Study on Minimum Environmental Flow for Hydropower Projects in Bhutan

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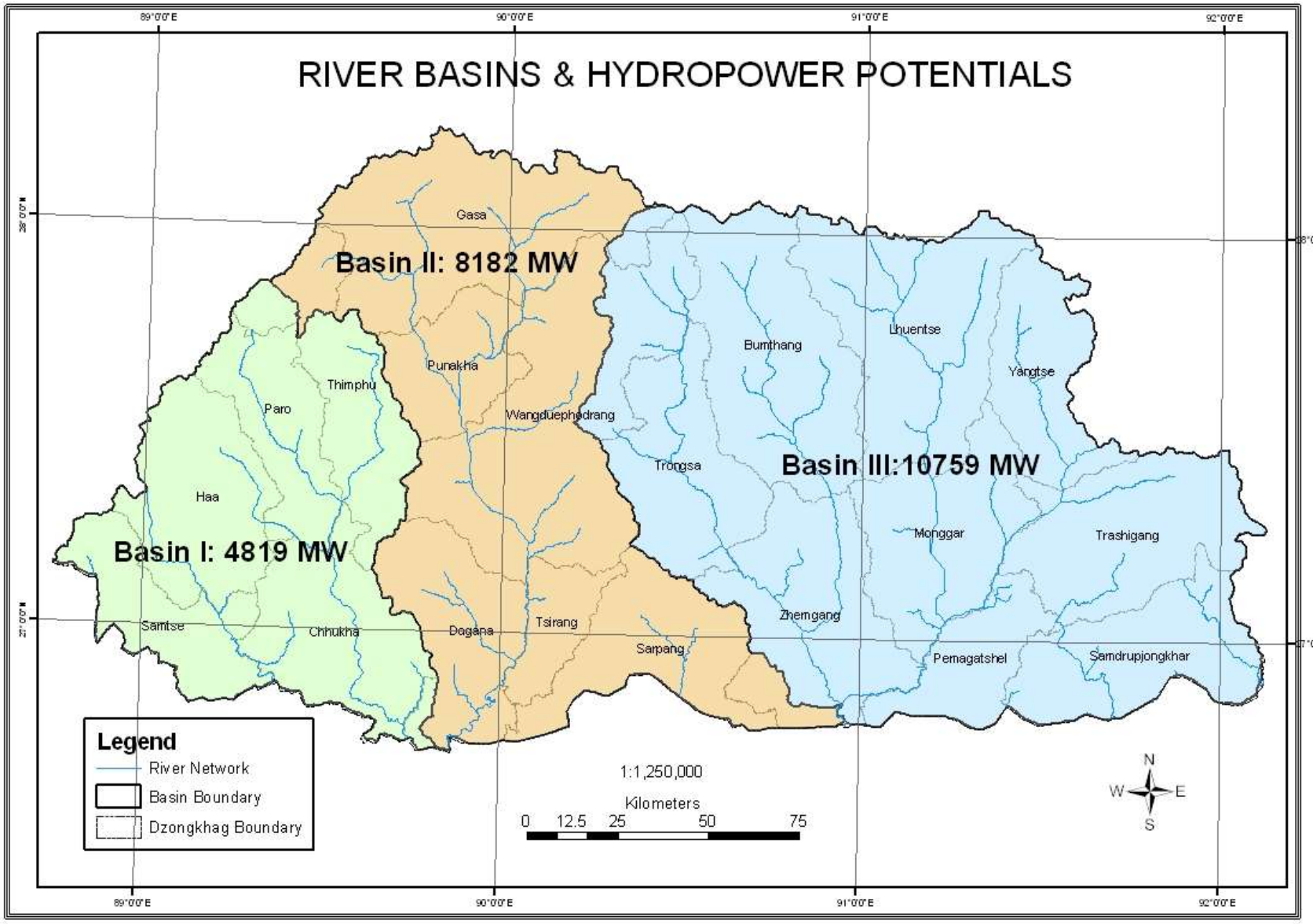
Country Profile

- Land Area : 38,394 Sq. km
- Forest Cover : 72%
- Population (2017) : 727,145
- Per Capita GDP (2016) : $2,879
- Per Capita Electricity Consumption (2017): ~3,000 kWh
- Electricity Contribution to GDP (2017): 12%

