Dye Movement in the Tahoe Keys:
Implications for Management of Aquatic Invasive Species Using Integrated Methods

Lars Anderson (USDA-ARS Retired)

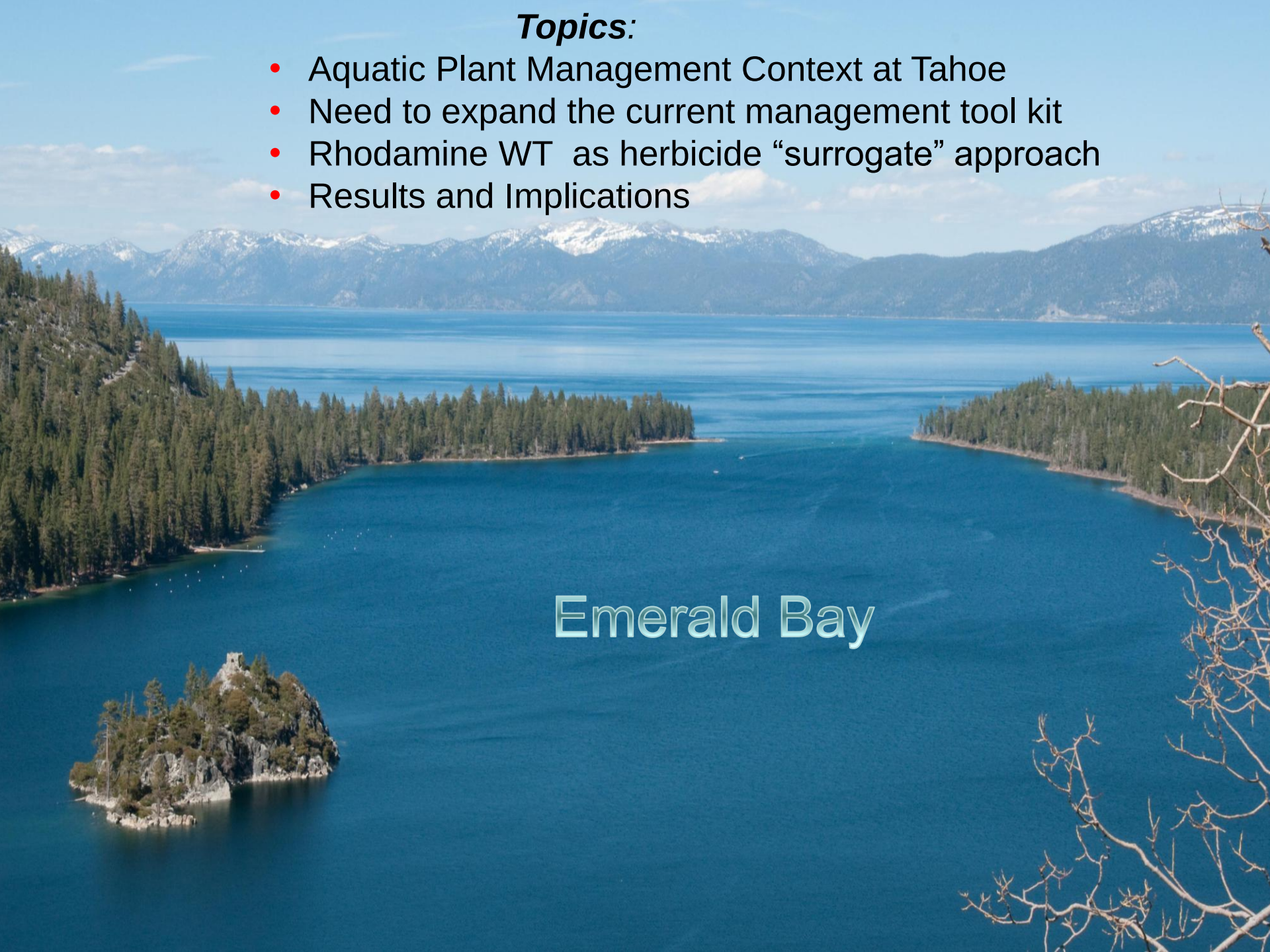
Acknowledgements:

Tom McNabb and Tom Moorhouse (Clean Lakes)

Ben Bradford & Vanessa Guzman (USDA- ARS), Tahoe Keys Property Owners Association, Tahoe Regional Planning Agency, Lahontan Regional Water Quality Control Board, Tahoe Resource Conservation District

***Topics**:*

- Aquatic Plant Management Context at Tahoe
- Need to expand the current management tool kit
- Rhodamine WT as herbicide “surrogate” approach
- Results and Implications



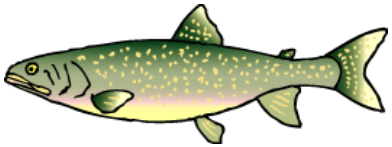
“Wicked Environmental Problems”
*Managing Uncertainty and Conflict**

- “...a high degree of scientific uncertainty and a profound lack of agreement on values, combined with the absence of a perfect solution…”
- Solution: “Learning Networks”
- *Consilience in Beliefs>Actions>Solutions*

(L. Anderson…2012)

*Peter J. Balint, Ronald E. Stewart, Anand Desai, Lawrence C Walters 2011, Island Press. 253 p.

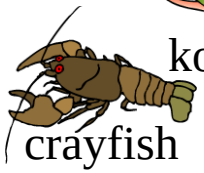
Lake Tahoe Exotic Aquatic Species Introduction (Detection) Timeline



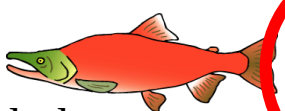
Establishment of lake trout

brown, rainbow, brook, lake trout

Mysis



crayfish

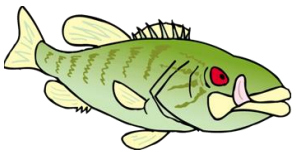


kokanee

Tahoe Keys Built

Eurasian watermilfoil

?



bass spp.

Curlyleaf pondweed

?

1st Zebra mussel Interdiction on boat- prevented from launching

Asian clam

Asian clam Removal begun

1880 1900 1920 1940 1960 1970 1980 1995 2003 2006 2007 2008 2011

RESPONSES

extirpation of cutthroat trout

& *Daphnia* spp.

USDA-ARS:Whole Lake Plant Surveys

AIS Working Group

ARS-TRCD Org. AIS Workshop

AIS Coordinating Committee; TRPA & USFWS Coordinators

AIS Plan Approved 2009, TRPA and USFWS appoint AIS coordinator

Tahoe Keys Project Started

After Sudeep Chandra (Univ.Nev-Reno); modified and updated by Lars Anderson (USDA-ARS-Davis, CA)

Adaptive Integrated AIS Management

- ✓ Maximize efficacy through an optimal choice and timing of control methods
- ✓ Minimize adverse impacts
- ✓ Coordinate actions to facilitate management of *all* AIS taxa
- ✓ Document and assess impacts of management actions
- ✓ Adjust future management actions


South Lake Tahoe
Tahoe Keys
West Basin
Entrance
East Basin
Entrance

Non-native and nuisance plants in the Tahoe Keys:

- Eurasian watermilfoil (*Myriophyllum spicatum*)
- Curlyleaf pondweed (*Potamogeton crispus*)
- Native Coontail (*Ceratophyllum demersum*)

M. spicatum

P. crispus

P. crispus turions:
Produced in early summer;
Sprout in fall

Eurasian watermilfoil-
Lake Tahoe December-2008

“Andian milfoil” (native)
Myriophyllum quitense

Current Prevention Measures

- Vessel Inspections: *No inspector = No launch*
- Mandatory inspection (TRPA)
  - Extensive Inspection & Decontamination (Major Highway Stations)
- CDFG Code 2301
- $5000 fine for decontamination refusal
- Signage, fliers, workshops
- Other public outreach *Examples of Signage:*

Current AIS Management Tools

- Harvesting
- Hand-pulling
- Benthic barriers
- Diver-assisted
- Electro-shocking (warmwater fish removal)

Photo: Lars Anderson

- ***No Herbicides or Molluscicides permitted at this time***

New Tools for IPM at Tahoe ?

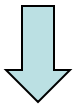
Potential for Use of Aquatic Pesticides-
Proposed Basin Plan Amendment

- **Lahontan Regional Water Quality Control Board Approved Basin Plan Changes (2011)**
- **State Water Resources Board Approved 2012**
- **Federal EPA review- Summer 2012?**
- **Rhodamine WT Study: 2011-2012**

