Evaluating uncertainty in physical habitat modelling in a high-gradient mountain stream

Turner, D., M.J. Bradford, J.G. Venditti, and R.M. Peterman. 2015, *in press River Research and Applications*

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Introduction

- Growing demand for fresh water resources around the British Columbia.
  - Agriculture, Domestic, Industry, Hydroelectric, etc.
- Concern to water resource managers is meeting demands during periods of low-flow in streams.
  - Assumed as a productivity-limiting period, especially for some fish species.
  - Reduced habitat availability, food production, water quality.

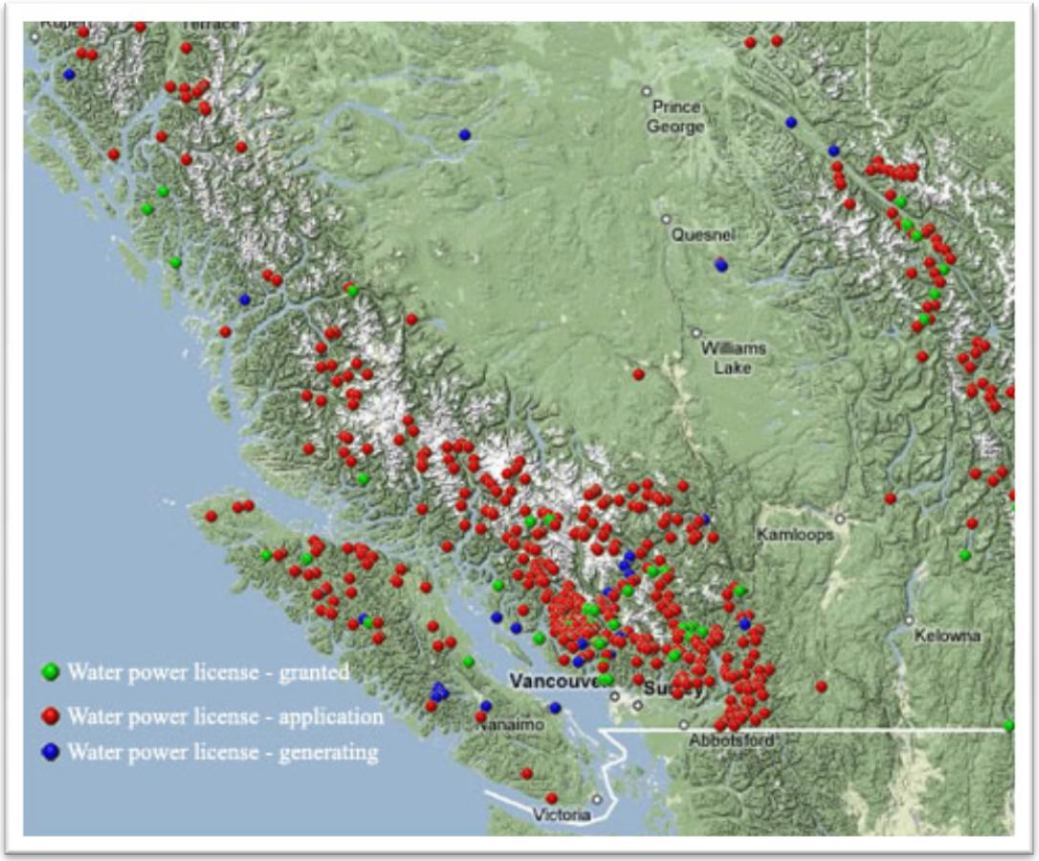
Instream flow requirements (IFR)

- Legislation protects fish and aquatic habitat
  - Federal *Fisheries Act*
  - Provincial *Fish Protection Act*
  - Provincial *Water Sustainability Act*
- Resource managers must make decisions regarding IFRs that allocate water during low-flow periods while avoiding causing serious harm to fisheries or aquatic habitat

Run-of-River hydro (ROR)

- Instream flow issues come to the forefront in BC with the emergence of ROR hydroelectricity as major component of BC clean energy policy.
- “Gold Rush” by Independent Power Producers (IPPs) to acquire water power licenses.

ROR “Gold Rush”

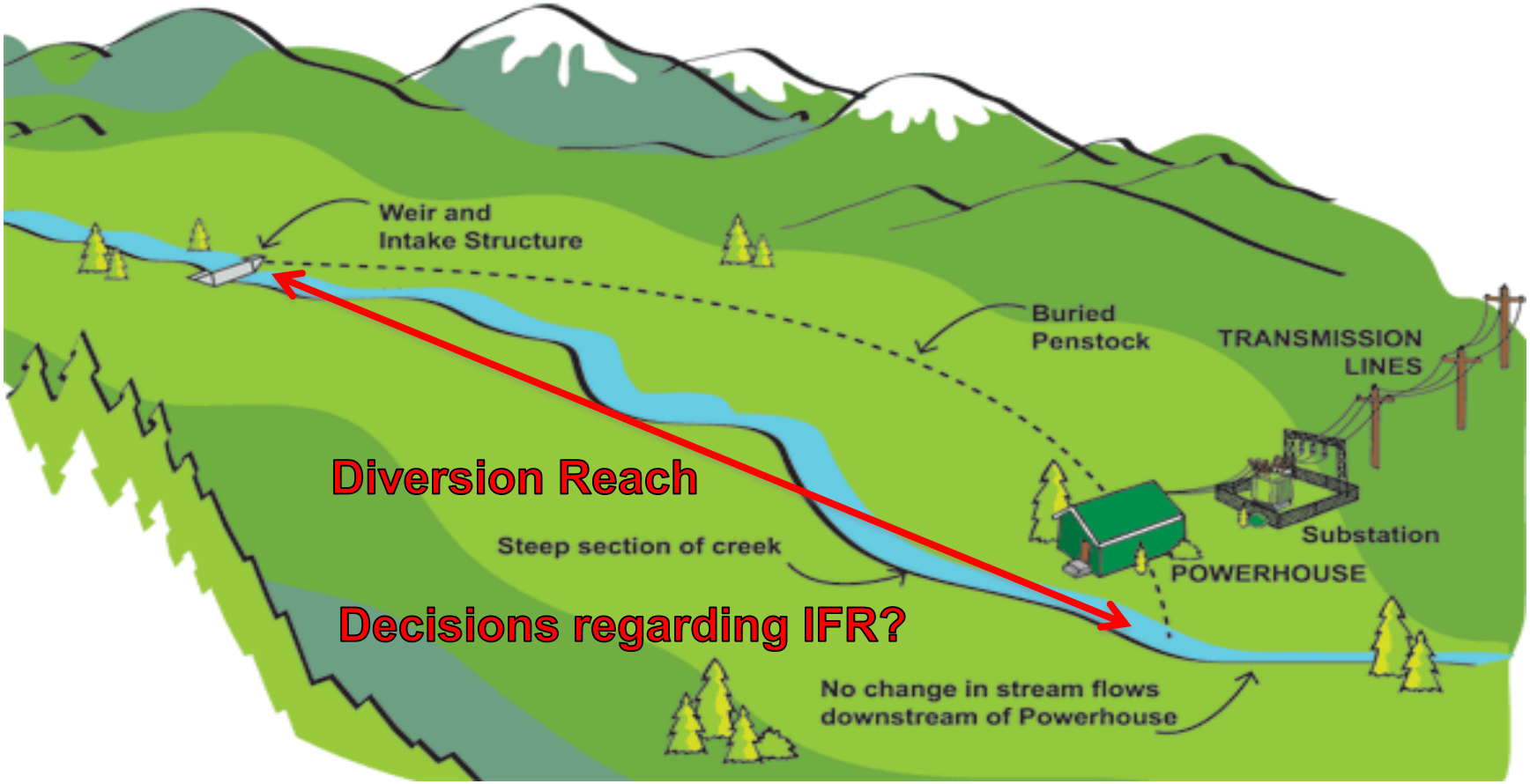


Water Power Licenses

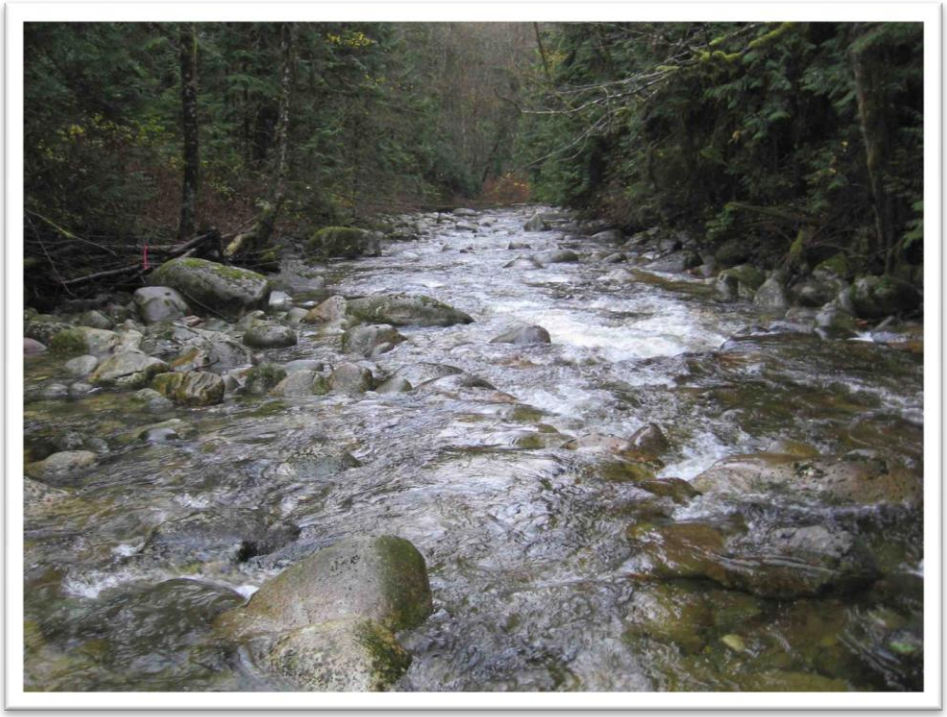
Status	Number
Application	761
Granted	139
Generating	37

http://www.ippwatch.com

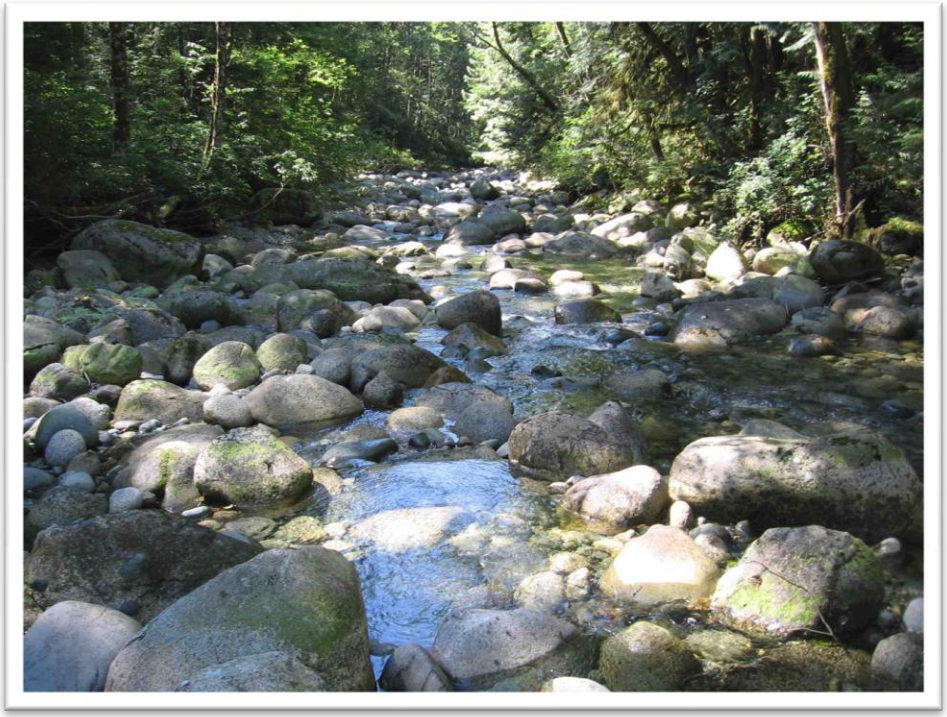
Typical ROR Hydroelectric facility



What is the instream flow requirement?



