



The Beaver Tool - a decision support and/or assessment tool for balancing beneficial and detrimental effects of beaver dams against each other

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Background

As the previous chapters have illustrated, the environmental and ecological impact of dam-building beavers is multifaceted and complex and can from an ecosystem service perspective be beneficial or detrimental. In addition, the direction and extent of the impact of beavers is scale-dependent – in both space and time. While dam-building has generally a more profound impact in flat areas, where large areas can be flooded by a single dam, such impacts are generally less pronounced in topographically more complex systems. From a temporal perspective, potential beneficial responses of beaver dams for nature conservation last generally over several decades, potential negative effects related to e.g. mercury methylation in beaver ponds are generally temporarily and any potential damage to infrastructure (e.g. flooding to roads) are mostly associated with the colonization phase of beavers.

Sectors affected by beaver dams and their assessment

Due to the complexity of beaver impacts and environmental responses, there is a need to assess the potentially beneficial and detrimental, respectively, effects of beaver in a standardized and objective way. Here, we present the Beaver Tool that can be used as a decision support and/or assessment tool. As a decision support tool, it can be used to make a recommendation whether a beaver dam should be removed or kept based on information on water quality, nature conservation and/or economic values that are either gained or lost by removing and keeping the dam, respectively. As an assessment tool, it helps to identify and quantify water quality as well as nature conservation and economic values of beaver systems. Basically, the tool considers three sectors: economy, water quality and nature conservation (Fig. 1).

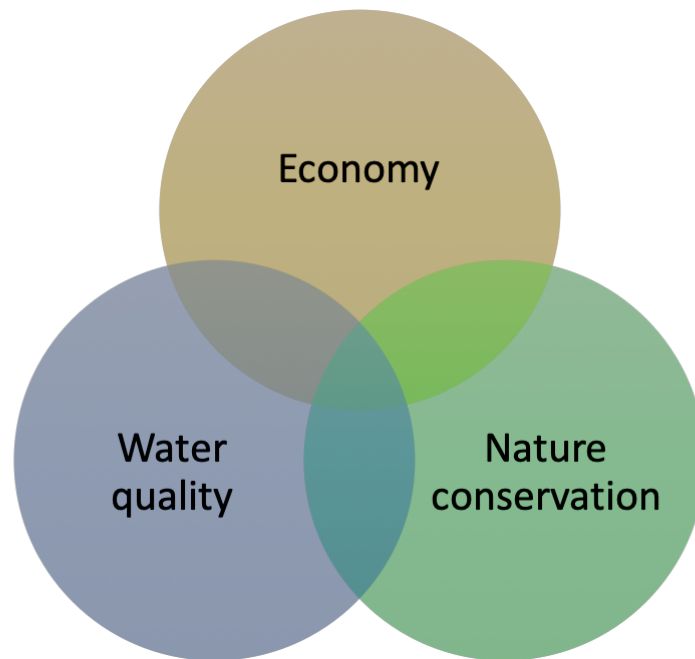


Figure 1. Three main sectors impacted by beaver systems: economy, water quality, and nature conservation values in beaver systems. A beaver system can have high values for several sectors, for example in terms of both water quality and nature conservation. Economic values are rather expressed as economic losses, e.g. due to loss of productive forest and/or damage to infrastructure.

The quality (accuracy and precision) of the outcome of an assessment of the three sectors relies on the quality of the input data. Preferably, the assessment is based on a combination of field-based assessments and measurements. The more reliable the input data, the more reliable the assessment and/or recommendation.

In case infrastructure is threatened or already affected (e.g. flooding of road or railway), the recommendation should be to remove the dam in case no other mitigation measure (e.g. drainage of dam) is possible. When removing a dam, it is crucial to consider national legislation e.g. related to animal welfare issues. It is also important to account for the risk of beavers almost instantly rebuilding a dam. Hence, in some cases, culling needs to be considered to minimize the risk of rebuilding dams.

How does the Beaver Tool work?

