WP4.4 Kokra river indicators database for MCA

General presentation and a detailed description of indicators & alternatives

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Summary

SHORT DESCRIPTION

The report summarizes the general methodological approach, the criteria and the indicators used to test the multi criteria analysis (MCA) on the Kokra pilot region test basin with a chosen hypothetical micro-location for small hydro power plant (SHP). The report highlights the progression of MCA model development due to cooperation with the stakeholders – Institutes and administration and is therefore reflecting a somewhat different approach/compromise that was implemented in Slovenia.

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Introduction

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1. General description of Kokra River pilot case study

1.1 General description - river Kokra

As a typical Slovenian Alpine river where also unexploited hydro potential is recognized, Kokra River was selected to be analyzed and tested during the SHARE project. Also a lot of data and different analyses on Kokra sub-basin were performed in the past especially in the field of water management which formed the basis for Water Framework Directive adoption and harmonization with Slovenian strategies and regulations.

Kokra is typical Alpine river with a catchment area of 224 km^2. It rises at 1400 m altitude on the Virnikova Mountain. The water catchment area (basin) consists of two bio-geographical regions, mountainous Alps and lowland Carniola. The Alps region extends from Storžič Mountain (2132 m) to the north and east to the Austrian border and through Jezersko Mountain (1218m) reaches the ridge of Kalec with Krvavec. Lowland area lies beneath the southern part of the Križ and Storžič Mountain, past the Tupaliče, Hotemaže, Visoko, Britof and largest city of Kranj. Western boundary follows the river route from Senično (600 m) over the Udin Borst and Kokrica to Kranj plain (nearly 400 m). Kokra flows into the river Sava in Kranj. Upper Sava basin catchment area with Kokra consist 1453 km2 (Globevnik et al. 1998).

In Preddvor the Kokra basin covers 128 km^2, at 24 kilometer mark reaches the average gradient of 1.8%. Kokra in this part flows through the gorge and has a strong torrential character, with number of boulders, gravel and pools. On the length of 12 kilometers, as it winds through the terrace deposits of lowland between Preddvor and Kranj, the water drops from 440 m above sea level to 343 m (with average gradient of 1.2%), full of picturesque canyons and flood arches maintaining special riparian habitats. In vicinity of Kranj, at village Rupa two smaller tributaries Rupovščica and Kokrica join Kokra (Globevnik et al. 1998).

The geological structure of the Kokra basin between lower Jezersko and Preddvor is dominated by carbonate rocks. These are limestone and dolomite of Triassic age and alternative keratofirs, tuffs and porphyrs. Slopes are for the most part covered with lateral gravel, composed of smaller rounded rocks. In upper part Kokra shows a shallow alluvial character with shallow sandy gravel. The middle and lower part Kokra deposited thick (30 m and more) sand gravel banks/terraces (Globevnik et al. 1998).

Measured mean annual discharges at the gauging station (GS) Kokra is 4,47 m^3/s and GS Kranj is 5,87 m^3/s. The Sava River before Kokra poured into in Kranj, has mean annual flow of 58 m^3/s. The mean of the low points in GS Kokra is 1,33 m^3/s and in GS Kranj 1,12 m^3/s. Extreme Low Water average for GS Kokra is calculated at 0,8 m^3/s and for GS Kranj 0 m^3/s. Month with lowest water levels is August. High water peaks are occurring in November, December and April (Globevnik, L. 2006). With the mean rainfall levels for area between Preddvor and Golnik between 1400 mm and 2000 mm in region around Jezersko. Most precipitation in the upper part of basin falls in October and November (Jezersko 200 mm/month), in the lowlands in July and November (160 mm/month). At least rain falls in February and March.

The bulk of mountainous river catchment area of Kokra is overgrown by forests. From the foothills to the forest frontier is represented by following communities: various beech communities with shrubs, black beech, spruces with moss and dwarf pines. Non forested areas are up to 1800 m mainly grasslands. In the lower hay meadows is dominated by sites with *Arrhenatheretum s. lat*. or golden oatgrass (*Trisetetum flavescentis*), located mainly in meadows, spread over 800 m above sea level. On steep slopes are pastures or grassland, classified in the thermophilic link Bromion erecti. Arable land appears only in the vicinity of settlements up to 1000 m altitude.

Water for the production of electricity is already being used in ten small hydro power plants (SHP) on Kokra River and one in location at Kokrica. The analysis of water balance segments was made, wherein the length of the river section parallel to the tube during the capture and release was measured. Length of the river with water withdrawal is ranging between 300 and 1000 meters. No fish tracks have been constructed in the past and what is even more problematic - hydro-biological continuum is not guaranteed during the whole year

1.2 Description of hypothetical location

On the basis of previous studies a new technically feasible hydropower potential was recognized. The design of SHP is the following: a facility for withdrawing water from the river Kokra near the existing SHP Virnik (variant 1, upper angle of the dam, 574,4 meters above sea level near Virnik, upper angle is 570,7 meters above sea level). Water would be diverted from the sites by tunnel pipeline to engine location. The pipeline would be bored into rocky structure of the massive Škrbina with a length of approximately 3000 m. Engine room (the approximate altitude: 510 meters above sea level) to regulate the flow at the approximate location of Čemšeniški brook in Kokra. All parcels (land) are located in the cadastral municipality Kokra in the municipality Preddvor. The investor would be potentially interested into construction of a facility (small power plant) to produce electricity.

In section where water withdrawal is planned are downstream flood plains (areas) and in the lower part where turbine is planned retentions areas. In the section where they provide ecologically acceptable flows, the flow of Trdovec (tributary) occurs in torrential erosion area (torrential fan). Right picture shows the hydrodynamic conditions in the stream. Visible are torrent active erosion sinks (red dashed line). In the section where they provide ecological acceptable flow, is river bed relatively stable, with no noticeable trend of deepening and deposition. In area of water withdrawal and before the affluent of Čemšenik (triburtary), stagnating sections and gravel accumulation occur (Globevnik et al. 1998).

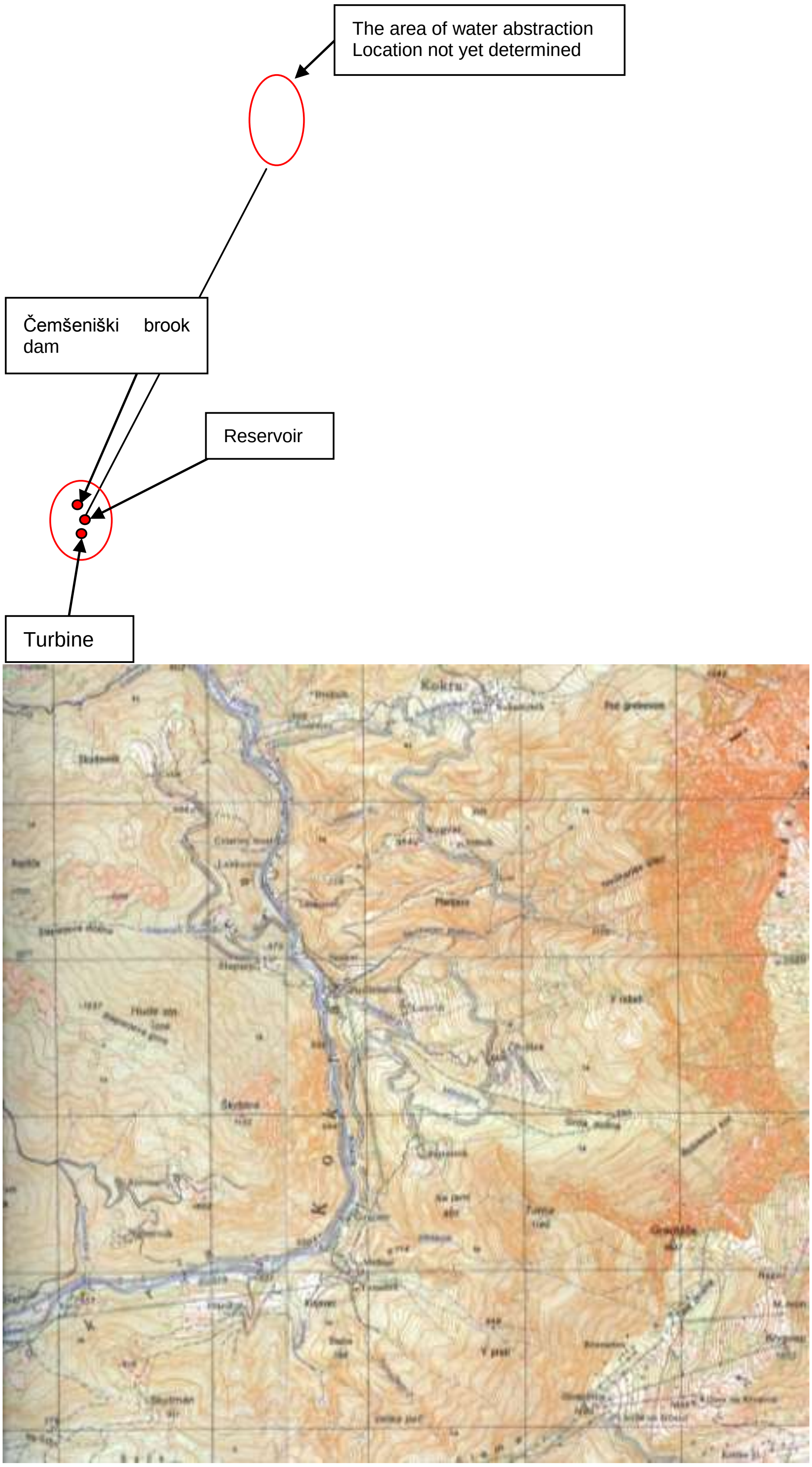


Figure 1: Location Kokra provided SHP (GURS, Map of Slovenia, 2010)

1.3 Models and alternatives

MODELS:

In the preparation of the MCA model generally useable for Slovenia's Alpine rivers, with the additional help of experts from Slovenian Institute for waters - IzVRS and help of people interested in our work (some of them acting as a PTP – Permanent Technical panel), we have come to the conclusion, that it is impossible to derive to the general set of indicators with generally applicable functions.

Therefore our focus divided into preparation of common/**general indicator set** (Model 1) for Slovenia's Alpine rivers with the functions that should be defined on location2location basis (Institute for waters insisted that general function are not to be applied, due to the uniqueness of each location). Our external experts defined set of *environmental indicators*, aggregated to three areas of special importance: Biological quality (defined with 9 indicators), Hydromorphological quality (8 indicators) and Chemical-physical quality (2 indicators). *Socio – economic indicators* were also prepared by external experts, with three defined indicators indicating the impacts of SHP production on social and economic well being and the production of renewable energy (RES).

Our focus then narrowed on the **specific MCA indicators set** (Model 2) for Kokra river.

For the selection of specific MCA indicators set and weighting for pilot area of Kokra River (PCS), it was determined, that in case of this PCS the environmental indicators sufficiently represent the problem at hand. Namely in all three main criteria (Environment, Economy and Social) all three types of trends of indicator score occurs (Figure 1). For example Indicator "CO_2" reduction" is environmental indicator, but it decreases with 'rise' of residual flow, since CO_2 reduction is directly proportional/ connected to the RES Hydropower electricity production.

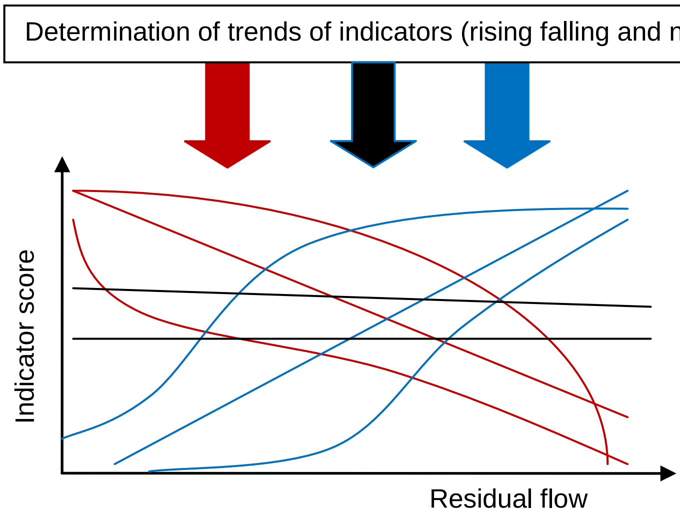


Figure 1: Determination of indicators by trend of their score

The same goes for the environmental criteria, where also all three trends occur (next Figure), where water dependent Nature preservation and Assurance of good water status reflect rising trend with Qres increase. Land scape indicator can be defined as neutral and can be expressed with or within weighting of first two criteria.

