Understanding juvenile salmon entrainment at junctions

Interactions between outmigrant behavior and hydrodynamics

J.R. Burau and Aaron Blake

4/16/2014

SWRCB Interior flows workshop

Acknowledgements

Funding for the field work for the 2008 north delta survival study from DWR: Victor Pacheco

Funding for the 2008 analysis, USBR: Erwin VanNieuwenhuyse

Funding for the Georgiana barrier investigations, DWR: Jacob McQuirk and Ryan Reeves

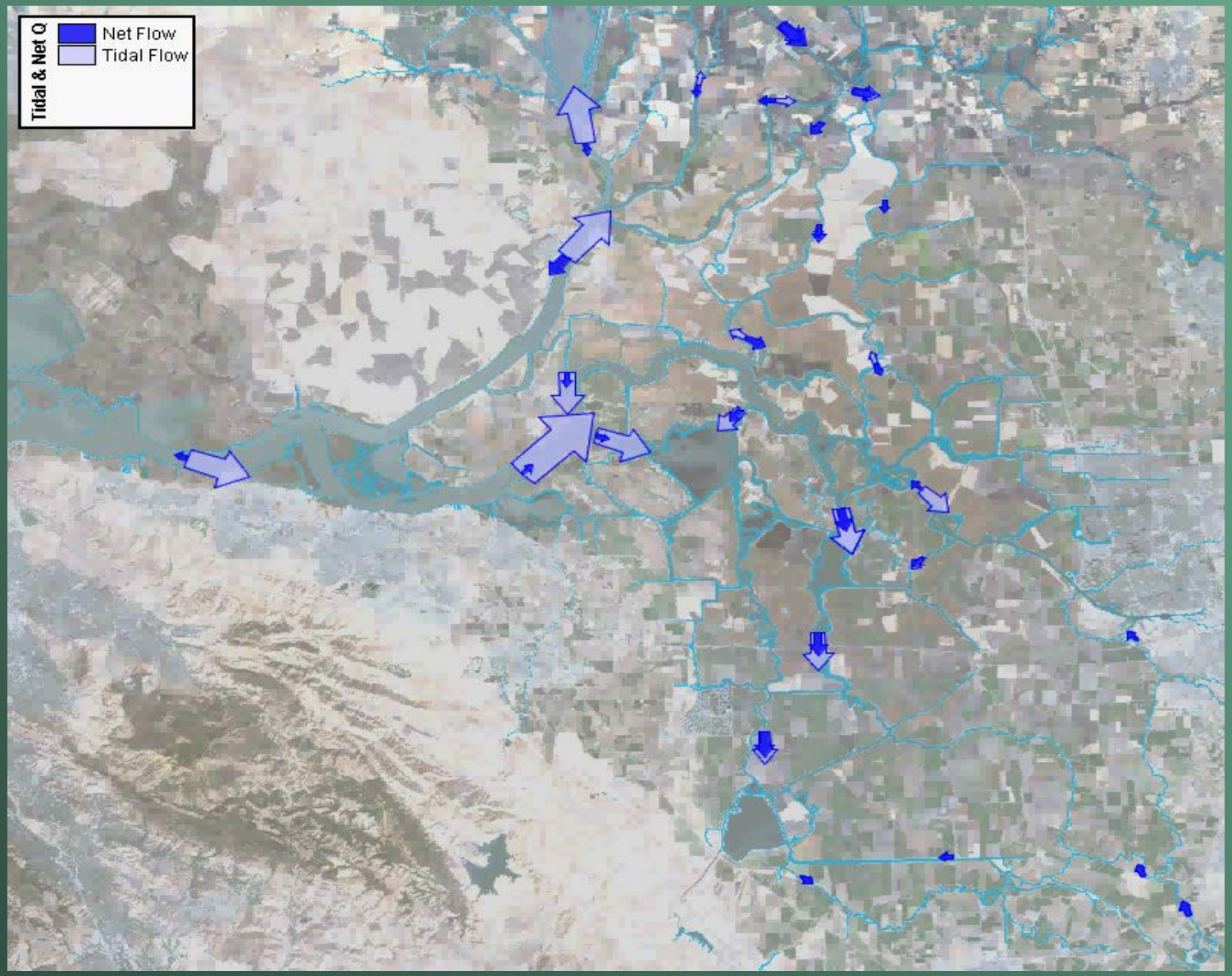
So why should the SWRCB care about juvenile salmon entrainment in junctions

Because inflows to the delta (timing and magnitude) and internal flow patterns will change with the tunnels changing their population level survival, changes in geometry and restoration will alter the routes that salmon take and also change their population level survival.

Route selection at the upstream junctions in the north delta is an extremely important factor in determining population level survival

