



SETON, CARPENTER AND DOWNTON RESERVOIRS CFD MODELING

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Mat Langford, M.Eng., P.Eng.; Abul Baki, M.Sc.; David Zhu, Ph.D., P.Eng.

Department of Civil and Environmental Engineering, University of Alberta



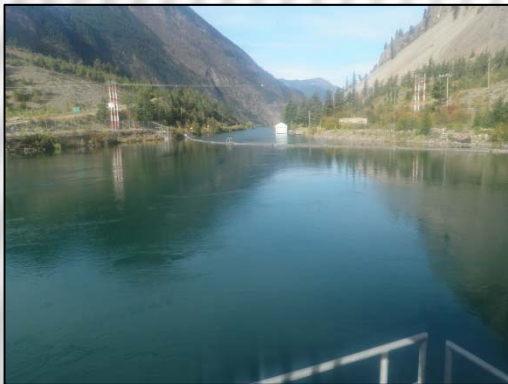
OUTLINE

- ✖ Project Overview
- ✖ CFD Model
 - + Model Development
 - + Model Setup and Initialization
 - + Model Results

PROJECT OVERVIEW

- ✖ Development of CFD models to simulate the hydraulic conditions of the forebays under various operational and environmental conditions.

Seton



Terzaghi



La Joie



CFD MODEL

+ What is Computational Fluid Dynamics (CFD)?

“CFD is the analysis of systems involving fluid flow, heat transfer and associated phenomena by means of computer based simulation” (Versteeg and Malalasekera, 2007)

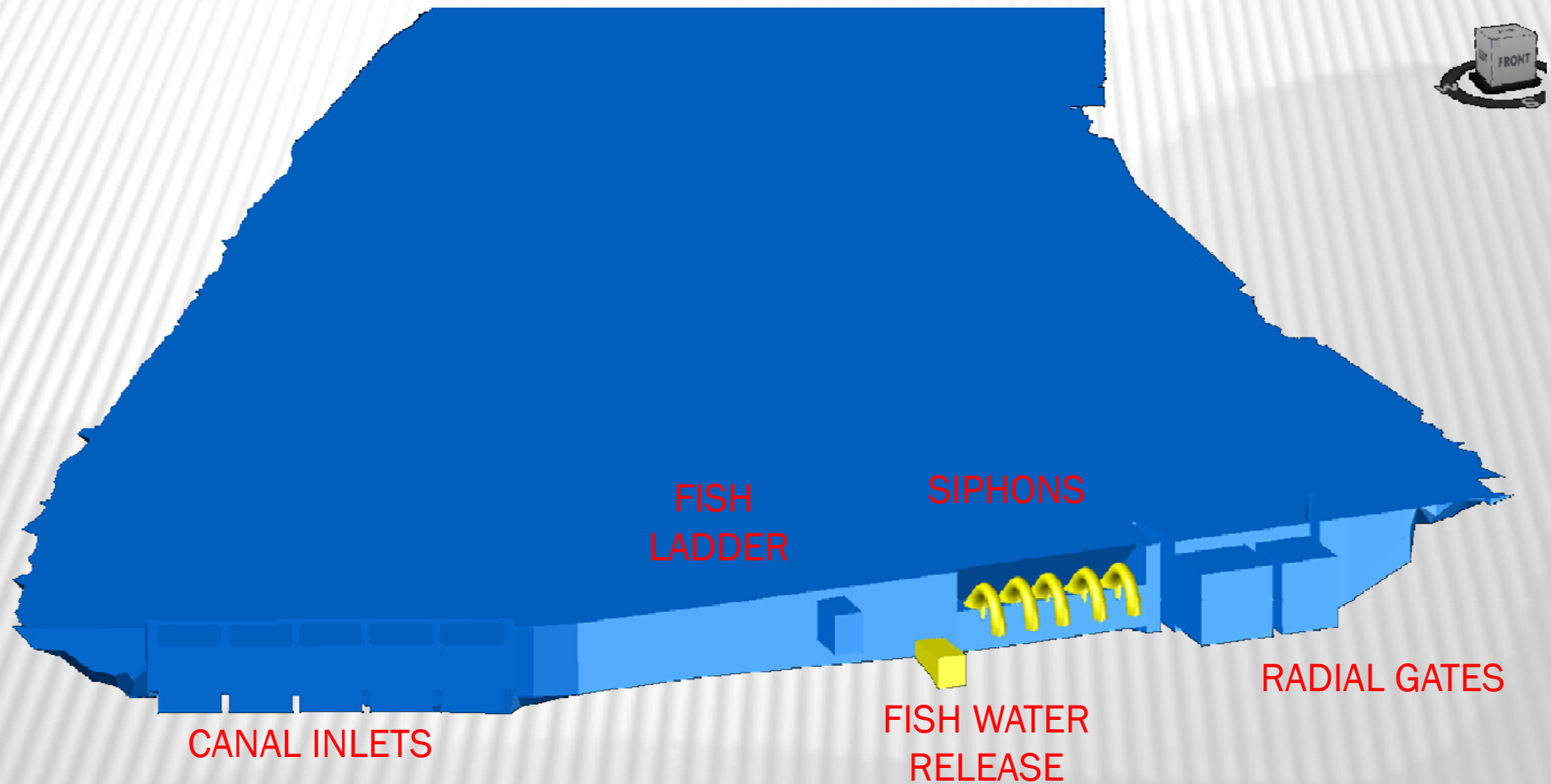
+ Model Development

- × Domain definition (model geometry)
- × Calculation elements definition (mesh)
- × Model setup and initialization
- × Iterative solver
- × Solution