Specific Objectives of Tahoe Keys Project

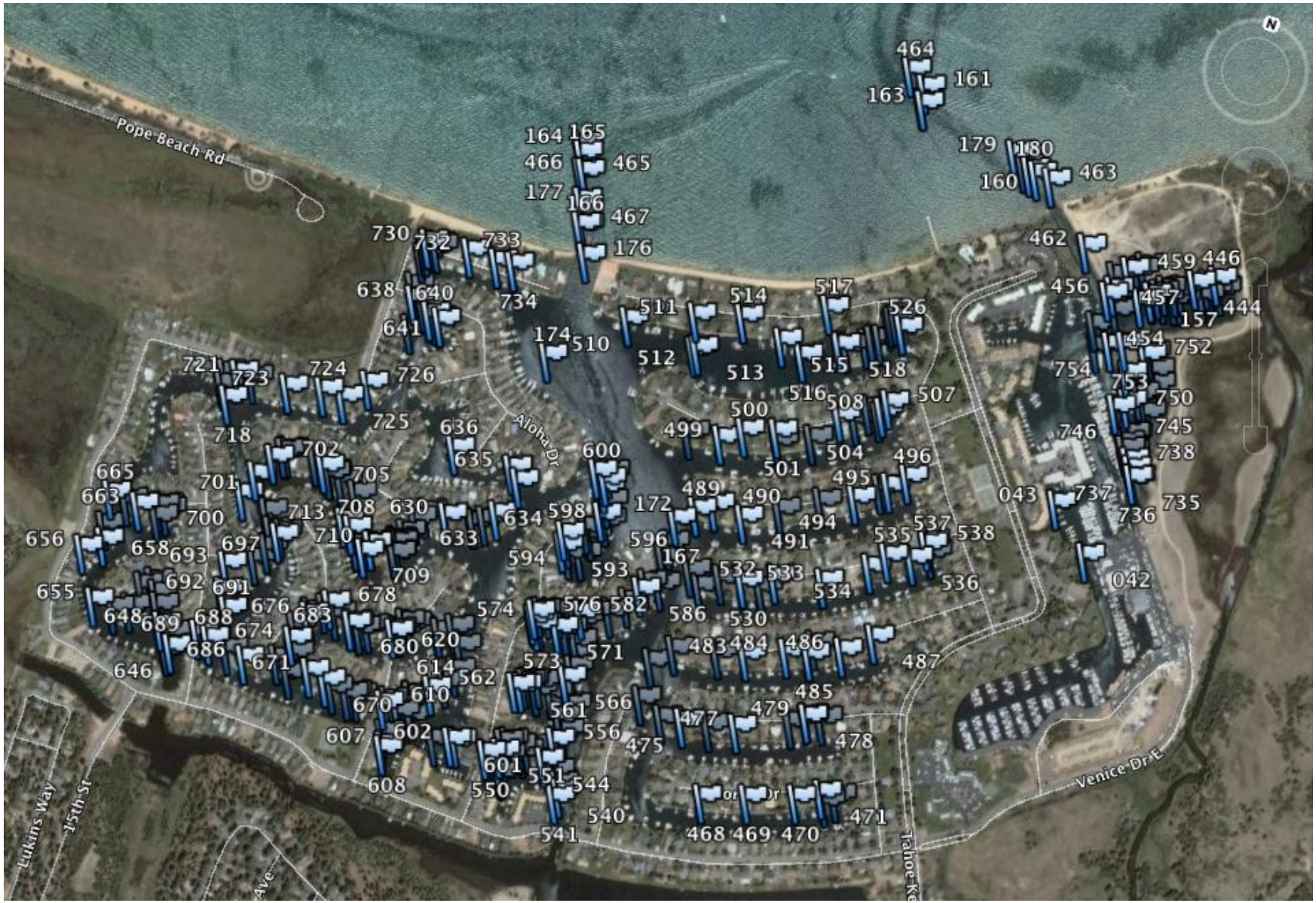
- Compare/ Assess Efficacy and Impacts of Bottom Barriers vs. Standard Cutting/Harvest/Remova
- **Determine Movement and Dissipation of Rhodamine WT (dye) as a Surrogate for Aquatic Herbicides.**
- Obtain Baseline Data on Benthic Invertebrates (sediment sampling).
- Determine Feasibility of Using Mechanical Removal Methods to Manage Non-Native Warmwater Fish

Outcome



- ✓Develop BMPs for AIS Management at Tahoe Keys (and Lake Tahoe)
- ✓Provide Basis for Any Future Applications for Using Aquatic Herbicides
- ✓Provide Background Data for Subsequent Programmatic EIR/EIS

Tahoe Keys


Pope Beach Rd
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Venice Dr E
Tahoe Ke
Lukins Way
25th St
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161
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610
561
566
479
607
602
556
475
478
601
551
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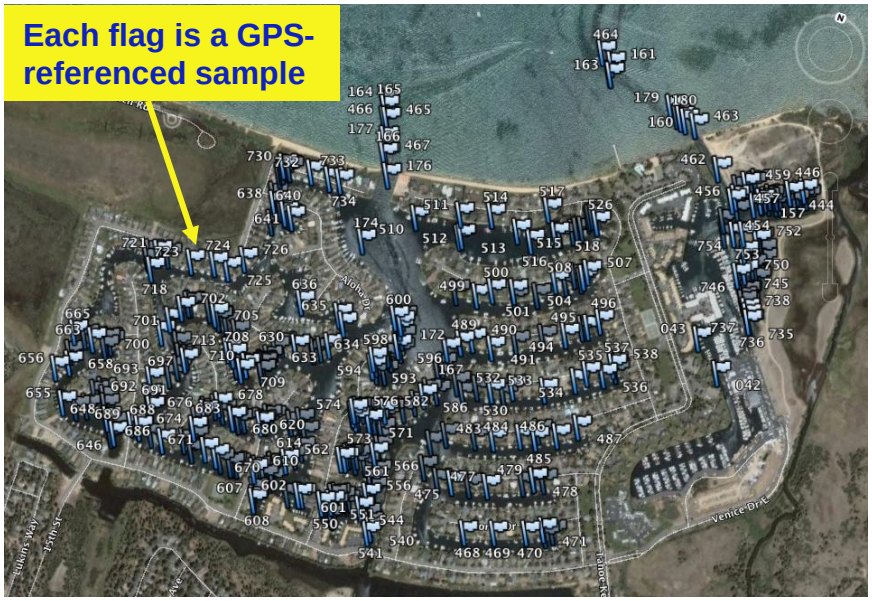
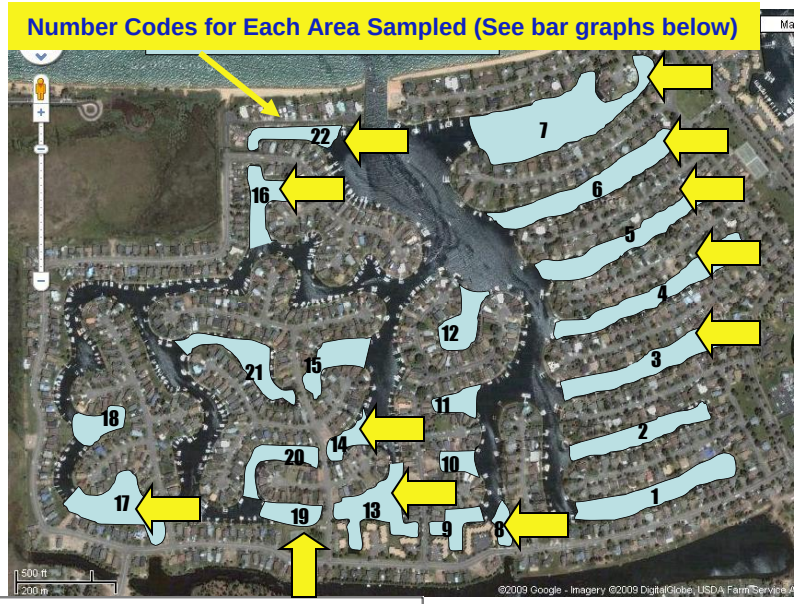
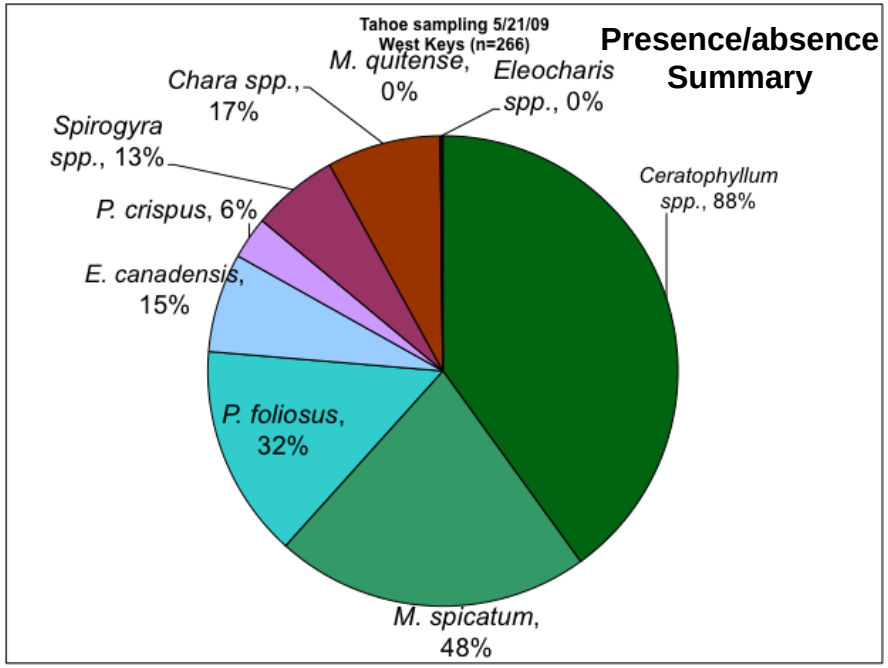
469
470
471
541

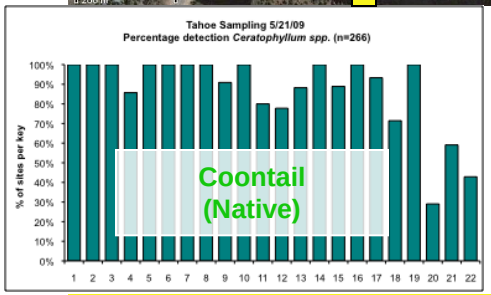
USDA -ARS Tahoe Keys Survey: **May 21, 22, 2009**

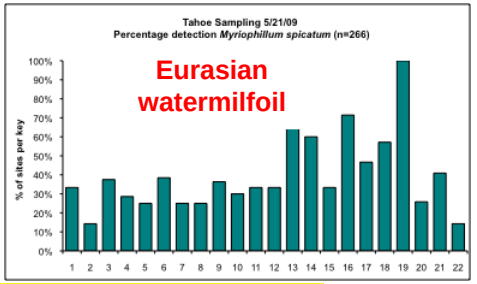
315 Samples Taken (includes 266 samples in the West Basin)