First: Basic Hydrodynamics

The Delta is Strongly Tidally Forced

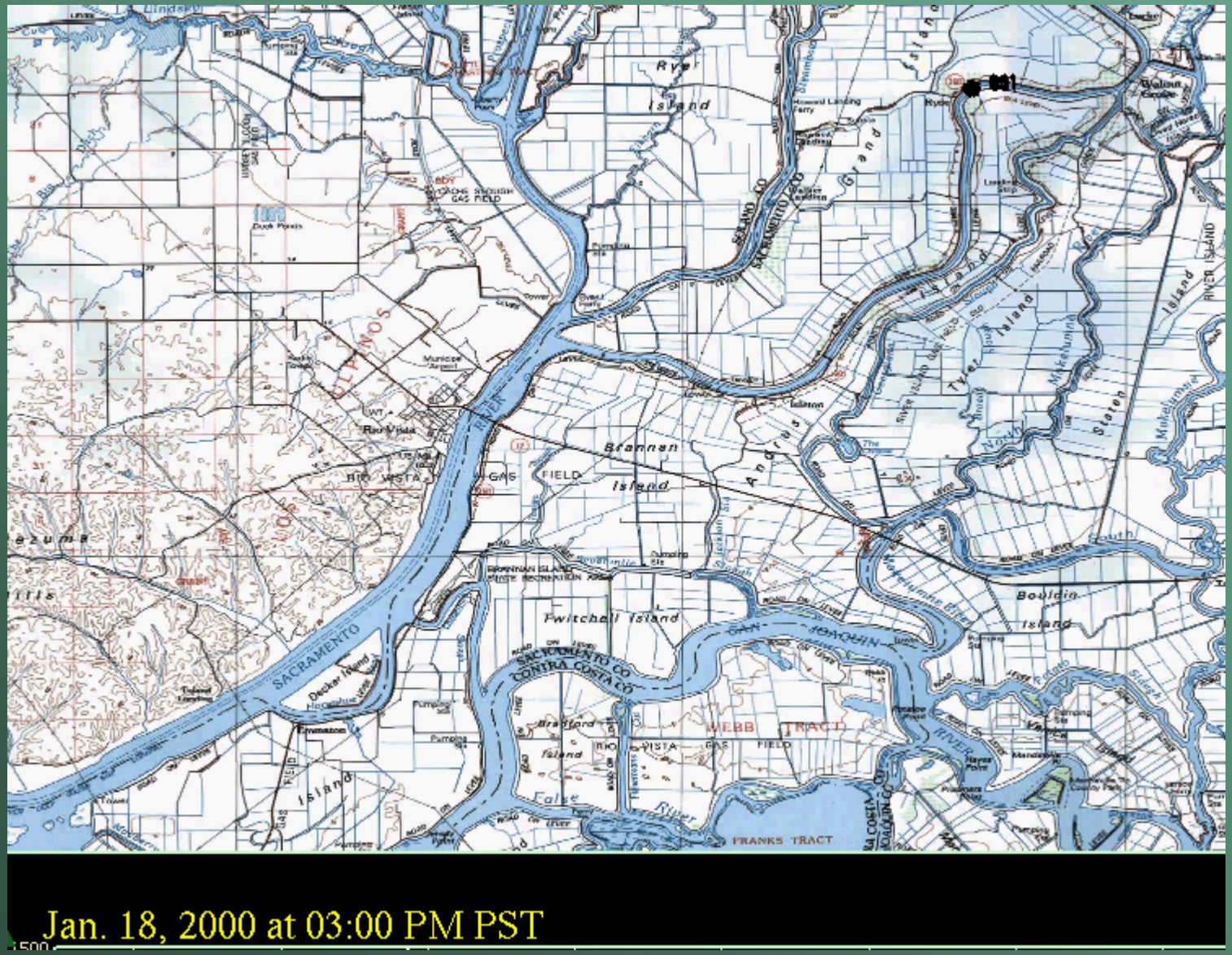


Courtesy of RMA

Things are always in motion
And can travel long distances

Courtesy of RMA

Why do we care: Organism (fish) movement

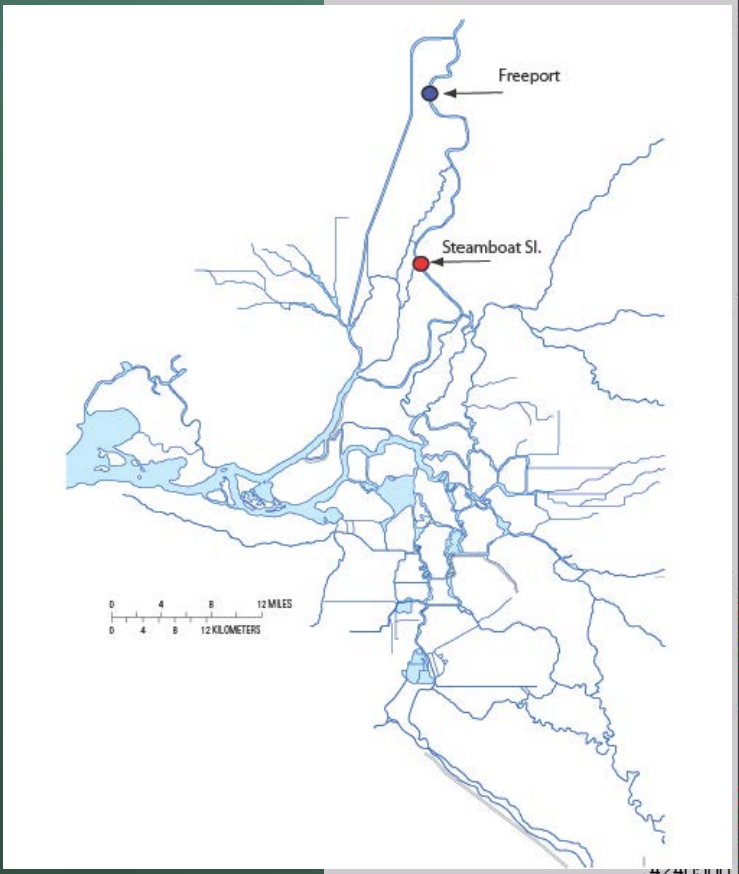


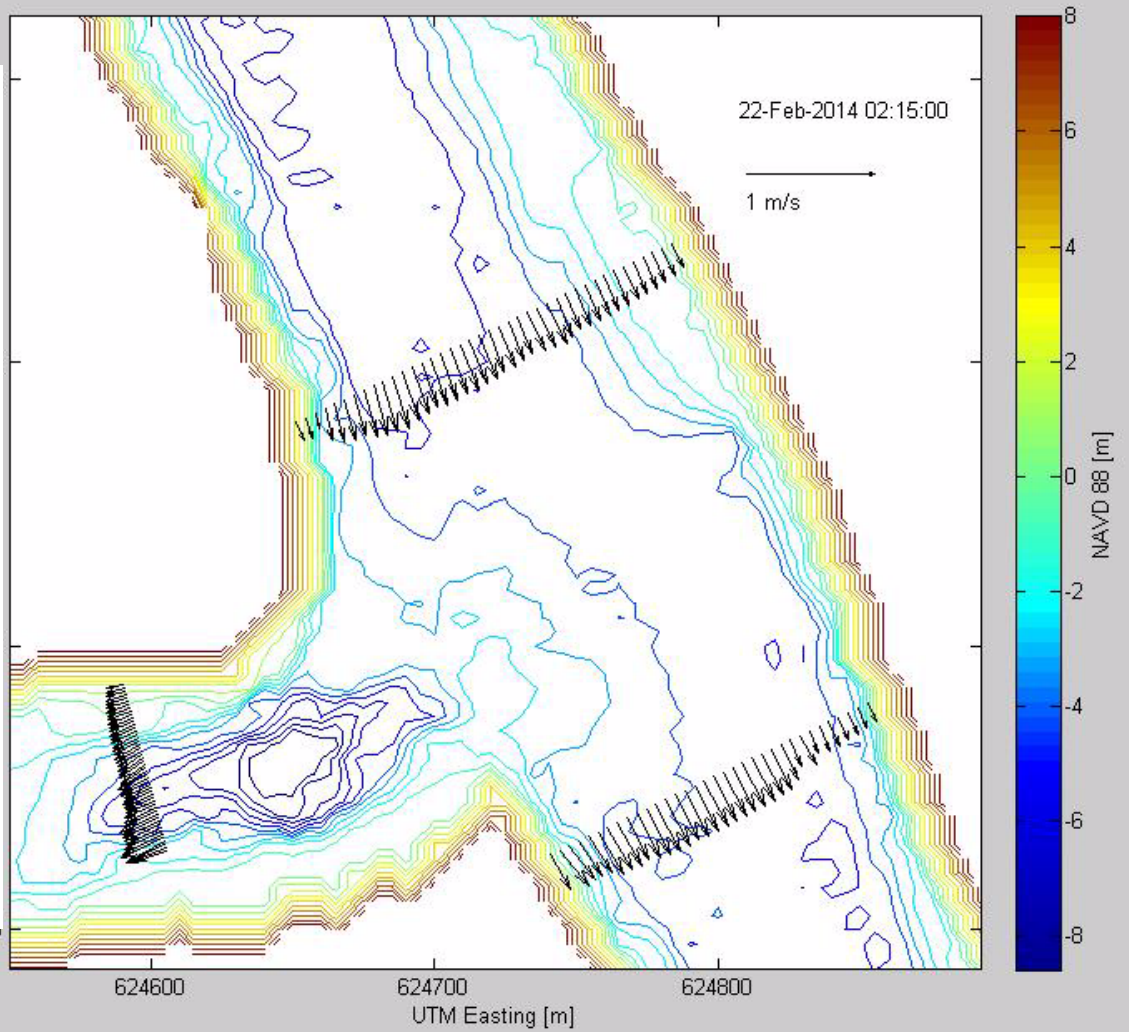
Courtesy of Dave Vogel

Jan. 25, 2000 at 01:00 PM PST

Courtesy of Dave Vogel

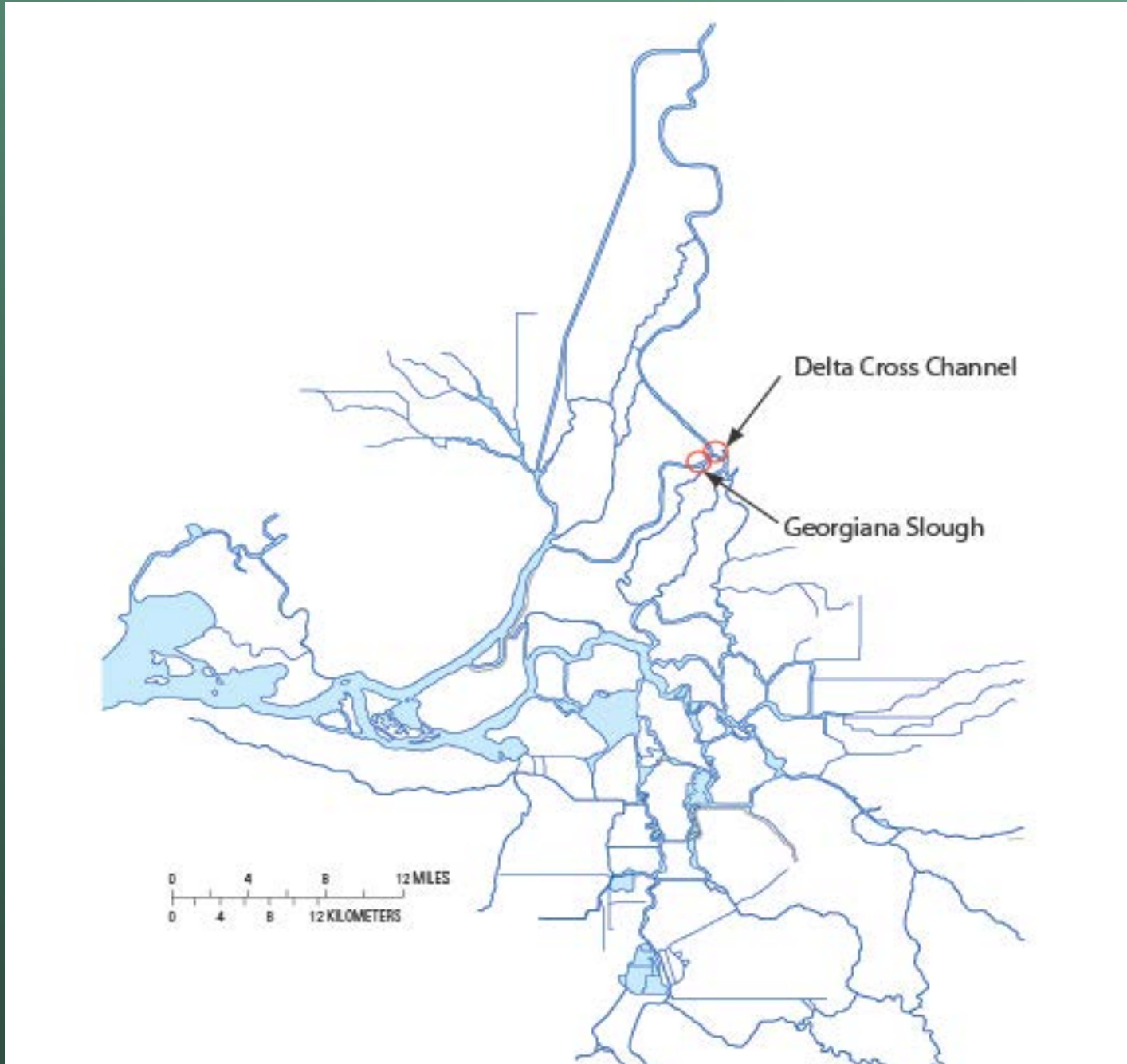
Steamboat Slough can reverse into the Sac River



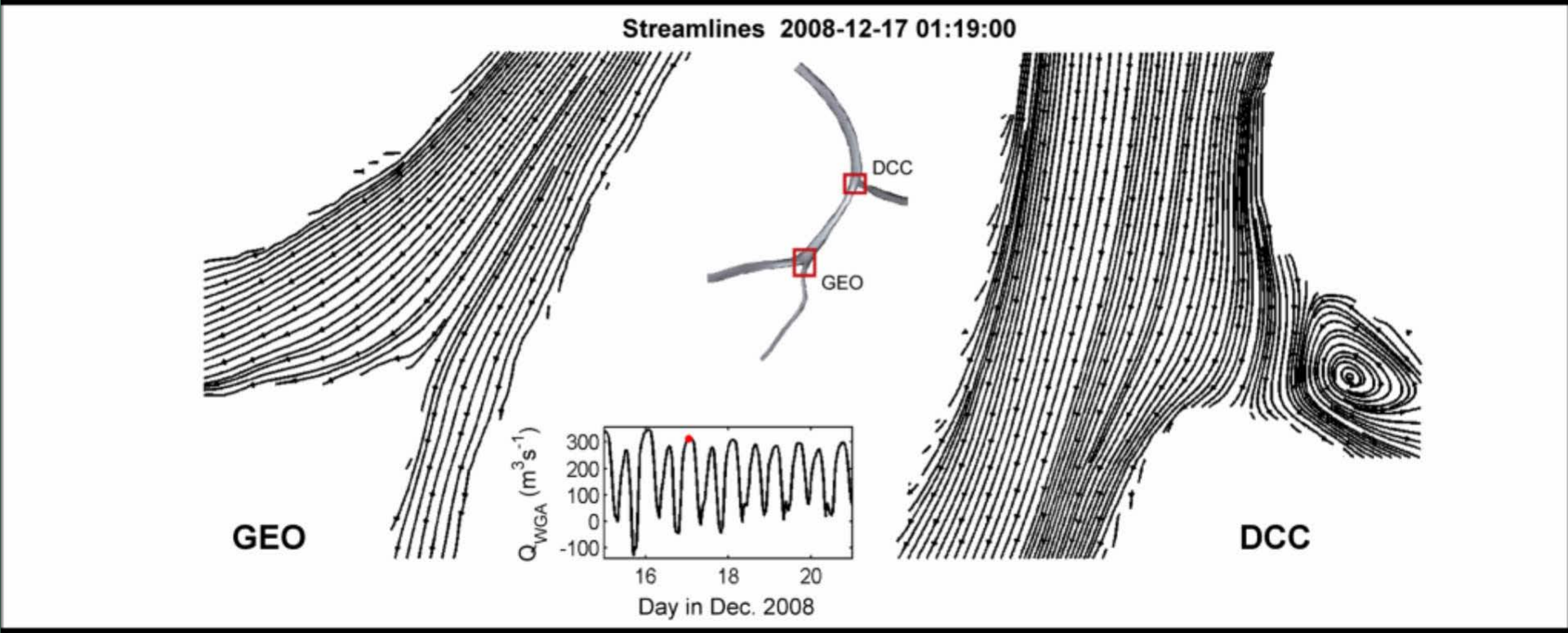


Water Surface Elevation NAVD 88

Delta Cross Channel and Georgiana (GEO) Slough



The velocity fields in the DCC and GEO are complicated



Courtesy of Casanas & Rueda (SI3D)

Do fish (salmon) go with the flow at junctions?

Depends on what you mean by flow

What we are finding at DCC and Geo is that :

- **(1) Juvenile salmon do not "go with" the tidal or net discharge (mass flux)**
- **(2) Juvenile salmon do "go with the tidal timescale surface velocity distributions"**

Our challenge is to "scale-up" the tidal timescale dynamics into something that is useful at management timescales [tidally averaged, 14 day average (like OMR), seasonal]

Acoustic Telemetry Studies

Studies of entrainment at the DCC and Georgiana Slough

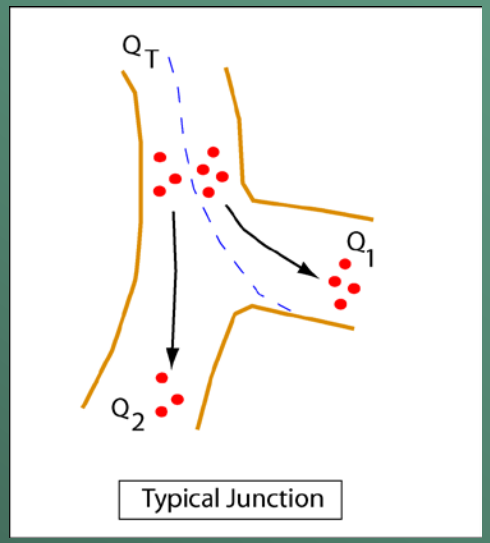
Use Acoustic Tags surgically implanted in fish

Each tag is individually Identifiable
(unique Pulse Width and Repetition Rate)

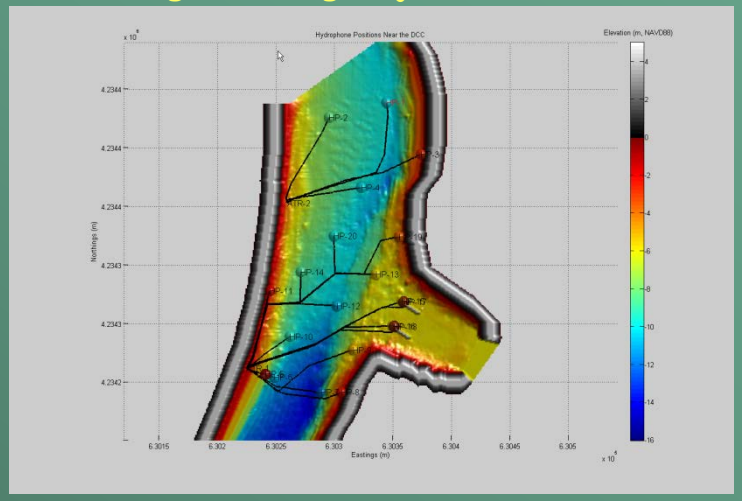
The problem of understanding salmon outmigration

Approach (2) : Divide problem into two parts

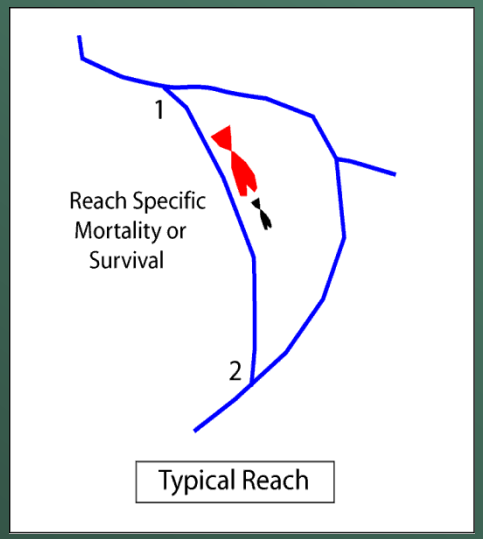
(1) Entrainment at Junctions (Route Selection)



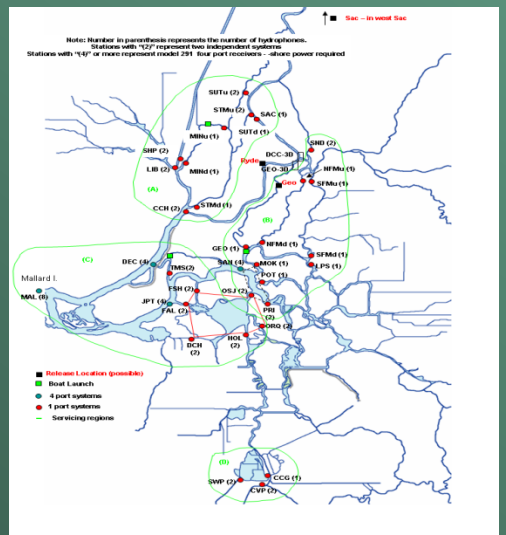
3D tag tracking in junctions (DCC)