1.46 m^3/s



0.13 m^3/s

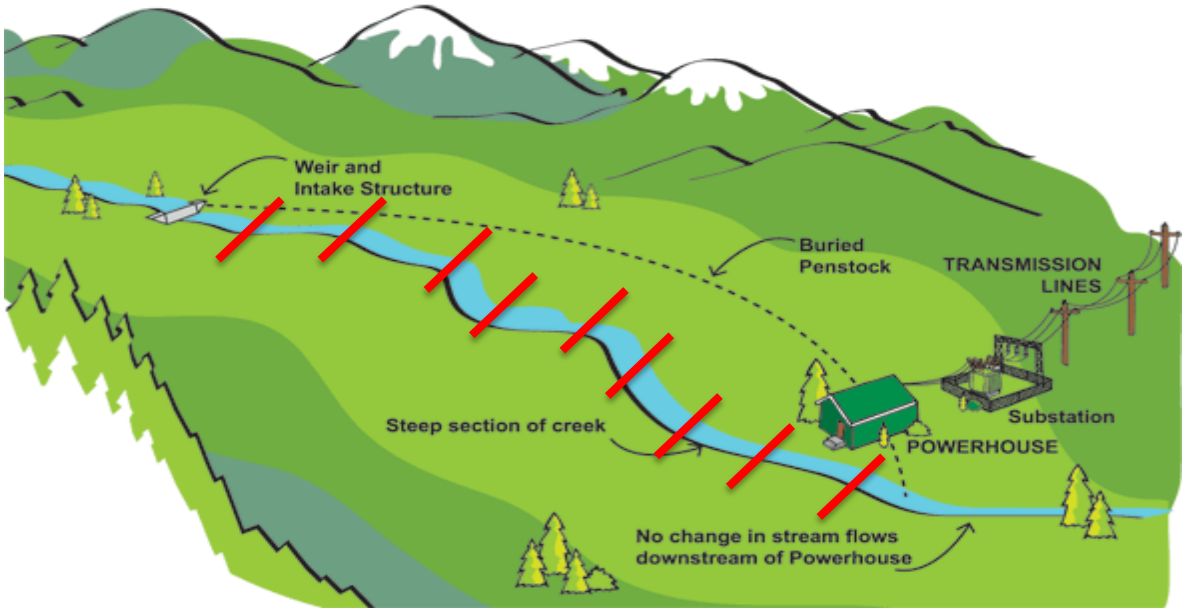
Instream Flow Assessment Methods

- Dozens of instream flow assessment methods have been developed to assist managers in setting IFRs.
  - Tennant's method
  - $7Q_{10}$
  - Physical Habitat Simulation Model (PHABSIM)
  - River 2D
  - ELOHA

British Columbia Instream Flow Methodology (BCIFM)

- Developed as part of the British Columbia Instream Flow Guidelines. (Lewis et al. 2004)
- Empirical habitat-based instream flow assessment method used to determine the amount of habitat available to certain species as a function of discharge.
- Combines measurements of physical habitat at different discharge levels with habitat suitability of the organism and life history stage of interest.

BCIFM

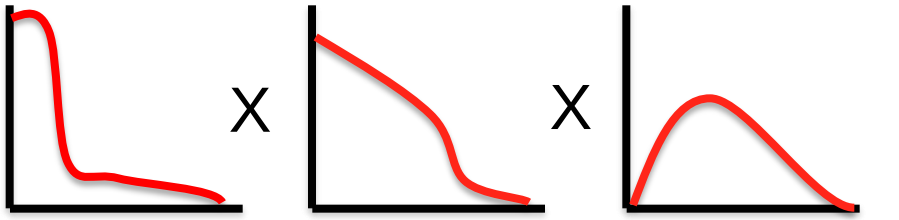


Physical Habitat Data
at Transects at multiple Discharges

X

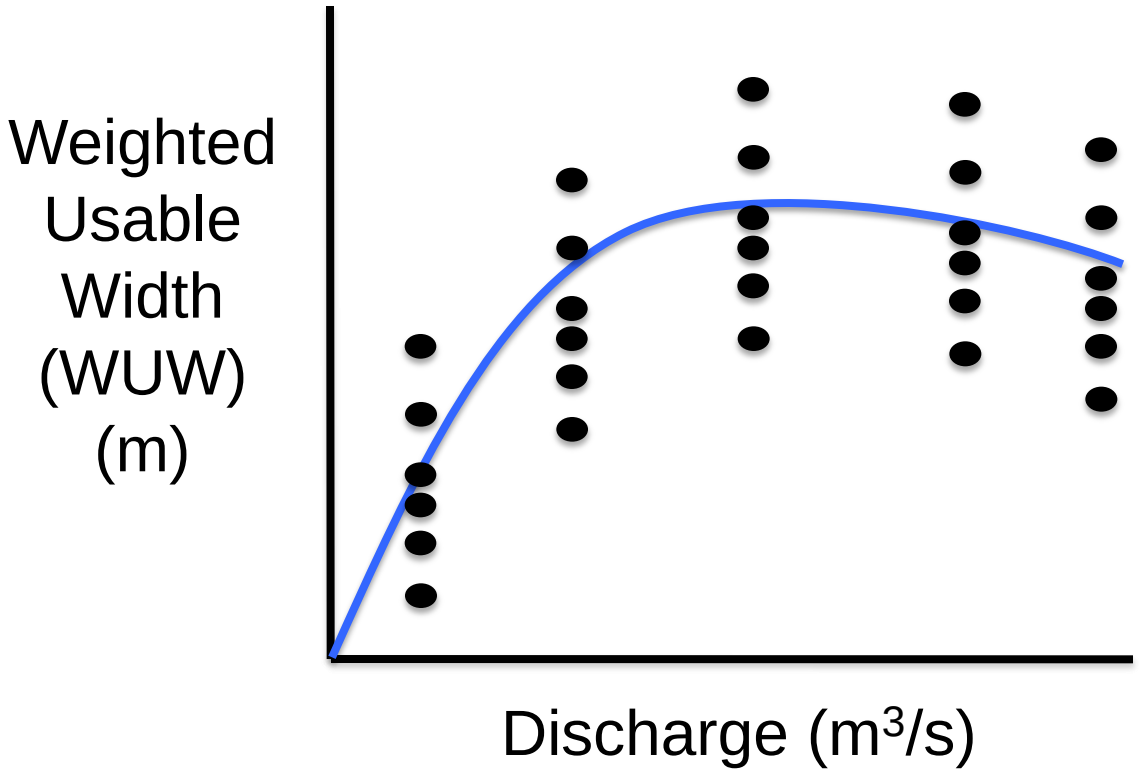
Habitat Suitability Indices for Species and Life History Stage of Interest