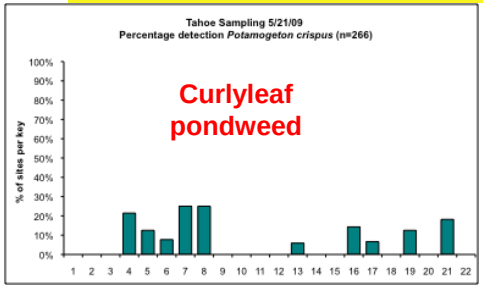


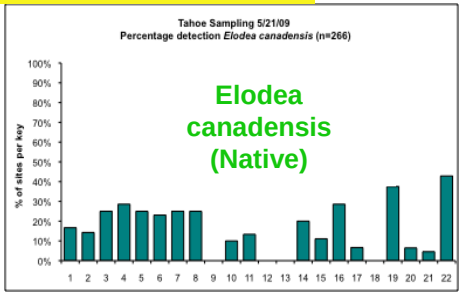






Number Codes for Each Area Sampled

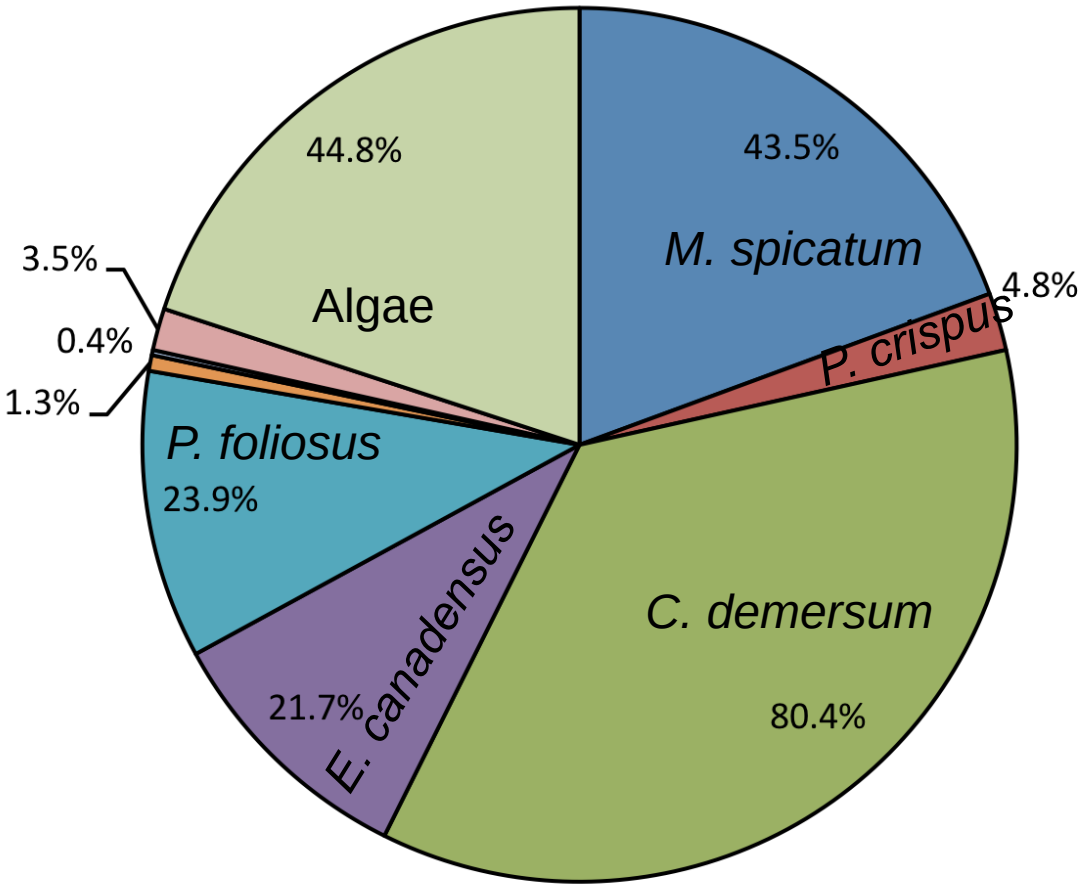




Number Codes for Each Area Sampled

Tahoe Keys submersed aquatics, **April 27, 2011**

Frequency of occurence (average of West Basin)

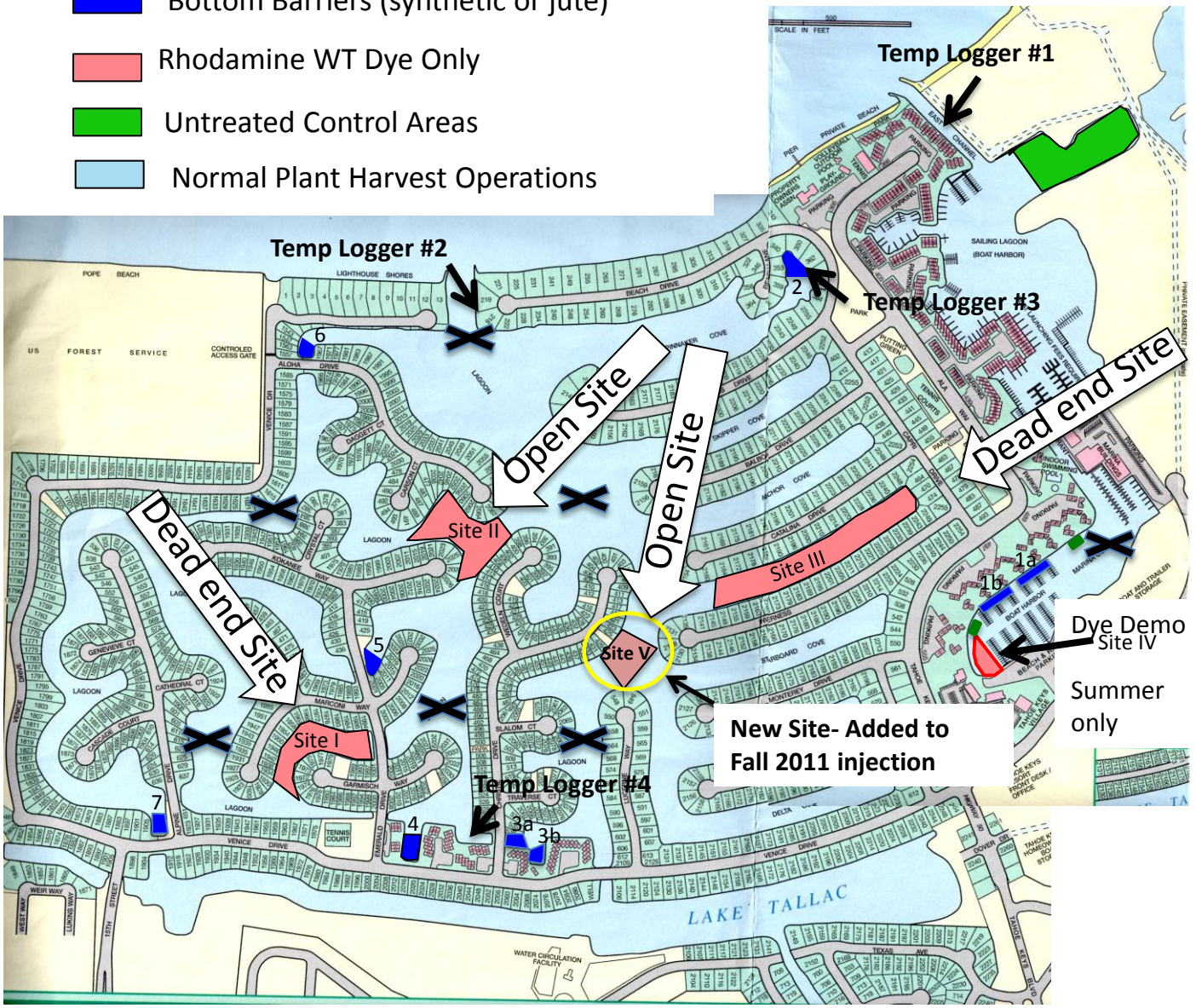


- Eurasian watermilfoil
  Myriophyllum spicatum
- Curlyleaf pondweed
  Potamogeton crispus
- Coontail
  Ceratophyllum demersum
- Common elodea
  Elodea canadensis
- Leafy pondweed
  Potamogeton foliosus
- American pondweed
  Potamogeton nodosus
- Andean watermilfoil
  Myriophyllum quitense
- Dwarf spikerush
  Eleocharis spp.
- Filamentous algae
  [Nitella, Chara, Spirogyra]

Tahoe Keys Rhodamine WT Dye Studies July 2011 and October 2011 Injection Sites

Legend

- Fixed Dye Sample Station
- Bottom Barriers (synthetic or jute)
- Rhodamine WT Dye Only
- Untreated Control Areas
- Normal Plant Harvest Operations



Measuring Fluorescence of Rhodamine WT

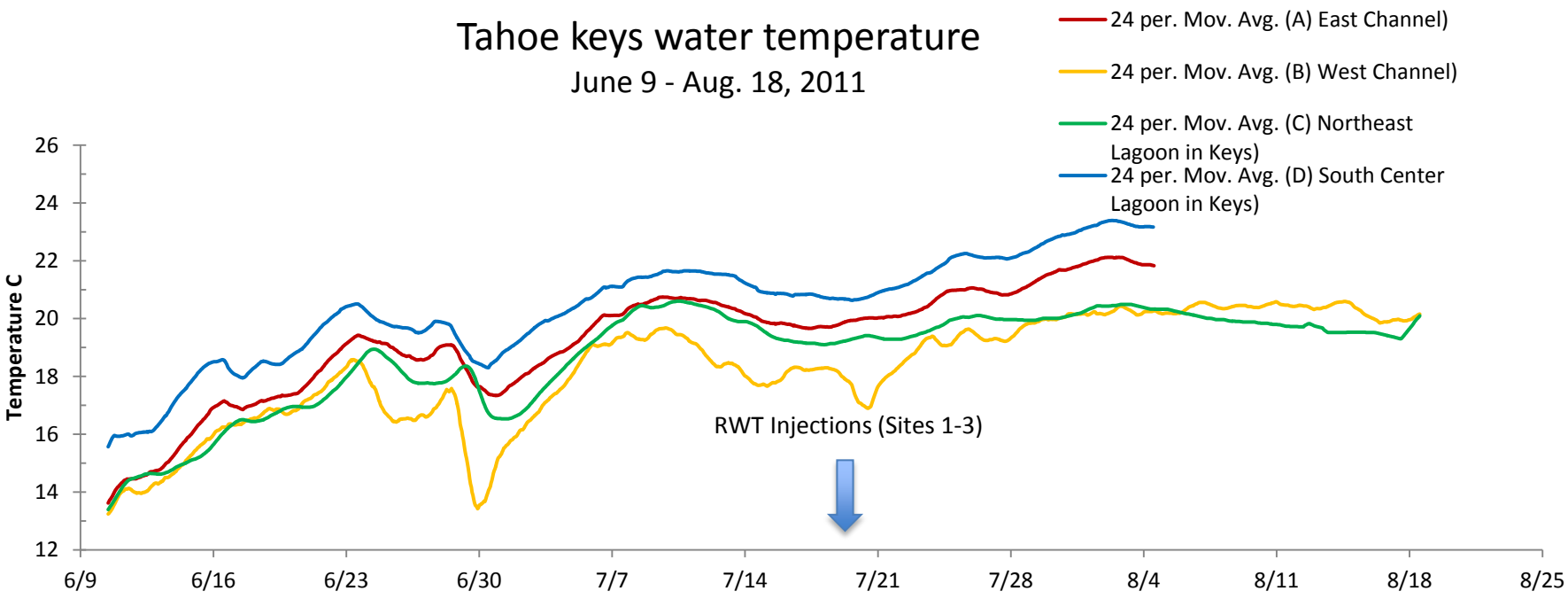
Flow-through fluorometer:
Continuous measurement of dye fluorescence calibrated to concentration (detects to ca. 50 pp trillion)