MODEL GEOMETRY - SETON



MODEL GEOMETRY - SETON



MODEL GEOMETRY - TERZAGHI



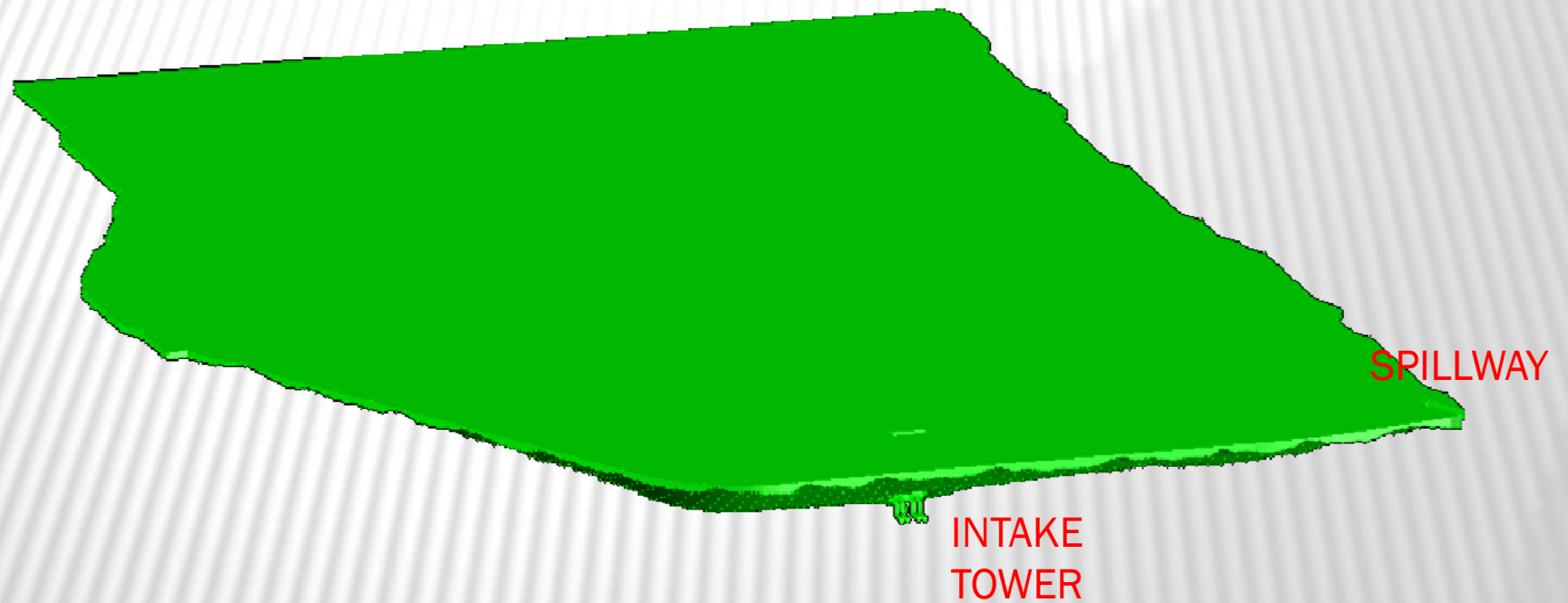
MODEL GEOMETRY - TERZAGHI



MODEL GEOMETRY – LA JOIE



MODEL GEOMETRY – LA JOIE

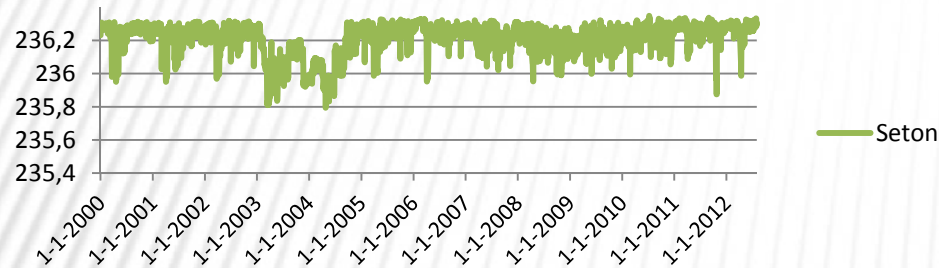


MODEL SCENARIOS

- ✖ Six or seven scenarios for each facility
 - + Freshet High Flow
 - + Freshet Low Flow
 - + Fall High Flow
 - + Fall Low Flow
 - + Winter High Flow
 - + Winter Low Flow
 - + Fall Extreme High Flow (LAJ)