Habitat Suitability



Depth X Velocity X Substrate

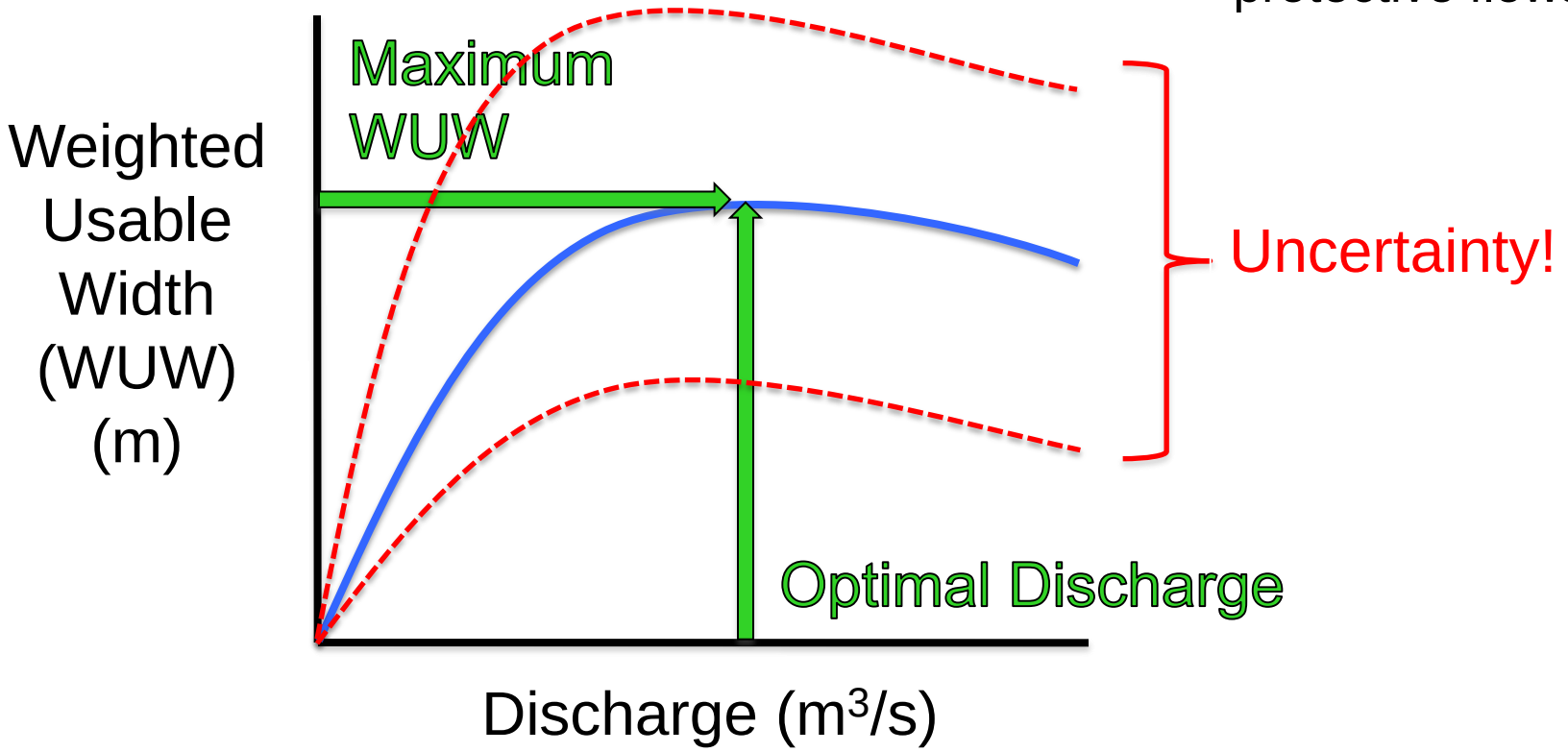
BCIFM: Habitat-Flow Relation



- Fit with function
- Scale up to WUA
- Habitat duration curves

BCIFM: Habitat-Flow Relation

- Inferences about protective flows



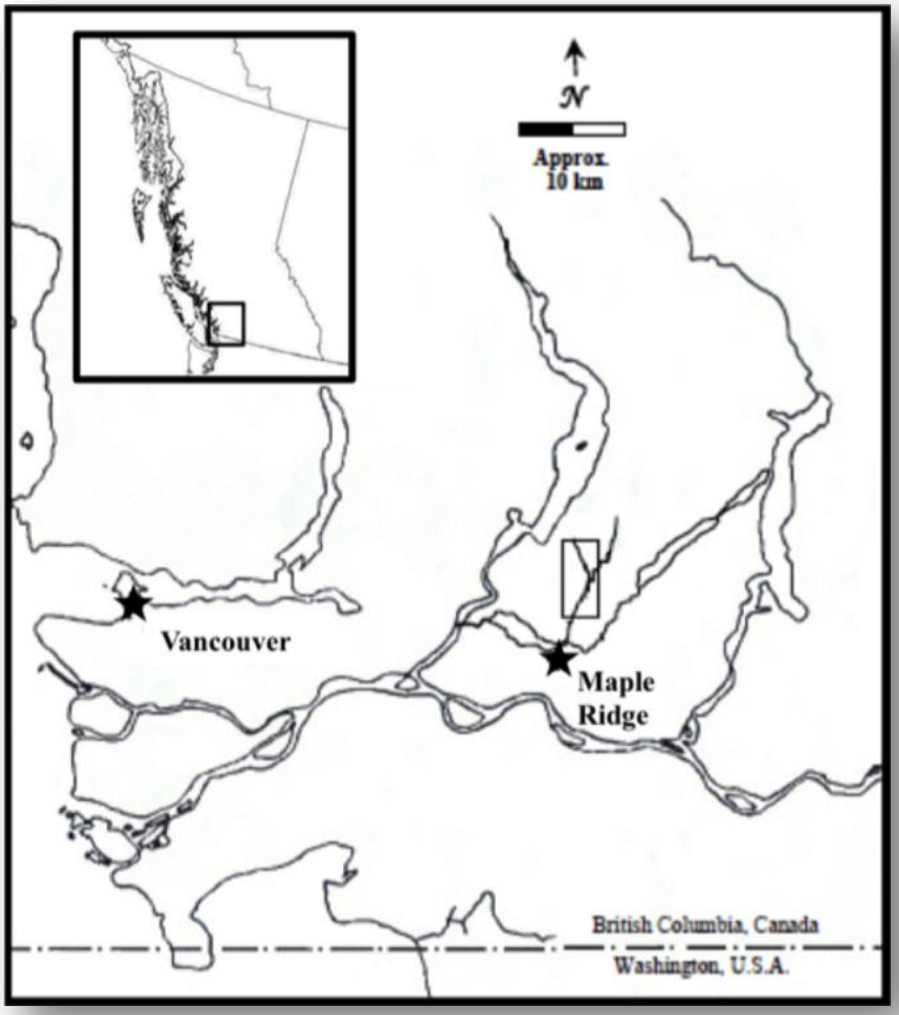
Question 1

- How do you incorporate and quantify uncertainty in physical habitat modelling?

1. Uncertainty in habitat suitability of the fish species of interest.

2. Variability in physical habitat among transects within the study reach of a river.

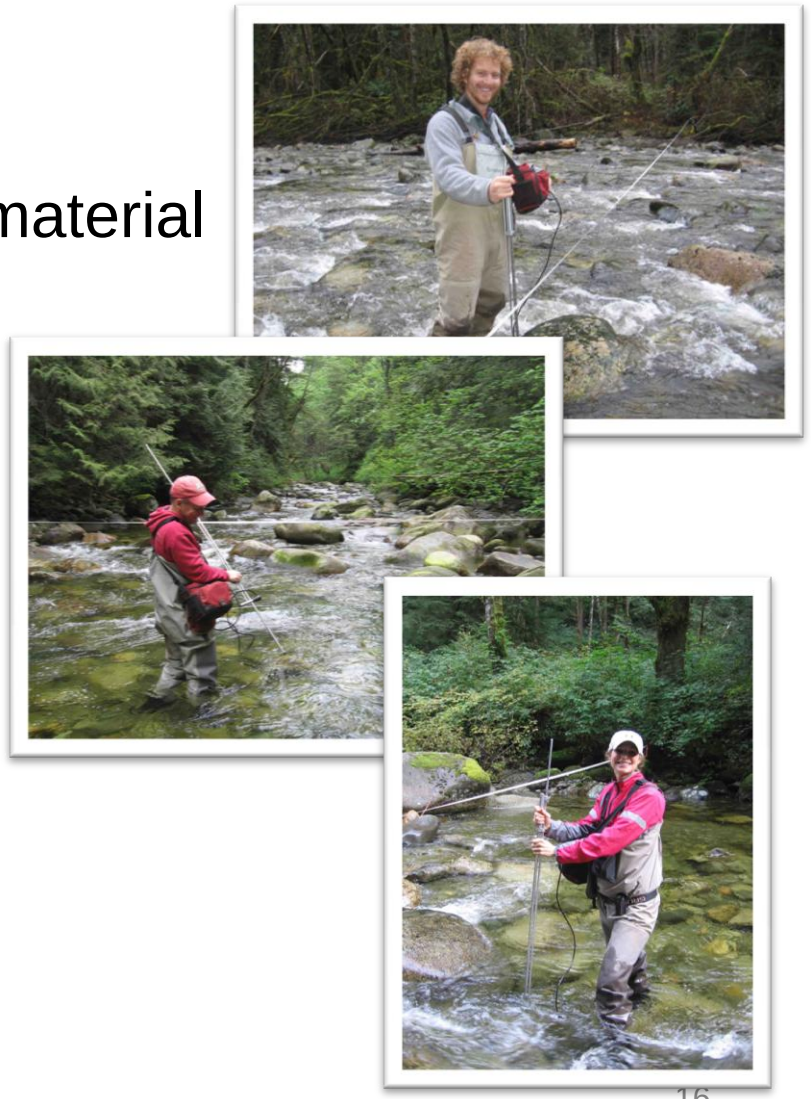
Case Study - North Alouette River



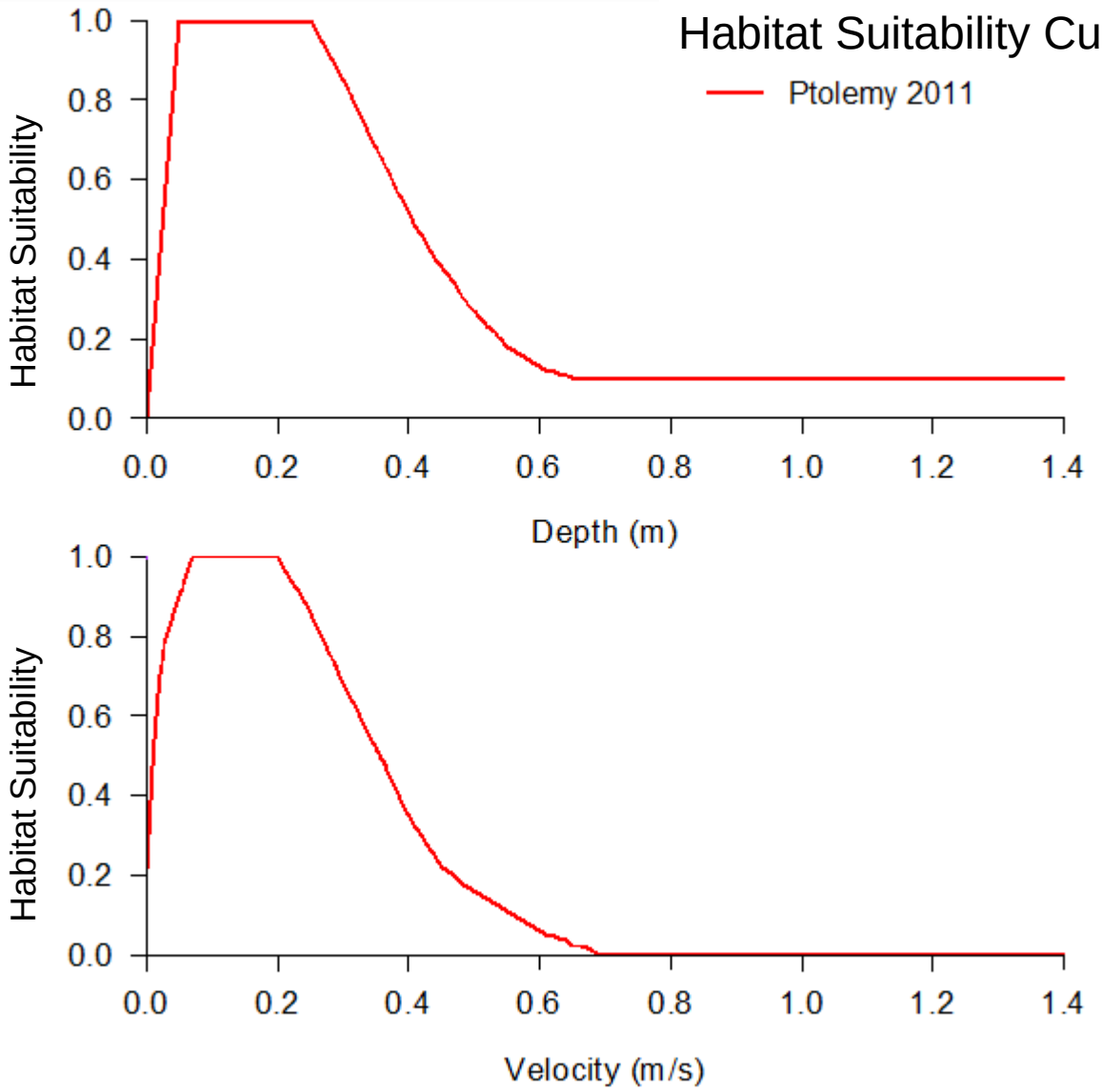
- High-gradient stream typical of those where ROR hydro facilities operate.

Physical Habitat Data

- Physical habitat data
  - width, depth, velocity & bed-material
- 20 cross-stream transects
  - Random systematic design
- 5 discharge levels
  - 0.13 - 1.79 m^3/s.