Water is pumped from pre-determined depth to bottom of flow-through cuvette

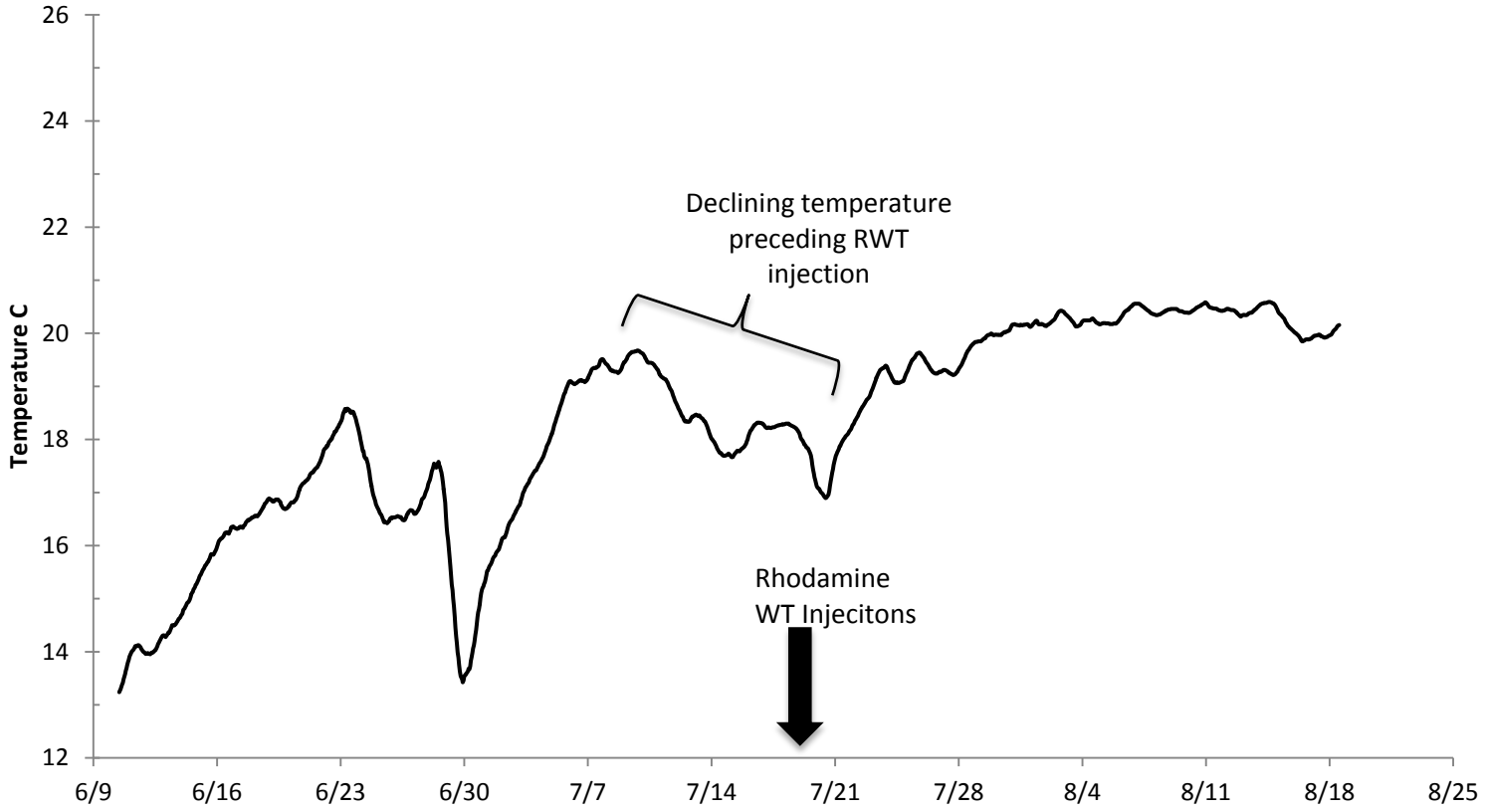
- Detection level in parts per trillion (0.050 parts per billion)
- Instantaneous monitoring (real-time)
- Target level: 5 to 10 ppb (parts per billion) after mixing
- Surrogate for *movement* and *dilution*

  -But NOT for half-life of herbicide active ingredient

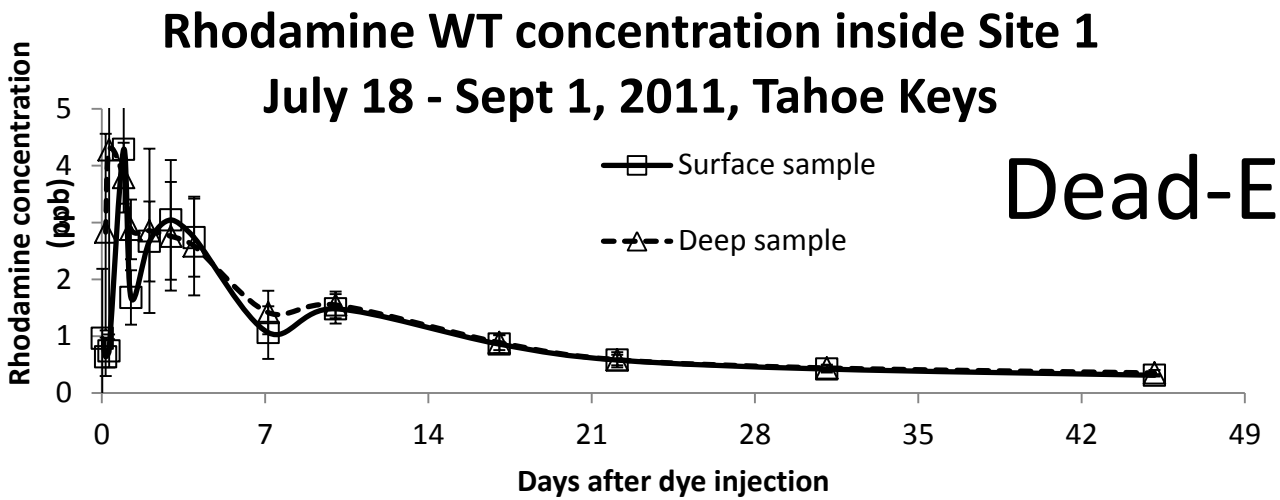
Bottom Water Temperatures- Tahoe Keys
June 9 to Aug. 18 2011



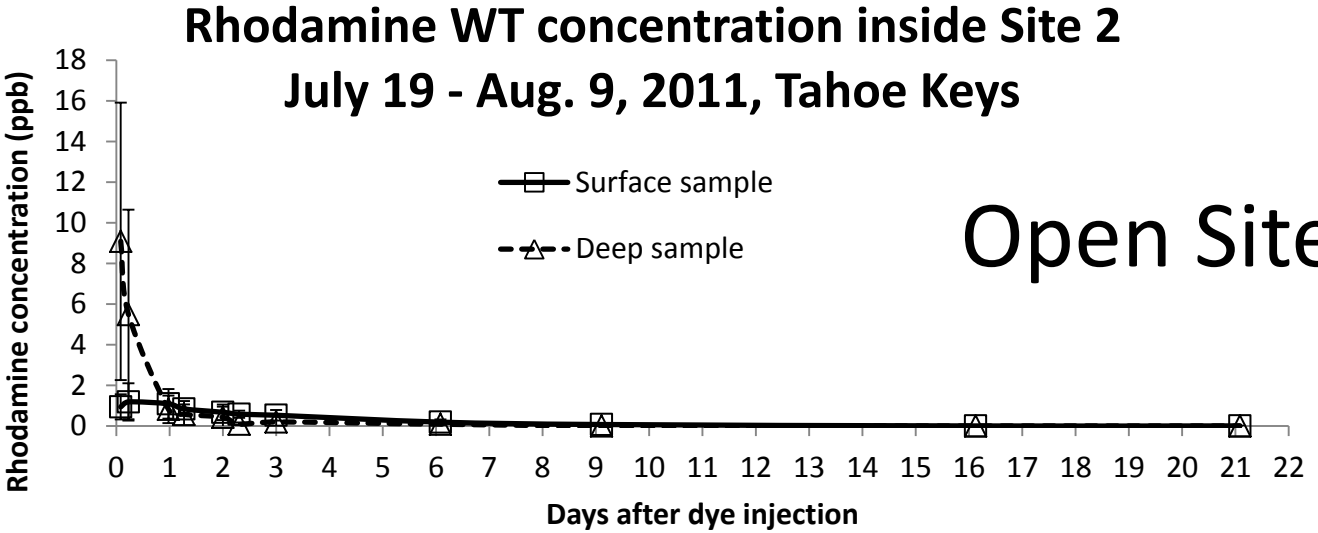
Bottom Water Temperature in West Basin Channel