OPERATIONS HISTORY - ELEVATION

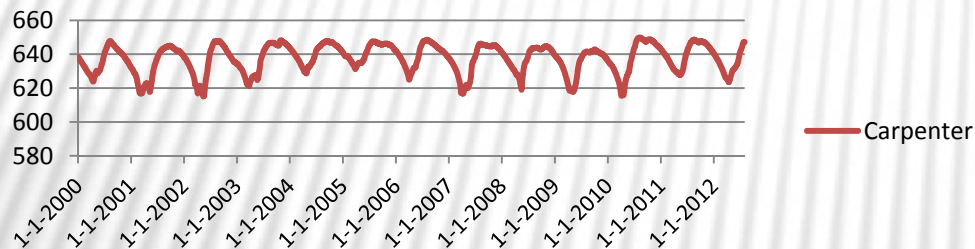
Reservoir Elevation



+ Seton

- × RSE fluctuates rapidly
- × Max: 236.3, Min: 235.8

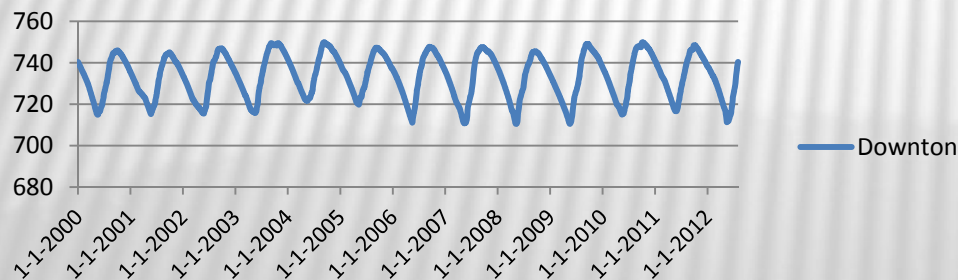
Reservoir Elevation



+ Carpenter

- × RSE fluctuates annually
- × Max: 650, Min: 615

Reservoir Elevation

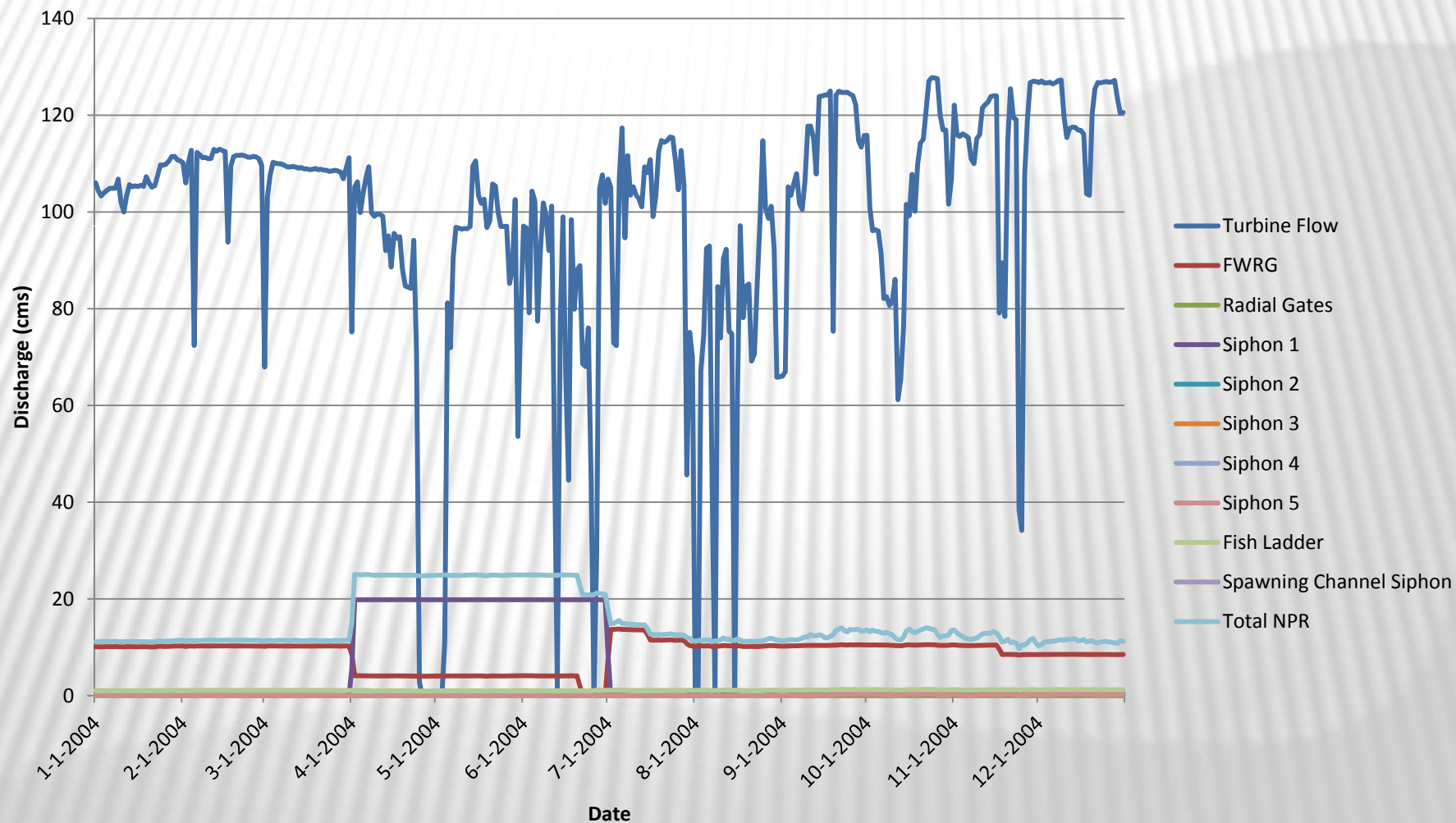


+ Downton

- × RSE fluctuates annually
- × Max: 750, Min: 710

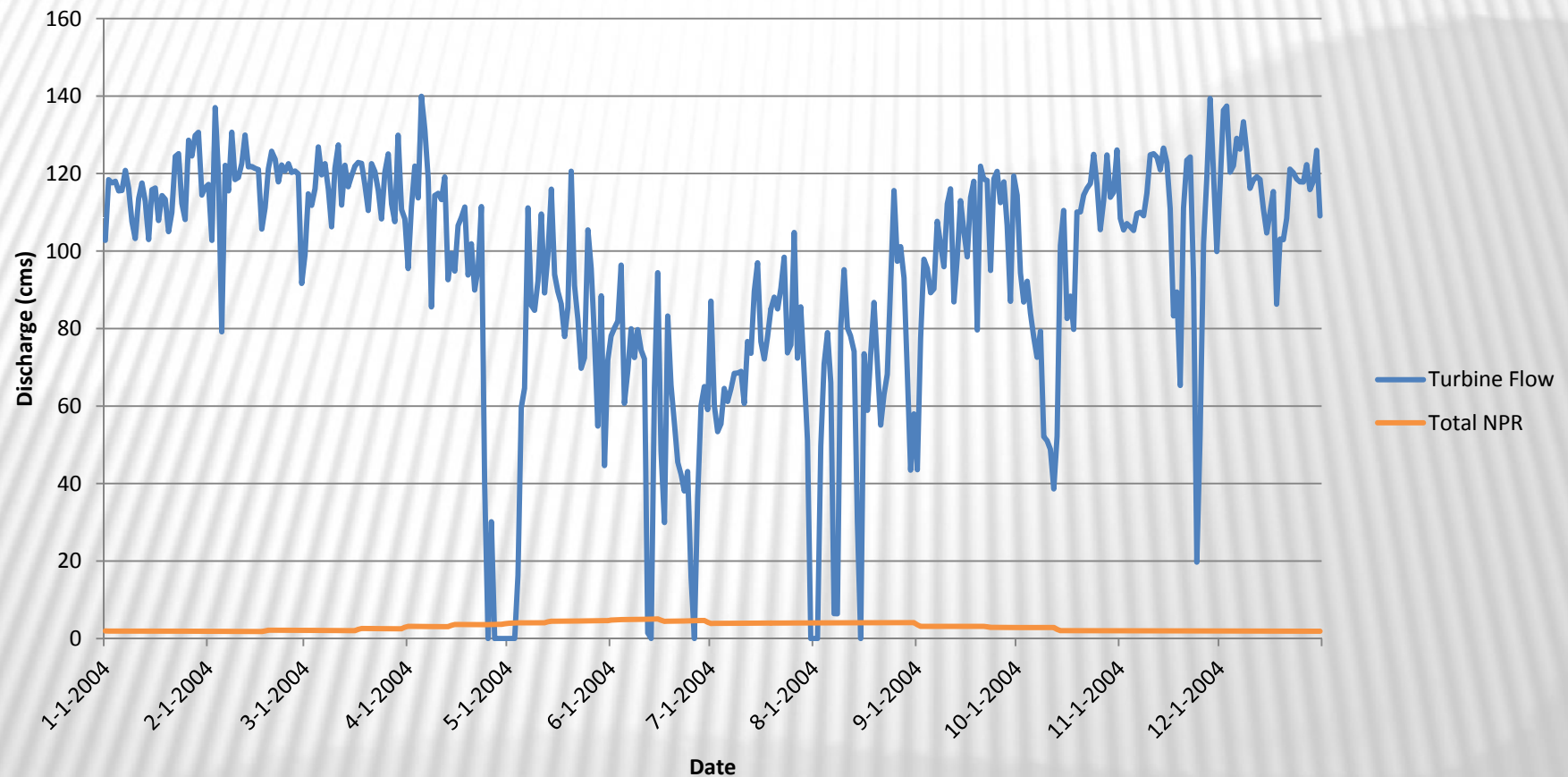
OPERATIONS HISTORY - SON

2004



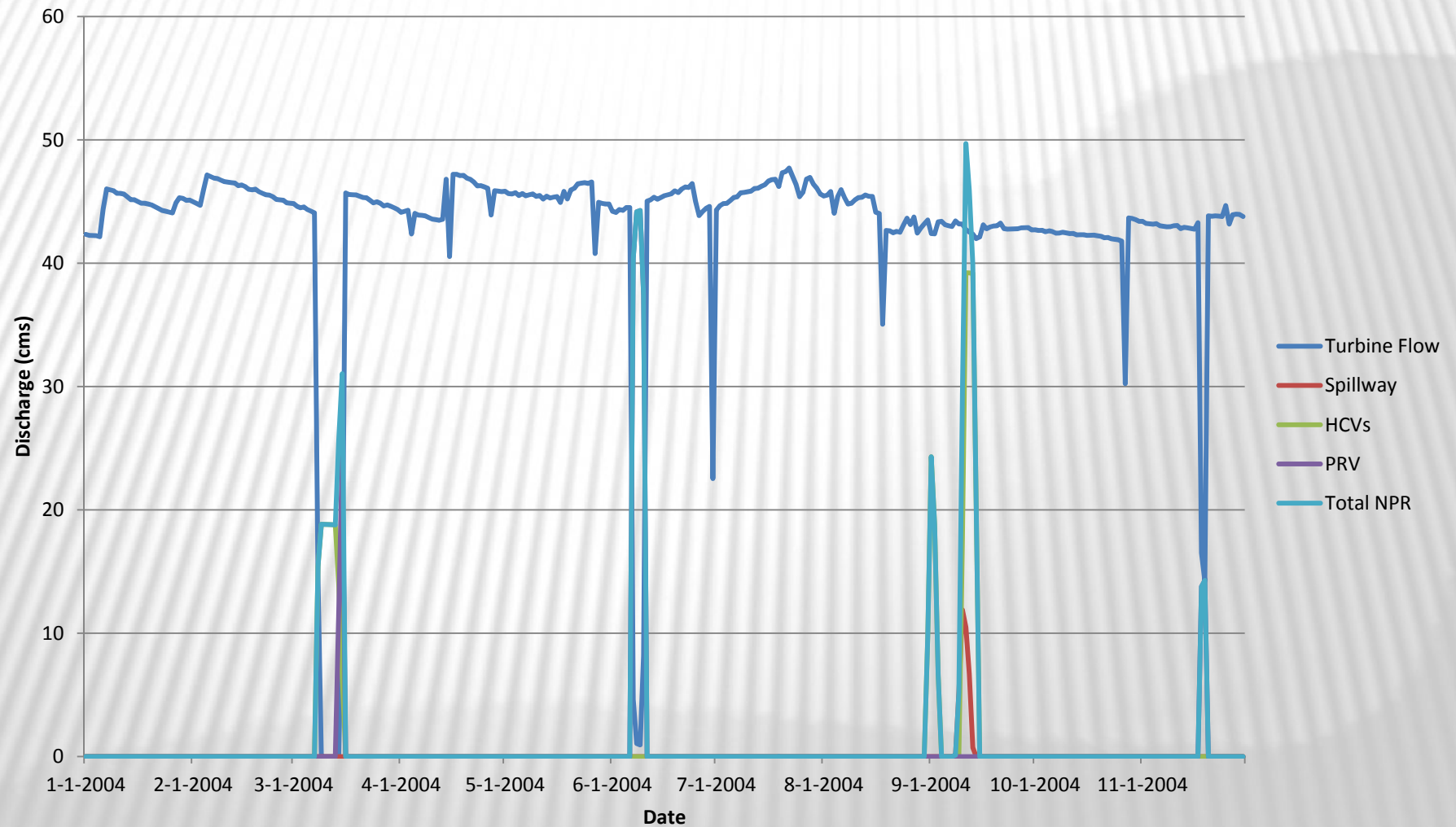
OPERATIONS HISTORY - TRZ

2004



OPERATIONS HISTORY - LAJ

2004



MODEL SCENARIOS DEVELOPMENT

- + High Flow

- × The averaged 90th percentile discharge over the years 2004-2012

- + Low Flow

- × The averaged 10th percentile discharge over the years 2004-2012

- + Freshet

- × Occurs during the months of March-May inclusive

- + Fall

- × Occurs during the months of September-November inclusive

- + Winter

- × Occurs during the months of December-February inclusive

Elevations are the average reservoir elevation for periods above the 90th percentile for high flow scenarios and below the 10th percentile for low flow scenarios