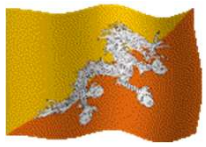
Water Resources & Hydropower in Bhutan



Study on Minimum Environmental Flow for Hydropower Projects in Bhutan

Project details

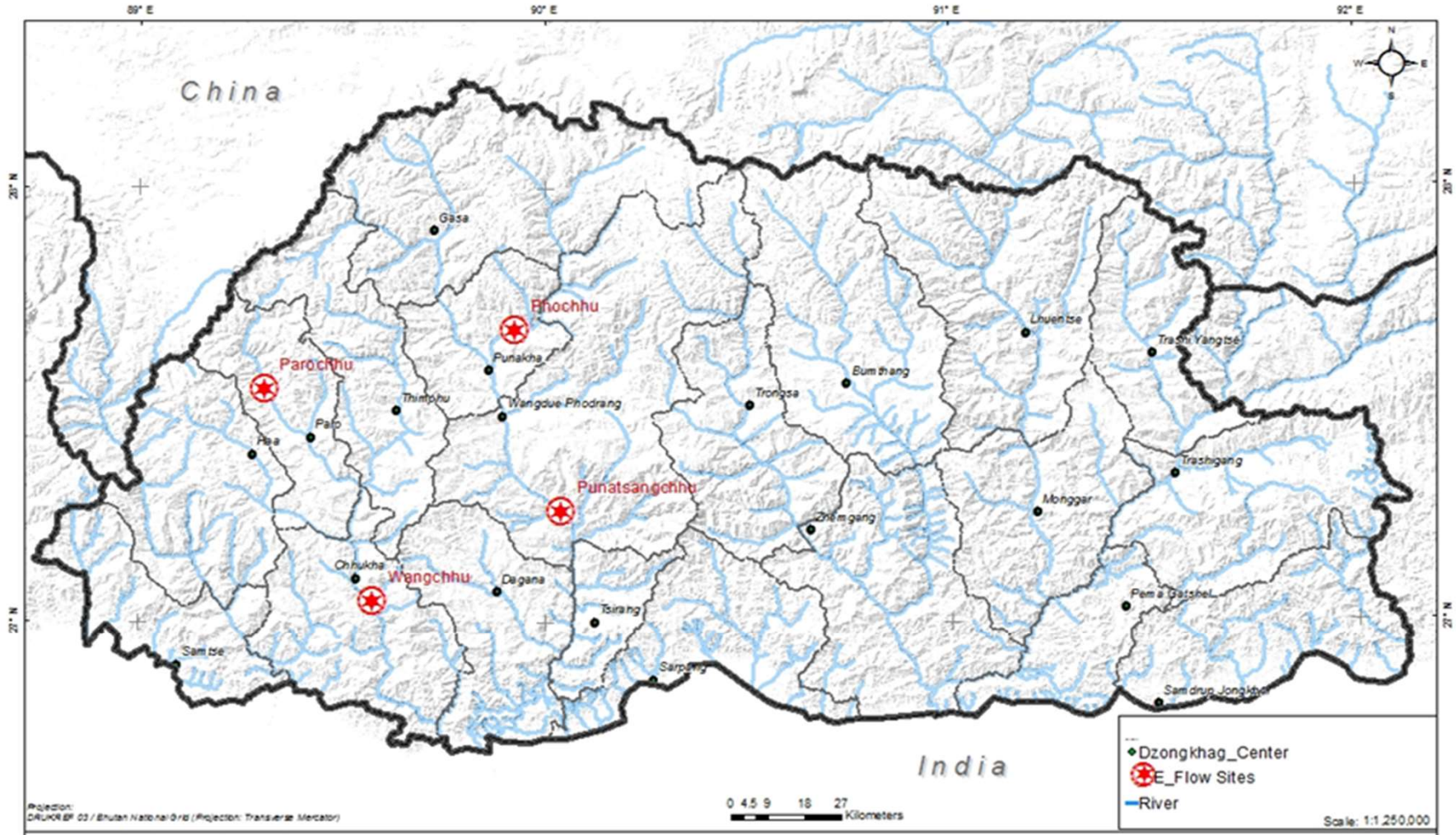
- Funding: Austrian Development Agency (ADA)
- Implementing Agency: NECS
- Expected Result:
  - Guidelines Development,
  - Minimum E-Flow standard established; and
  - Capacity development
- Project duration: October 1, 2014 to March, 2018



E-Flow Guideline of Bhutan

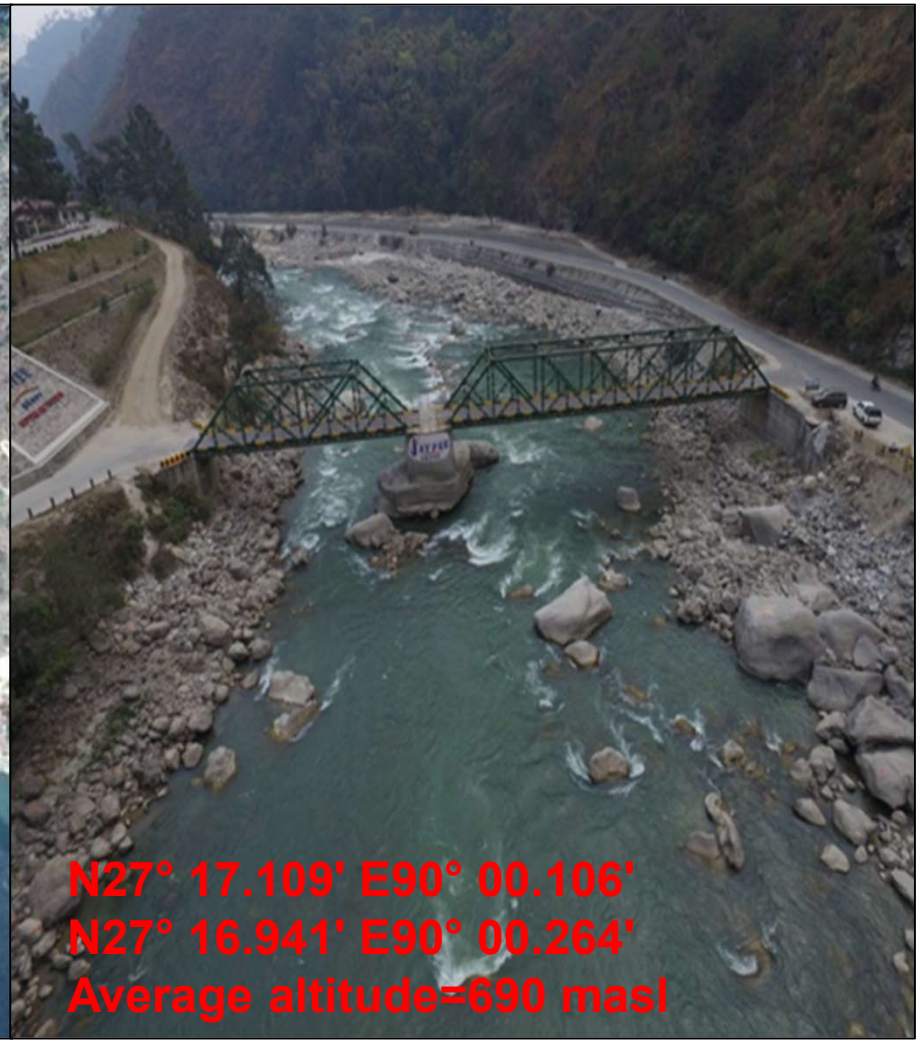
- NEC is mandated to ensure minimal environmental impact from development activities.
- Establishing Minimum environmental flow as required under the National Environment Protection Act 2007 and the Water Act of Bhutan 2011.
- The environmental flow has been assessed in at least 4 river basins.
- 26 officials from universities, relevant Ministries and the National Environment Commission have been trained on assessment and determination of e-flow; 13 of them have also been trained at site for field sampling and data collection.