Comparison of Rhodamine Dissipation in Sites 1,2,3

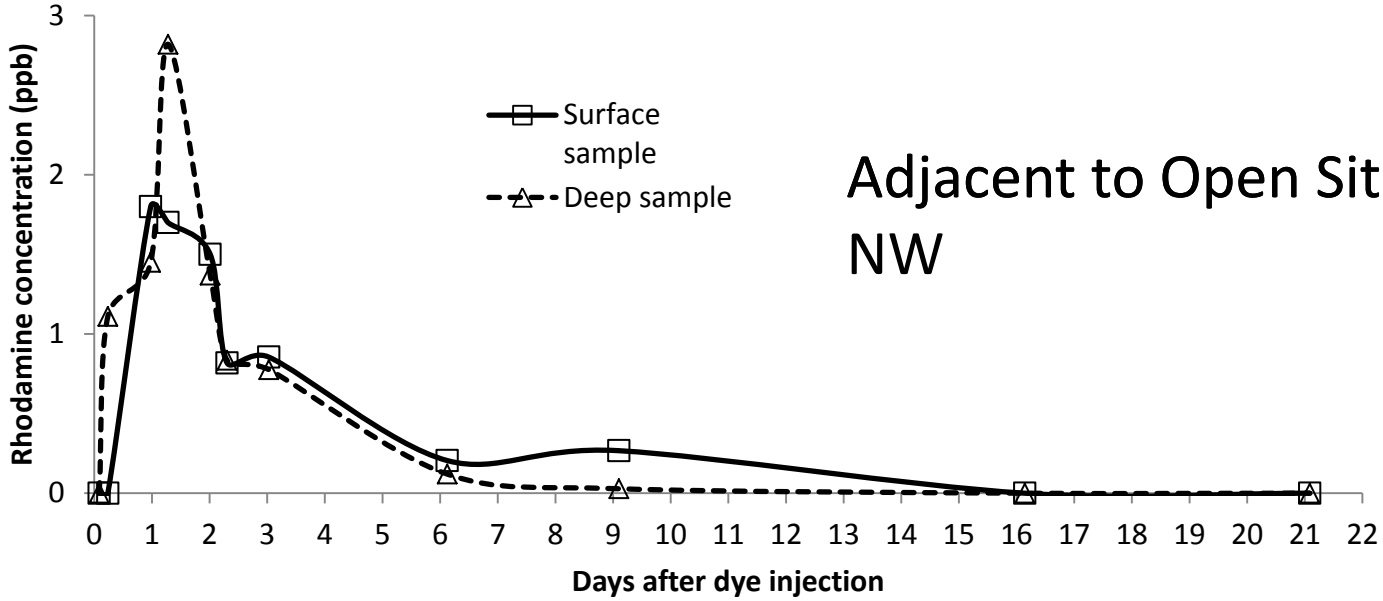


Dead-End Site



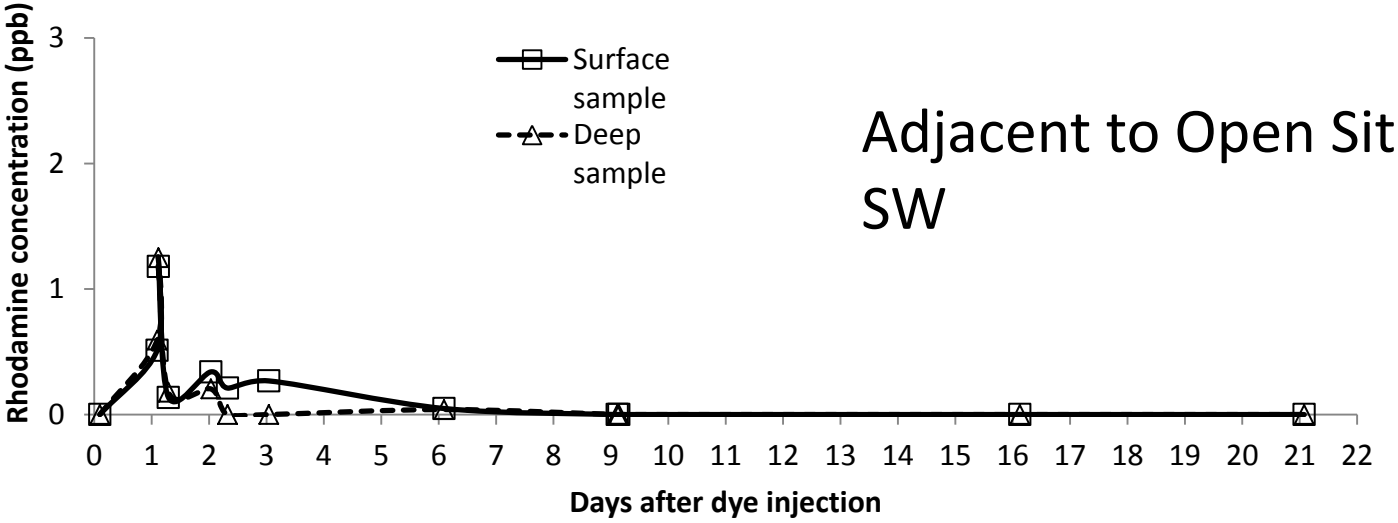
Open Site

Rhodamine WT concentration outside Site 2 @ NW buoy
July 19 - Aug. 9, 2011, Tahoe Keys

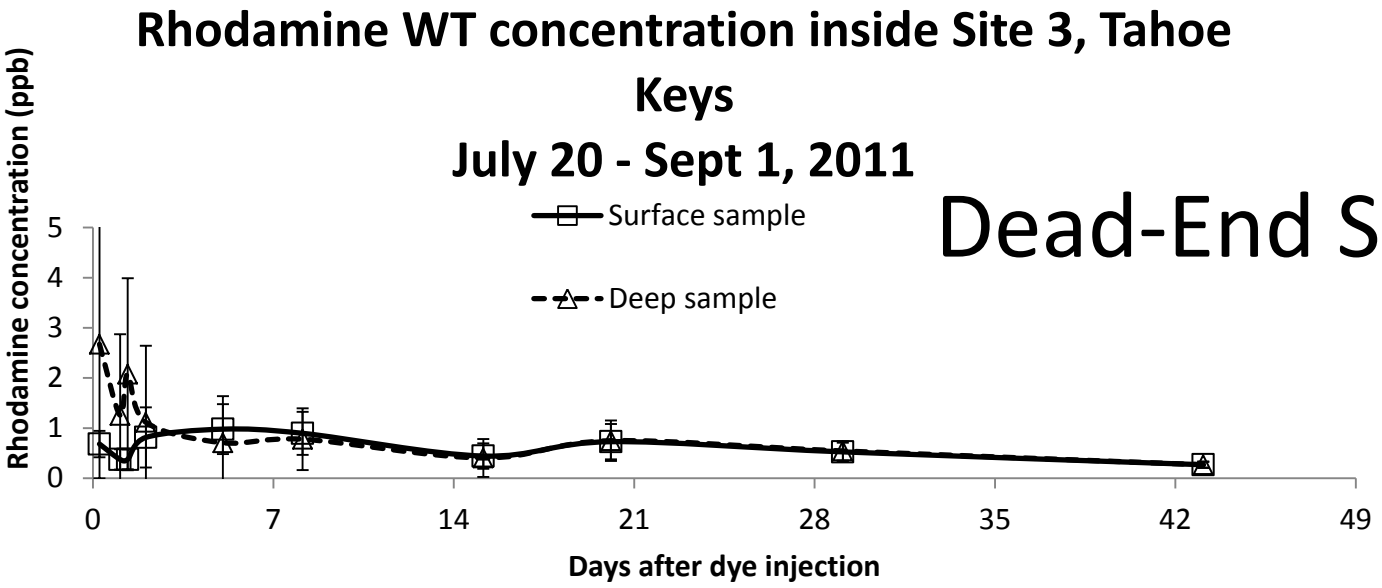


Adjacent to Open Site: NW

Rhodamine WT concentration outside Site 2 @ SW buoy
July 19 - Aug. 9, 2011, Tahoe Keys

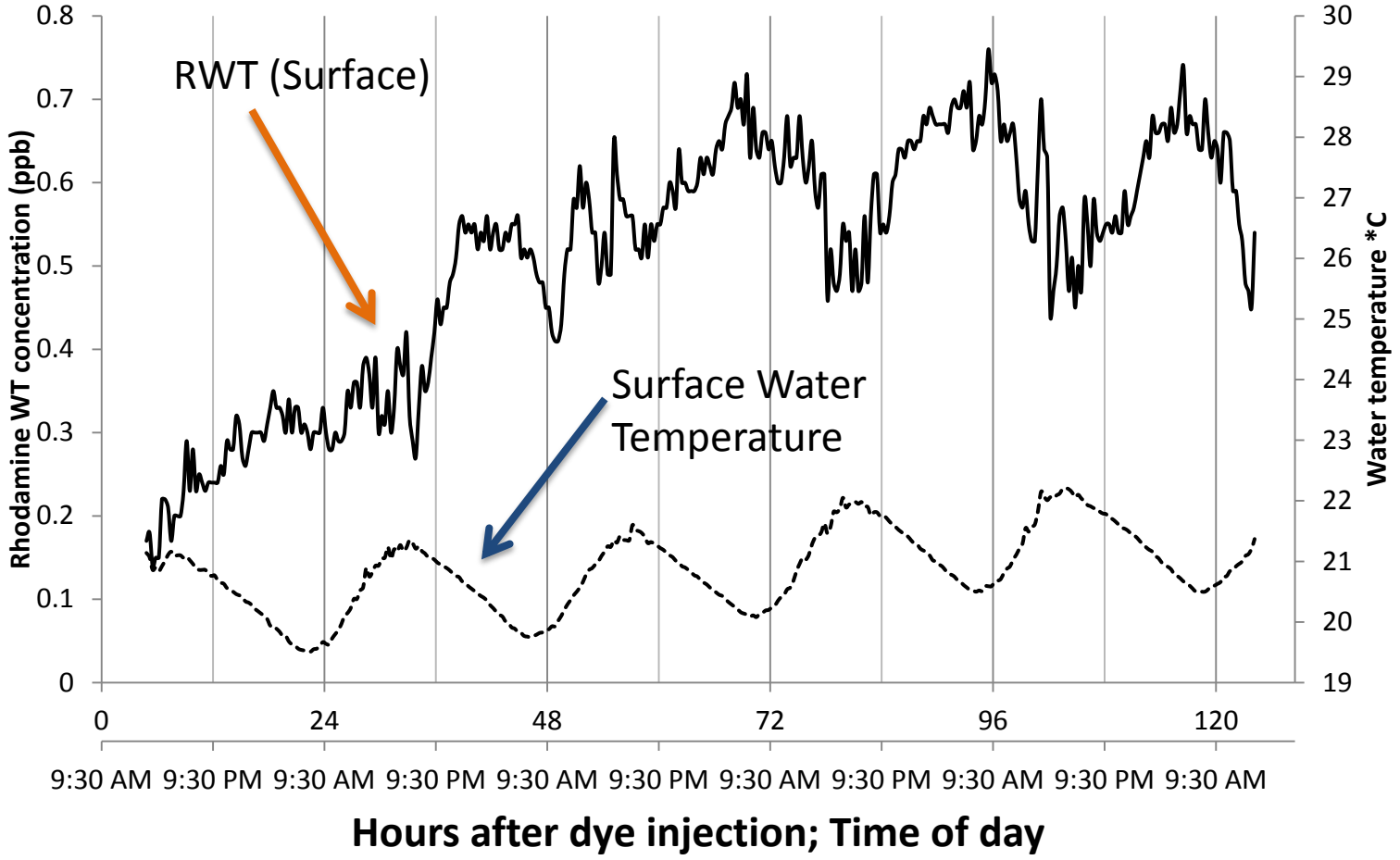


Adjacent to Open Site: SW

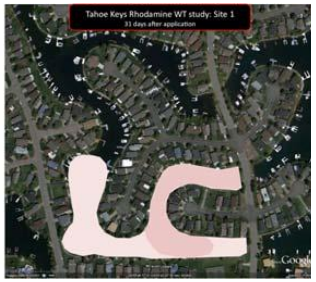


Dead-End Site

Site 1: Effect of Diurnal Temperature on RWT Mixing



Rhodamine WT Dye Dispersion (Sites 1-3)-Summer (July 17,18 Injections)



