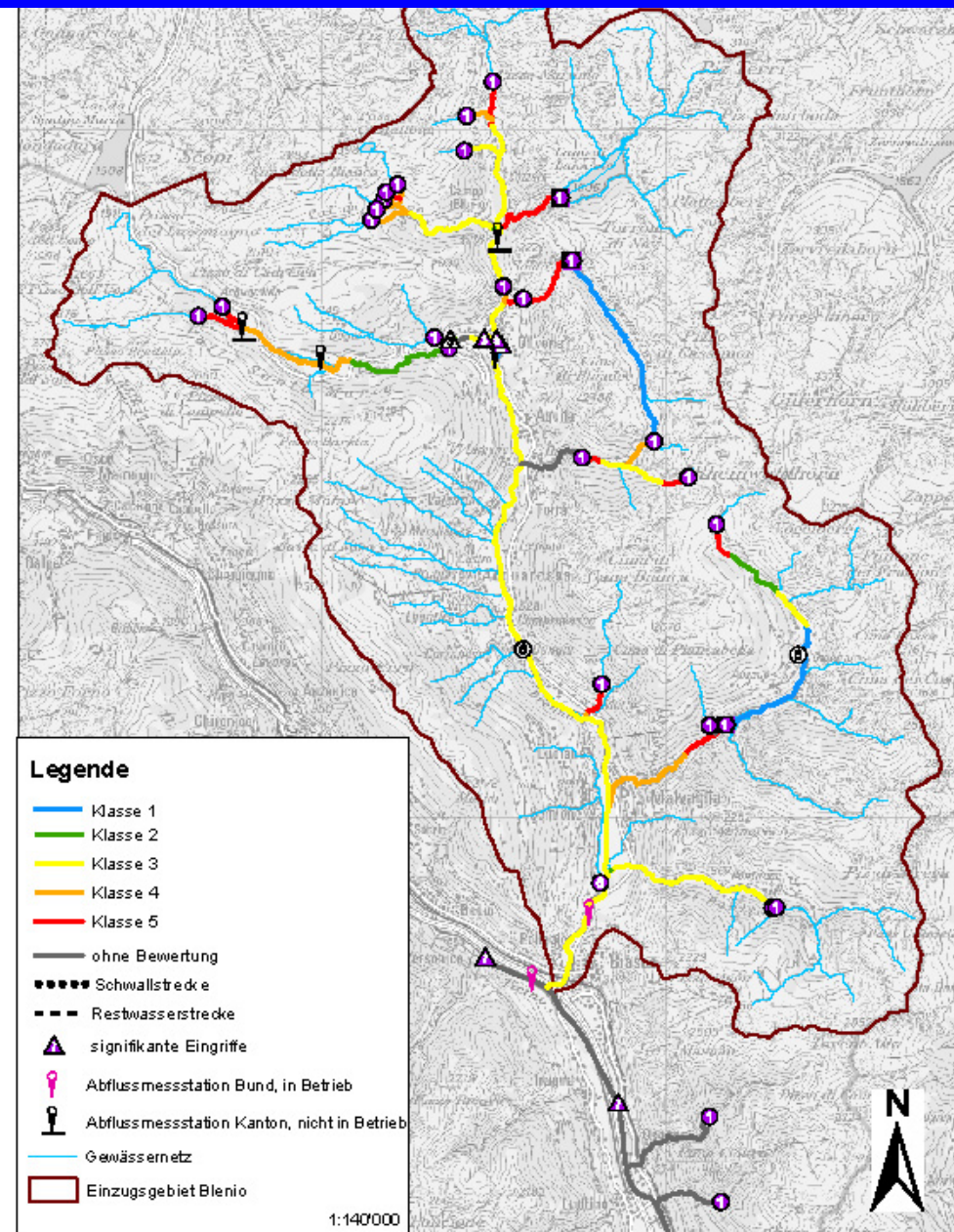
Def: Dilution Capacity: Amelioration and Recovery Capacity of the River after a „Disturb Signal“ at a Point, due to natural water inflow from subbasins below the impact point.