SETON SCENARIOS

Scenario	Description	Power Canal	FWRG	Radial Gate	Siphon 1	Siphon 2	Siphon 3	Siphon 4	Siphon 5	Fish Ladder	Elevation
SON-01	Freshet High	112.88	11.61	11.33	17.67	6.46	3.47	0.32	0.32	1.25	236.22
SON-02	Freshet Low	25.95	3.87	0.00	2.59	0.04	0.05	0.03	0.03	1.12	236.22
SON-03	Fall High	113.59	12.77	0.00	10.17	0.30	0.29	0.29	0.29	1.26	236.22
SON-04	Fall Low	63.73	6.30	0.00	0.20	0.09	0.09	0.09	0.09	1.16	236.22
SON-05	Winter High	119.82	10.71	0.00	0.47	0.30	0.30	0.30	0.30	1.26	236.22
SON-06	Winter Low	99.30	9.12	0.00	0.24	0.11	0.11	0.11	0.11	1.18	236.22

× Discharges are in m³/s and Elevations are in m

CARPENTER SCENARIOS

Scenario	Description	BR 1	BR 2	SPOG 1	SPOG 2	LLOG 1	LLOG 2	Elevation	Thermal Characteristics
TRZ-01	Freshet High	55.34	75.95	0.00	0.00	4.84	6.05	629.02	Isothermal
TRZ-02	Freshet Low	7.75	31.56	0.00	0.00	1.89	1.47	625.75	Isothermal
TRZ-03	Fall High	54.45	70.88	1.53	0.00	2.69	1.51	645.215	Thermally Stratified
TRZ-04	Fall Low	31.31	36.81	0.00	0.00	1.78	0.71	645.215	Thermally Stratified
TRZ-05	Winter High	55.02	74.31	0.00	0.00	1.98	0.86	637.78	Isothermal
TRZ-06	Winter Low	38.43	53.47	0.00	0.00	1.55	0.77	637.78	Isothermal

× Discharges are in m³/s and Elevations are in m

DOWNTON SCENARIOS

Scenario	Description	Intake 1	Intake 2	Intake 3	Intake 4	Spillway	Elevation	Thermal Characteristics
LAJ-01	Freshet High	30.34	30.34	6.84	6.84	0.00	725.34	Isothermal
LAJ-02	Freshet Low	15.00	15.00	0.00	0.00	0.00	719.55	Isothermal
LAJ-03	Fall High	37.77	37.77	7.77	7.77	0.00	745.585	Thermally Stratified
LAJ-04	Fall Low	15.15	15.15	0.00	0.00	0.00	745.585	Thermally Stratified
LAJ-05	Winter High	22.44	22.44	13.53	13.53	0.00	733.40	Isothermal
LAJ-06	Winter Low	19.40	19.40	0.00	0.00	0.00	735.50	Isothermal
LAJ-07	Fall Extreme High	21.61	21.61	33.59	33.59	159.81	750.70	Thermally Stratified

× Discharges are in m³/s and Elevations are in m

THERMAL STRATIFICATION

+ Freshet

- × Isothermal, average surface temperature over the time period

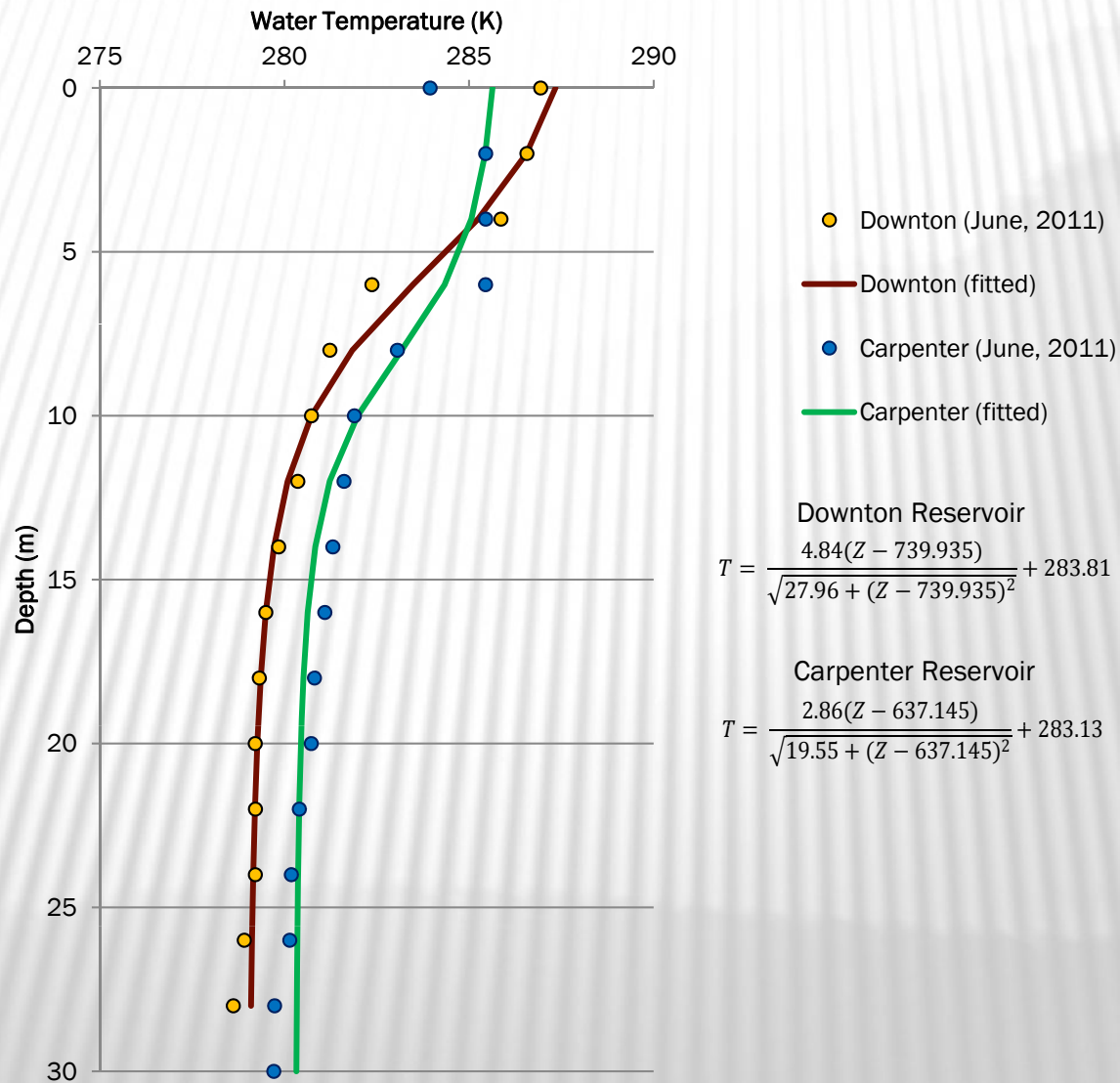
+ Fall

- × Thermally stratified (TRZ, LAJ),
- × Isothermal, average surface temperature over the time period (SON)

