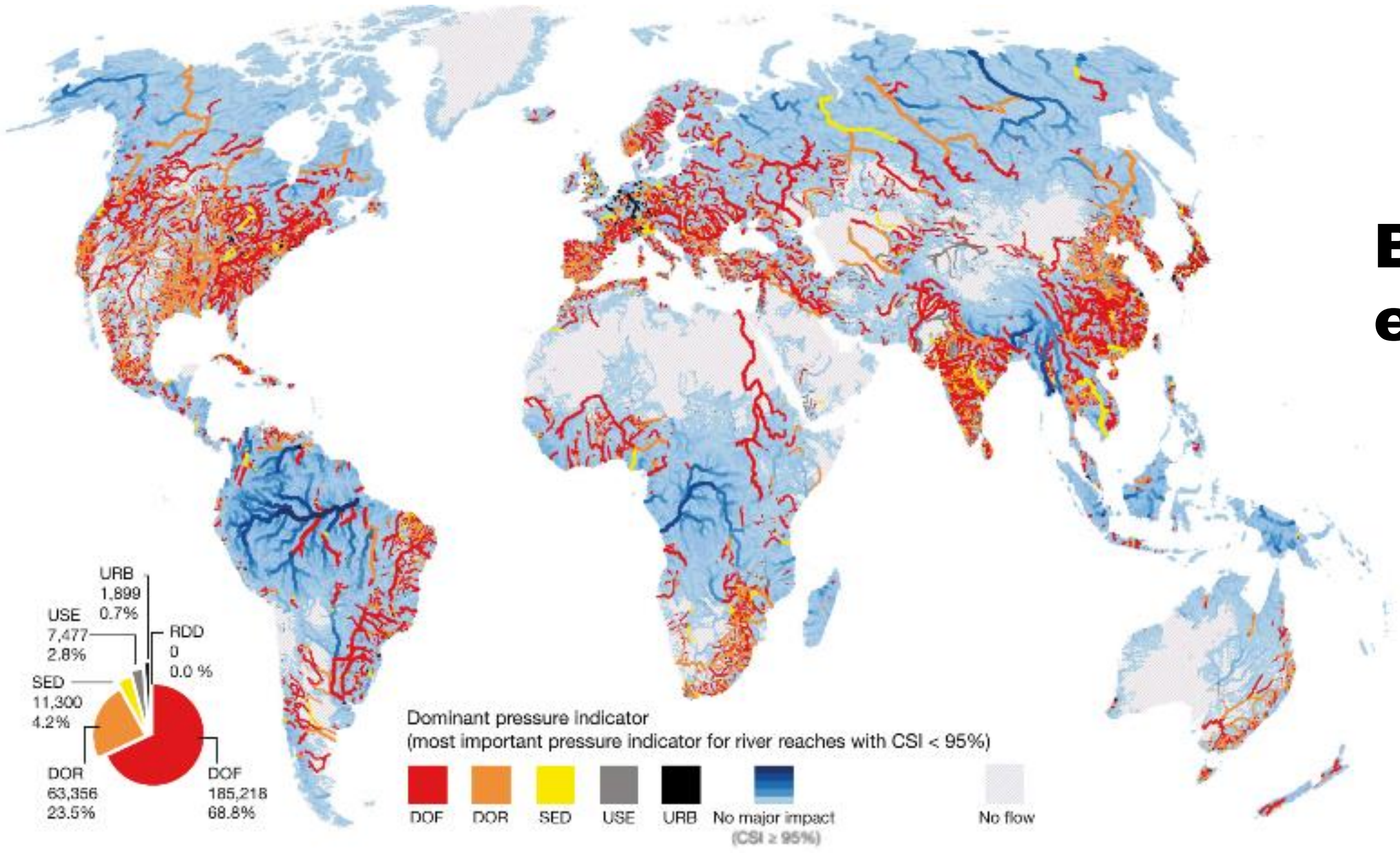
Cost-effective mitigation measures

Ana Adeva-Bustos

et. al…

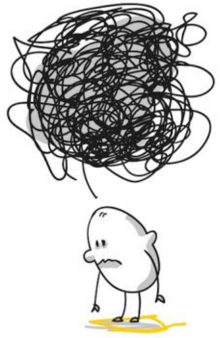
Background



(Grill, Lehner et al. 2019)

UNCERTAINITY

But….what? Will it be effective? At what price?



Background

Many Potential Challenges and Impacts for specific cases

Flow and Habitat	Upstream Migration	Downstream Migration	Sediments
Spawning and rearing habitat	Missing fish pass	Missing physical barriers	Sediment deficit
Downstream flow	Height drop	Turbine passage	Sediment surplus
Attraction flow for UP and DOWN	Missing monitoring	Trash rack too wide	Clogging of substrate
Environmental flow in bypassed reach	Fish pass discharge	Missing monitoring	Wood and sediments
Operational strategy	Missing fishway data	Guidance device	
Habitat in bypassed reach	Fish entrance	Fish entrance	
Hydropeaking	Effect of cumulative dams	Maintenance	
		Effect of cumulative HPp	

Background

SINTEF

Many Potential Mitigation Measures

Environmental Flow Release	Habitat Adjustments	Fish Migration	Sediment Control
Dynamic flow release	Adult fish habitat	Concrete and nature-like fishways	Sediment flushing
Static flow release	Spawning habitat	Monitoring facilities	Debris removal
Hydropeaking rate reduction	Riparian zone restoration	Downstream guiding facilities	Mechanical removal of fine sediment
	Rearing/juvenile habitat	Archimedes screw	
	Retention pools	Smolt traps	
		Trash rack	
		General maintenance	

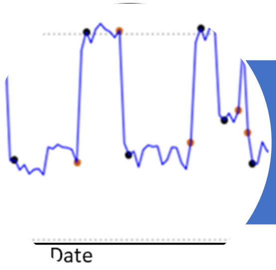
Objective

To identify potential mitigation measures that are **most likely to succeed** and that are **cost-effective**.

Test cases

Habitat improvements

Fish Migration

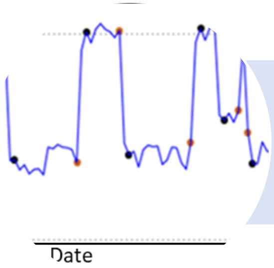


Hydropeaking

Test cases

Habitat improvements

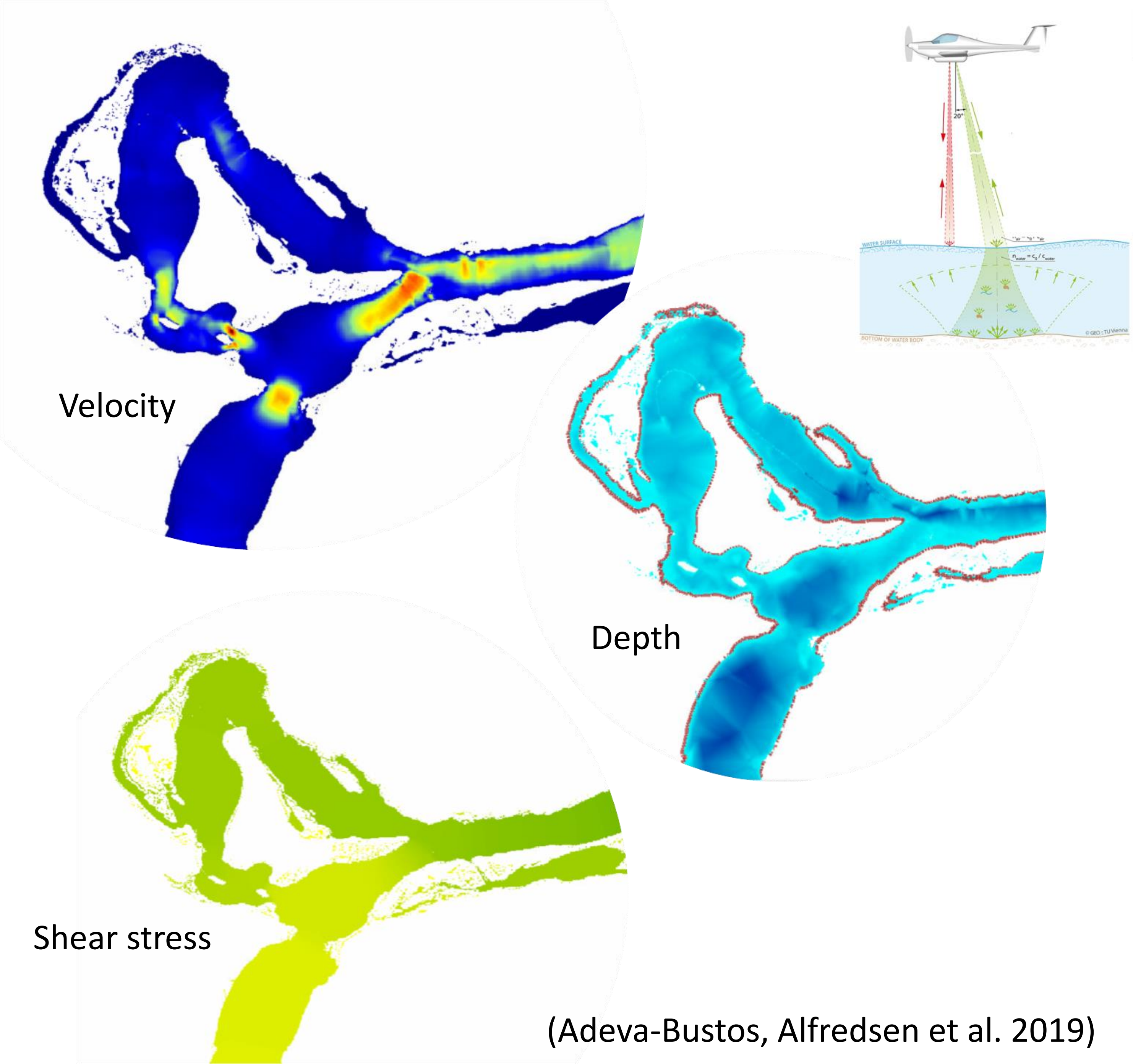
Fish Migration



Hydropeaking

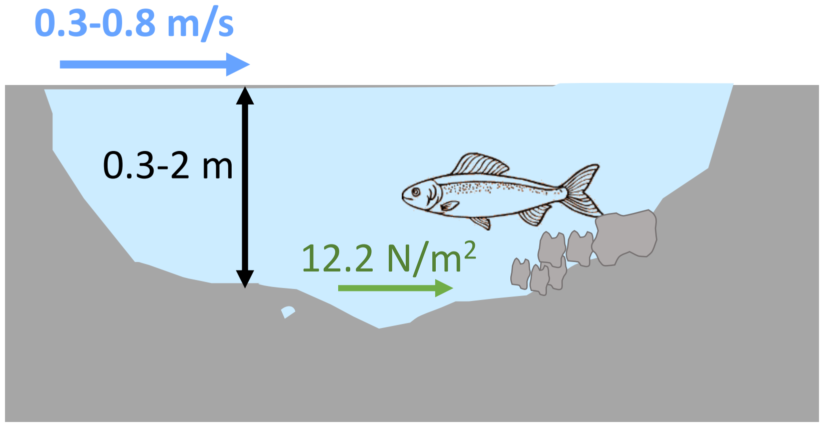
Ljungan River (Sweden)


