Stakeholder Preferences and Decision Support for River Rehabilitation

REFORM Stakeholder Meeting, Sevilla, Spain, June 2, 2014

Peter Reichert, Eawag, Switzerland

Eawag: Swiss Federal Institute of Aquatic Science and Technology

eawag aquatic research

Content

1. Concepts of Decision Support Techniques
   … and their application in Environmental Management

2. Decision Support for River Management

3. Case Study
   a. Assessment of Ecological State of a River Section
   b. Assessment of Ecological State of a River Network
   c. Formulation of Synergies/Trade-offs with other Societal Goals

4. Conclusions

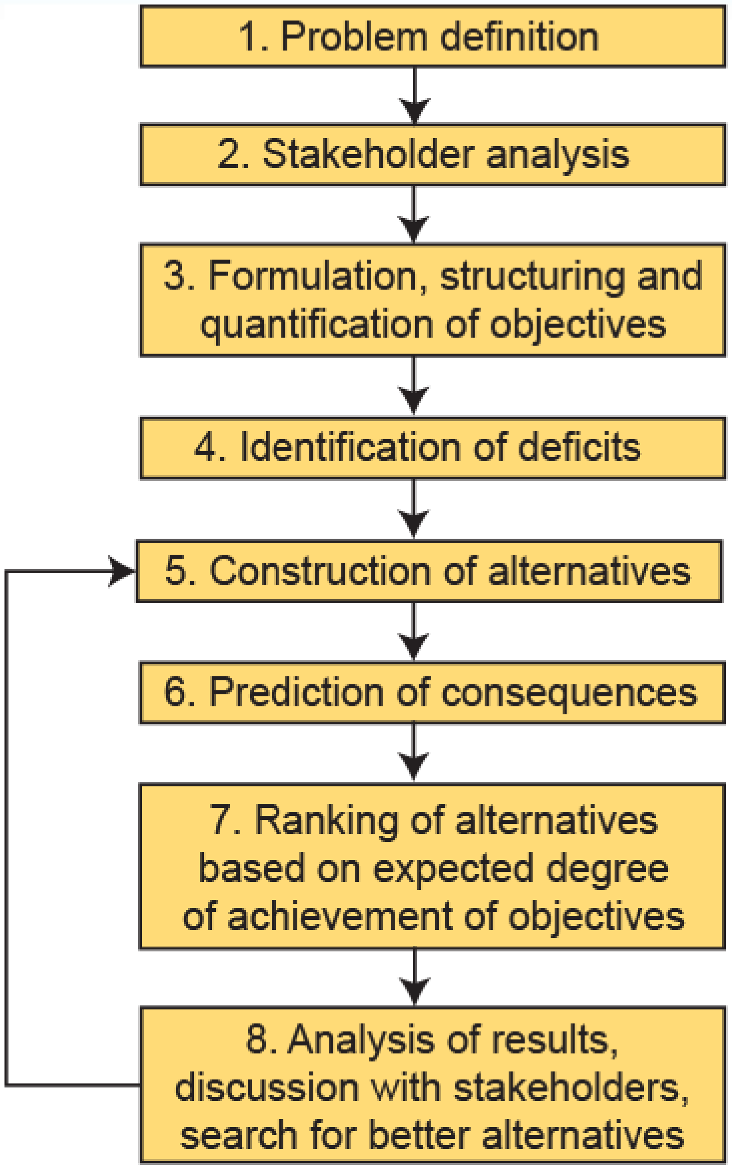
Note: The focus is on the methodology; all quantitative results are preliminary

Content

1. Concepts of Decision Support Techniques

   … and their application in Environmental Management

1. Concepts of Decision Support Techniques

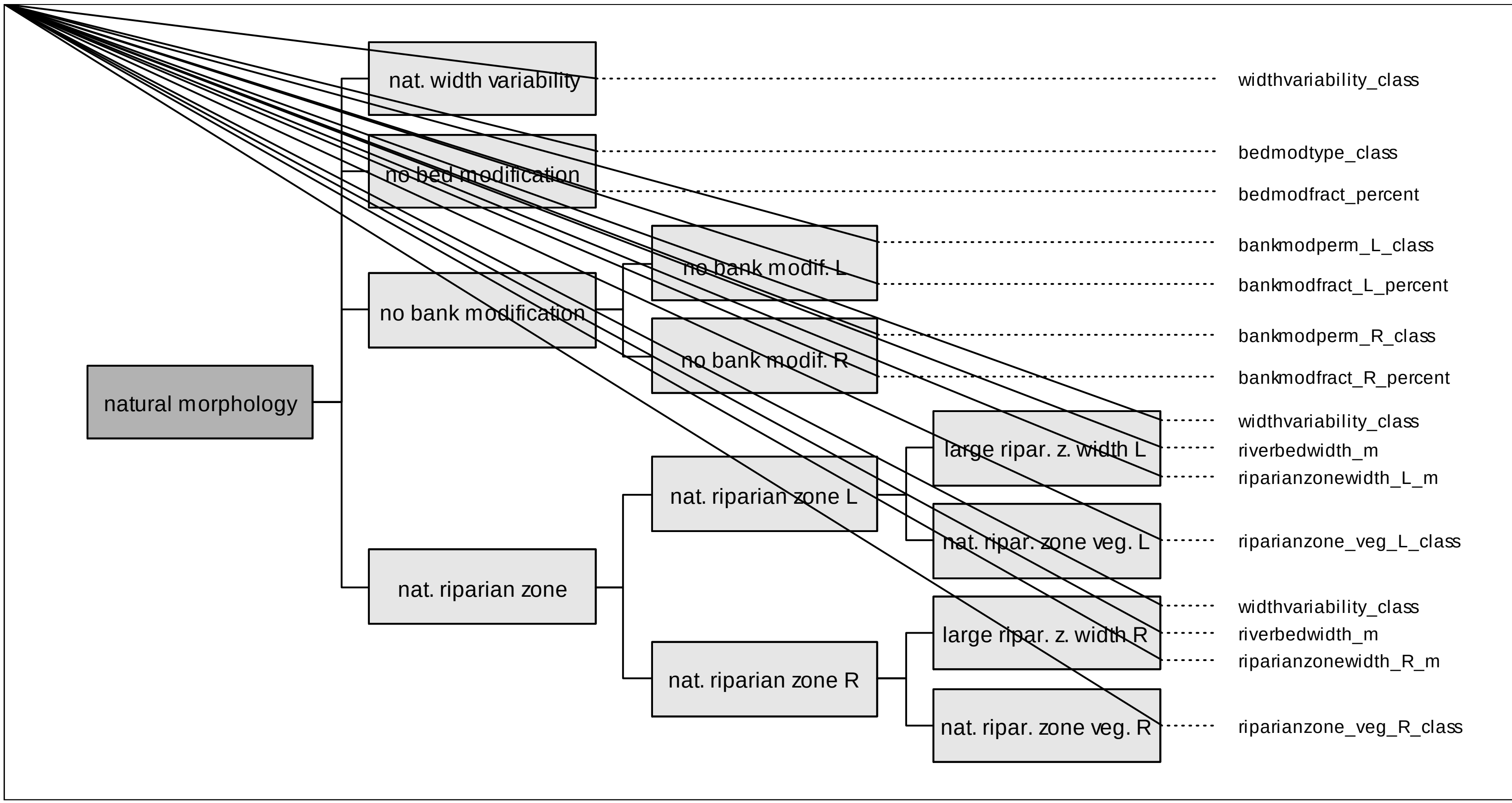


Important Principles:

- Define **problem framing**
- **Structure the decision making process**
- **Discuss objectives**, not alternatives («value-focused thinking)
- Explicitly distinguish **«objective», scientific predictions** from **subjective, societal valuations**
- Increase **transparency**
- Stimulate **creative thinking**
- Consider **uncertainty**
- **Iterate**, if possible

1. Concepts of Decision Support Techniques

An objectives hierarchy resolves aspects of overarching objectives into complementary subobjectives at the next lower level



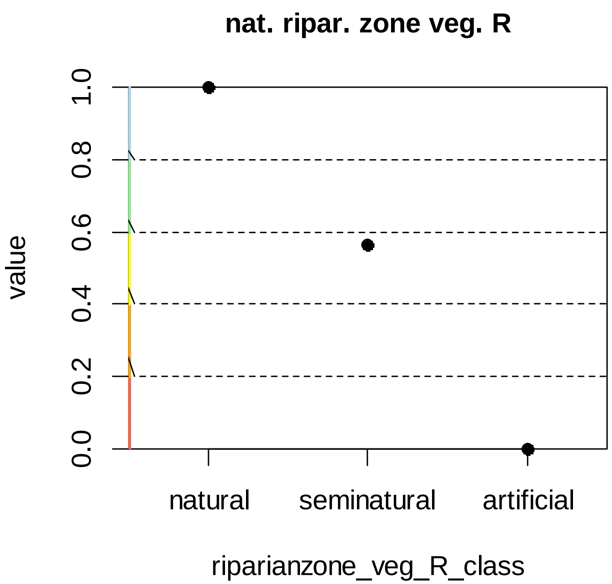
overall objective | 1st level | 2nd level subobjectives | 3rd level | attributes

1. Concepts of Decision Support Techniques

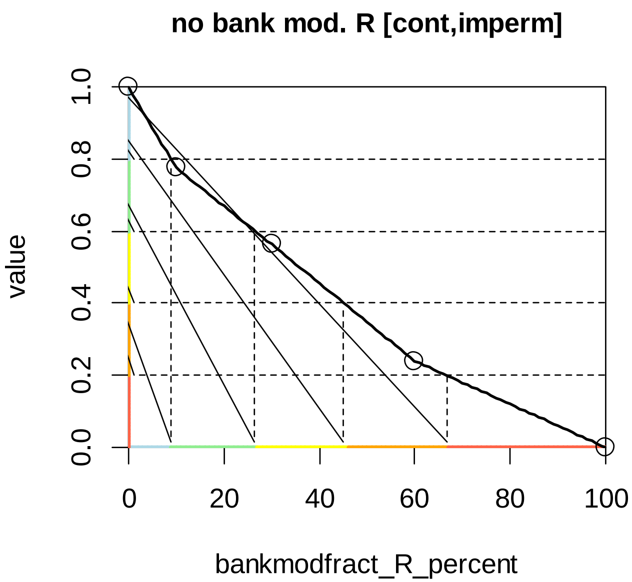
A value function quantifies the degree of achievement of an objective.

Value functions can be constructed using objectives hierarchies.

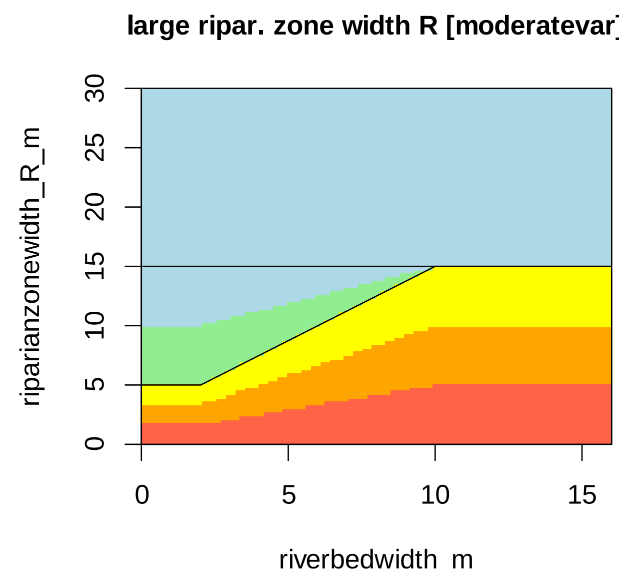
Value functions of end nodes are defined as functions of observed/predicted attributes:



single attribute
discrete



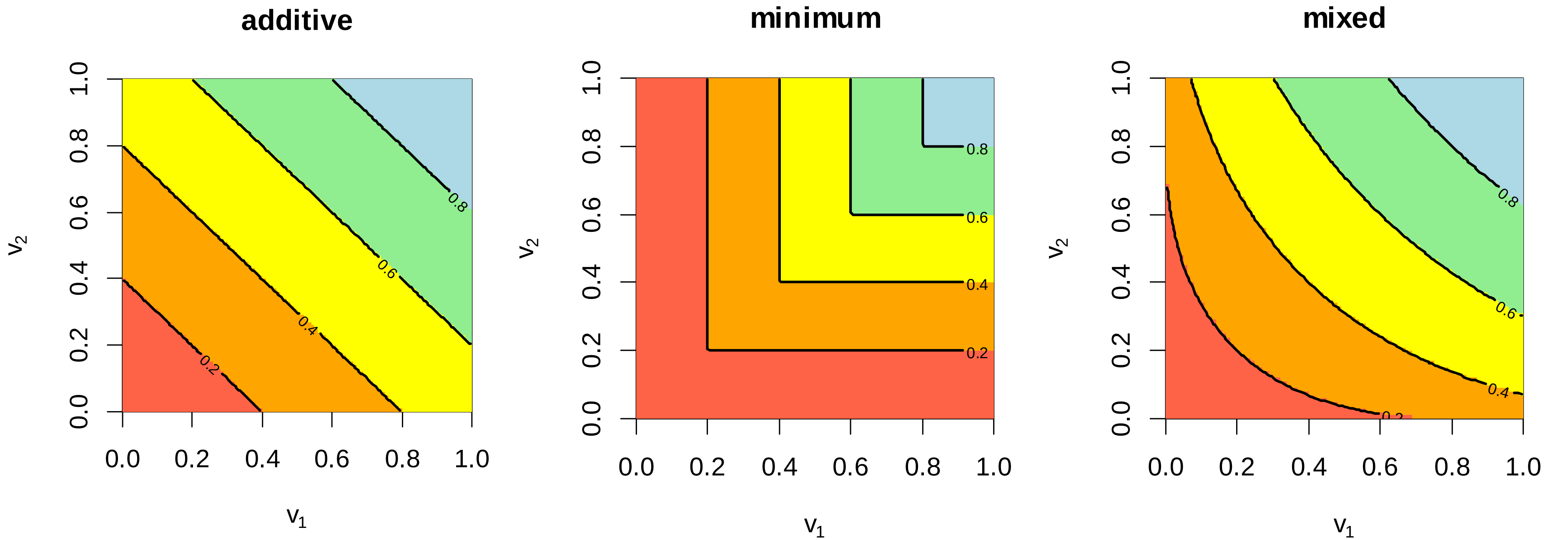
single attribute
continuous



multiple attribute
continuous

1. Concepts of Decision Support Techniques

Values at higher nodes are constructed by aggregating values from nodes at the next lower hierarchical level



full compensation .. no compensation .. partial compensation ..

of poor values at some subobjectives by good values of other subobjectives

1. Concepts of Decision Support Techniques

To evaluate the current state, value functions can be evaluated at observed attribute levels.