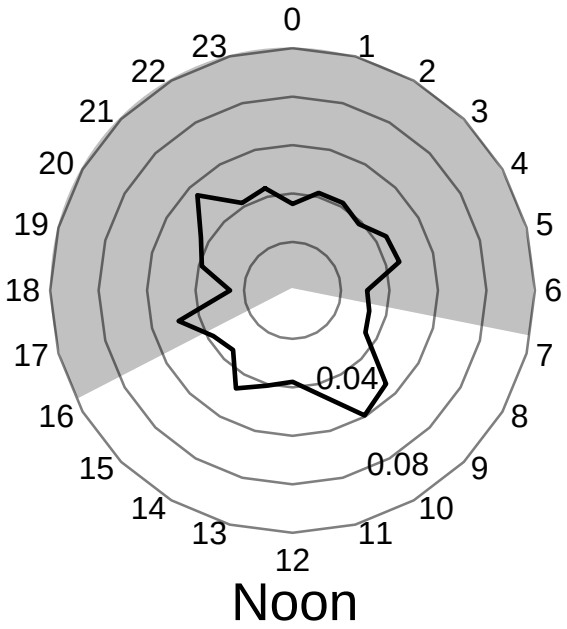
(2) Survival within each reach



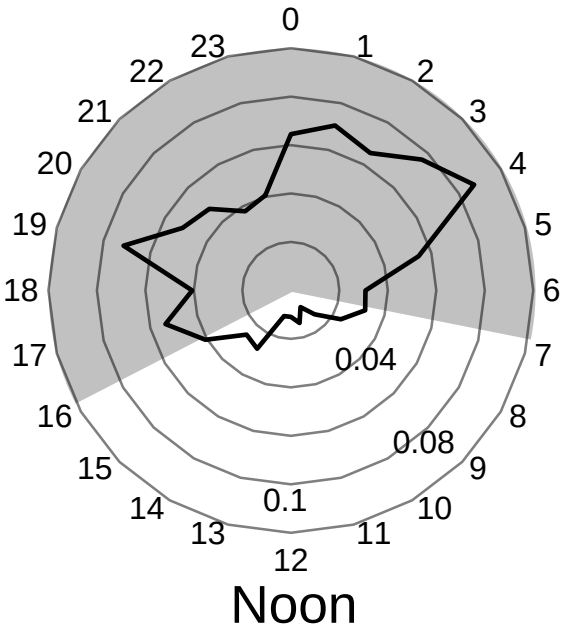
Tracking of tags throughout delta



Release and Arrival Times at DCC of tagged fish

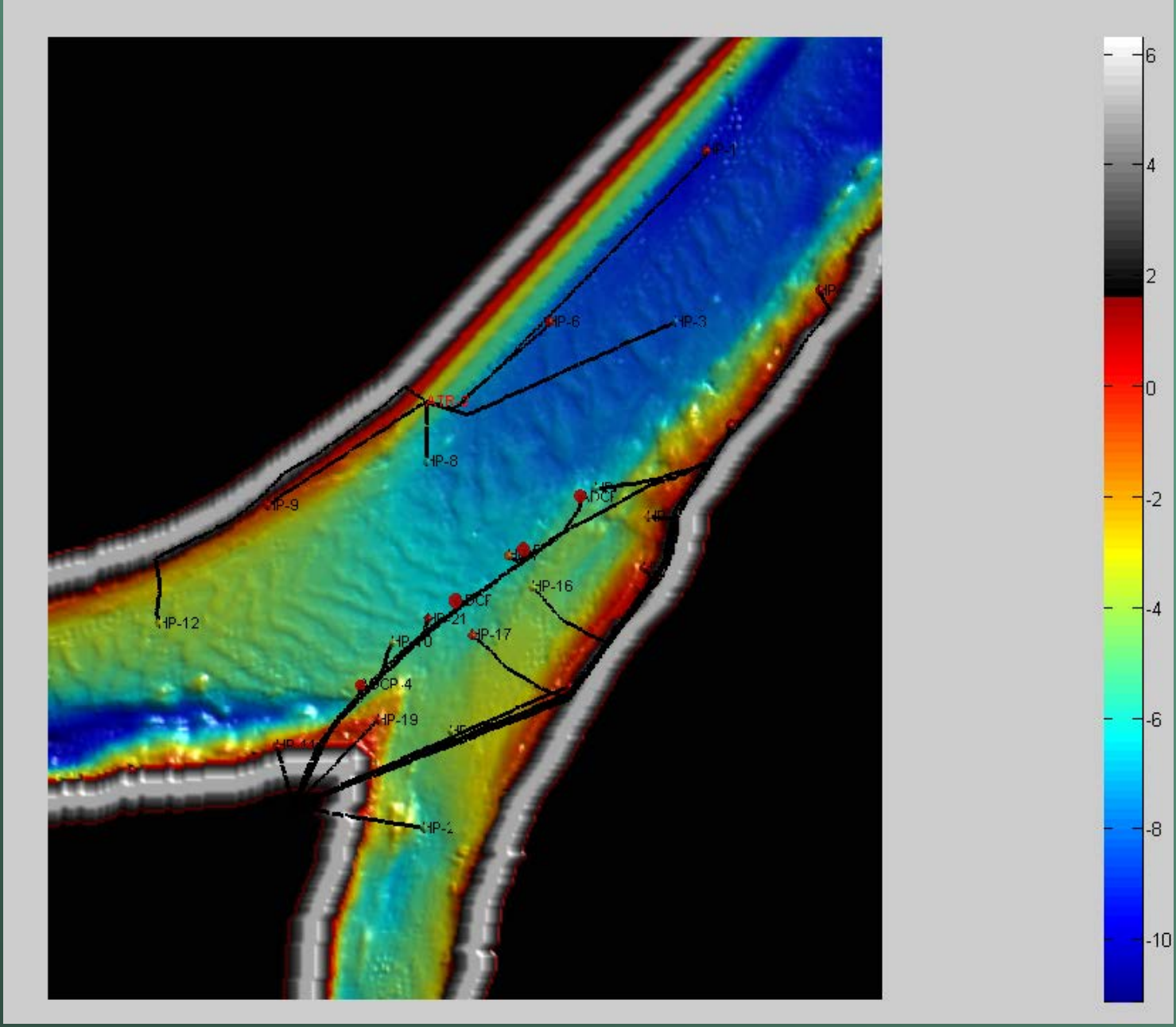


61% released at night

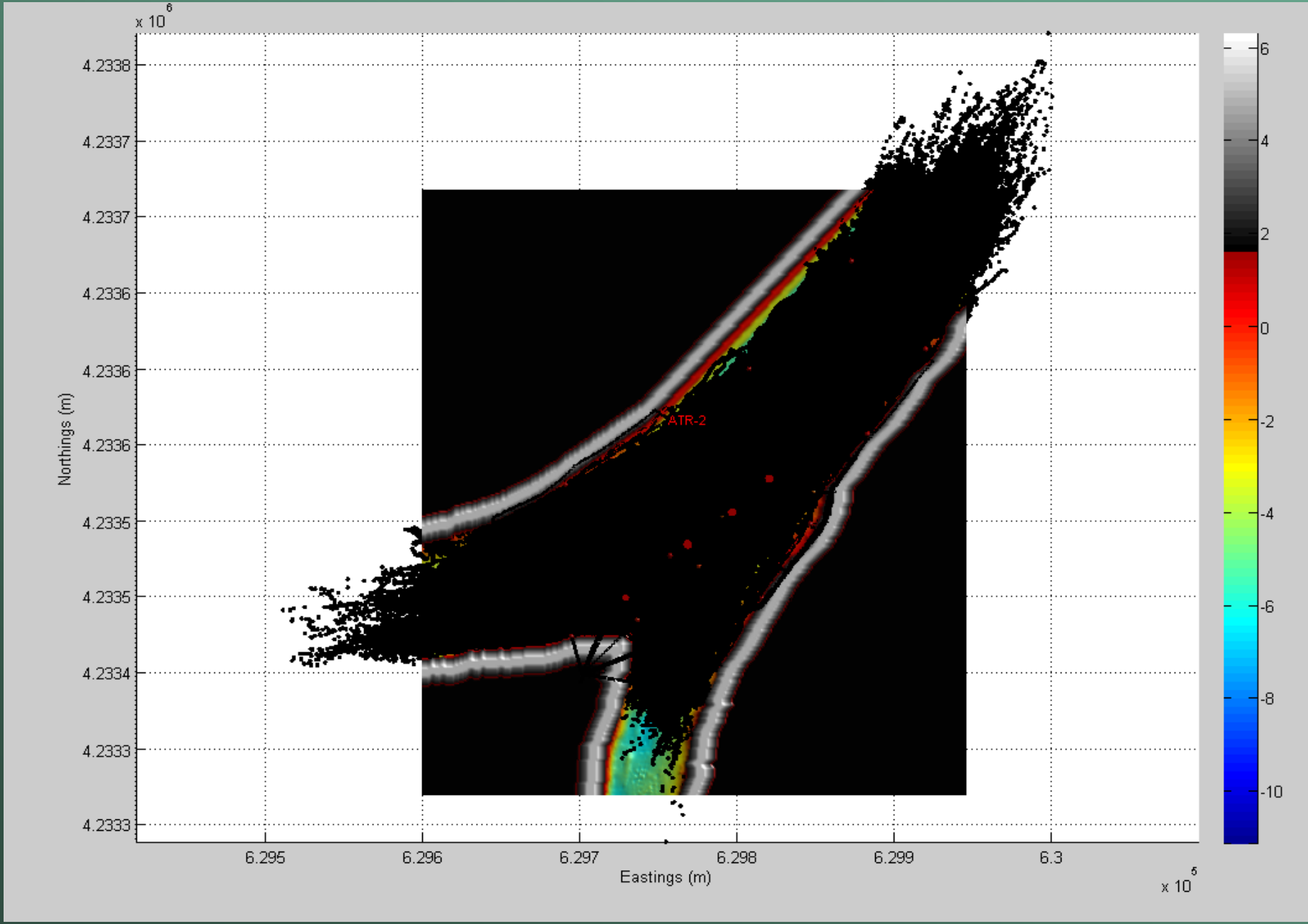


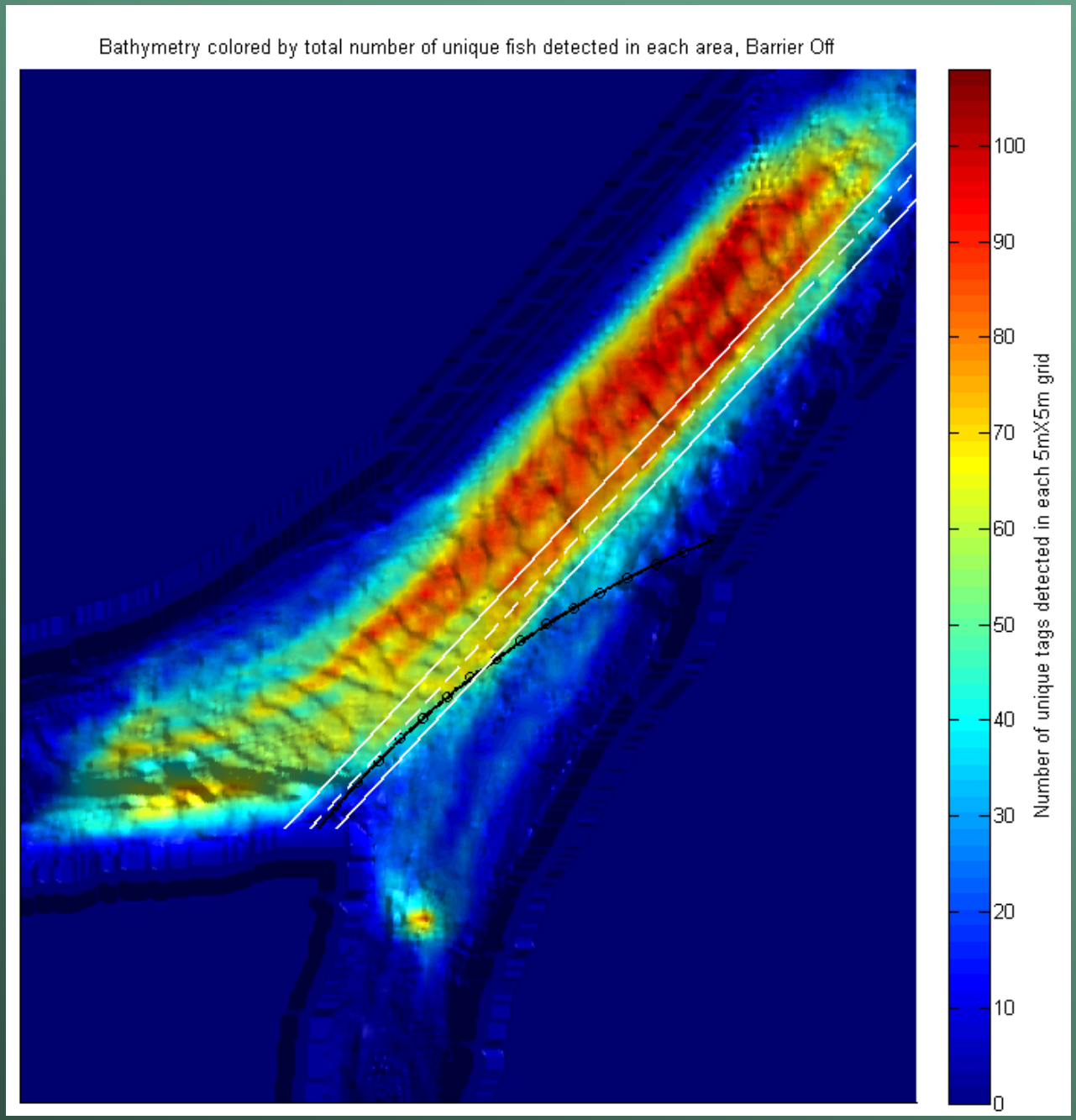
83% nocturnal

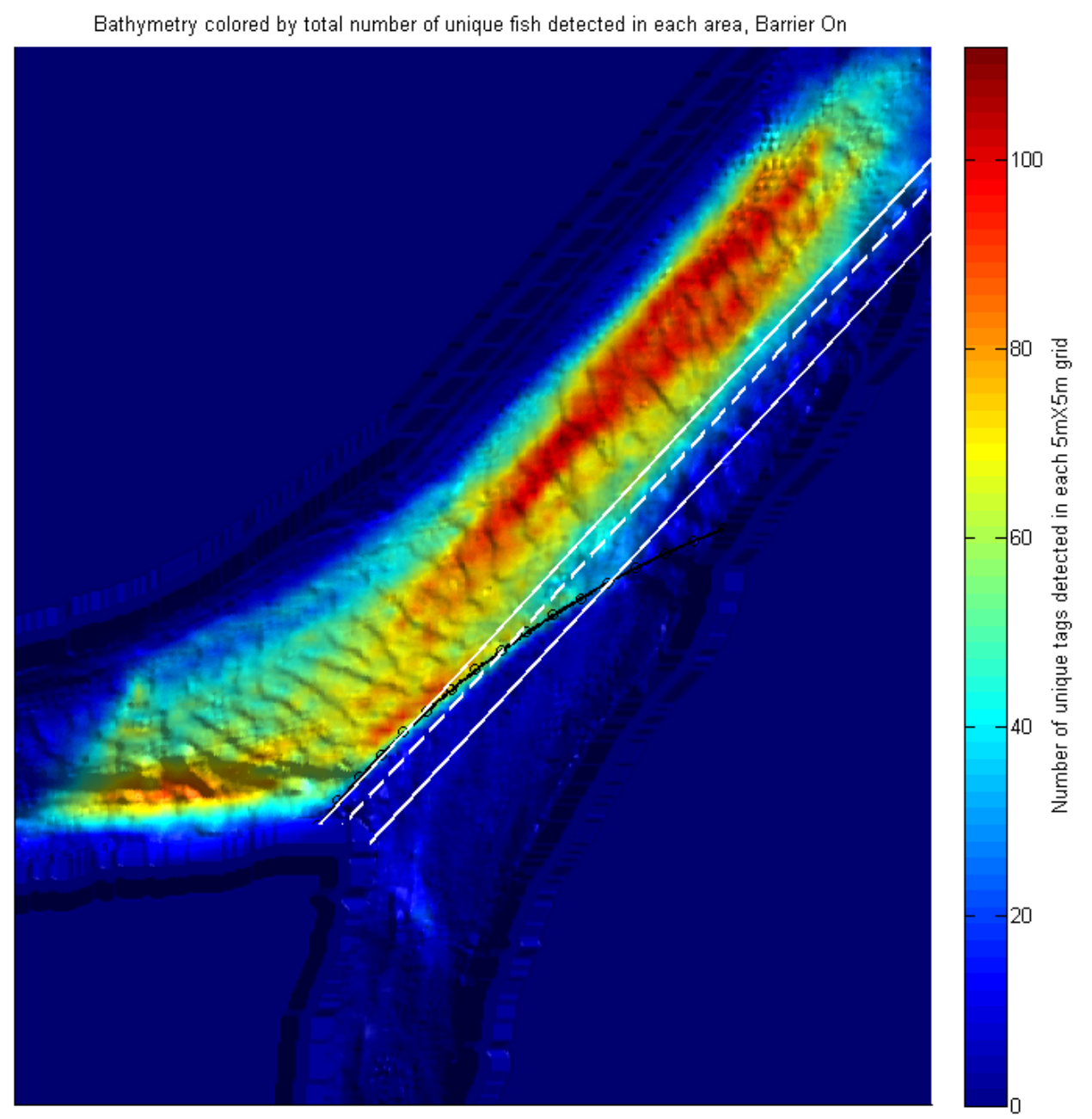
Barrier location and hydrophone positions