Site 1 7.5 h 1.25 Day 2 Days 31 Days 45 Days

DEAD END

Site 3 6 h 1 Day 2 Days 29 Days 43 Days

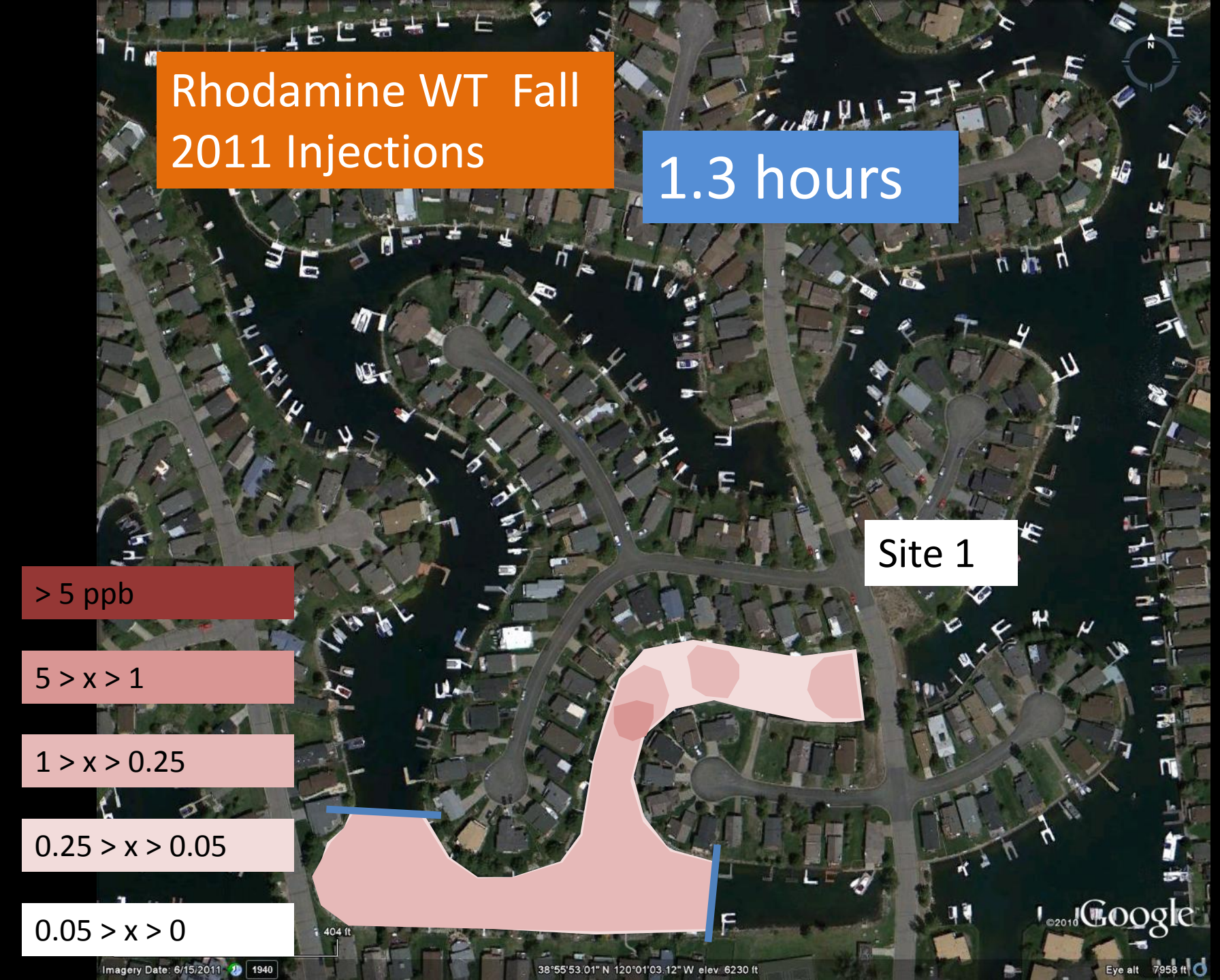
DEAD END

Site 2 2 h 5.5 h 1 Day 1.25 Days 6 Days

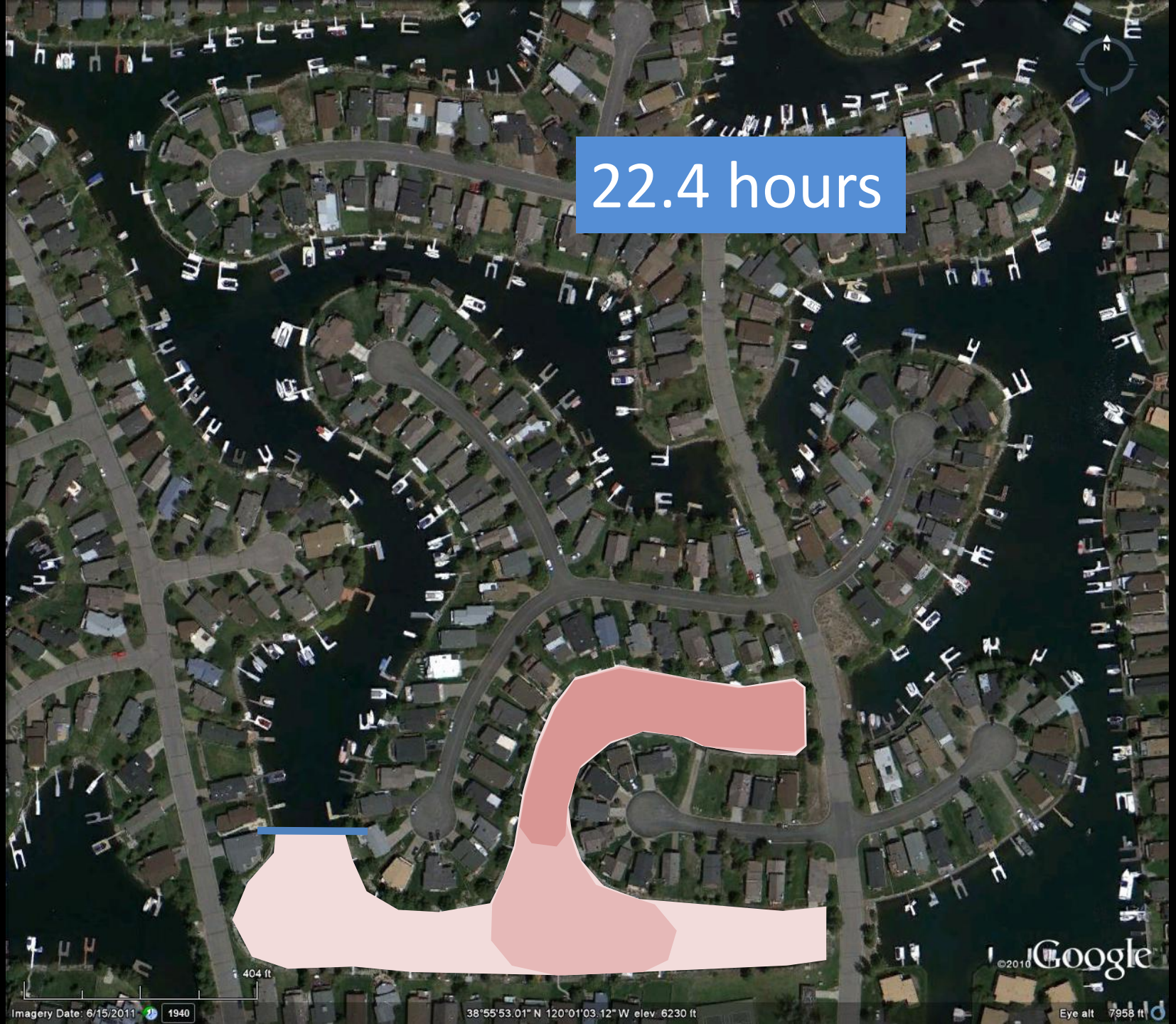
OPEN

Rhodamine WT Concentrations in Polygons

> 5 ppb	>1 <5 ppb	>.25 <1 ppb	>0 <0.25 ppb


Rhodamine WT Fall 2011 Injections
1.3 hours
Site 1
> 5 ppb
5 > x > 1
1 > x > 0.25
0.25 > x > 0.05
0.05 > x > 0
404 ft
Imagery Date: 6/15/2011
1940
38°55'53.01" N 120°01'03.12" W elev 6230 ft
Eye alt 7958 ft
©2010 Google


4.1 hours
404 ft
©2010 Google
Imagery Date: 6/15/2011
1940
38°55'53.01" N 120°01'03.12" W elev 6230 ft
Eye alt 7958 ft