E-Flow Sites

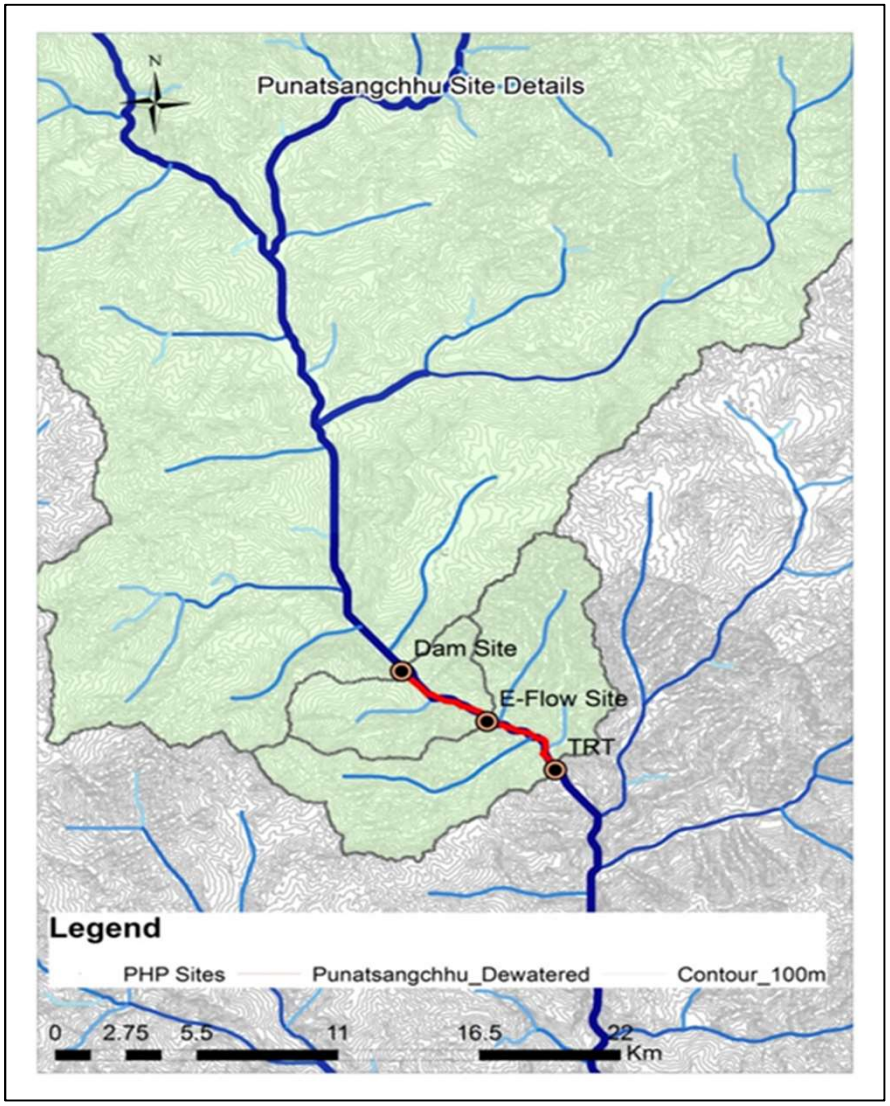


Map of Bhutan with Location of E_Flow Sites

Punatsangchhu Pilot Study Reach



Punatsangchhu catchment and pilot study reach



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Punatsangchhu Field Measurements