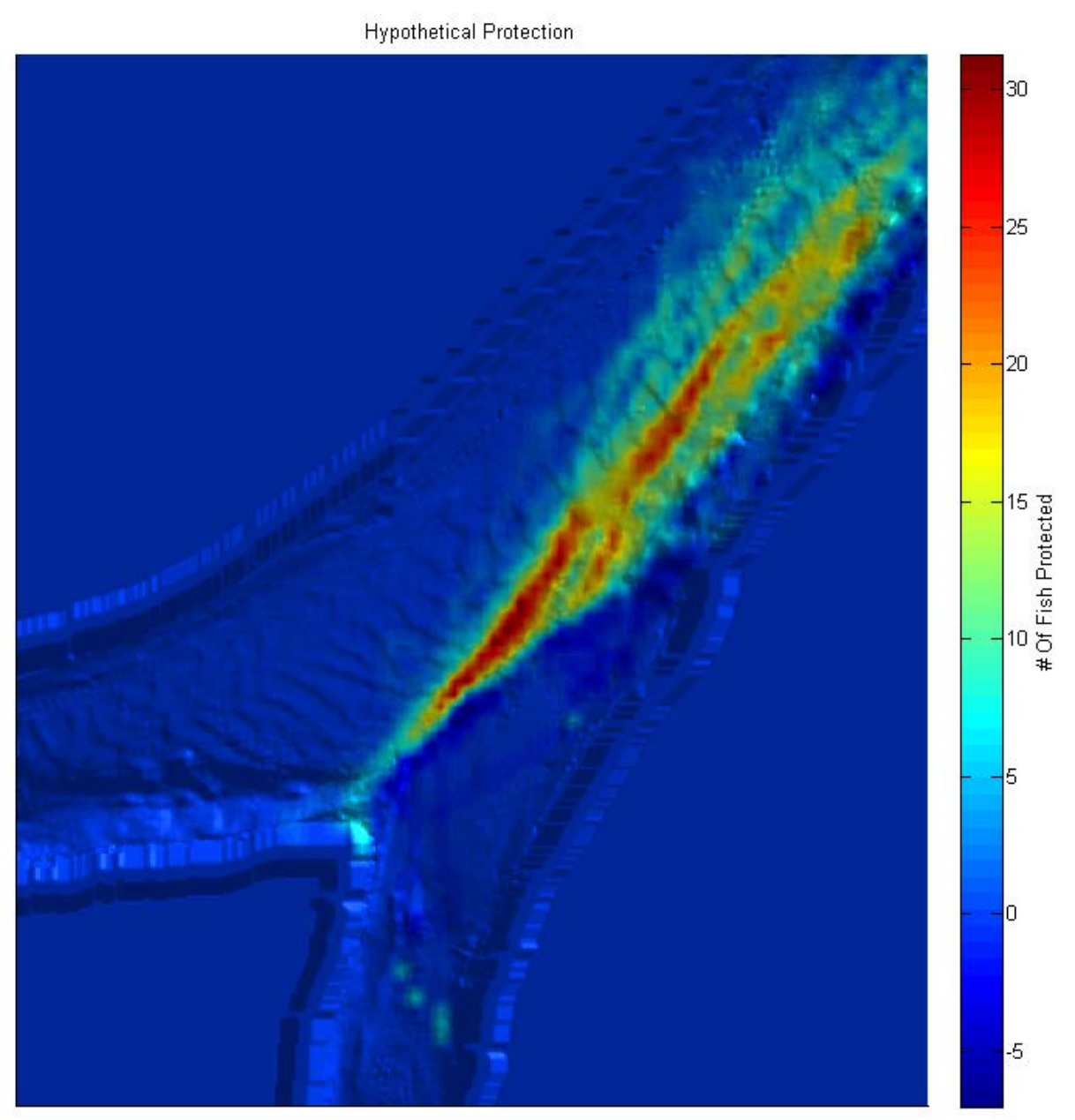
Fish tracks – entire experiment




Bathymetry colored by total number of unique fish detected in each area, Barrier Off
Number of unique tags detected in each 5mX5m grid
0
10
20
30
40
50
60
70
80
90
100


Bathymetry colored by total number of unique fish detected in each area, Barrier On
100
80
60
40
20
0
Number of unique tags detected in each 5mX5m grid

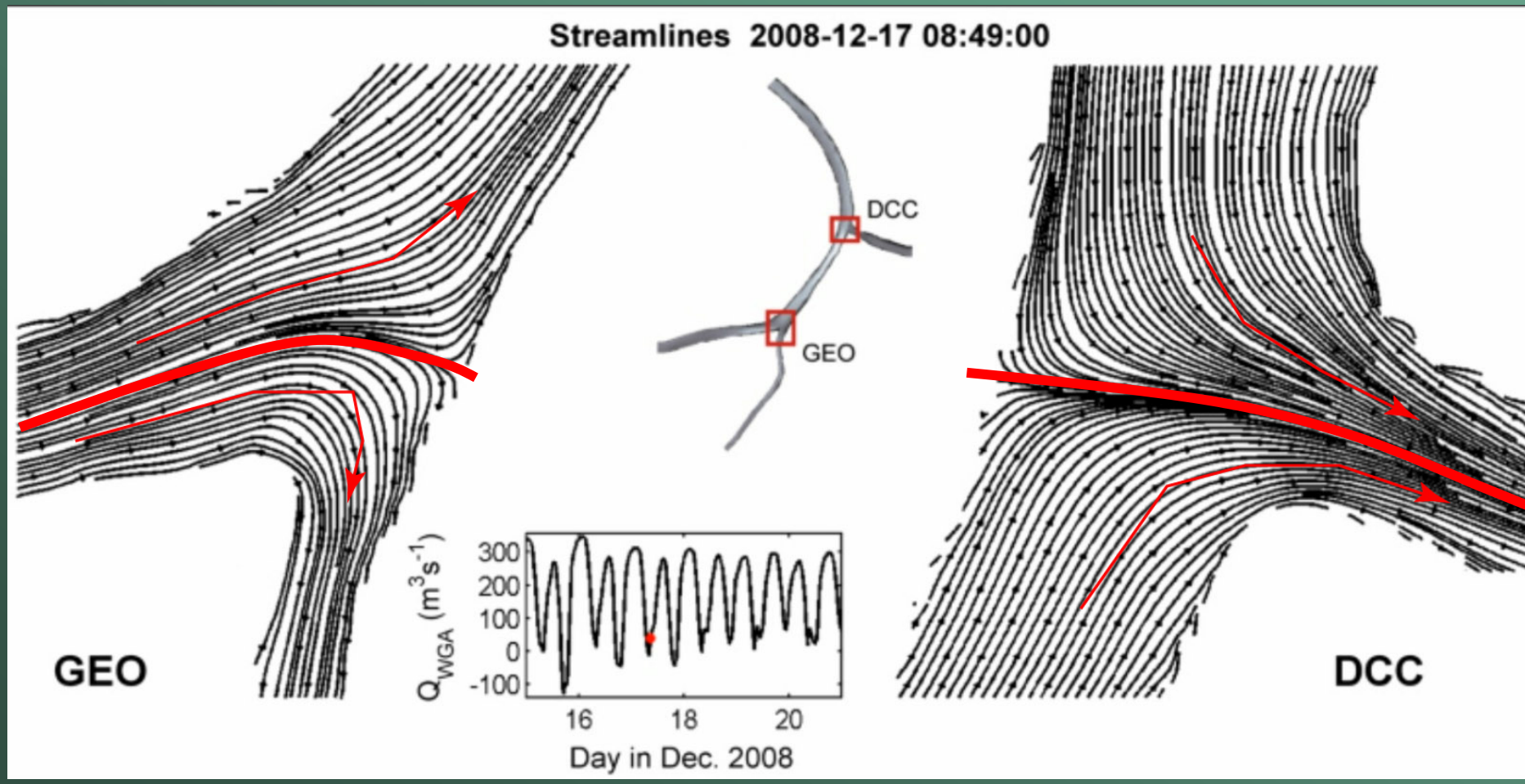
Change in spatial distribution on vs off



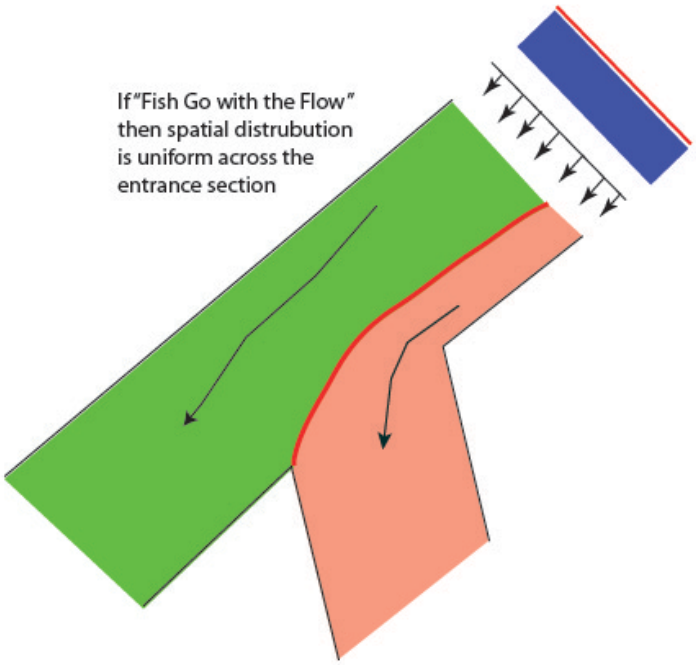
Conclusion

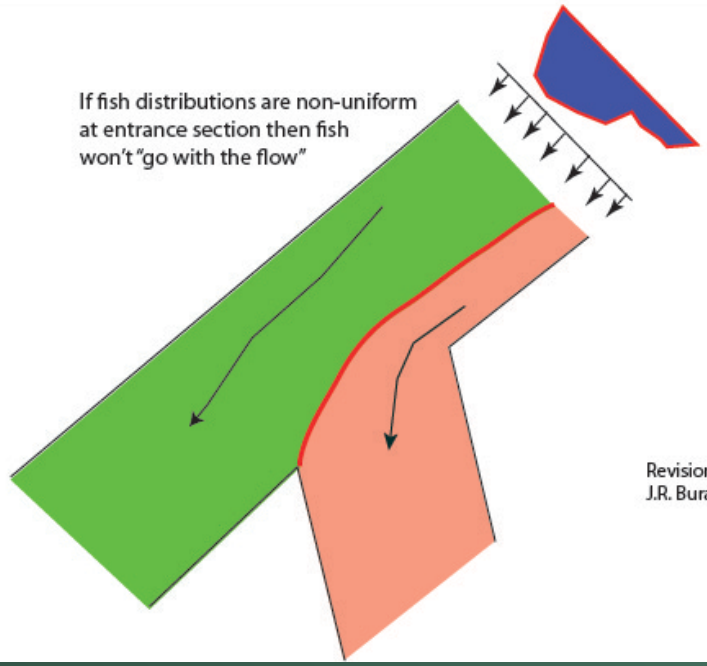
Juvenile salmon do not “go with” the tidal or net discharge (mass flux) because their (1) arrival time distributions and (2) spatial distributions are not uniform

Collapsing flow field complexity in junctions: The Critical Streakline



FLOW and FISH FIELDS IN THE GEORGIANA SLOUGH/SACRAMENTO RIVER JUNCTION

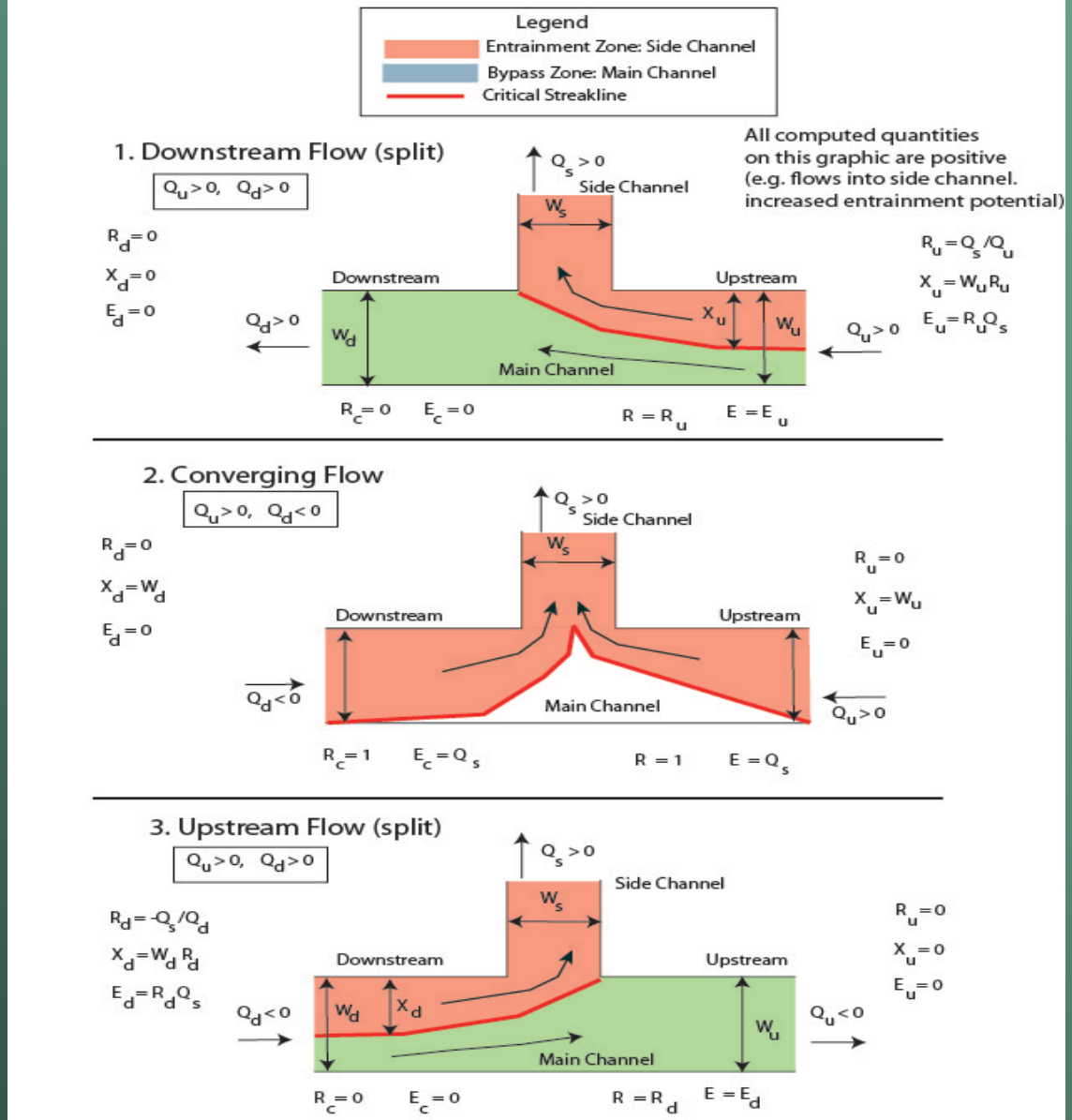




Revision 3
J.R. Burau 9/14/11

IDEALIZED FLOWS IN A JUNCTION

Positive Side Channel Flows



List of Variables

J.R. Burau 3/11/2013

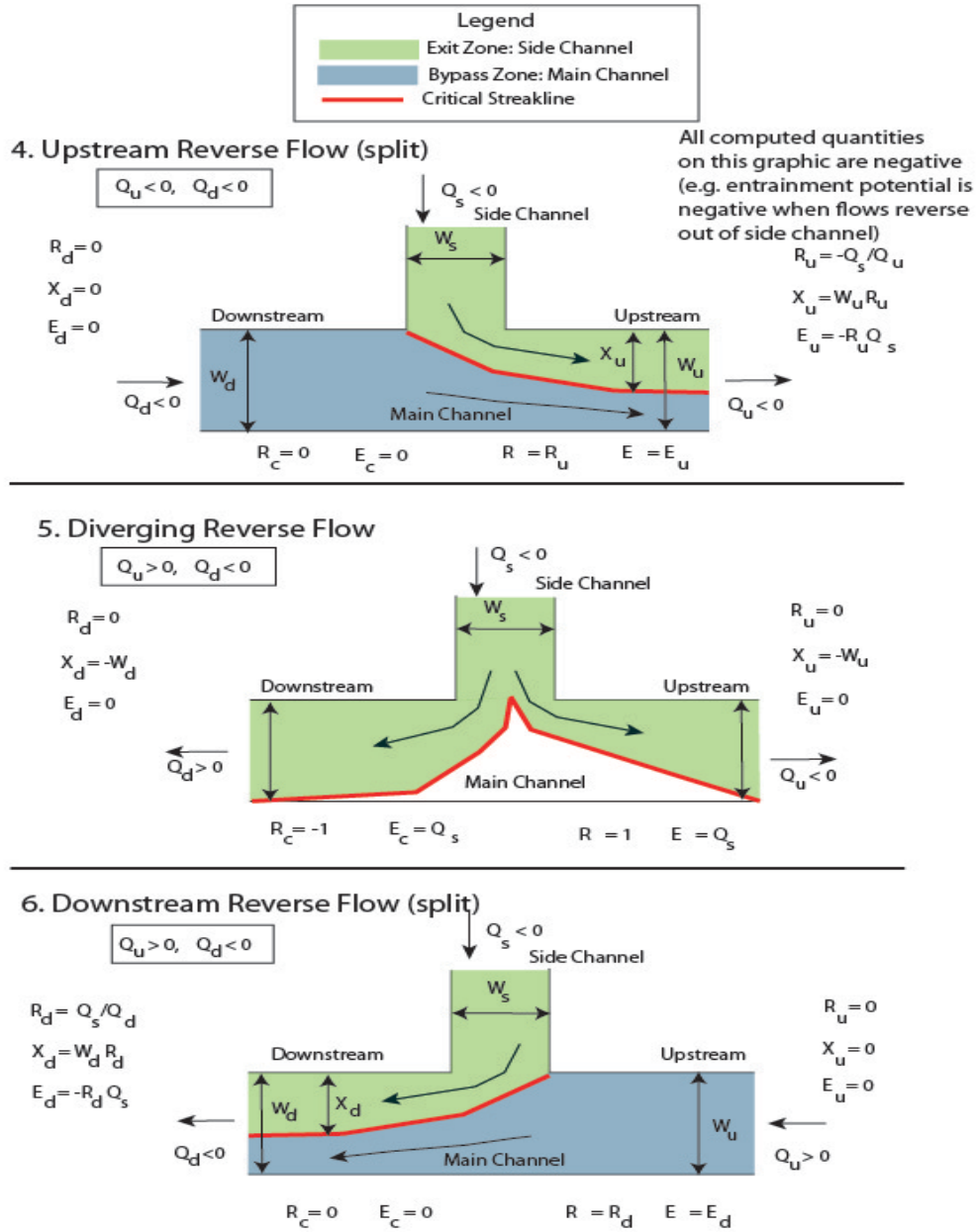
Q = Discharge
W = Width
X = Entrainment distance

