Introduction to CHaMP Hydraulic Modeling

Presenter:
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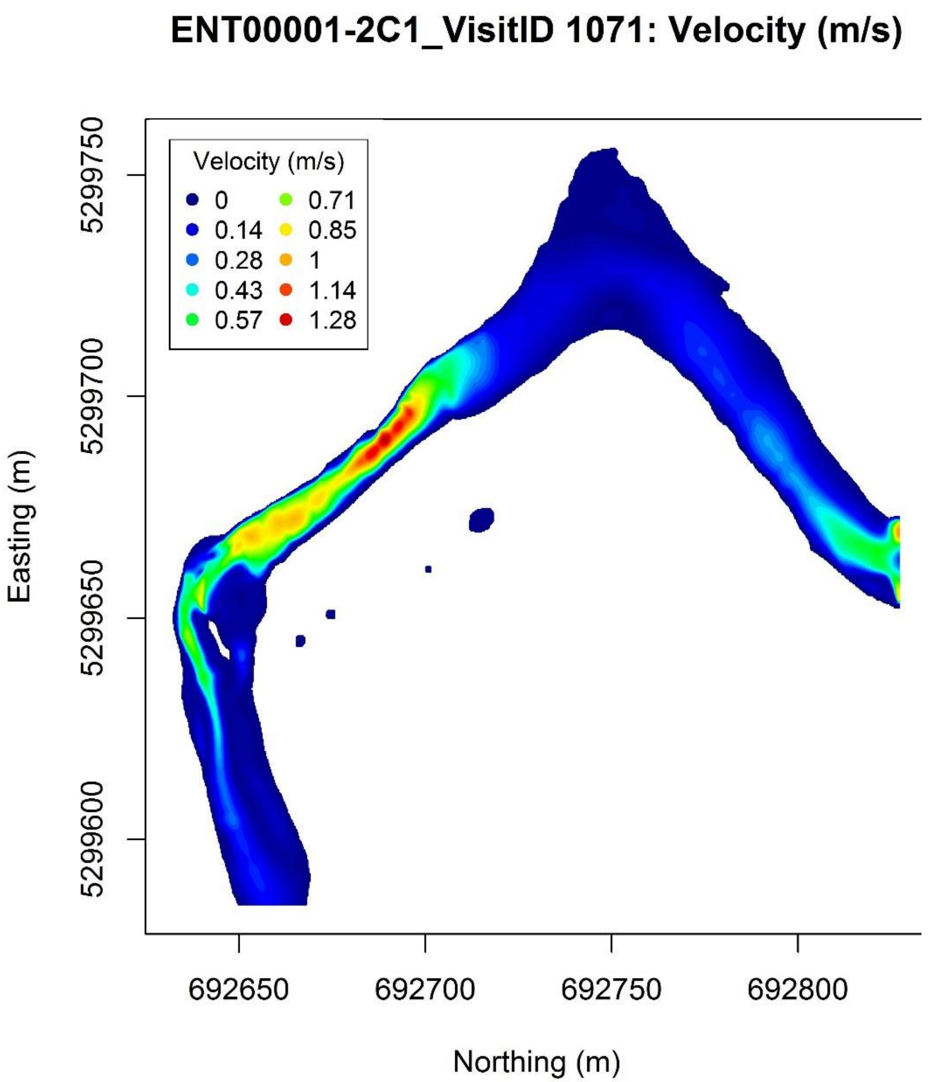
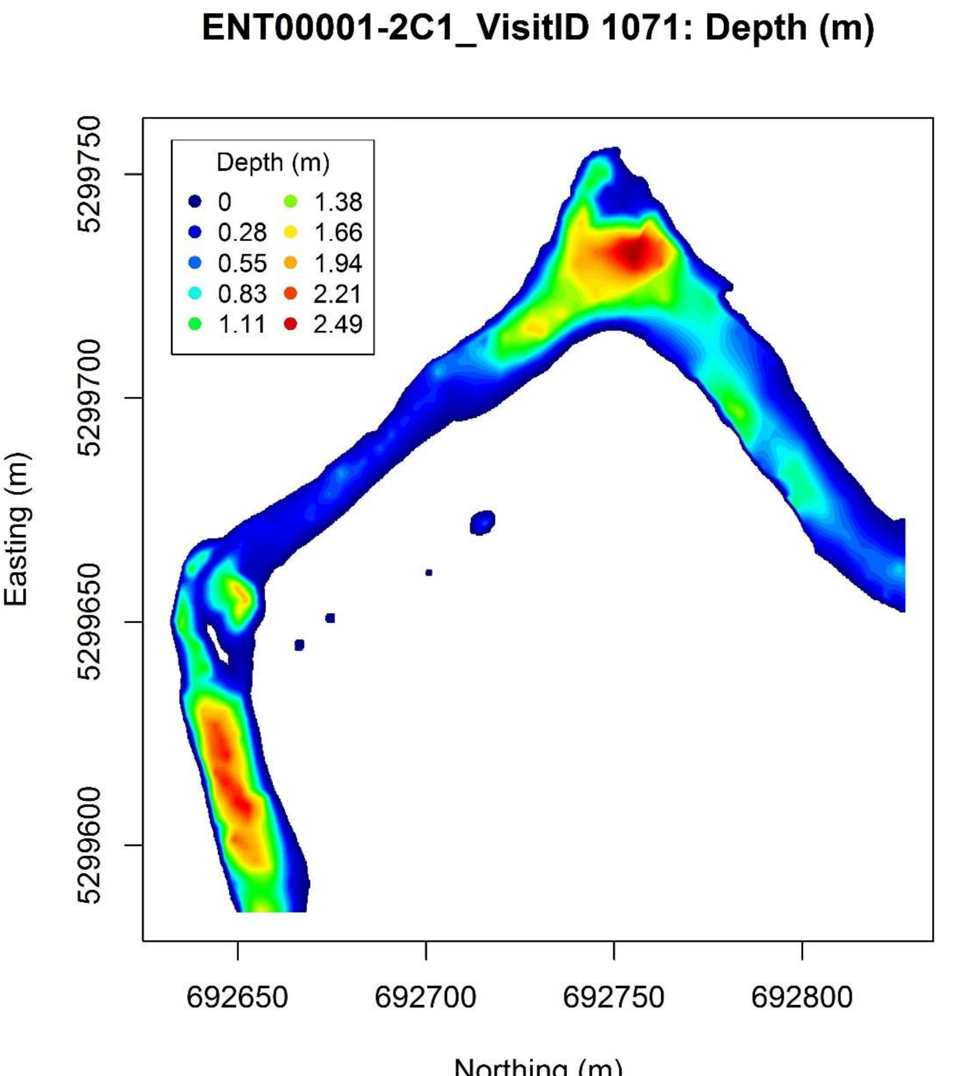
Introduction to CHaMP Hydraulic Modeling

- What is CHaMP hydraulic modeling?

From CHaMP survey data (elevation survey, discharge, surface roughness), we numerically estimate the water depth and velocity at every point at the site, at a 10 cm resolution

Introduction to Hydraulic Modeling





CHaMP Hydraulic Modeling

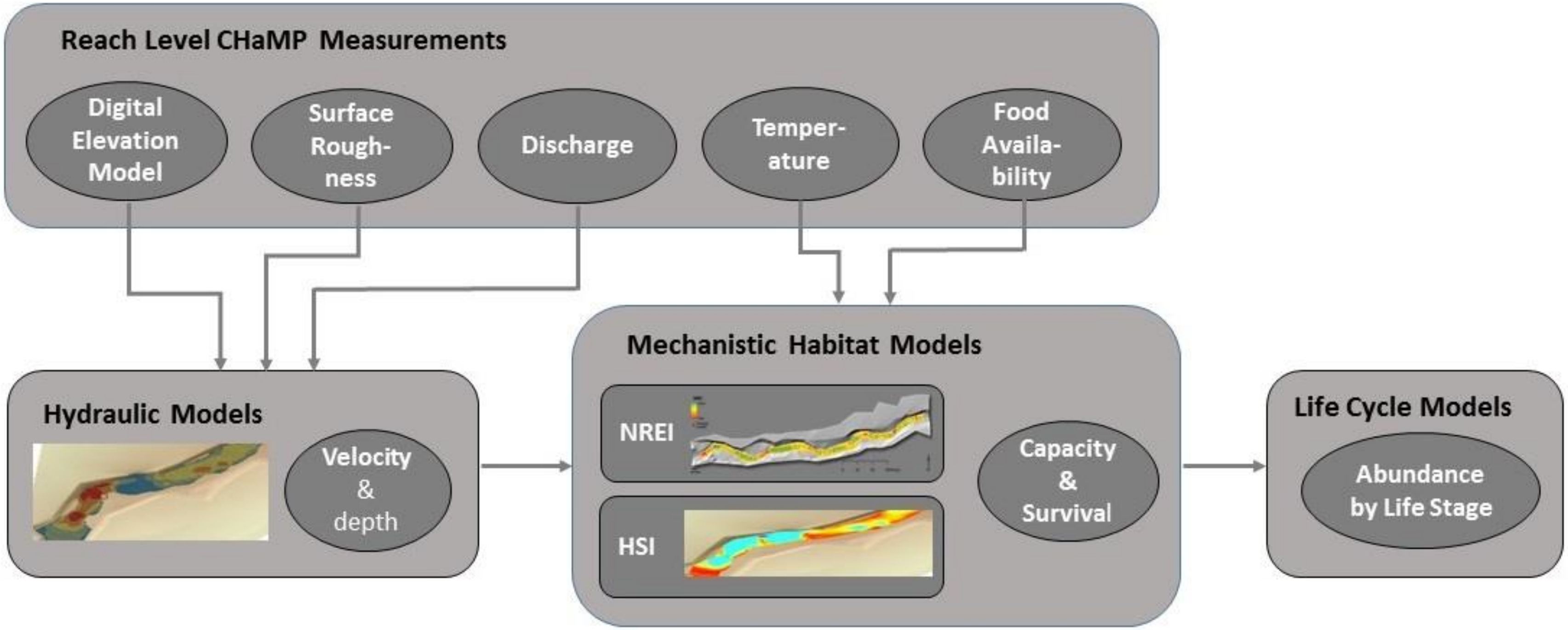
- Why do hydraulic modeling of CHaMP Sites?
  - Provide Inputs for:
    - NREI, HSI, and other Model Inputs
    - Other Interested Parties?

More than 1000 Completed Site Level Hydraulic Models!