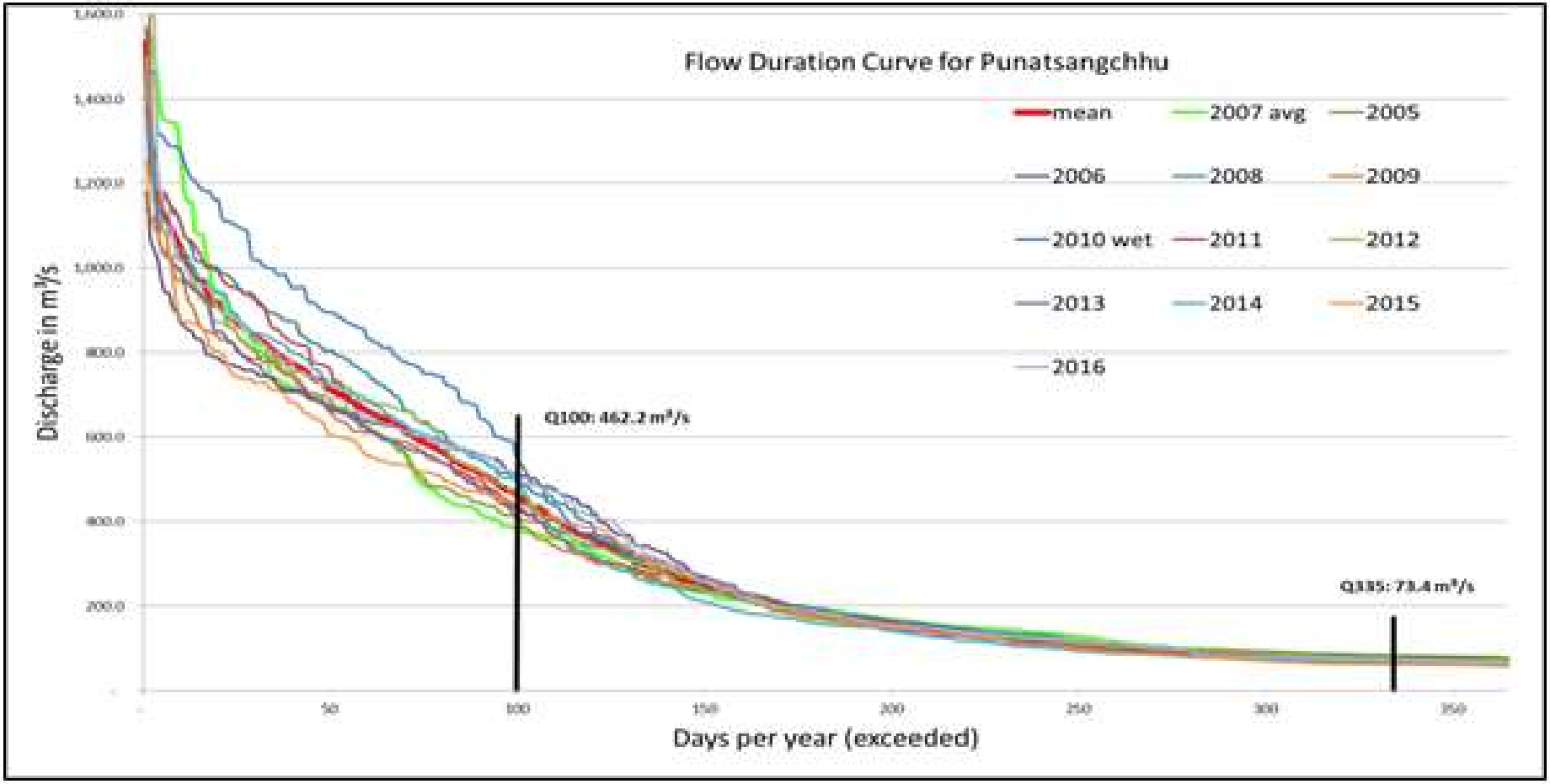
- Main focus : terrestrial and bathymetric survey with the total station as well as the bathymetric survey of the deep and fast sections with the Echosounder (CeeScope) mounted on a Kayak.
- Beside cross sections (CS), water lines (WL) were measured with the total station.
- The ground control points (GCPs) for UAV based survey, were measured.
- Discharge was measured with the ADCP (RiverSurveyor) mounted on the hydroboard .
- The UAV (unmanned aerial vehicle) was used in addition to get additional terrestrial data.

Echo Sounder on kayakmount in the Punatsangchhu

ACDP on hydroboard in the Punatsangchhu

Punatsangchhu Hydrological Analysis

Flow Duration Curves for Punatsangchhu



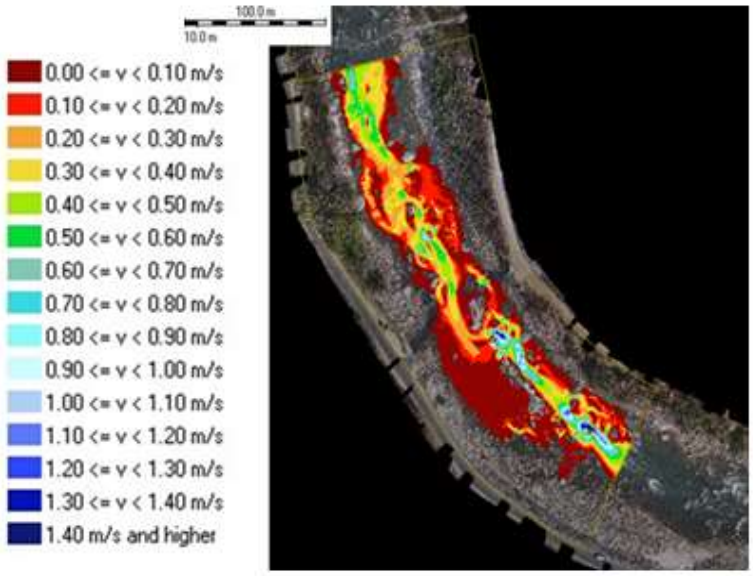
Reference flow in winter $Q_{335} = 73\ m^3/s$