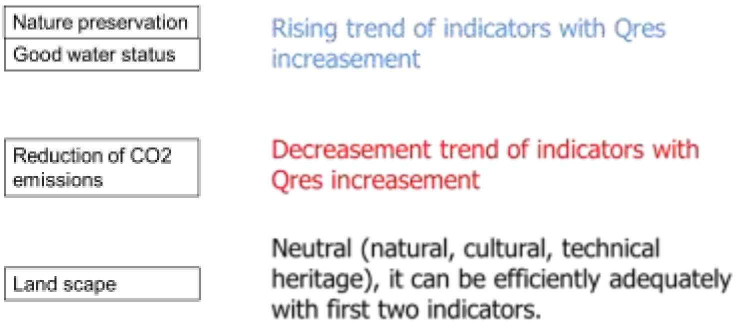


Figure 2: Evaluation of indicators trends of Environment criteria

Based on those arguments we decided to establish the MCA decision three with only two main criteria, ecology (nature preservation and good water status) on one side and CO_2 reduction on the other side. CO_2 reduction is on the other hand efficiently represented by indicator HP electricity production.

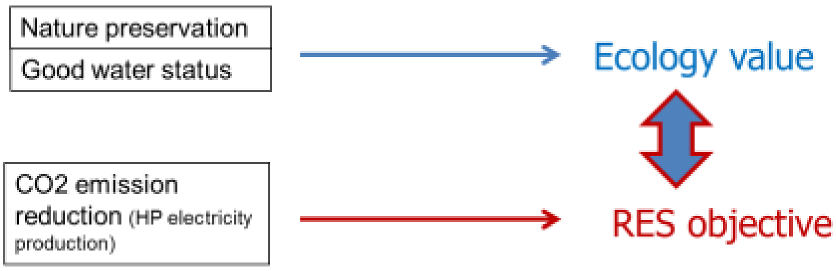
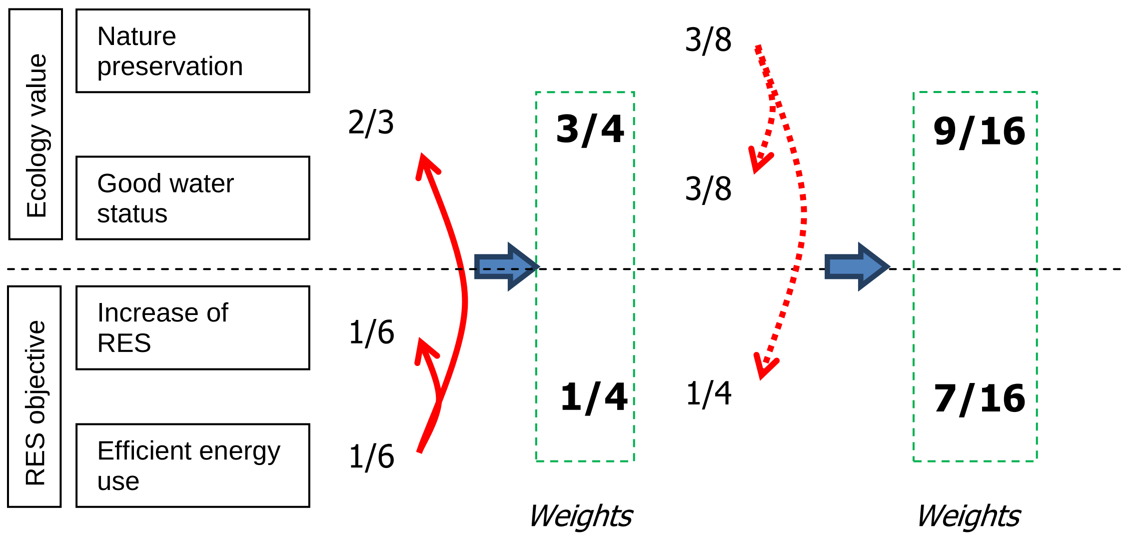


Figure 3: Determination of two main criteria Ecology value and RES objective

To assign the weights to the criteria, at first *overview* of EU directives was weighted. Next Figure (Figure 3) represent the proportionality of criteria 'Ecology value' to the two EU directives (Habitat and WFD Directive) and 'RES objectives' is supported with RES Directive. Those three directives form the basis for weights addressing. Since "RES objective" can be also achieved with efficient energy use, half of weight (1/6) of "RES objective" is evenly distributed among "RES objective" and "Ecology value". But on the other hand water depended Natura areas are not present in all cases. If analyzed river section is not designated as water related Natura area, then the half of weight (3/8) of "Ecology value" is evenly distributed among "RES objective" and "Ecology value". Intermediate cases can be weighted between those two values according to the share of length of Natura areas compared to the total length of relevant water body (see next Figure 4).



$$W_{ECOLOGY} = 9/16 \div 3/4 = 0.5625 + 0.1875 * (L_{natura}/L_{water\ body})$$

$$W_{RES} = 1/4 \div 7/16 = 0.25 + 0.1875 * (L_{natura}/L_{water\ body})$$

Figure 4: Procedure of weights addressing among criteria RES objective and criteria Ecology value

After the establishment of decision tree and basic weighting approach, representative indicators were selected. For RES objective an indicator of potential HP production depending on Qres was selected. For Ecology value representative indicators which are described in continuation (Fish Fauna, Fitobentos, Longitudinal continuity, Lateral/transversal continuity and Temperature) were selected. The selected indicators are described in the following chapter.

ALTERNATIVES:

On Kokra River we divided alternatives on basic alternatives (which are identical for all indicators) and additional alternatives (which are unique and specific for each indicator). This means that all indicators have basic alternatives and some of them can have additional alternatives, but not necessarily.

Basic alternatives are different residual discharges. They are divided into 10 different discharges from the lowest possible minimum low-flow (Qlow) to the mean annual flow (Qmean). These 10 discharges are chosen for the first calculation. When the results reflect the best alternative/s, we can make additional alternatives by interpolation between two best results. This way we can get results with required accuracy.

BASIC ALTERNATIVES:

- ***Alternative 0***: Current situation
- ***Alternatives n***: different values for residual instream flow from the lowest possible minimum low-flow (Qlow) to the mean annual flow (Qmean).

In addition to the basic alternatives we left possibility that each indicator can have its own additional alternatives. If it is possible to apply an additional measure on some indicator, which can improve condition of the indicator, than this measure could be a corresponding alternative. This method enables consideration of the current situation and gives an opportunity for the investor to improve the current situation.

ADDITIONAL ALTERNATIVES:

Introduction of the additional measures will be explained on the longitudinal continuum indicator. On the evaluated river section there are 4 impassable sills. Slovenian legislation demands building a fish passage when placing SHP in environment. This way if investor builds a weir on one of the impassable sills, he has to build fish passage and we have improvement for the environment. The worst result/scenario for this indicator is status quo situation (when nothing is changed) and the best is for situation where there would be no anthropogenic influence. Investor has 5 different options.

ADDITIONAL ALTERNATIVES (MEASURES) FOR INDICATOR LONGITUDINAL CONTINUUM:

- Investor can build a weir on location where there is no impassable sills -***Measure 0***
- Investor can build a fish pass on one of the impassable sills - number of built fish passes is 1 ***- Measure 1***
- Investor can build fish passes on 2 of the impassable sills - number of built fish passes is 2***- Measure 2***,
- Investor can build fish passes on 3 of the impassable sills - number of built fish passes is 3 ***- Measure 3*** and
- Investor can build fish passes on 4 of the impassable sills - number of built fish passes is 4 ***- Measure 4***.

More fish passes investor builds (makes more impassable sills passable) with the same amount of intake, better the score of longitudinal continuum aggregation function is. The aggregation functions for indicator longitudinal continuum are represented in next graph:

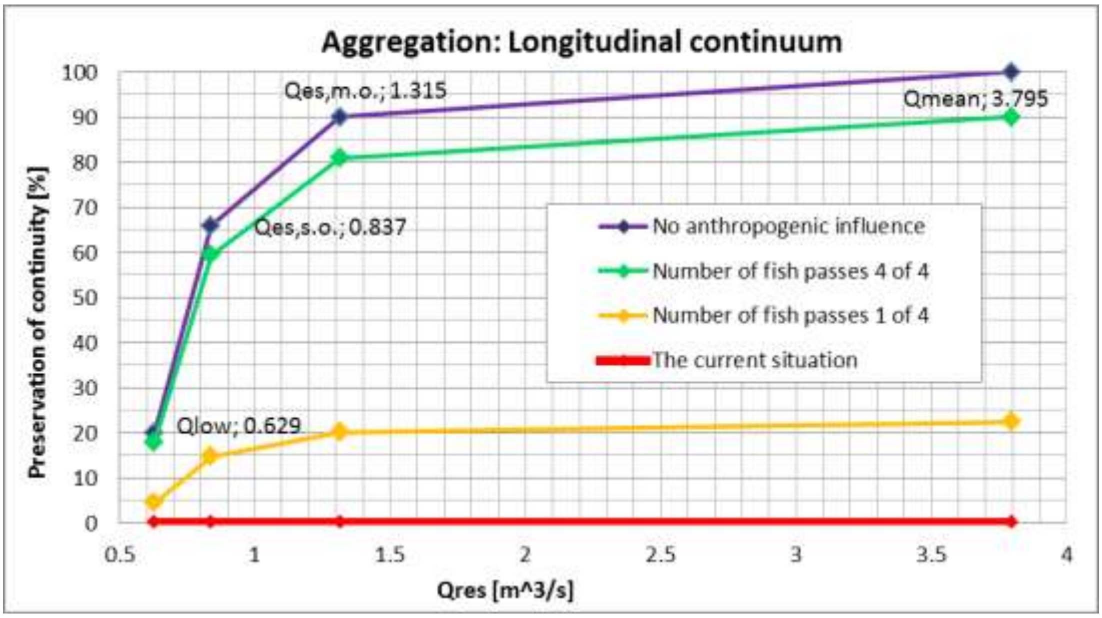


Figure 5: Aggregation function for indicator longitudinal continuum with different alternatives

From overall perspective we have n x 5 different combinations of alternatives for this indicator. We can combine basic alternatives with additional measures as it is represented on next table:

Table 1: All combinations of alternatives for indicator longitudinal continuum

Qres \ Measure	Measure 0	Measure 1	Measure 2	Measure 3	Measure 4
Alternative 0	A0,0	A0,1	A0,2	A0,3	A0,4
Alternative 1	A1,0	A1,1	A1,2	A1,3	A1,4
Alternative 2	A2,0	A2,1	A2,2	A2,3	A2,4
…	…	…	…	…	…
Alternative (n-1)	A(n-1),0	A(n-1),1	A(n-1),2	A(n-1),3	A(n-1),4
Alternative n	A5,0	A5,1	A5,2	A5,3	A5,4

At this moment we have additional measures determent only for indicator longitudinal continuum. Option for additional measures exists for indicator transversal continuum which describes connectivity between river and its slopes. Current situation on evaluating section of the Kokra River is that 3.6 % of all slopes are impassable. Investor couldn't in any way make those slopes passable because they are part of road or some other infrastructure. This is the reason that we didn't include additional alternatives in evaluation of this indicator. But we leave the option for some other section of some river where additional measures could be possible. In example if riverbed or slopes are channeled and investor converts them into more sustainable status.

The value of the aggregation function for indicator transversal continuum depends on residual discharge and on the percent of the regulated slopes as it is represented in next graph.