Results available on champmonitoring.org

CHaMP Watershed	Visit Year			
	2011	2012	2013	2014
Methow	20	12	25	19
Entiat	42	46	53	33
Wenatchee	17	18	20	16
Tucannon	15	18	22	21
John Day	52	85	59	39
Upper Grande Ronde	78	46	52	57
Lemhi	40	46	39	22
South Fork Salmon	31	25	21	21
Totals	295	296	291	228
	1110			

CHaMP Data Flow from Reach Level Measurements to Life Cycle Modeling

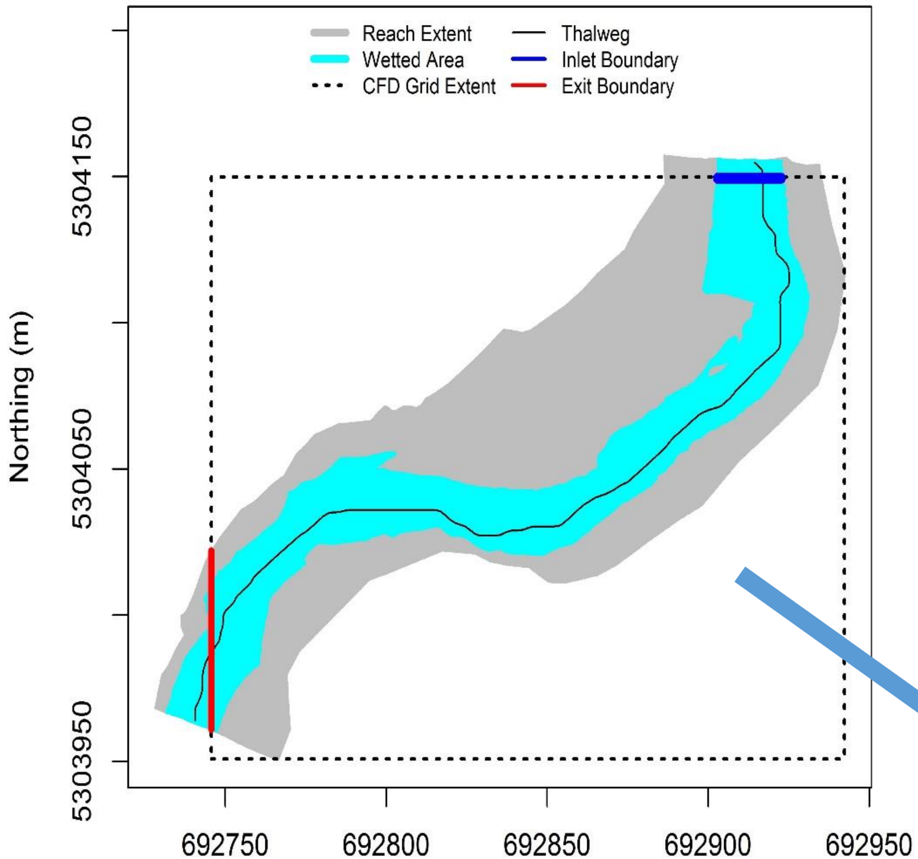


Hydraulic Modeling Steps

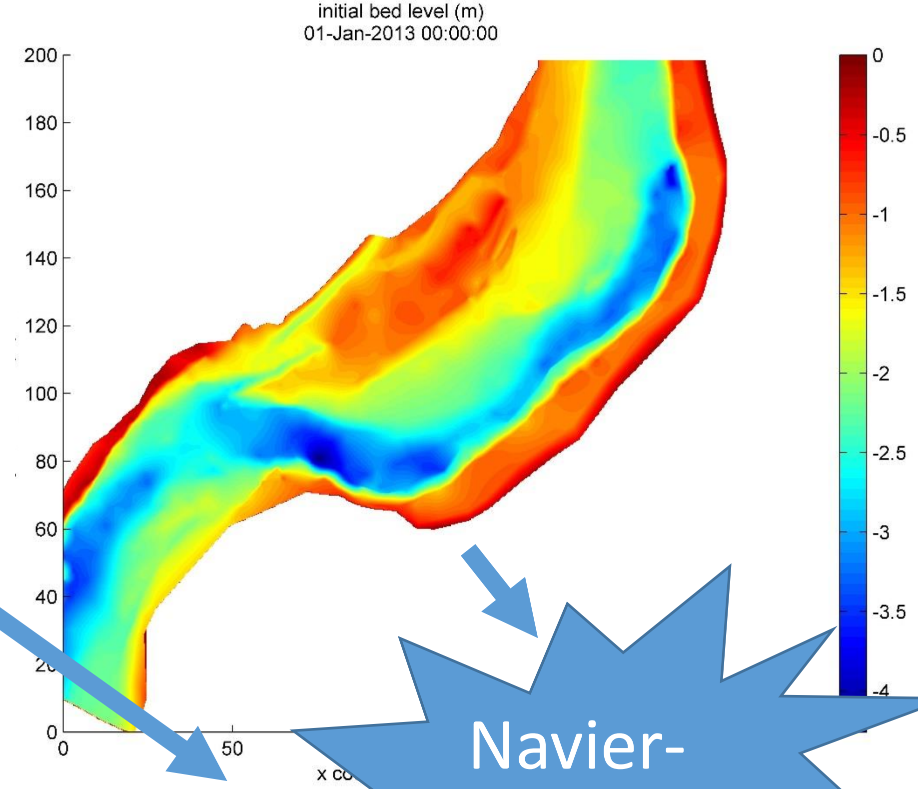
1. Gather Input Data (DEM, Thalweg, D84, Discharge
    - GIS: Convert DEM to .csv format
2. Convert Raw Data into Delft-3D Input Files
    - R-Code #1
3. Run the fluidics modeling software
    - Delft 3D application “Flow”
4. Convert Output Files into text files
    - Delft 3D Application “Quickplot”
5. Map Delft-3D results back onto DEM Grid
    - R-Code #2
6. Upload Results to champmonitoring.org
7. Q/A Check Results