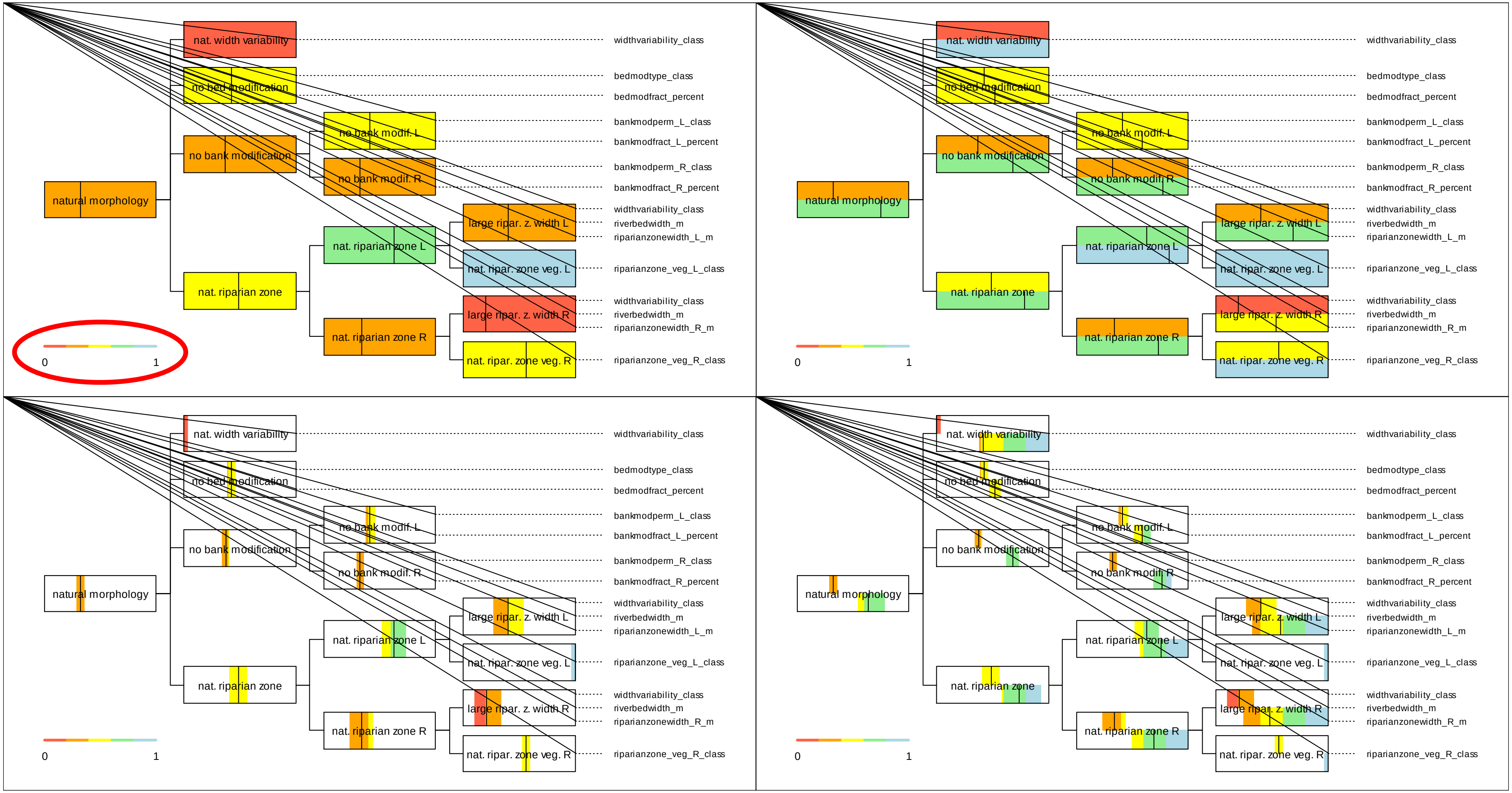
To evaluate decision alternatives, there consequences in the form of attribute levels must be predicted and the value function must be evaluated for all these predictions.

The alternative with the highest predicted value is the preferred alternative.

Uncertainty can be considered by propagation to the values and by considering risk attitudes.

1. Concepts of Decision Support Techniques

Visualization of results:

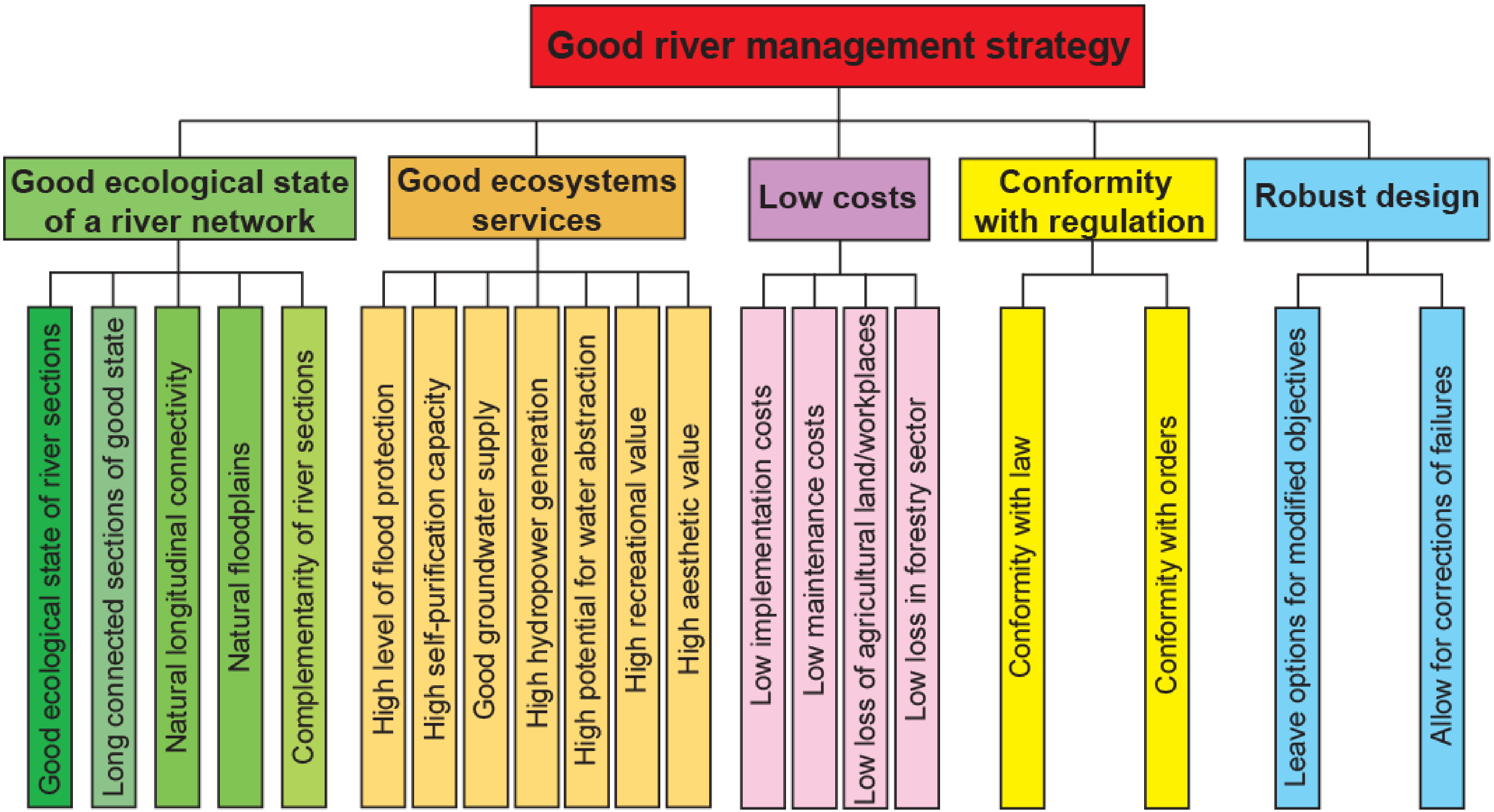


Content

2. Decision Support for River Management

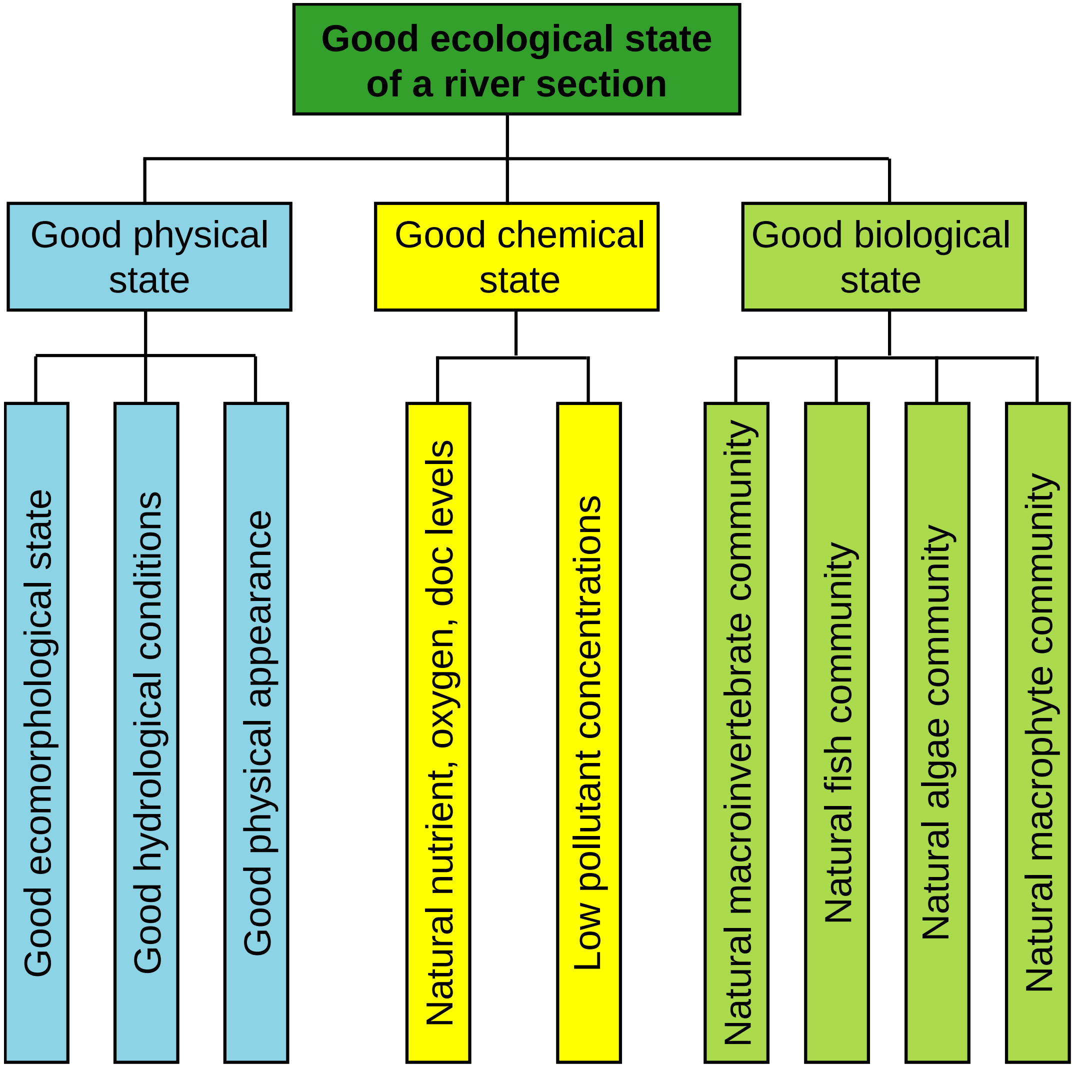
2. Decision Support for River Management

Societal objectives of river management:



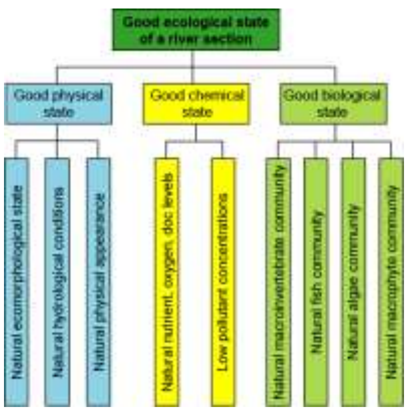
2. Decision Support for River Management

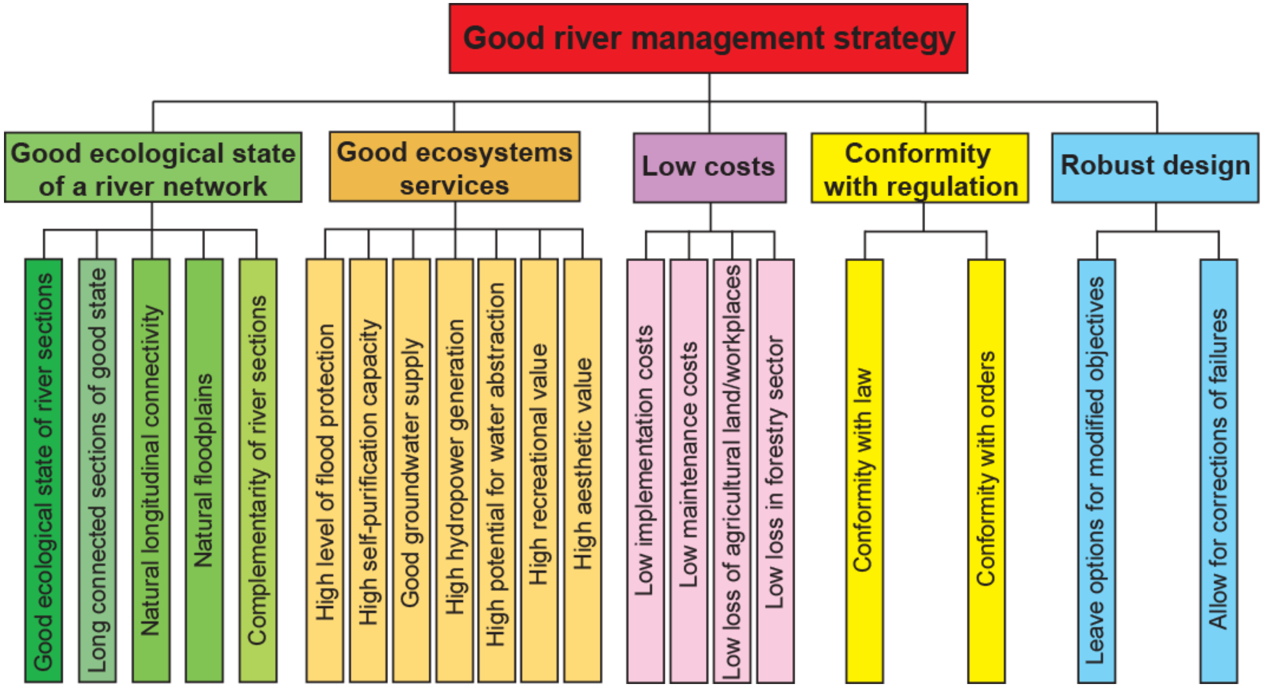
Ecological objectives for a river section:



2. Decision Support for River Management

Elicitation of values:





Experts
(researchers, practitioners)

Society
(elicitation from stakholders or public)

2. Decision Support for River Management

Elicitation of values:

- **Ecological value of river reach:** **Established, generic procedures**; only improvements required.
- **Ecological value of river network**: **New innovative concepts needed**; accounting for connectivity, resilience, etc.
- **Trade-offs between the ecological state, other ecosystem services and costs**: **must be elicited from the society**:
  - Elicitation from selected stakeholders, discussion in stakeholder committees
  - Derivation from discrete choice experiments from a broader public