HYDMOD Test Application: Evaluation MQ/PK



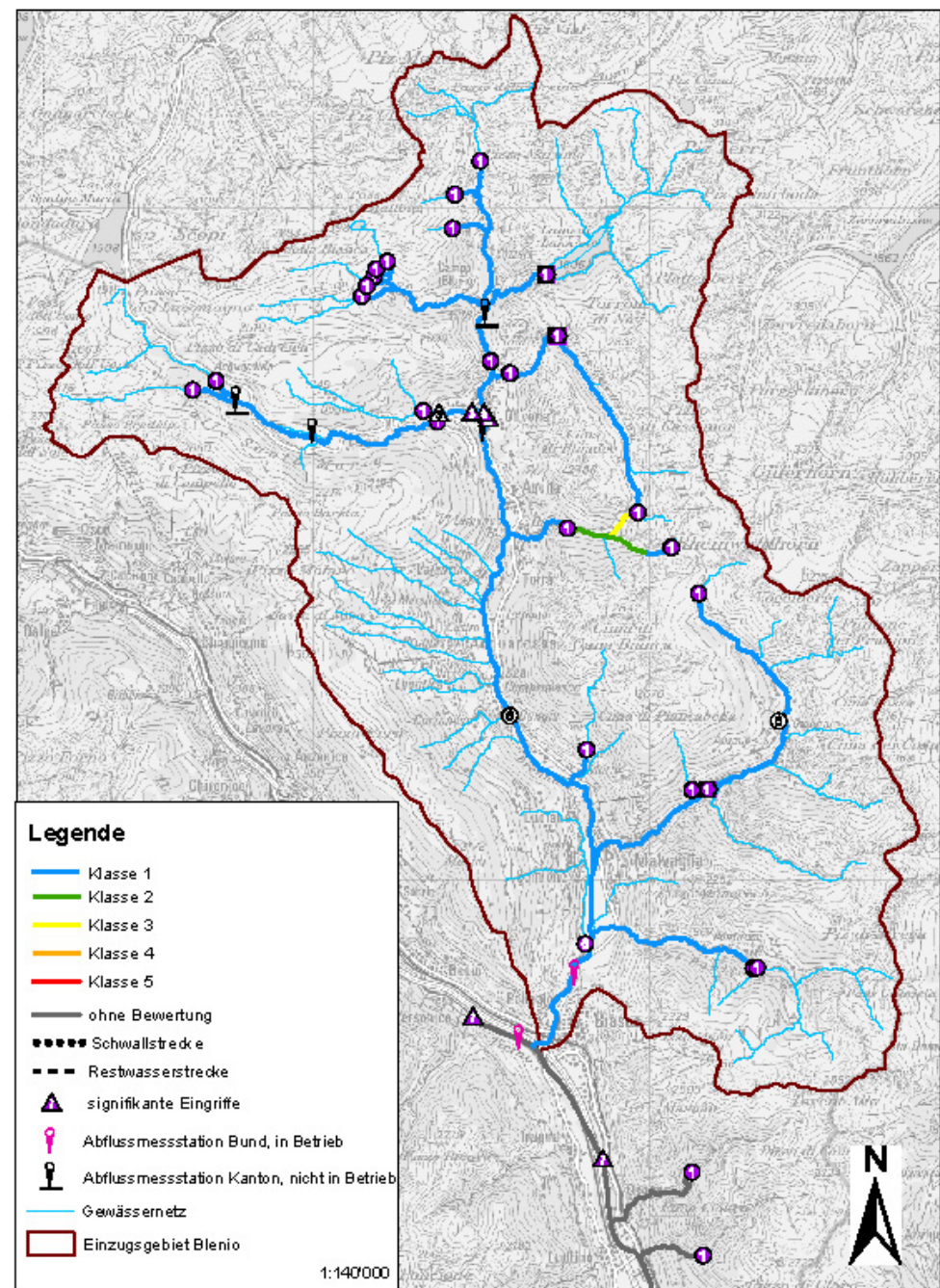
Results Flood-Frequency

- Heavy Influence at the Location of intervention
- Slight „Dilution“ downstream
- Brenno Main River: Class 3