+ Winter

- × Isothermal, 4 °C

THERMAL STRATIFICATION



THERMAL STRATIFICATION

Temperature vs. Depth

$$T = \frac{a(y-b)}{\sqrt{c+(y-b)^2}} + d$$

Density vs. Temperature

$$\rho = -0.0057 T^2 + 3.1373 T + 568.2$$

Density vs. Depth

$$\rho = \frac{p(y-q)}{\sqrt{r+(y-q)^2}} + s$$

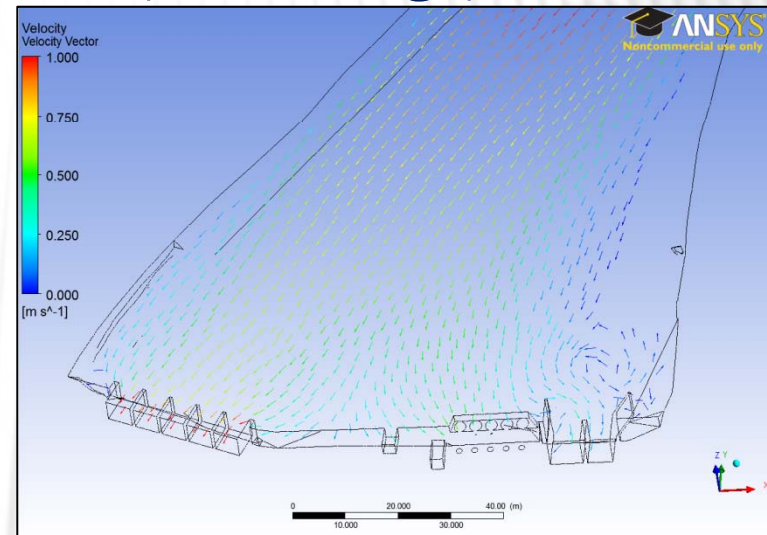
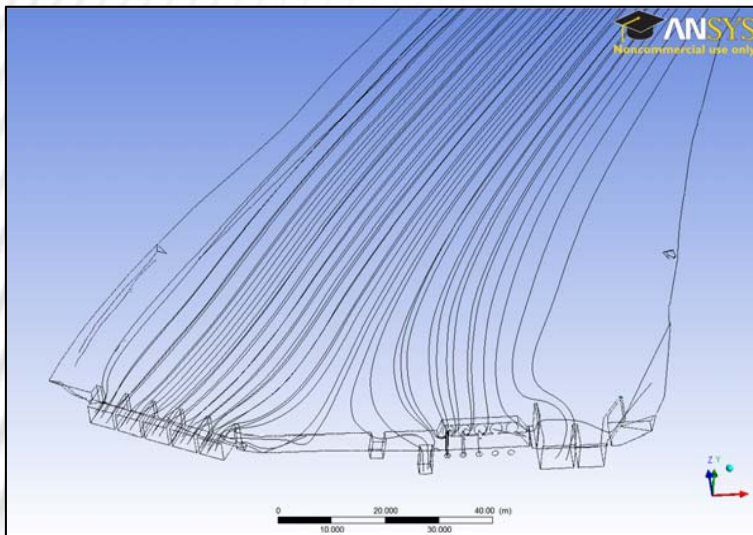
Pressure vs. Depth

$$\int dP = \int (\rho - \rho_{ref}) g dy$$

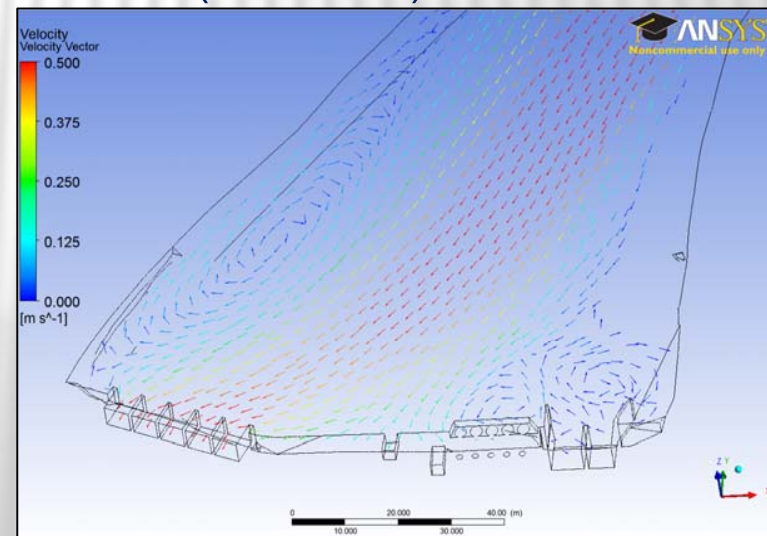
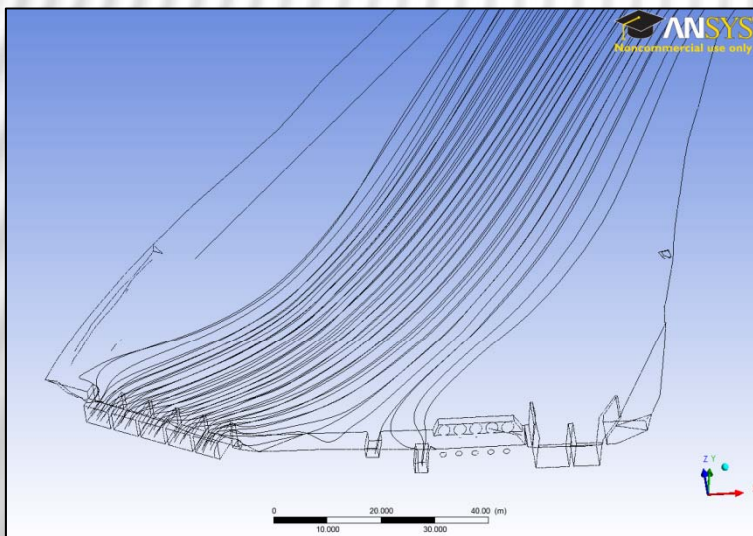
$$P = gp \left(\sqrt{(y-q)^2 + r} - \sqrt{(h-q)^2 + r} \right) + g(s - \rho_{ref})(y-h)$$

MODEL RESULTS - SETON

Seton – Scenario SON-01 (Freshet High)

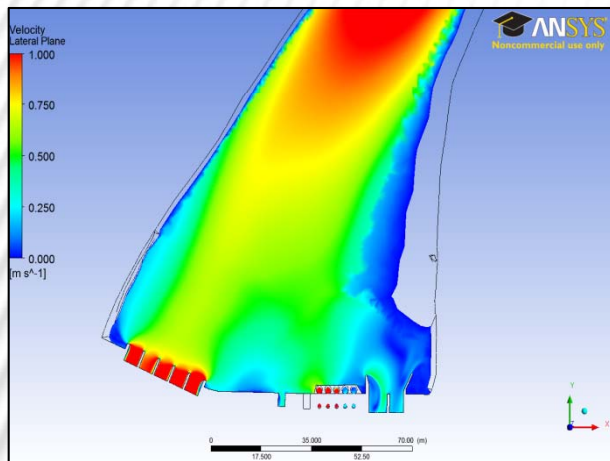


Seton – Scenario SON-04 (Fall Low)