u = Upstream main channel
d = Downstream main channel
s = Side channel

Flows are, by definition, positive downstream (see panel 1 above)

$$Q_u = Q_s + Q_d$$

IDEALIZED FLOWS IN A JUNCTION
Reverse Side Channel Flows



List of Variables

J.R. Burau 3/11/2013

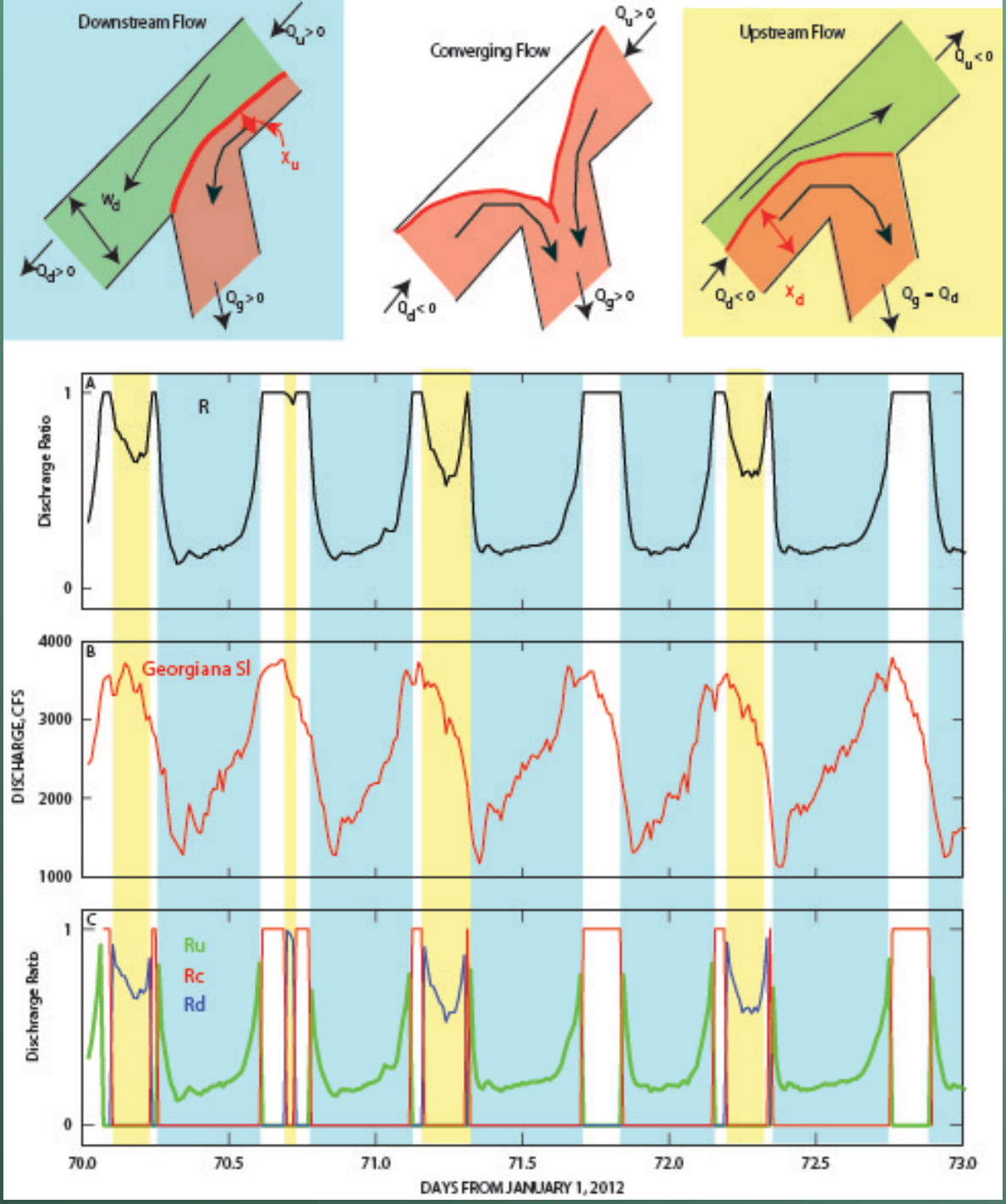
Q = Discharge
W = Width
X = Entrainment distance

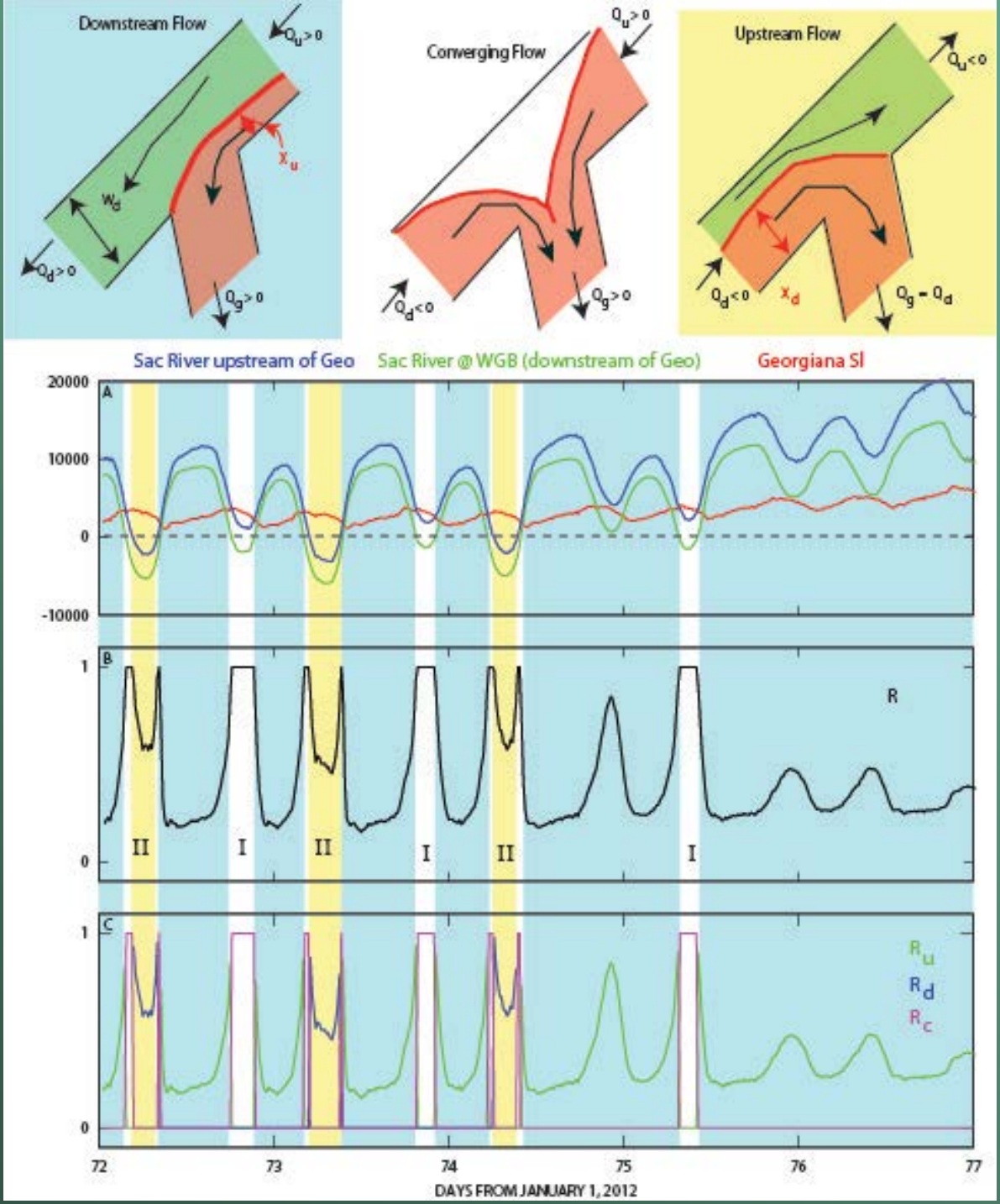
u = Upstream main channel
d = Downstream main channel
s = Side channel

Flows are, by definition, positive downstream (see panel 3 above)