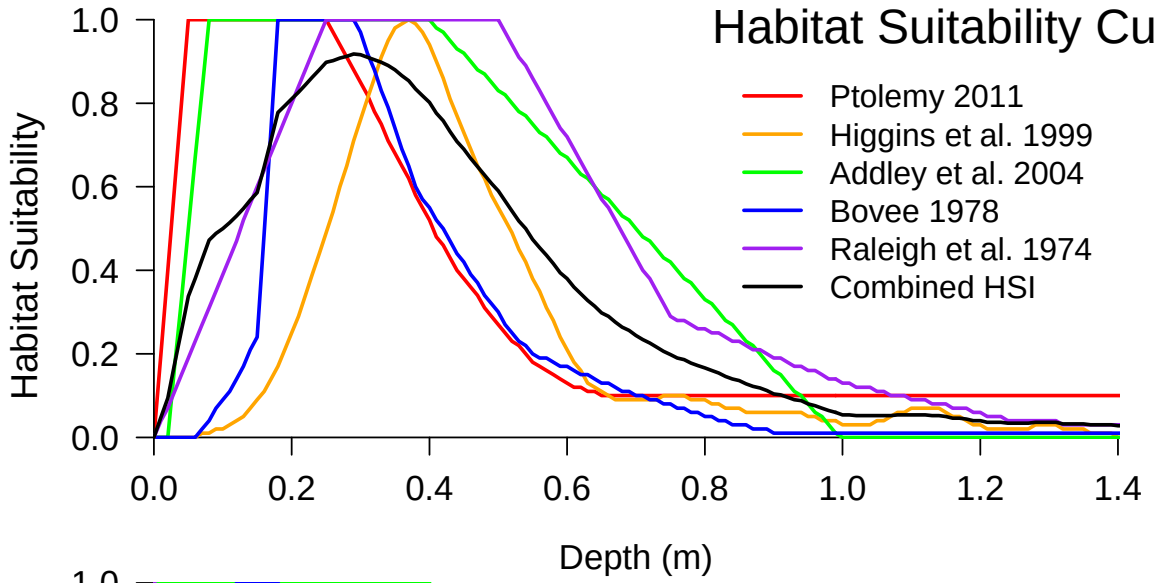
Habitat Suitability Data

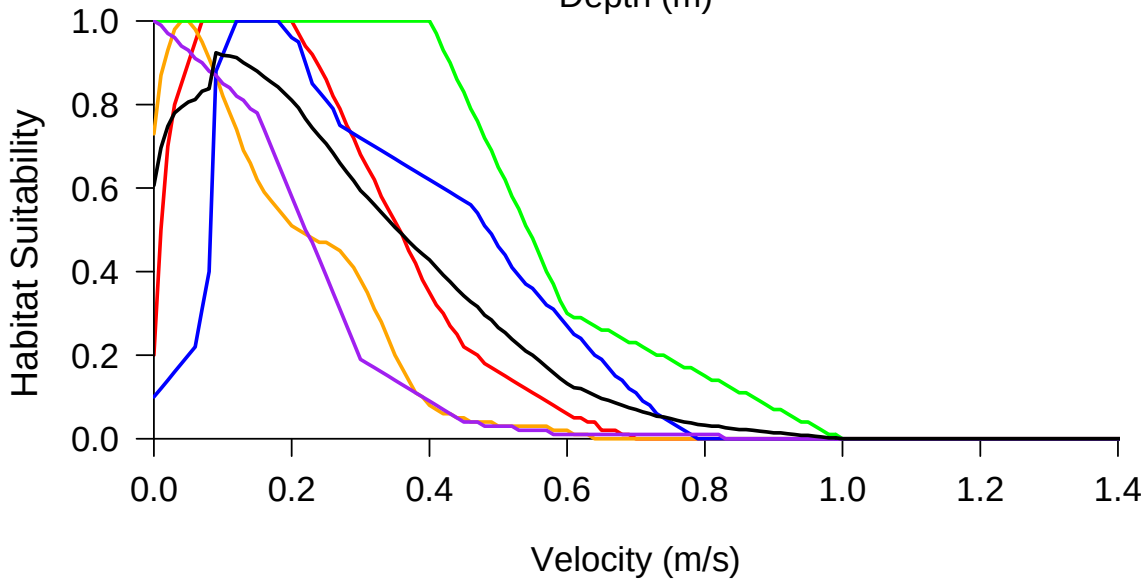


Rainbow trout / steelhead fry

- Standard HSI curve provided by BC Ministry of Environment

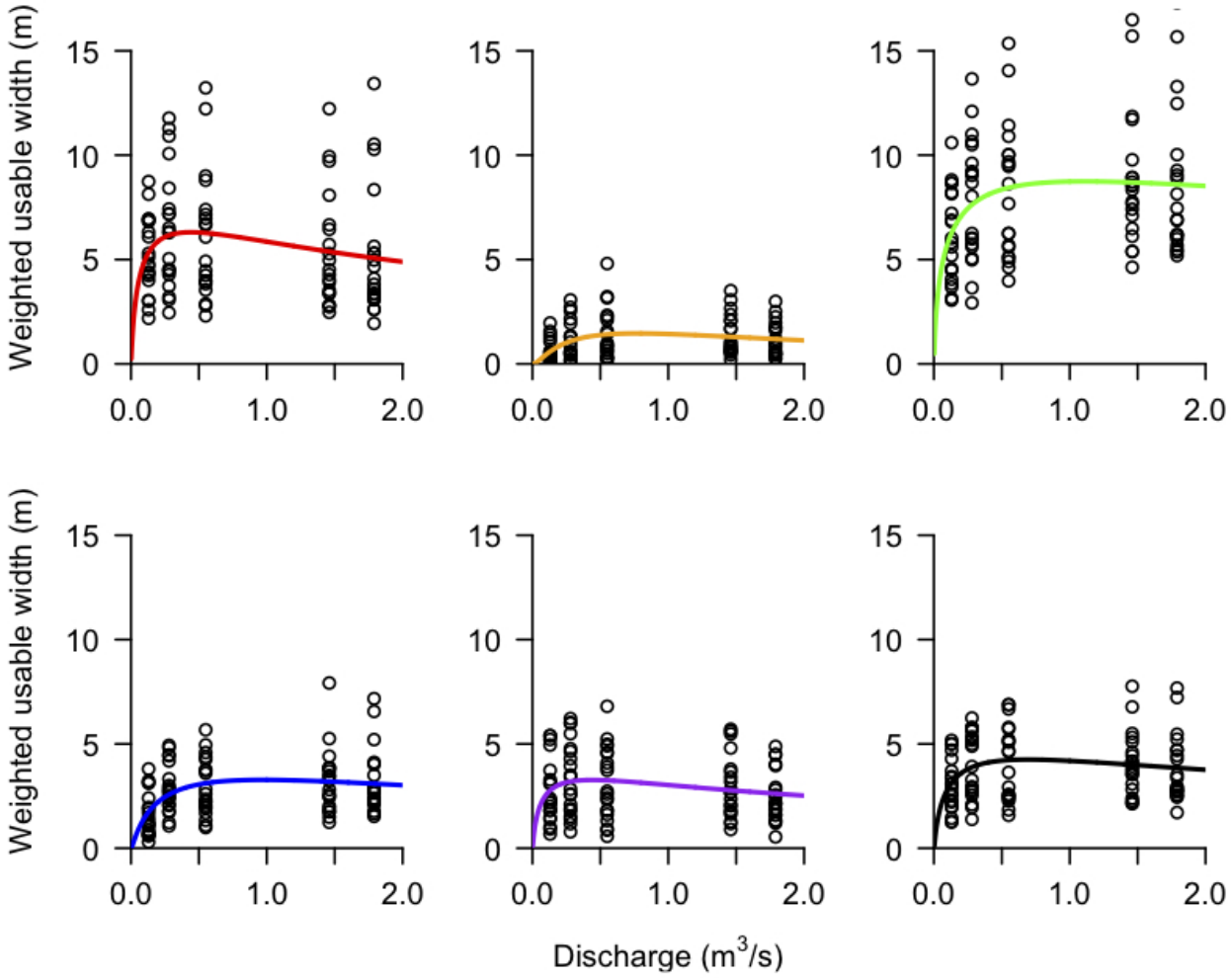
Uncertainty in choice of HSI





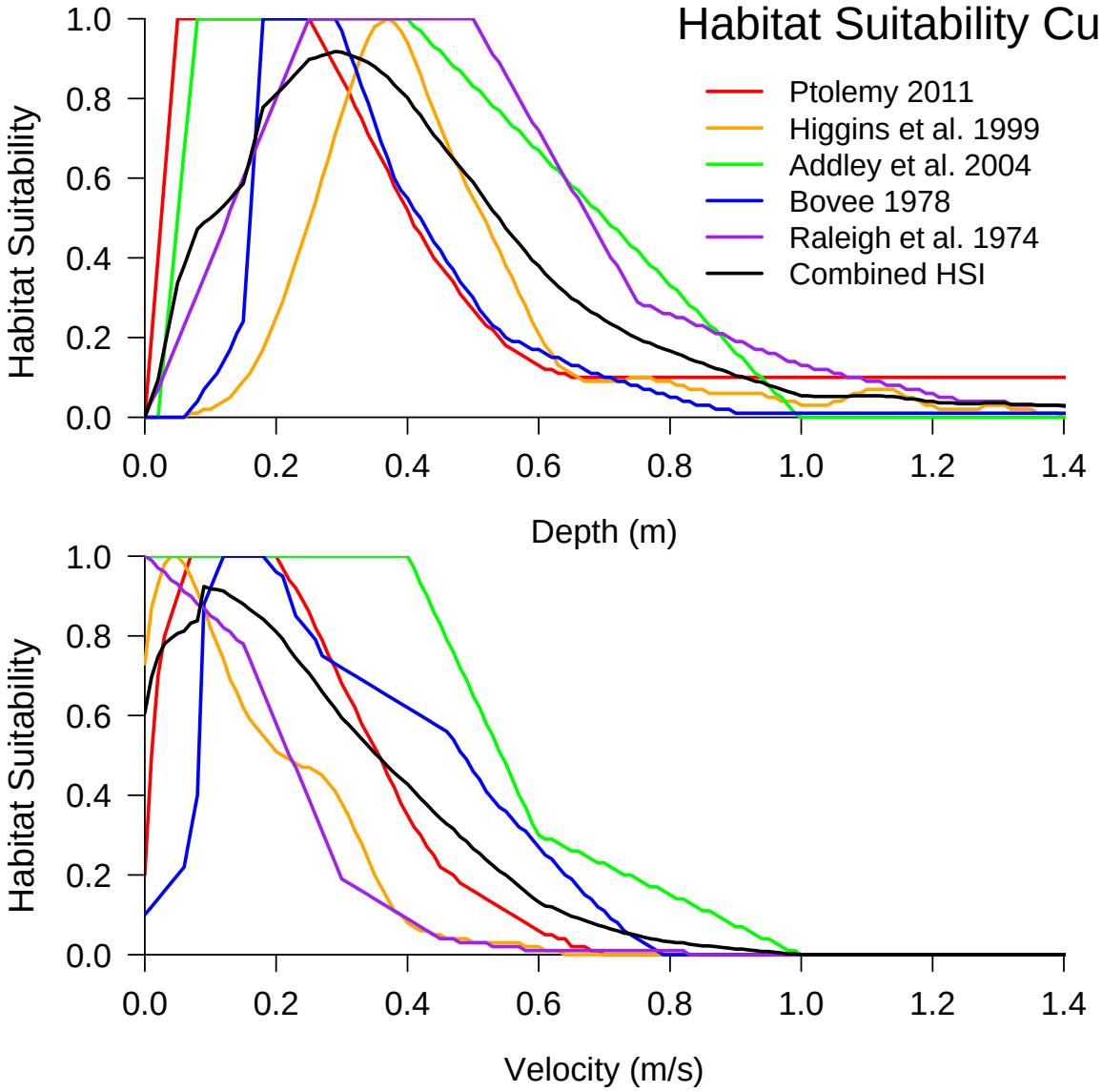
- What is the effect of choice of HSI on results of BCIFM?