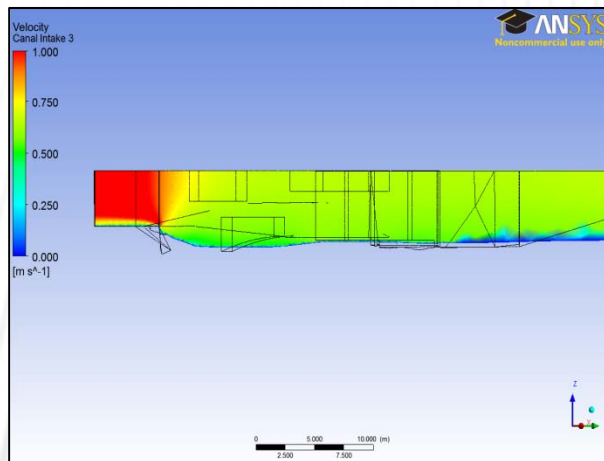


MODEL RESULTS - SETON

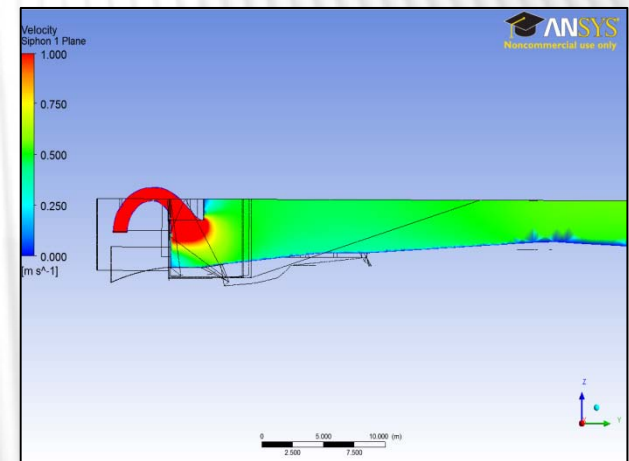
Seton – Scenario SON-01 (Freshet High)



Plan

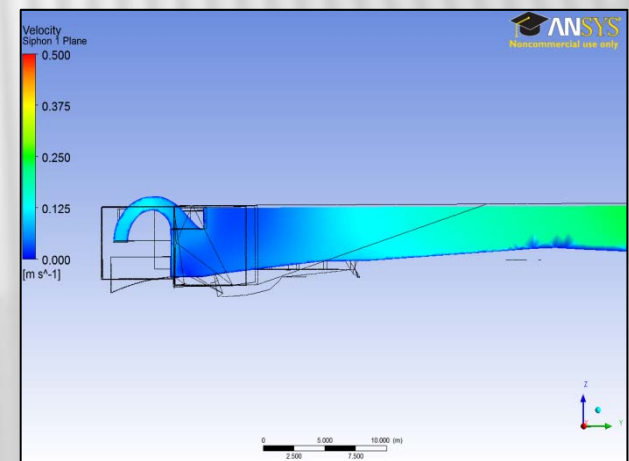
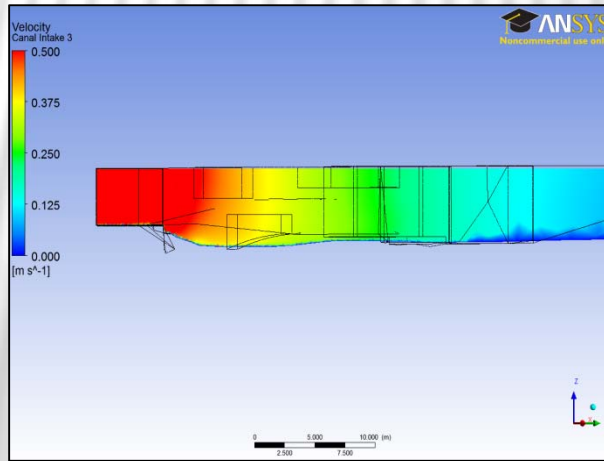
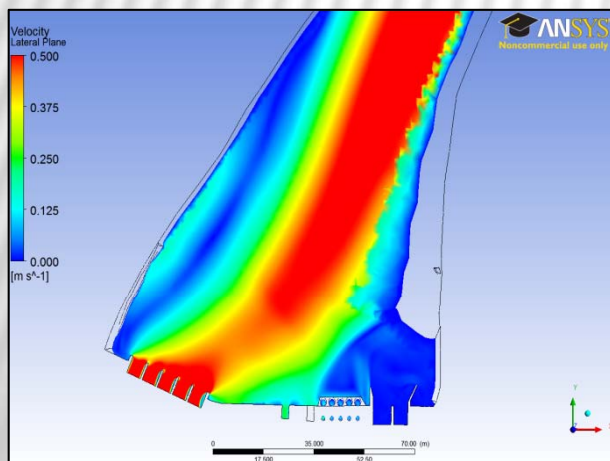


Canal



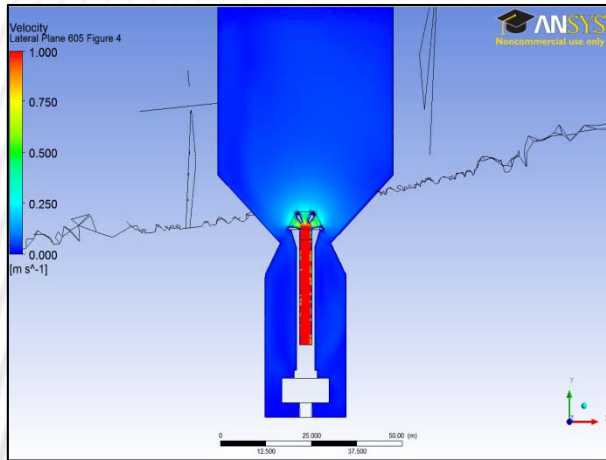
Siphon 1

Seton – Scenario SON-04 (Fall Low)

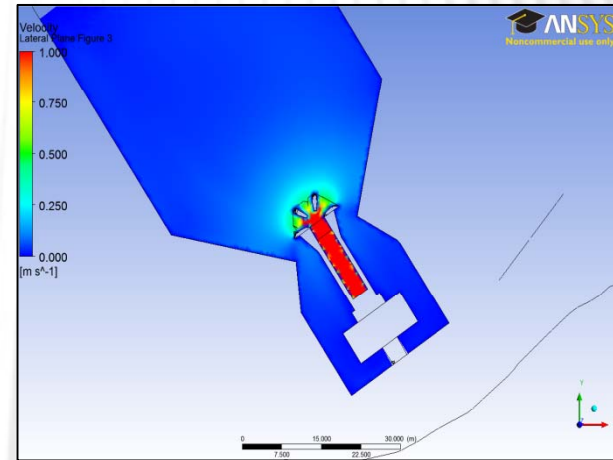


MODEL RESULTS - CARPENTER

Seton – Scenario TRZ-01 (Freshet High)

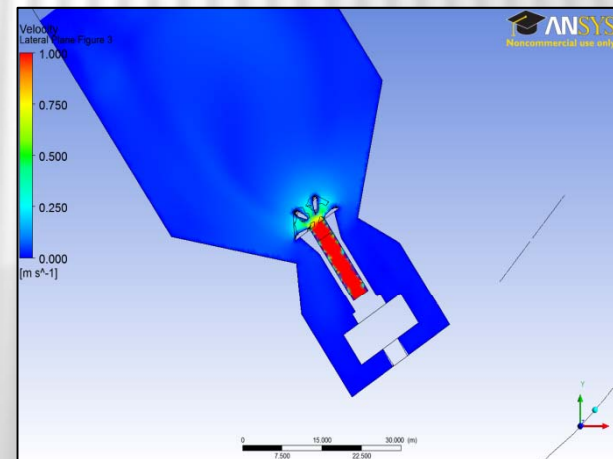
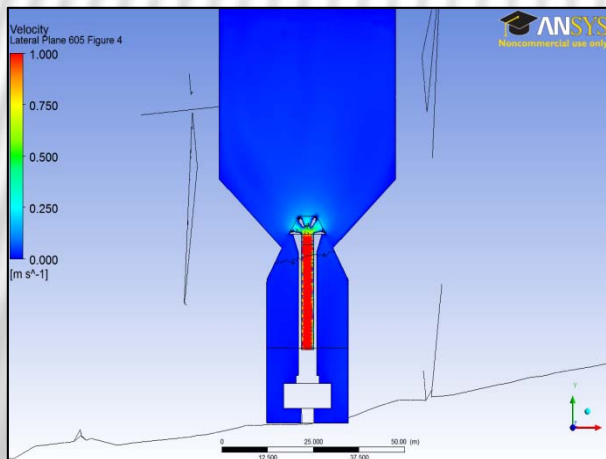