Content

3. **Case Study**

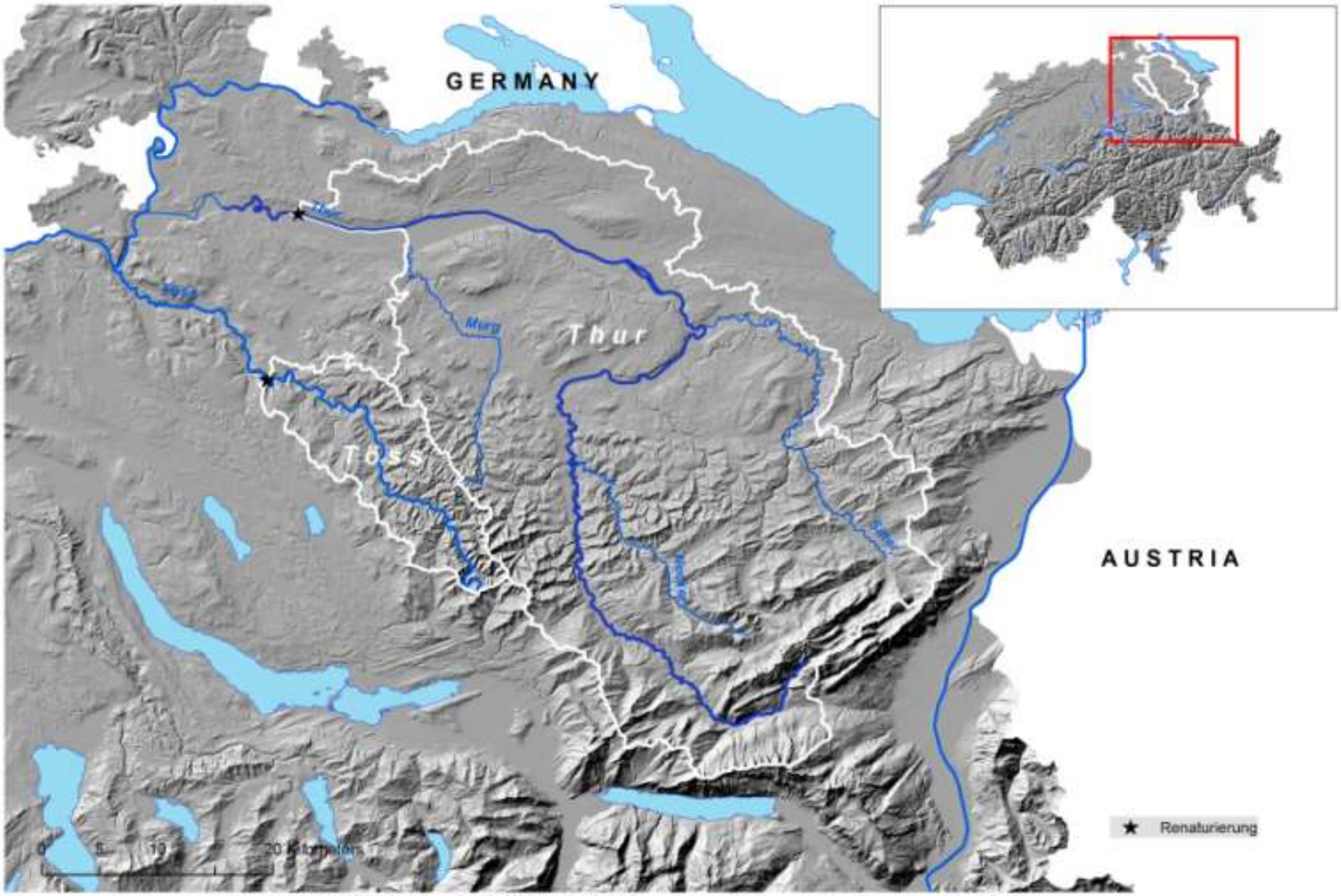
    a. Assessment of Ecological State of a River Section

    b. Assessment of Ecological State of a River Network

    c. Formulation of Synergies/Trade-offs with other Societal Goals

3. Case Study: a. Ecological State of River Section

Thur and Töss restoration sites (Reform case study location)



Data source: swisstopo (Art. 30 GeoIV): 5704 000 000 / Vector25©2008, DHM25©2003 (reproduced with permission of swisstopo / JA100119); Arealstatistik 1992/97, Bundesamt für Statistik (BFS), GEOSTAT

Catchment areas:
1610 km2
187 km2

3. Case Study: a. Ecological State of River Section

Thur and Töss restoration sites (Reform case study location)

degraded | rehabilitated | Overview

Thur

Töss

3. Case Study: a. Ecological State of River Section

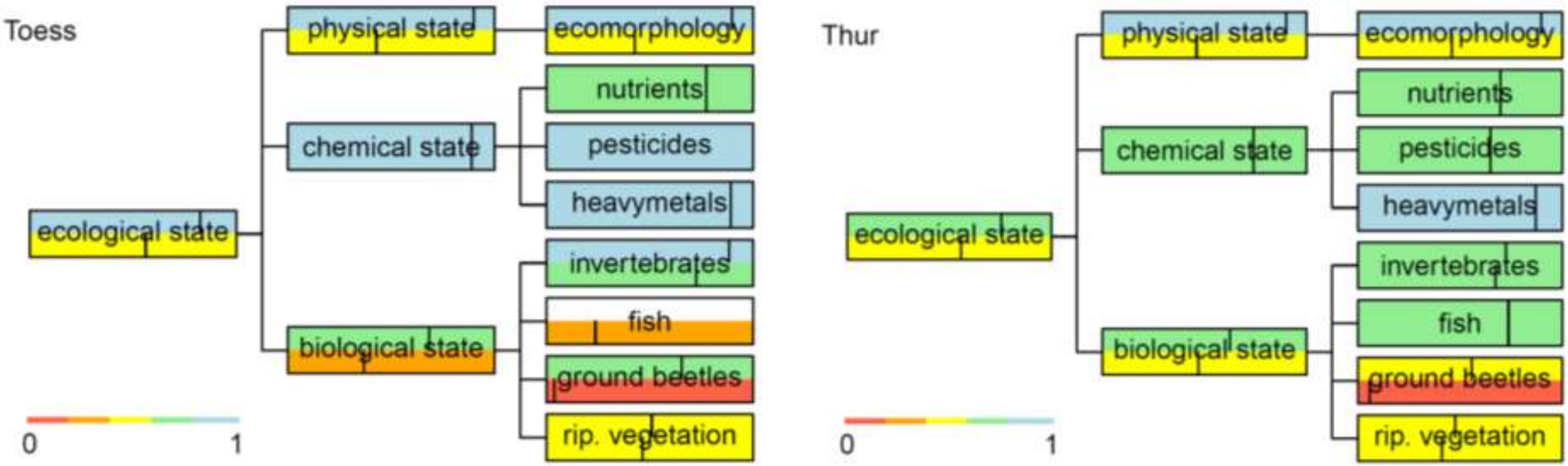
Quantify the ecological state of these sections by establishing the

- physical state
- chemical state
- biological state

and aggregating these into the overall ecological state

3. Case Study: a. Ecological State of River Section

Overall Ecological State (upper part: rehabilitated / lower part: degraded)



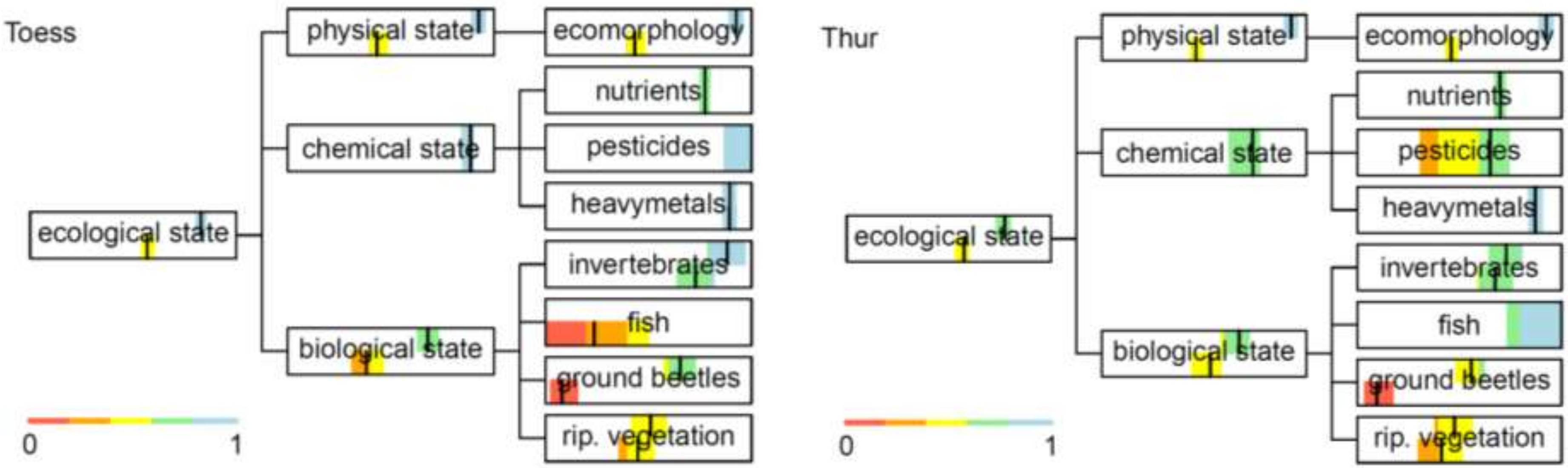
physical state: similar improvement for Töss and Thur rivers

chemical state: no change (pesticides still problematic for Thur)

biological state: higher effect in Töss river compared to Thur

3. Case Study: a. Ecological State of River Section

Overall Ecological State (upper part: rehabilitated / lower part: degraded)



physical state: similar improvement for Töss and Thur rivers

chemical state: no change (pesticides still problematic for Thur)

biological state: higher effect in Töss river compared to Thur

Content

3. Case Study

a. Assessment of Ecological State of a River Section

b. Assessment of Ecological State of a River Network

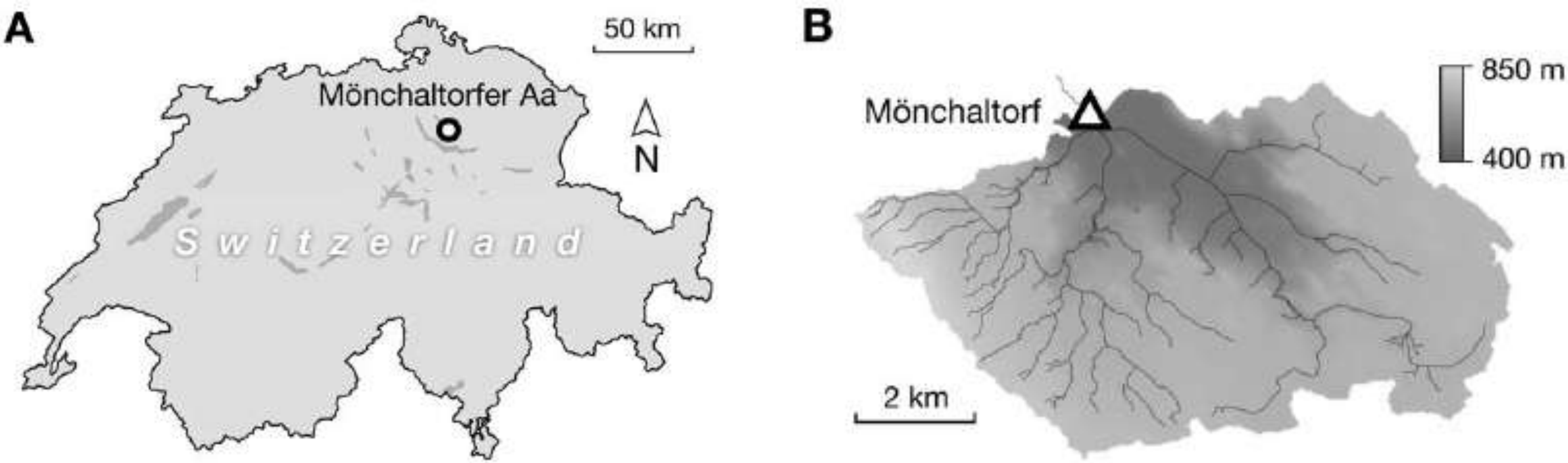
c. Formulation of Synergies/Trade-offs with other Societal Goals

3. Case Study: b. Ecological State of River Network

What is a good ecological state of a river network?

Illustration based on the ecomorphological state; the concepts are extensible to other assessment areas, but the prediction of the consequences of rehabilitation actions is usually more difficult.

Example: Catchment of Mönchaltorfer Aa, Switzerland (46 km2)



3. Case Study: b. Ecological State of River Network

Goals for a good ecological state of the river network:

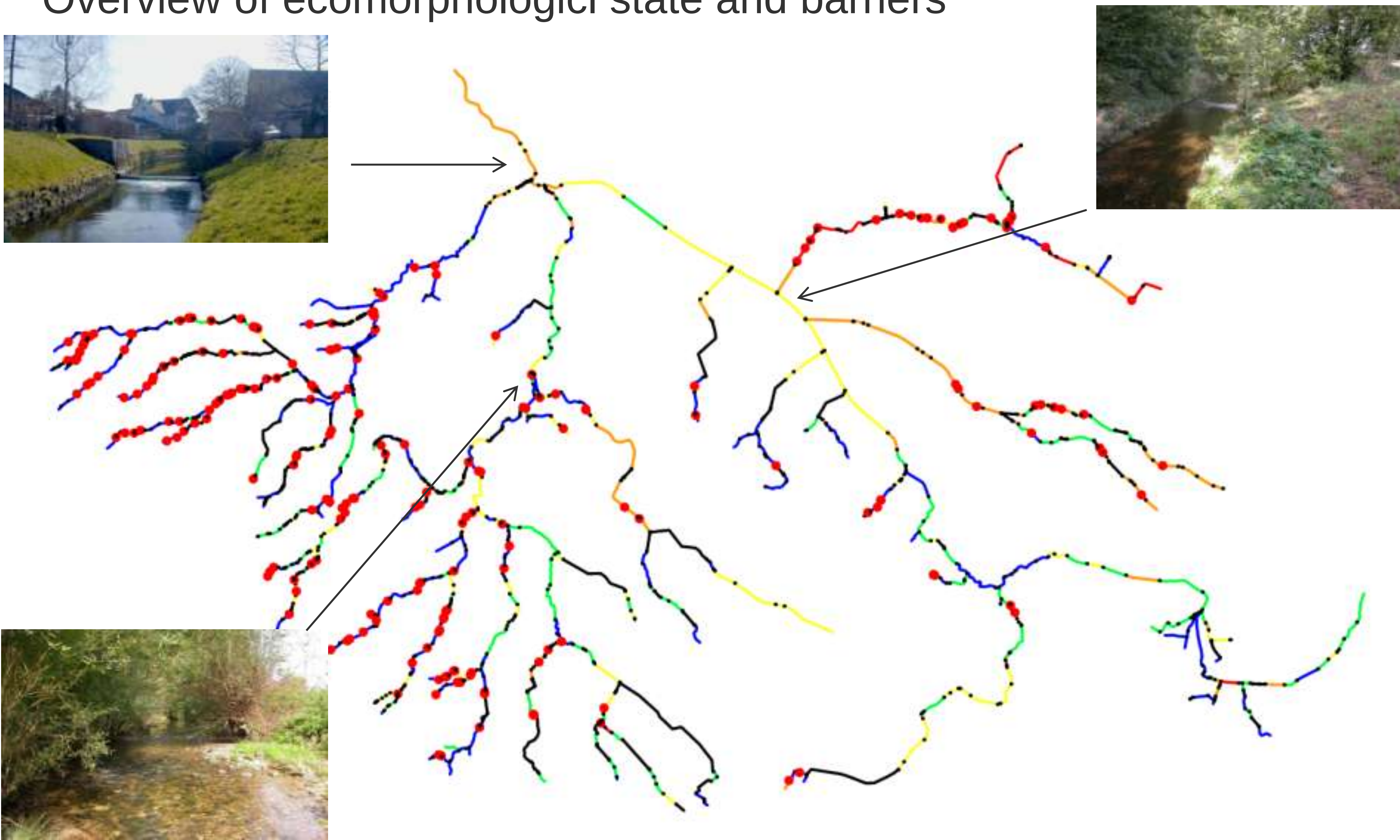
- **many reaches in a good state**
- **high connectivity** (in particular fish migration)
- **high resilience** (good recovery potential after disturbance)

Quantifiable attributes («proxies»; to be improved!!):

- **mean average value**
- **fraction of reachable headwaters**
- **river length of largest region with adjacent reaches in a good state** (normalized with the total river length)