Reference flow in summer $Q_{100} = 462\ m^3/s$

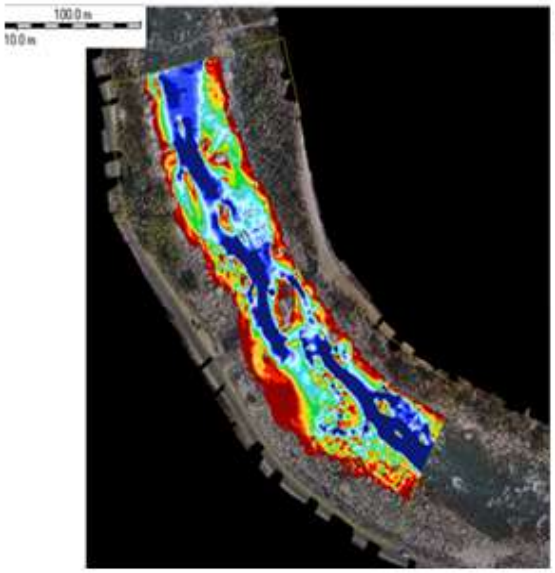
Hydrodynamic model development

- Model runs for a series of flows
- xx flows modeled
- 5.0 m^3/s – 200.0 m^3/s

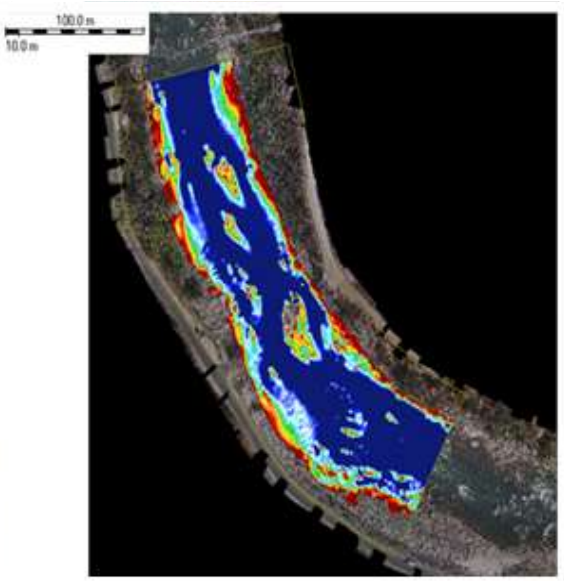
Flow velocity



5.0 m^3/s

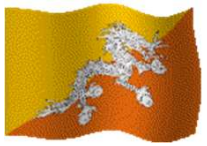


59 m^3/s

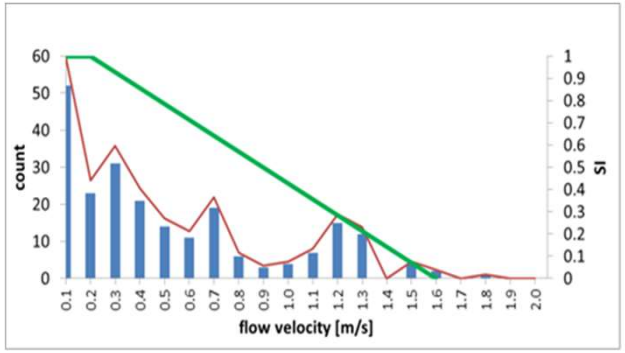


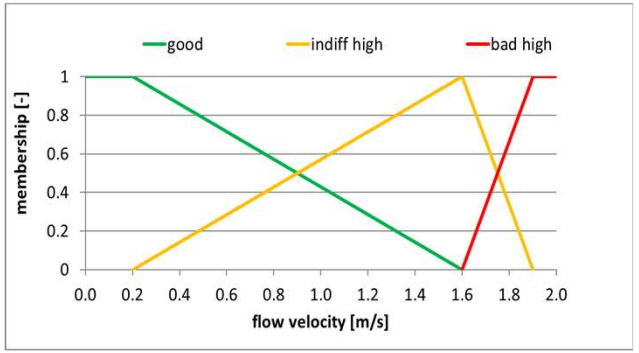
200 m^3/s

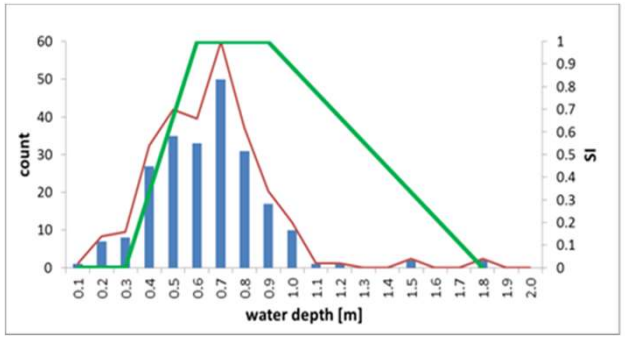
Electrofishing in Kamichhu

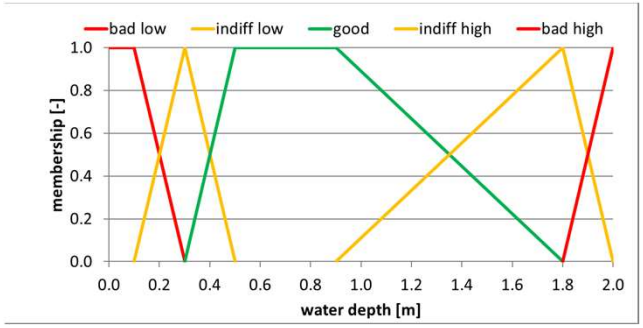


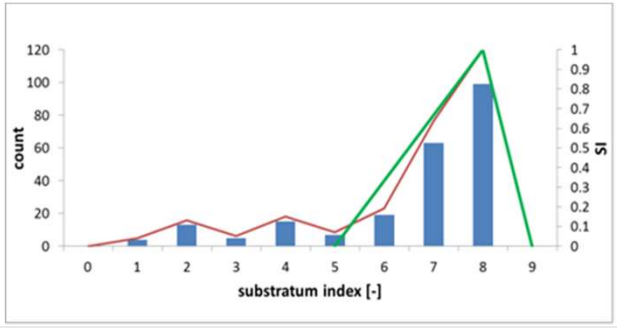
Fish catches and suitability fuzzy sets, snow trout (*Schizothorax richardsonii*) medium size