Spawning site
Side channel
Foto © Göran Hultgren 2015

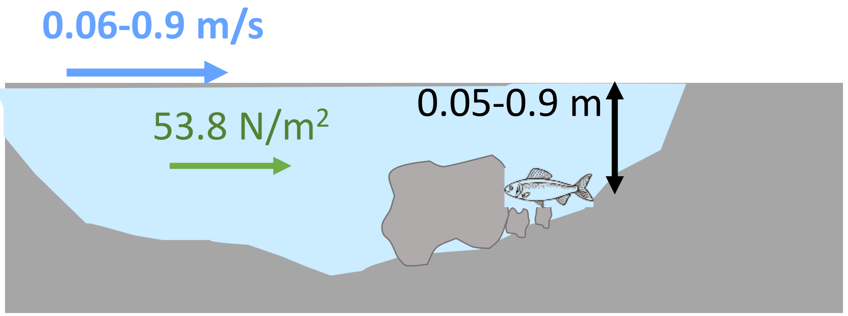


(Adeva-Bustos, Alfredsen et al. 2019)

SPAWNING AREA*

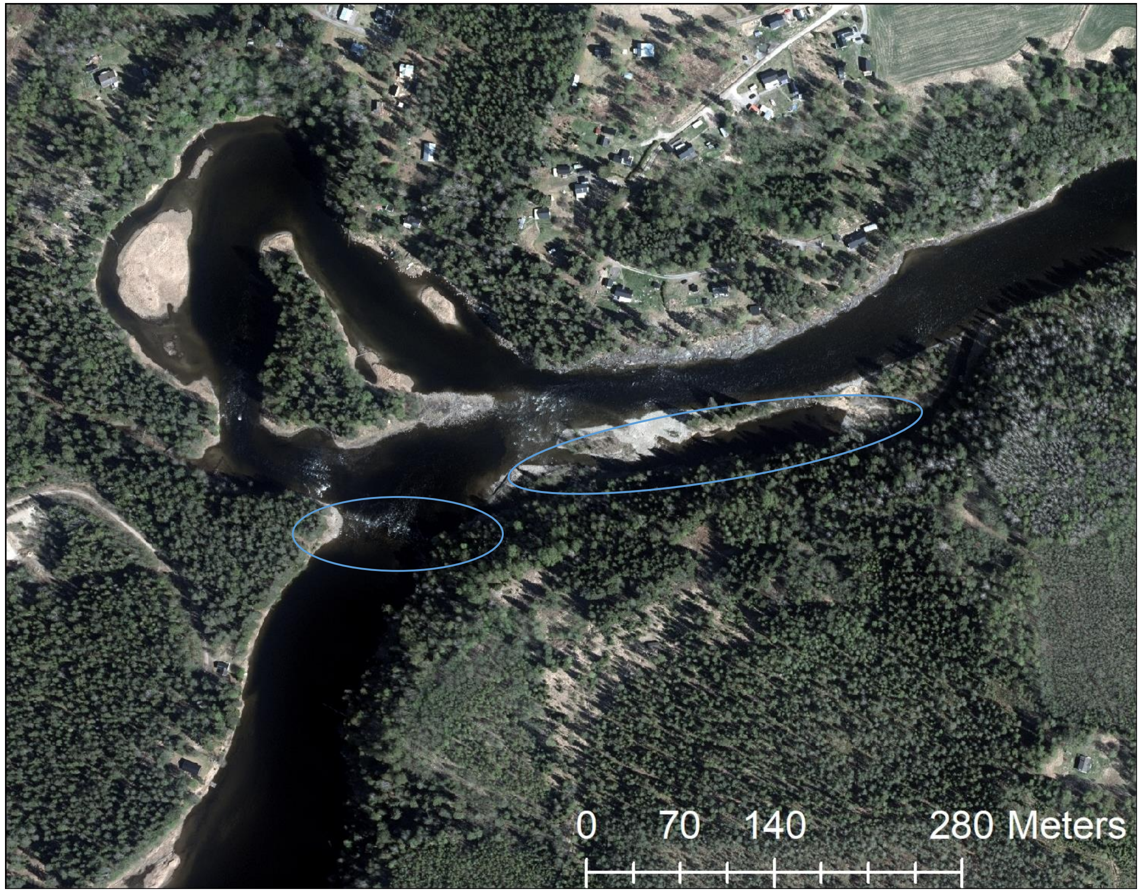


NURSERY AREA*



Sources: *(Armstrong, Kemp et al. 2003), (Forseth and Harby 2014)/ field Experiments Helge Skoglund*

Cost per effective area created



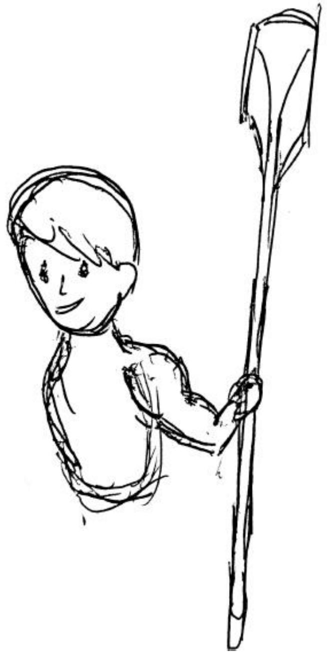
SPAWNING AREA

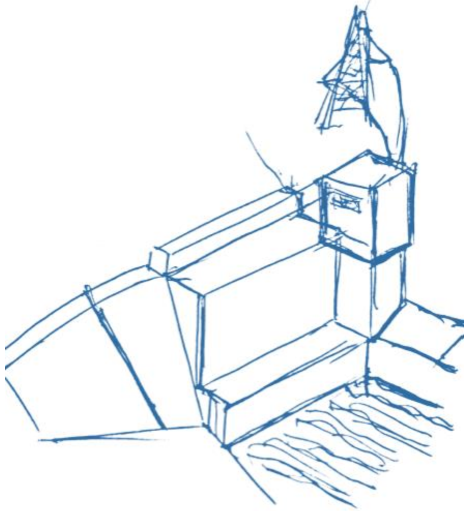
Discharge ($m^3.s^{-1}$)	Depth PSA %	Depth Cost (EUR/m^2)	Velocity PSA %	Velocity Cost (EUR/m^2)	Shear Stress PSA %	Shear Stress Cost (EUR/m^2)
60	9.60	50.31	15.01	47.64	-10.26	41.50
100	17.91	51.60	8.09	47.77	-22.49	65.94
138	13.69	61.66	2.33	57.31	-8.58	71.46
380	-10.04	359.56	-3.59	0.00	-0.80	0.00

NURSERY AREA

Discharge ($m^3.s^{-1}$)	Depth PSA %	Depth Cost (EUR/m^2)	Velocity PSA %	Velocity Cost (EUR/m^2)	Shear Stress PSA %	Shear Stress Cost (EUR/m^2)
20	94.82	2.94	34.34	8.12	56.82	4.91
30	17.87	1.66	21.49	5.95	10.90	3.20
35	-3.21	0.72	9.75	4.87	14.31	2.14
40	3.30	0.69	15.30	2.54	22.24	1.05
60	-2.04	0.61	28.26	1.10	62.79	0.46
138	-1.42	0.46	49.75	0.35	1.50	0.25

(Adeva-Bustos, Alfredsen et al. 2019)





Mandal River (Norway)