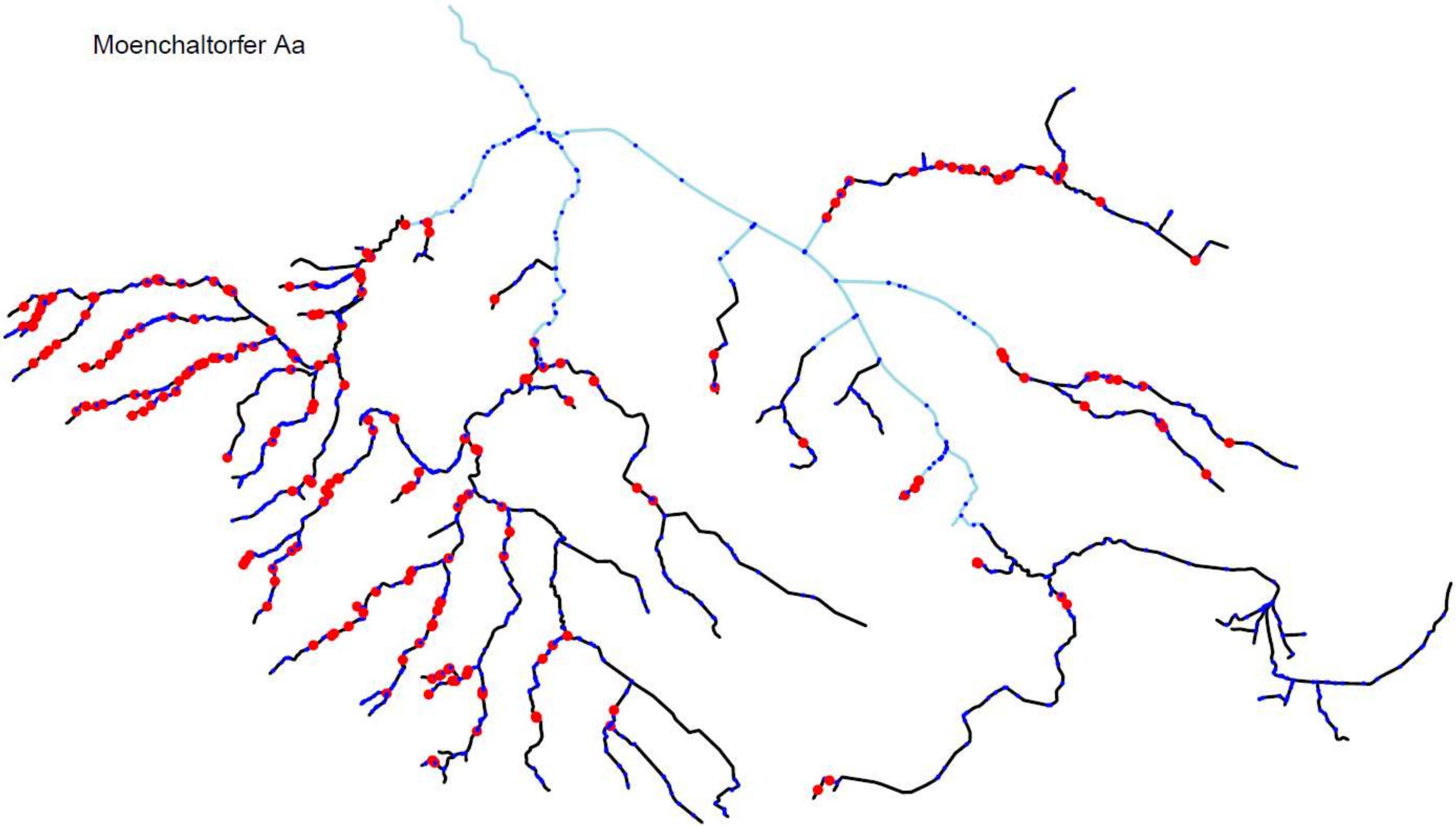
3. Case Study: b. Ecological State of River Network

Overview of ecomorphologicl state and barriers



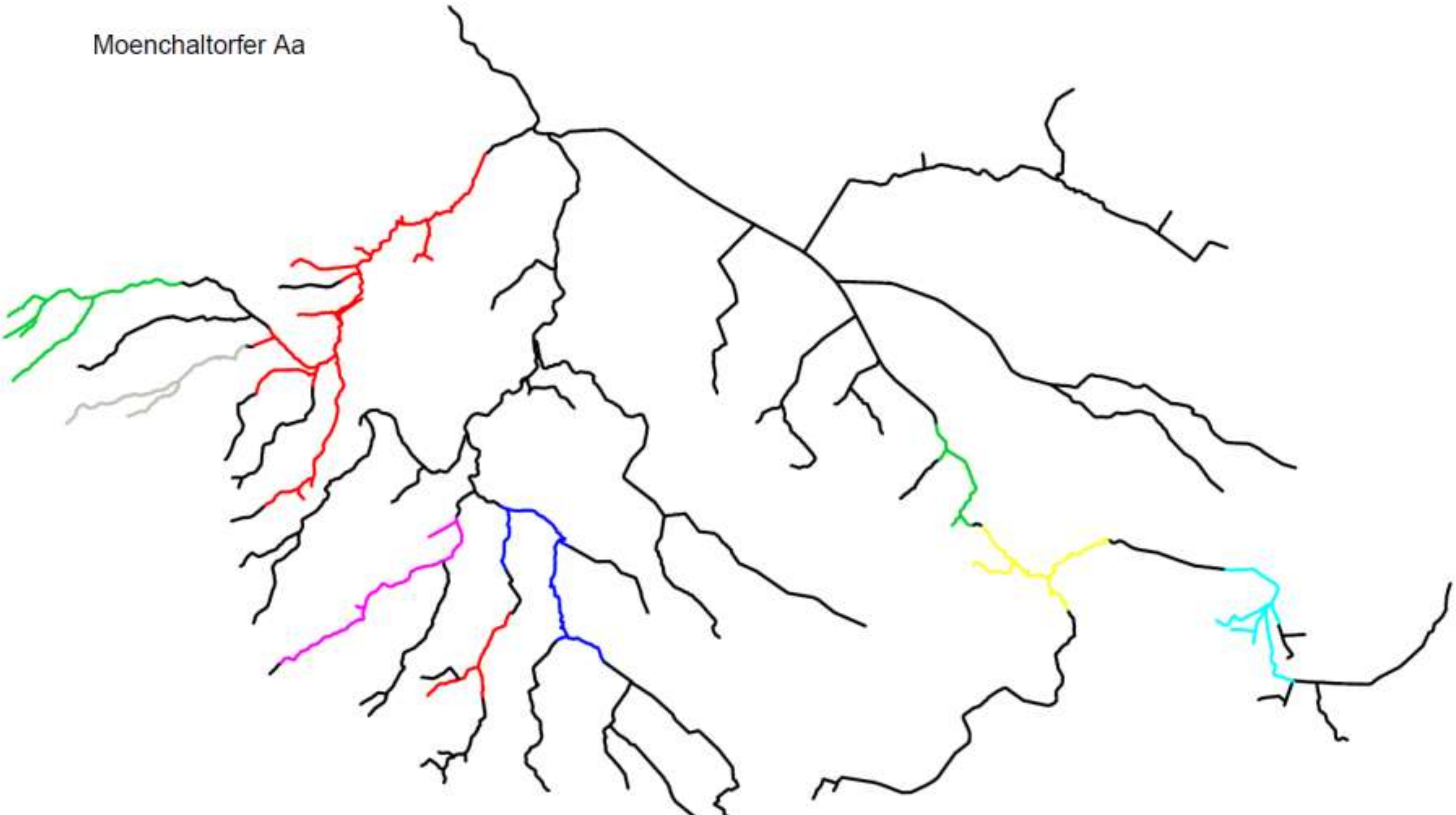
3. Case Study: b. Ecological State of River Network

Overview of reachable headwaters



3. Case Study: b. Ecological State of River Network

10 largest regions with adjacent reaches in a good state:



3. Case Study: b. Ecological State of River Network

Obviously, to improve the criteria, it is crucial which barriers to remove and which reaches to rehabilitate.

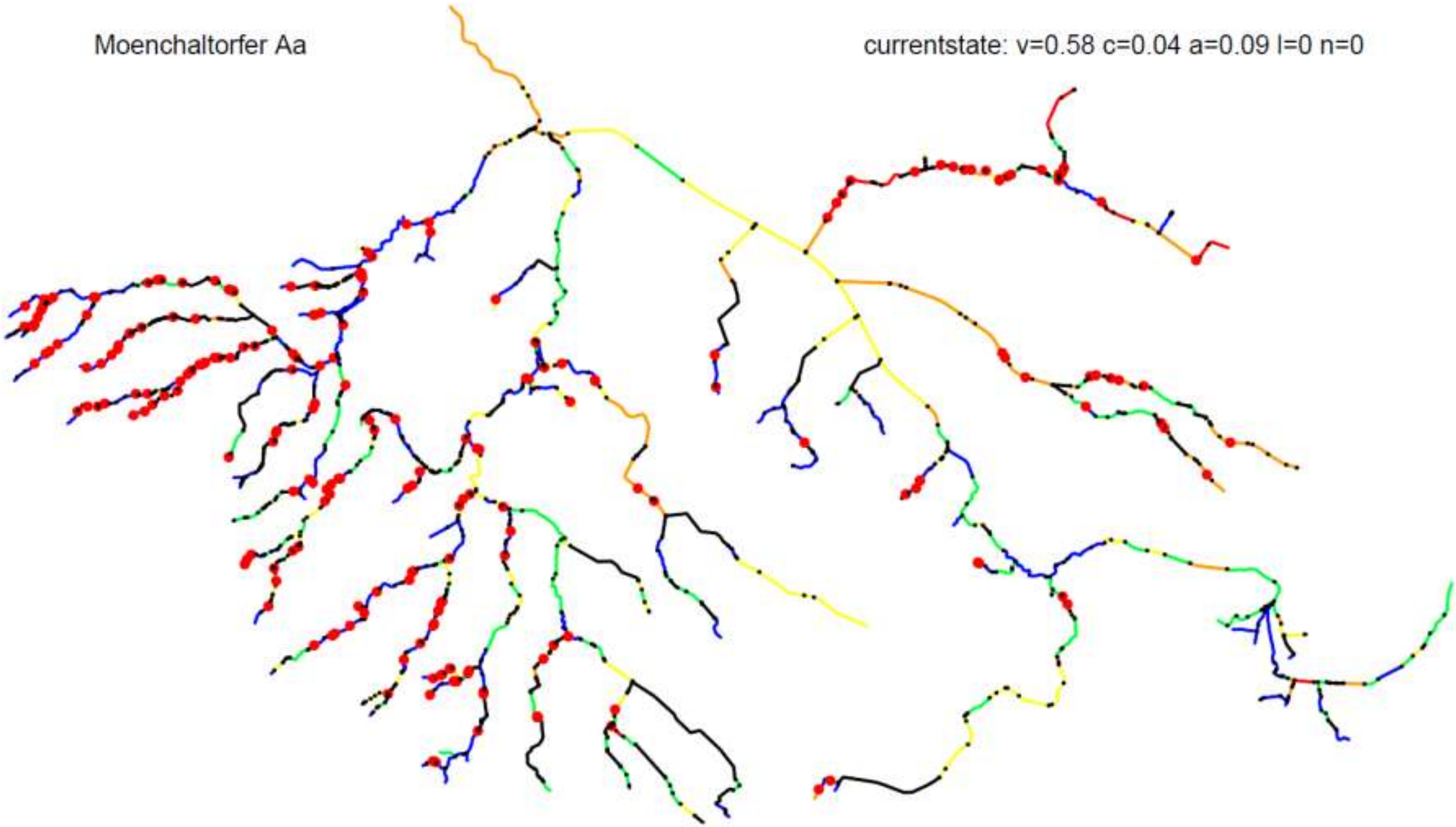
The average state improves with whichever reach is rehabilitated; additional gains are particularly high if

- reaches adjacent to regions of good state are rehabilitated,
- reaches bridging between regions of good state are rehabilitated,
- barriers are removed that extend reachable reaches to headwaters.

Some examples on the following slides:

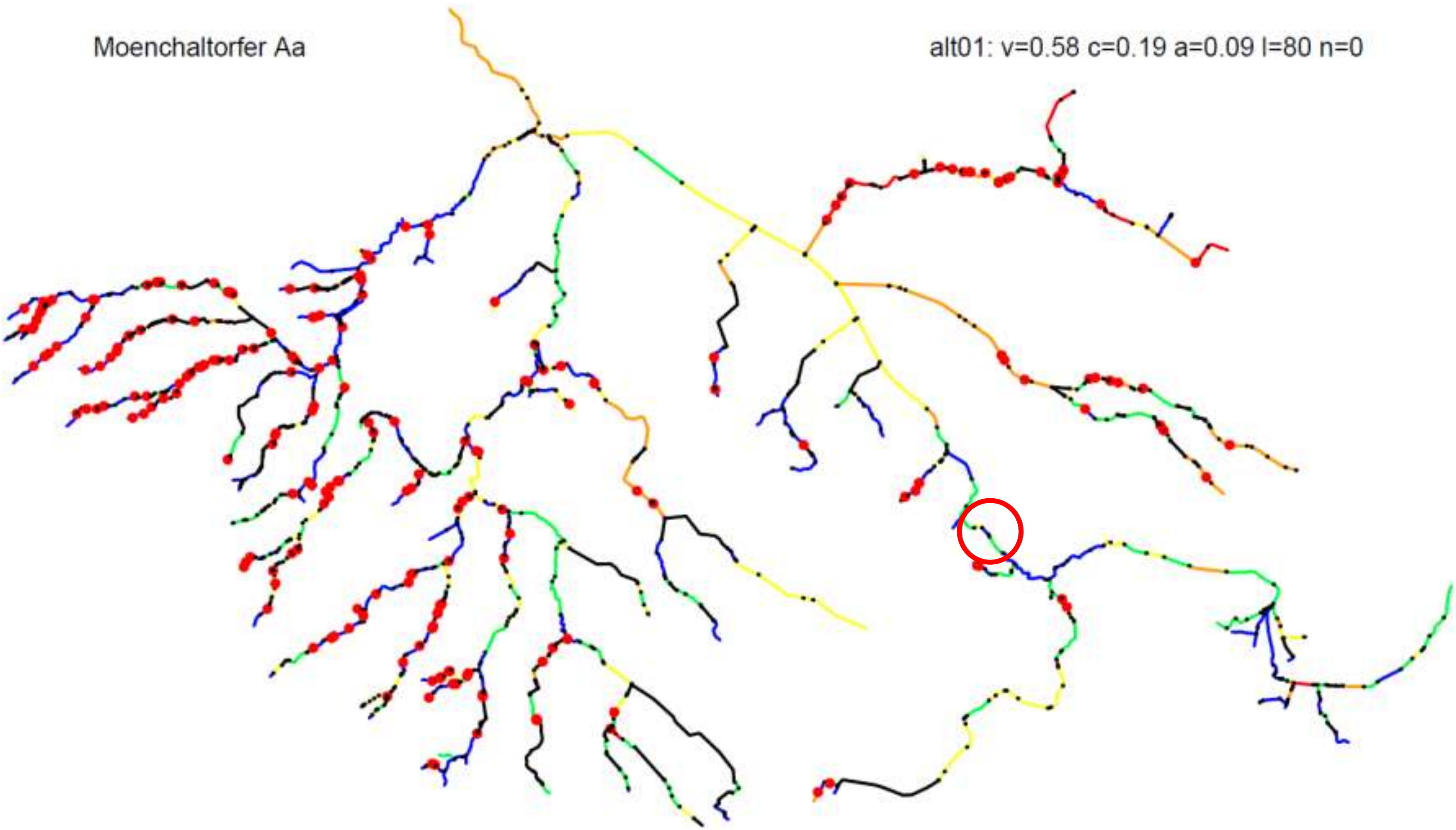
3. Case Study: b. Ecological State of River Network