Uncertainty in choice of HSI



Optimal Discharge (m^3/s)	Maximum WUW (m)
0.4	6.3
0.8	1.5
1.1	8.7
1.0	3.3
0.4	3.3
0.7	4.3

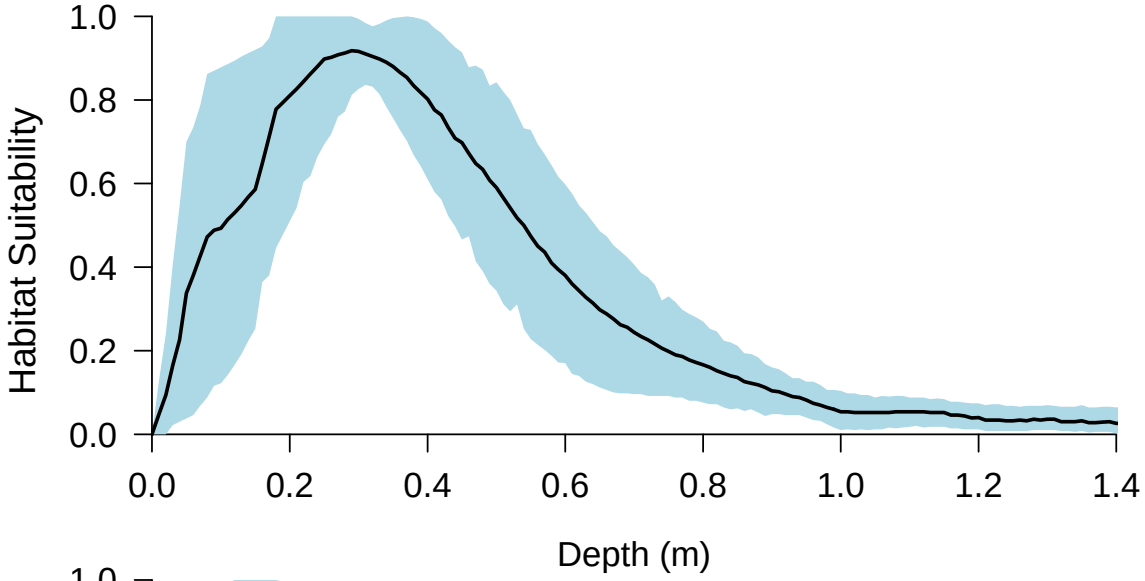
Uncertainty in Choice of HSI

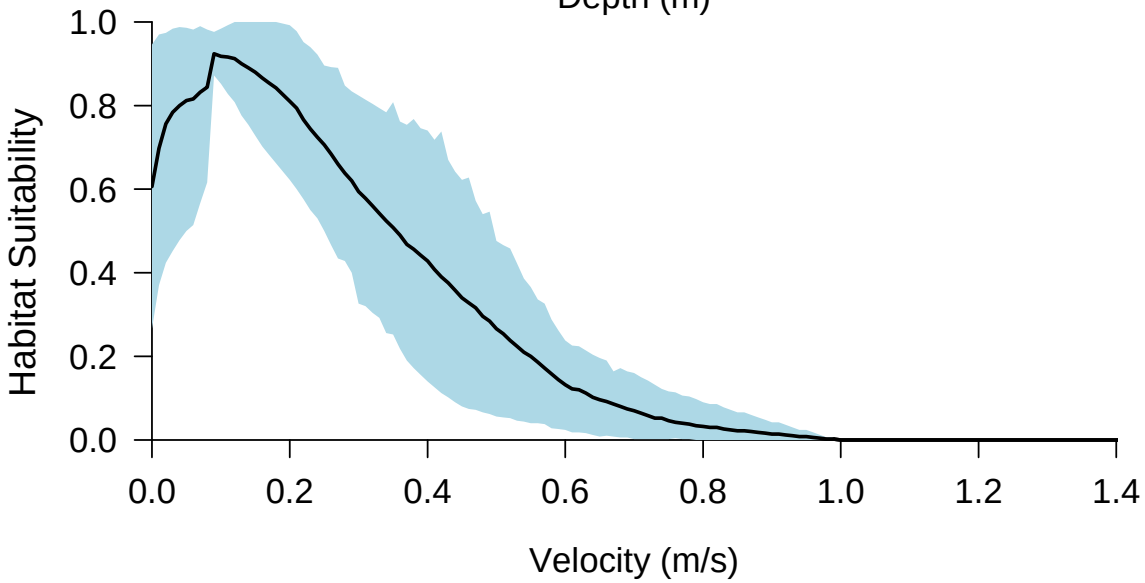


Rainbow trout / steelhead fry

- How can we incorporate the choice of HSI into the BCIFM?

Combined HSI (cHSI)

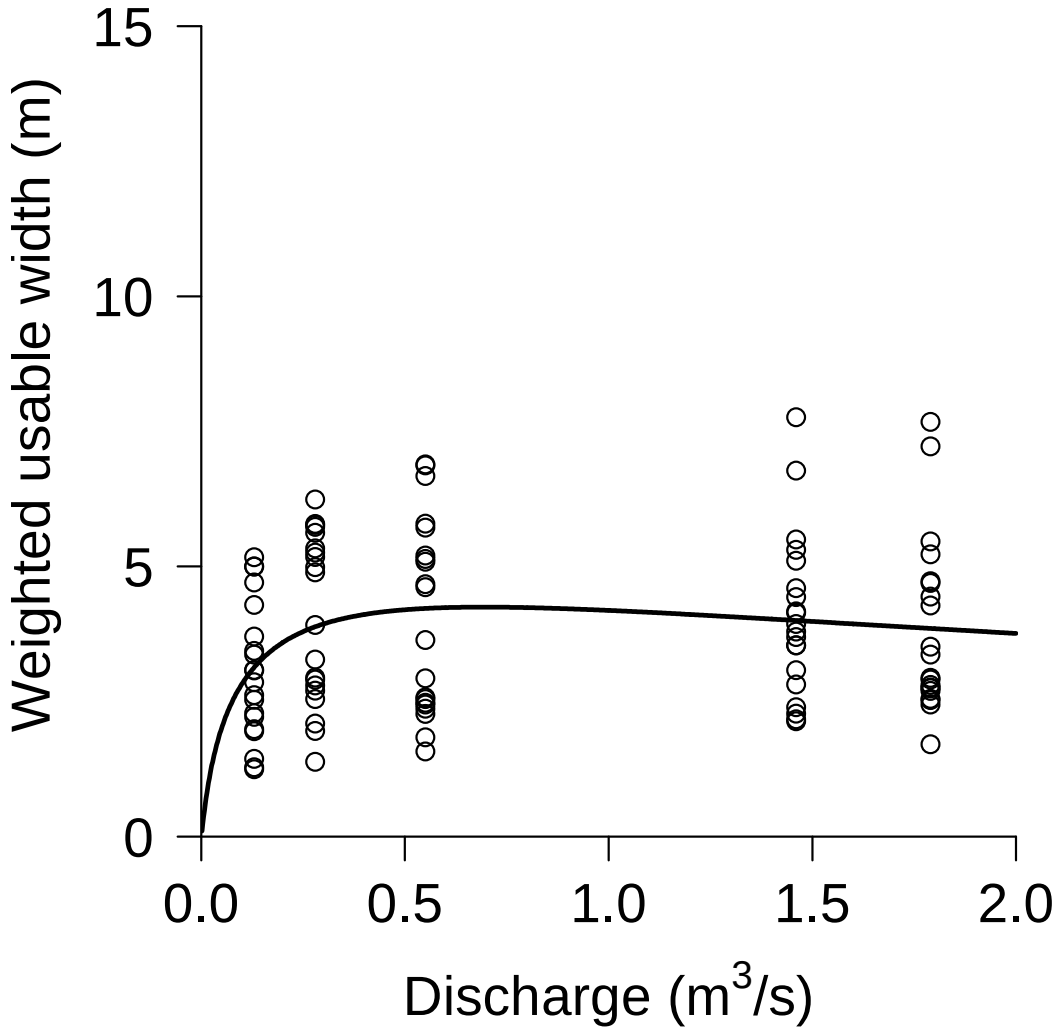




Solution:

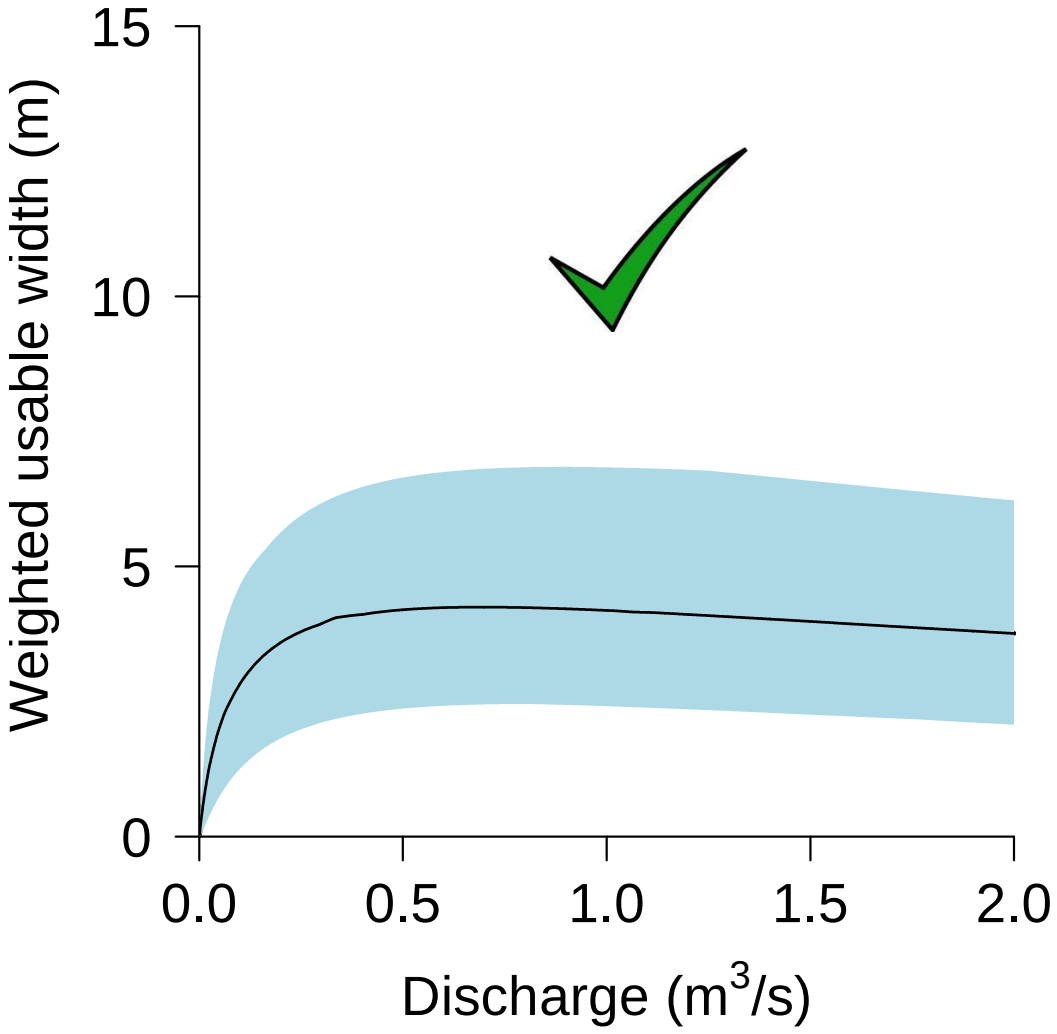
- Assume each curve is equally likely.
- Bootstrap the mean.
  - 95% Confidence intervals