LAUDAL

0 65 130 260 Meters

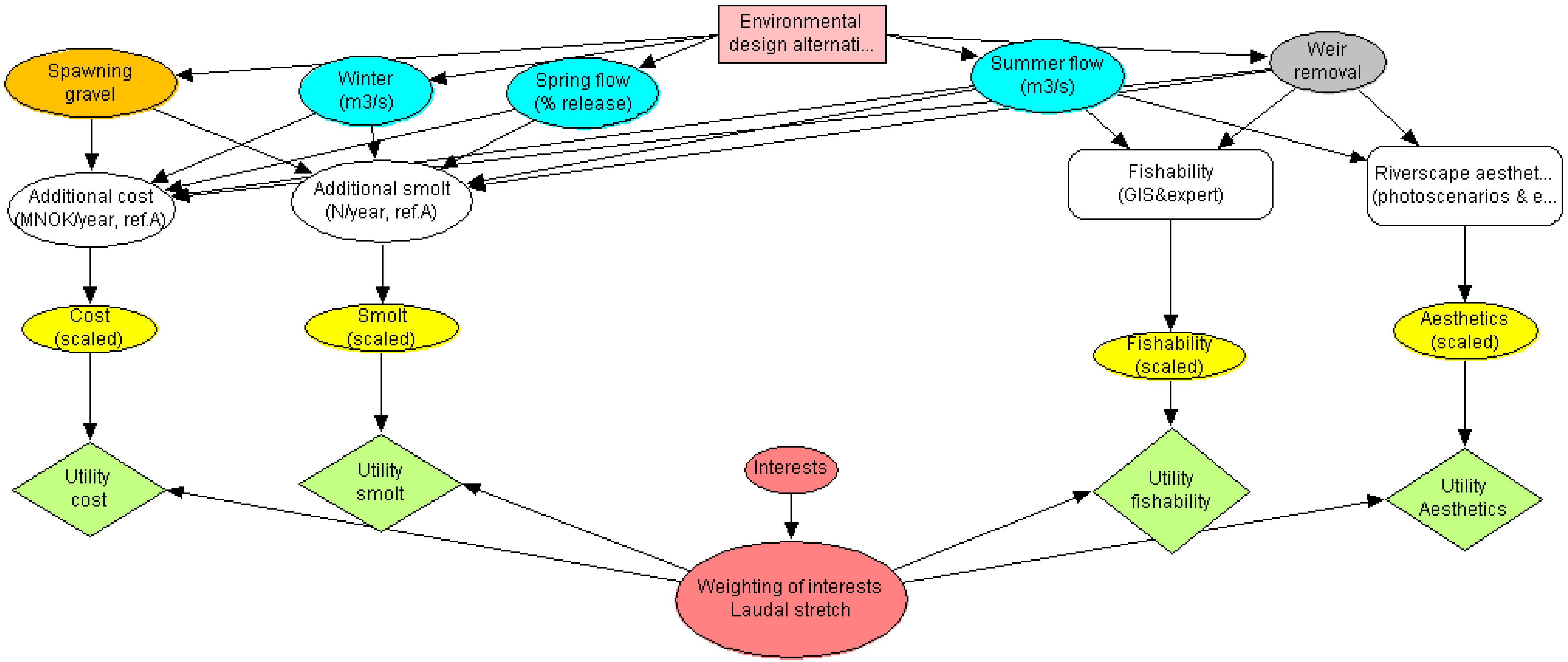
©Fb Upper Mandal

Without weir 6m³/s

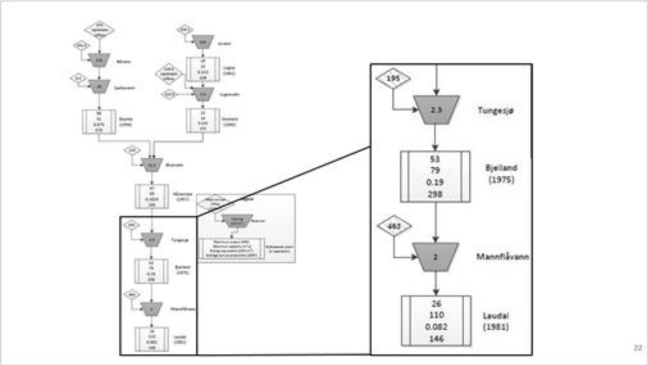
©Uni MIljø

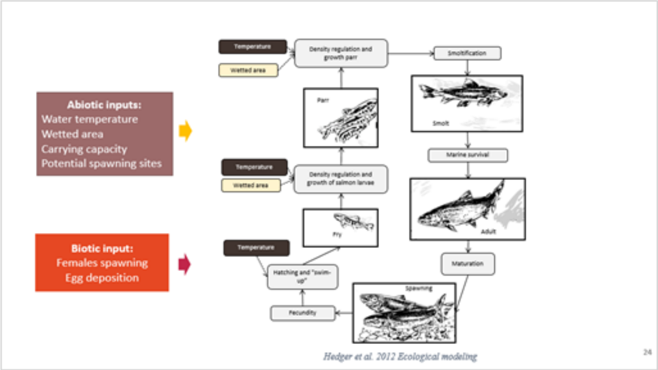
14

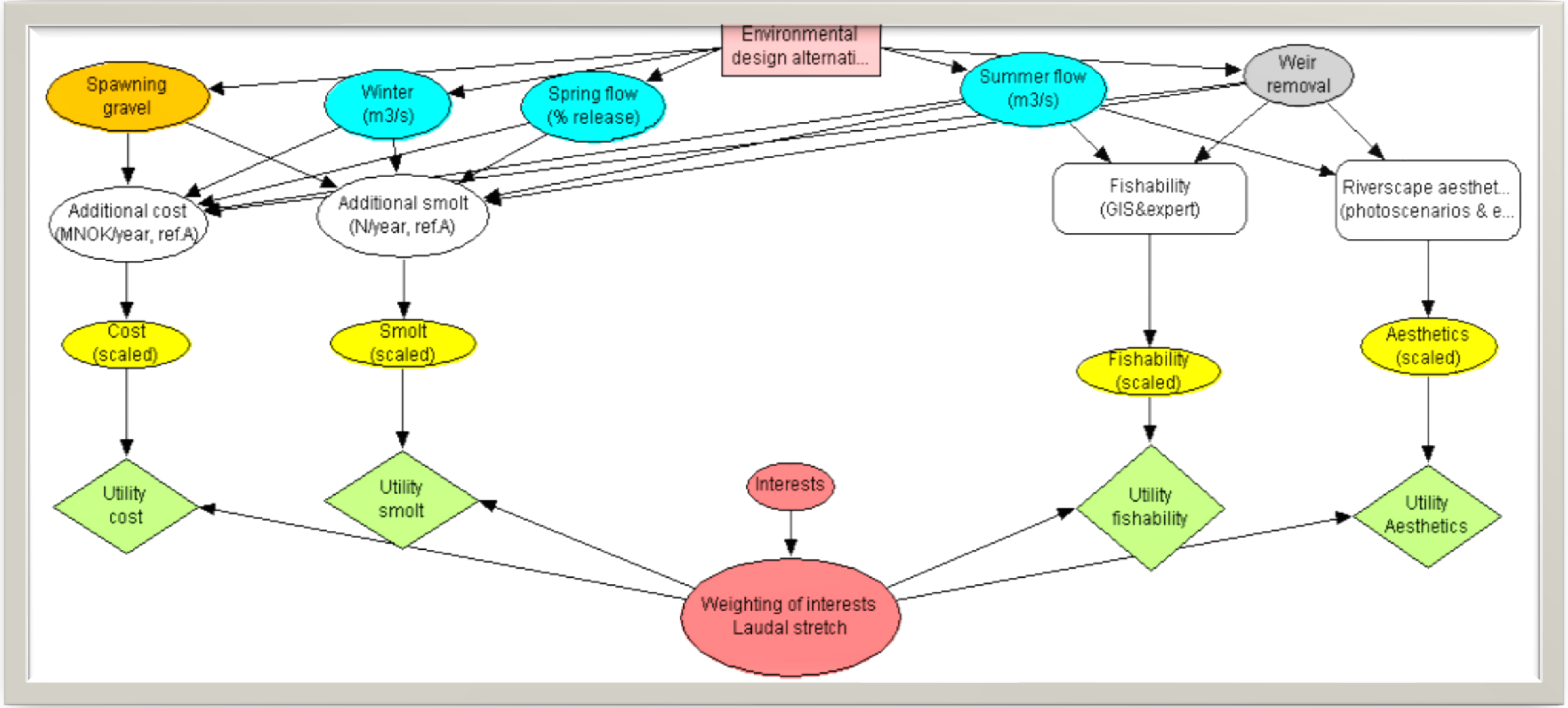
Multicriteria Decision Analyses



(Barton, Sundt et al. 2020)

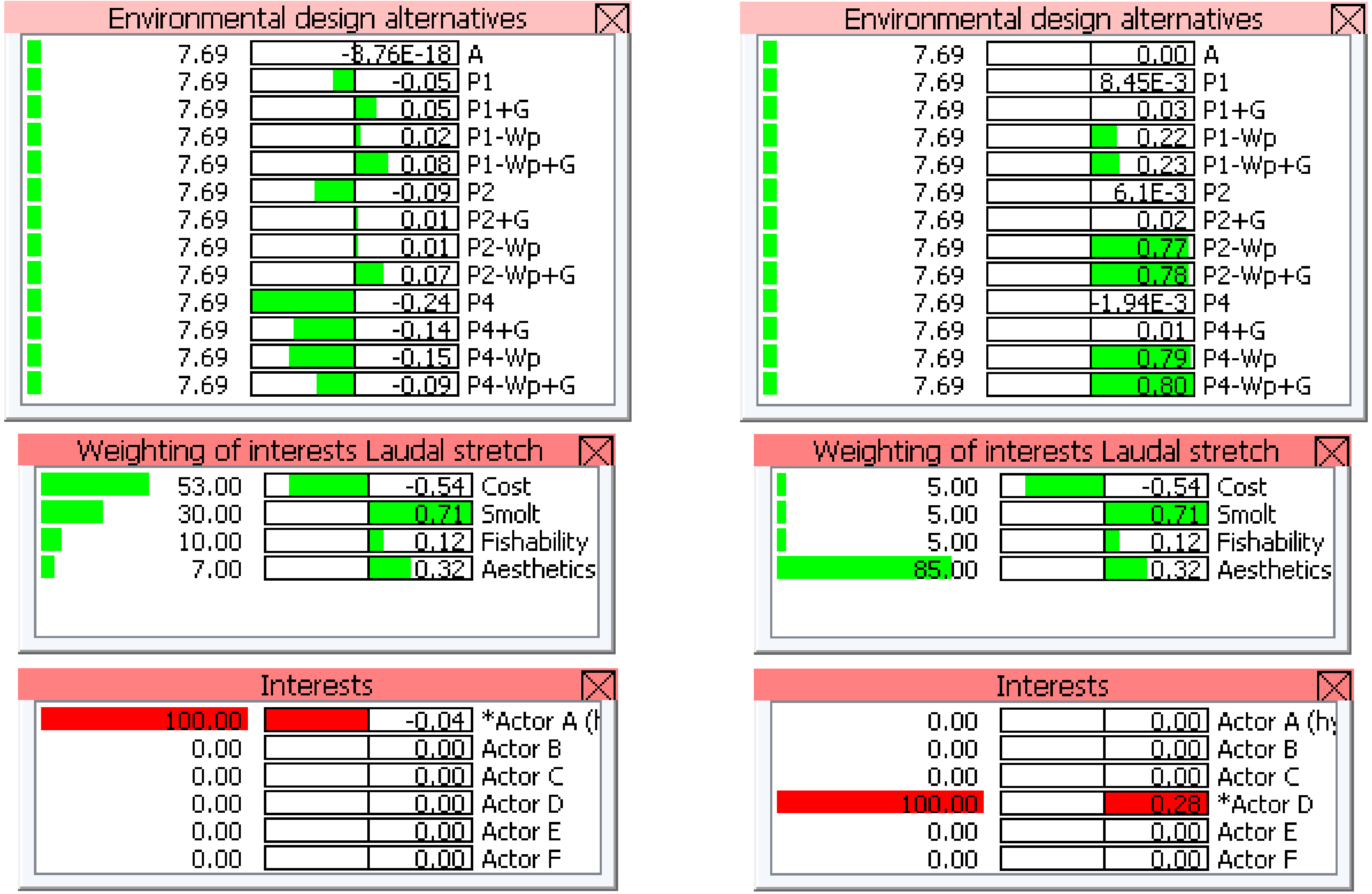






(Barton, Sundt et al. 2020)

Multicriteria Decision Analyses

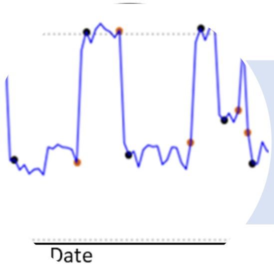


(Barton, Sundt et al. 2020)