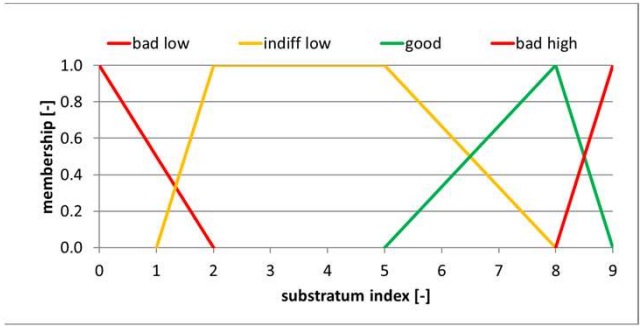






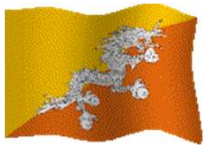




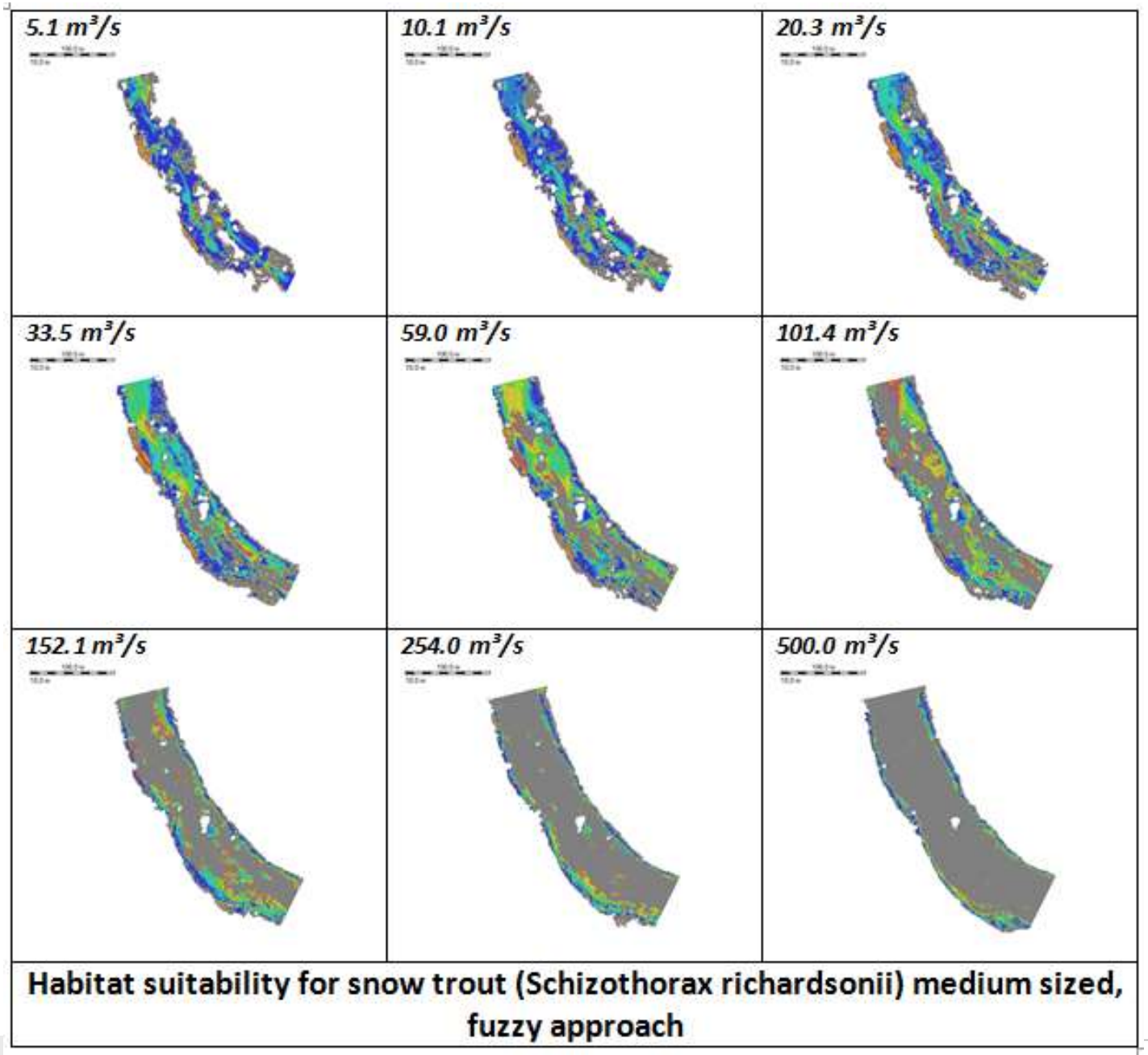


The sets define **ranges** of velocity, depth and substratum that are good, indifferent and bad in terms of habitat quality .