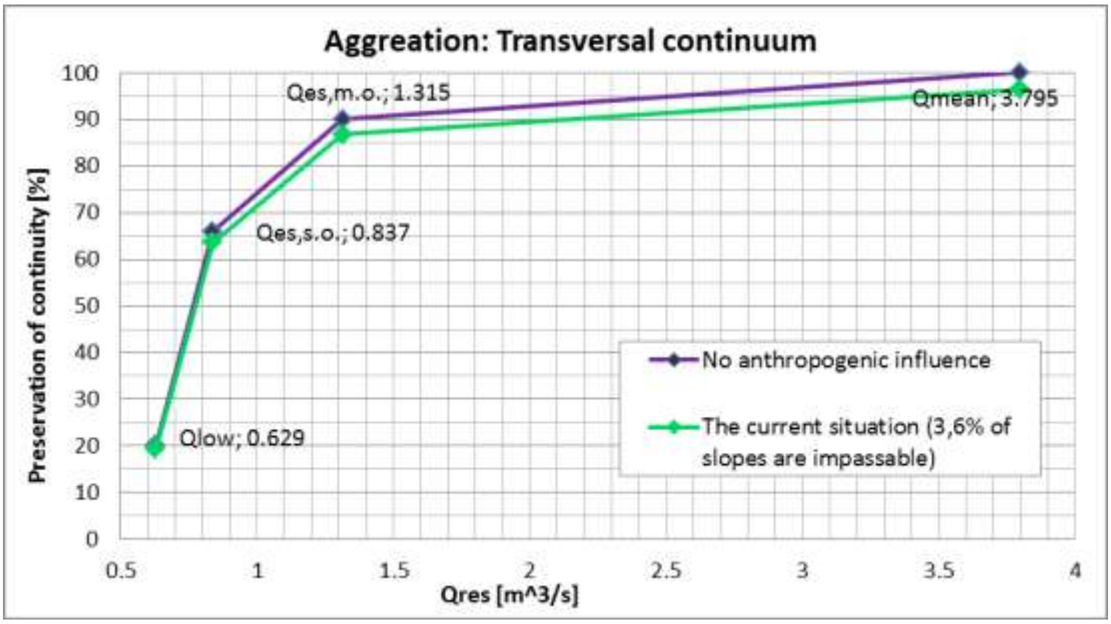
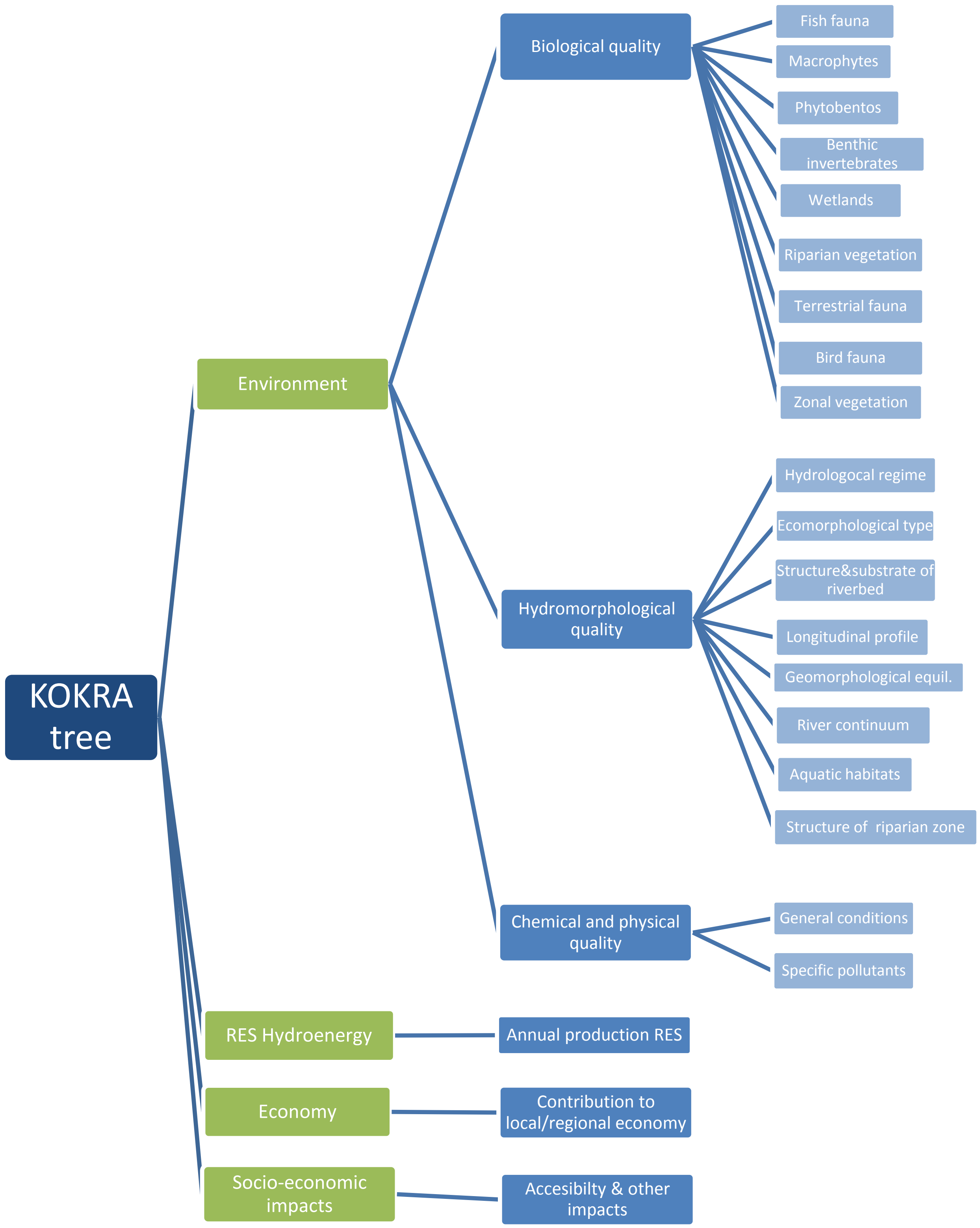


Figure 6: Aggregation function for indicator transversal continuum

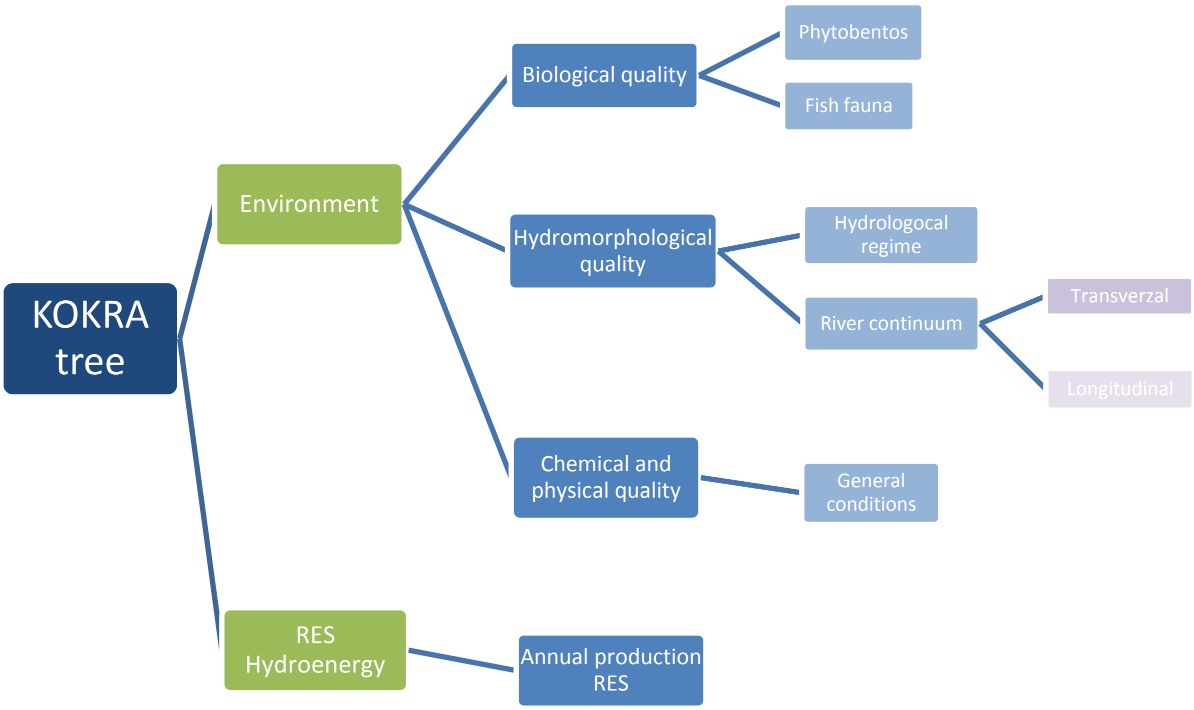
This concept is not made only for Kokra River, but is universal for any river section. Each river has its own range of additional measures. Those measures can be for example emplacement of compensatory habitat, improving the morphology of river, riverbed regulation or re-naturalization of riparian areas that are under concrete sealing.

1.4 MCA tree

River Kokra case study tree's constructed
MODEL 1 (General model for Slovenian Alpine rivers)



MODEL 2 (Kokra river PCS, directly related to the specific location):



2. Indicators description - Kokra River PCS

The following section contains the metadata of every indicator used in the Kokra River example directly related to MCA model Sesamo software.

Kokra tree | ENVIRONMENT | Phytobenthos

FIELD	DESCRIPTION
INDICATOR NAME	Ecological status based on **phytobenthos** (REK value) – response of phytobenthos on changed flow regime due to hydropower plant
ACRONYM	*Phytobenthos* (e_{phyto})
THEME/ SUB-THEME	2
DPSIR	R (Response)
DESCRIPTION	Purpose of the indicator is to demonstrate the relation of "ecological quality ratios" or so called REK values (obtained from phytobenthos status) and the values of instream flow. Changed quantity of instream flow due to hydropower operation is reflected in composition, abundance and biomass of phytobenthos. REK value is on Kokra river based only on phytobenthos status and is used for indirect comparison between phytobenthos and values of different instream flows (nQn, Qes, sQs).
AIM	The aim of this indicator is to evaluate the impact of the operation of HPP and released flow regime on ecological status of phytobenthos.
KEY MESSAGE	Purpose of the indicator is to describe negligible impact of HPP on phytobenthos status by providing ecologically acceptable flow.
MEASURE UNIT	REK
REFERENCES	– Decree of ecological status of surface water (OG RS No. 14/09). – Directive 2000/60/EC of the European Parliament and of the Council. – Growns IO, Growns JE. Ecological effects of flow regulation on macroinverterbrate and periphytic diatom assemblages in the Hawkesbury-Nepean River, Australia. Regulated Rivers: Research and Management 17(3): 275–293. – Smolar-Žvanut N, Mikoš M, Breznik B. The impact of the dam in the Bistrica River on the aquatic ecosystem. Acta hydrotechnica 23(39): 99-115. – Evaluation methodology at: http://www.mop.gov.si/si/delovna_podrocja/voda/ekolosko_stanje_povrsinskih_voda/

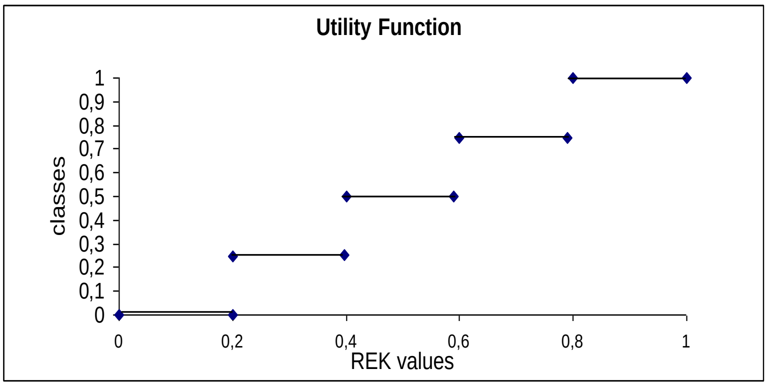
FIELD	METHODS AND MONITORING STANDARDS
METHODS & MONITORING STANDARDS	Evaluation of the ecological status represents the measuring of alternation in structure and function of the ecosystem compared with the natural ecosystem - the reference condition. The classification is done in 5 categories, each with corresponding REK values, which describes ecological status of the water according to Water Framework Directive. This 5 categories are: High, good, moderate, poor and bad ecological status of surface water:

CATEGORIES	REK values
High status	> 0,8
Good status	0,6 - 0,79
Moderate status	0,40 - 0,59

<table>
<tr><td></td><td>
<table>
<tr><td>Poor status</td><td>0,20 - 0,39</td></tr>
<tr><td>Bad status</td><td>> 0,20</td></tr>
</table>

REK values is ratio between the observed value and the reference value. The indicator REK value is calculated on the basis of different modules (trophic and saprobic module, hydromorphological change) belonging to different biological and supporting elements. All calculated indexes needs to be normalize and transformed. Final REK value is determined on the basis of all biological elements - the value determines the worst outcome. On Kokra river the REK value is based only on one ecological element – phytobenthos.
</td></tr>
<tr><td>INDICATOR ELABORATION</td><td>Phytobenthos samples from the field (sampling methodology available at http://www.mop.gov.si/si/delovna_podrocja/voda/ekolosko_stanje_povrsinskih_voda/) are processed in laboratory and ecological status is evaluated. The evaluation is based on methodology and expert opinion. To evaluate the ecological status of the sub-element phytobenthos, only diatoms are considered and the calculation of two modules is required:
– level of pollution of rivers by nutrients through trophic index,
– level of organic pollution of rivers through saprobic index.</td></tr>
<tr><td>INDICATOR LIMITS</td><td>The value of indicator is also dependent on other pressures in the river ecosystem. These pressures can be point or disperse sources of pollution as e.g. nutrients from agriculture or from wastewater treatment systems.
Despite that is indicator value very good reflection of actually status due to quick reactions of species composition, diversity and biomass on hydrological changes. It is also one of important indicators for evaluation of ecological status of surface water.</td></tr>
<tr><td>INDICATORS SHARE FITNESS</td><td>2</td></tr>
<tr><td>AVAILABLE UF</td><td>YES</td></tr>
<tr><td>UF</td><td>The Utility Function adopted is:

f = v(d)
d = The form of the Utility function is non-continuous represented below and it considers the objectives of retaining the general conditions

if d ≤ 0,2 : v(d) = 0;
if 0,2 < d ≤ 0,4: v(d) = 0,25;
if 0,4 < d ≤ 0,6: v(d) = 0,5;
if 0,6 < d ≤ 0,8: v(d) = 0,75;
if 0,8 < d ≤ 1: v(d) = 1;


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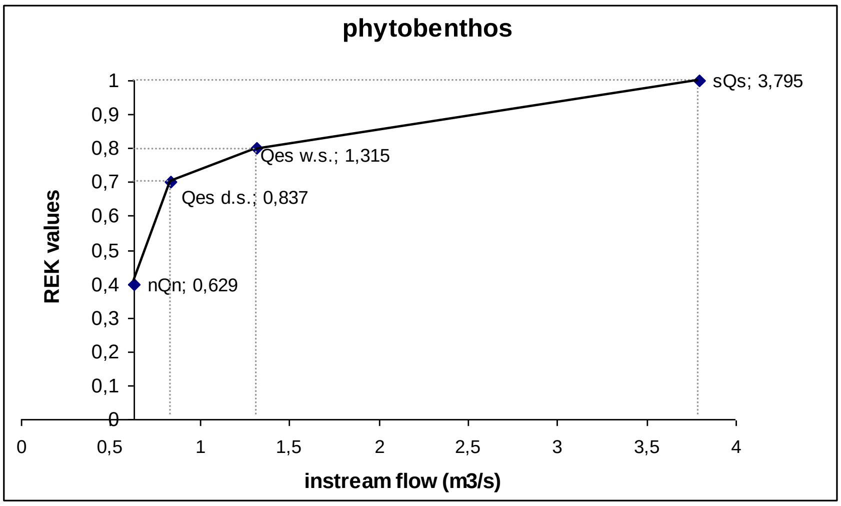
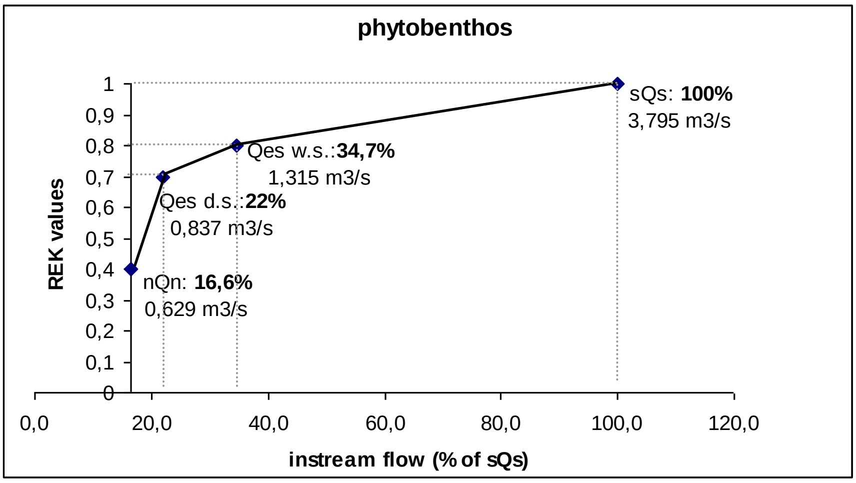
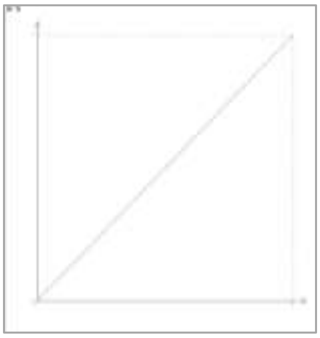
CAUSAL RELETATIONSHIP **(PRESSURE INDICATORS)**	Causal factor related to indicator phytobenthos for each alternative is the value of instream flow. The form of the Causal relationship between REK values for phytobenthos and instream flow is represented below:  Legend: nQn = mean minimum flow, the lowest recorded flow in m3/s in the period Qes d.s = EAF in dry season of the year Qes w.s. = EAF in wet season of the year sQs = mean annual flow, average mean daily flow in m3/s for each year during the period % from sQs: Causal factor related to indicator phytobenthos for each alternative is the percentage of residual instream flow. The form of the Causal relationship between REK values for phytobenthos and instream flow (% of sQs) is represented below:  Legend: nQn = mean minimum flow, the lowest recorded flow in m3/s in the period Qes d.s = EAF in dry season of the year Qes w.s. = EAF in wet season of the year sQs = mean annual flow, average mean daily flow in m3/s for each year during the period
ALTERNATIVE INDICATORS	\

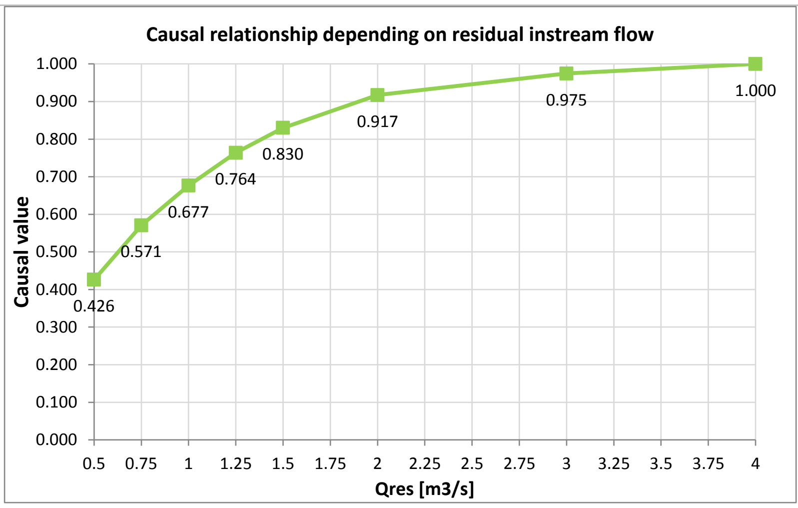
SHARE RELATED IND.	Linear annual power produced
COUNTRY CODE	SLO
WFD HER	SOUTHERN PRE-ALPS AND DOLOMITES

FIELD	DATASOURCES
DATA SOURCE	Expert opinion according to available data from study *Determination of ecologically acceptable flow for Kokra river on the abstraction site for SHPP Oljarica, Water Management Institute, 1999*
DATASETS FORMAT	*.xls*
DATA GEOREFERENCE	\
TIME COVER	1999
UPDATE FREQUENCY	Single data
NUT III CODE	
NORMATICE REFERENCE	/
NORMATIVE RELEVANCE	/
SHARE PILOT CASE STUDY	Sava - Kokra

Kokra tree | ENVIRONMENT | Fish Fauna

FIELD	DESCRIPTION
INDICATOR NAME	Fish Fauna
ACRONYM	*Fish*
THEME/ SUB-THEME	1 (Environment)
DPSIR	I (Impact)
DESCRIPTION	A fish is any aquatic vertebrate animal that is typically ectothermic (or cold-blooded), covered with scales, and equipped with two sets of paired fins and several unpaired fins.
AIM	Environmental objective is to achieve GES (Good ecological status).
KEY MESSAGE	Analyses of the population structure of fish (age determinations, recording of the juvenile fish stand) in the occurring habitats in order to determine water quality.
MEASURE UNIT	m2/m’
REFERENCES	Schneider M, 2001: Habitat- und Abflussmodellierung für Fließgewässer mit unscharfen Berechnungsansätzen. Dissertation, Mitteilungen des Instituts für Wasserbau, Heft 108, Universität Stuttgart, Eigenverlag. http://www.casimir-software.de/

FIELD	METHODS AND MONITORING STANDARDS
METHODS & MONITORING STANDARDS	To evaluate the indicator depending on residual instream flow habitat modeling for analysed river stretch was applied (CASiMiR tool). To support habitat modeling the data for hydraulic parameters (velocities, depths at analysed discharges) must be gathered (use of hydraulic modeling) and for substrate and cover. Predefined fuzzy sets and rules for reference fish species were then applied. The result was WUA (weighted usable area) index which was used to define causal relationship in dependence of residual instream flow. For more proper determination of this indicator additional calibration of fuzzy sets and rules should be performed which should be based on detail ichthyologic study.
INDICATOR ELABORATION	Fish are one of the biological quality elements for the evaluation of ecological status of rivers in accordance with Directive 2000/60/EC of the European Parliament and Council. Methodology of sampling and laboratory processing of samples to evaluate the ecological status of rivers with fish is describing the sampling of fish communities with electrofishing in streams and rivers of Slovenia, the morphometric measurements and laboratory processing of fish for the purpose of evaluating the ecological status. Slovenian methodology for evaluation of ecological status of waters with fish is still in the pipeline. Methodology of sampling and laboratory processing of the samples is available on: http://www.mop.gov.si/si/delovna_podrocja/voda/ekolosko_stanje_povrsinskih_voda
INDICATOR LIMITS	/
INDICATORS SHARE FITNESS	
AVAILABLE UF	YES
UF	The Utility Function adopted is: f = v(d) The form of the Utility function is non-continuous represented below: 
CAUSAL RELETATIONSHIP **(PRESSURE INDICATORS)**	Causal factor related to indicator Fish for each alternative is the residual instream flow. The form of the Causal relationship is represented below:



Causal function is created as:

CFish(Qres) = g(Qres) / max|g(Qres)|

Where:
g(Qres) = WUA(Qres); WUA [m2/m] … weighted usable area

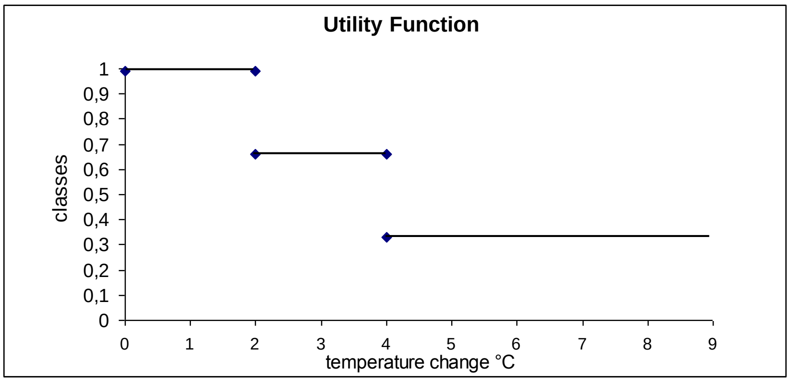
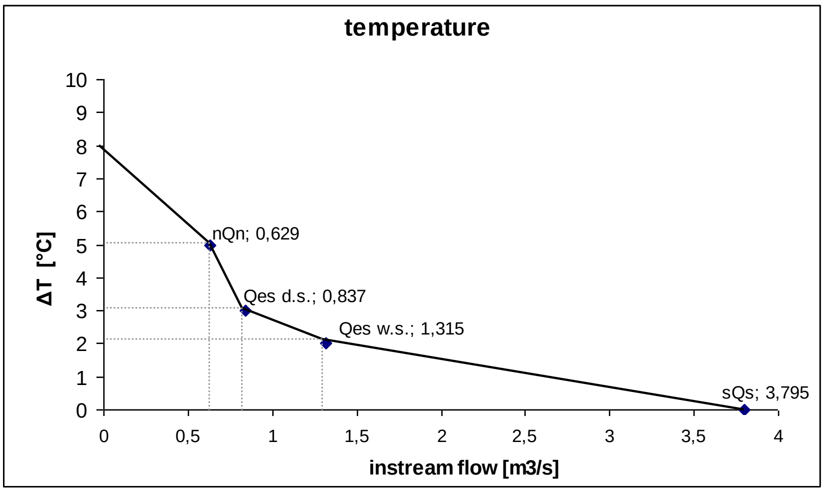
ALTERNATIVE INDICATORS	Other reference fish species, other useable Fish indexes
SHARE RELATED IND.	
COUNTRY CODE	SI
WFD HER	/

FIELD	**DATASOURCES**
DATA SOURCE	Hydraulic modeling (HEC-RAS), Adult brown trout fuzzy sets and rules, CASiMiR model results on WUA index
DATASETS FORMAT	*Excel, HEC-RAS and CASiMiR Input/export files formats*
DATA GEOREFERENCE	/
TIME COVER	2011
UPDATE FREQUENCY	Single data
NUT III CODE	
NORMATICE REFERENCE	/
NORMATIVE RELEVANCE	
SHARE PILOT CASE STUDY	

Kokra tree | ENVIRONMENT | Temperature

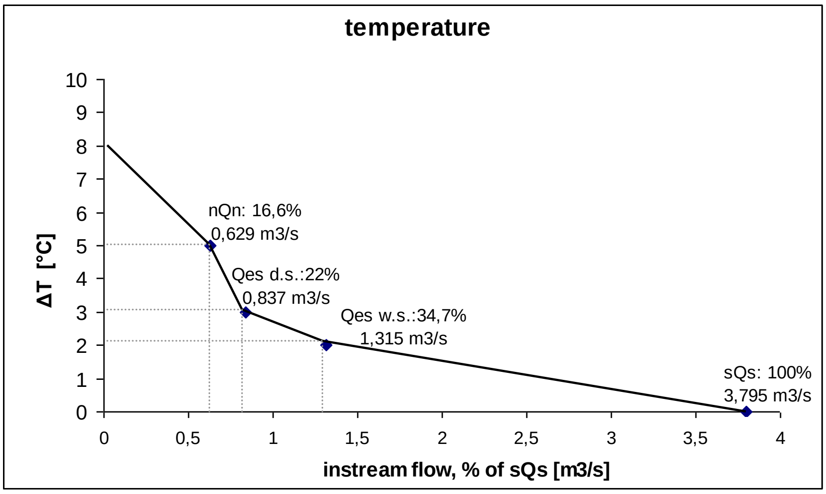
FIELD	DESCRIPTION
INDICATOR NAME	Temperature – response based on changed flow regime due to water abstraction for hydropower plant
ACRONYM	*Temperature* (e_{tem})
THEME/ SUB-THEME	2
DPSIR	R (Response)
DESCRIPTION	Purpose of the indicator is to demonstrate the relation of temperature and the values of instream flow. Changed quantity of instream flow due to hydropower operation (water abstraction) is reflected in changes of water temperatures - smaller amount of water in the stream, lower water depth and velocities can cause higher water temperatures in the summer and freezing in the winter. In the impoundment the temperature stratification can occur. Changes in water temperature impact structure and abundance of aquatic flora and fauna.
AIM	The aim of this indicator is to evaluate the impact of the operation of HPP and released flow regime on water temperatures.
KEY MESSAGE	Purpose of the indicator is to describe negligible impact of HPP on temperature by providing ecologically acceptable flow.
MEASURE UNIT	°C
REFERENCES	– Decree of ecological status of surface water (OG RS No. 14/09). – Directive 2000/60/EC of the European Parliament and of the Council. – Growns IO, Growns JE. Ecological effects of flow regulation on macroinverterbrate and periphytic diatom assemblages in the Hawkesbury-Nepean River, Australia. Regulated Rivers: Research and Management 17(3): 275–293. – Turner MA, Huebert DB, Findlay DL, Hendzel LL, Jansen WA, Bodaly RA, Armstrong LM, Kasian SEM. 2005. Divergent impacts of experimental lake-level drawdown on planktonic and benthic plant communities in a boreal forest lake. Can. J. Fish. Aquat. Sci. 62(5): 991–1003. – Wetzel RG. 2001. Limnology: Lake and River Ecosystems, Third edition. Academic press, San Diego.

FIELD	METHODS AND MONITORING STANDARDS
METHODS & MONITORING STANDARDS	The indicator value (temperature change) is evaluated from the monitoring values. The classification is done in a 3-point rating scale, in which the smaller change in temperature (<2°C) due to HP production belongs to higher class and a larger temperature change (>4°C) belongs in lower class. The impact of changed temperature: 0 – 2 °C = small impact on aquatic organisms 2 – 4 °C = middle impact on aquatic organisms ≥ 4 °C = big impact on aquatic organisms This method is based on expert assessment.

INDICATOR ELABORATION	Temperature can be measured with special device for measurement in the water and the results can be evaluated on the basis of permitted values defined in Decree of ecological status of surface water (OG RS No. 14/09).
INDICATOR LIMITS	The value of indicator is also dependent on other pressures in the river ecosystem (e.g. inflows from treatment systems).
INDICATORS SHARE FITNESS	2
AVAILABLE UF	YES
UF	The Utility Function adopted is: f = v(d) d = The form of the Utility function is non-continuous represented below and it considers the objectives of retaining the general conditions if d < 2: v(d) = 1,0; if 2 ≤ d < 4: v(d) = 0,66; if d ≥ 4: v(d) = 0,33; 
CAUSAL RELETATIONSHIP **(PRESSURE INDICATORS)**	Causal factor related to indicator temperature for each alternative is the value of instream flow. The form of the Causal relationship between 3 temperature classes and instream flow is represented below: 

Legend:
nQn = mean minimum flow, the lowest recorded flow in m3/s in the period
Qes d.s = EAF in dry season of the year
Qes w.s. = EAF in wet season of the year
sQs = mean annual flow, average mean daily flow in m3/s for each year during the period

% from sQs:
Causal factor related to indicator temperature for each alternative is the percentage of instream flow.
The form of the Causal relationship between 3 temperature classes and instream flow (% of sQs) is represented below:



Legend:
nQn = mean minimum flow, the lowest recorded flow in m3/s in the period
Qes d.s = EAF in dry season of the year
Qes w.s. = EAF in wet season of the year
sQs = mean annual flow, average mean daily flow in m3/s for each year during the period

ALTERNATIVE INDICATORS	\
SHARE RELATED IND.	Linear annual power produced
COUNTRY CODE	SLO
WFD HER	SOUTHERN PRE-ALPS AND DOLOMITES

FIELD	DATASOURCES
DATA SOURCE	Expert opinion according to available data from study *Determination of ecologically acceptable flow for Kokra river on the abstraction site for SHPP Oljarica, Water Management Institute, 1999*
DATASETS FORMAT	*.xls*
DATA GEOREFERENCE	\
TIME COVER	1999
UPDATE FREQUENCY	Single data
NUT III CODE	/
NORMATICE REFERENCE	/

NORMATIVE RELEVANCE	/
SHARE PILOT CASE STUDY	Sava - Kokra

Kokra tree | ENVIRONMENT | Longitudinal connectivity

FIELD	DESCRIPTION
INDICATOR NAME	Preservation of longitudinal river continuity.
ACRONYM	
THEME/ SUB-THEME	
DPSIR	
DESCRIPTION	This indicator represents the percentage of the conservation of longitudinal river continuity. The comparison is made on the unaffected river section. Assessment of the indicator on the selected section on Kokra river is based on the number of transversal structures that prevent longitudinal river continuity.
AIM	Purpose of the indicator is to describe the impact of SHP plant operation on fluvial ecosystem and the effect to the biological and morphological processes on the river section from the dam downstream to inflow of abstracted water back to the river. The main negative ecological effect of a dam construction on ecosystems is that the connectivity of river system will be permanently interrupted. It can affect bedload budget, bank and riverbed structure, water quality, the longitudinal connectivity of river systems and the status of riverine biocoenoses.
KEY MESSAGE	The "Preservation of longitudinal river continuity" indicator had been developed to describe how much the different quantity of water affect the longitudinal river continuity.
MEASURE UNIT	
REFERENCES	

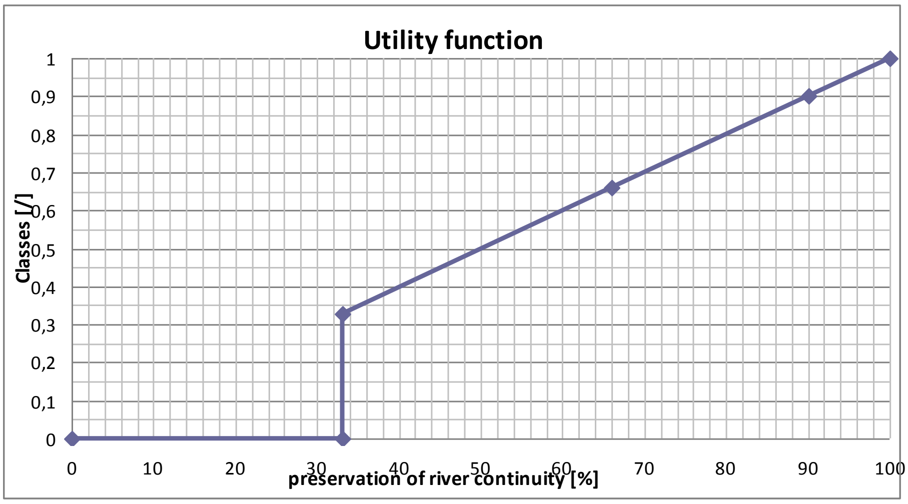
FIELD	METHODS AND MONITORING STANDARDS
METHODS & MONITORING STANDARDS	The indicator value (preservation of longitudinal river continuity) is calculated on the percentage of the conservation of longitudinal river continuity according to the unaffected river section.