cHSI Uncertainty



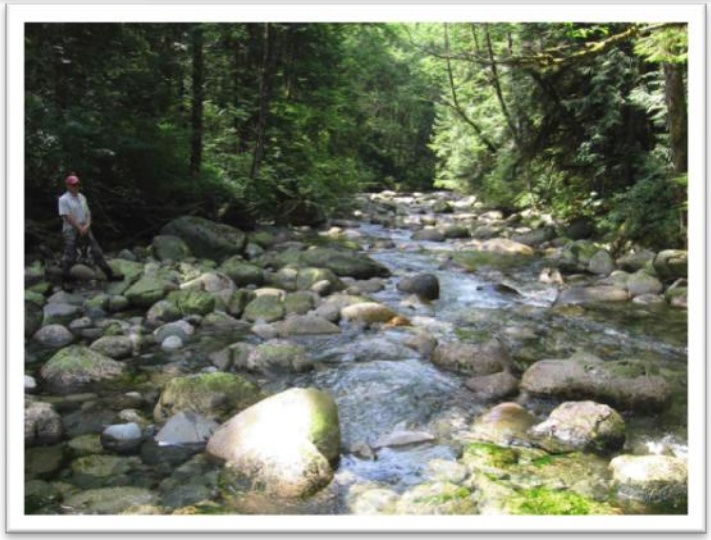
Optimal Discharge (m^3/s)	Maximum WUW (m)
0.7	4.3

cHSI Uncertainty

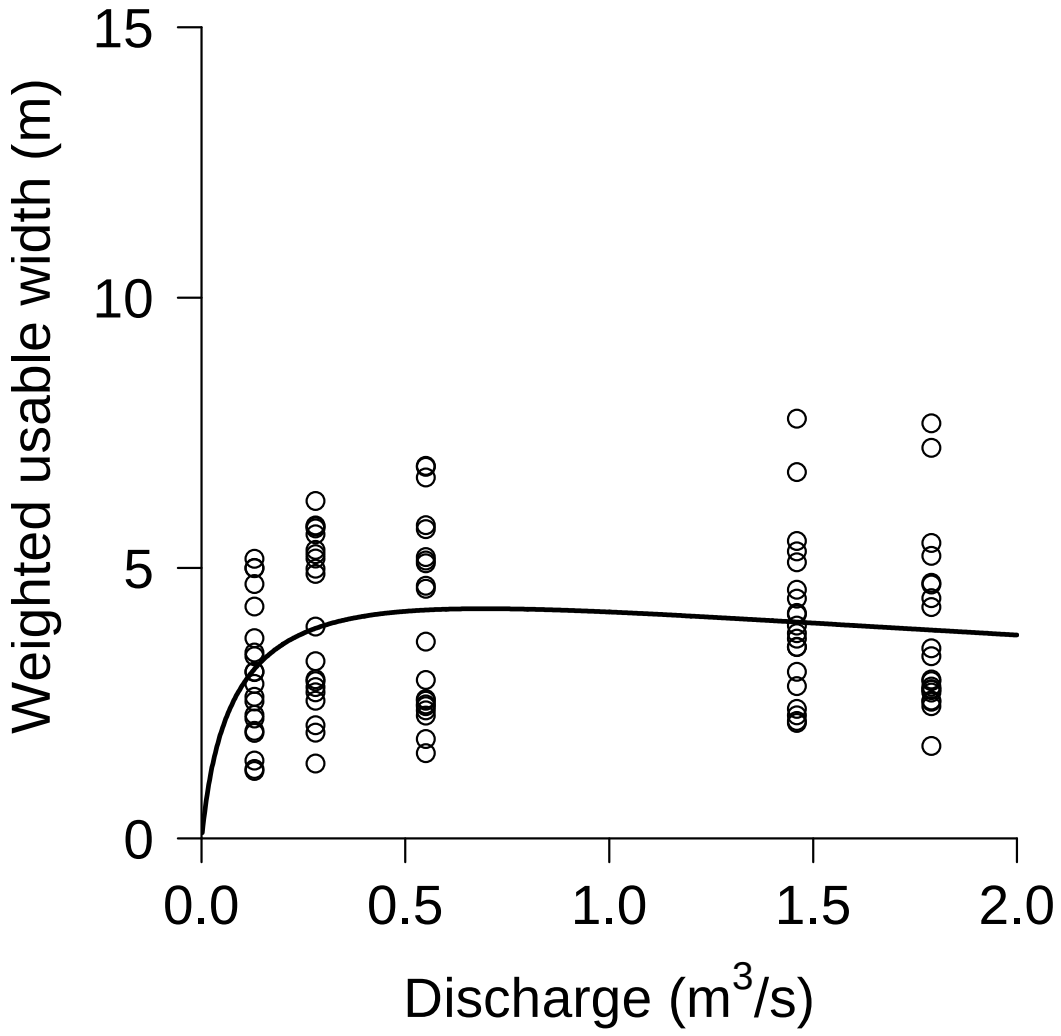


Optimal Discharge (m^3/s)	Maximum WUW (m)
0.7	**4.3**
0.5 - 1.0	2.5 - 6.8

Variation in physical habitat among transects

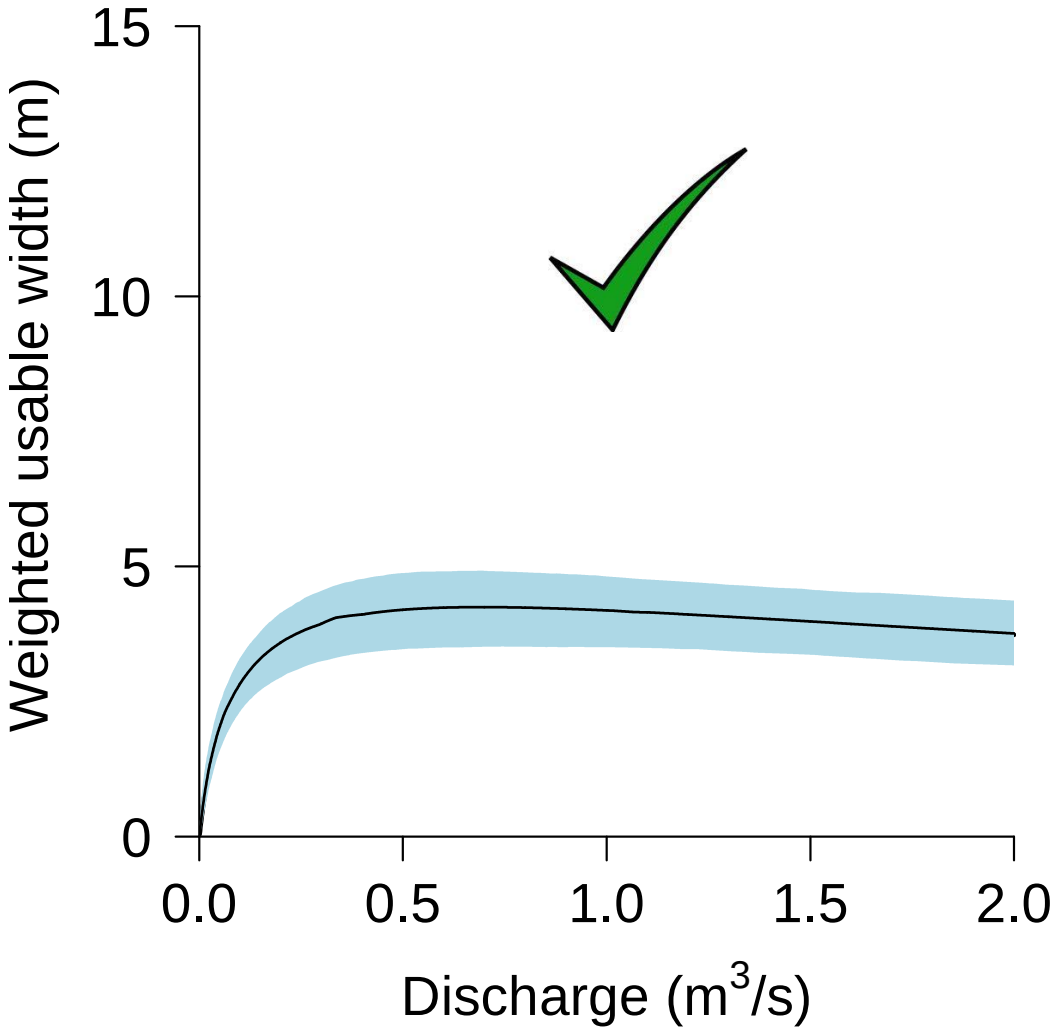


Transect Variability



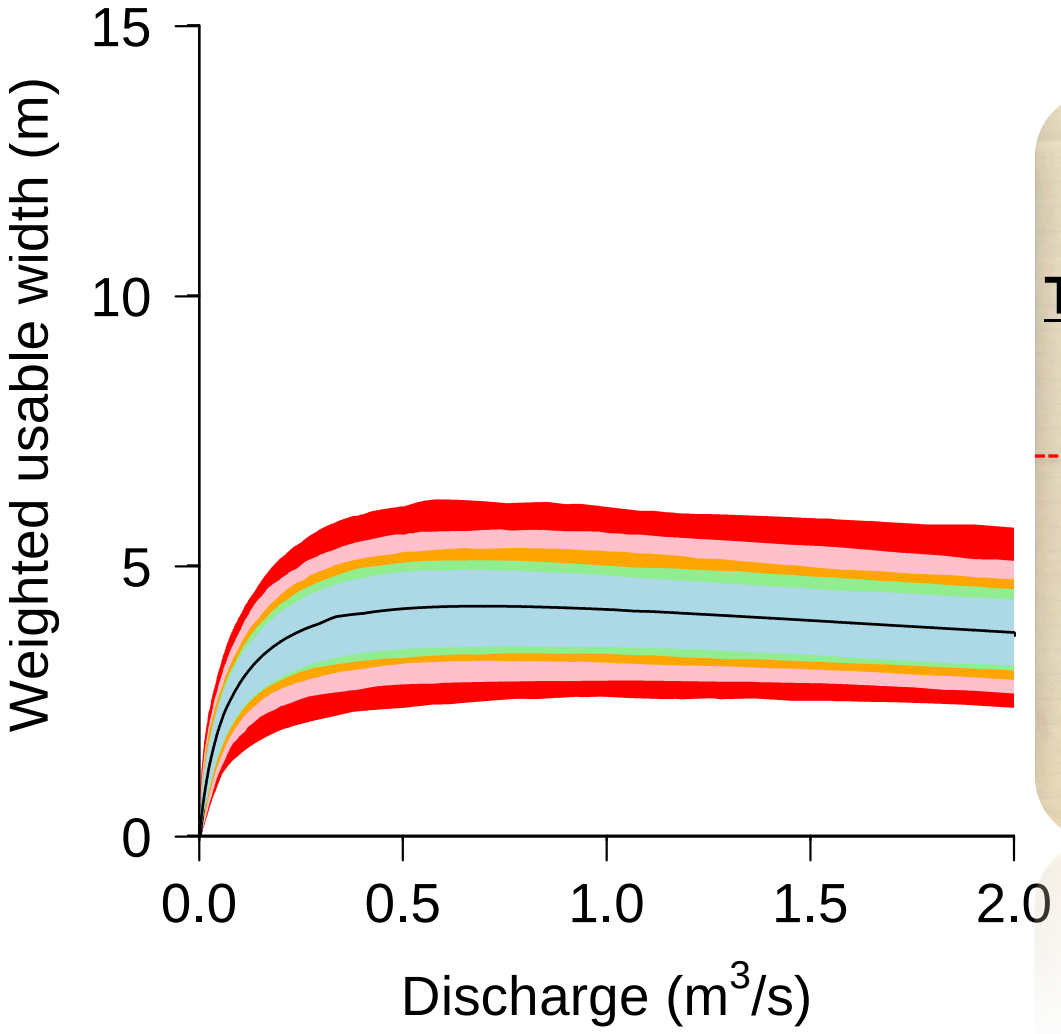
Optimal Discharge (m^3/s)	Maximum WUW (m)
0.7	4.3