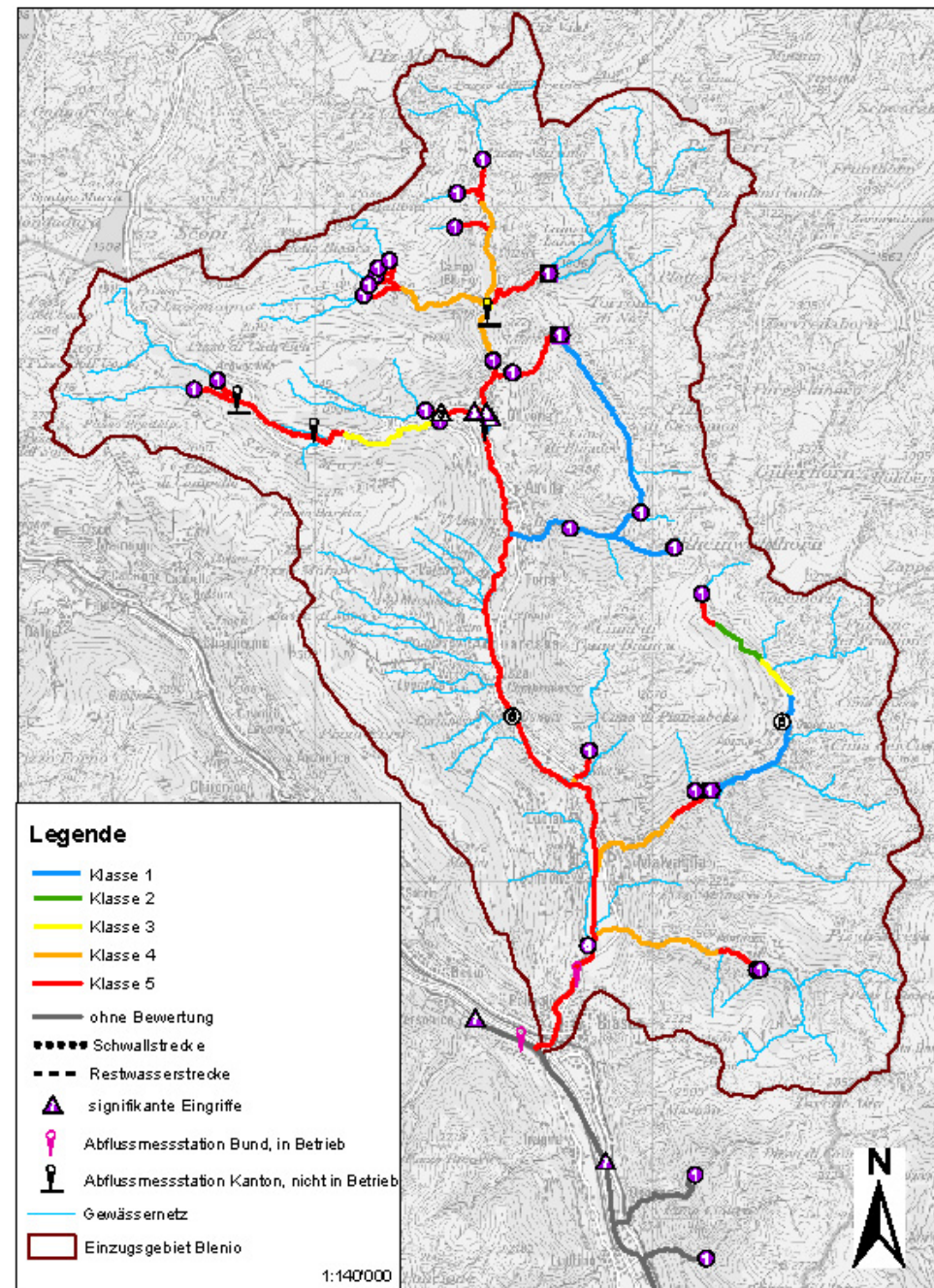
Results High-Flow-Seasonality

- All River Reaches are natural or nearly natural
- No Alteration of the Flood Seasonality (limited max. water diversion capacity; Hydropower plants produce no artificial floods along the main river)
- The influence of the water diversion upon the flood generation process better described by the „Flood Frequency“ Indicator