Ecomorphological state and barriers: current situation



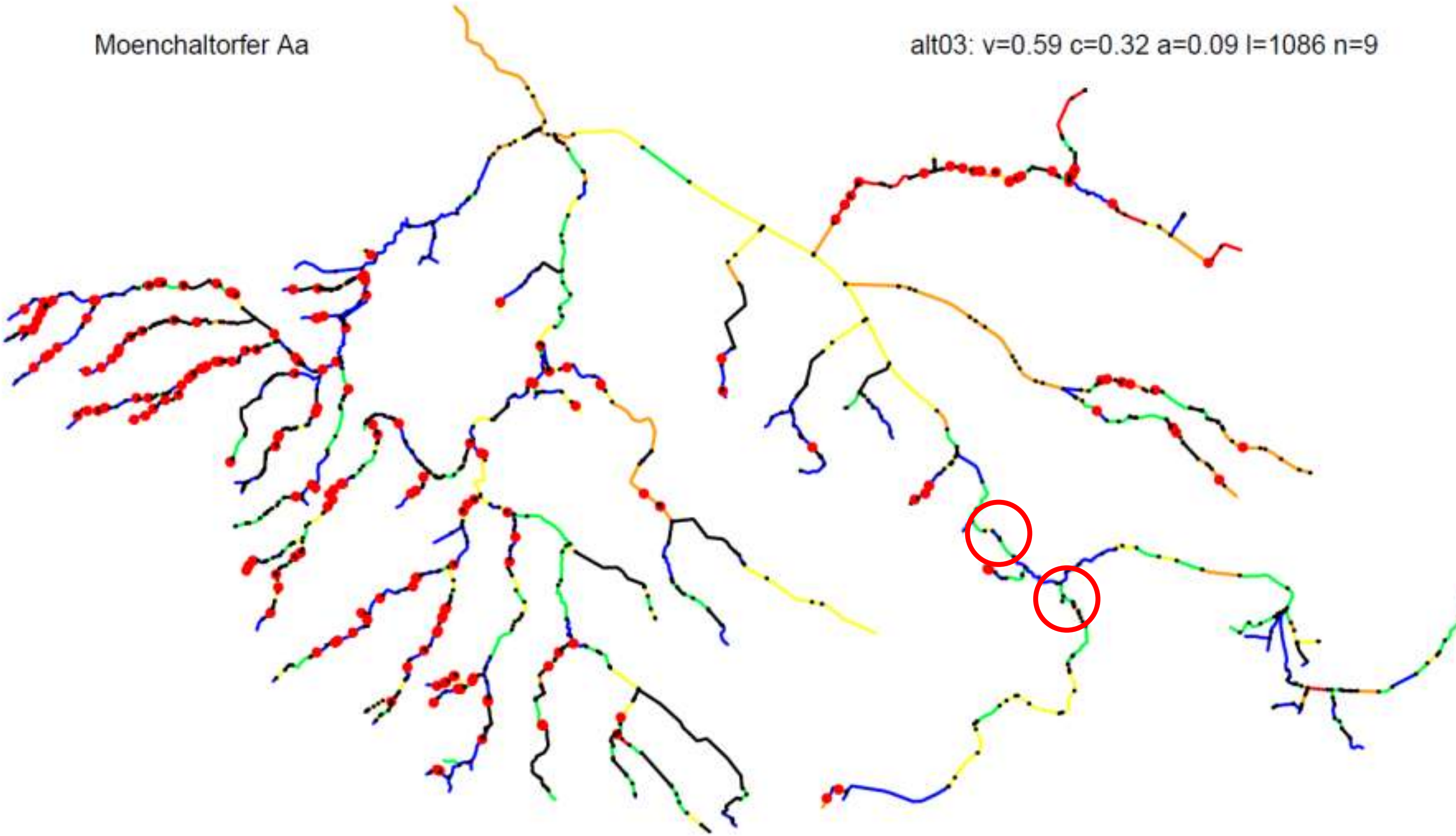
3. Case Study: b. Ecological State of River Network

Ecomorphological state and barriers: alternative 1



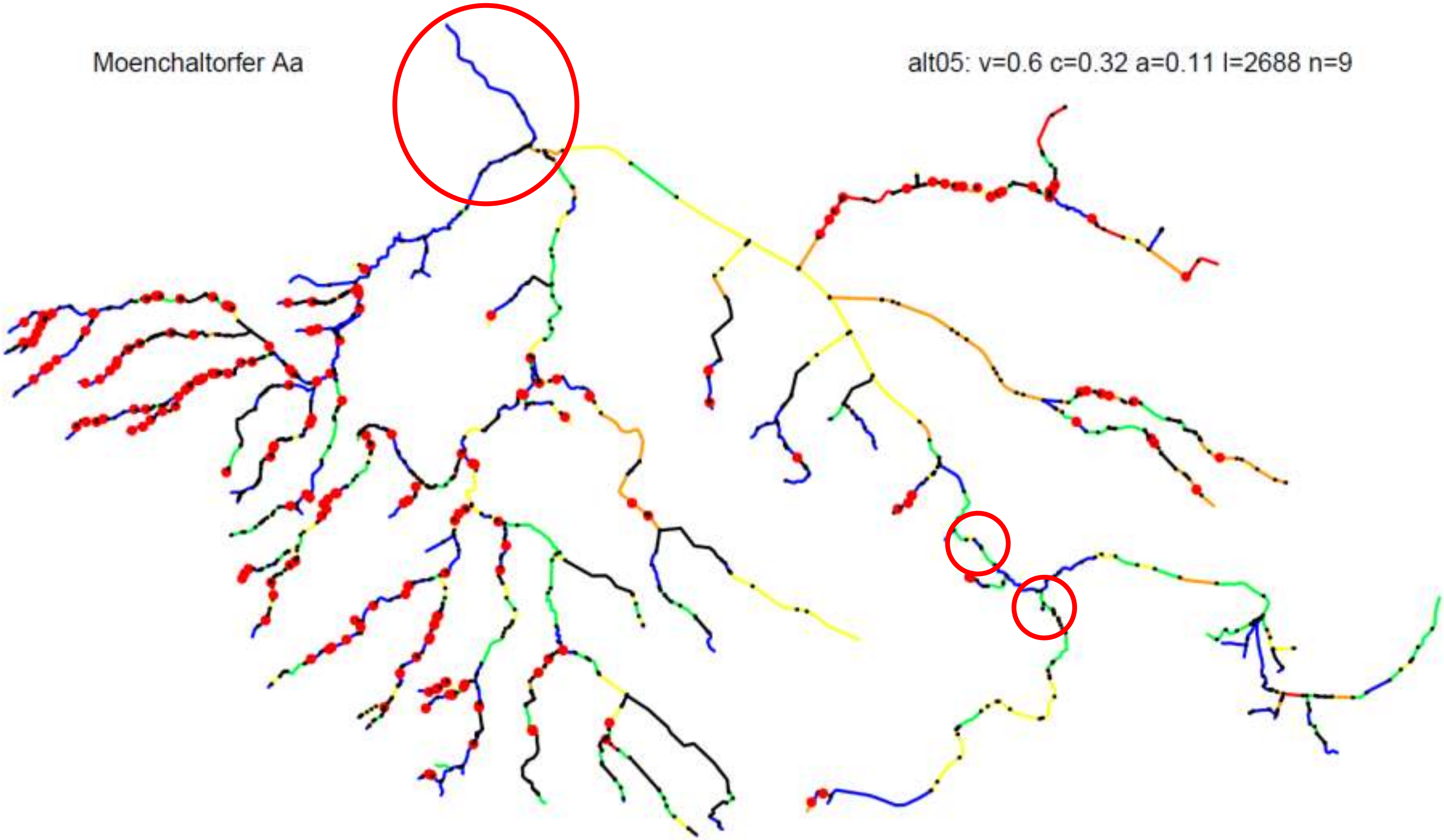
3. Case Study: b. Ecological State of River Network

Ecomorphological state and barriers: alternative 3



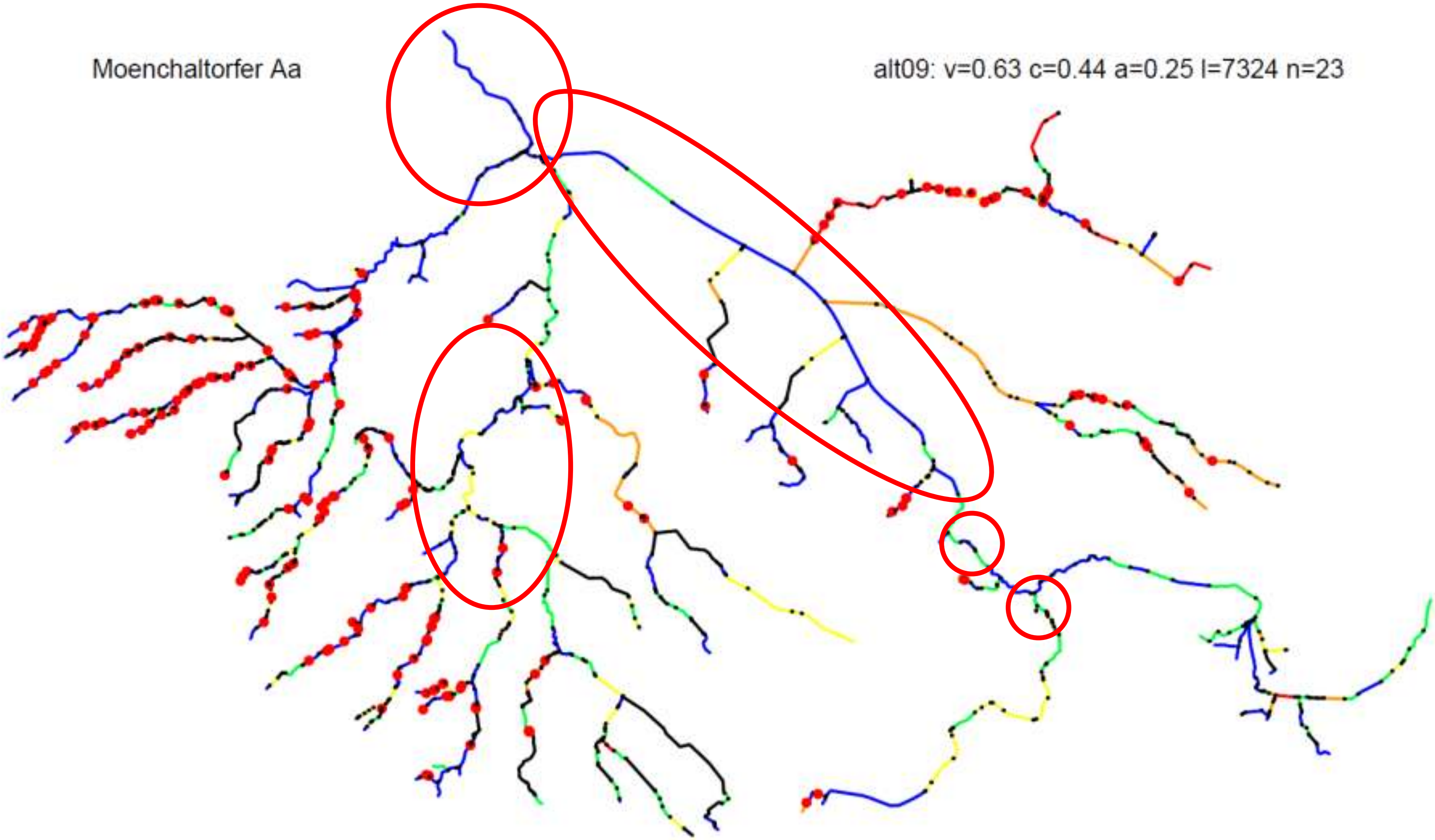
3. Case Study: b. Ecological State of River Network

Ecomorphological state and barriers: alternative 5



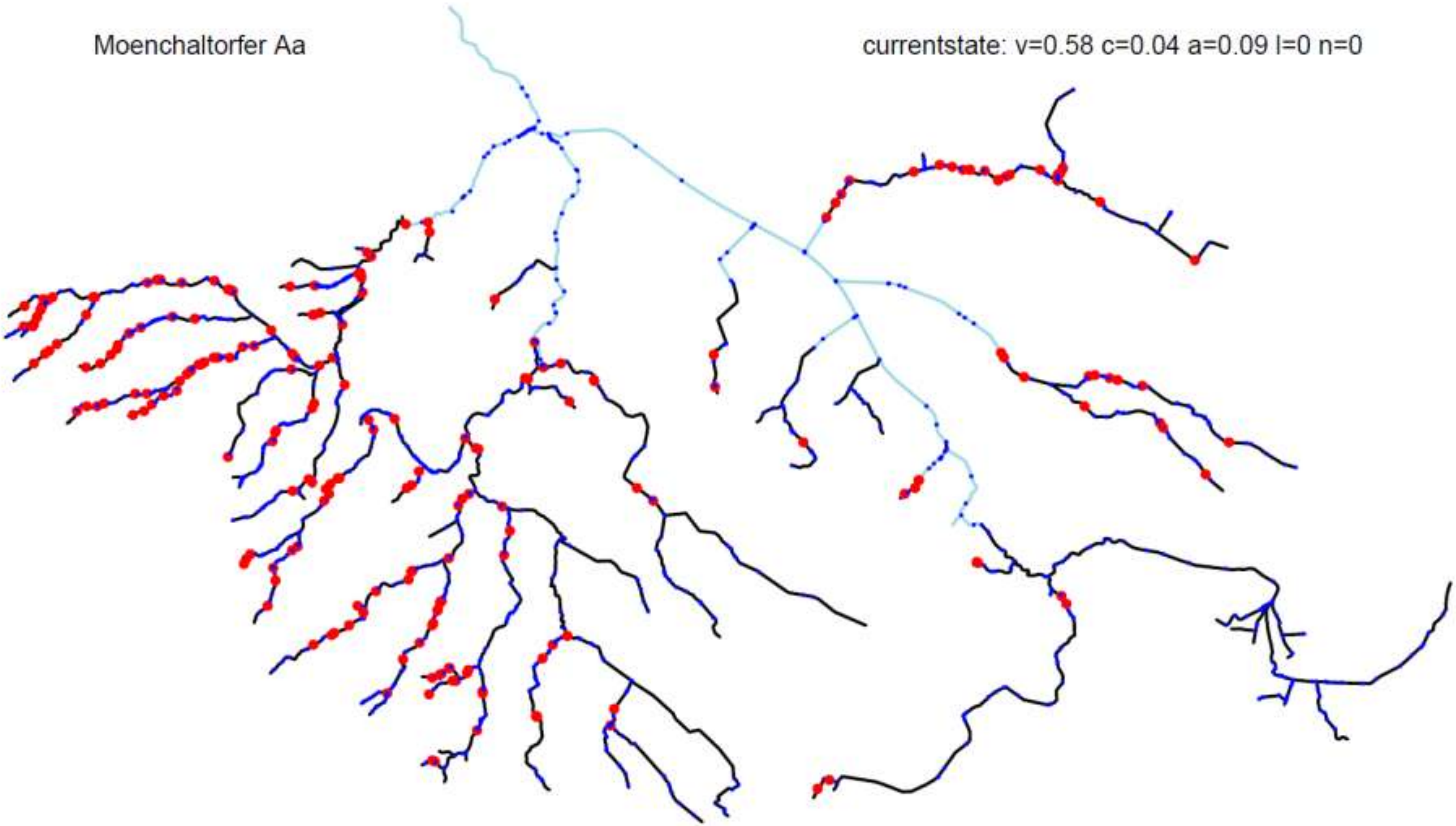
3. Case Study: b. Ecological State of River Network