Test cases

Habitat improvements

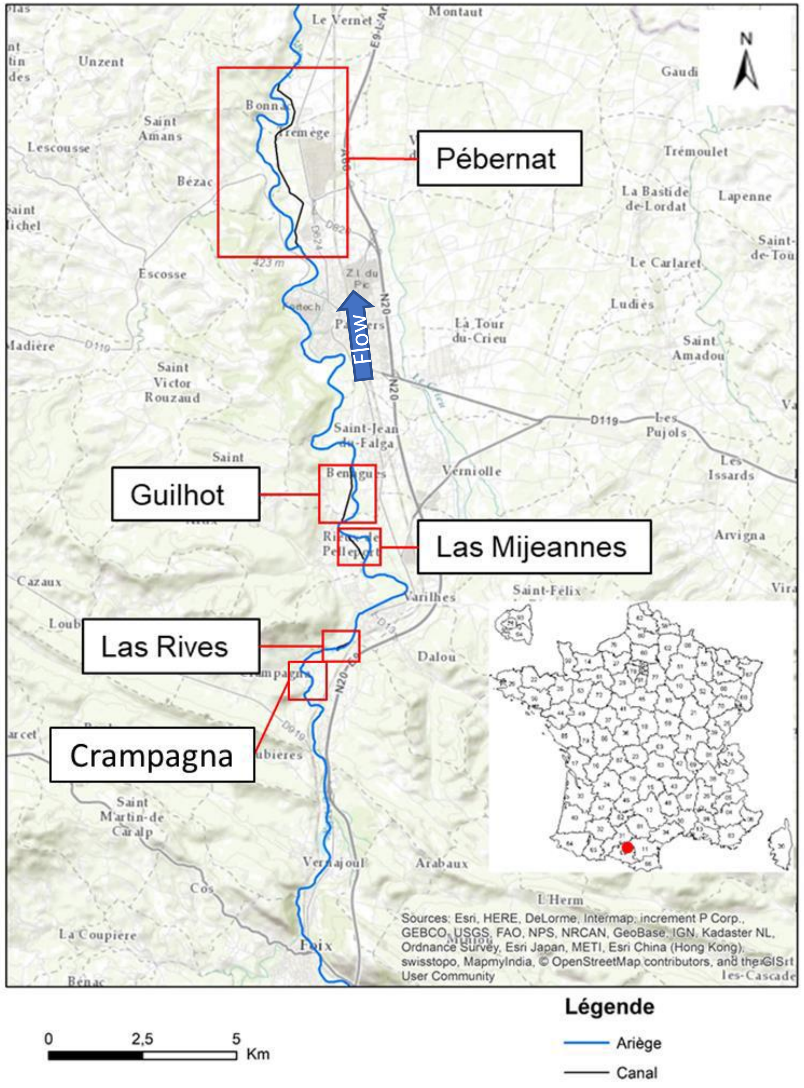
Fish Migration



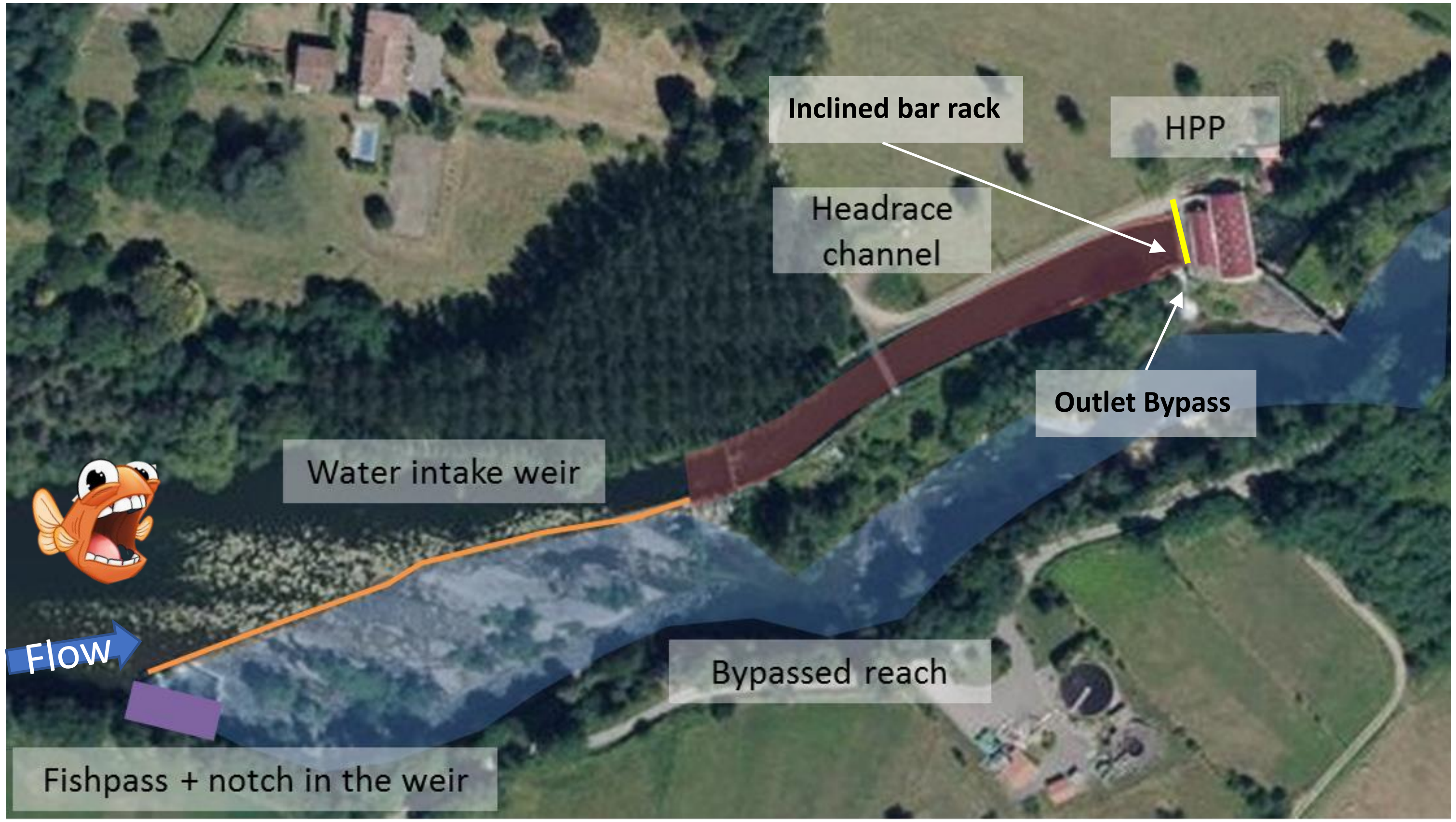
Hydropeaking

Las Rives (France)

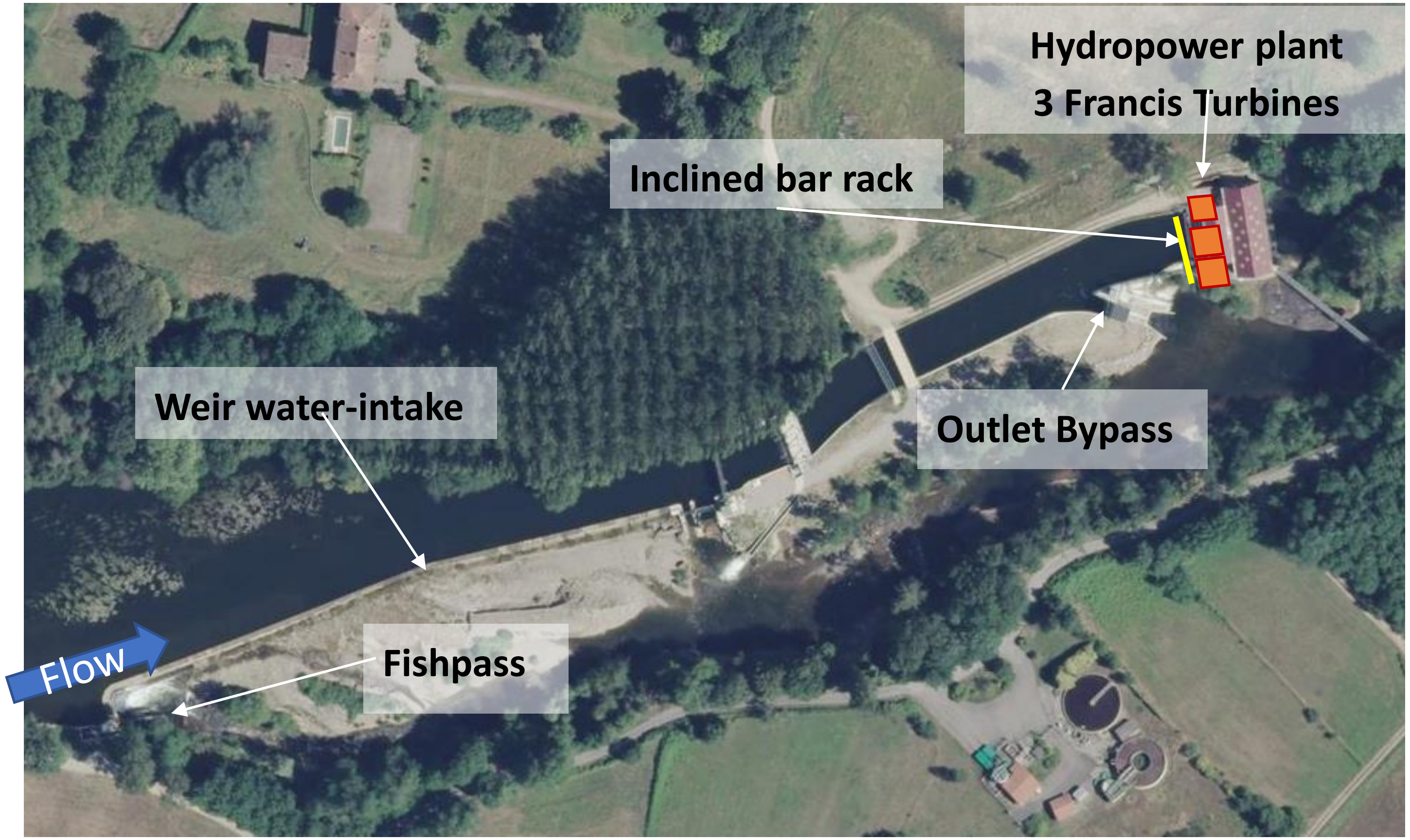
TEST CASE: LAS RIVES



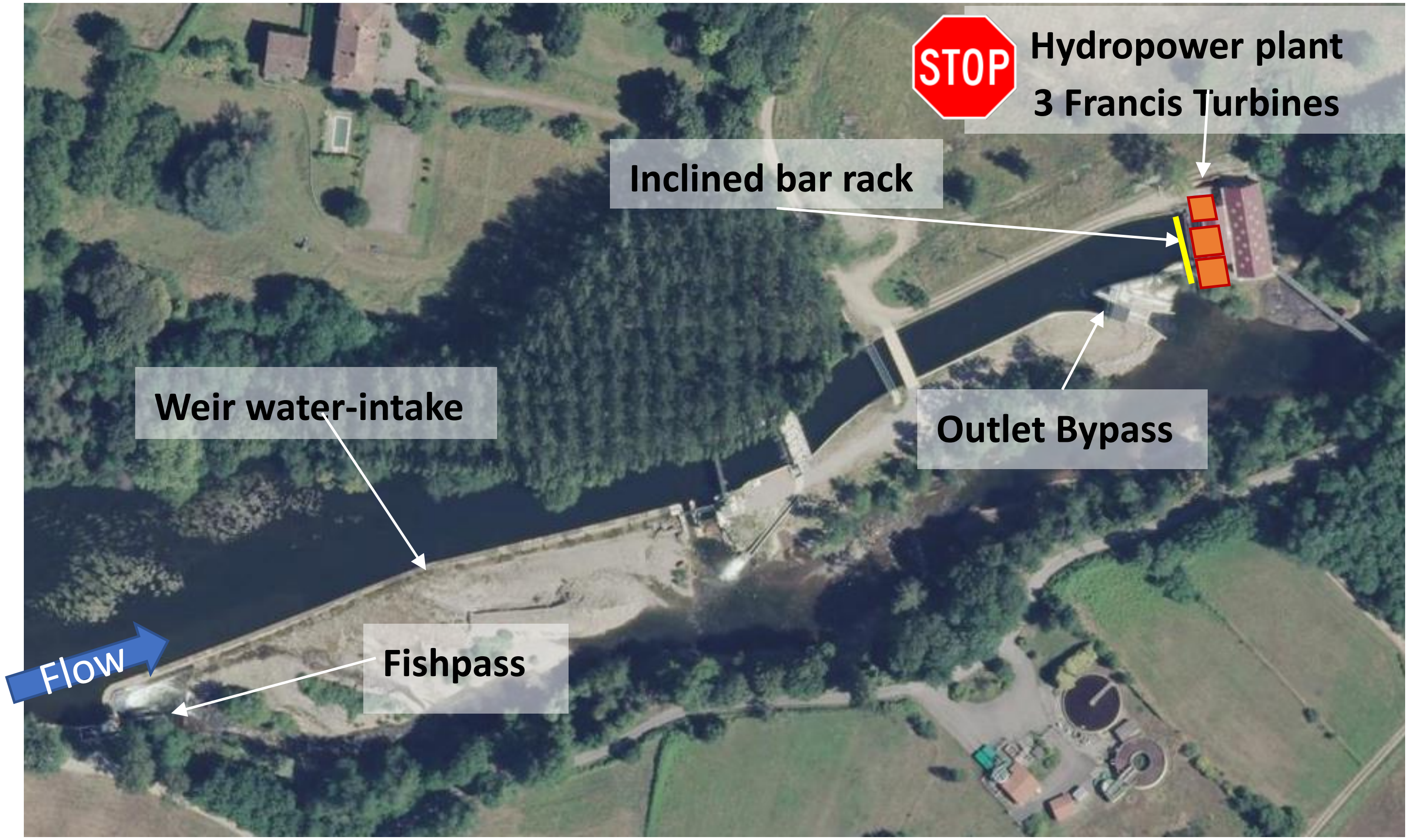
AFB, 2017



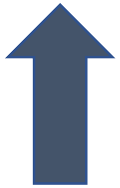
FORMER (Scenario)



FORMER (Shutting down turbines)