The questions in the protocol are partly detailed and might be experienced as even far too detailed. Here, it is important to have in mind that not all information is necessary to make an assessment and/or recommendation to either keep or remove a dam. Information that is asked for relates to variables that have been shown to either increase or decrease the value of a beaver system at local and/or catchment level (e.g. concentration of methylmercury in water, occurrence of red-listed species and damage to infrastructure). We are aware of that information might be unavailable for some or even many of the listed variables. However, the more information that is available, the more reliable the assessment/recommendation.

The final assessment of the values of and damage caused by beaver dams, respectively, based on the protocol¹ is done in a matrix using color codes for the respective variables (grey: missing data, green: beaver system has a positive impact, red: beaver system has a negative impact). From experience, we know that in many beaver systems, the benefits for nature conservation prevail (all fields for nature conservation are green and no red fields for either water quality and/or affected economic values). In other cases, one red field (e.g. damage to productive forest) might be sufficient to motivate dam removal. Hence, the Beaver Tool provides only guidance. The actual decision to keep or remove a beaver dam needs to be based on the pros and cons provided by the assessment and by balancing the values of the different sectors against each other.



EUROPEAN
REGIONAL
DEVELOPMENT
FUND

EUROPEAN UNION

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If you are willing to contribute to improve the Beaver Tool and/or if you would like to share your data, please send your comments/data to Frauke Ecke at the Swedish University of Agricultural Sciences (Frauke.Ecke@slu.se)



Version 1.0
Date of version: 26 January 2019

Aim of the beaver tool

The beaver tool serves as a decision support and/or assessment tool. As a decision support tool, it can be used to make a recommendation whether a beaver dam should be removed or kept based on information on water quality, nature and/or economic values that are either gained or lost by removing and keeping the dam, respectively. As an assessment tool, it helps to identify and quantify water quality as well as nature and economic values of beaver systems

General comment to the protocol

The questions in the protocol are partly detailed and you might experience them as even far too detailed. Please have in mind that not all information is necessary to make an assessment and/or recommendation to either keep or remove a dam. Information that is asked for relates to variables that have been shown to either increase or decrease the value of a beaver system at local and/or catchment level. We are aware of that information might be unavailable for some or even many of the listed variables. However, the more information that is available, the more reliable the assessment/recommendation

Definition of beaver system

A beaver system comprises either a single or multiple dams and ponds occupied by one and the same family

Definition of beaver pond

Flooded and non-flooded area affected by the dam

Definition of beaver dam

The construction built by beavers that dams the water and results in the beaver pond

Instructions

The questions can preferably be answered by using a combination of GIS-analyses and field survey

To answer the questions, a field visit of 1/2 to 1 day per beaver system is recommended

If a beaver system consists of multiple ponds, pond/dam-specific questions should be based on information from the largest pond in a system

Explanations for the different variables are given in a separate sheet

The protocol contains fields to fill in where a colon (":") is given after the information we ask for. In these fields, you are asked to give specific information (e.g. values). For fields with requested information that lack a colon, we offer multiple choices and we ask you to encircle the most appropriate alternative

If space is too limited, please use the comment field at the bottom of the protocol to provide additional information

Site information

Beaver system (name):

Name of observer:

Role of observer:

Date:

Country:

Province:

Coordinates: X:

Y:

Coordinate system:

Background data

Total size of the beaver pond (sqm):

Number of dams in the beaver system

Total:

Upstream:

Downstream:

Total water surface in the beaver pond (sqm):

Age of the beaver pond < 5 yrs

≥ 5 - 10 yrs

> 10 yrs

Colonization history of beaver pond

Pioneer

Re-colonized

Unknown

Height of beaver dam (m):

Is the dam maintained by beavers?

Yes

No

Comment:

Flooded area (%)

Forest:

Arable land:

Mire/swamp:

Other:

Flooded forest type

Broad-leaved

Coniferous

Mixed

Is the beaver dam built in a ditch or natural stream?

Ditch

Natural stream

Heavily modified natural stream

Are the trees in the flooded forest still alive?

Yes

No

Partly

Comment:

Water quality & hydrology

Is the stream a clear- or brown water system?

Not colored

Colored

Very colored

Unknown

Water transparency. Visual assessment.