Ecomorphological state and barriers: alternative 9



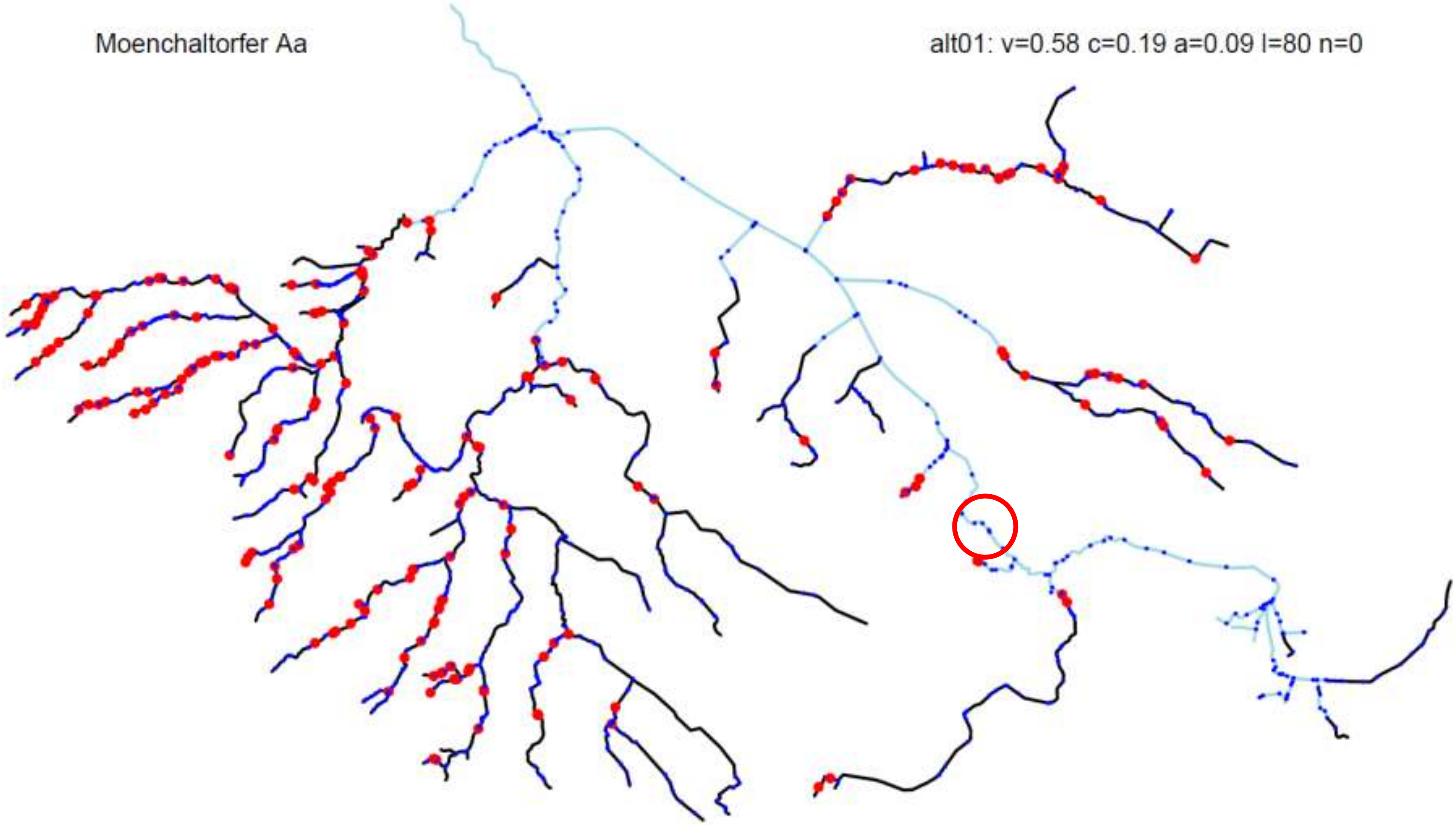
3. Case Study: b. Ecological State of River Network

Reachable headwaters: current situation



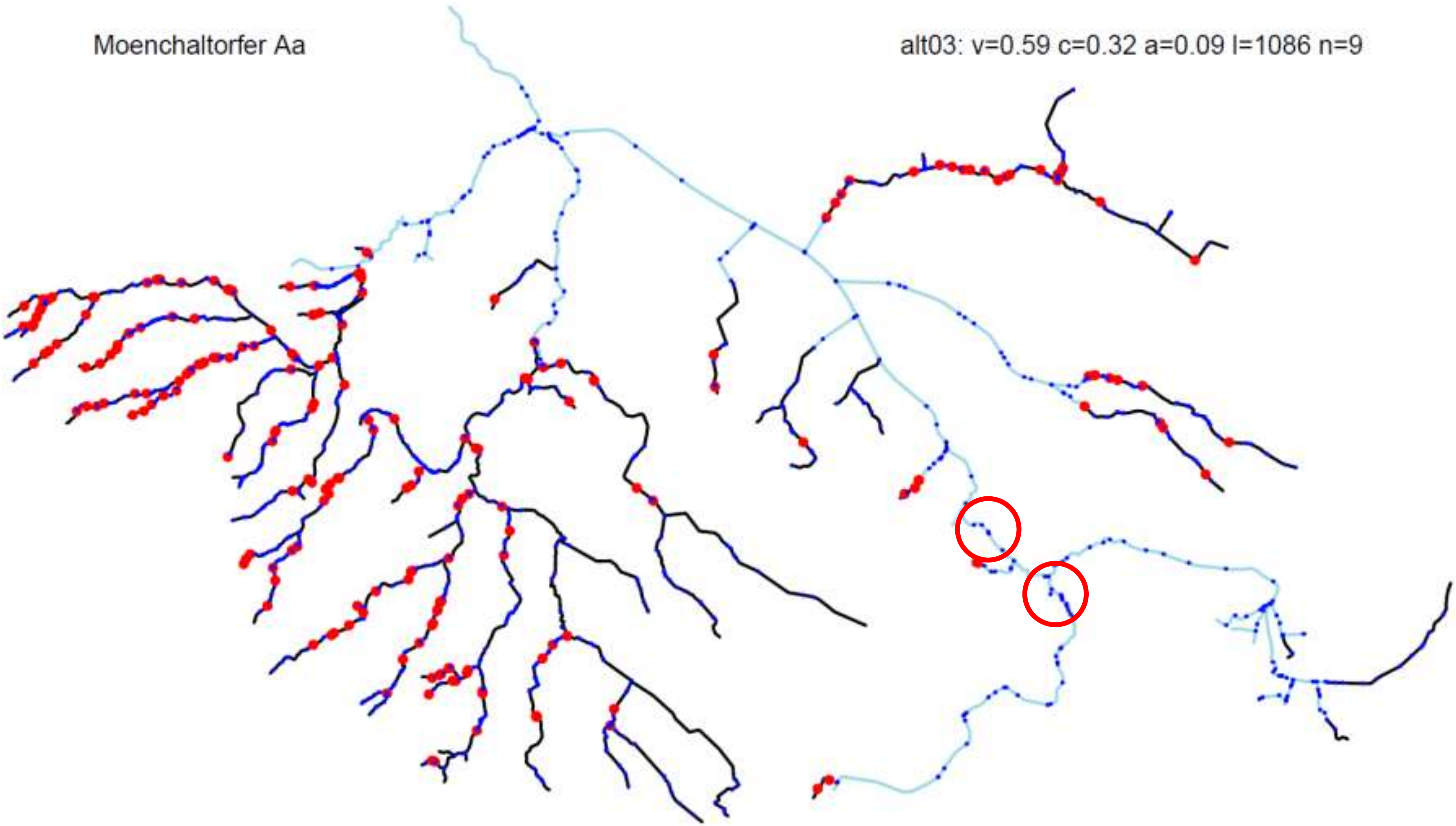
3. Case Study: b. Ecological State of River Network

Reachable headwaters: alternative 1



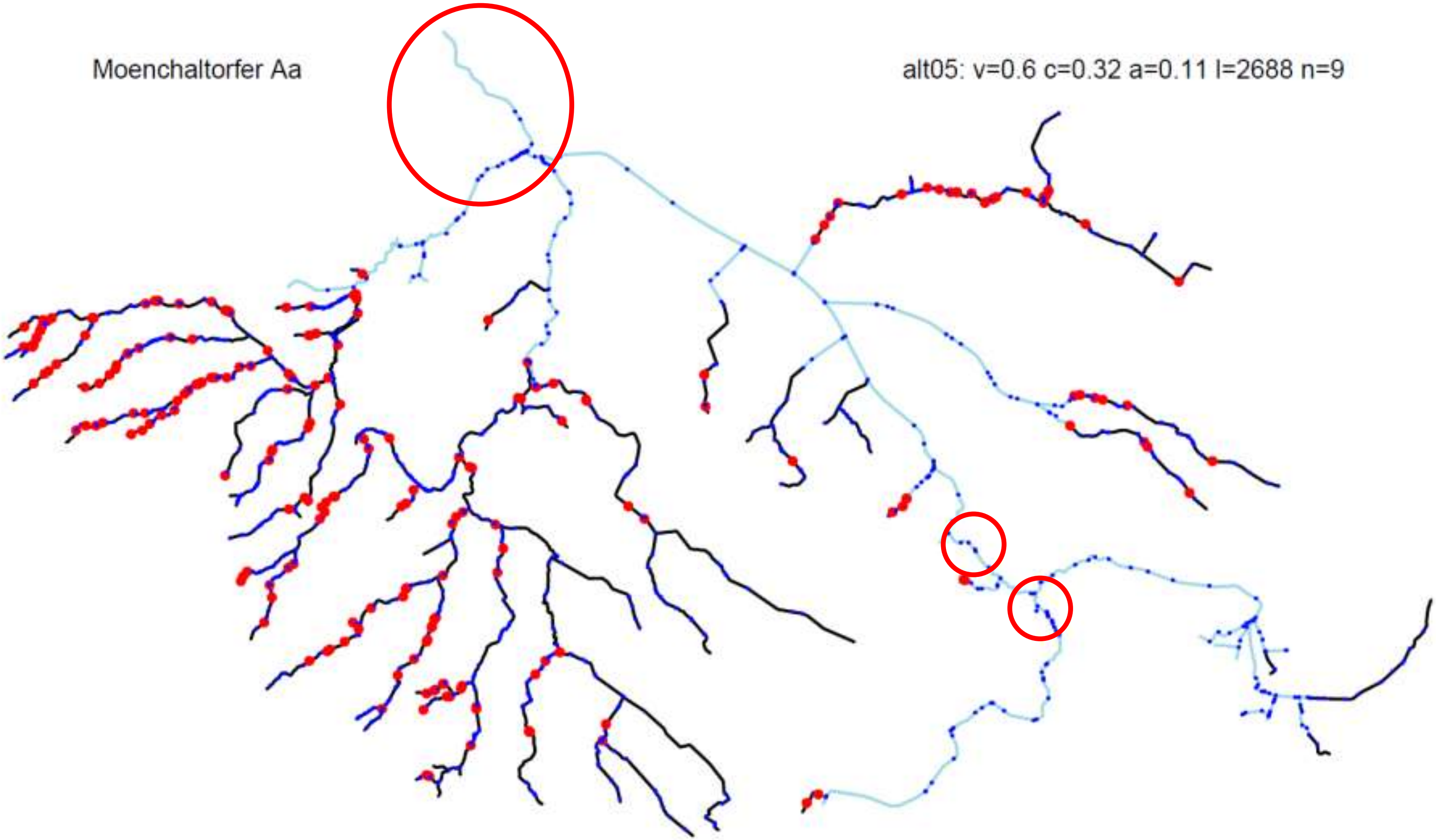
3. Case Study: b. Ecological State of River Network

Reachable headwaters: alternative 3



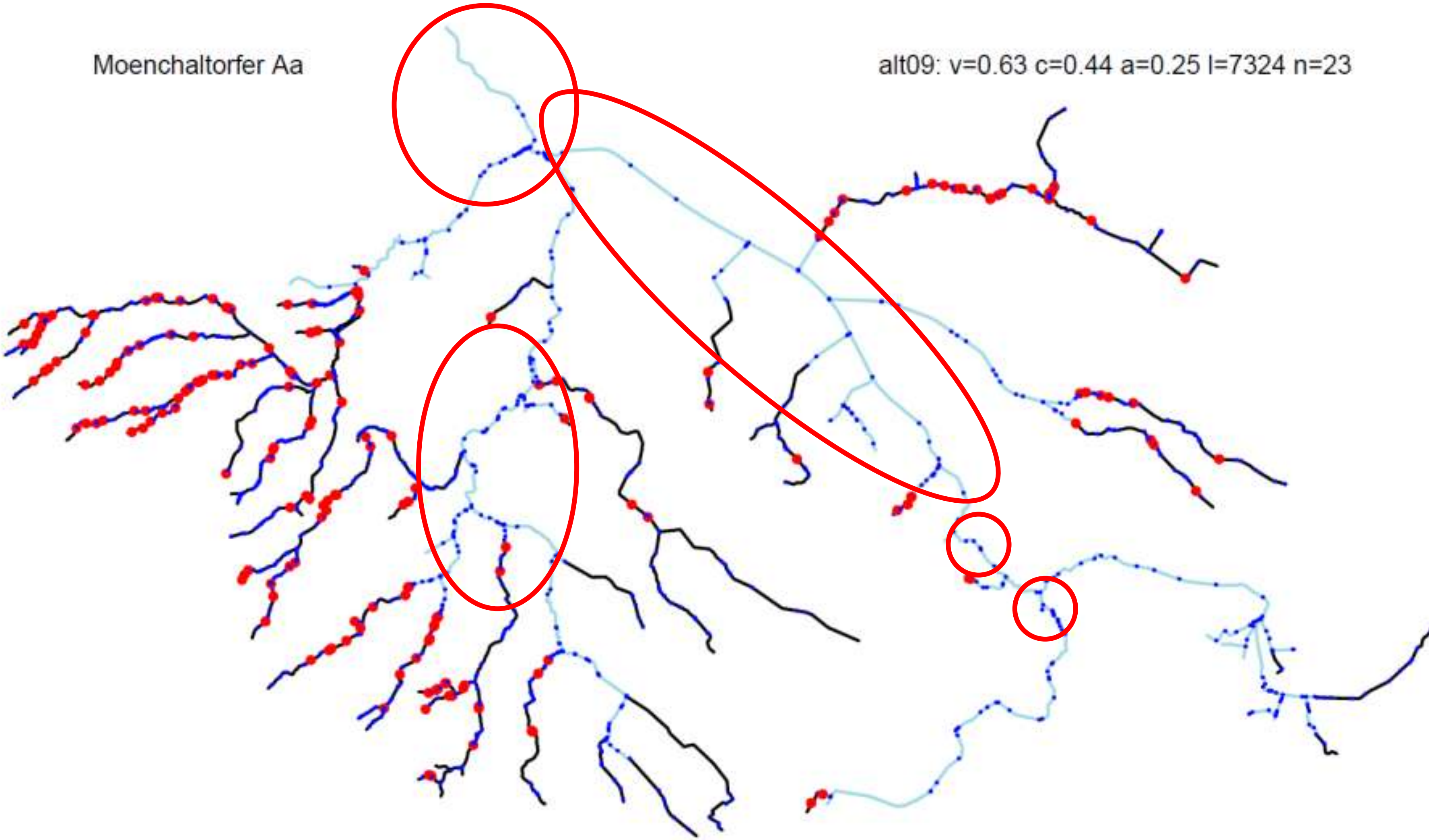
3. Case Study: b. Ecological State of River Network