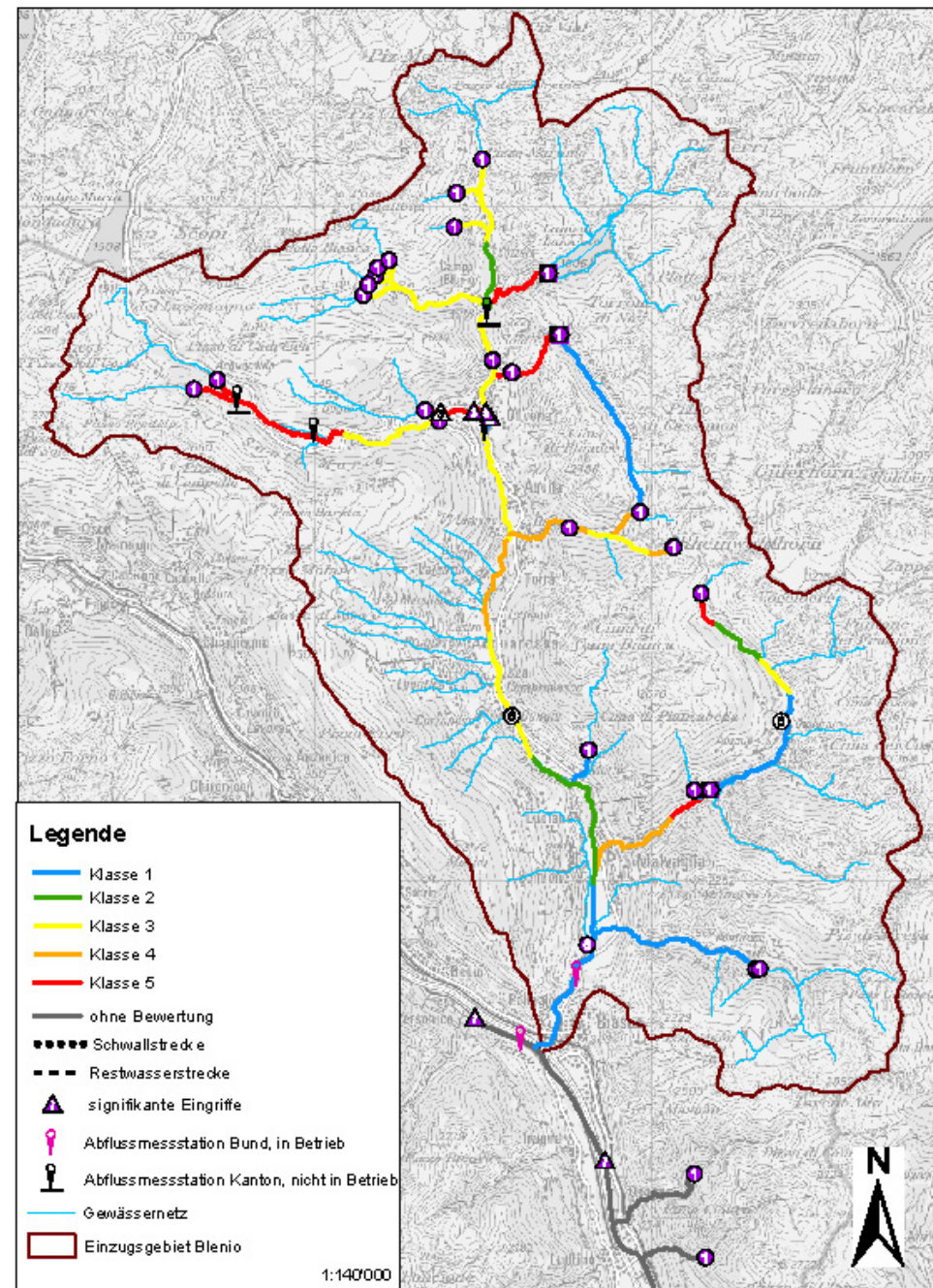
Results Q347 (low flow discharge)

- Severe influence of Hydropower activity along the majority of the „Residual waterflow reaches“ (Dominance of Classes 3 up to 5)
- Better assessment in the Malvaglia Valley
- Brenno below Olivone belongs to Class 5