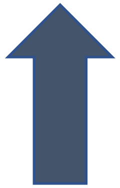
Scenario A-RackHP+1Div.HP



Energy

Attraction flow at the entrance of the bypass

Scenario B-RackHP+1Div.DAM



Energy

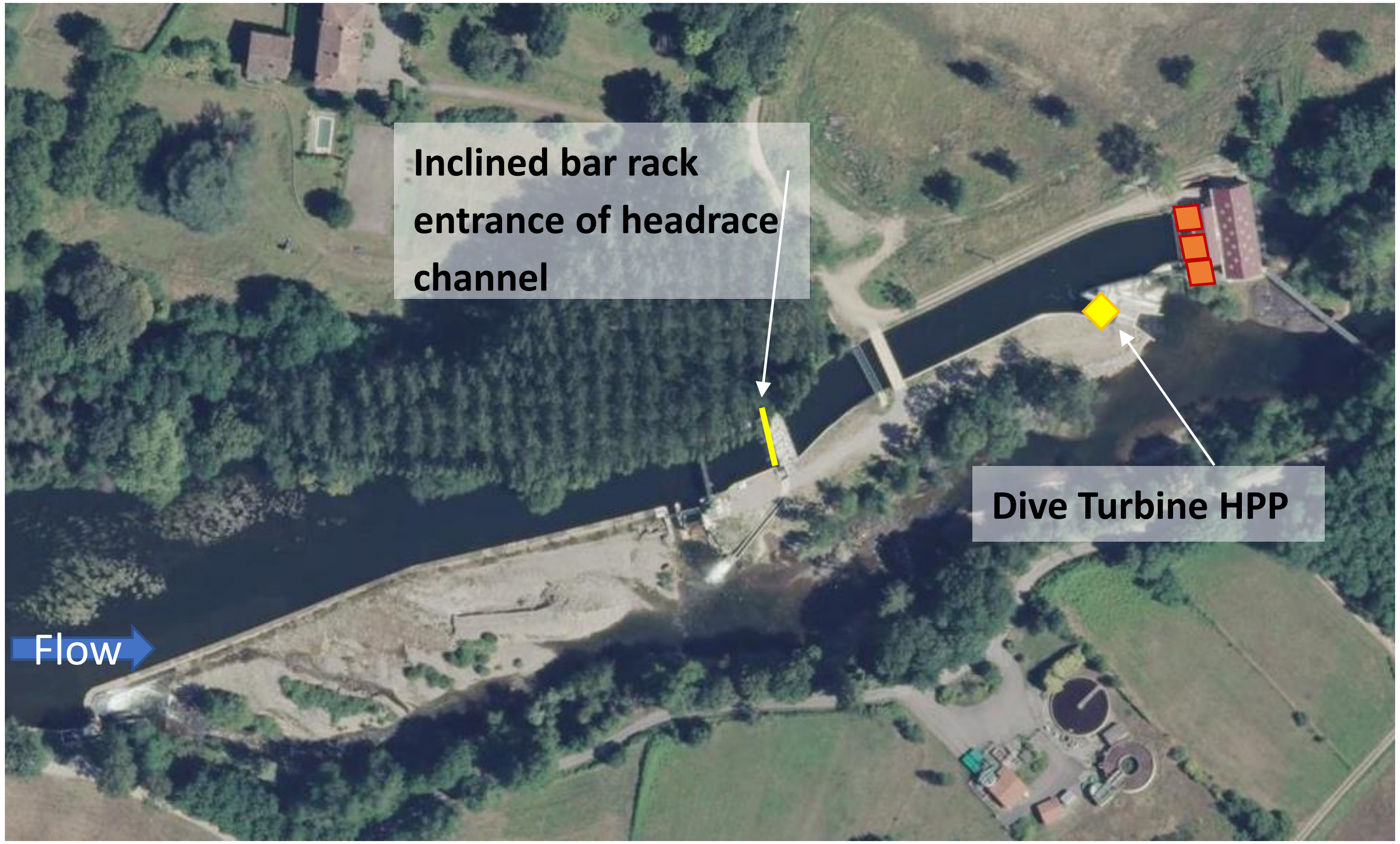
Attraction flow at the dam

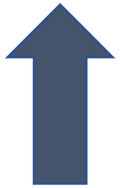
Scenario C-RackHP+2Div.

Energy

Attraction flow both at the entrance and at the dam

Scenario D-RackHeadR+Div.HP

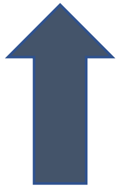




Energy

Attraction flow at the entrance of the bypass

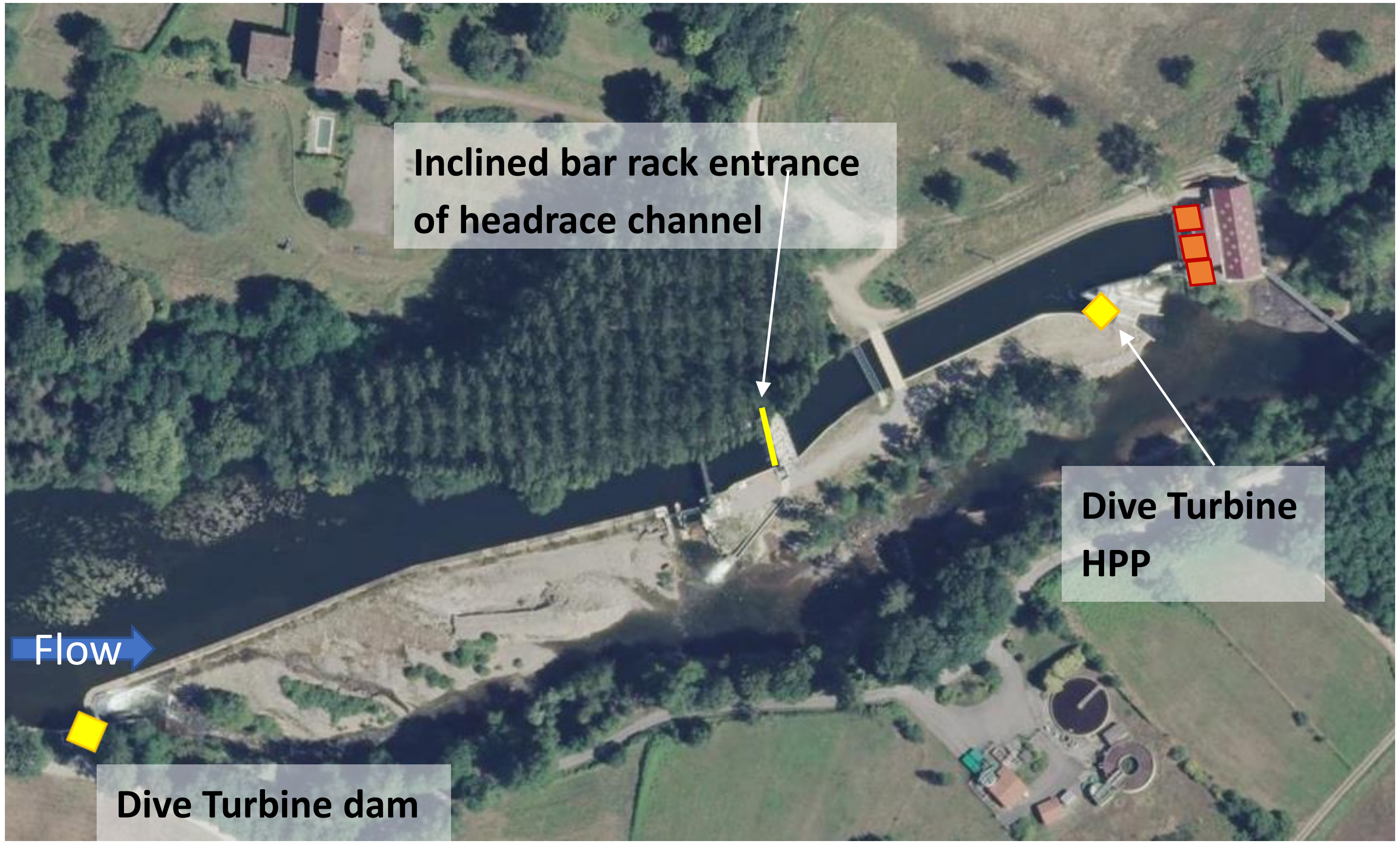
Scenario E-RackHeadR+1Div.DAM



Energy

Attraction flow at dam

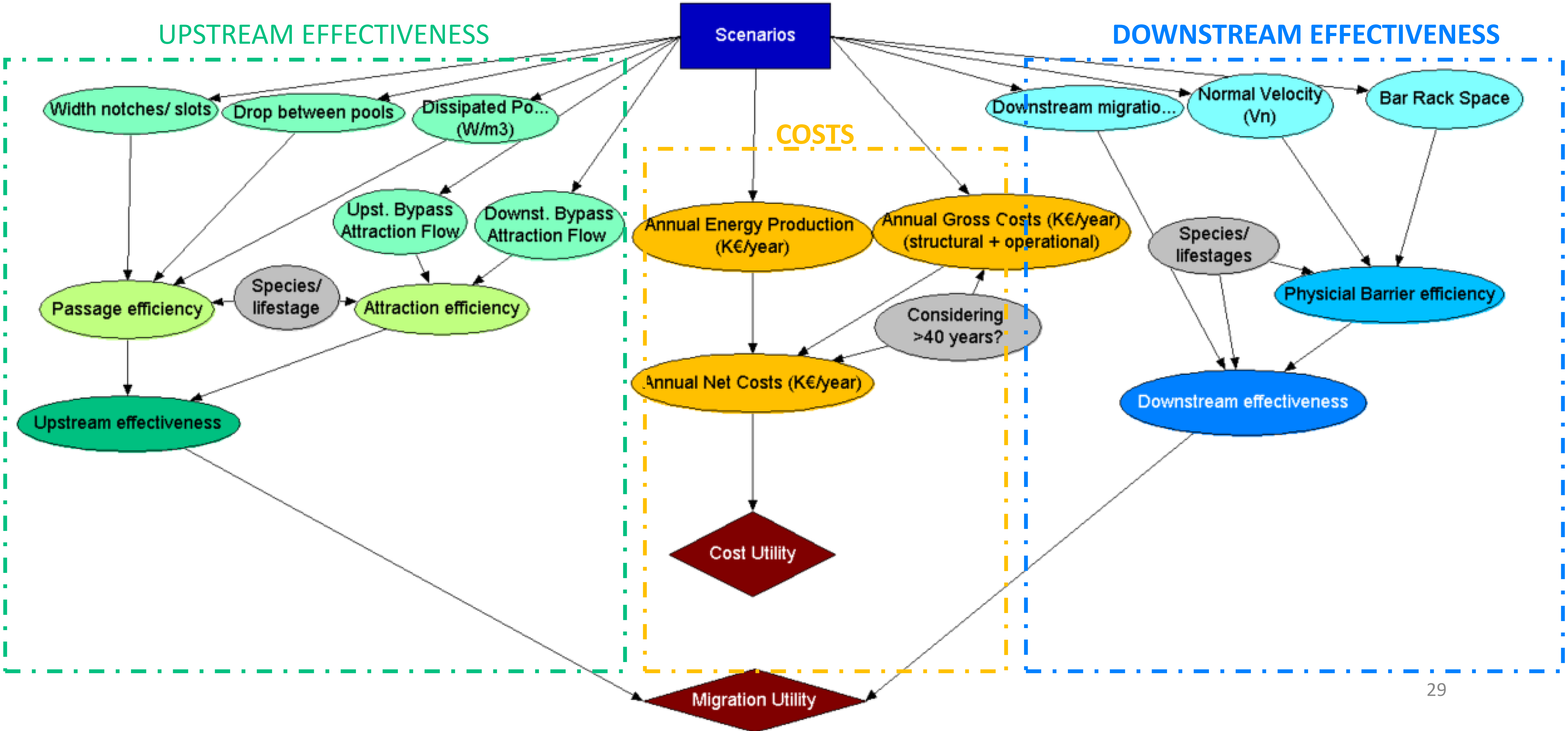
Scenario F-RackHeadR+2DIVE (Present situation)