Reachable headwaters: alternative 5



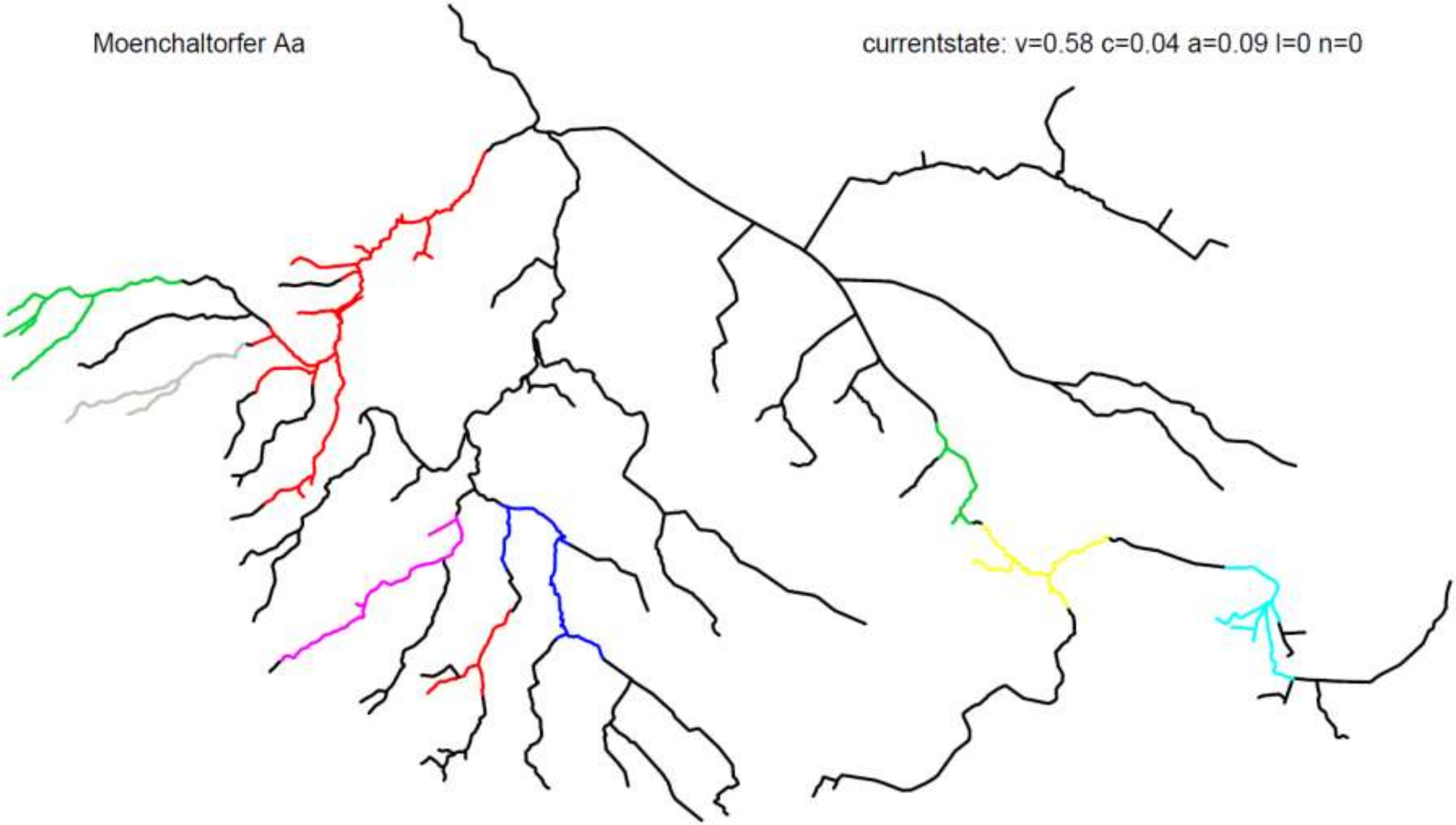
3. Case Study: b. Ecological State of River Network

Reachable headwaters: alternative 9



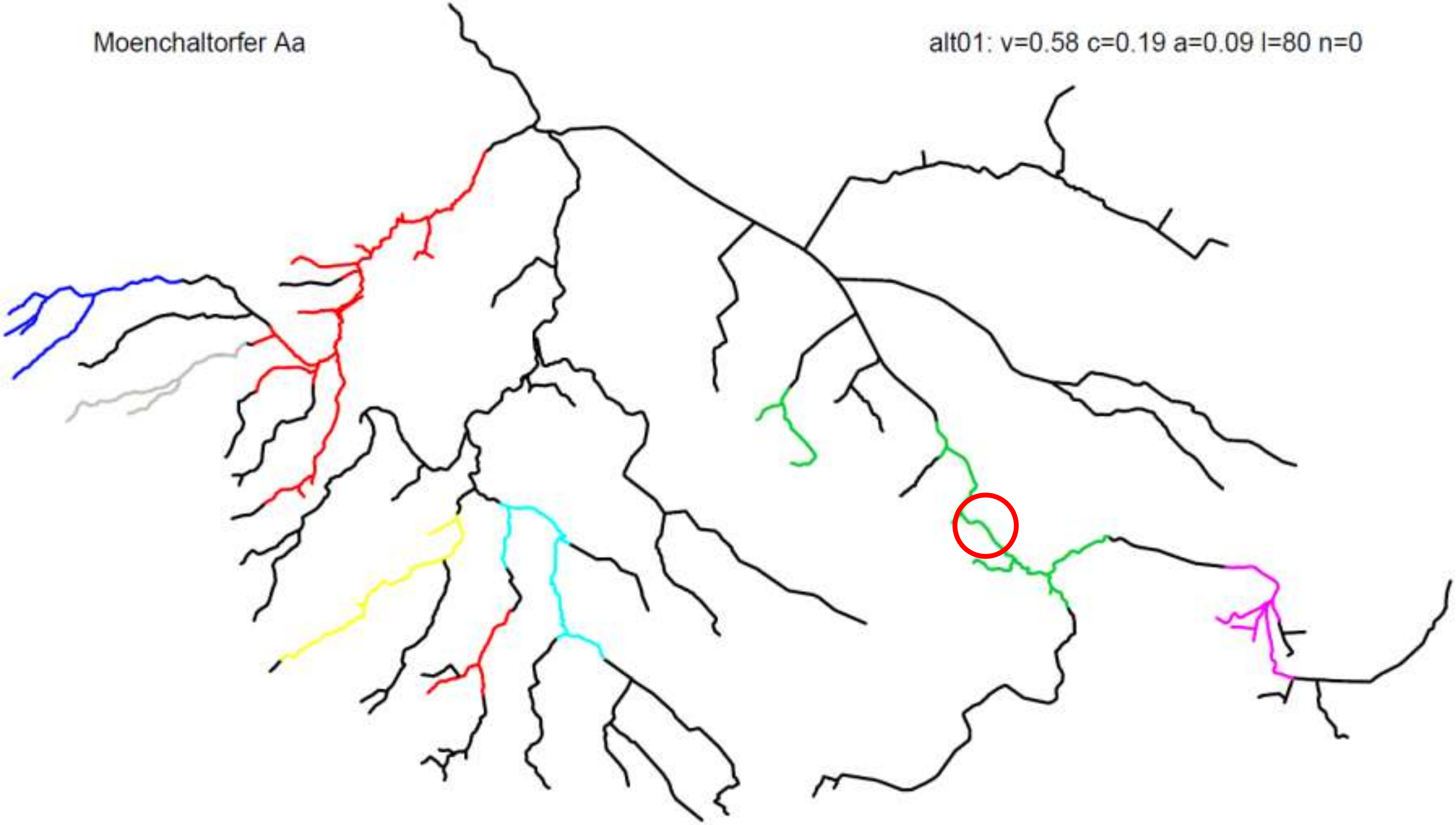
3. Case Study: b. Ecological State of River Network

Largest regions with adjacent reaches in good state: current situation



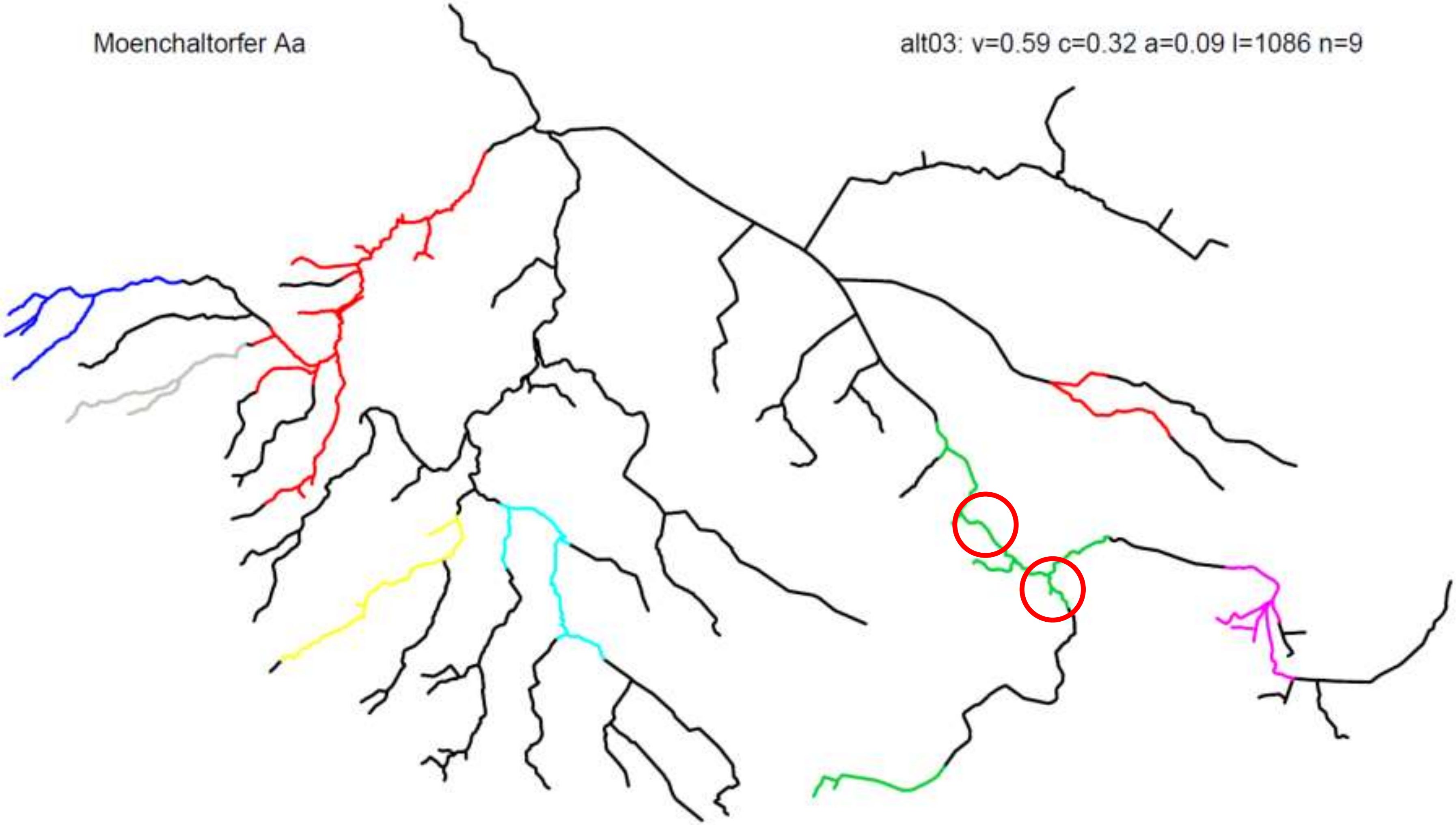
3. Case Study: b. Ecological State of River Network

Largest regions with adjacent reaches in good state: alternative 1



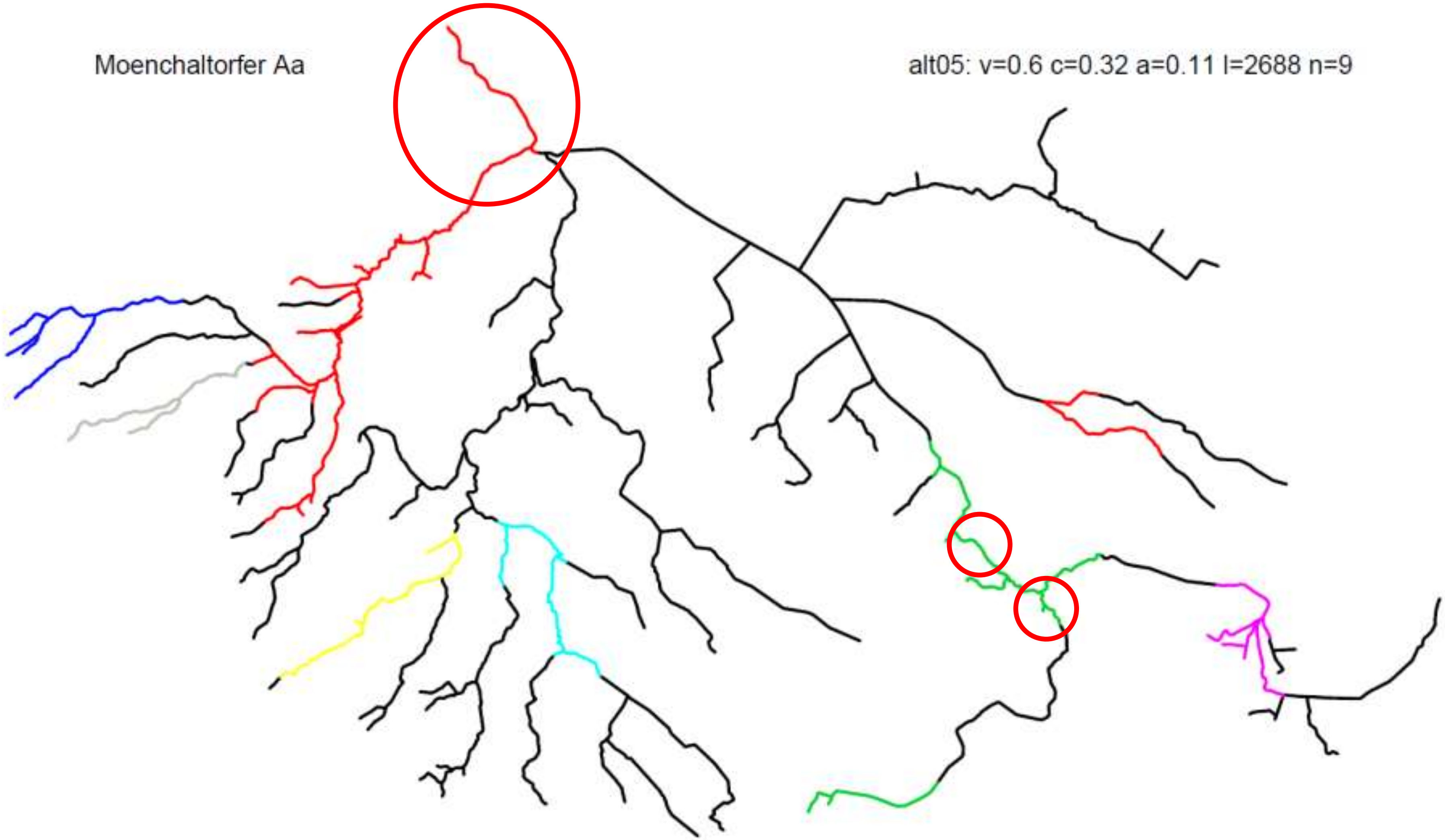
3. Case Study: b. Ecological State of River Network