CHaMP Hydraulic Modeling

Boundary Conditions



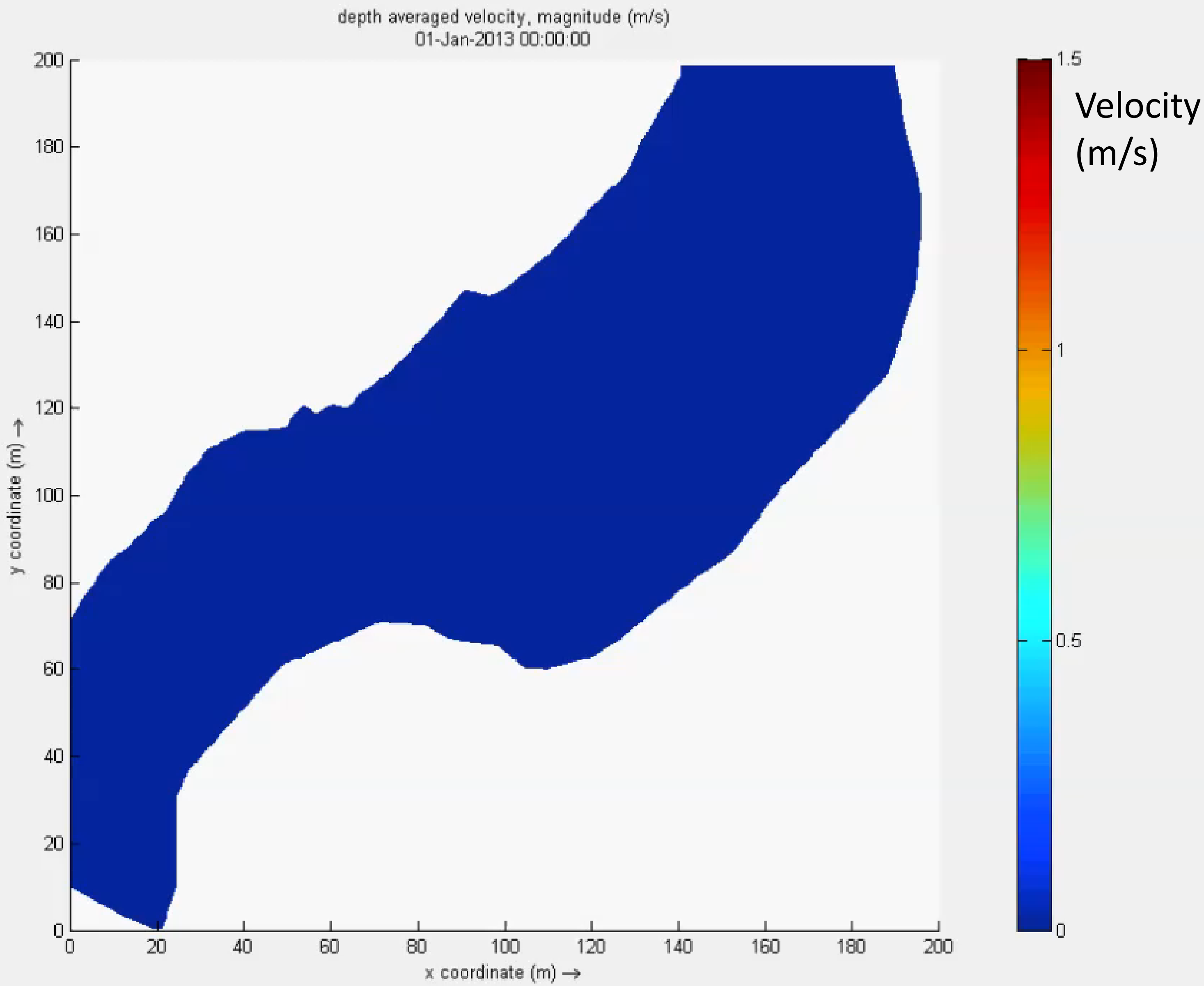
Bathymetry



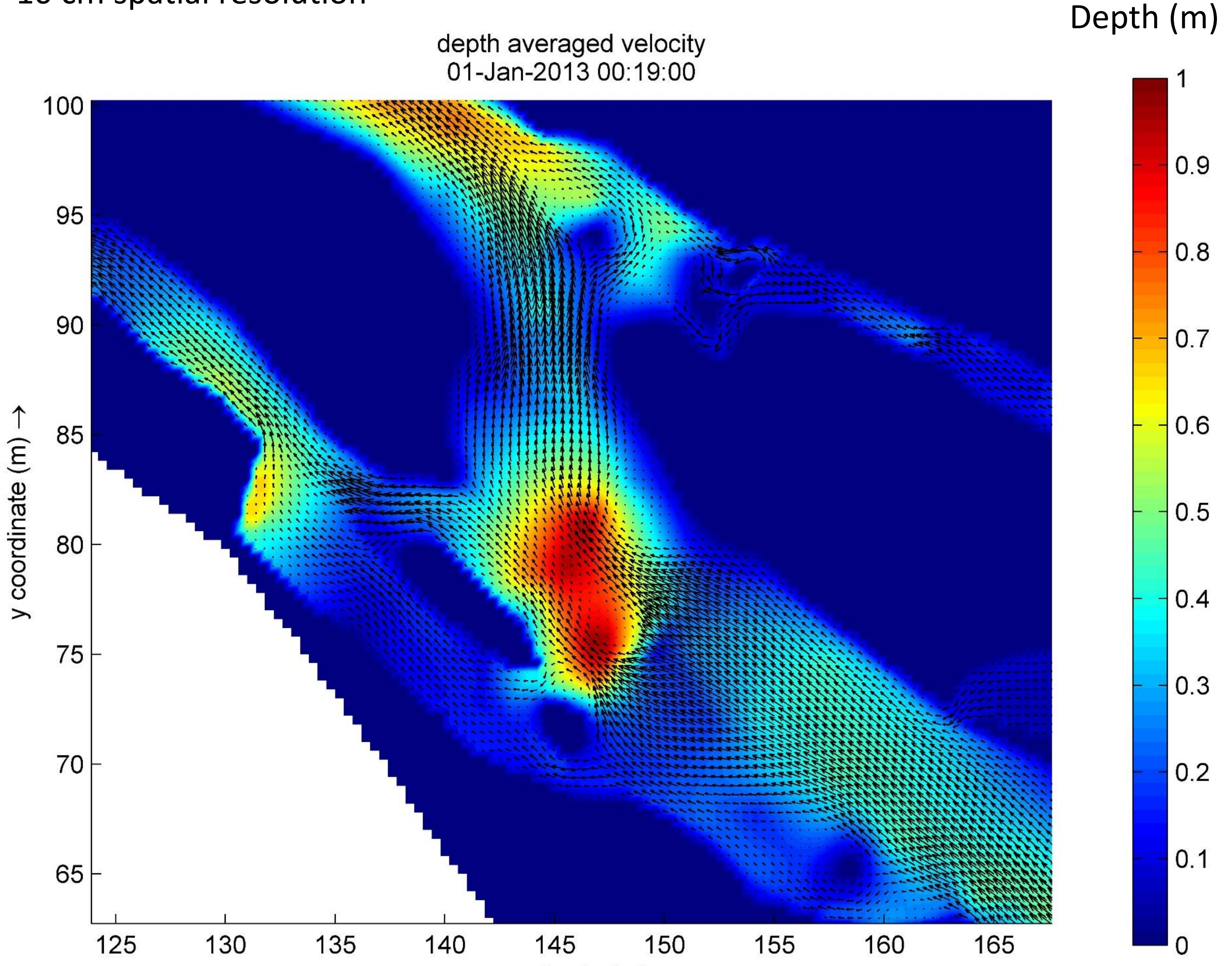
Navier-Stokes

Upstream BC: Discharge
Downstream BC: Water Level

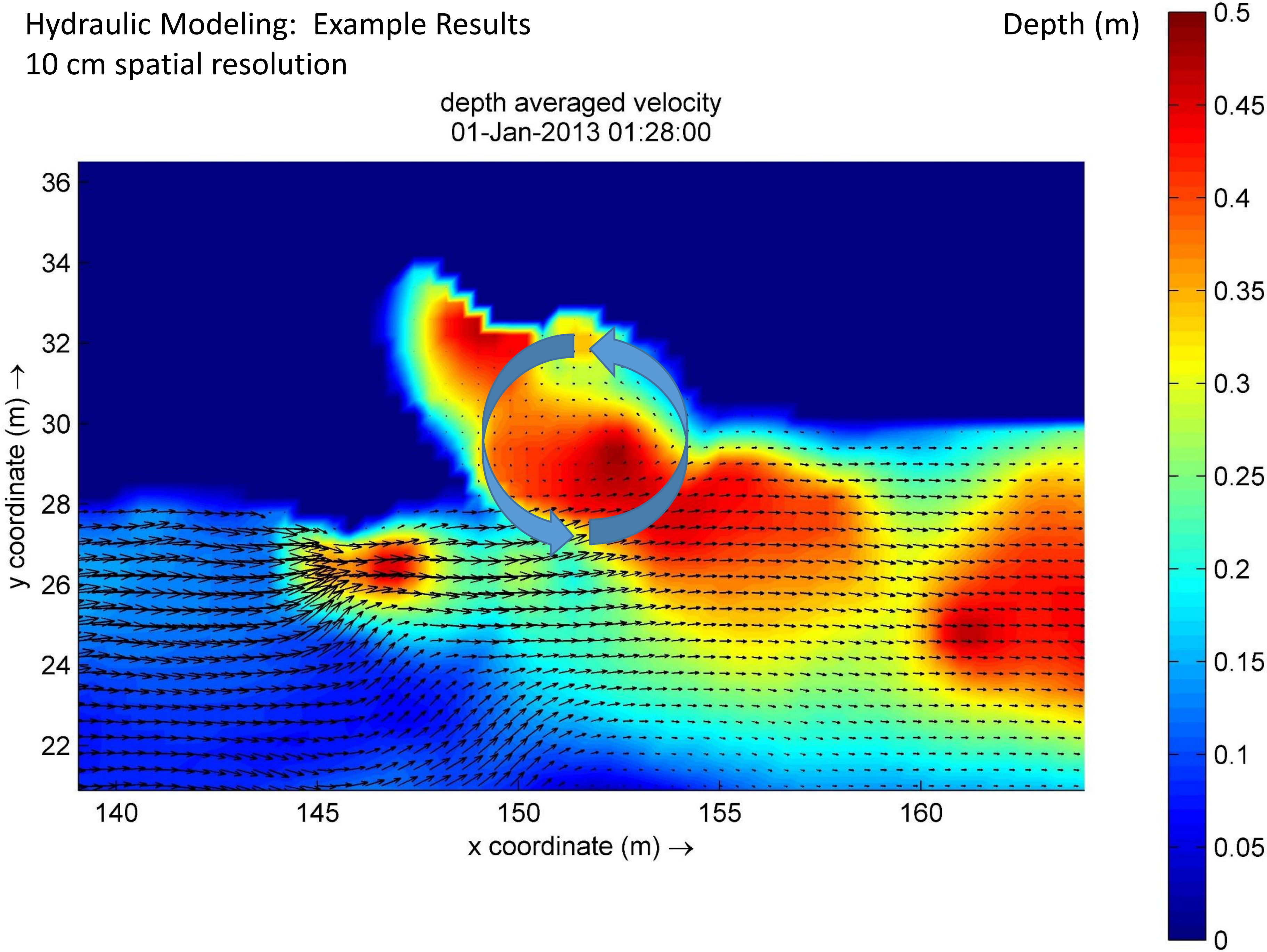
CHaMP Hydraulic Model Solution: ENT00001-3A2: Velocity Magnitude



Hydraulic Modeling: Example Results
10 cm spatial resolution



Hydraulic Modeling: Example Results
10 cm spatial resolution



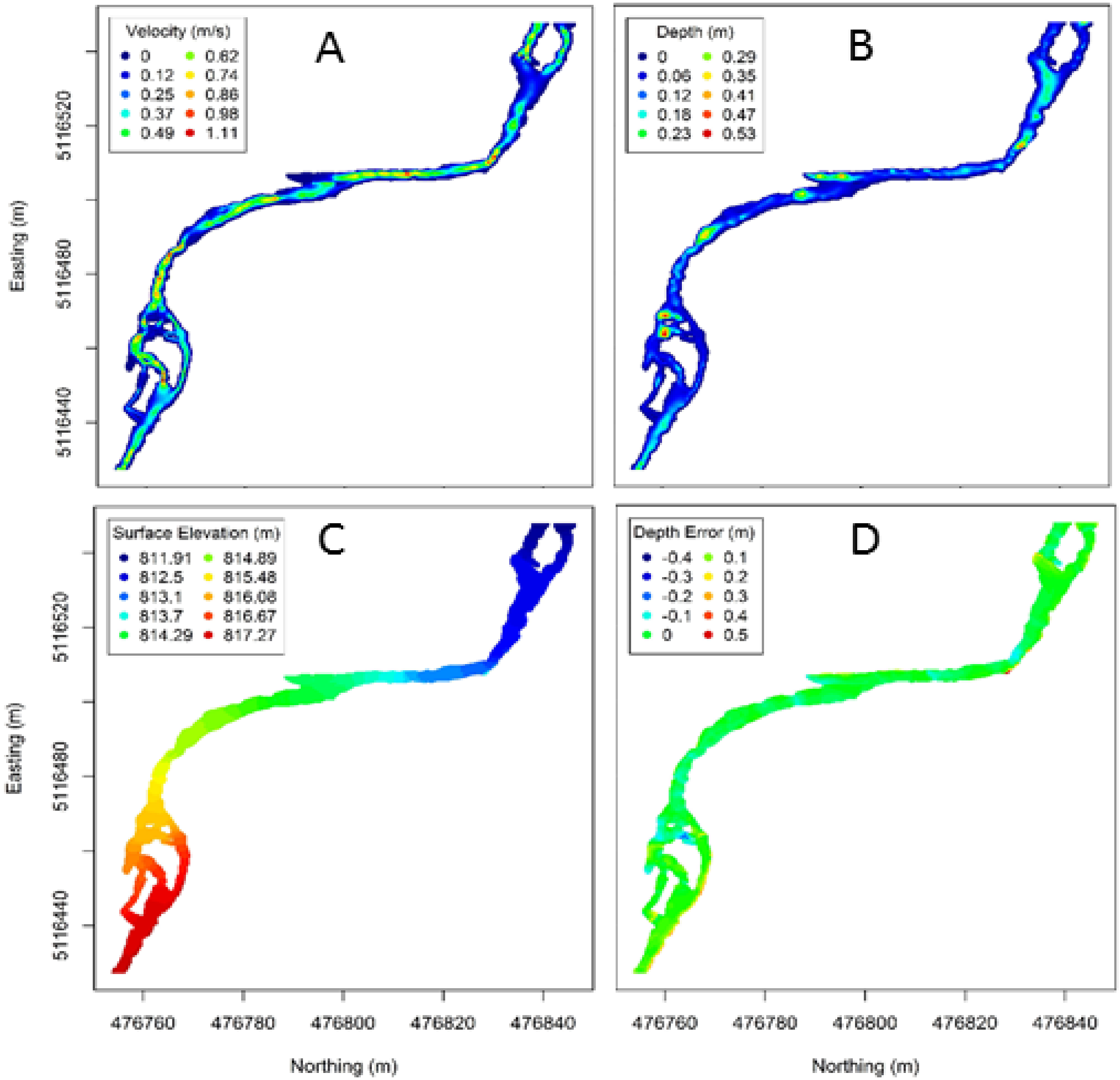
Hydraulic Model Output

- CFD Model Output Generate for each Site includes:
  - Velocity (m/s)
    - X and Y Component Vectors
  - Depth (m) and Water Surface Elevation (m)
  - Bed Shear Stress (N/m^2)
    - X and Y Component Vectors