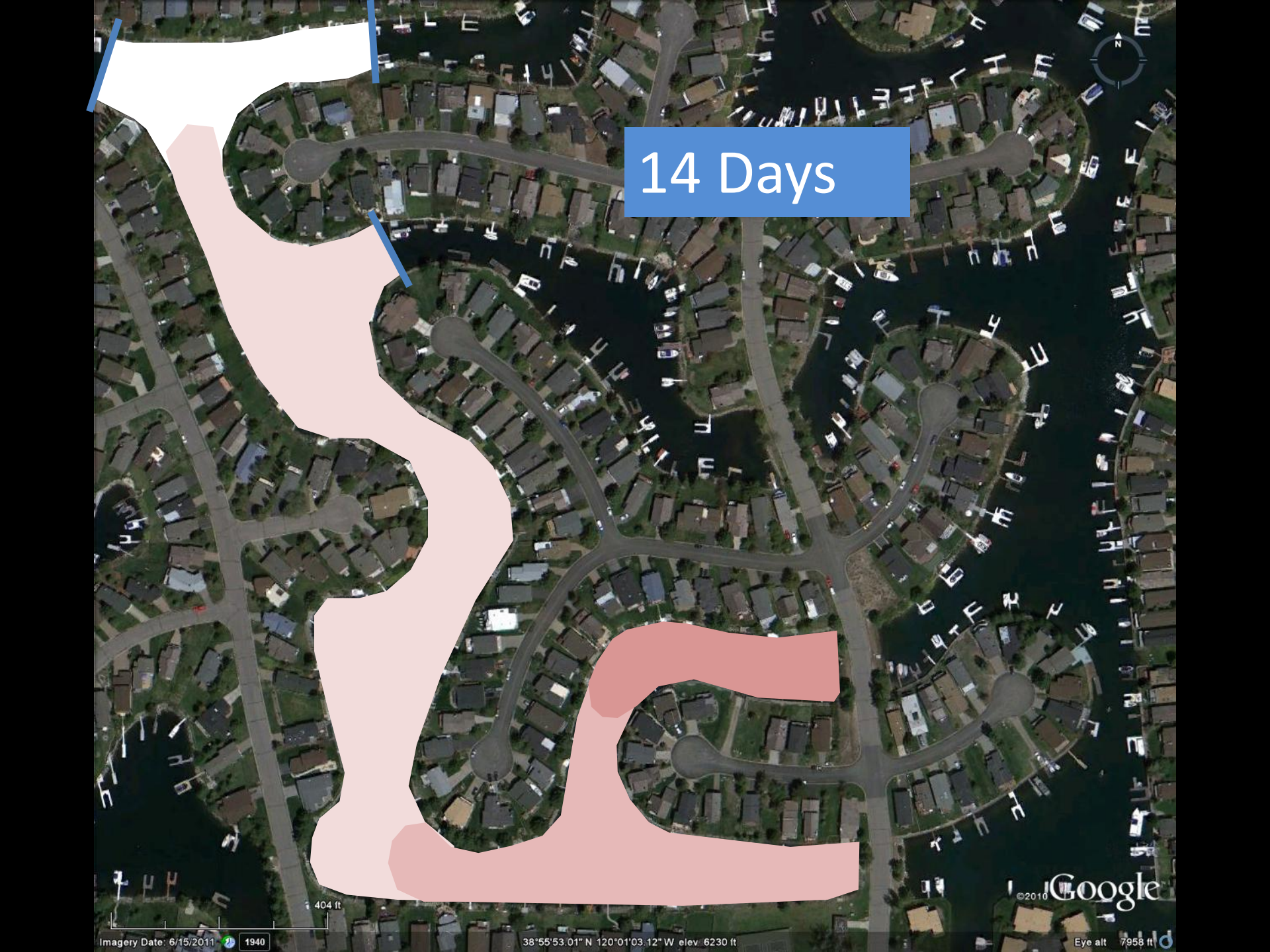

22.4 hours
404 ft
©2010 Google
Imagery Date: 6/15/2011
1940
38°55'53.01" N 120°01'03.12" W elev 6230 ft
Eye alt 7958 ft


28.7 hours
404 ft
©2010 Google
Imagery Date: 6/15/2011
1940
38°55'53.01" N 120°01'03.12" W elev 6230 ft
Eye alt 7958 ft


48 hours
404 ft
©2010 Google
Imagery Date: 6/15/2011
1940
38°55'53.01" N 120°01'03.12" W elev 6230 ft
Eye alt 7958 ft


5 Days
404 ft
©2010 Google
Imagery Date: 6/15/2011
1940
38°55'53.01" N 120°01'03.12" W elev 6230 ft
Eye alt 7958 ft


8 Days
404 ft
Imagery Date: 6/15/2011
1940
38°55'53.01" N 120°01'03.12" W elev 6230 ft
Eye alt 7958 ft
©2010 Google


14 Days
404 ft
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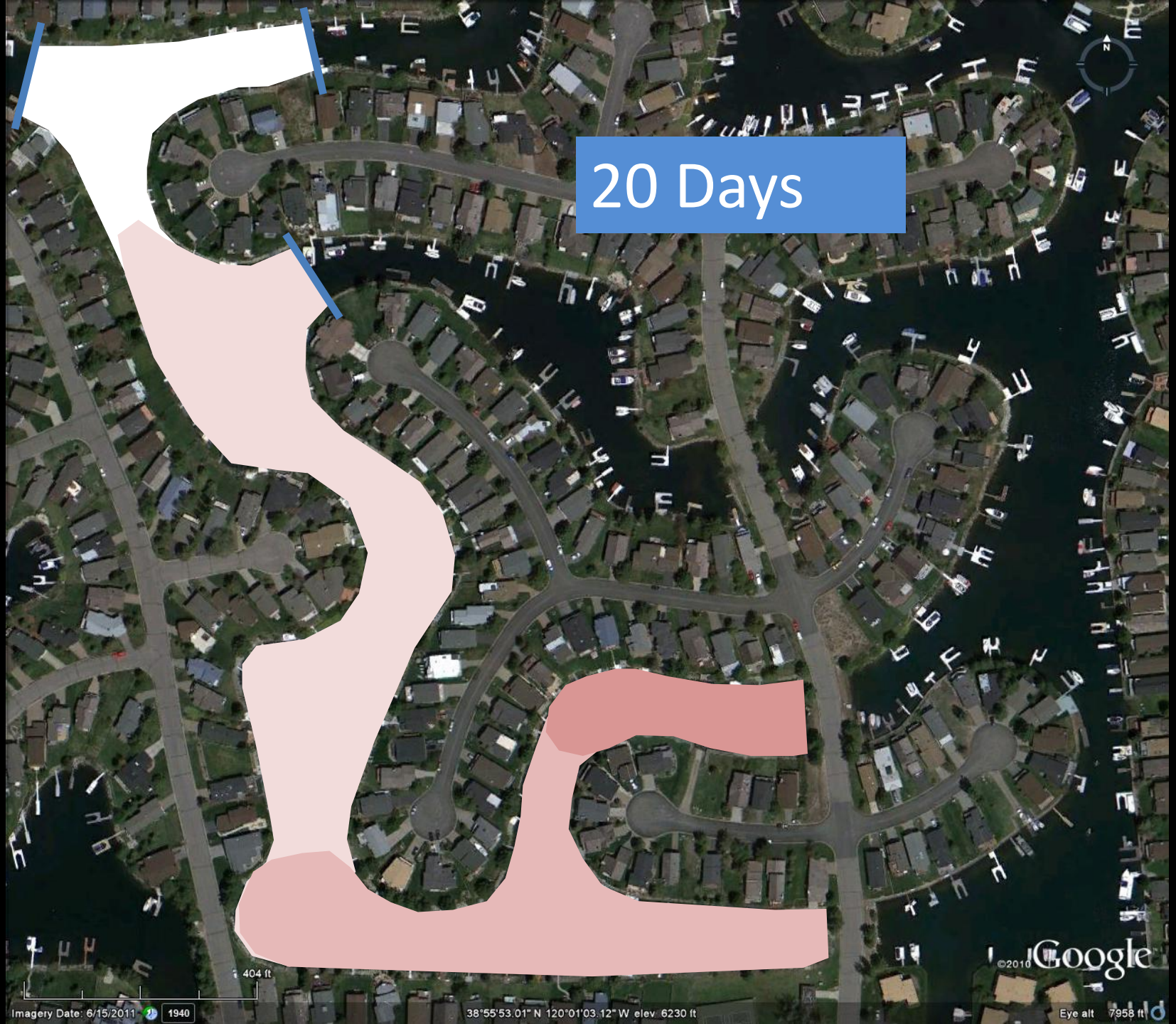
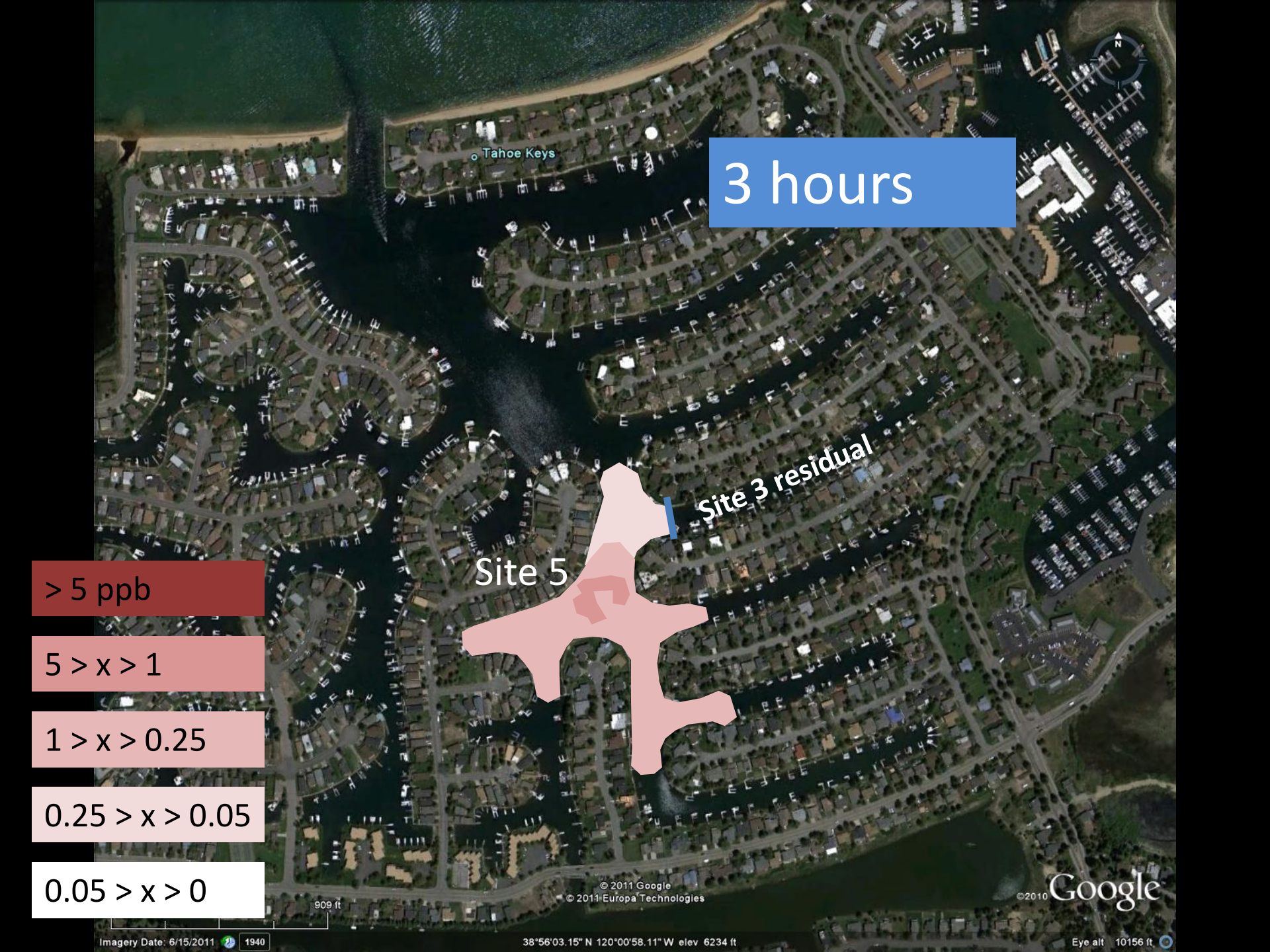
38°55'53.01" N 120°01'03.12" W elev 6230 ft
Eye alt 7958 ft
©2010 Google