BR1 - Plan



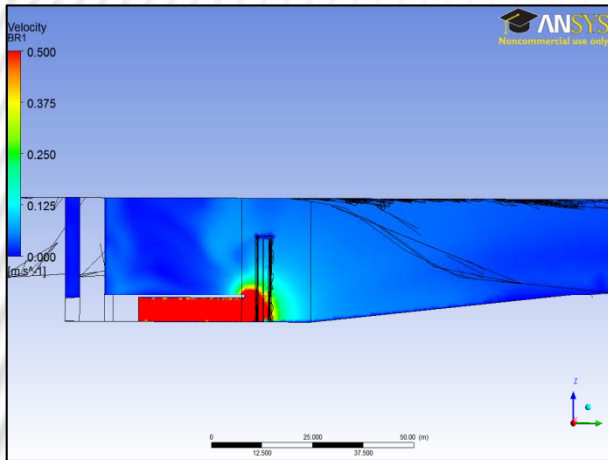
BR2 - Plan

Seton – Scenario TRZ-04 (Fall Low)

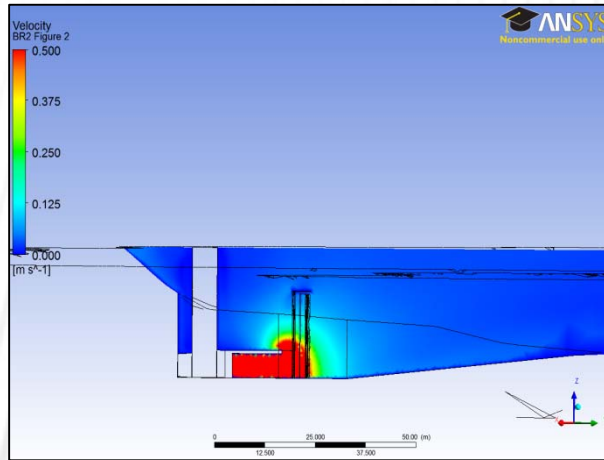


MODEL RESULTS - CARPENTER

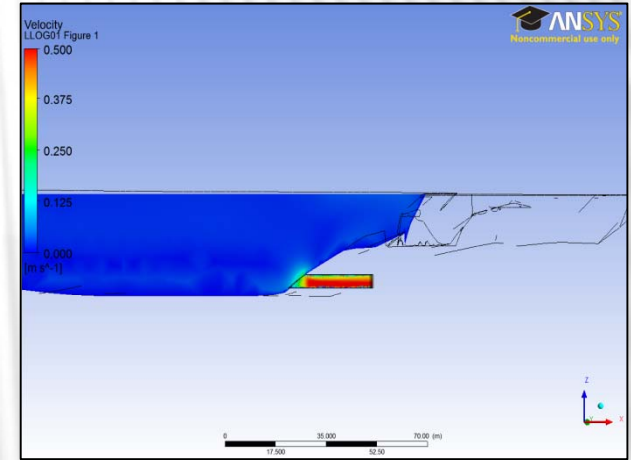
Seton – Scenario TRZ-01 (Freshet High)



BR1

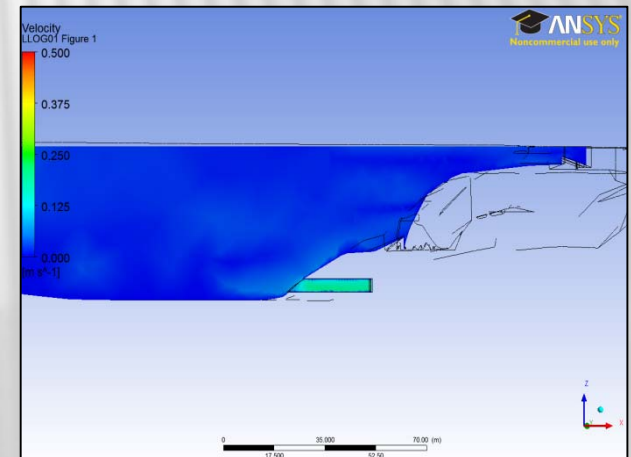
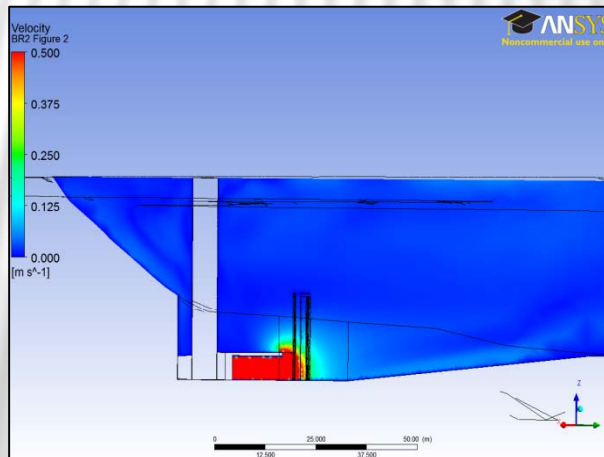
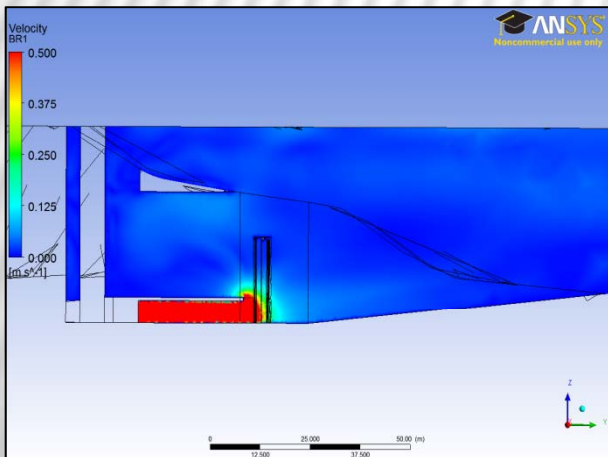


BR2



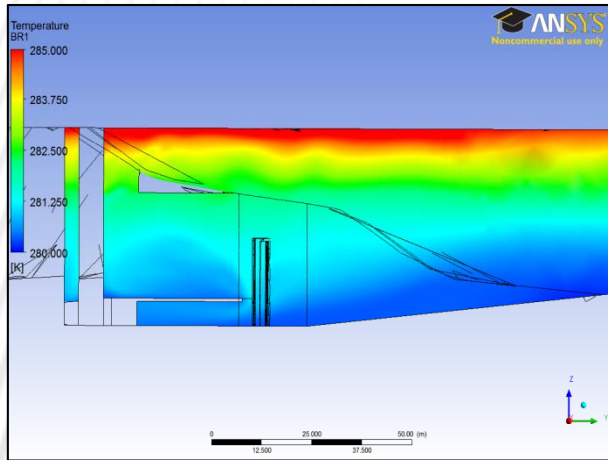
LLO1

Seton – Scenario TRZ-04 (Fall Low)

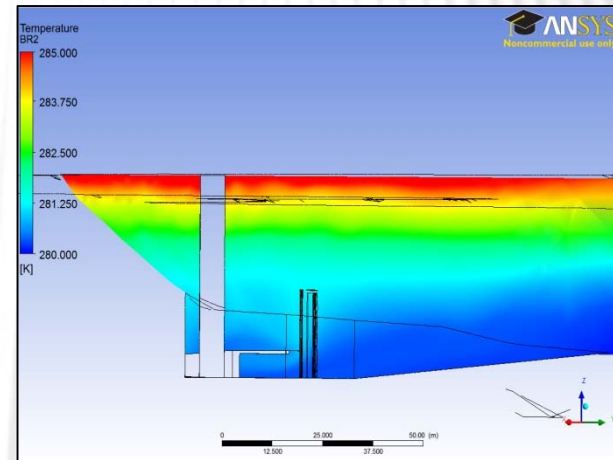


MODEL RESULTS - CARPENTER

Seton – Scenario TRZ-03 (Fall High)