Transect Variability



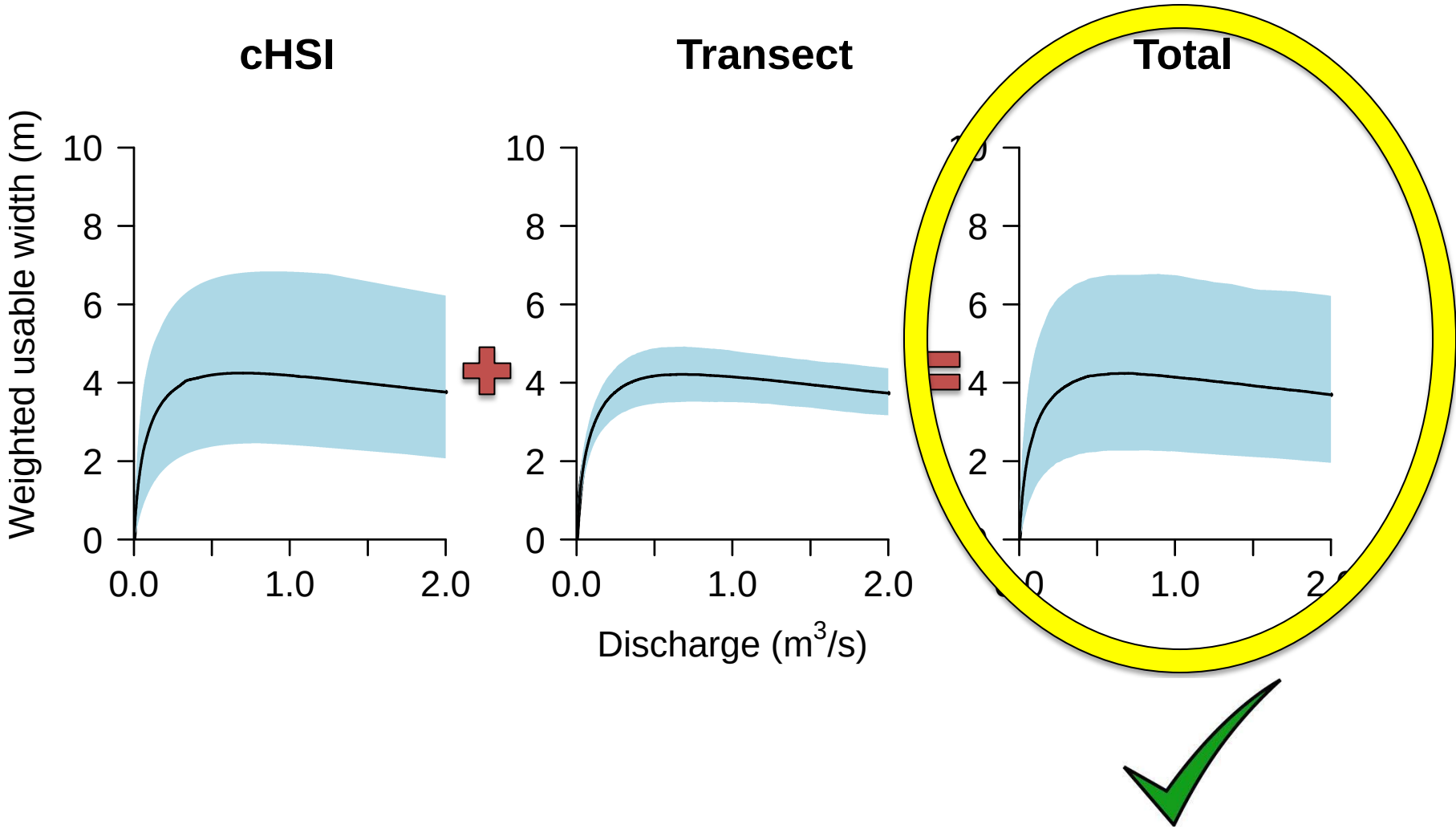
Optimal Discharge (m^3/s)	Maximum WUW (m)
0.7	**4.3**
0.5 - 1.1	3.5 - 4.9

Number of Transects

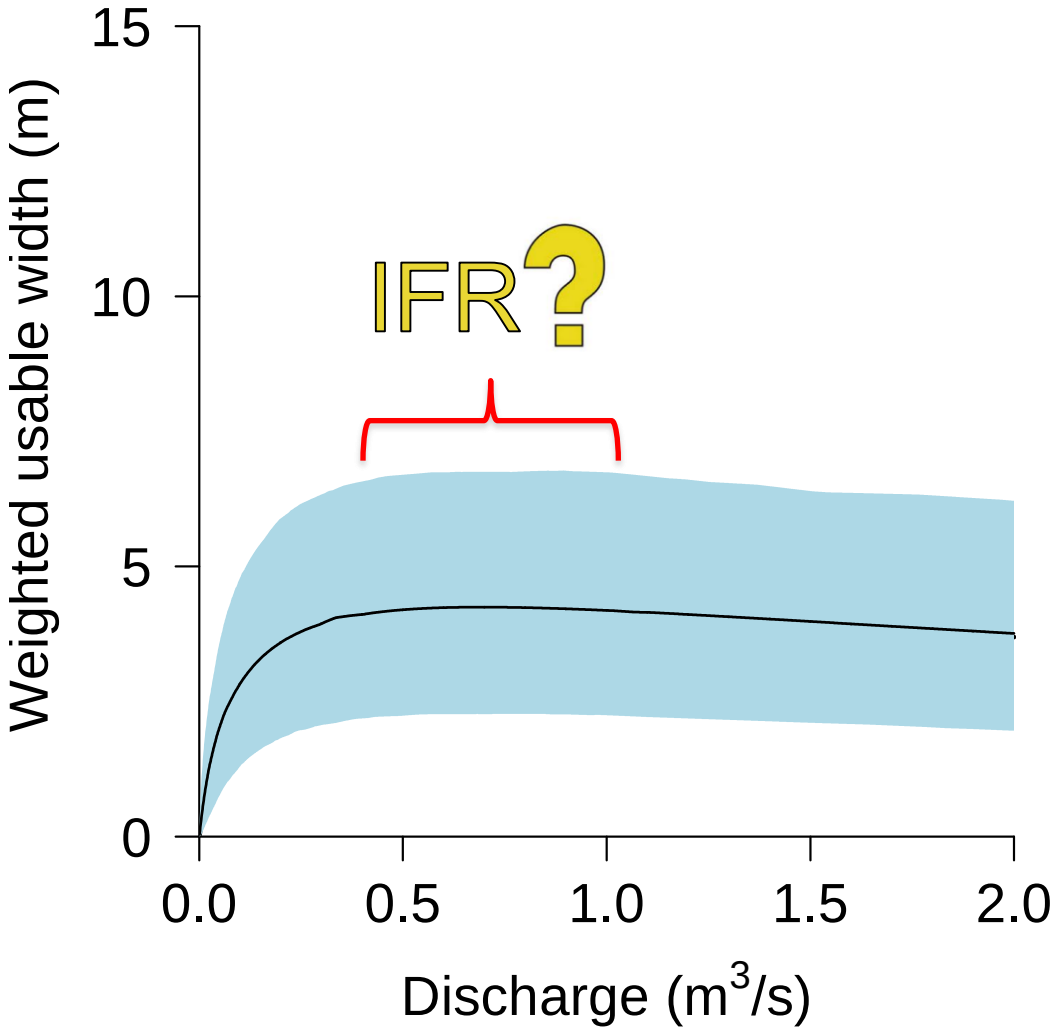


# Trans.	Optimal Discharge (m^3/s)	Maximum WUW (m)
	0.7	**4.3**
20	0.5 - 1.1	3.5 - 4.9
15	0.5 - 1.1	3.4 - 5.1
10	0.5 - 1.3	3.3 - 5.4
5	0.4 - 2.1	2.9 - 5.7
3	**0.3 - 2.7**	**2.7 - 6.2**