Preserved longitudinal continuity	0,90-1,00
Ensured longitudinal continuity	0,66-0,90

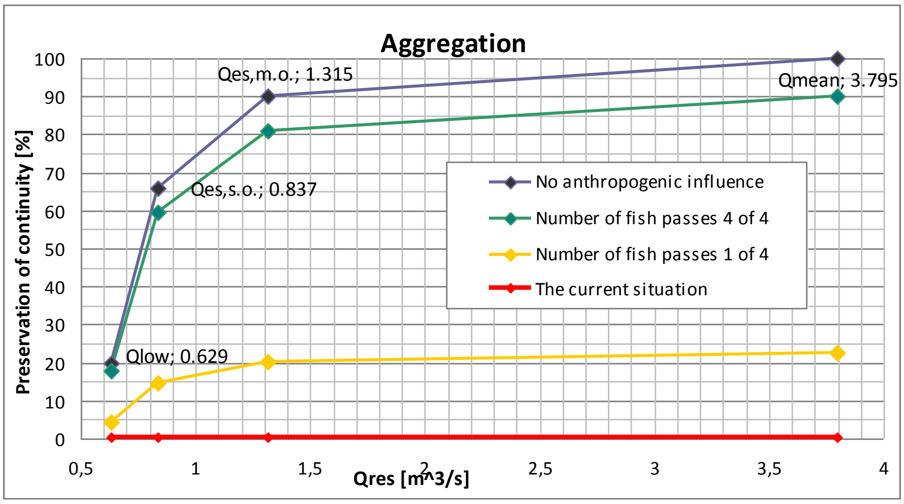
<table>
<tr><td></td><td>
<table>
<tr><td>Partially ensured longitudinal continuity</td><td>0,33-0,66</td></tr>
<tr><td>Longitudinal continuity is not ensured</td><td><0,33</td></tr>
</table>
This method is based on expert assessment.
</td></tr>
<tr><td>INDICATOR ELABORATION</td><td>The evaluation of the indicator is based on expert opinion. For the selected section on Kokra river the evaluation was made on the base of the number of transversal structures which they were provided to us by Slovenian Environment Agency (MOP-ARSO Kranj). The data used were obtained on the basis of the fieldwork.</td></tr>
<tr><td>INDICATOR LIMITS</td><td>The value of indicator is dependent on the composition of mezohabitats on the selected section on Kokra river.</td></tr>
<tr><td>INDICATORS SHARE FITNESS</td><td></td></tr>
<tr><td>AVAILABLE UF</td><td>YES</td></tr>
<tr><td>UF</td><td>The Utility Function adopted is:

f = v(d)
d = The form of the Utility function is continuous represented below and it considers the objectives of retaining the general conditions

if $0,33 < d \leq 1$



</td></tr>
</table>

CAUSAL RELETATIONSHIP **(PRESSURE INDICATORS)**	The Causal Relationship adopted is: 
ALTERNATIVE INDICATORS	\
SHARE RELATED IND.	
COUNTRY CODE	SLO
WFD HER	\

FIELD	DATASOURCES
DATA SOURCE	Slovenian Environment Agency (MOP-ARSO Kranj).
DATASETS FORMAT	*.xls*
DATA GEOREFERENCE	/
TIME COVER	/
UPDATE FREQUENCY	/
NUT III CODE	/
NORMATICE REFERENCE	/
NORMATIVE RELEVANCE	/
SHARE PILOT CASE STUDY	River Kokra

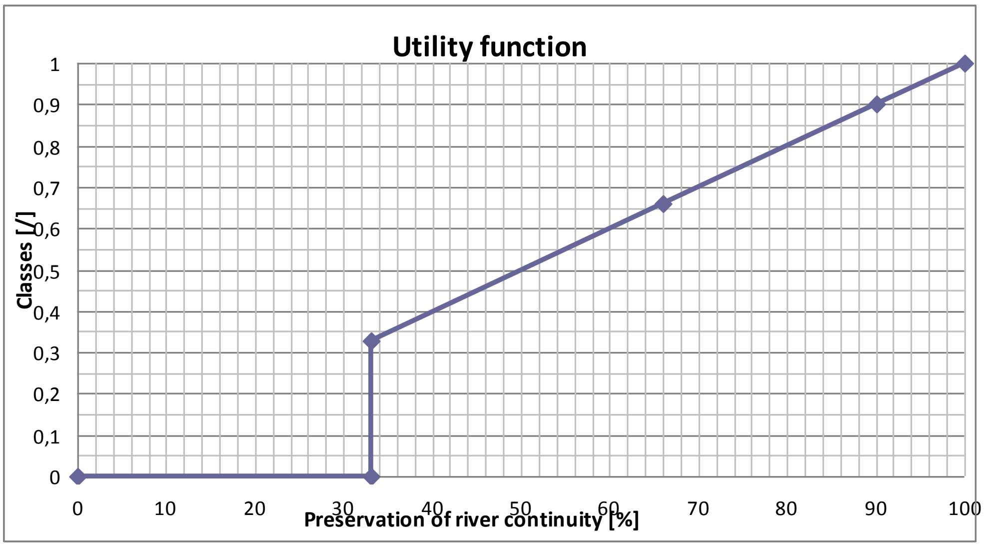
Kokra tree | ENVIRONMENT | Lateral connectivity

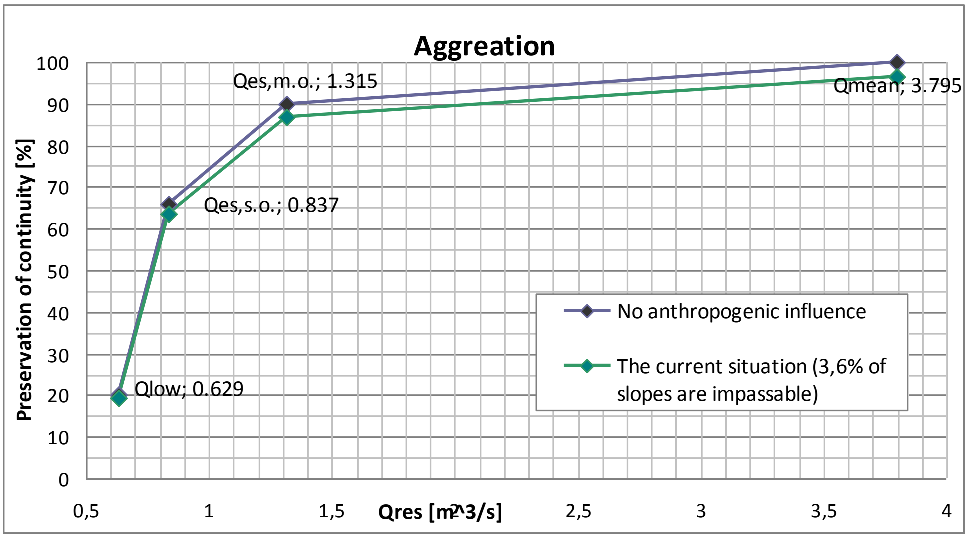
FIELD	DESCRIPTION
INDICATOR NAME	Preservation of transversal river continuity

ACRONYM	
THEME/ SUB-THEME	
DPSIR	
DESCRIPTION	This indicator represents the percentage of the conservation of transversal river continuity. The comparison is made on the unaffected river section. Assessment of the indicator on the selected section on Kokra river is based on the percent of hydraulic works (reinforced embankments) on the river stretch that prevent transversal river continuity.
AIM	Purpose of the indicator is to describe the impact of SHP plant operation on fluvial ecosystem and the effect to the biological and morphological processes on the river section from the dam downstream to inflow of abstracted water back to the river. The main negative ecological effect of a dam construction on ecosystems is that the transversal connectivity of river system will be permanently interrupted. It can affect bank and riverbed structure, water quality, the transversal connectivity of river systems and the status of riverine biocoenoses.
KEY MESSAGE	The “Preservation of transversal river continuity” indicator had been developed to describe how much the different quantity of water affect the river continuity.
MEASURE UNIT	
REFERENCES	

FIELD	METHODS AND MONITORING STANDARDS
METHODS & MONITORING STANDARDS	The indicator value (preservation of longitudinal and transversal river continuity) is calculated on the percentage of the conservation of longitudinal and transversal river continuity according to the unaffected river section. Preserved transversal continuity: 0,90-1,00 Ensured transversal continuity: 0,66-0,90 Partially ensured transversal continuity: 0,33-0,66 Transversal continuity is not ensured: <0,33 This method is based on expert assessment.

Preserved transversal continuity	0,90-1,00
Ensured transversal continuity	0,66-0,90
Partially ensured transversal continuity	0,33-0,66
Transversal continuity is not ensured	<0,33

INDICATOR ELABORATION	The evaluation of the indicator is based on the estimation and available data. The assessment is made on the basis of riverbed wetness ratio as a function of flow. For the selected section on Kokra river the evaluation was made on the base of the percent of hydraulic works that prevent transversal river continuity (reinforced embankments on both sides of the river banks). Detailed view and accurate measurement ware not made.
INDICATOR LIMITS	The value of indicator is dependent on the composition of mezohabitats on the selected section on Kokra river.
INDICATORS SHARE FITNESS	
AVAILABLE UF	YES
UF	The Utility Function adopted is: f = v(d) d = The form of the Utility function is continuous represented below and it considers the objectives of retaining the general conditions if $0{,}33 < d \leq 1$ 
CAUSAL RELETATIONSHIP **(PRESSURE INDICATORS)**	The Causal Relationship adopted is:

	
ALTERNATIVE INDICATORS	/
SHARE RELATED IND.	/
COUNTRY CODE	SLO
WFD HER	/

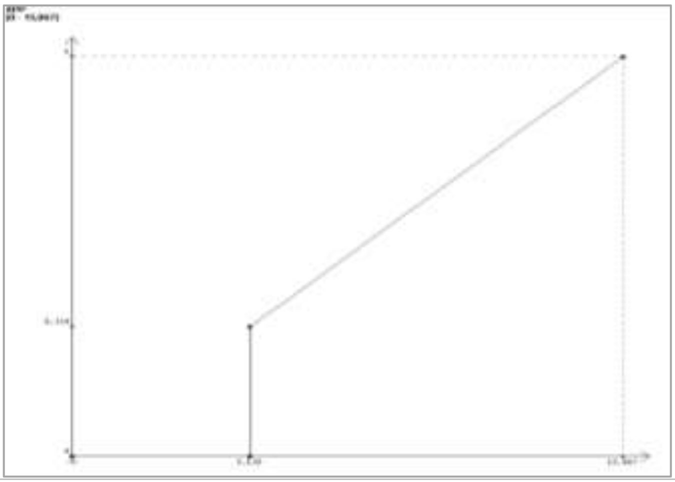
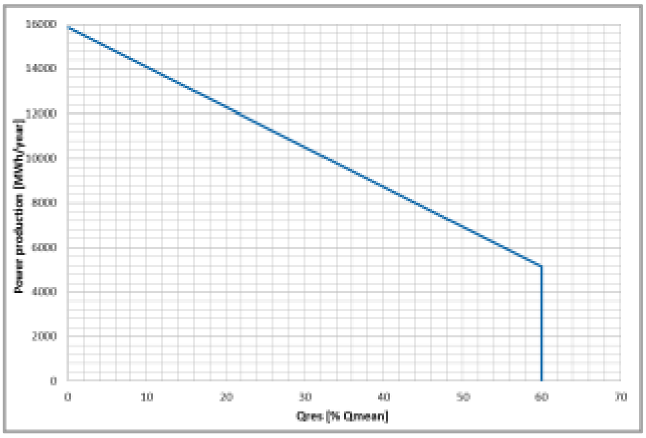
FIELD	DATASOURCES
DATA SOURCE	Slovenian Environment Agency (MOP-ARSO Kranj).
DATASETS FORMAT	*.xls*
DATA GEOREFERENCE	/
TIME COVER	Single data
UPDATE FREQUENCY	/
NUT III CODE	/
NORMATICE REFERENCE	/
NORMATIVE RELEVANCE	/
SHARE PILOT CASE STUDY	Kokra river

Kokra tree | ECONOMY | Annual production of RES

FIELD	DESCRIPTION
INDICATOR NAME	Annual Production of RSE
ACRONYM	*RSE*

THEME/ SUB-THEME	4
DPSIR	R
DESCRIPTION	This indicator represents the impact of SHPP on production of RES and quality of the air. Value of the indicator is directly expressed with the amount of produced electric energy.
AIM	Purpose of the indicator is to describe positive impact of SHP production on the quality of air (less CO_2 in the air) and RES production. (The main aim is to reduce consumption of fossil fuels by increasing RES.)
KEY MESSAGE	The river energy production related to bypassed river length evaluates the energy river capacity linked to the withdrawal.
MEASURE UNIT	MWh/year
REFERENCES	