Hydraulic Model: Example Results

Location		Velocity			Depth			Bed Shear		Error
X	Y	X.Velocity	Y.Velocity	Velocity.Magnitude	Depth	WSE	BedLevel	BedShear_X	BedShear_Y	Depth.Error
718228.6	5363682.0	0.99	-0.02	0.99	0.21	651.84	651.63	389.23	-7.98	0.10
718228.7	5363682.0	1.08	-0.05	1.08	0.20	651.78	651.57	364.52	-23.95	0.04
718228.8	5363682.0	1.14	-0.08	1.15	0.19	651.72	651.53	342.51	-36.34	-0.02
718228.9	5363682.0	1.17	-0.12	1.18	0.19	651.68	651.49	323.21	-45.13	-0.06
718229.0	5363682.0	1.17	-0.14	1.18	0.19	651.64	651.46	295.13	-43.09	-0.09
718229.1	5363682.0	1.13	-0.13	1.14	0.19	651.61	651.43	258.27	-30.21	-0.12
718229.2	5363682.0	1.07	-0.12	1.07	0.20	651.59	651.40	211.63	-20.14	-0.13
718229.3	5363682.0	0.97	-0.10	0.98	0.22	651.59	651.37	155.21	-12.87	-0.14
718229.4	5363682.0	0.88	-0.09	0.89	0.24	651.58	651.34	110.62	-8.28	-0.14
718229.5	5363682.0	0.79	-0.08	0.79	0.26	651.58	651.32	77.87	-6.36	-0.14
718229.6	5363682.0	0.71	-0.08	0.72	0.28	651.58	651.29	54.95	-5.15	-0.14
718229.7	5363682.0	0.65	-0.08	0.65	0.30	651.57	651.27	41.87	-4.65	-0.15
718229.8	5363682.0	0.59	-0.08	0.60	0.31	651.56	651.26	32.78	-4.35	-0.15
718229.9	5363682.0	0.55	-0.09	0.55	0.31	651.57	651.26	27.68	-4.23	-0.14
718230.0	5363682.0	0.51	-0.09	0.52	0.30	651.57	651.27	23.86	-4.15	-0.14
718230.1	5363682.0	0.47	-0.09	0.48	0.30	651.58	651.28	21.31	-4.11	-0.13
718230.2	5363682.0	0.44	-0.09	0.45	0.30	651.59	651.29	18.95	-4.07	-0.12
718230.3	5363682.0	0.41	-0.09	0.42	0.29	651.59	651.30	16.79	-4.02	-0.12
718230.4	5363682.0	0.37	-0.09	0.39	0.28	651.59	651.30	14.73	-3.96	-0.11
718230.5	5363682.0	0.34	-0.09	0.35	0.28	651.59	651.31	12.76	-3.89	-0.11
718230.6	5363682.0	0.31	-0.09	0.32	0.27	651.59	651.32	10.95	-3.84	-0.11
718230.7	5363682.0	0.28	-0.09	0.29	0.26	651.59	651.33	9.29	-3.80	-0.11
718230.8	5363682.0	0.25	-0.09	0.27	0.25	651.59	651.34	7.78	-3.78	-0.11

Velocity (A), depth (B), surface elevation (C), and the depth error estimated as the difference between surveyed depth and modeled depth (D), for CHaMP site ASW00001-SF-F5_P3BR

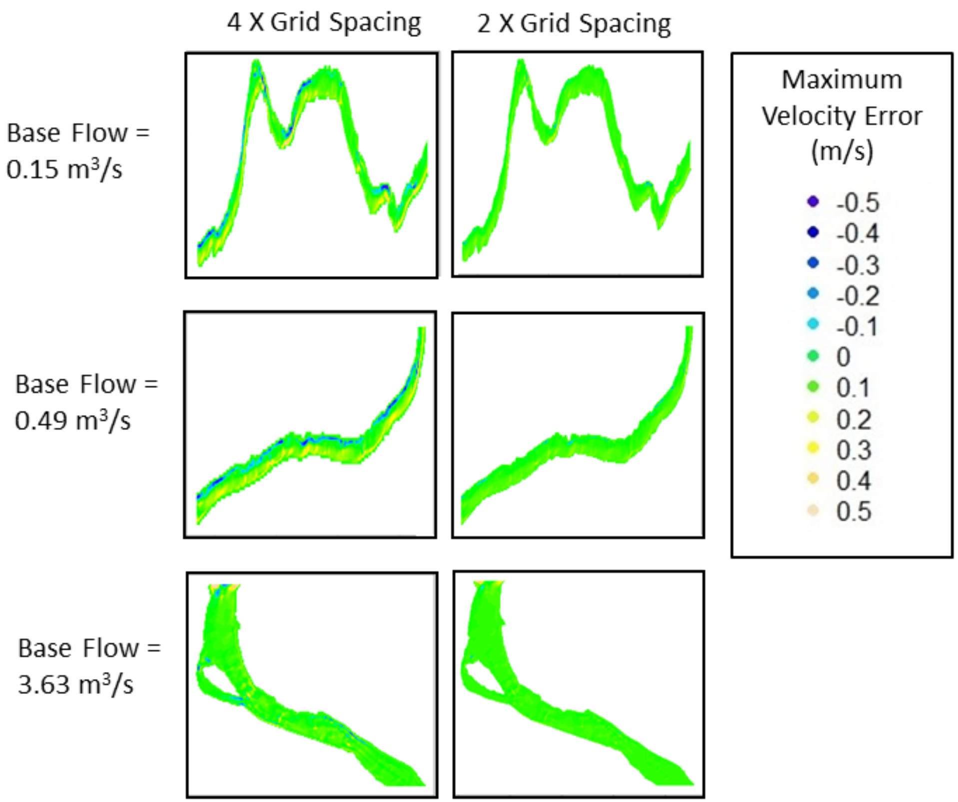


Example Hydraulic Model Results

← Validation: Error vs measured depth

CHaMP Site CFD Modeling: Error Sources

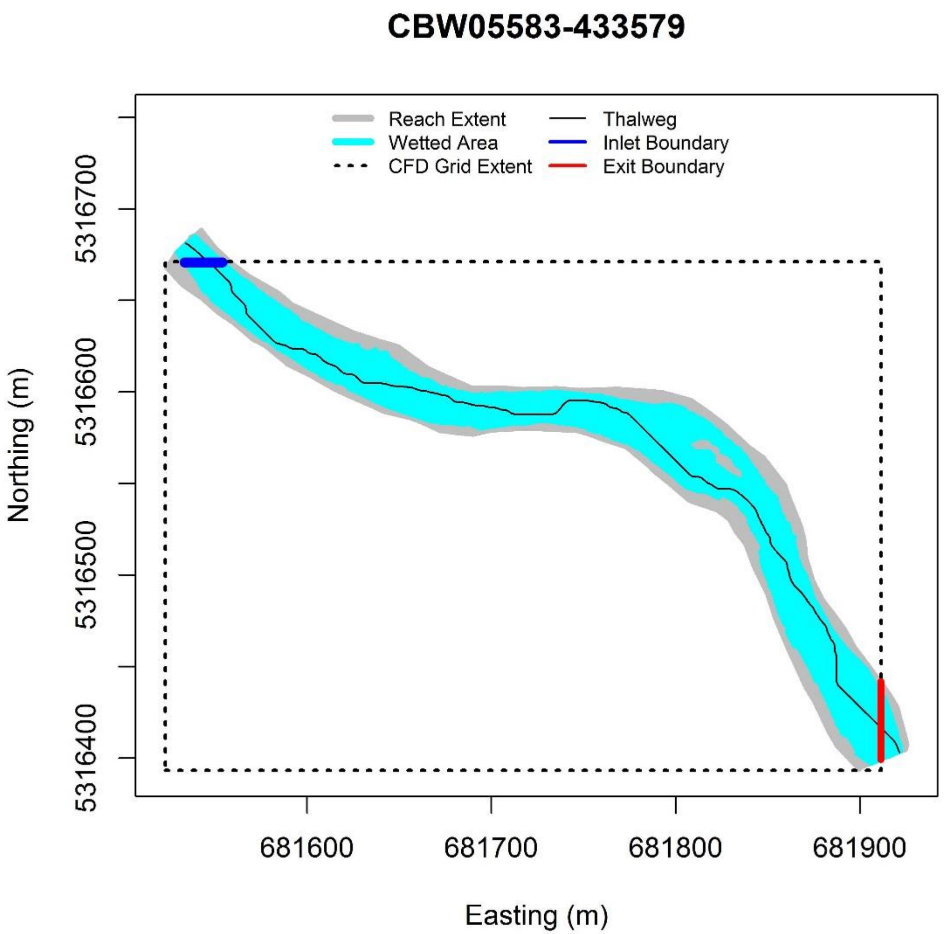
- Sources of Error*:
  - Numerical Simulation Imperfect
    - Grid Spacing or time step too Large to model in sufficient detail, or to obtain stable solution
    - Turbulent and/or localized 3D flows not modeled accurately
      - Localized Eddies difficult to model accurately
    - Surface roughness inputs not optimized



* Items in **BOLD** are what I believe are our current limiters for accuracy

CHaMP Site CFD Modeling: Error Sources

- Sources of Error*:
  - Boundary Conditions Imperfect
    - Distribution of discharge along inlet to modeled stream section
    - Water Surface elevation along outlet to modeled stream section
      - Effect of Boundary Condition Errors usually limited to stream areas near inlet or outlet



CHaMP Site CFD Modeling: Error Sources

- Sources of Error*:
  - **Error in Discharge Estimates**
  - **Error and Lack of Detail in Bathymetry data (DEM)**
    - **Important Geometry (pebbles, rocks) exists on a finer scale than DEM can map.**
      - **DEM data tends to smooth out localized variability**
      - Modeling using "roughness" is an imperfect approximation.
    - **Features affecting flow may not be represented in DEM data**
      - **Bushes, woody debris, etc.**
    - **Porous or hidden features may be represented as solid features in DEM data**
      - Beaver Dams
      - Bank Undercuts
    - **Local variation in Surface roughness not captured**

* Items in **BOLD** are what I believe are our current limiters for accuracy

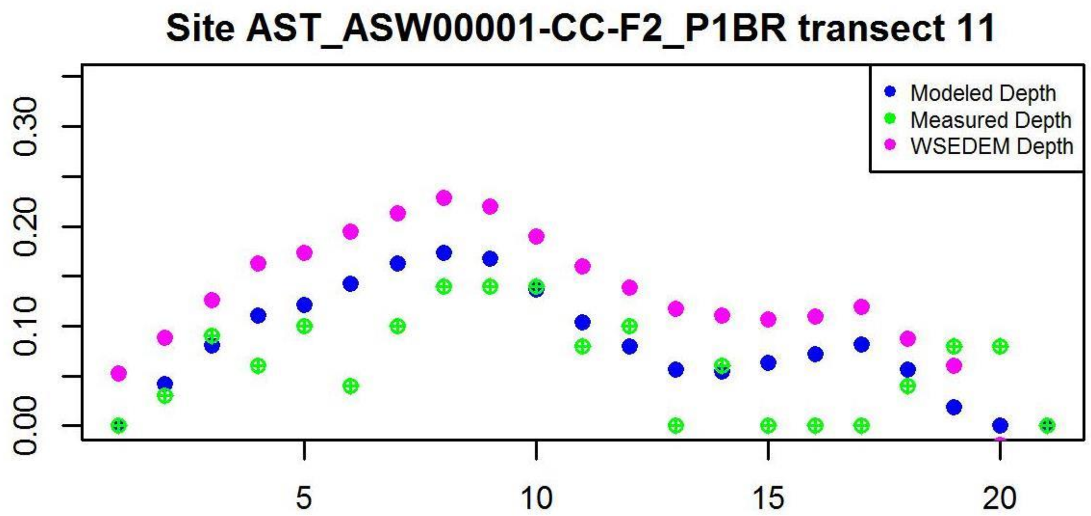
Hydraulic Model Validation

- Field Data useful for validation includes
  - Depth
    - At all DEM points
    - Along Validation Transects
  - Velocity
    - Along Validation Transects