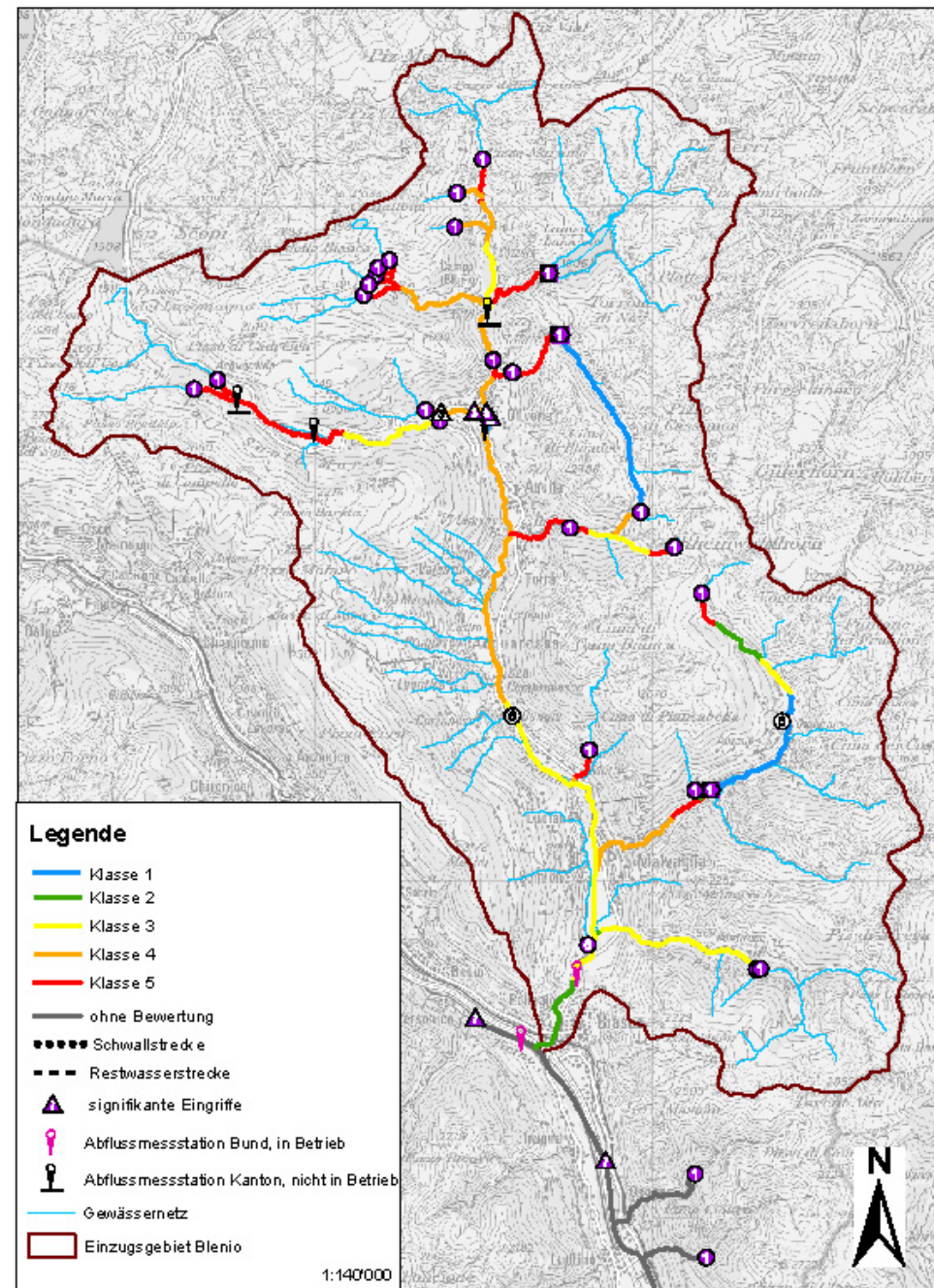
Results NQ (Low-Flow)-Seasonality

- The pattern is similar to the Q347 pattern (the influence is small)
- Among the Low Flow Indicators, the Indicator NQ-Duration is the most meaningful (together with Q347)