Higher transparency upstream

No difference

Higher transparency downstream

Water transparency

Unit:

Upstream:

Pond:

Downstream:

Unknown

Absorbance

Unit:

Upstream:

Pond:

Downstream:

Unknown

Oxygen

Unit:

Upstream:

Pond:

Downstream:

Unknown

Concentrations of nutrients and metals

Nitrogen

N-type & unit:

Upstream:

Pond:

Downstream:

Unknown

Phosphorous

P-type & unit:

Upstream:

Pond:

Downstream:

Unknown

Eutrophication status (oligotrophic (O), mesotrophic (M), eutrophic (E); visual assessment)

Upstream:

Pond:

Downstream:

Unknown

Mercury

Hg-type & unit:

Upstream:

Pond:

Downstream:

Unknown

Smell of rotten eggs? (Yes (Y), No (N))

Upstream:

Pond:

Downstream:

Unknown

Temperature

Unit:

Upstream:

Pond:

Downstream:

Unknown

pH

Upstream:

Pond:

Downstream:

Unknown

Does the dam significantly increase water quantity upstream of the dam?

Yes

No

Nature values

Nature values upstream of dammed area

The stream downstream is mainly natural (not channelized)?

Yes

No

Comment:

Freshwater pearl mussel or other protected mussels occur upstream of dammed area?

Yes

No

Comment:

Coarse dead wood occurs (>20 cm diameter, >1 m length, >7 pieces per 100 m) in the water upstream?

Yes

No

Estimated average total length per 100 m stream:

Are there important spawning grounds for migratory fish upstream of the beaver system?

Yes

No

Unknown

If yes, is the beaver system a significant barrier for fish species?	Yes	No	Unknown		
	Expert knowledge	Measured	If yes, fish species:		
Do amphibians occur and reproduce?	Occurrence	Reproduction	No	Unknown	
	Species:				
Nature values downstream of dammed area (<1 km from dam)					
The stream downstream is mainly natural (not channelized)?	Yes	No	Comment:		
Freshwater pearl mussel or other protected mussels occur downstream of dammed area?	Yes	No	Comment:		
Coarse dead wood occurs (>20 cm diameter, >1 m length, >7 pieces per 100 m) in the water downstream?	Yes	No	Estimated average total length (m) per 100 m stream:		
Are there important spawning grounds for migratory fish downstream of the beaver system?	Yes	No	Unknown		
If yes, is the beaver system a significant barrier for fish species?	Yes	No	Unknown		
	Expert knowledge	Measured	If yes, fish species:		
Are there barriers other than beaver dams for migratory fish downstream of the beaver system?	Yes	No	Unknown	If yes, specify:	
Do amphibians occur and reproduce?	Occurrence	Reproduction	No	Unknown	Species:
Nature values in the dammed area					
Trees are standing on socles (root system emerged with epiphytic vegetation)?	Yes	No	Comment:		
Number of snags (standing dead trees >2 m height with diameter >20 cm):	<10	>10 - 50	>50 - 100	>100	
Logs (coarse dead wood > 20 cm diameter)?	Total length (m):				
Broadleaved trees (living)?	Number: < 10	≥ 10	≥ 100		
There are red-listed or protected species in the dammed area?	Yes	No	Unknown		
	List of species:	Type of protection:			
If yes, are the red-listed species threatened by the dammed area?	Yes	No	Unknown	List of species:	
Floating-leaved vegetation occurs?	Yes	No	Percent cover of water surface:		
Do amphibians occur and reproduce?	Occurrence	Reproduction	No	Unknown	Species:

Economic values					
Arable land is affected by the damming?	Yes	No	Area (ha) damaged:		
Damming of forest land has resulted in economic losses?	Significant loss	Minor loss	Unknown		
Percentage productive forest flooded (% of all forest flooded)	%:				
Area (ha) productive forest that risks to be lost (flooded) if beavers increase dam size or build additional dams?					