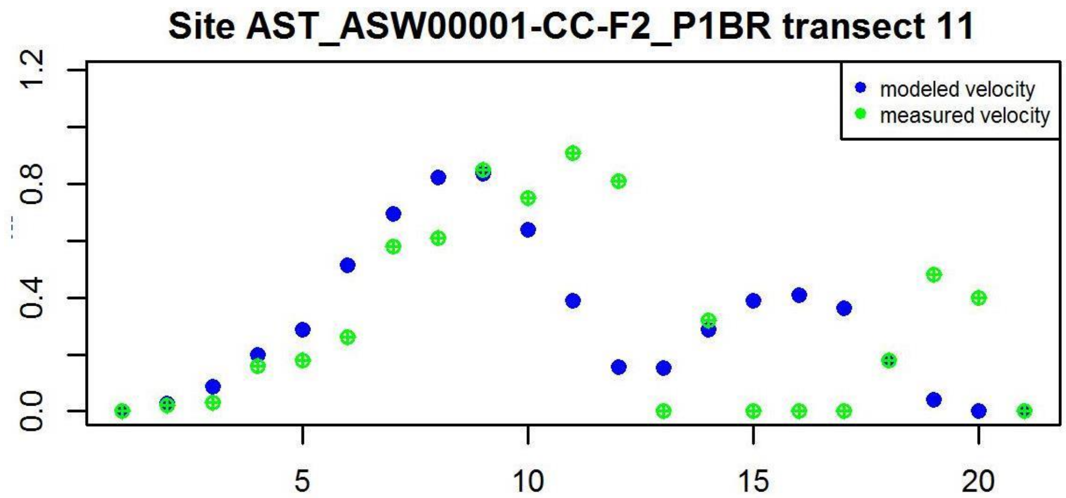
Comparison Plots Between Modeled and Validation Data for Depth and Velocity

Plots Created for Each Validation Transect at Each Site

Depth (m)



Depth Averaged Velocity (m/s)



Comparison Plots Between Modeled and Validation Data for Depth and Velocity

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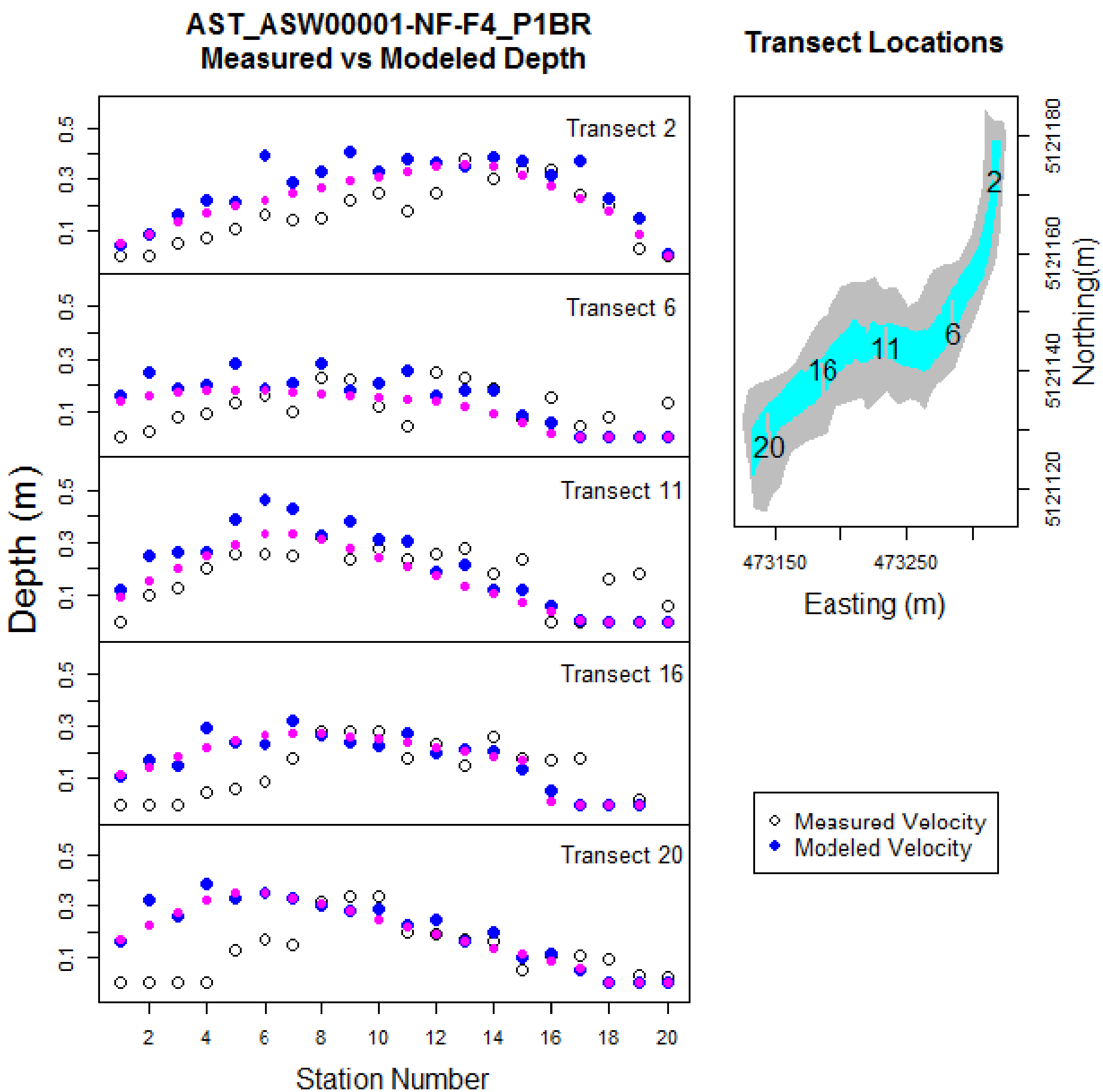
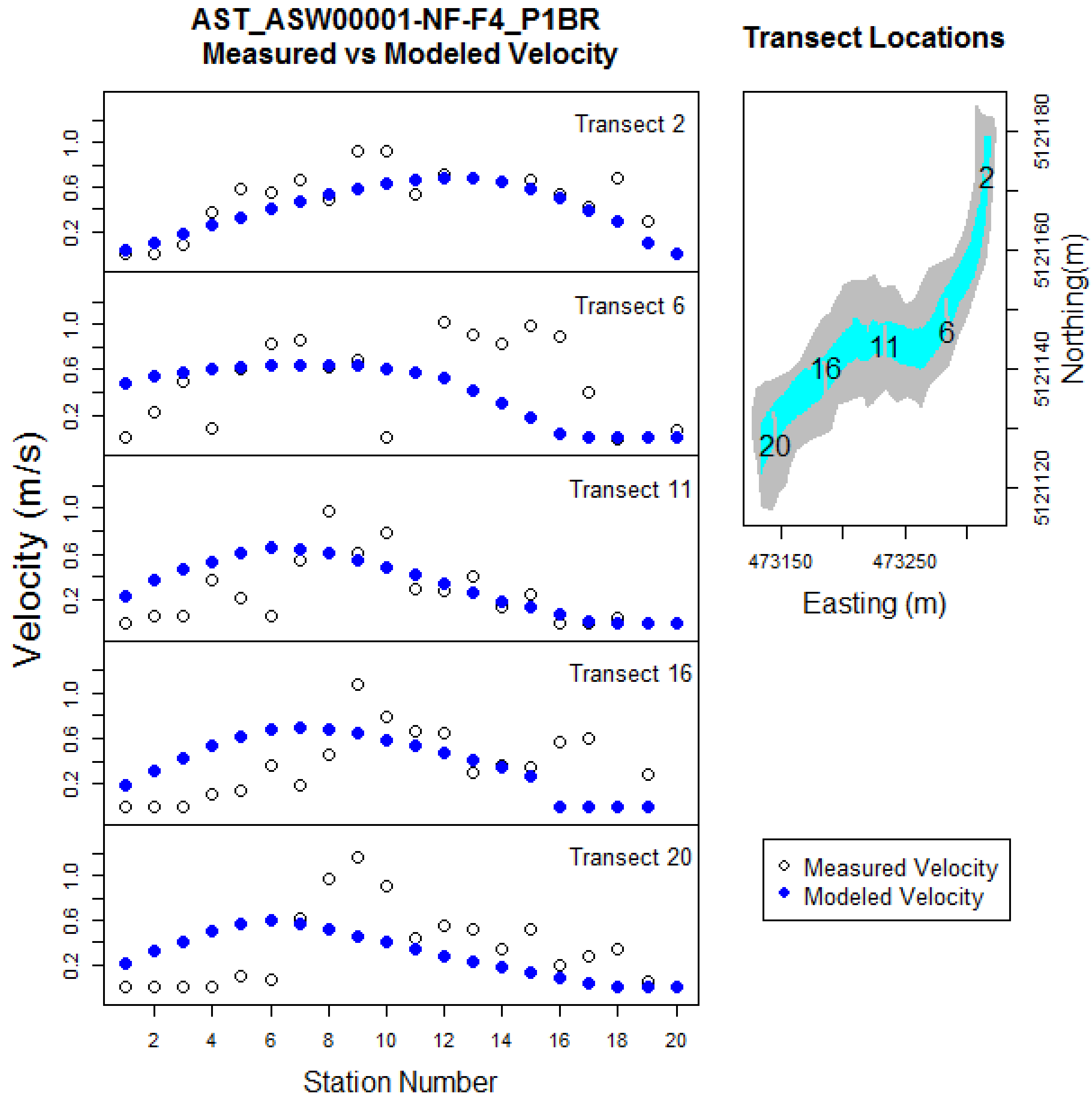


Comparison Plots Between Modeled and Validation Data for Depth and Velocity

Plots Created for Each Validation Transect at Each Site

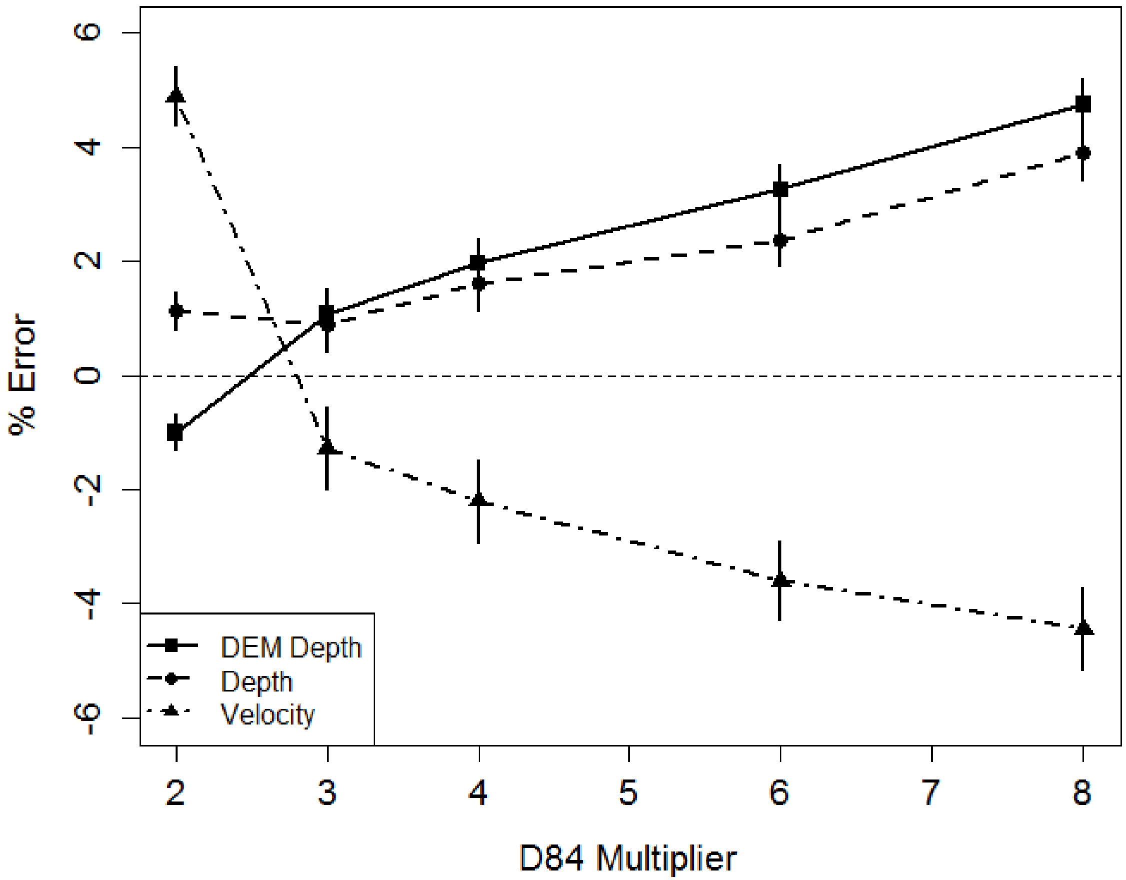


Model Calibration

- Surface Roughness (White-Colebrook Coefficient)
  - Metrics of surface roughness (D16, D50, D84) are available.
  - Goal is to use a consistent, optimized function of one or more metrics to define White-Colebrook coefficient for each sites
    - A scalar on D84 is currently used
  - A range of scalar values to convert D84 to a WC coefficient were used, and scalar the minimized bias over depth and velocity results, over all sites, was selected