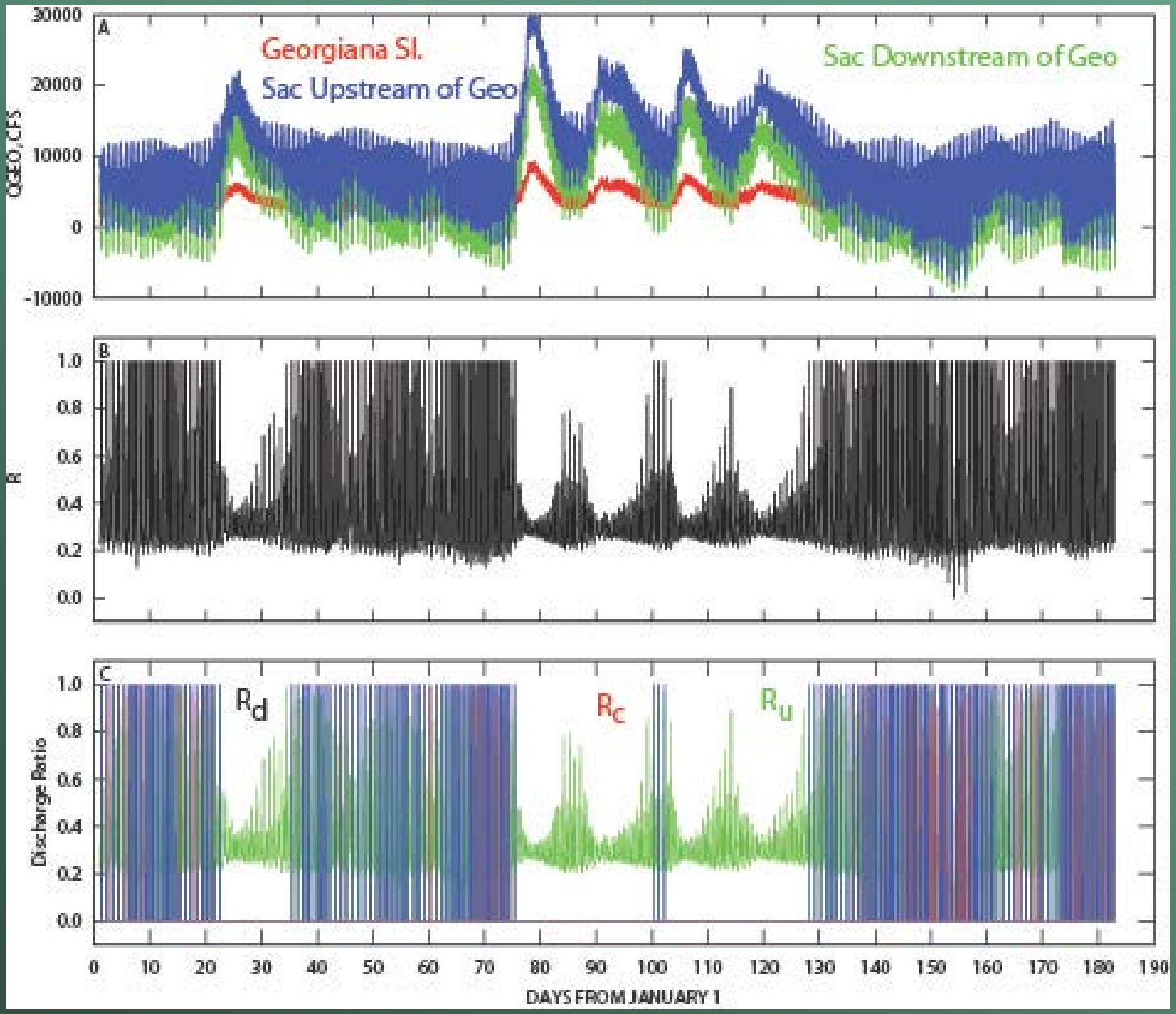
$Q_u = Q_s + Q_d$

Flows in Georgiana Slough

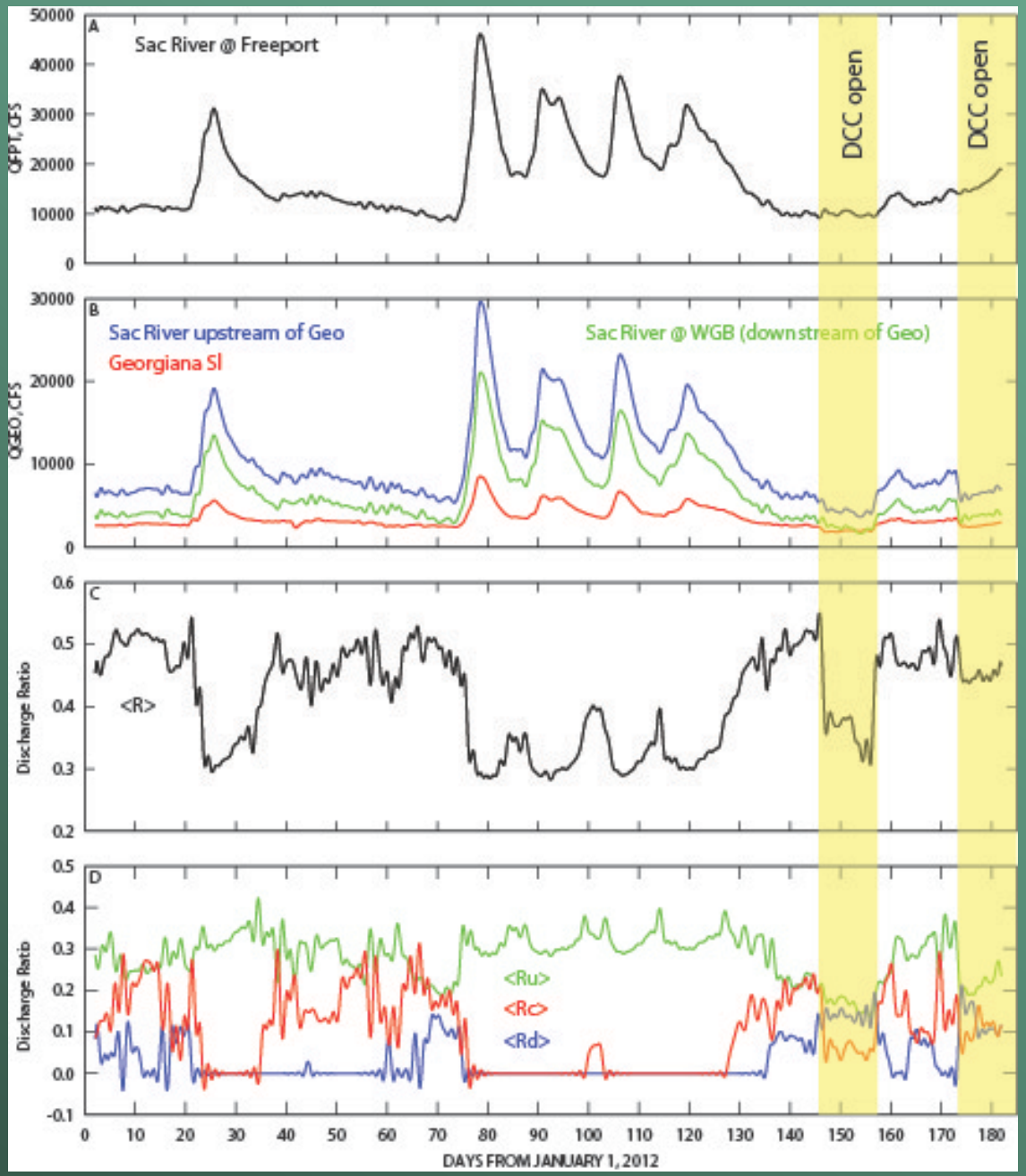



Downstream Flow
$Q_u > 0$
x_u
w_d
$Q_d > 0$
$Q_g > 0$
Converging Flow
$Q_u > 0$
$Q_d < 0$
$Q_g > 0$
Upstream Flow
$Q_u < 0$
$Q_d < 0$
x_d
$Q_g = Q_d$
Sac River upstream of Geo
Sac River @ WGB (downstream of Geo)
Georgiana Sl
A
B
C
R
II
I
R_u
R_d
R_c
DAYS FROM JANUARY 1, 2012

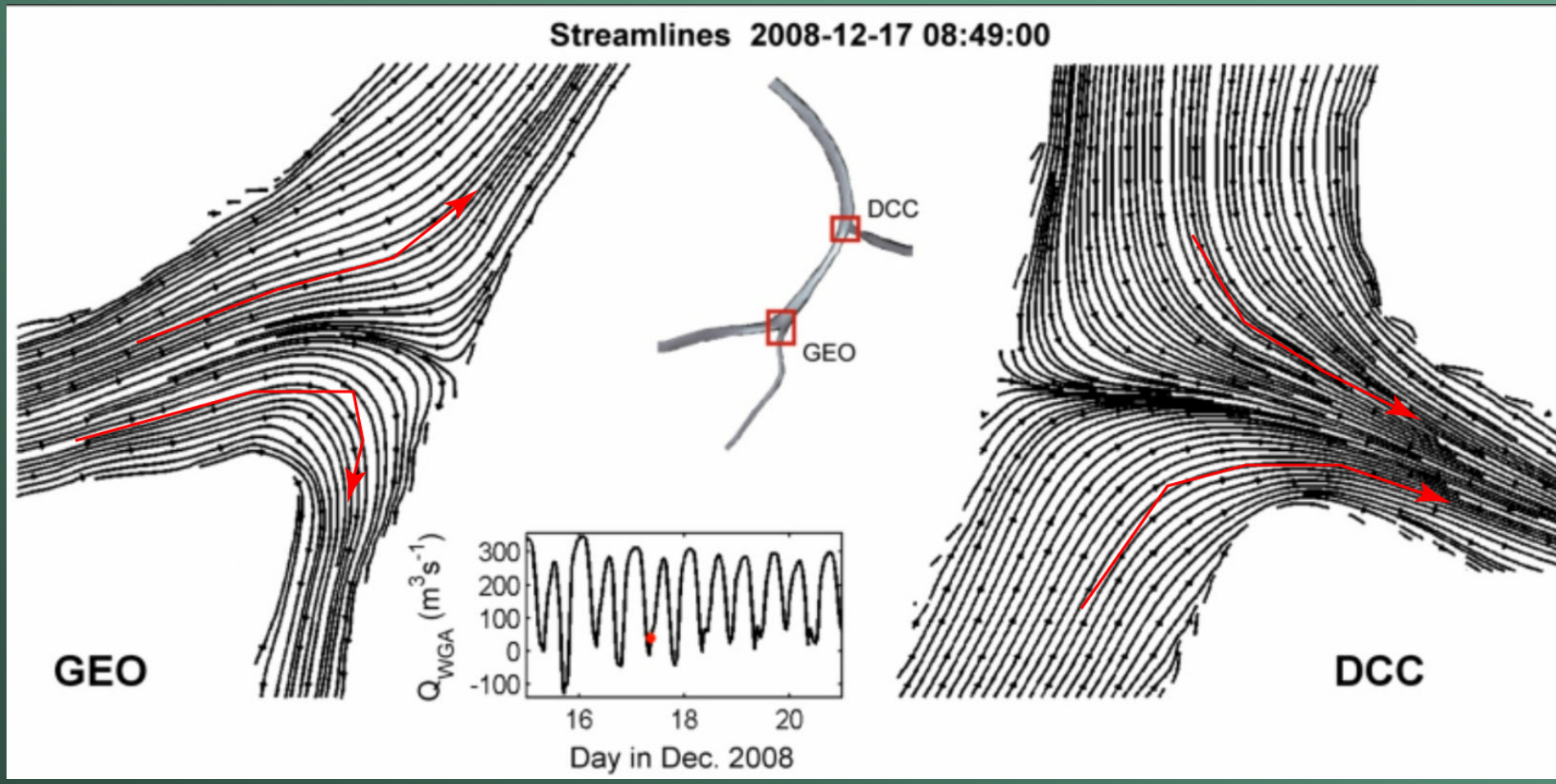
Tidal timescale R



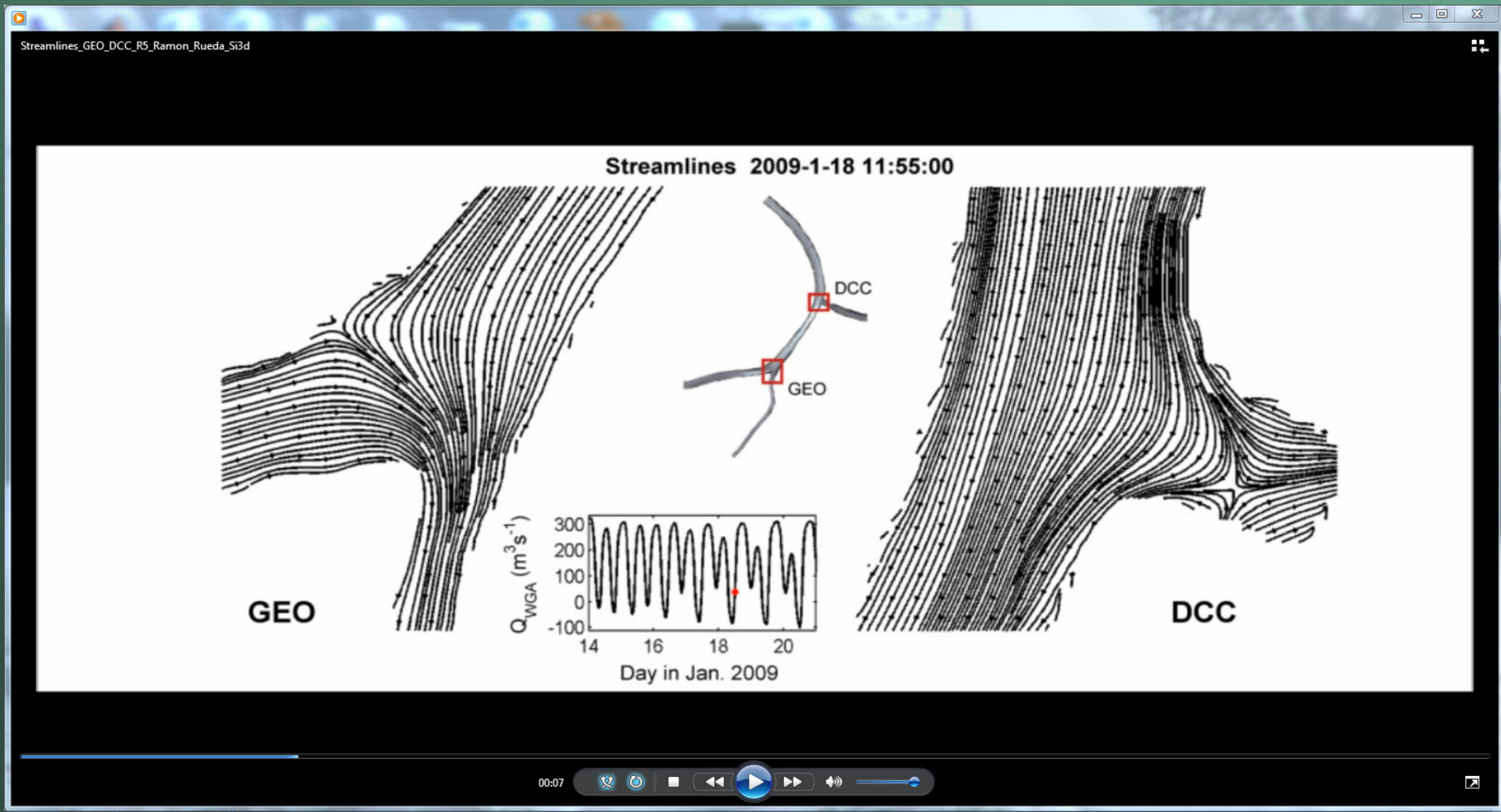
Discharge Ratios
in Georgiana Slough



Converging Flow in DCC
Reversing Flow in GEO
(typical with gate open)

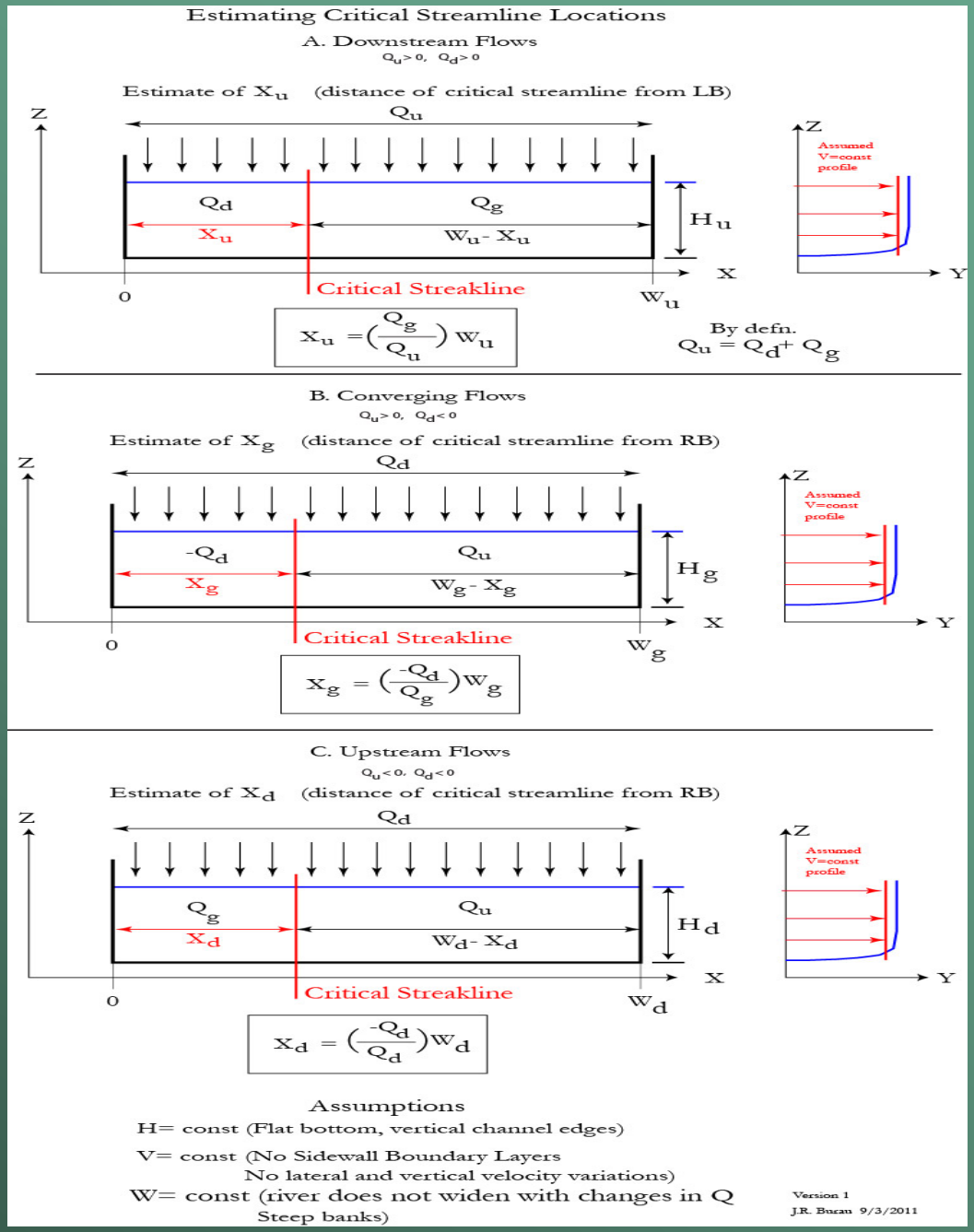


Converging Flow shifts from DCC to Geo
When DCC gates are closed!
Entrainment goes way up in GEO even though net flow their increases only slightly!
because the period of converging flow increases