Age and structure of damaged forest (first check if even- or mixed-aged, then check the age)	Even-aged	Young (half of the legal age for final cutting)	Old (legal age for final cutting)
	Mixed-aged	Young (half of the legal age for final cutting)	Old (legal age for final cutting)
Infrastructure is affected by the damming? (roads, railroads, paths, bridges etc.)	Yes	No	Specify:

Landscape and catchment level			
Number of dams per stream kilometre	Number:		
Non-beaver wetlands in the catchment	Number:	Total size (ha):	
Beaver-wetlands in the catchment	Number:	Total size (ha):	
The catchment has a shortage of coarse dead wood?	Yes	No	
Beaver species	<i>Castor fiber</i>	<i>Castor canadensis</i>	
Distance (km) to nearest formally protected forest			
Do Eurasian otters (<i>Lutra lutra</i>) occur in the catchment	Yes	No	Unknown
Does the beaver system significantly increase the heterogeneity of the landscape?	Yes	No	Unknown

Additional values			
The dam is part of a protected area /nature reserve / eco-park etc.?	Yes	No	Specify:
Cultural heritage values are damaged by the damming?	Yes	No	Specify:
The area has a high recreational value?	Yes	No	
If yes, does the beaver system significantly decrease the recreational value?	Yes	No	Unknown
If yes, what type of recreational value?	Canoeing Fishing	Hiking Other:	Birdwatching

Potential conflicts with other environmental objectives			
Do white-backed woodpeckers or other endangered bird species nesting in deciduous trees occur in the catchment?	Yes	No	Unknown Species:
If yes, are these threatened by the beavers' activities?	Yes	No	Unknown
Is the beaver system a Natura 2000 area?	Yes	No	Specify the Natura 2000 type:
If yes: Is the Natura 2000 type threatened by the damming?	Yes	No	Unknown
Are there other species threatened by the damming?	Yes	No	Specify:

Management

What would be the approximate costs to remove the dam?:

Currency:

Comments (e.g. list of species; specify to which question the comment refers to)

Variable	Explanation
Site information	
Beaver system (name):	Name of the beaver system based on e.g. The locality given on a map
Name of observer:	Name of person(s) providing the information
Role of observer:	e.g. Representative for NGO for nature conservation values, forester, county administration etc.)
Date:	YYYY/MM/DD
Country:	Name of country
Province:	Name of the province/district
Coordinates: X: Y:	X (East-West) and Y (North-South) coordinates of the beaver dam
Coordinate system:	Name of the coordinate system used for the X- and Y-coordinates (e.g. WGS 1984)
Background data	
Total size of the beaver pond (sqm):	Area of the beaver pond, i.e. area of the flooded and non-flooded area affected by the dam
Number of dams in the beaver system	Number of dams that belong to the beaver system divided by total as well as upstream and downstream of the focal beaver dam
Total water surface in the beaver pond (sqm):	Area of the water surface flooded by the dam incl. The area that is covered by floating or floating-leaved vegetation
Age of the beaver pond	Age of the beaver pond
Colonization history of beaver pond	A pioneer system is a beaver system that has been colonized by beavers for the first time in general or for the first time since their extirpation. For detailed definition and classification see Levanoni, O., et al. (2015). "Impact of Beaver Pond Colonization History on Methylmercury Concentrations in Surface Water." <i>Environmental Science & Technology</i> 49(21): 12679-12687. Available via open access: https://doi.org/10.1088/1748-9326/aa8979
Height of beaver dam (m):	Height difference (m) between the dam crest and the current water level downstream of the beaver dam
Is the dam maintained by beavers?	Visual assessment of the maintenance of a dam. A beaver dam that is abandoned leaks water (due to holes in the dam) and the crest of the dam is often overgrown by vegetation without any fresh signs of beaver activity (e.g. no fresh mud on the dam crest, no fresh twigs/branches added to the dam). A maintained dam shows clear signs of beaver activity.
Flooded area (%)	Percentage area of different land cover types covered by the pond
Flooded forest type	Forest type flooded by the beaver dam
Is the beaver dam built in a ditch or natural stream?	If the beaver dam is built in a water course that partly is a natural stream and a ditch, give the dominating type. A heavily modified natural stream has features that negatively affect the hydro-morphological properties if the stream according to the Water Framework Directive (e.g. presence of hydropower dam, water regulation dam)
Are the trees in the flooded forest still alive?	Assessment based on the greenness of the leaves of the trees
Water quality	
Is the stream a clear- or brown water system?	Water colour refers to the amount of humic substances in the stream water. Not colored: <30 mg Pt/l, colored: 30-60 mg Pt/l, very colored: >60 mg Pt/l
Water transparency. Visual assessment.	Water transparency refers to the "clarity" of the water and can be due to humic substances, suspended material etc.
Water transparency	Give units and values; if multiple values are available, give range
Absorbance	Give units and values; if multiple values are available, give range
Oxygen	Give units and values; if multiple values are available, give range
Concentrations of nutrients and metals	
Nitrogen	Give units and values; if multiple values are available, give range
Phosphorous	Give units and values; if multiple values are available, give range
Eutrophication status (oligotrophic (O), mesotrophic (M), eutrophic (E); visual assessment)	If no measurements of nutrients are available, a visual assessment can be used. High abundance of filamentous algae and/or floating plants like duckweed (<i>Lemna</i> spp.) indicates eutrophication.
Mercury	Give units and values; if multiple values are available, give range
Smell of rotten eggs? (Yes (Y), No (N))	Smell of rotten eggs can indicate the presence of methylating bacteria and might hence be an indicator of high mercury concentrations
Temperature	Give units and values; if multiple values are available, give range
pH	Give values; if multiple values are available, give range
Does the dam significantly increase water quantity upstream of the dam?	At least double of water volume compared to stream/ditch without beaver dam