Model calibration

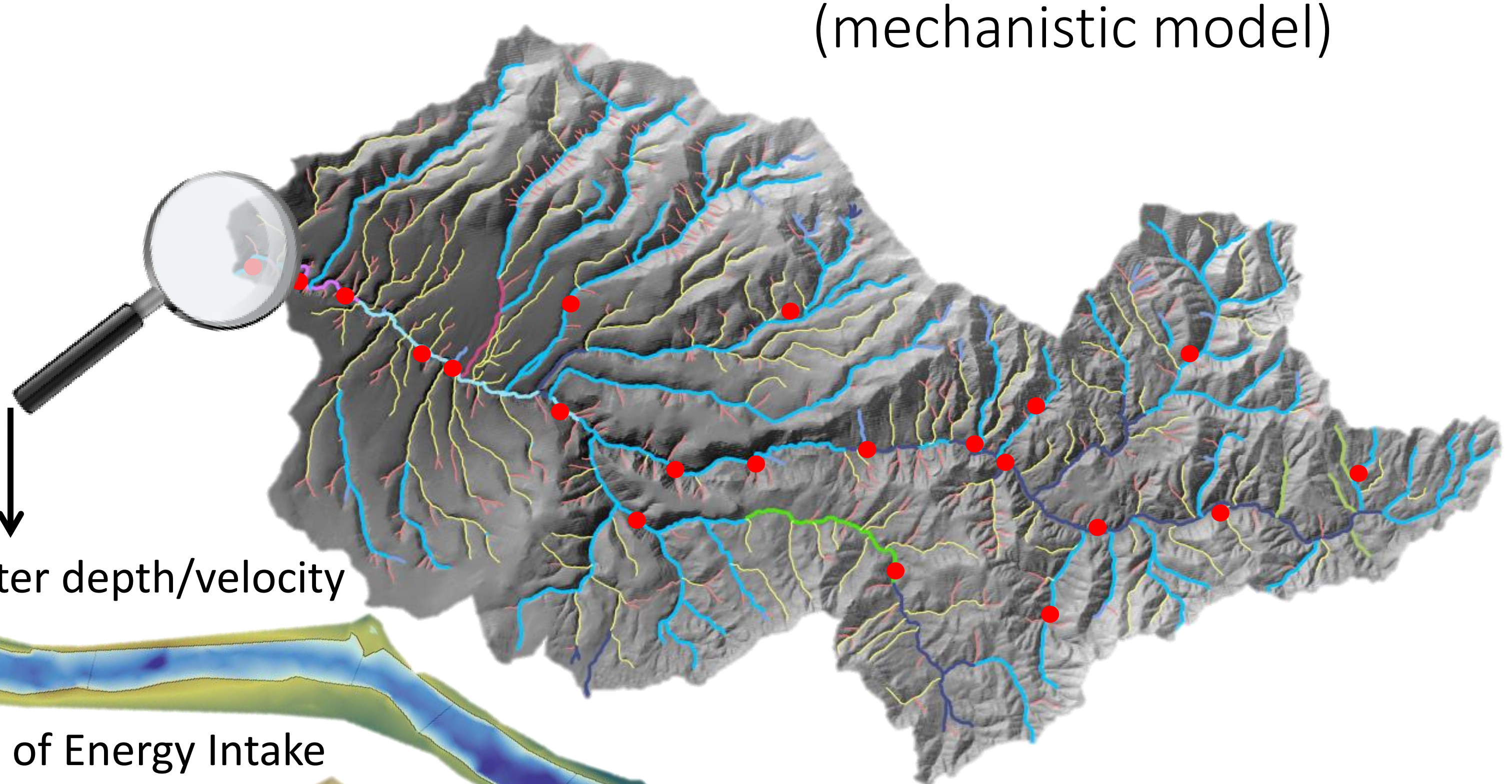
Estimated mean error at validation locations vs multiplier applied to scale D84 as surface roughness input to model. Error is defined as the percent difference between modeled values for a) depth as measured in the DEM survey, b) direct depth measurements at validation points, and c) direct velocity measurements at validation points. Vertical bars indicate 95% confidence bounds.

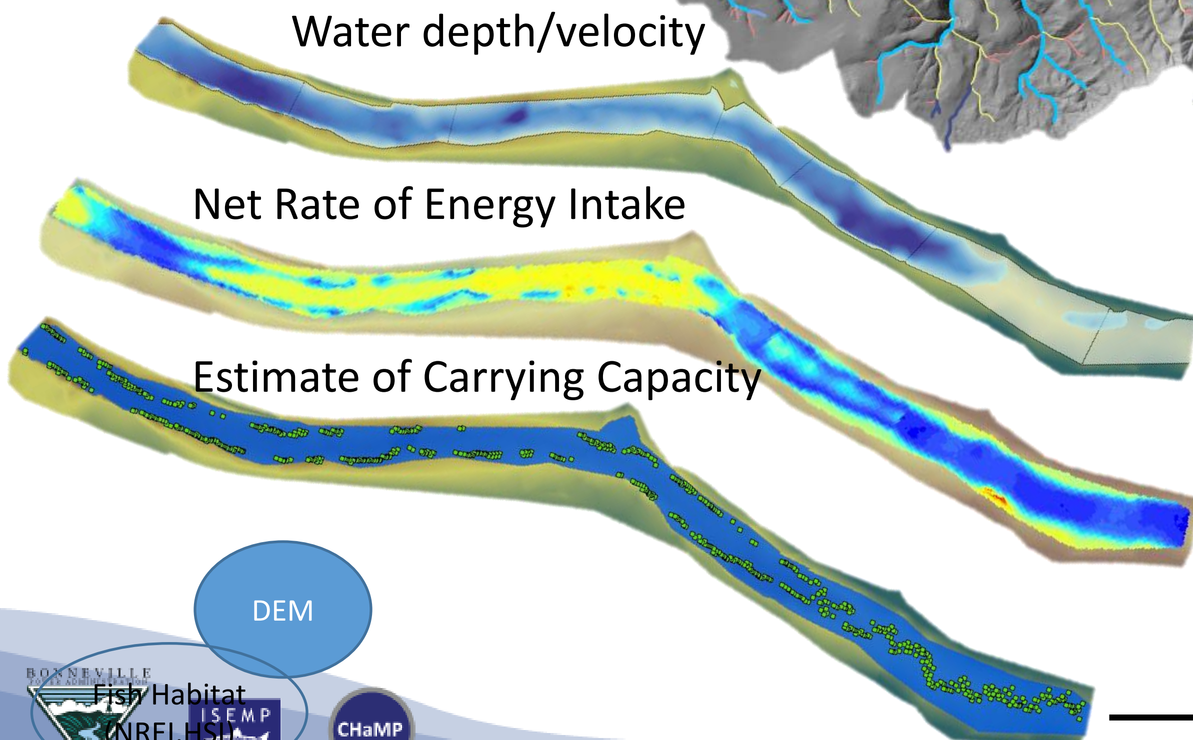


Hydraulic Model Applications

- NREI, HSI capacity estimates
  - For as-measured sites
  - Measured sites at un-measured discharge rates
  - Simulated restoration scenarios
    - Manually change DEM, re-run hydro model

DEM based protocol → NREI → Juvenile abundance (mechanistic model)





CHaMP Surveys collect:

- Temperature
- Bugs
- Topography/Channel Units

→ e.g. GRTS rollup to get basin level abundance of juveniles

DEM

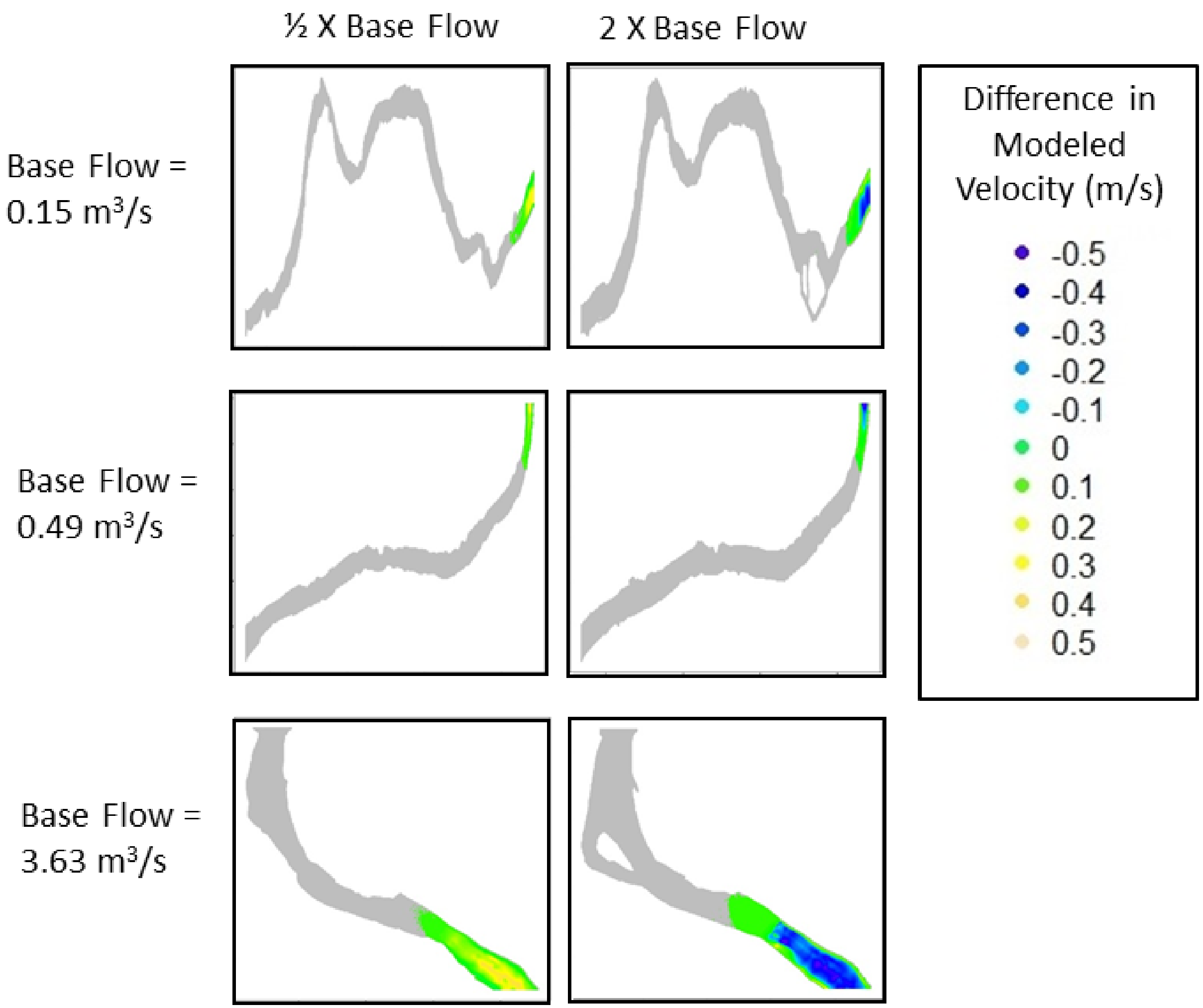
Fish Habitat (NREI,HSI)