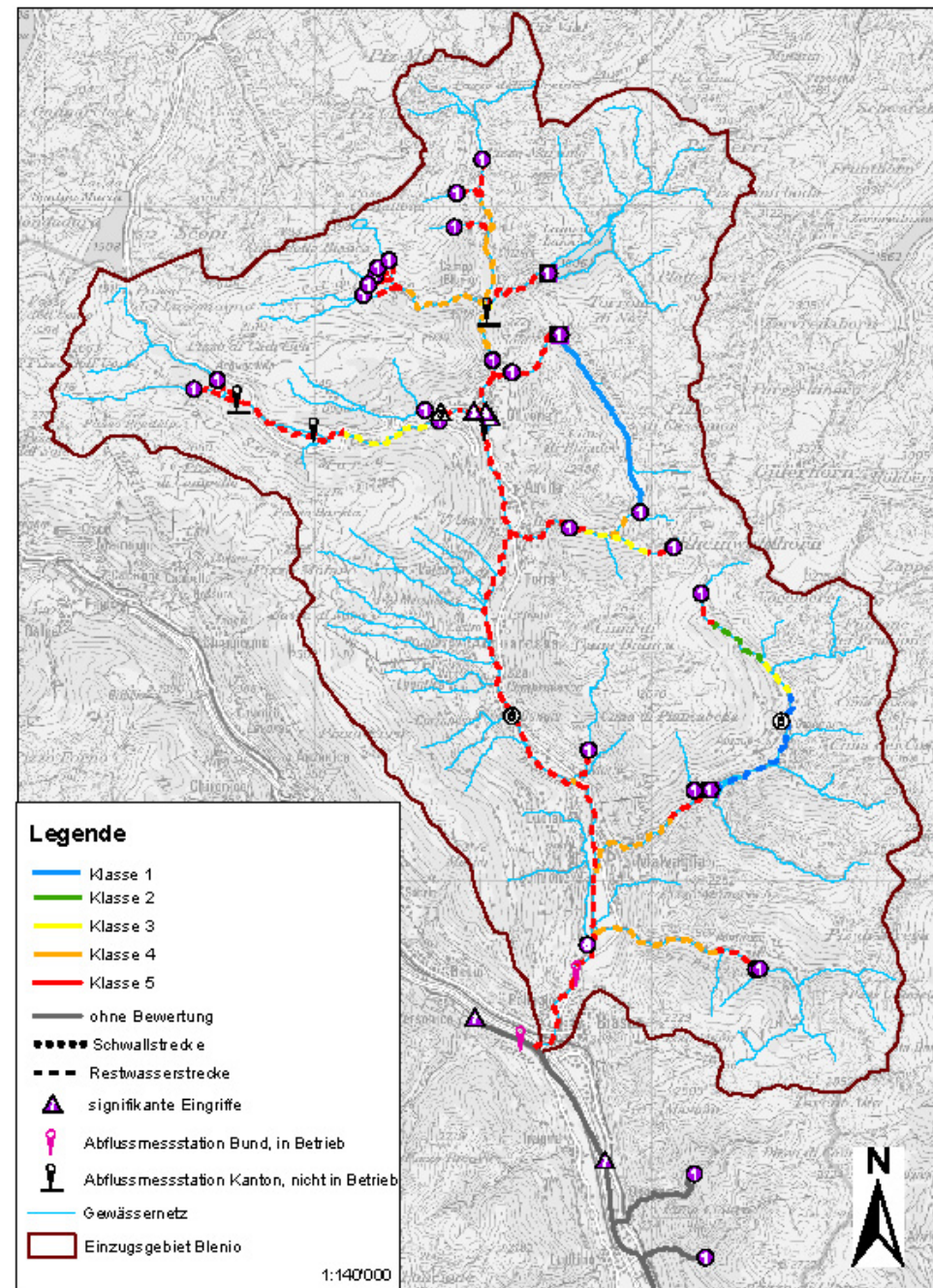
Results NQ (Low-Flow)-Duration

- All river reaches below a water abstraction belong to Class 5 (also where other Indicators obtain a better ranking)
- The pattern along the secondary river network is comparable with the Q347-Assessment



Global Assessment

- Hyp.: „worst-case“ Aggregation Rule
- Is the Aggregation Rule applicable? In the lower reach of the Brenno River this rule leads to a pessimistic evaluation, even though only the Q347 Indicator belongs to Class 5 (at Olivone Class 5 is „justified“ from different Indicators)
- The development of a different Aggregation Rule is required



Conclusions

Significance and Power of the Methodology

- All the Classes for the different Indicators are represented (good Variability) → suggesting that the pre-defined thresholds for the classification are reasonable
- The assessment of NQ (low-Flow)-Duration Indicator (originally foreseen as „optional“) is recommended....and meanwhile implemented
- The implementation of the method requires detailed knowledge of the theoretical basis and some effort to get familiar with the method`s procedure
- Availability of hydrologic data and information about the man-made interventions is an indispensable condition. The acquisition of basic data can be extremely time-consuming