→ beneficial for data scarce situations



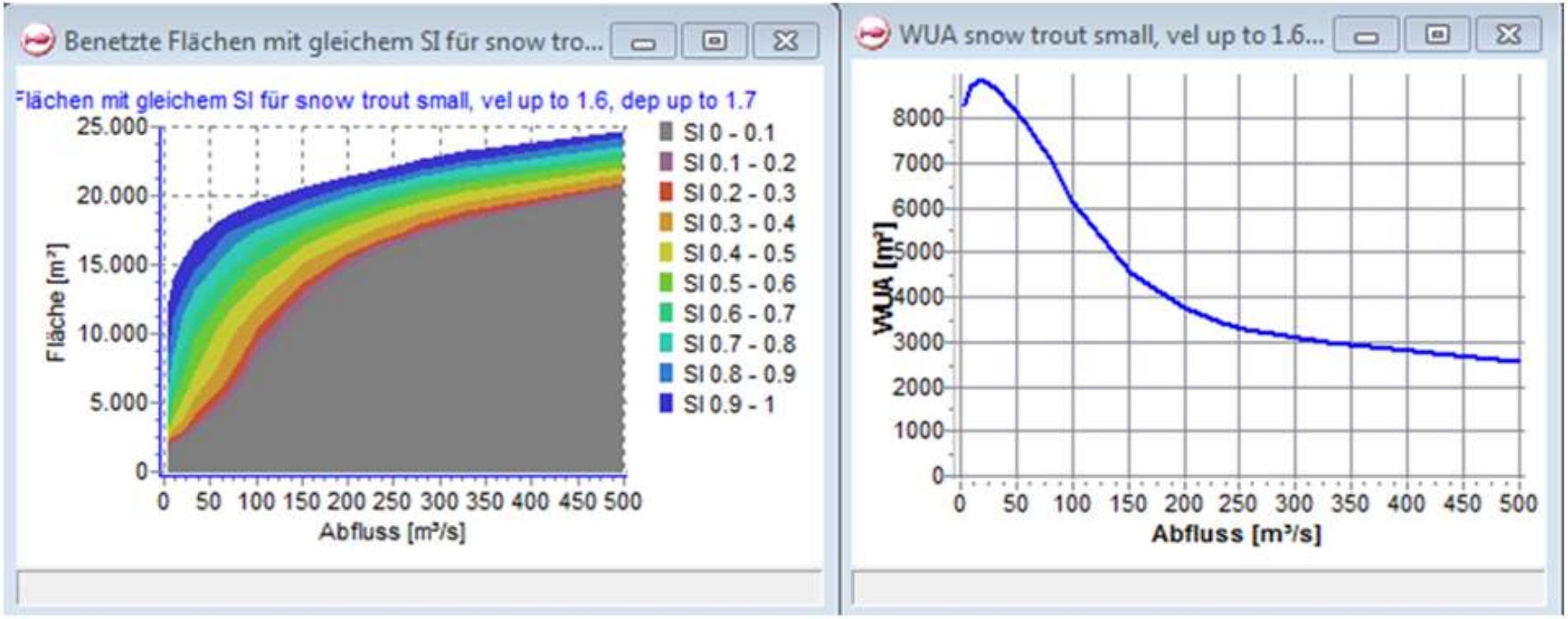
CASiMiR results



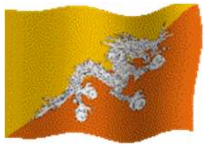
Habitat suitability for snow trout (Schizothorax richardsonii) medium sized, fuzzy approach

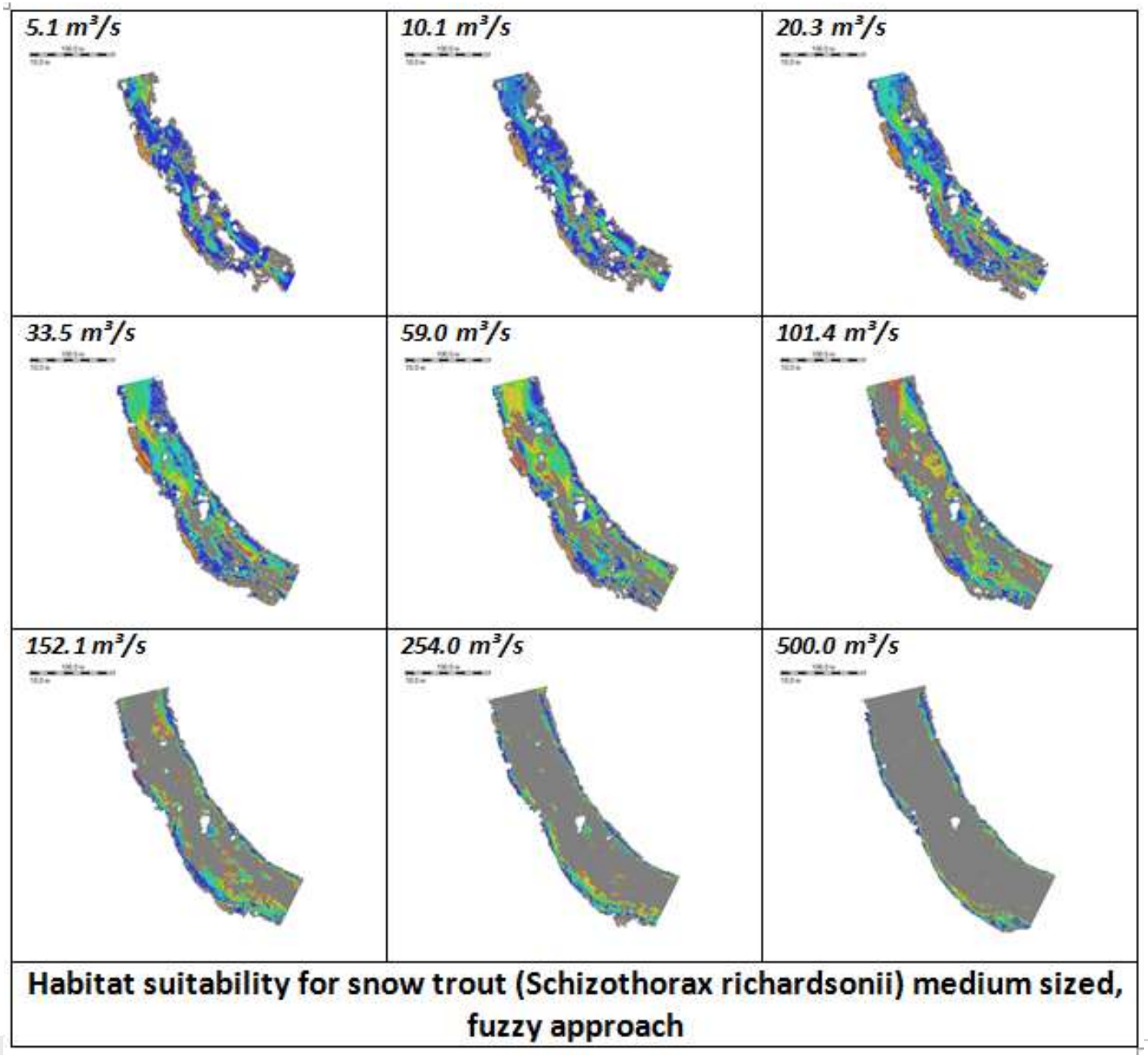
Habitat suitability, modeling results

- Snow trout medium



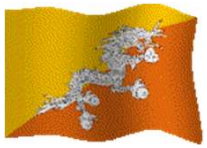
- Snow trout: very low flows are sufficient