Nature values

Nature values upstream of dammed area

The stream downstream is mainly natural (not channelized)?

Values up to 1 km upstream of the dam

Freshwater pearl mussel or other protected mussels occur upstream of dammed area?

Naturalness of the stream in terms of e.g. Ditching, straightening

Coarse dead wood occurs (>20 cm diameter, >1 m length, >7 pieces per 100 m) in the water upstream?

Species that are protected according to national law or international directives occur upstream of the dammed area. If possible give population size.

Are there important spawning grounds for migratory fish upstream of the beaver system?

All three requirements must be fulfilled (for both diameter, length and number)

If yes, is the beaver system a significant barrier for fish species?

Important to provide the source of information (mactually measured by field study or based on expert knowledge?)

Are there barriers other than beaver dams for migratory fish downstream of the beaver system?

E.g. Dam(s) for water regulation)

Do amphibians occur and reproduce?

If multiple species occur, please use the comment field to specify

Nature values downstream of dammed area (<1 km from dam)

The stream downstream is mainly natural (not channelized)?

Freshwater pearl mussel or other protected mussels occur downstream of dammed area?

Species that are protected according to national law or international directives occur upstream of the dammed area. If possible give population size.

Coarse dead wood occurs (>20 cm diameter, >1 m length, >7 pieces per 100 m) in the water downstream?

All three requirements must be fulfilled (for both diameter, length and number)

Are there important spawning grounds for migratory fish downstream of the beaver system?

Important to provide the source of information (mactually measured by field study or based on expert knowledge?)

If yes, is the beaver system a significant barrier for fish species?

Are there barriers other than beaver dams for migratory fish downstream of the beaver system?

E.g. Dam(s) for water regulation)

Do amphibians occur and reproduce?

Nature values in the dammed area

Trees are standing on socles (root system emerged with epiphytic vegetation)?

Number of snags (standing dead trees >2 m height with diameter >20 cm):

Logs (coarse dead wood > 20 cm diameter)?

Broadleaved trees (living)?

There are red-listed or protected species in the dammed area?

Protection type: National red-list, IUCN, Habitat Directive etc

If yes, are the red-listed species threatened by the dammed area?

Floating-leaved vegetation occurs?

Floating-leaved vegetation (rooted species with floating-leaves) includes water lilies and certain pondweeds

Do amphibians occur and reproduce?

Economic values

Arable land is affected by the damming?

Damming of forest land has resulted in economic losses?

Percentage productive forest flooded (% of all forest flooded)

Area (ha) productive forest that risks to be lost (flooded) if beavers increase dam size or build additional dams?

Age and structure of damaged forest

Infrastructure is affected by the damming? (roads, railroads, paths, bridges etc.)

Landscape and catchment level

Number of dams per stream kilometre

Non-beaver wetlands in the catchment

Beaver-wetlands in the catchment

The catchment has a shortage of coarse dead wood?

Beaver species

Distance (km) to nearest formally protected forest

Linear distance

Do Eurasian otters (*Lutra lutra*) occur in the catchment

Does the beaver system significantly increase the heterogeneity of the landscape?