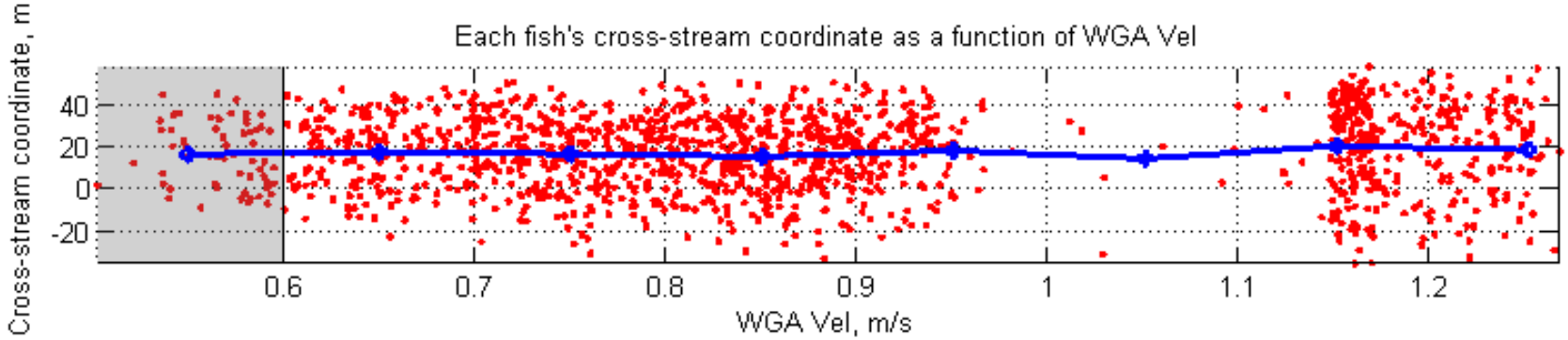
Conclusion:
The net flow is relevant to entrainment because it changes the tidal timescale velocity distributions at junctions

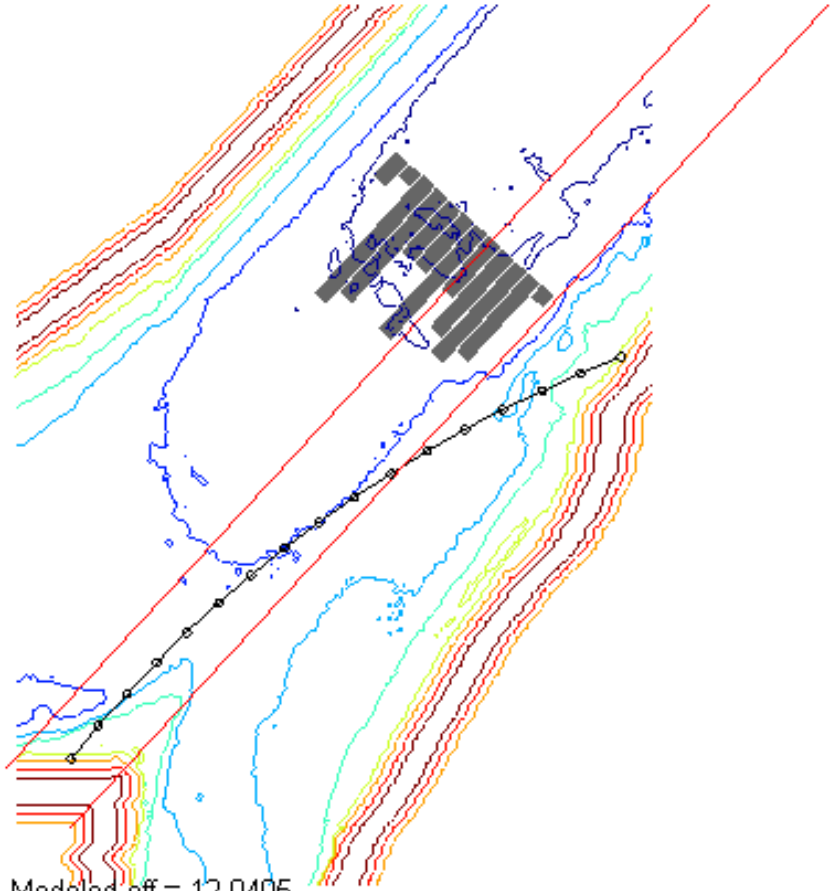
In a prismatic channel The streakline position is simply Xu = (Ru)(Wu)



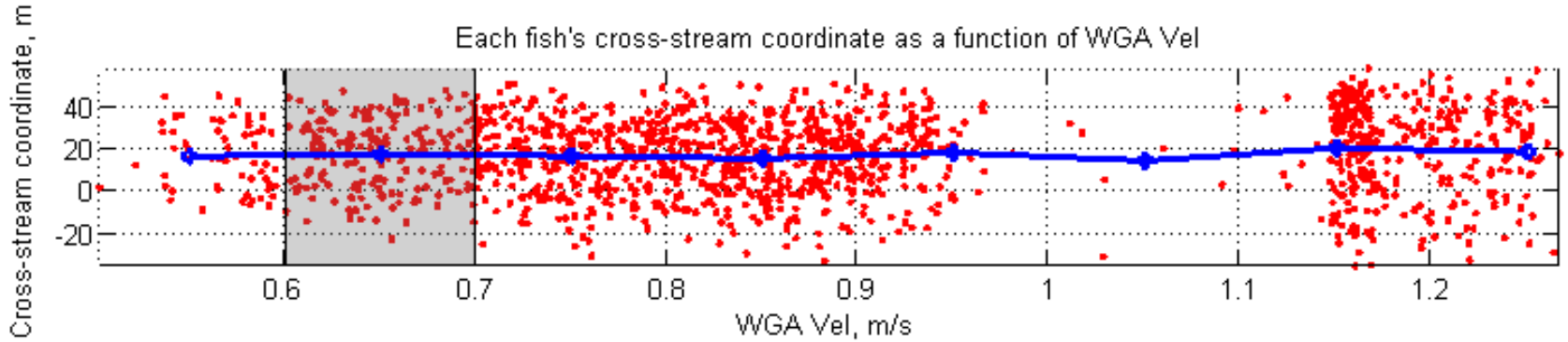
Putting it all together:

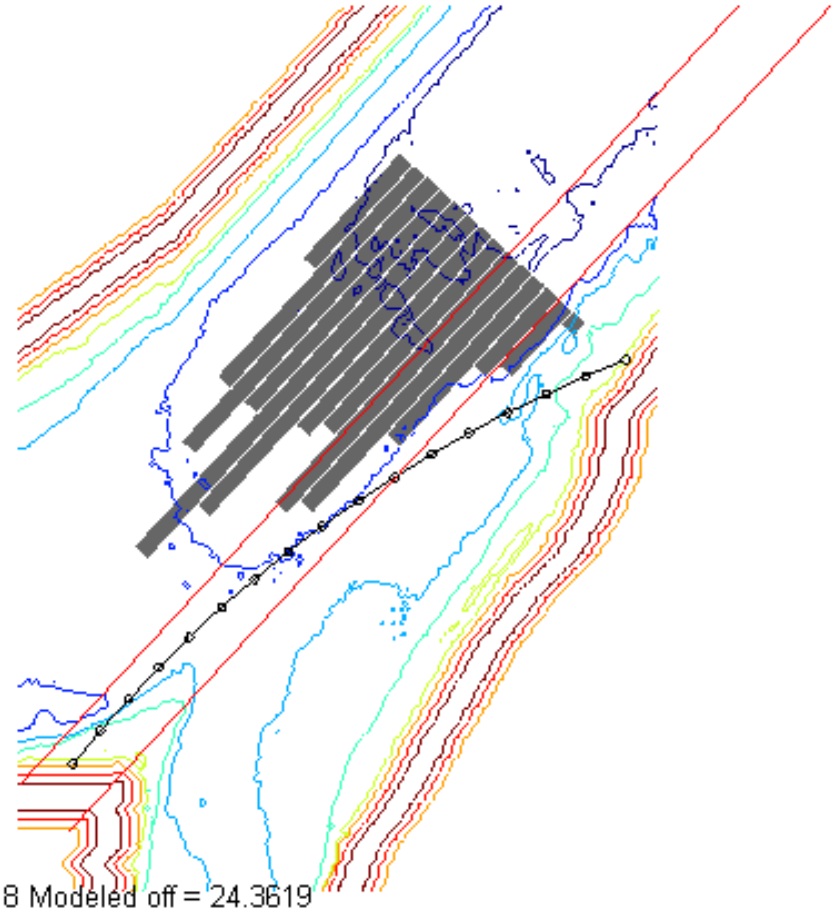
Simple mechanistic model of entrainment based on:
Fish entrance position in the junction relative to critical streakline position



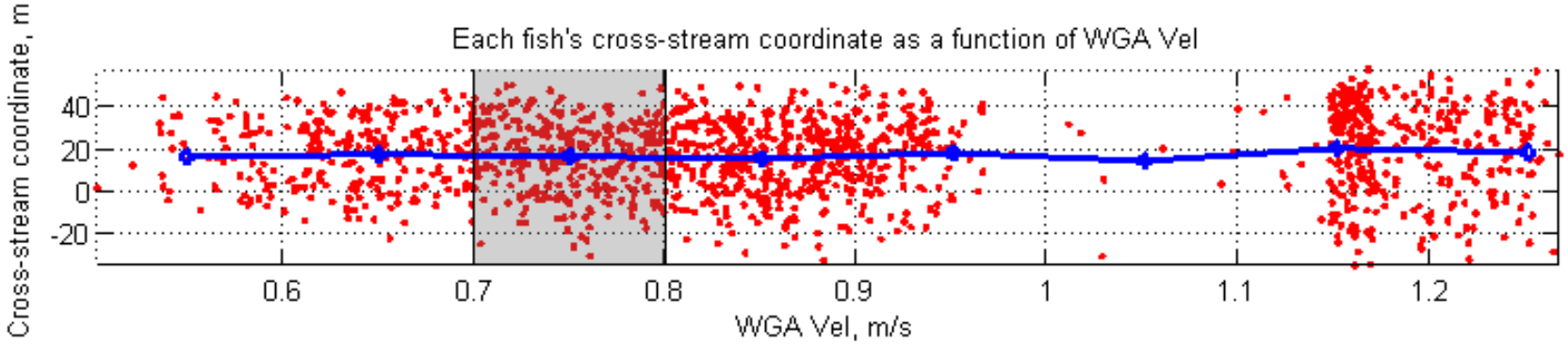


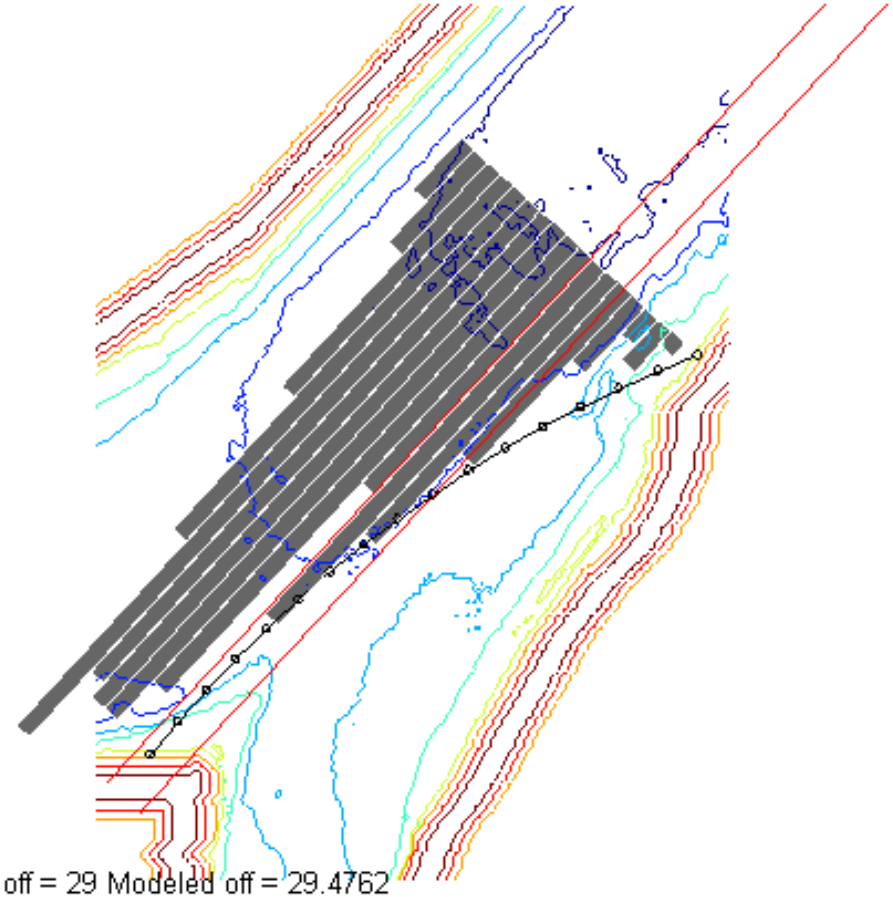
Actual off = 7 Modeled off = 12.0405
Actual on = 1 Modeled on = 0



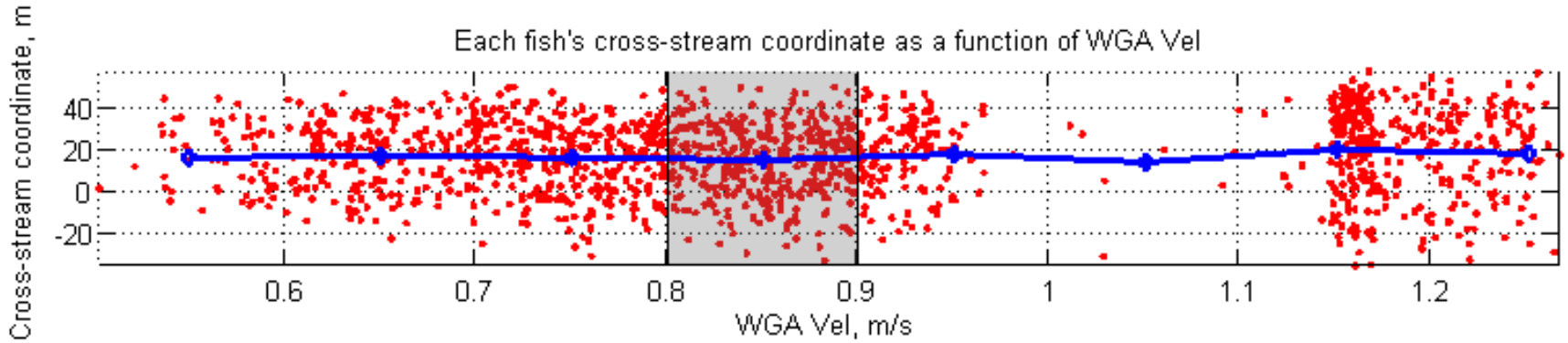


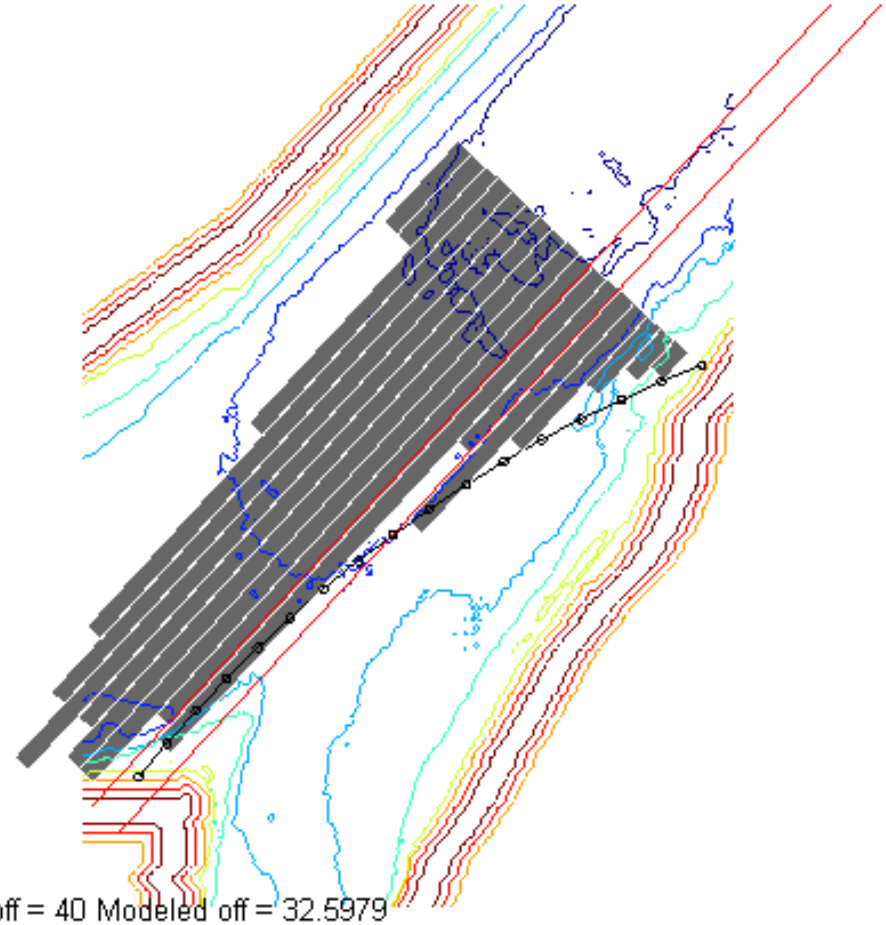
Actual off = 18 Modeled off = 24.3619
Actual on = 3 Modeled on = 1.5244