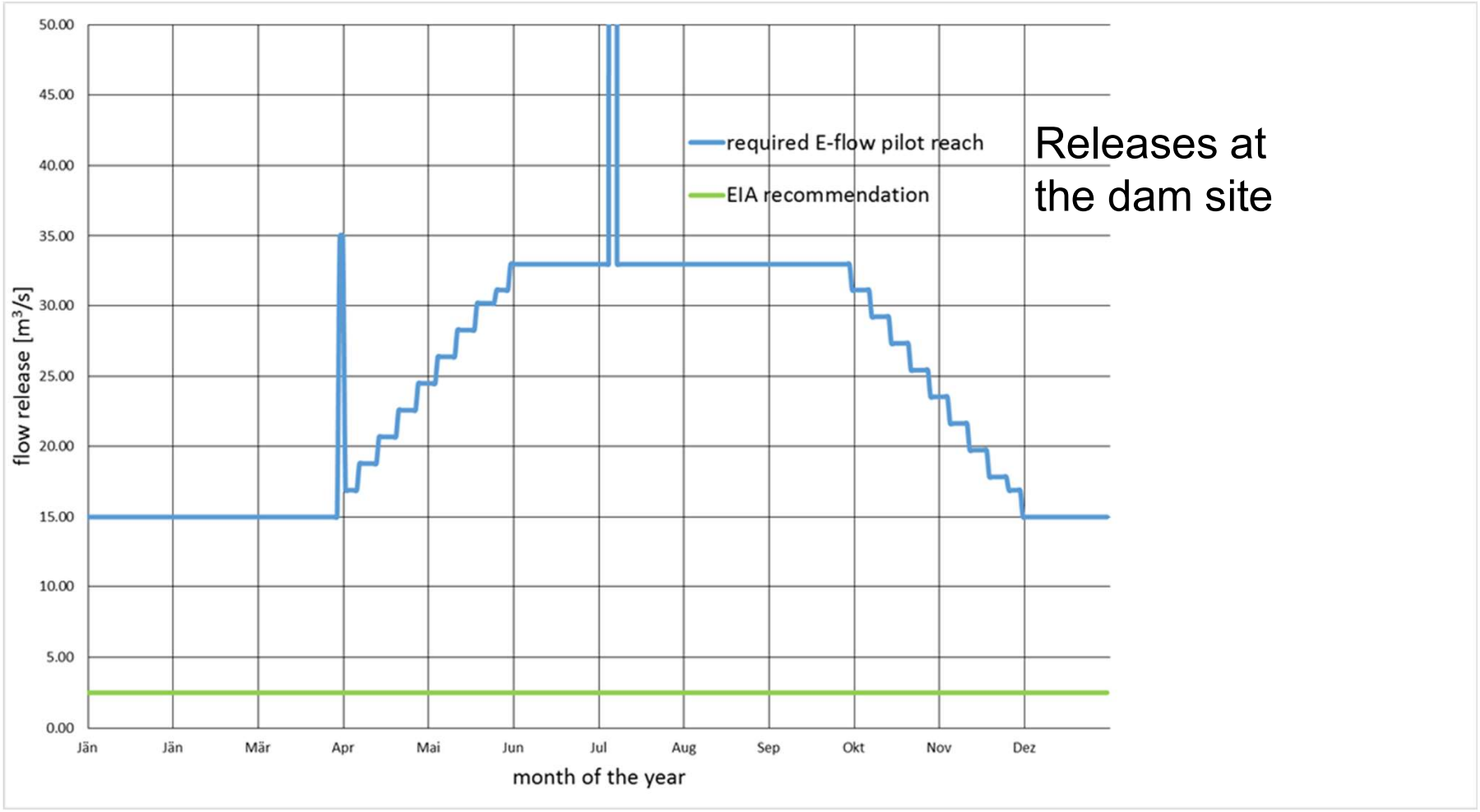


0.00 <= v < 0.10 m/s
0.10 <= v < 0.20 m/s
0.20 <= v < 0.30 m/s
0.30 <= v < 0.40 m/s
0.40 <= v < 0.50 m/s
0.50 <= v < 0.60 m/s
0.60 <= v < 0.70 m/s
0.70 <= v < 0.80 m/s
0.80 <= v < 0.90 m/s
0.90 <= v < 1.00 m/s
1.00 <= v < 1.10 m/s
1.10 <= v < 1.20 m/s
1.20 <= v < 1.30 m/s
1.30 <= v < 1.40 m/s
1.40 m/s and higher

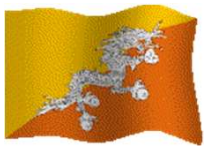
Habitat suitability for snow trout (Schizothorax richardsonii) medium sized, fuzzy approach



E-Flow

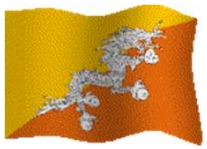


Releases at the dam site



Socio-economic and cultural assessment

- Summary
  - Screening and assessment reveals no potential impacts
  - Dispersed settlements are located along the Wangdue-Tsirang highway but have no clear links to the river
- Settlements
  - Kamechu (7 households): Roadside shops and restaurant, next to river, no use of river
  - Pinsa (7 households): Agricultural settlement, 4km away, no use of river
- Requirements
  - No significant links between the socio-cultural and socio-economic uses and the river
  - No aspects need to be considered for the E-Flow determination.



Energy generation

- CASiMiR hydropower model:
  - 2 scenarios
  - baseline with 2.5 m^3/s constant E-flow release
  - E-flow release at dam for full required flow in pilot study reach

- PHP 2 as described
  - Simplified analysis with constant head
  - Constant efficiency of 85% including all losses

Comparison of annual energy generation based on E-flow scenarios

Impact	Annual energy generation [MWh]	Annual revenue [Mio USD]	Relative to scenario 0 [%]
Scenario 0	4 216 579	210.8	100
Scenario 1	3 922 625	196.1	93.0

THANK YOU

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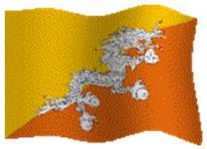

Indicator species and fish protection category

- **Golden Mahseer**
  - complex life cycle and specific habitat requirements
  - Adult fish arrive by mid-February and stay in main stream (holding)
  - Migrate up into spawning streams by May/June
  - Spawning site selection and spawning from July through September followed by downstream migraton
  - Hatchlings appear in October/November in tributaries
  - Swim-up fry in November-December
  - Downstream migration starts January through April
  - Migration up to 200 km
  - Migration and holding habitats between February and May/June

Chocolate mahseer

- **Snow trout**
  - spawn between late winter and July – October, spawning and rearing habitat required