Additional values

The dam is part of a protected area /nature reserve / eco-park etc.?

Cultural heritage values are damaged by the damming?

The area has a high recreational value?

If yes, does the beaver system significantly decrease the recreational value?

If yes, what type of recreational value?

Potential conflicts with other environmental objectives

Are there white-backed woodpeckers in the catchment?

If yes, are these threatened by the beavers' activities?

Is the beaver system a Natura 2000 area?

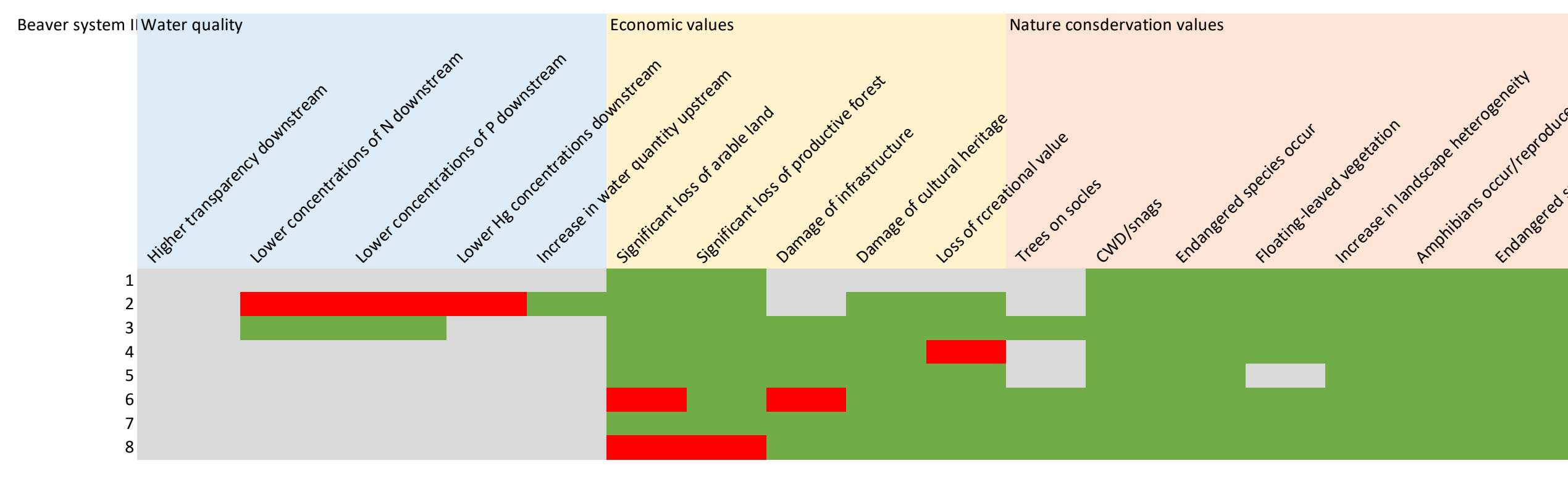
If yes: Is the Natura 2000 type threatened by the damming?

Are there other species threatened by the damming?

Management

What would be the approximate costs to remove the dam?:

Comments (e.g. list of species; specify to which question the comment refers to)



Missing data
 Beneficial effect of beaver system (no adverse effect on economic values)
 Detrimental affect of beaver system

Conclusion

No known adverse effect of the beaver system. High value of the system for nature conservation.
 High value of the system for nature conservation. However, the beaver system contributes to eutrophication and high(er) NH concentrations. Need to decide if water quality values are more important than nature conservation values or vice versa.

No known adverse effect of the beaver system. High value of the system for nature conservation.
 Except for loss of recreational values, there are only known positive effects of the beaver system. Need to decide if the recreational values are that valuable that they motivate to remove the dam.

No known adverse effect of the beaver system. High value of the system for nature conservation.
 Likely need to remove the dam. Damage to infrastructure is too severe.

No known adverse effect of the beaver system. High value of the system for nature conservation.
 Likely need to remove the dam. Damage agriculture and forestry is too severe to keep the dam. From a nature conservation perspective this is however unfortunate.