Hydraulic modeling at unmeasured discharge rates

- We can set discharge to something other than measured values, but:
    - Downstream boundary condition (water surface elevation) is unknown
    - Error from unknown boundary condition will propagate upstream
        - Usually no more than a few wetted widths upstream

Hydraulic modeling at unmeasured discharge rates

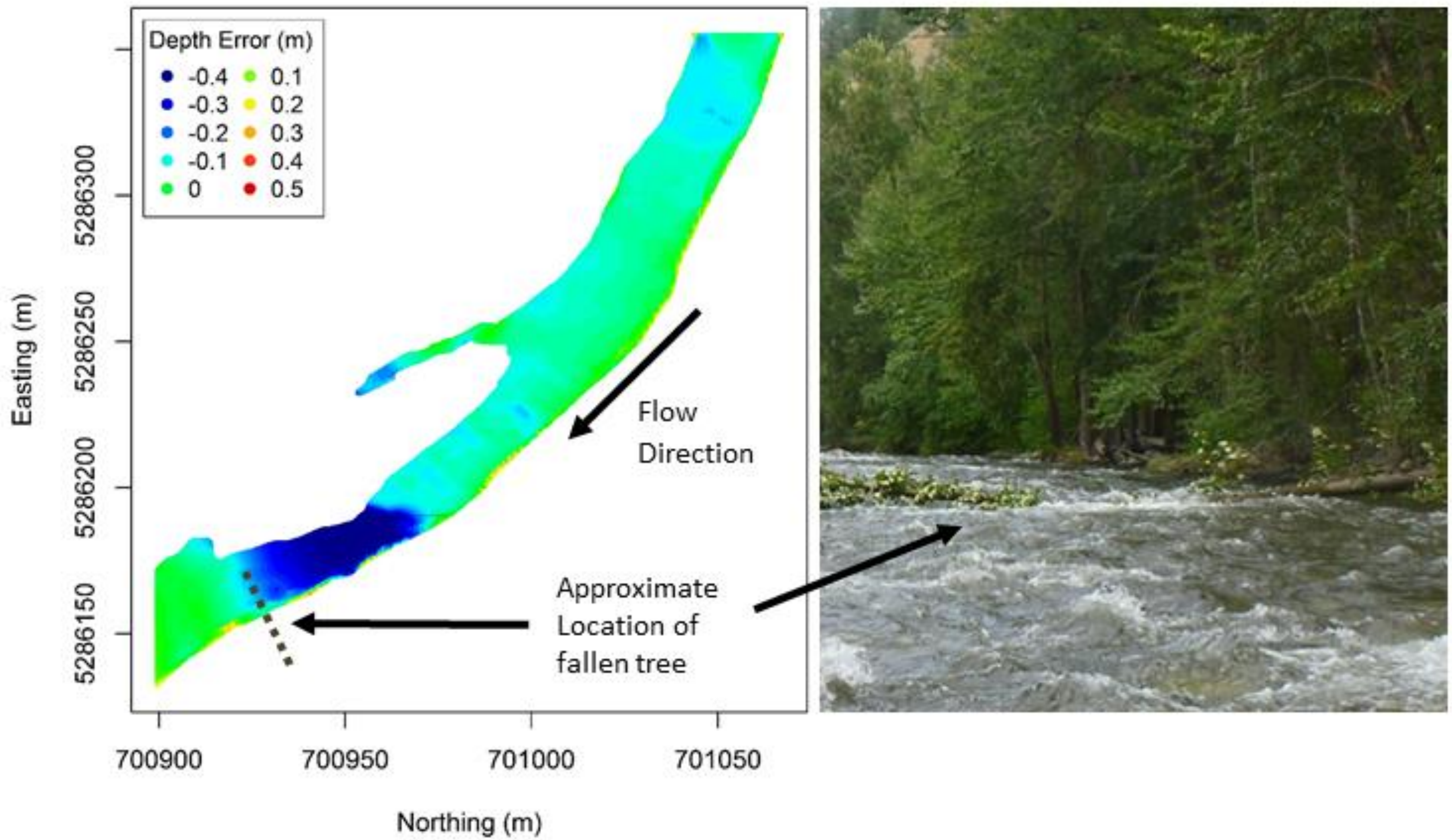
Maximum velocity error and extent of error propagation at low, medium, and high flow rate CHaMP reaches, resulting from assumed exit boundary condition when modeling at discharge rates with unknown downstream water surface elevation. Maximum velocity errors are estimated as the velocity field differences (a-b) between modeled velocities at where downstream water surface elevations are assumed: a) unchanged from base flow, and b) downstream water surface elevation is adjusted such that exit boundary wetted areas are scaled proportional to discharge. Gray indicates no change in modeled velocities.



Problem Areas

Introduction to CHaMP Hydraulic Modeling

Hydraulic Modeling Problem Areas: Woody Debris



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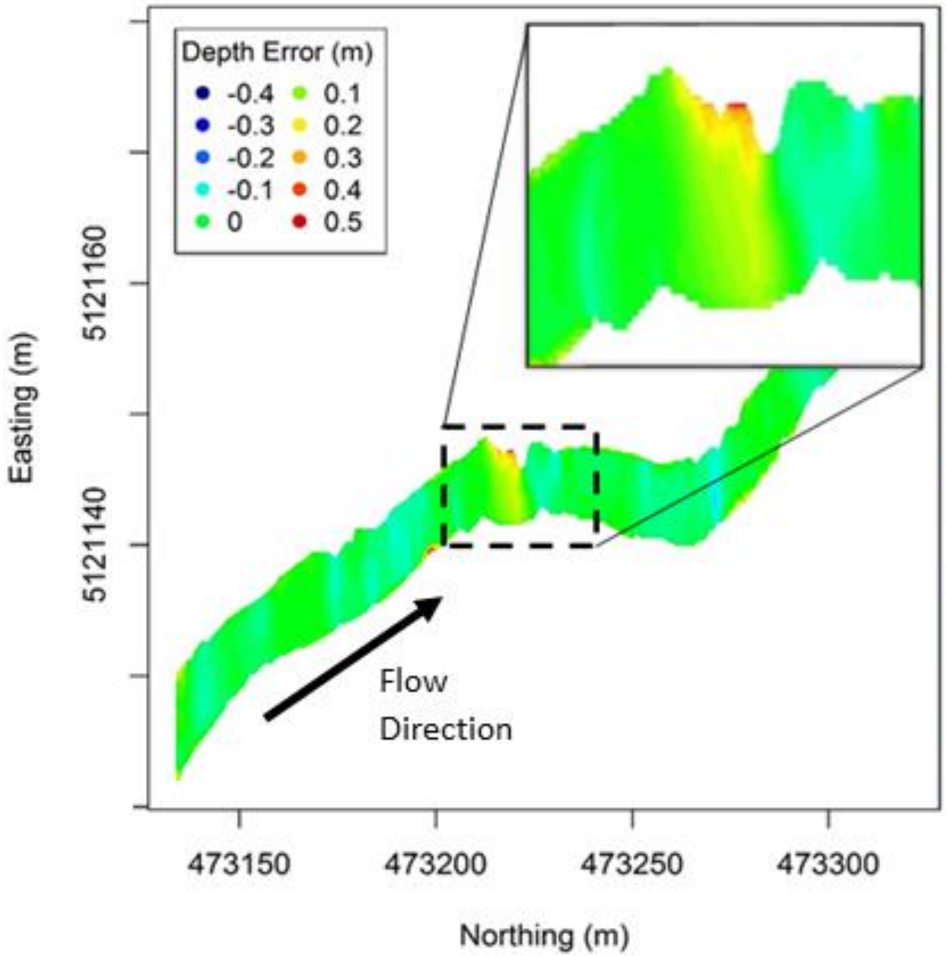
ISEMP