FIELD	METHODS AND MONITORING STANDARDS
METHODS & MONITORING STANDARDS	The indicator value of generated incomes is calculated on the annual hydro power production. Program Vapidro Aste is calculating power production as if SHPP is operating all the time throughout the year, where a use coefficient takes into consideration the time when SHPP doesn't operate due to defects or renovation. The formula to calculate the amount of energy produced in one year: $E(x,L) = \eta_o \cdot 9{,}81 \cdot H \cdot Q_{der} \cdot 8760 \cdot C_{ut},$ where: E is maximum energy produced per year, η_0 is the overall electrical efficiency, Cut is use coefficient, H is geodetic net head available and Qder is derivable average flow [m3/s]. Program selects with optimization those locations that have the best benefit/cost ratio and are still worthwhile having all costs.
INDICATOR ELABORATION	This indicator is calculated with Vapidro Aste and it represents the optimal power production. It considers the amount of water taken for HP production and all the investment and operating costs.
INDICATOR LIMITS	A little available data for calibration cost curves to determine optimal power production (with program Vapidro Aste).
INDICATORS SHARE FITNESS	5
AVAILABLE UF	YES
UF	The Utility Function adopted is: f = v(z)

	z = is the annual power produced [MWh/year] if z < 5139: v(z) = 0 if 5139 > z < 15867 : linear function: v(z) = 0.0000426*z+0.324 if z = 15867: v(z) = 1. 
CAUSAL RELETATIONSHIP **(PRESSURE INDICATORS)**	Causal factor related to indicator Annual production of RSE for each alternative is the percentage of residual instream flow. The form of the Causal relationship is represented below:  if Qres < 60% of Qannual: f(Qres) = -178.8 * Qres + 15867 if Qres > 60% of Qannual: f(Qres) = 0.
ALTERNATIVE INDICATORS	\
SHARE RELATED IND.	Annual power produced
COUNTRY CODE	SLO
WFD HER	en11

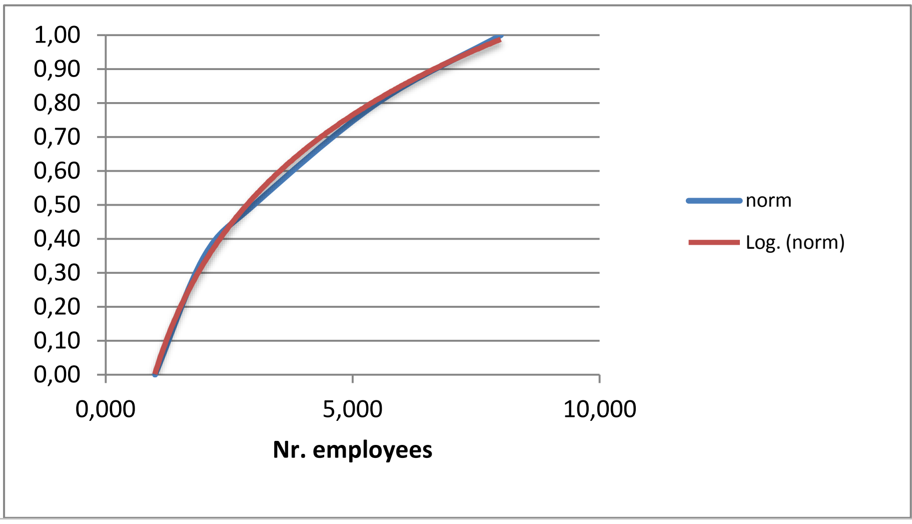
FIELD	DATASOURCES
DATA SOURCE	ARSO (Agency of Republic Slovenia for Environment)
DATASETS FORMAT	Excel file, DEM, Vapidro Aste
DATA GEOREFERENCE	Yes

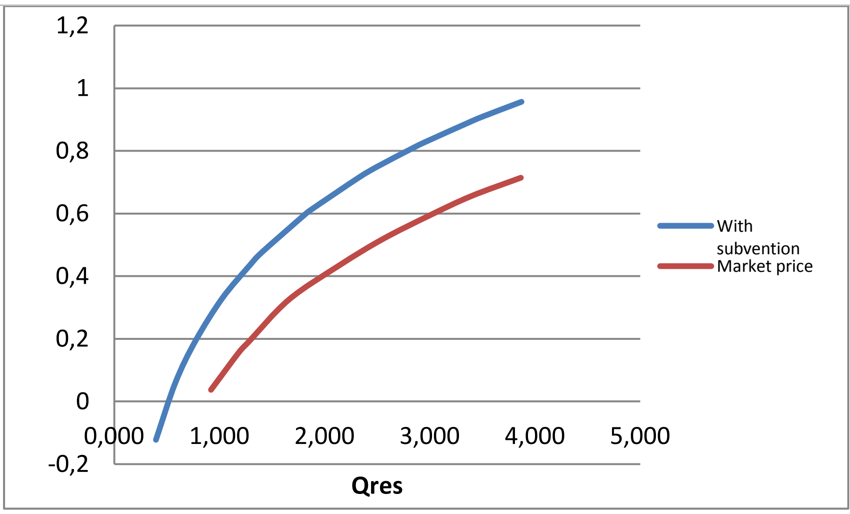
TIME COVER	1957-2009 (discharges)
UPDATE FREQUENCY	Annually
NUT III CODE	SI022
NORMATICE REFERENCE	5
NORMATIVE RELEVANCE	2

Kokra tree | ECONOMY | Contribution of Economic effects of small hydropower plants

FIELD	DESCRIPTION
INDICATOR NAME	Contribution of economic effects of small hydropower plants on local, and regional economic environment
ACRONYM	*Contribution to economic effects*
THEME/ SUB-THEME	4
DPSIR	R
DESCRIPTION	Purpose of the indicator is to demonstrate what the economic effects of small hydropower plant operation are. This indicator furnishes an evaluation of wider direct economic outcomes on the territories in the same administrative region of HP plant location; it assess the degree of satisfaction of regional administrator related to the different management alternatives considered in the MCA. The effects are measured by paid taxes and derivation concession in 60 year of economic period to local and national authorities from the generated income of hydro energy production. The amount of income distributed to taxes and concessions is converted to created average paid jobs from the produced hydro power. It can represent an exiguous percentage to be appreciated and valued; the utility of this indicator can often be represented in the phase of planning on territorial scale where the whole of the new fees related to the new planned plants can have a meaningful weight on the local administration budgets.
AIM	The aim of this indicator is to evaluate the impact of production of hydro energy on number of new job created in order to maximize the economical benefits for local communities.
KEY MESSAGE	Purpose of the indicator is to describe the collateral positive impact of SHP on local/regional economic environment.
MEASURE UNIT	Number of jobs from hydro power production on local/regional scale
REFERENCES	

FIELD	METHODS AND MONITORING STANDARDS
METHODS & MONITORING STANDARDS	The indicator value of generated incomes is calculated on the annual hydro power production.

	Assumption of the model: → **Optimal P** = Optimal annual production of hydro power → **% C** = % of annual concession from generated income → **PP**= guaranteed purchasing price of 1MW → **E** = economic period of SHP is 60 years → **T**= Annual property taxes for land use → **Tv/m2**= yearly tax value of 1 m2 in € → **A**= national average gross salary **STEP 1: Generated income from annual concession** **Annual concession income** = **Optimal P x PP % C x** **STEP 2: Generated income from annual property taxes for land use** **Annual T income** = **area sq.mt. of land used X Tv/sq. mt.** **STEP 3: Potential generation of new jobs** **Number of jobs per year = SUM INCOME (STEP 1+STEP2)/ A/12**
INDICATOR ELABORATION	Operation of hydro power plants is not only production of hydro energy but through generation of income deducted to local community and national authorities it can be also seen as a economic activity which can contribute to economic development of the area.
INDICATOR LIMITS	Besides mentioned direct effects which can be monitored through presented model, there are also indirect effects that have multiplying effects on other economic sectors.
INDICATORS SHARE FITNESS	4
AVAILABLE UF	YES
UF	

	The Utility Function adopted is: f(x)= 0,4741ln(x) + 0,0012 x= Nr. employees
CAUSAL RELETATIONSHIP **(PRESSURE INDICATORS)**	 *** MWh price with subvention** f(e)= 0,4734*ln(e)+0,3152 e=Qres
ALTERNATIVE INDICATORS	\
SHARE RELATED IND.	Financial outcomes – HP production level
COUNTRY CODE	SLO
WFD HER	\

FIELD	**DATASOURCES**
DATA SOURCE	Ministry of economy, European Energy Exchange AG
DATASETS FORMAT	*Excel file*
DATA GEOREFERENCE	/
TIME COVER	Yearly production, Energy price
UPDATE FREQUENCY	Annually
NUT III CODE	\
NORMATICE REFERENCE	\
NORMATIVE RELEVANCE	\

3. Evaluation of alternatives performance

Calculations to determine which alternative gives best result have been made at predetermined weights (W_{ECO} = 9/16 = 0.5625 and W_{RES} =7/16 = 0.4375; in this case there is no Natura 2000 area). Calculations have been made for different combinations of different residual discharges and additional alternatives where different number of fish passes on existing barriers is planned as described above under Alternatives paragrpah (Measure 0, Measure 1, Measure 2, Measure 3 and Measure 4).

Main objective is to determine residual discharge (Qres) which would be optimal solution for two European directives WFD and RES Directive. To determine optimal Qres we had to calculate two different possibilities (two cases). In first case (Case 1) investor doesn't invest in any additional measures to improve ecology criteria. This means that Case 1 is with introducing Measure 0 (Investor can build a weir on location where there are no impassable sills). In this case »Alternative Qmean« (alternative with no withdrawal) represents current situation (without withdrawal) and all other Alternatives with different Qres values represent current situation (with withdrawal). Second case (Case 2) includes alternatives when all possible additional measures for improvement of criteria ecology are taken in. For Kokra river only building fish passes is the additional measure so Case 2 is case with introduction of Measure 4 (Investor can build fish passes on 4 of the impassable barriers - number of built fish passes is 4). This way there is improvement for the ecology criteria and therefore Case 2 gives better score since additional score for indicator Longitudinal connectivity is gained. For optimal result we have to calculate and determine best score in Case 1 (next Figure) .
Results of Case 1 are represented in next figure (no additional measures are taken in):

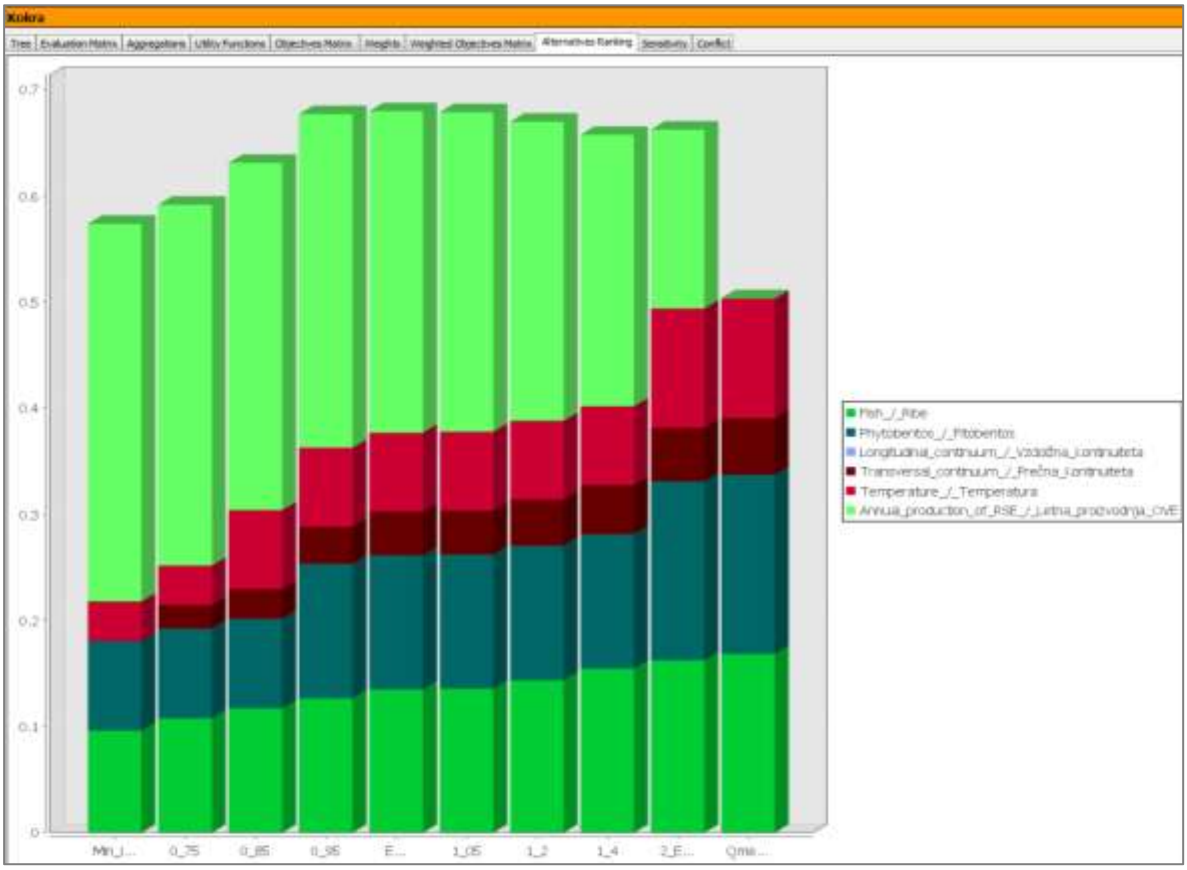


Figure 7: Results of Case 1 (introducing Measure 0)