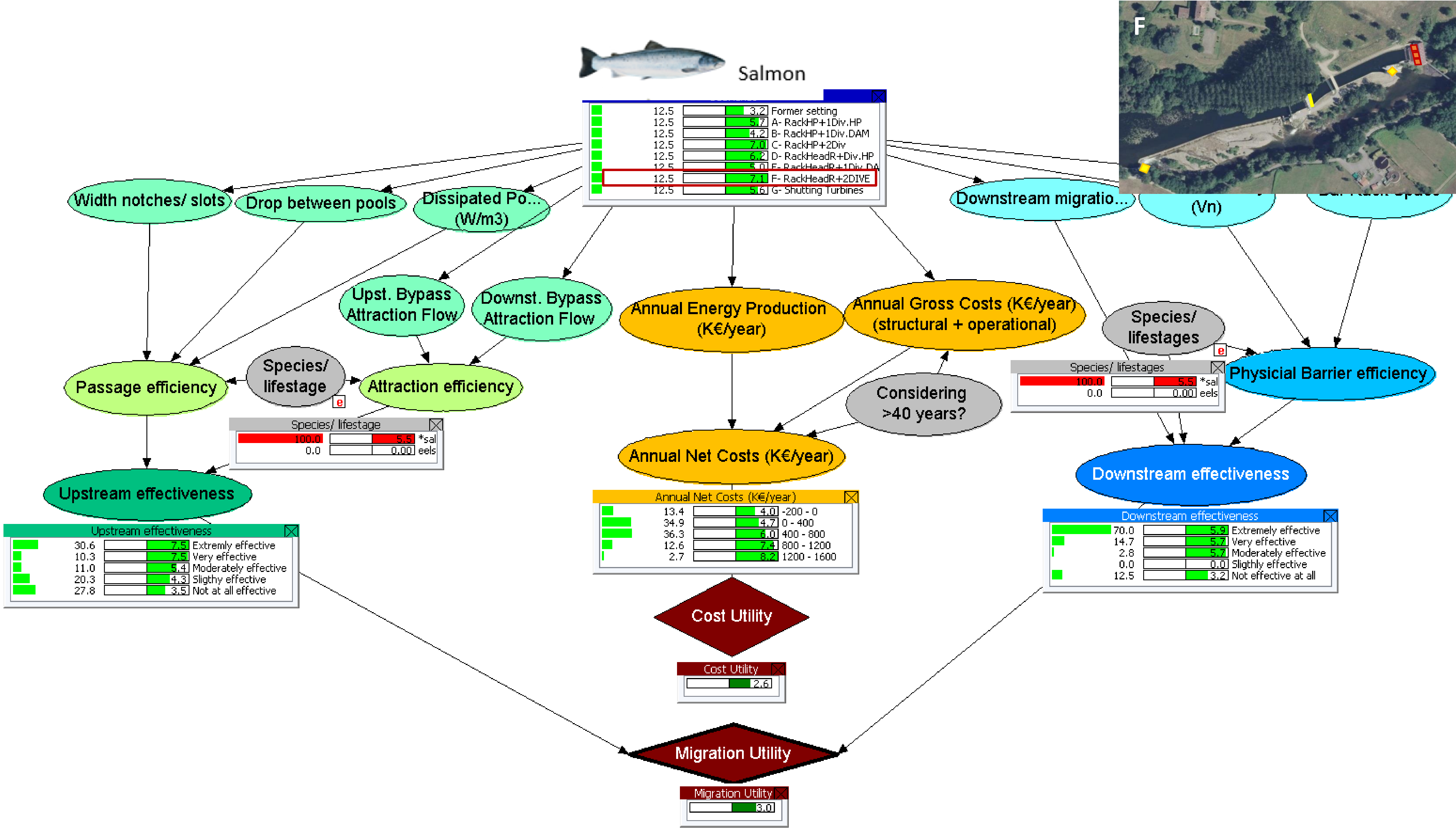
Energy

Attraction flow both at the entrance and at the dam

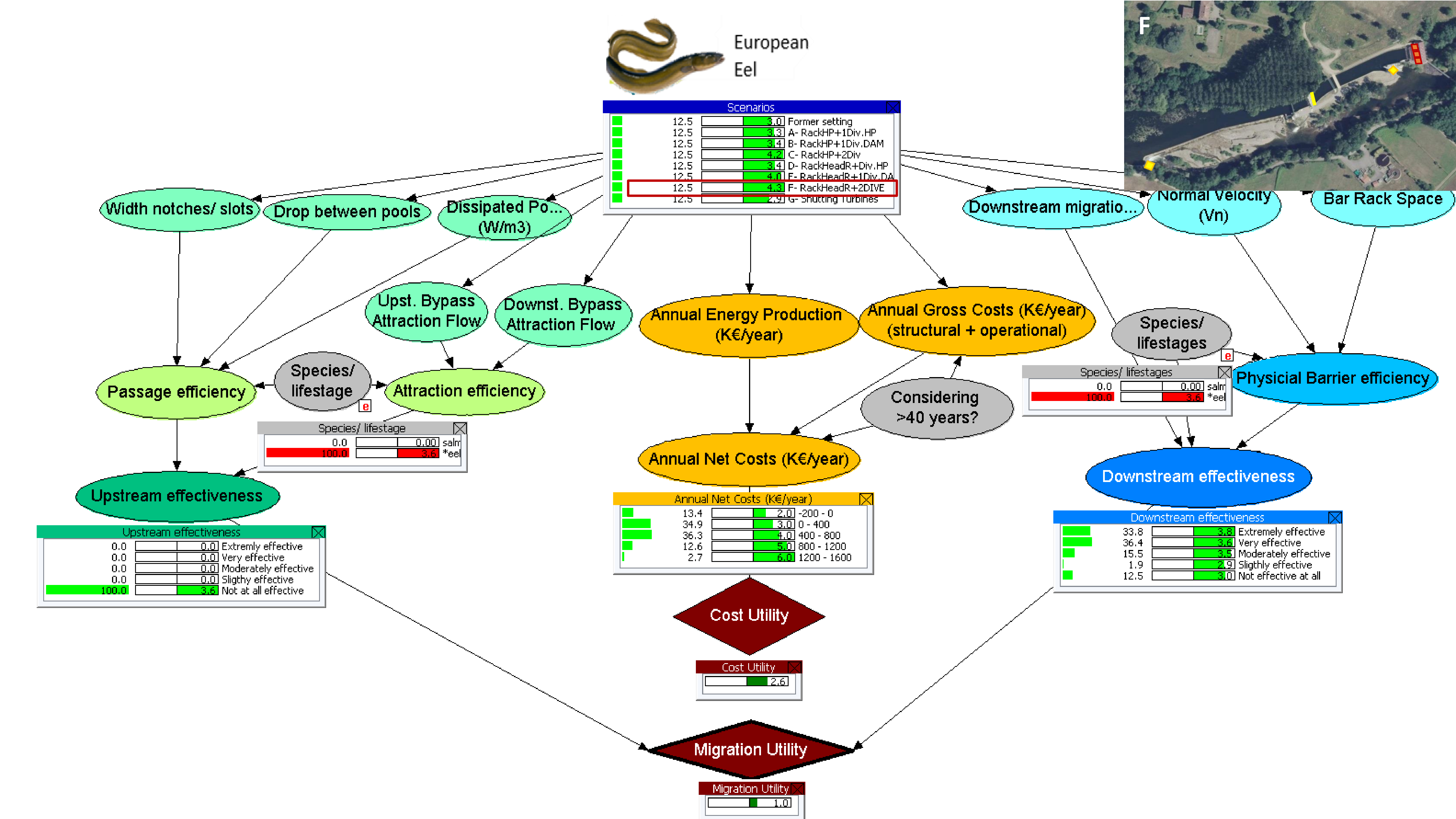
BN: Las Rives



UPSTREAM EFFECTIVENESS
Scenarios
DOWNSTREAM EFFECTIVENESS
Width notches/ slots
Drop between pools
Dissipated Po...
(W/m3)
COSTS
Downstream migratio...
Normal Velocity
(Vn)
Bar Rack Space
Upst. Bypass
Attraction Flow
Downst. Bypass
Attraction Flow
Annual Energy Production
(K€/year)
Annual Gross Costs (K€/year)
(structural + operational)
Species/
lifestages
Species/
lifestage
Passage efficiency
Attraction efficiency
Considering
>40 years?
Physicial Barrier efficiency
Annual Net Costs (K€/year)
Downstream effectiveness
Upstream effectiveness
Cost Utility
Migration Utility



F
Salmon
12.5 3.2 Former setting
12.5 5.7 A- RackHP+1Div.HP
12.5 4.2 B- RackHP+1Div.DAM
12.5 7.0 C- RackHP+2Div
12.5 6.2 D- RackHeadR+Div.HP
12.5 7.1 F- RackHeadR+2DIVE
12.5 5.6 G- Shutting Turbines
Width notches/ slots
Drop between pools
Dissipated Po... (W/m3)
Downstream migratio...
(Vn)
Upst. Bypass Attraction Flow
Downst. Bypass Attraction Flow
Annual Energy Production (K€/year)
Annual Gross Costs (K€/year) (structural + operational)
Species/ lifestages
Species/ lifestage
Passage efficiency
Attraction efficiency
Considering >40 years?
Physicial Barrier efficiency
Species/ lifestages
100.0 5.5 *sal
0.0 0.00 eels
Species/ lifestage
100.0 5.5 *sal
0.0 0.00 eels
Annual Net Costs (K€/year)
Downstream effectiveness
Upstream effectiveness
Upstream effectiveness
30.6 7.5 Extremly effective
10.3 7.5 Very effective
11.0 5.4 Moderately effective
20.3 4.3 Sligthy effective
27.8 3.5 Not at all effective
Annual Net Costs (K€/year)
13.4 4.0 -200 - 0
34.9 4.7 0 - 400
36.3 6.0 400 - 800
12.6 7.4 800 - 1200
2.7 8.2 1200 - 1600
Downstream effectiveness
70.0 5.9 Extremely effective
14.7 5.7 Very effective
2.8 5.7 Moderately effective
0.0 0.0 Sligthly effective
12.5 3.2 Not effective at all
Cost Utility
Cost Utility
2.6
Migration Utility
Migration Utility
3.0

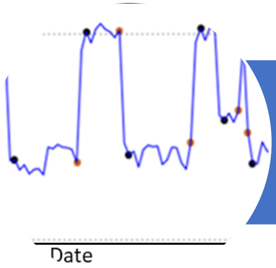


European Eel
Scenarios
12.5 3.0 Former setting
12.5 3.3 A- RackHP+1Div.HP
12.5 3.4 B- RackHP+1Div.DAM
12.5 4.2 C- RackHP+2Div
12.5 3.4 D- RackHeadR+Div.HP
12.5 4.0 E- RackHeadR+1Div.DA
12.5 4.3 F- RackHeadR+2DIVE
12.5 2.9 G- Shutting Turbines
F
Width notches/ slots
Drop between pools
Dissipated Po... (W/m3)
Upst. Bypass Attraction Flow
Downst. Bypass Attraction Flow
Annual Energy Production (K€/year)
Annual Gross Costs (K€/year) (structural + operational)
Downstream migratio...
Normal Velocity (Vn)
Bar Rack Space
Species/ lifestage
Species/ lifestages
Passage efficiency
Attraction efficiency
Considering >40 years?
Physicial Barrier efficiency
Species/ lifestage
0.0 0.00 salm
100.0 3.6 *eel
Species/ lifestages
0.0 0.00 salm
100.0 3.6 *eel
Annual Net Costs (K€/year)
Upstream effectiveness
Downstream effectiveness
Annual Net Costs (K€/year)
13.4 2.0 -200 - 0
34.9 3.0 0 - 400
36.3 4.0 400 - 800
12.6 5.0 800 - 1200
2.7 6.0 1200 - 1600
Upstream effectiveness
0.0 0.0 Extremly effective
0.0 0.0 Very effective
0.0 0.0 Moderately effective
0.0 0.0 Sligthy effective
100.0 3.6 Not at all effective
Downstream effectiveness
33.8 3.8 Extremely effective
36.4 3.6 Very effective
15.5 3.5 Moderately effective
1.9 2.9 Slithly effective
12.5 3.0 Not effective at all
Cost Utility
Cost Utility
2.6
Migration Utility
Migration Utility
1.0