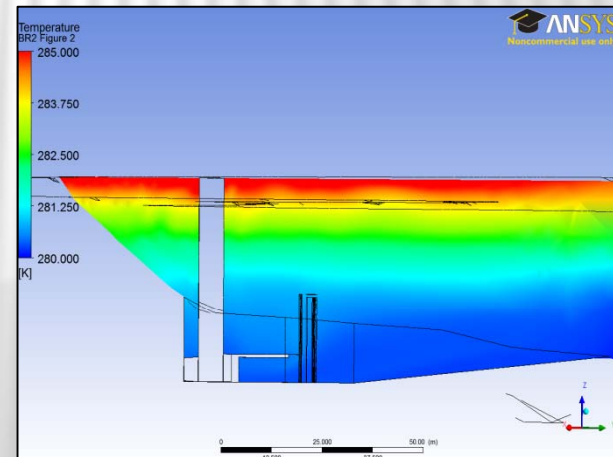
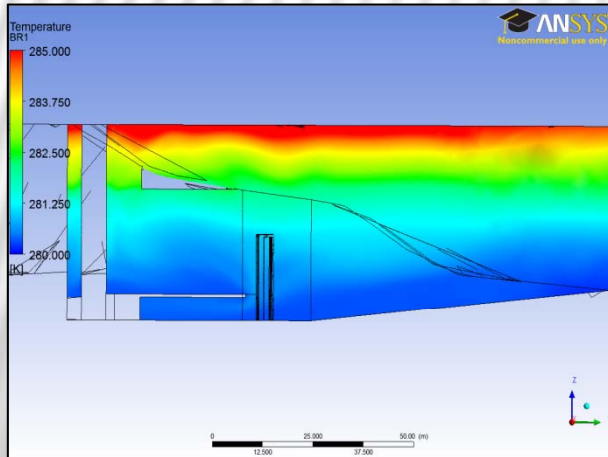


BR1



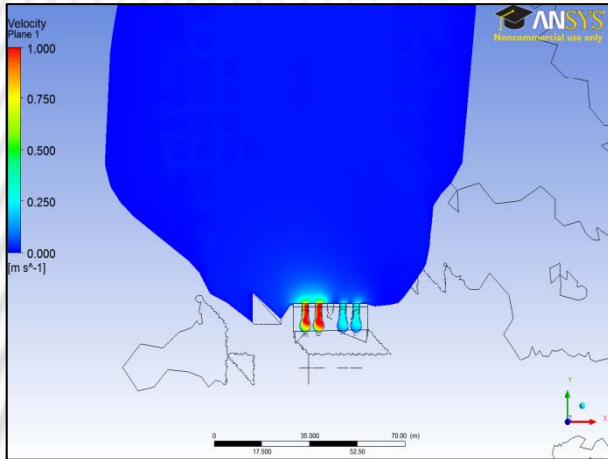
BR2

Seton – Scenario TRZ-04 (Fall Low)

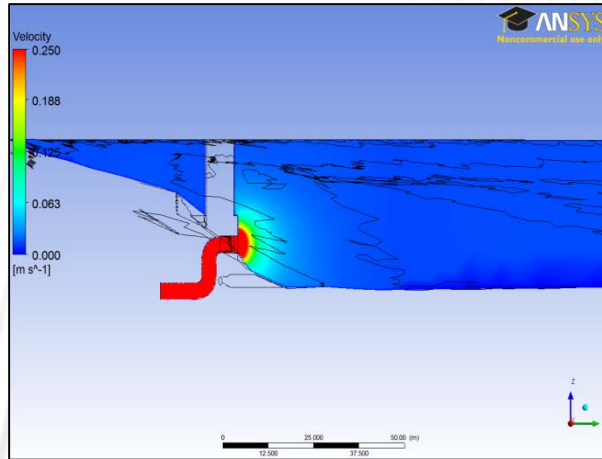


MODEL RESULTS - DOWNTON

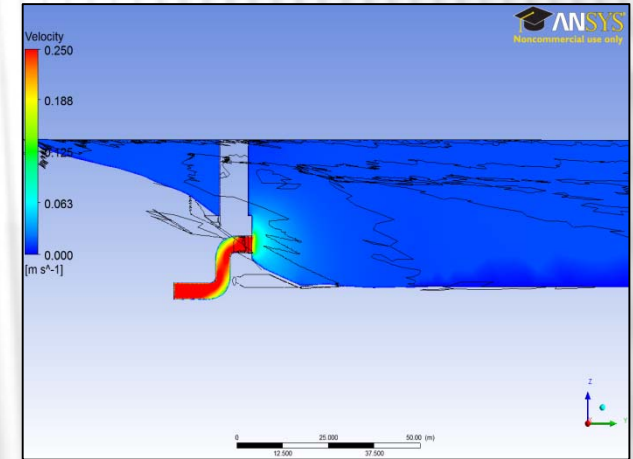
Seton – Scenario LAJ-01 (Freshet High)



Plan

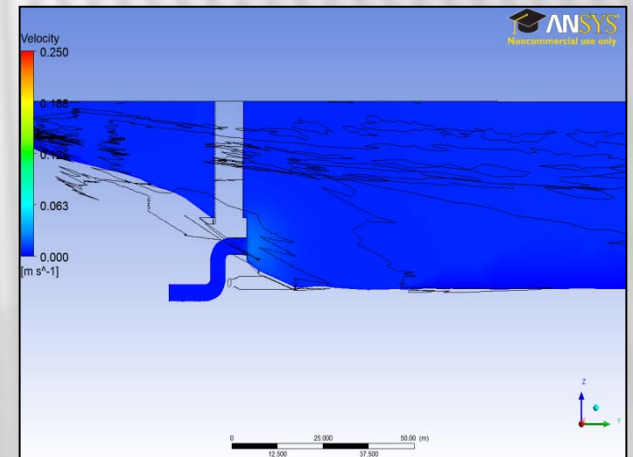
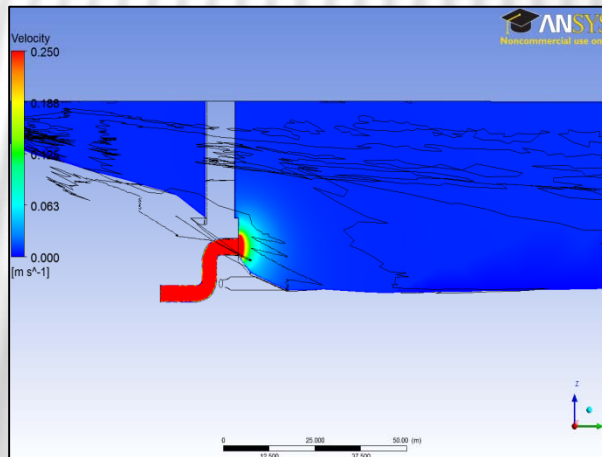
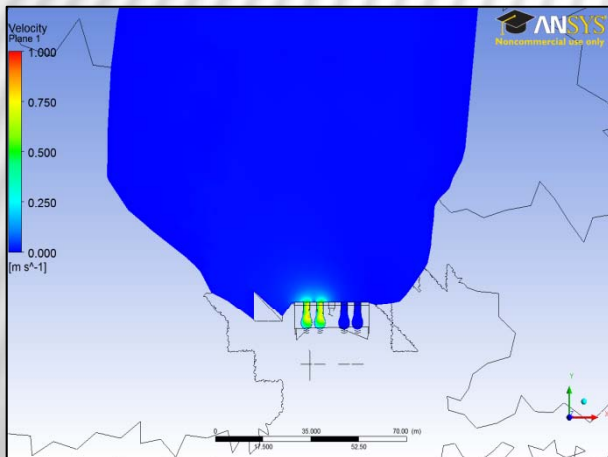


Intake 2 (South)



Intake 3 (North)

Seton – Scenario LAJ-06 (Winter Low)



QUESTIONS/DISCUSSION