Best score in Case 1 is 0.68 for residual flow Qres = 1.036 m^3/s. This is also discharge which is determined as ecologically acceptable flow (Qes) for Kokra according to Slovenian legislation. Alternative with no withdrawal has the lowest score. Calculations for Case 2 show that winning alternative is also Qres = 1.036 m^3/s, but in this case it has the value of 0.718. Next figure shows results in Sesamo for Case 2.

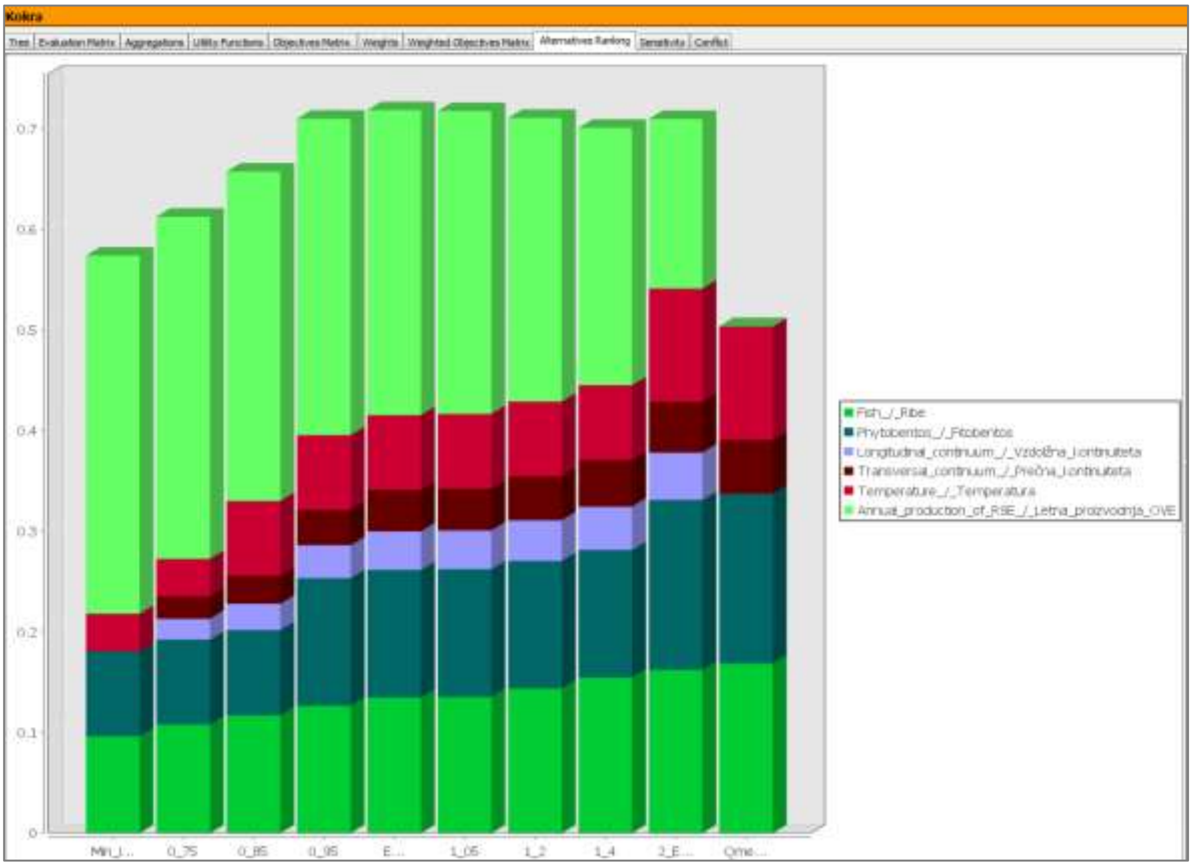


Figure 8: Results of Case 2 (introducing Measure 4)

Comparison of results of Case 1 and Case 2 is represented in next graph. We can see that distribution of different residual flows is same for both cases, only scores are generally higher for Case 2. For “Alternative Qmean” the results are the same since it represent a current situation.

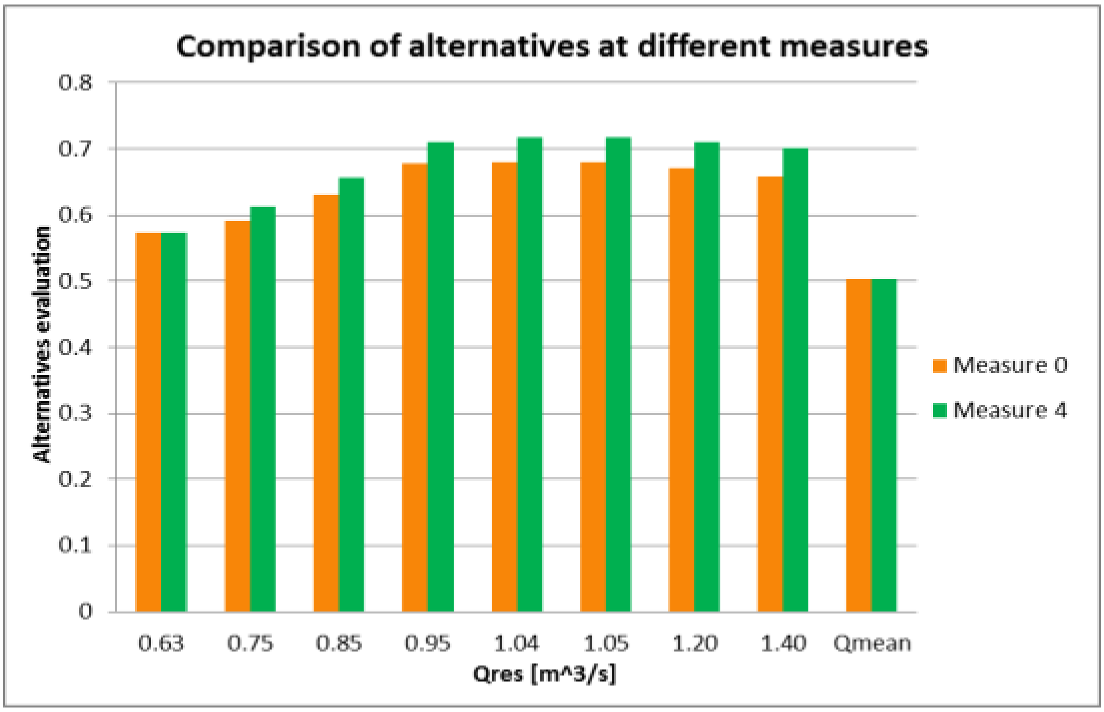


Figure 9: Comparison of results of two different cases

To get optimal Qres we need to find the Qres in Case 2, with the same score value as the maximum value in Case 1 (0.68). Determination of that Qres in Case 2 is represented in next Figure.

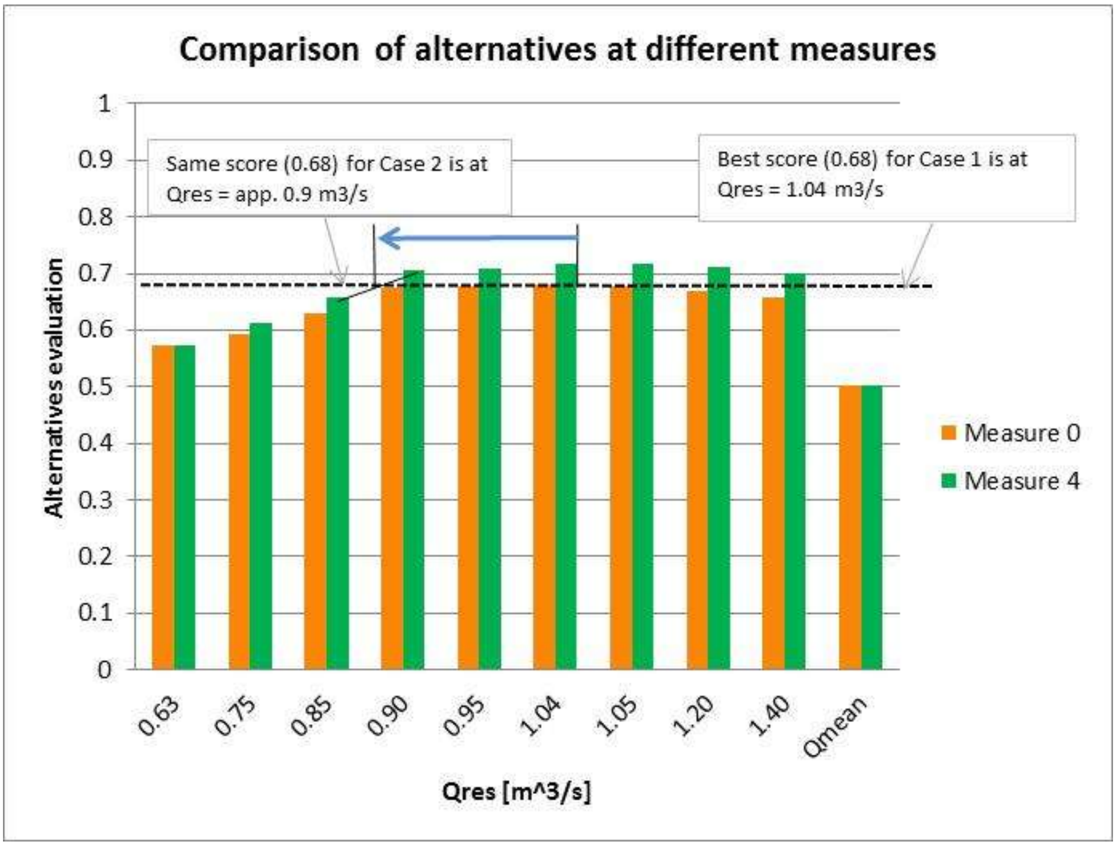


Figure 10: Determination of Qres in the Case 2

We can see that in Case 2 Qres = 0,9 m^3/s achieves score arround than 0.68. We could determine exact Qres by additional interpolation between Qres = 0,85 m^3/s and Qres = 0,87 m^3/s (aditional alternatives). We can assume that result is aproximately Qres = 0,9 m^3/s. This is approximately 140 l/s less than Qes determined according to Slovenian legislation, if no additonal measures takes place (building fiss passes on barriers in analysed river section).

Presented case study shows how value of Qres can be harmonized (lowered) when additional measures takes plas. We didn't take into account costs of these additional measures. Investor has to decide in how many additional measures he can invest and the amount of water for withdrawal that the investment is still profitable.