Test cases

Habitat improvements

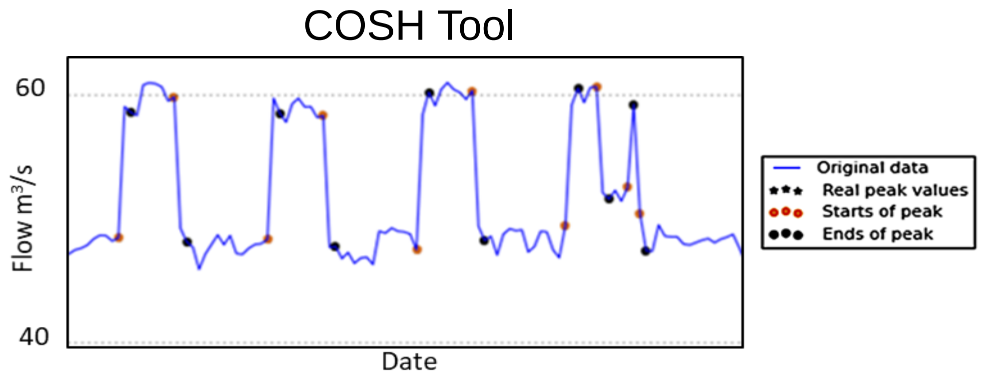
Fish Migration



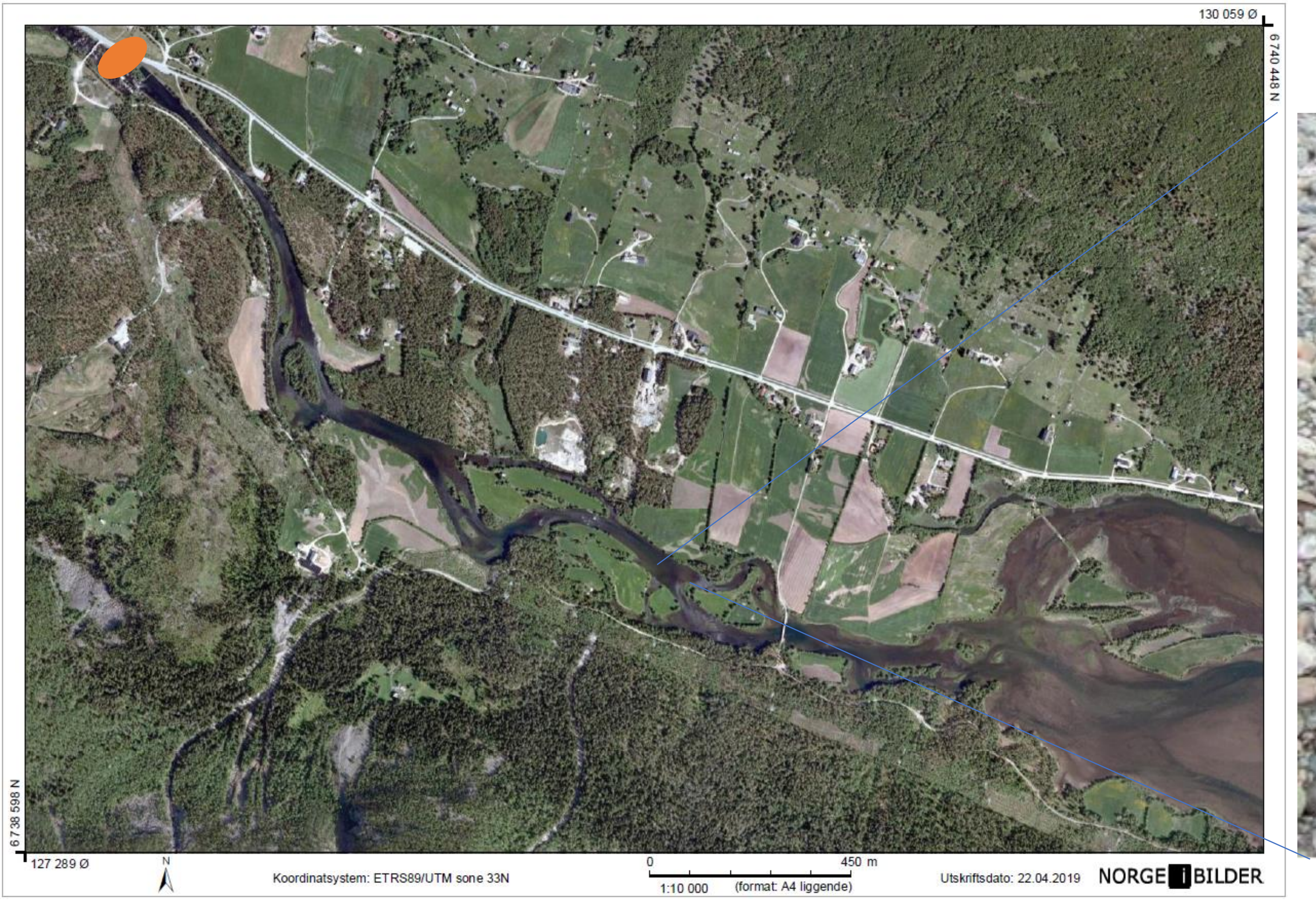
Hydropeaking

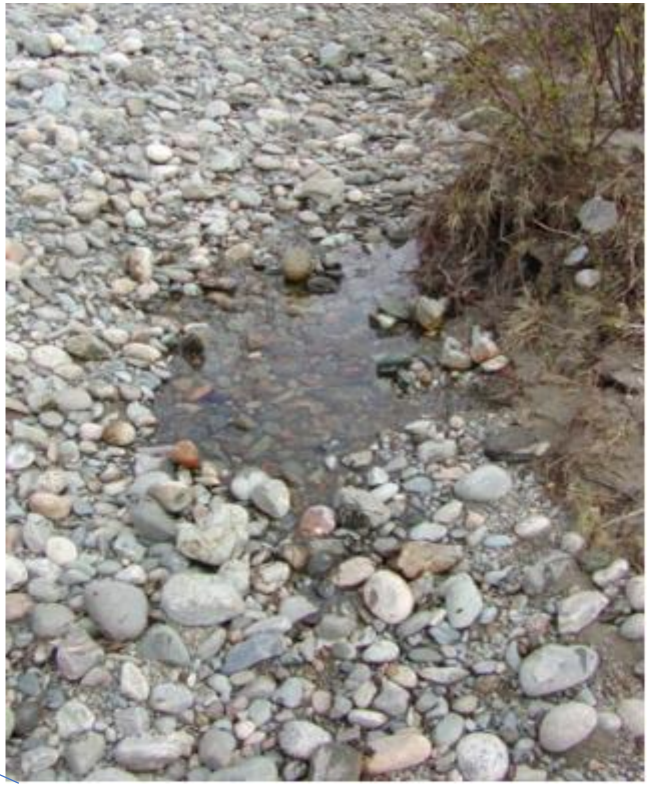
Storåne (Norway)

Hydropeaking - stranding areas

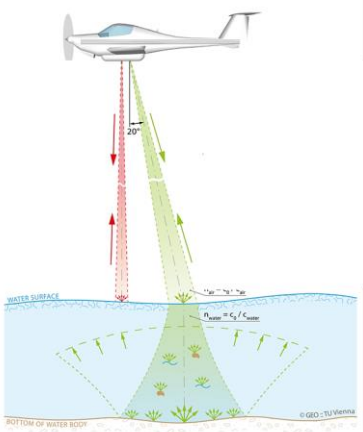


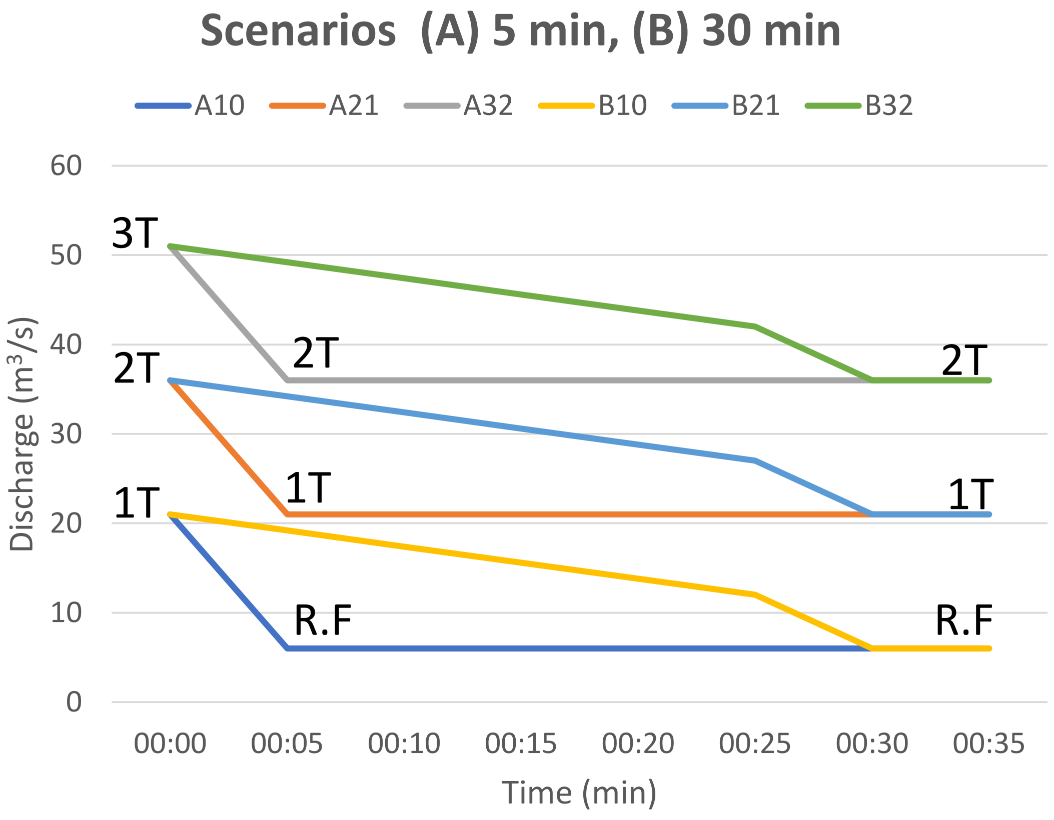
(Sauterleute and Charmasson, 2014)