Largest regions with adjacent reaches in good state: alternative 3



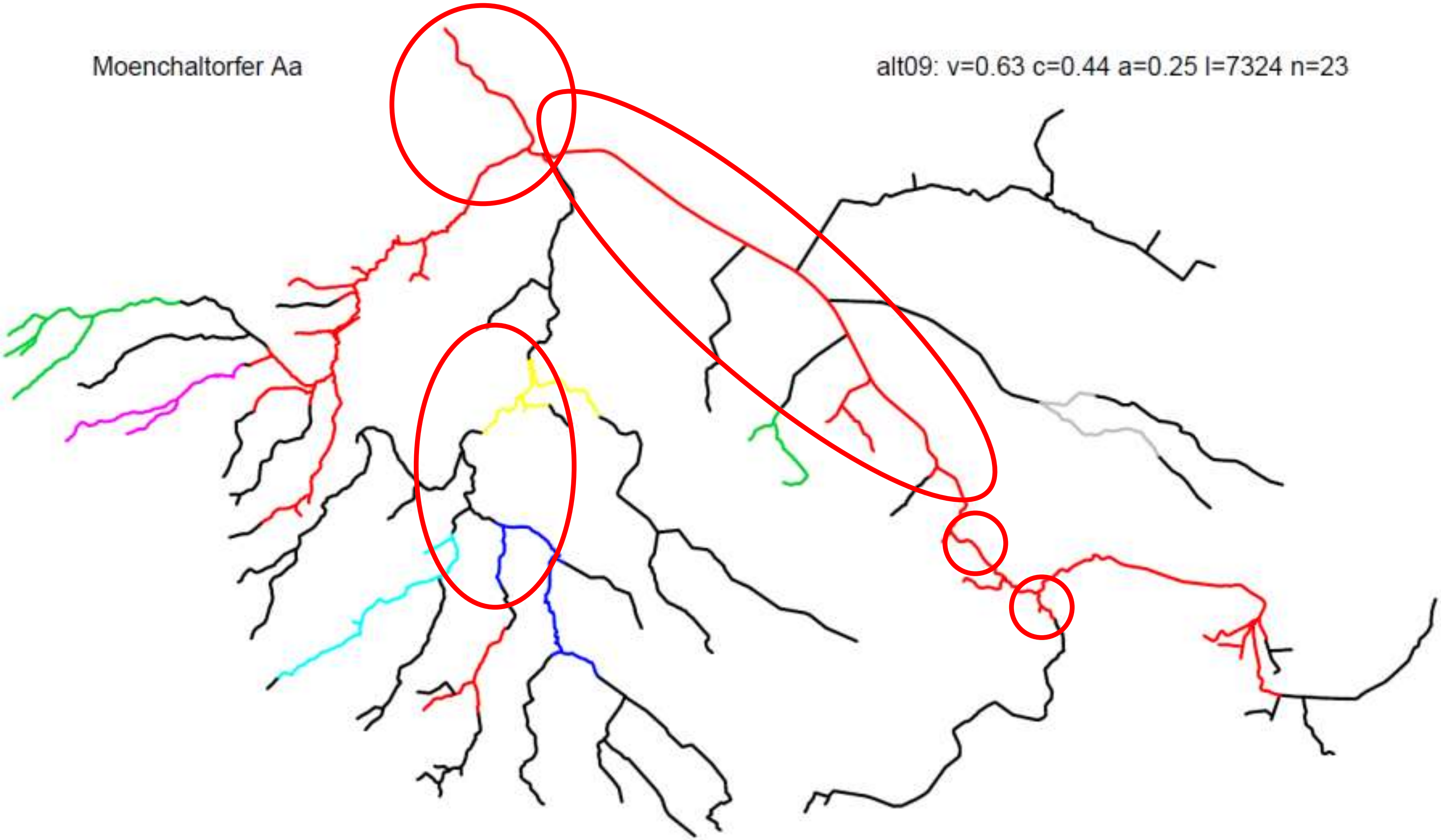
3. Case Study: b. Ecological State of River Network

Largest regions with adjacent reaches in good state: alternative 5



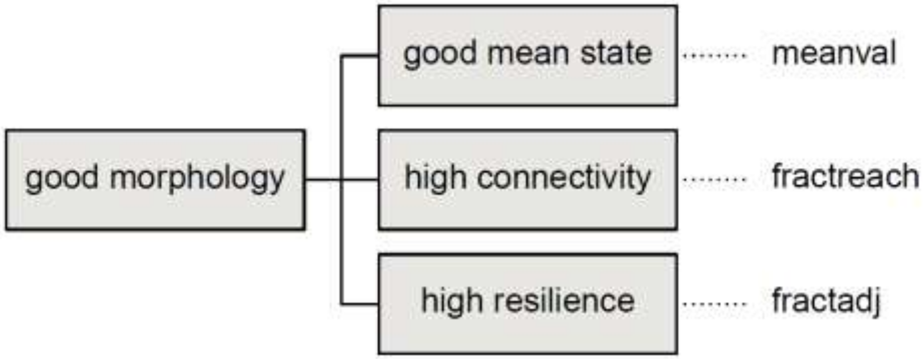
3. Case Study: b. Ecological State of River Network

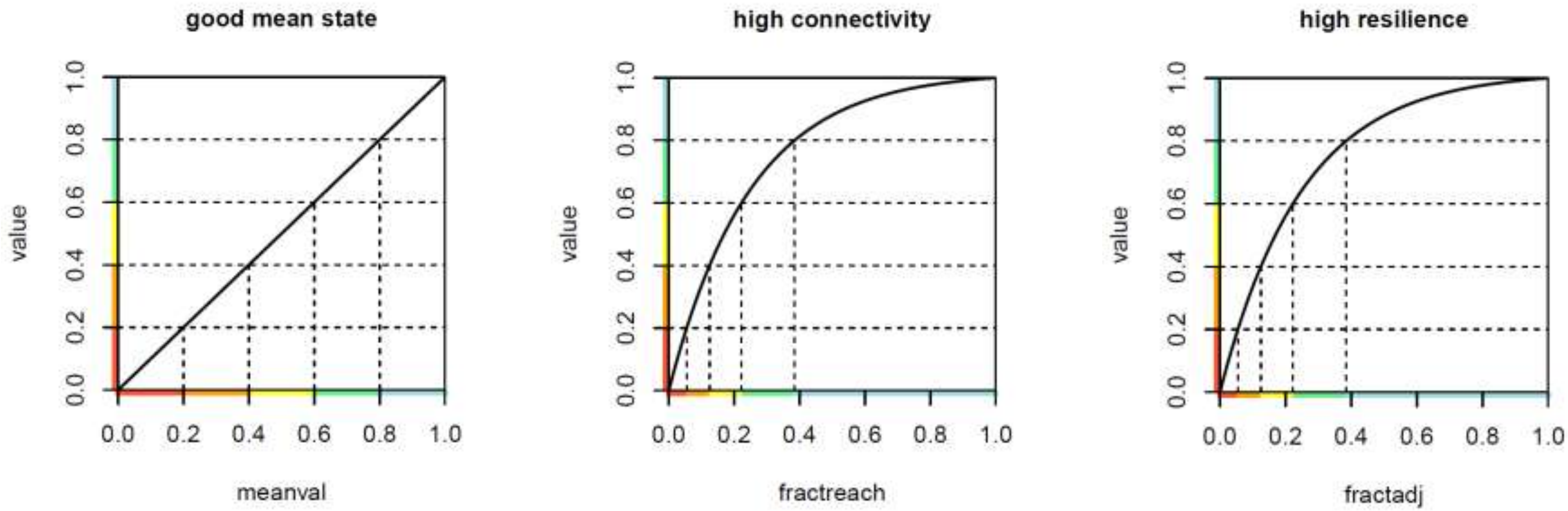
Largest regions with adjacent reaches in good state: alternative 9



3. Case Study: b. Ecological State of River Network

Morphological state

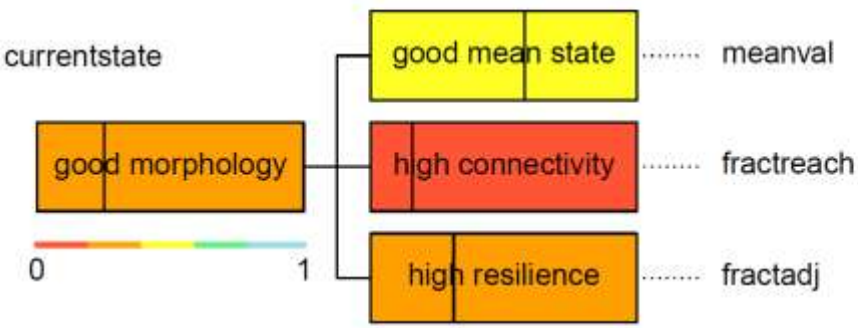




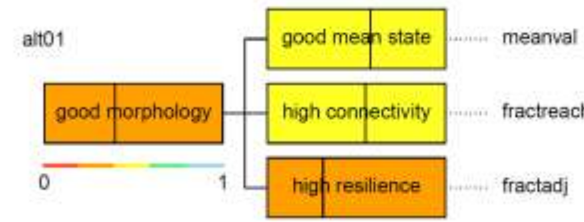
3. Case Study: b. Ecological State of River Network

Morphological state

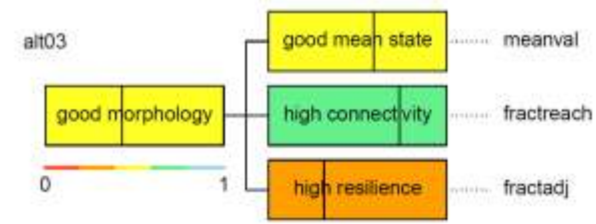
Current state:



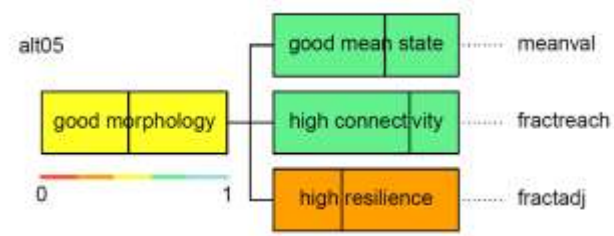
Alt. 1:



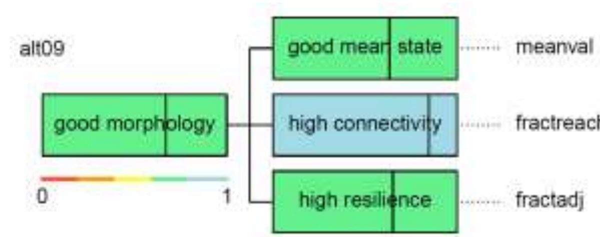
Alt. 3:



Alt. 5:



Alt. 9:



Content

3. Case Study

a. Assessment of Ecological State of River Section

b. Assessment of Ecological State of River Network

c. Formulation of Synergies/Trade-offs with other Societal Goals

3. Case Study: c. Trade-offs with other societal goals

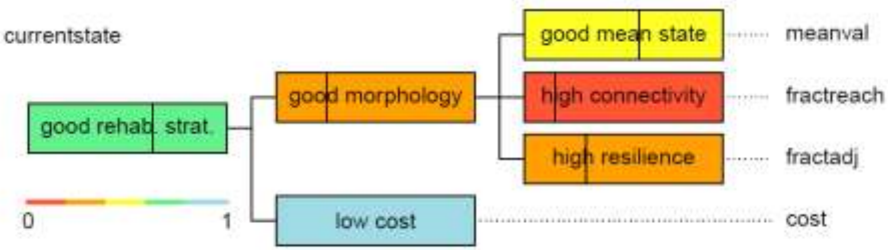
To trade-off ecological gain versus costs we need to know the willingness to pay of the society for river rehabilitation.

We can get a rough preliminary estimate from the result of a popular vote to spend SFr 30 Mio per year for rehabilitating 4000 km of Swiss rivers within the next 80 years. This is federal funding only and will be complemented by funding from the cantons.

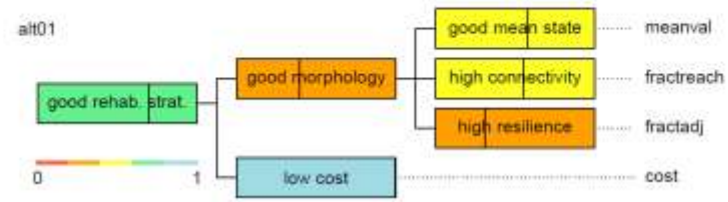
3. Case Study: c. Trade-offs with other societal goals

Rehabilitation management

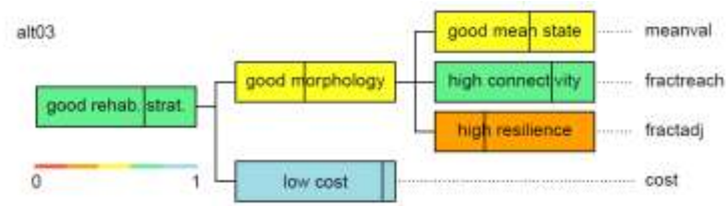
Current state:



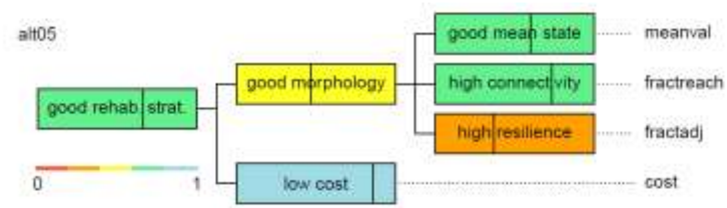
Alt. 1:



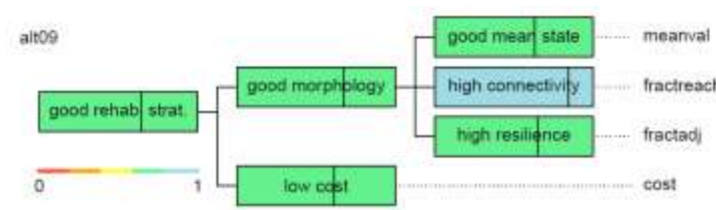
Alt. 3:



Alt. 5:



Alt. 9:



Good result for our rehabilitation strategy. Outcome is much worse for random choice of reaches and nodes.

Content

4. Conclusions

4. Conclusions (1)

Advantages of structured decision support for combining stakeholder values with scientific predictions:

- The structured decision making process **makes arguments transparent and supports the communication** of decisions
- Transparency **increases trust and supports negotiations**
- Explicit statement of predictions and subsequent success control supports a **learning process** to improve decision making for future projects
- Quantification of preferences (and predictions) supports the **auto-matic search for good solutions** (to be checked in practice)
- Visualizing the degree of (actual, expected) fulfillment of objectives **supports creative thinking** about even better alternatives

4. Conclusions (2)

We showed promising results about scientific decision support in river management. However, further steps are needed:

- **Consideration of other ecosystem services**:
  Valuing ecomorphology vs. costs is an important first step for rehabilitation planning, but it must be extended to considering other ecosystem services as well
- **Improving spatial criteria**:
  The proposed three criteria address relevant subobjectives; however, improving these criteria and thinking beyond these subobjectives is required to better characterize a good ecological state.
- **Improving scientific predictions**:
  In particular, when considering assessment areas beyond morphology, this becomes a very serious issue.
- **Getting feedback from stakeholders**:
  Feedback from stakeholders is essential for improving any aspects of the suggested procedure.

4. Conclusions (3)

Despite the usefulness of the outlined techniques, we have to keep in mind that more is needed for a constructive societal decision making process:

- Good moderation of stakeholder workshops
- Cooperative stakeholders who are willing to think about their objectives and make them explicit (no hidden agendas, etc.)
- Cooperative scientists who are willing to quantify their predictions, expose them to review, and be part of the learning process
- Cooperative communities and land owners
- A good regulatory framework that supports such a process
- And much more …

The outlined techniques are very useful tools;
but also not more than that.

Tools need actors who operate them creatively. Maybe you!

Acknowledgements

This work is based on many fruitful collaborations:

- Eawag, decision analysis: Nele Schuwirth, Simone Langhans, Judit Lienert, Ivana Logar, Amael Paillex, Lisa Scholten, Roy Brouwer







- Eawag, other topics: Rosi Siber, Mario Schirmer, Hong Yang
- Swiss authorities: Federal Office of the Environment, authorities of the cantons ZH, TG, AG and more.
- Reform: Tom Buijse, Jan Vermaat, Erik Mosselmann, Ian Cowx, and more

Thank you for your attention

Questions? Comments?

Now or at reichert@eawag.ch

Tools

R packages for valuation

- **utility**

  Construction, evaluation and visualization of value and utility functions

  (published)

- **ecoval**

  Evaluation and visualization of river assessment procedures

  (under development)

- **rivernet**

  Structural analysis, evaluation of attributes and visualization of assessements in river networks

  (under development)

Tools

Models for prediction

- **streambugs**
  Prediciton of invertebrate communities as a function of external conditions
  (published, currently in extension to become more useful for rehabilitation)

- **fish**
  Fish meta-community model
  (Brown trout population model finished, extensions planned)

- **other conceptual models**
  River morphology and habibat structure elements

- **other communities**
  We currently rely on expert predicitions

Uncertainty

Attribute prediction

- Elicitation of probability distributions from experts
- Model predictions in the form of samples from prior or posterior distributions

Valuation

- Uncertainty in attributes can easily be propagated to values
  (this is implemented in the R packages mentioned before)
- Values can be converted to utilities to account for risk attitudes; rankings of alternatives are then done using expected utilities
  (this is also implemented in the R packages)
- Uncertainty in the representation of preferences by values or utilities is considered by sensitivity analysis