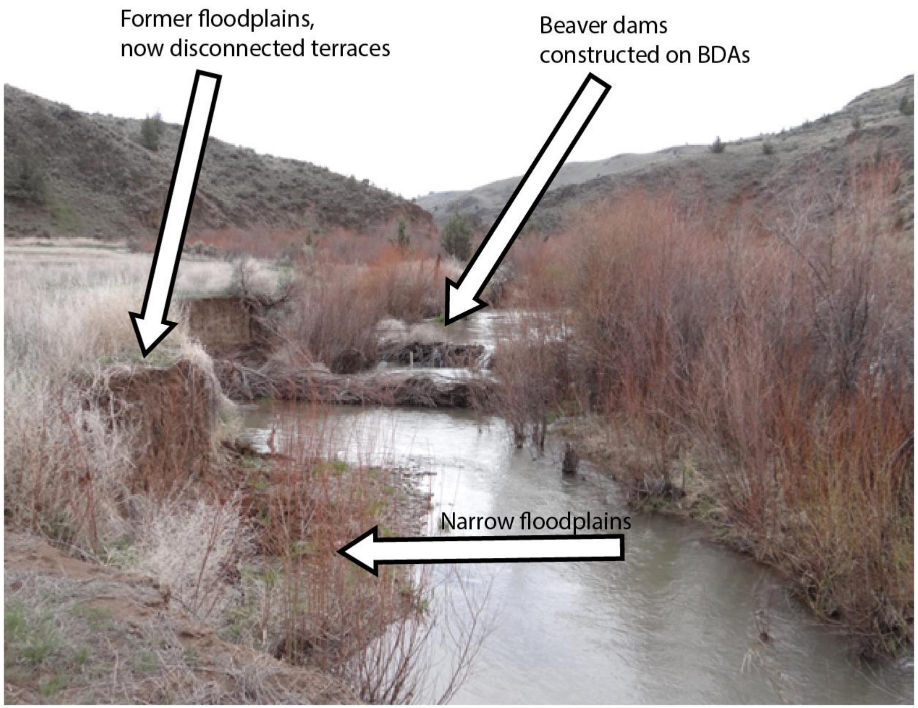
CHaMP

Hydraulic Modeling Problem Areas: Undercuts



Modeling porous structures

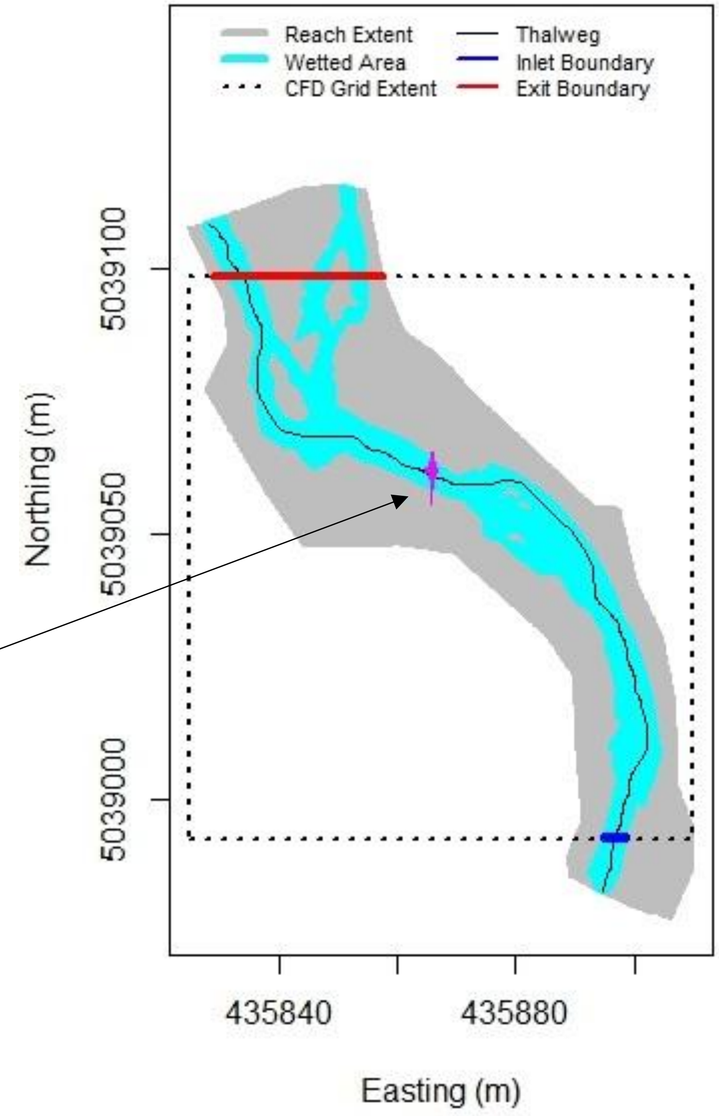
- TBD: Investigate modeling porous structures as series of porous plates



Modeling porous structures

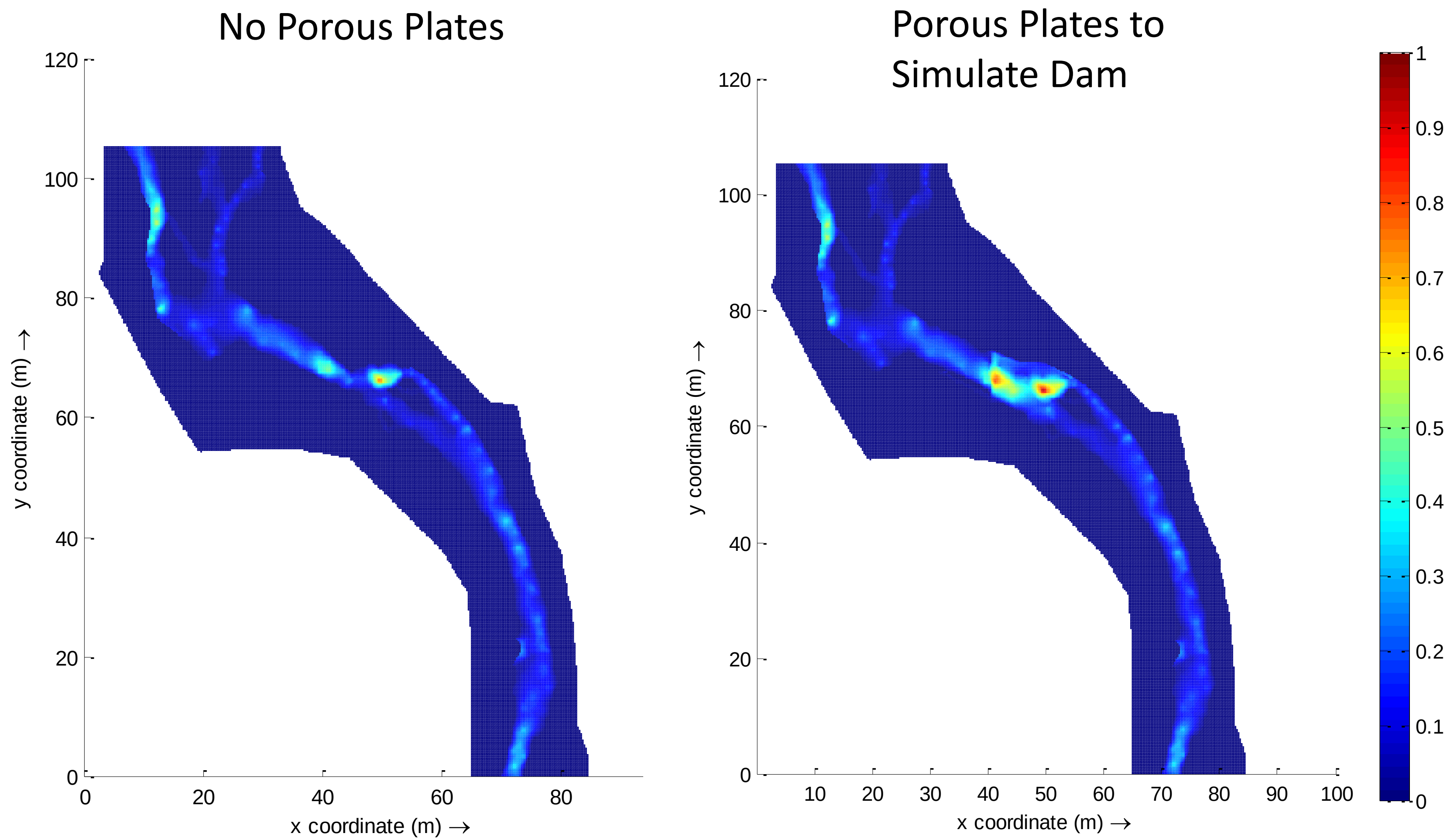
Hydraulic Modeling of Site CBW00583-142490

Series of Porous Plates used to simulate porous dam

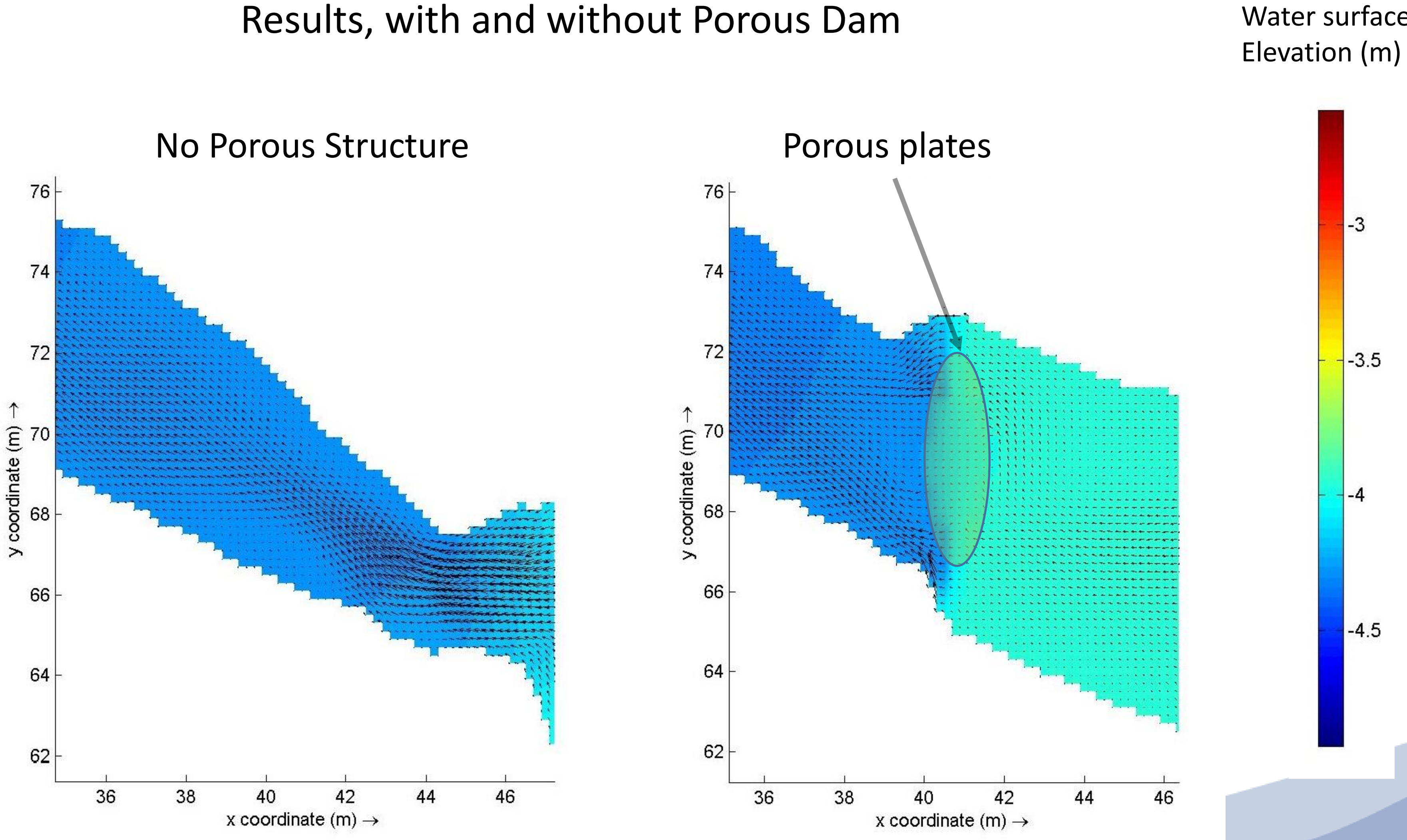


Modeling porous structures

Water Depth with and without porous dam



Water Surface Level and Velocity Vector Results, with and without Porous Dam



CHaMP Hydraulic Modeling: Summary

- Hydraulic modeling of CHaMP sites has successfully been completed for 1000’s of completed CHaMP site visits
- Model accuracy is generally good, except where porous structures or undercuts impact flow greatly
- NREI, HSI models are well supported
- Opportunities for further development

CHaMP Hydraulic Modeling

- Acknowledgements
  - Joe Wheaton
  - Eric Wall
  - Kelly Whitehead
  - Phillip Bailey
  - Timothy Smith
  - Christopher Eykamp
  - Steve Rentmeester

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Backup Slides

CHaMP Hydraulic Modeling