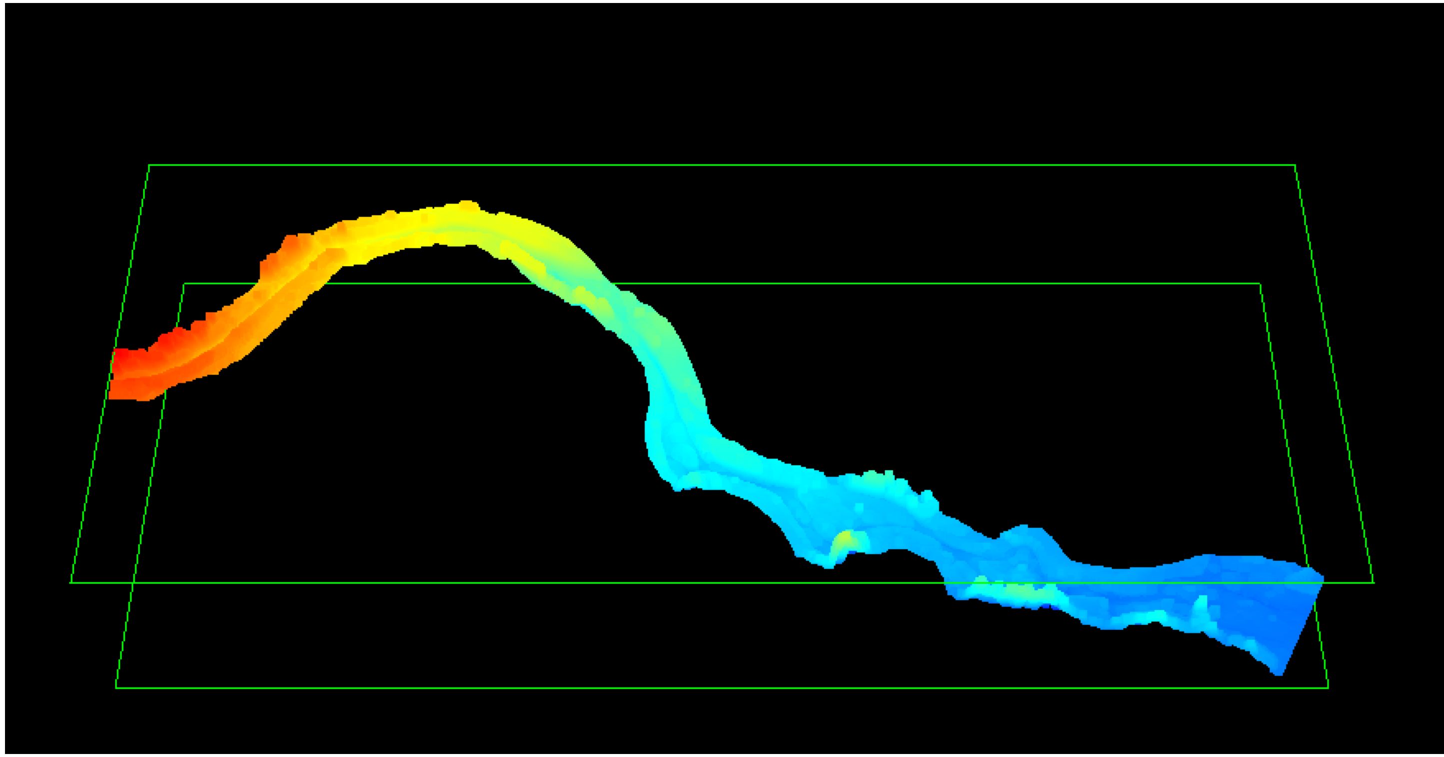




Alternative scenarios



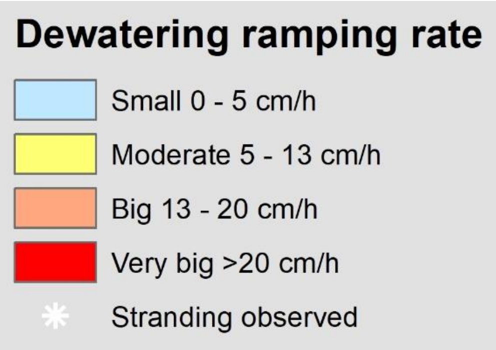


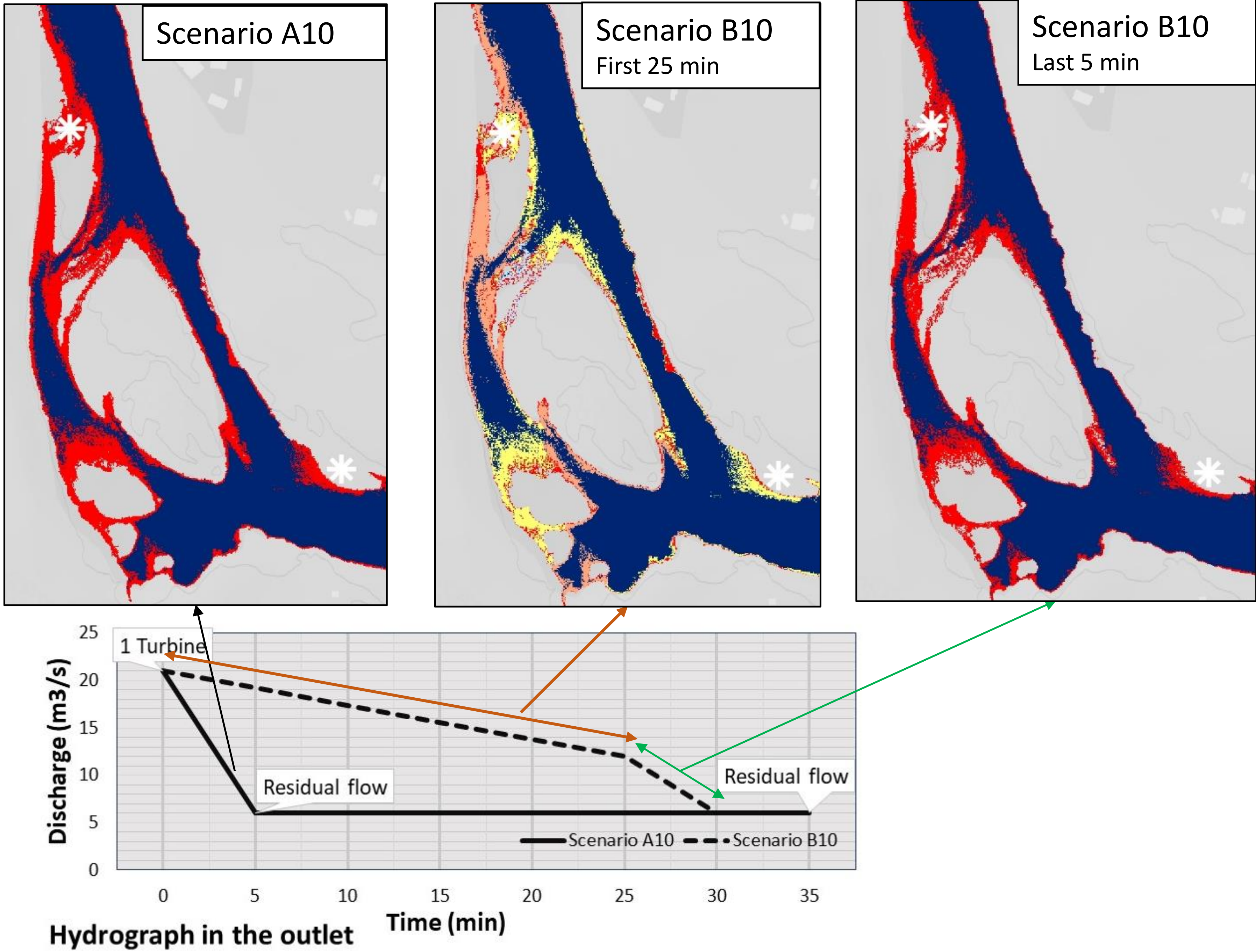


(Juárez, Adeva-Bustos et al. 2019)

(Juárez, Adeva-Bustos et al. 2019)

Dewatering rate





(Juárez, Adeva-Bustos et al. 2019)

Reducing hydropeaking costs

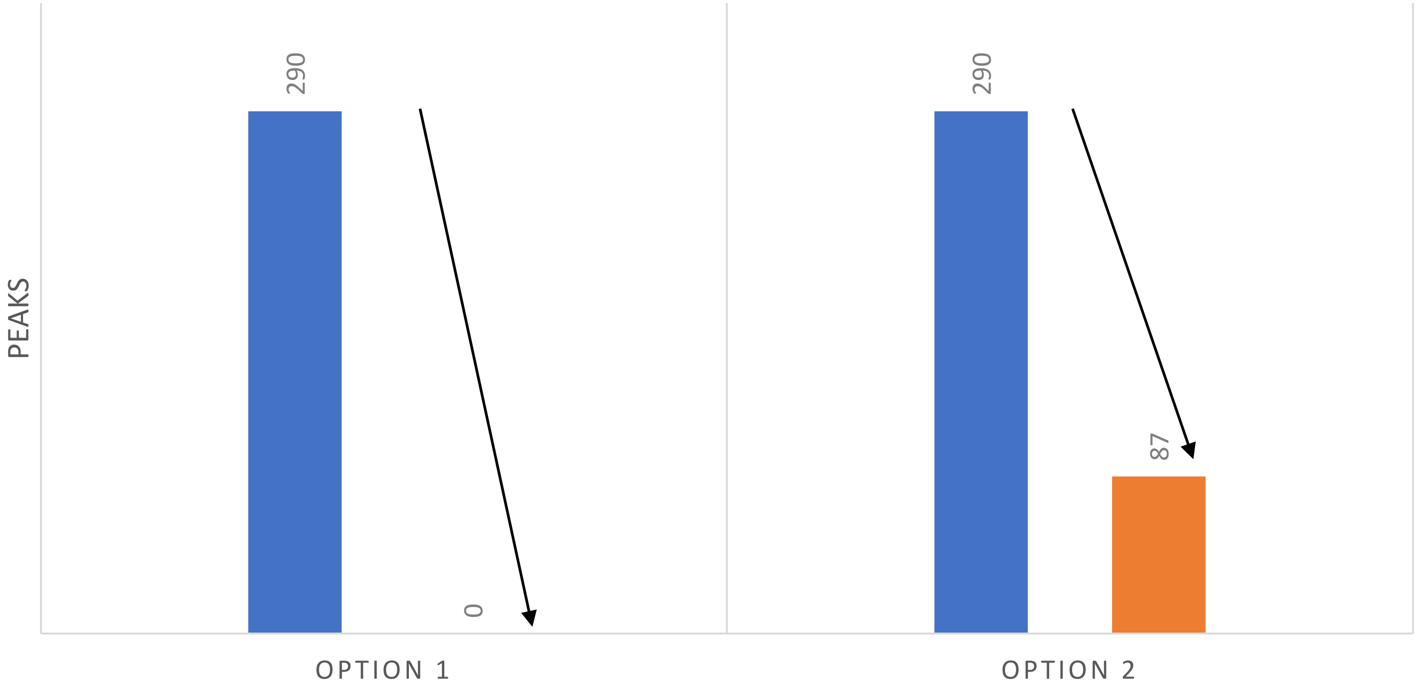
374,587.20 NOK/year

43,826.70 US$/year

COSTS

112,376.16 NOK/year

13,148.20 US$/year



(Juárez, Adeva-Bustos et al. 2019)

Conclusions

- ❖Cost-effective analyses provide an indication and support decisions and prioritizations of mitigation measures

- ❖Scenario modelling open the possibility to investigate alternative solutions and their trade-offs

- ❖Bayesian Networks are useful decision support tools to handle uncertainties, combine different source of data and transparently communicate with the stakeholders and decision makers

References

Adeva-Bustos, Adeva-Bustos, A., et al. (2019). "Ecohydraulic Modelling to Support Fish Habitat Restoration Measures." Sustainability **11**(5): 1500.

Barton, D. n., et al. (2019). "Multi-criteria decision analysis in Bayesian networks - Diagnosing ecosystem service trade-offs in a hydropower regulated river." Environmental Modelling & Software: 104604.

Juárez, A., et al. (2019). "Performance of A Two-Dimensional Hydraulic Model for the Evaluation of Stranding Areas and Characterization of Rapid Fluctuations in Hydropeaking Rivers." Water **11**(2): 201.