Total Uncertainty



Total Uncertainty



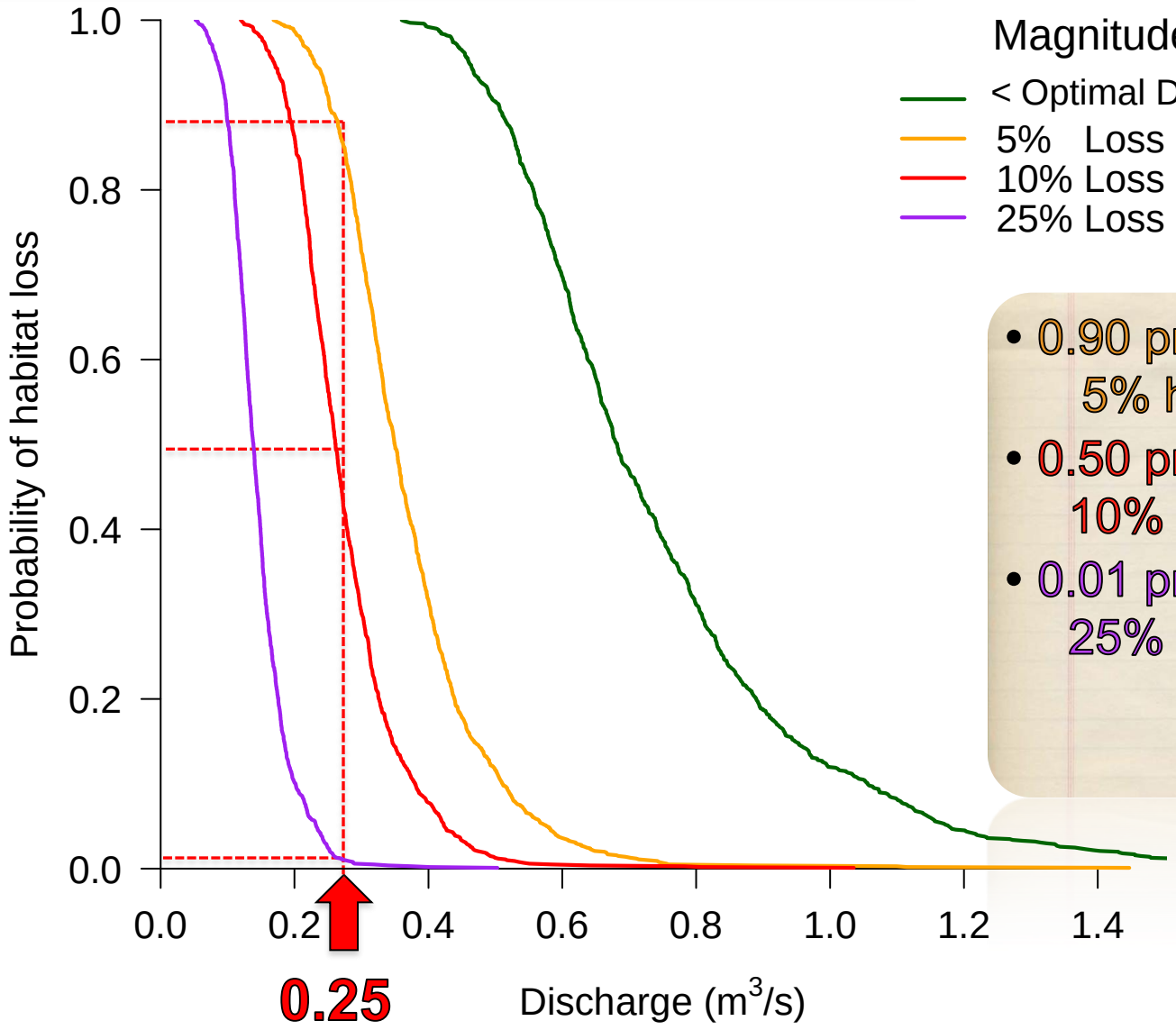
Optimal Discharge (m^3/s)	Maximum WUW (m)
0.7	**4.2**
0.4 - 1.3	2.3 - 6.8

Question 2

- How do you interpret and manage this uncertainty?

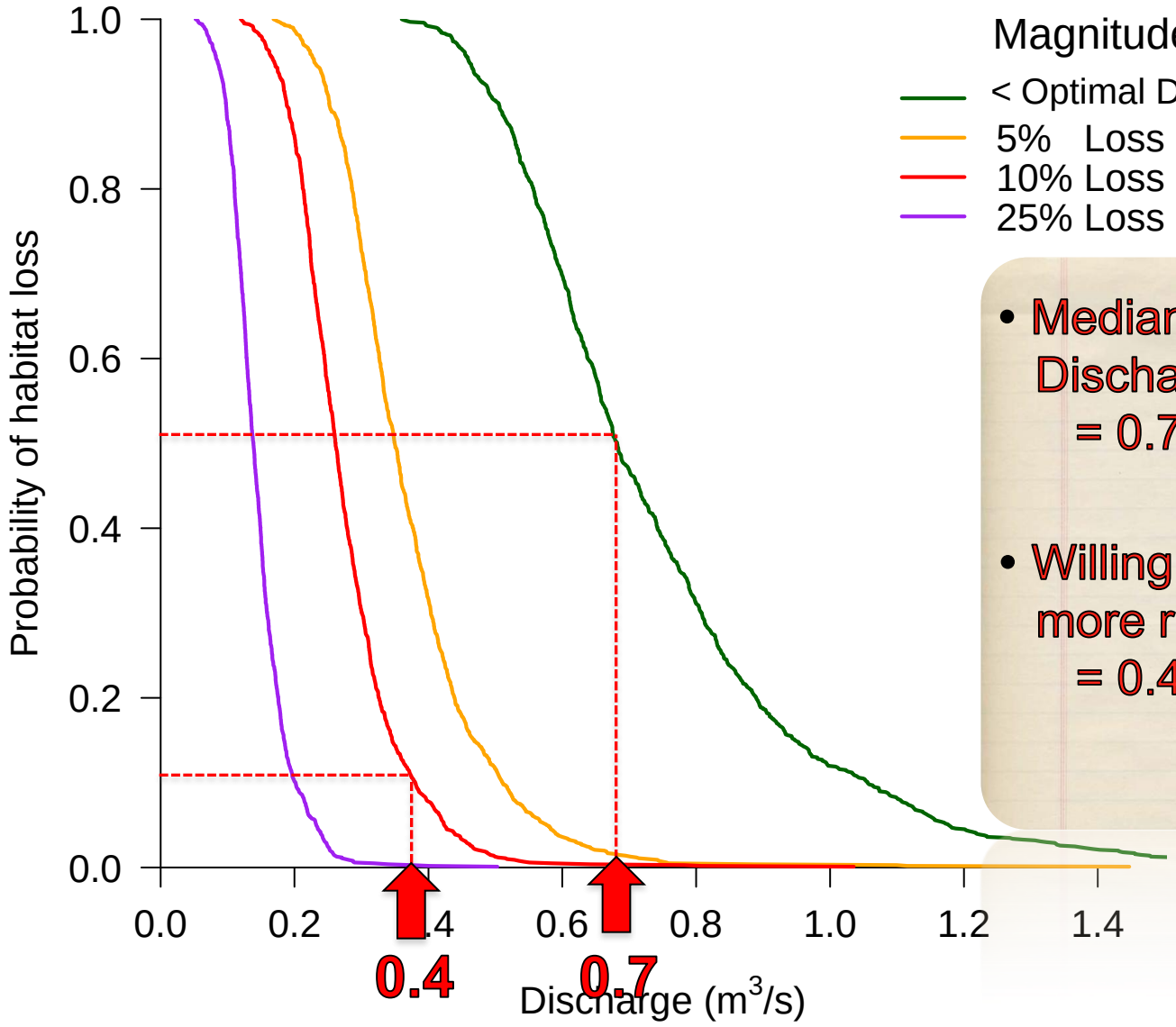
SO WHAT!

Probability-of-loss Curve



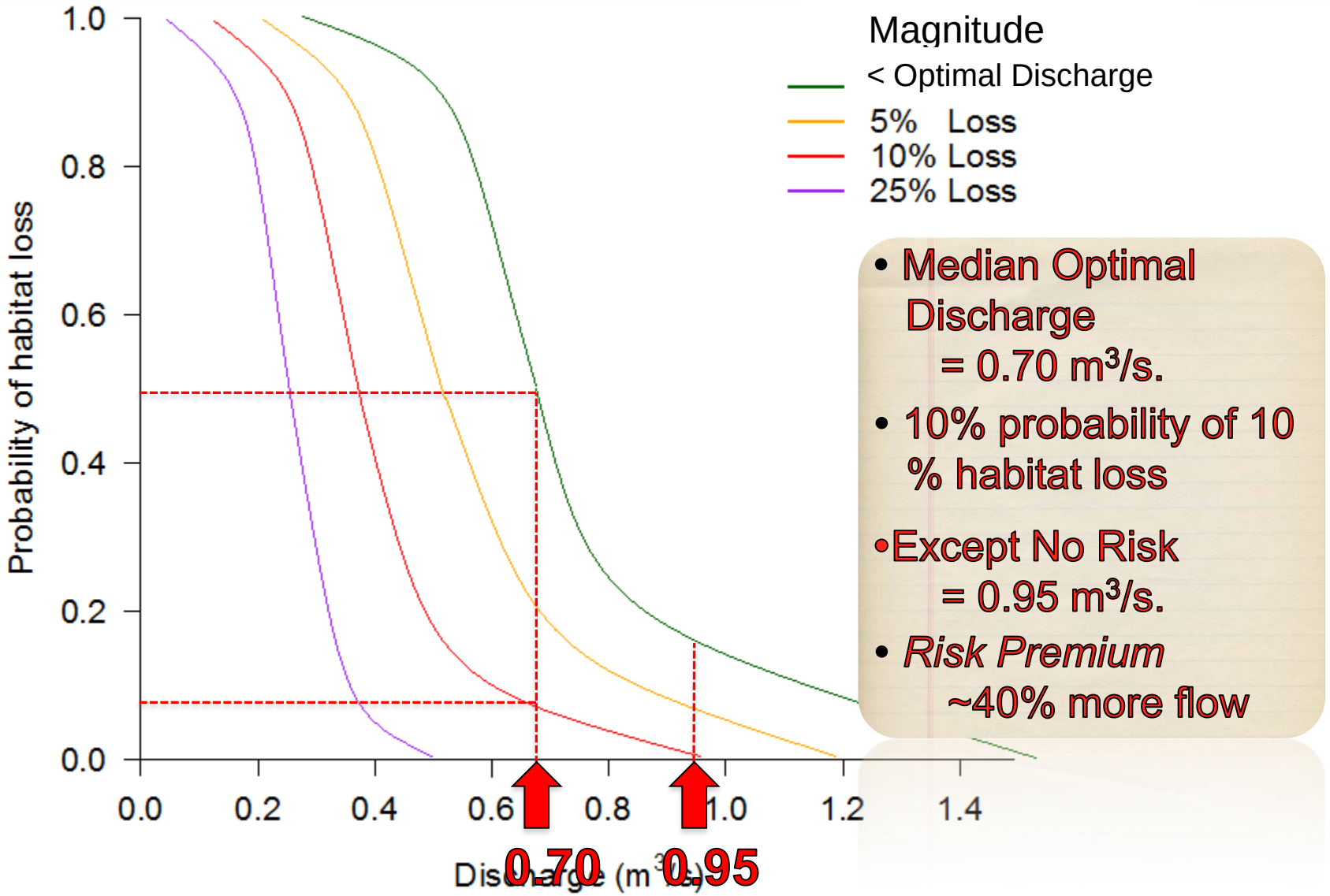
- 0.90 probability of 5% habitat loss.
- 0.50 probability of 10% habitat loss.
- 0.01 probability of 25% habitat loss.

Managing Uncertainty - Risk Tolerance



- Median Optimal Discharge:
  = 0.70 m^3/s.
- Willing to accept more risk:
  = 0.40 m^3/s.

More Uncertain Data - Risk Premium



- Median Optimal Discharge = 0.70 m^3/s.
- 10% probability of 10 % habitat loss
- Except No Risk = 0.95 m^3/s.
- *Risk Premium* ~40% more flow

Conclusion

- Incorporating uncertainty in physical habitat modeling is important IFR decisions.
- Presentation of uncertainty in terms of probability of different magnitudes of habitat loss allows managers to choose IFRs based on individual risk tolerance.
- Precautionary approach to water management.
  - *Risk premium* penalizes water users for uncertain data
  - Hedge away from large magnitude, uncertain event.
  - Integrate data in Bayesian decision/risk analysis

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- Rachel Romero
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- Water Research Group
- Fish Sticks!! (AKA Jim, Mal, Sabs and Lise)

BC hydro
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