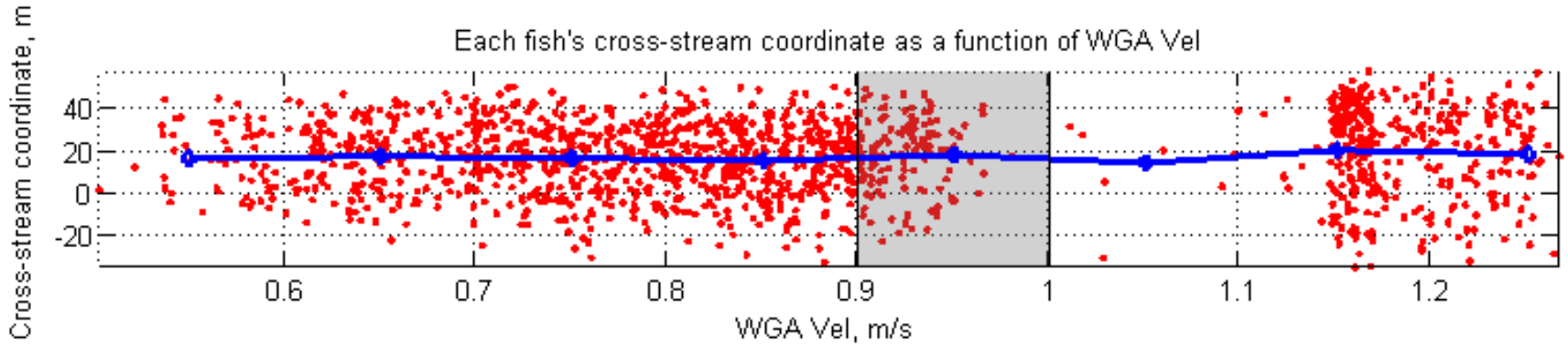


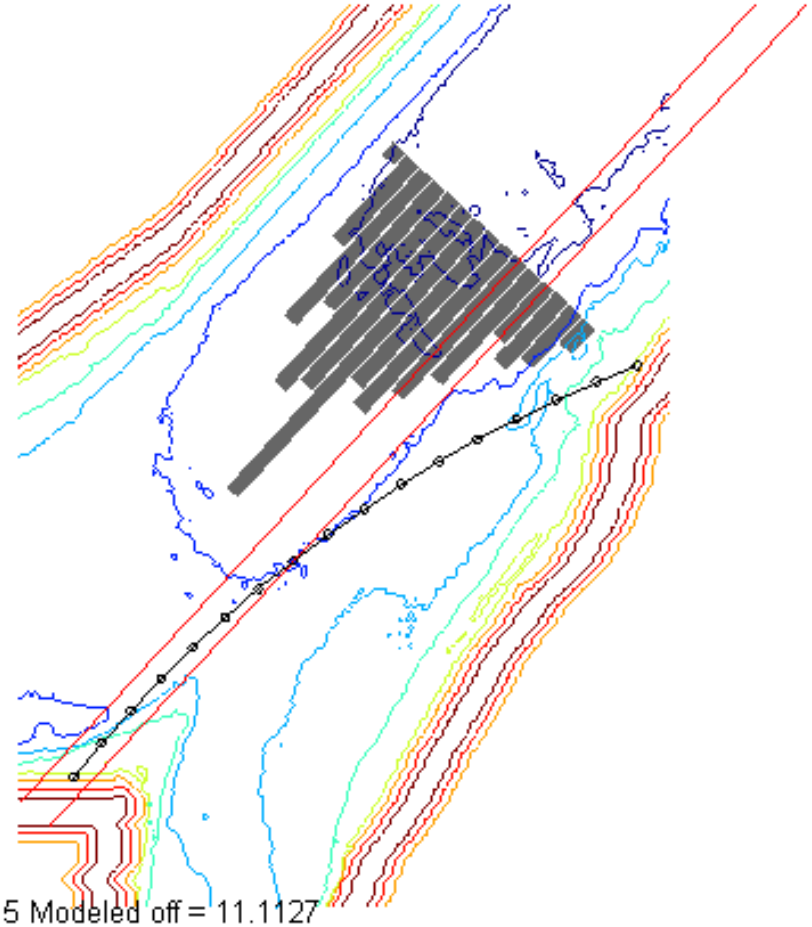
Actual off = 29 Modeled off = 29.4762
Actual on = 14 Modeled on = 6.023



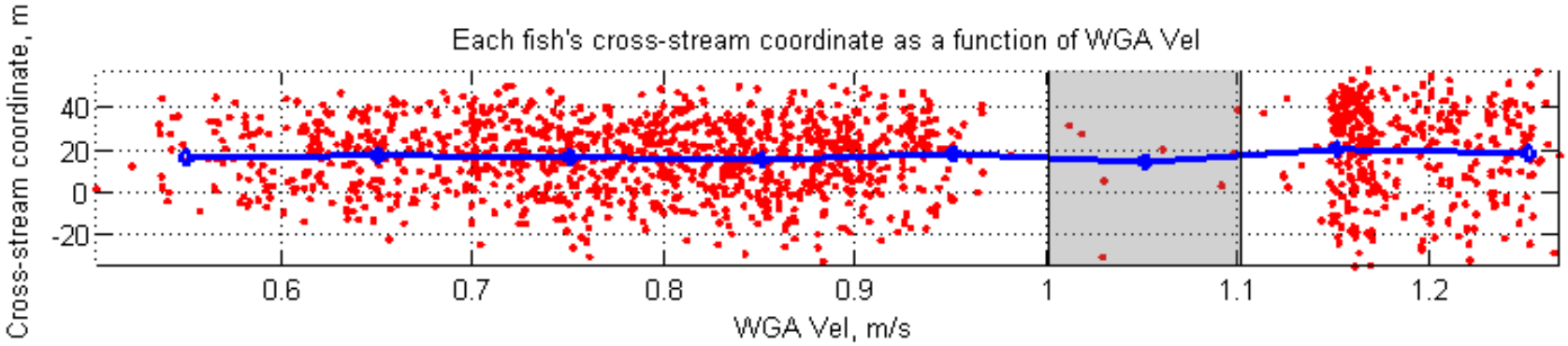


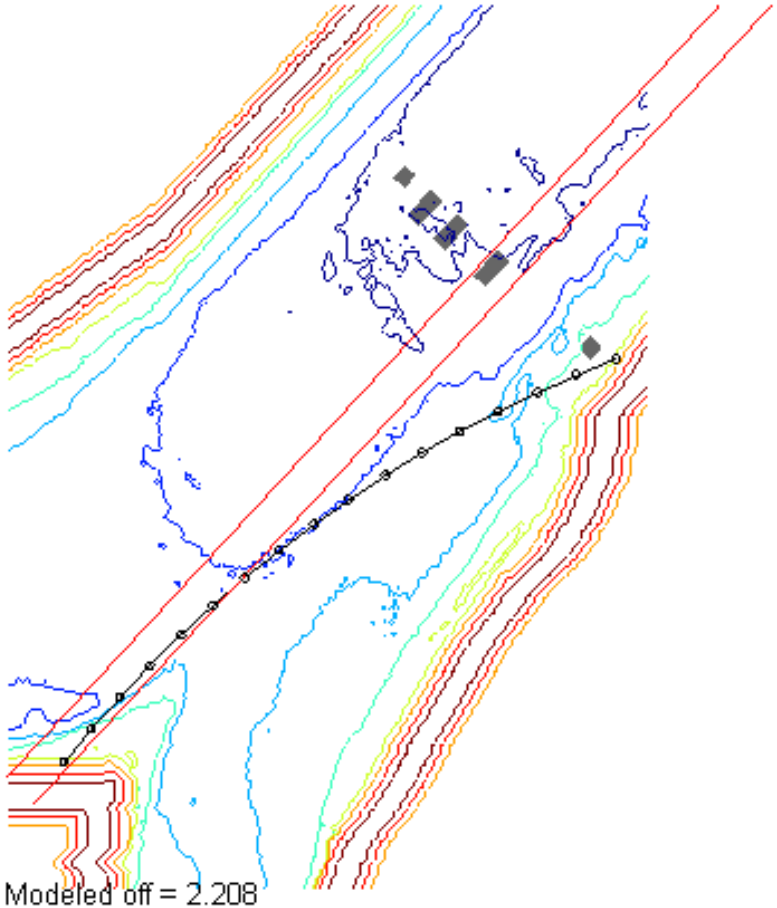
Actual off = 40 Modeled off = 32.5979
Actual on = 10 Modeled on = 17.0098



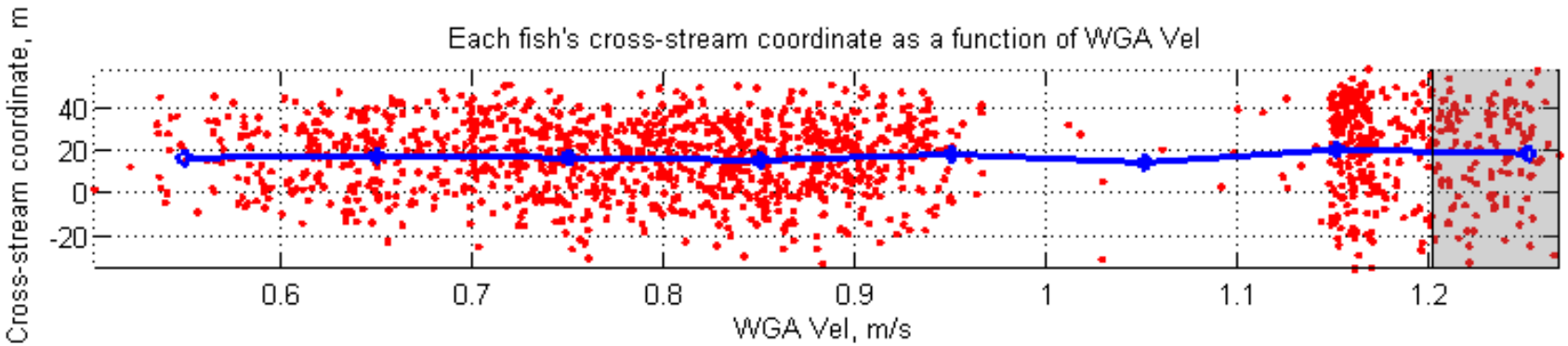


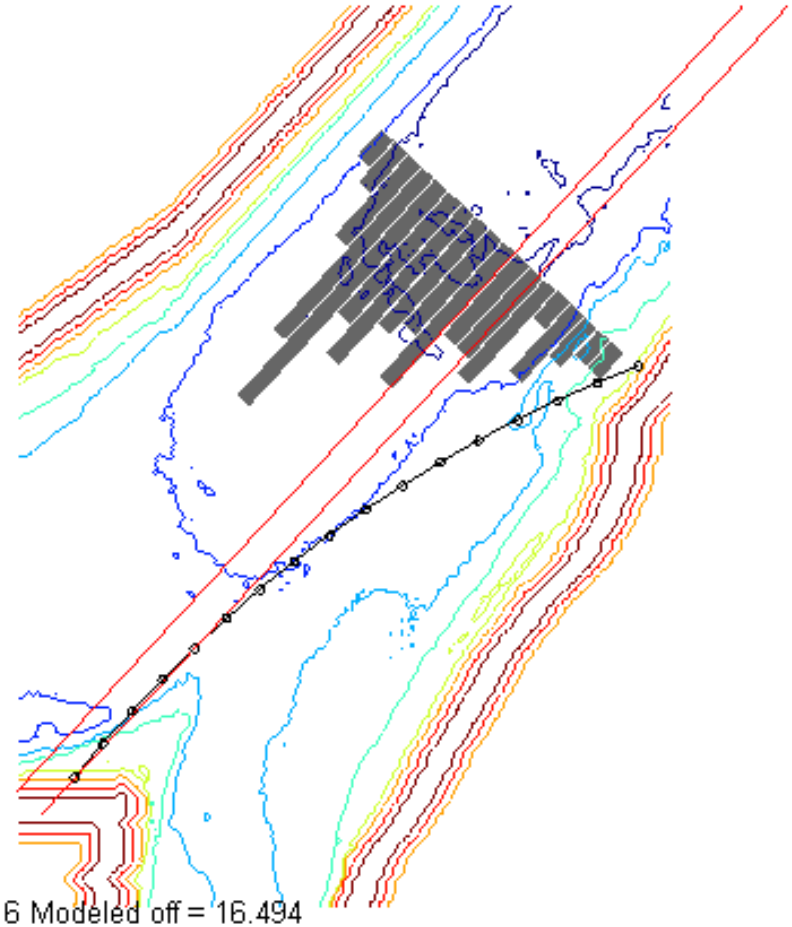
Actual off = 15 Modeled off = 11.1127
Actual on = 2 Modeled on = 5.8045





Actual off = 1 Modeled off = 2.208
Actual on = 0 Modeled on = 0





Actual off = 16 Modeled off = 16.494
Actual on = 12 Modeled on = 9.0659

Model performance

- Barrier Off
  - Incorrectly predicted the individual fate of 57 fish out of 387 – 85% individual accuracy
  - Under estimated entrainment by 0.394 fish out of 387 – 99.9% accuracy
- Barrier On
  - Incorrectly predicted the individual fate of 22 fish out of 370 - 94% individual accuracy
  - Under estimated entrainment by 0.894 fish out of 370 – 99.8% accuracy

Conclusions (a):

(1) Juvenile salmon are entrained based on their position relative to the critical streakline (a simple surrogate for the velocity field)

Conclusions (b):

(2) The trick in predicting entrainment will be in understanding entrance positions and arrival timing

(3) We are working on simple metrics (R, streakline position, etc.) that we hope will allow us to scale-up these detailed mechanics to the management timescales.

See DWR report entitled: Georgiana Slough Non-Physical Barrier Study 2012

Google: “GSNPB 2012”

Thanks!

Courtesy of Derek Stein (DFG)