20 Days
404 ft
Imagery Date: 6/15/2011
1940
38°55'53.01" N 120°01'03.12" W elev 6230 ft
Eye alt 7958 ft
©2010 Google


34 Days
404 ft
Imagery Date: 6/15/2011
1940
38°55'53.01" N 120°01'03.12" W elev 6230 ft
Eye alt 7958 ft
©2010 Google


Tahoe Keys
3 hours
Site 3 residual
Site 5
> 5 ppb
5 > x > 1
1 > x > 0.25
0.25 > x > 0.05
0.05 > x > 0
909 ft
© 2011 Google
© 2011 Europa Technologies
©2010 Google
Imagery Date: 6/15/2011
1940
38°56'03.15" N 120°00'58.11" W elev 6234 ft
Eye alt 10156 ft


Tahoe Keys
22 hours
Site 2
© 2011 Google
© 2011 Europa Technologies
©2010 Google
909 ft
Imagery Date: 6/15/2011
1940
38°56'03.15" N 120°00'58.11" W elev 6234 ft
Eye alt 10156 ft


Tahoe Keys
26 hours
© 2011 Google
© 2011 Europa Technologies
©2010 Google
909 ft
Imagery Date: 6/15/2011
1940
38°56'03.15" N 120°00'58.11" W elev 6234 ft
Eye alt 10156 ft


Tahoe Keys
48 hours
© 2011 Google
© 2011 Europa Technologies
©2010 Google
909 ft
Imagery Date: 6/15/2011
1940
38°56'03.15" N 120°00'58.11" W elev 6234 ft
Eye alt 10156 ft


Tahoe Keys
5 Days
© 2011 Google
© 2011 Europa Technologies
©2010 Google
909 ft
Imagery Date: 6/15/2011
1940
38°56'03.15" N 120°00'58.11" W elev 6234 ft
Eye alt 10156 ft

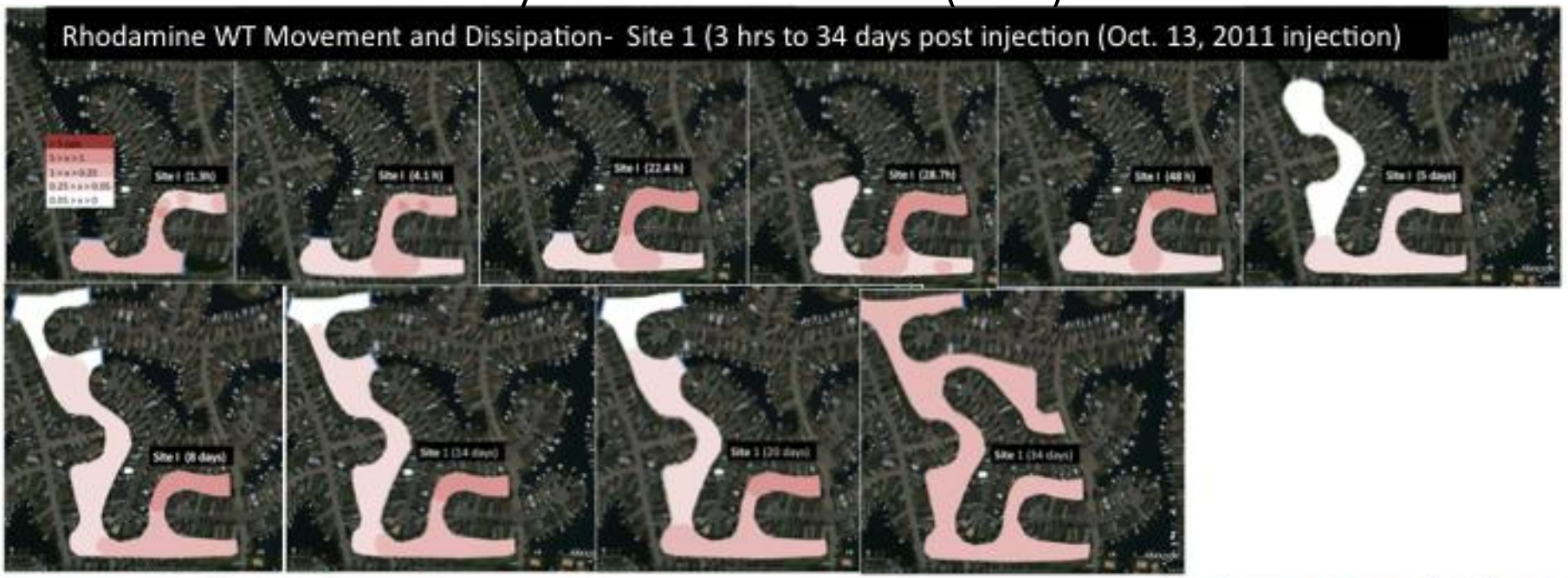

Tahoe Keys
8 Days
© 2011 Google
© 2011 Europa Technologies
©2010 Google
909 ft
Imagery Date: 6/15/2011
1940
38°56'03.15" N 120°00'58.11" W elev 6234 ft
Eye alt 10156 ft

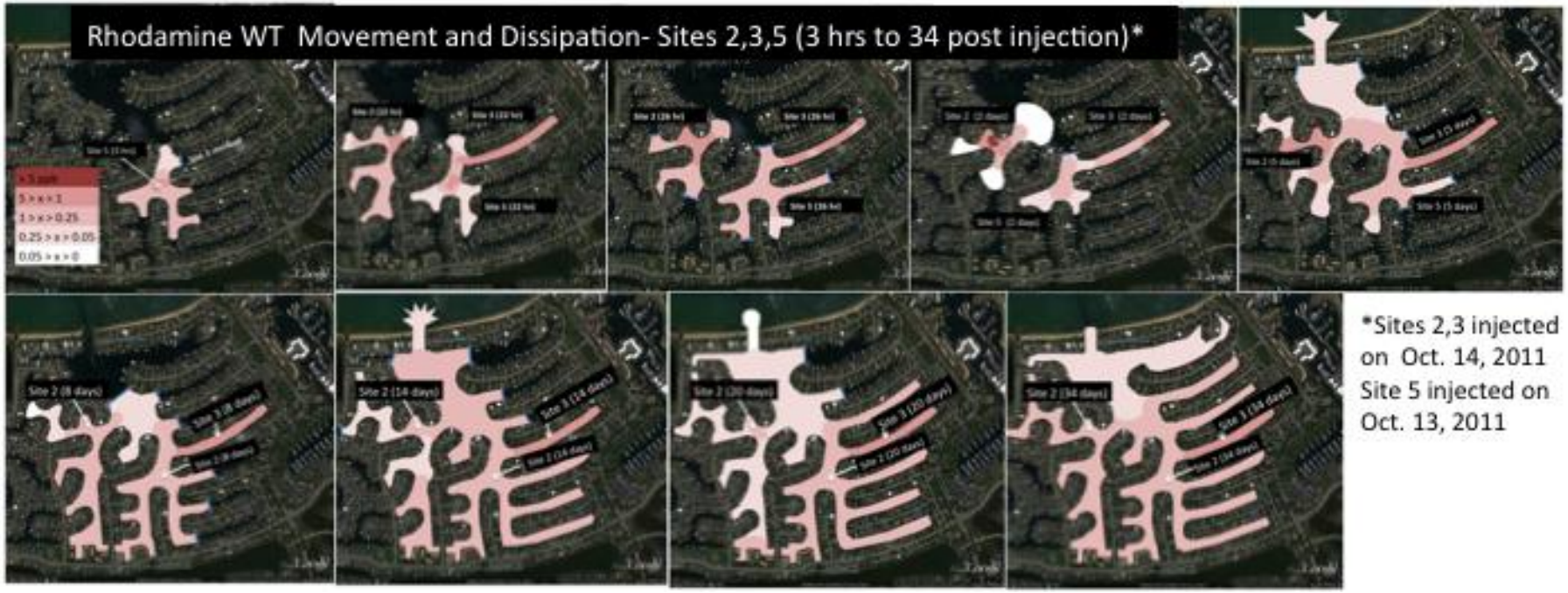

Tahoe Keys
14 Days
© 2011 Google
© 2011 Europa Technologies
©2010 Google
909 ft
Imagery Date: 6/15/2011
1940
38°56'03.15" N 120°00'58.11" W elev 6234 ft
Eye alt 10156 ft


Tahoe Keys
20 Days
© 2011 Google
© 2011 Europa Technologies
©2010 Google
909 ft
Imagery Date: 6/15/2011
1940
38°56'03.15" N 120°00'58.11" W elev 6234 ft
Eye alt 10156 ft


34 Days
Tahoe Keys
© 2011 Google
© 2011 Europa Technologies
©2010 Google
909 ft
Imagery Date: 6/15/2011
1940
38°56'03.15" N 120°00'58.11" W elev 6234 ft
Eye alt 10156 ft

Summary: Fall Rhodamine WT (2011)





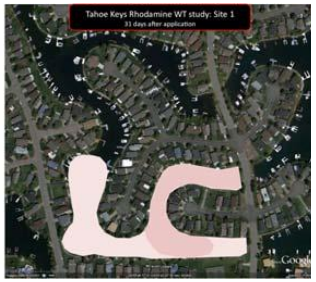
*Sites 2,3 injected on Oct. 14, 2011
Site 5 injected on Oct. 13, 2011

Rhodamine WT Dye Dispersion (Sites 1-3)-Summer (July 17, 18 Injections)

Site 1 7.5 h

1.25 Day

2 Days



31 Days

45 Days

Site 3 6 h

1 Day

2 Days

29 Days

43 Days

Site 2 2 h

5.5 h

1 Day

1.25 Days

6 Days

Rhodamine WT Concentrations in Polygons

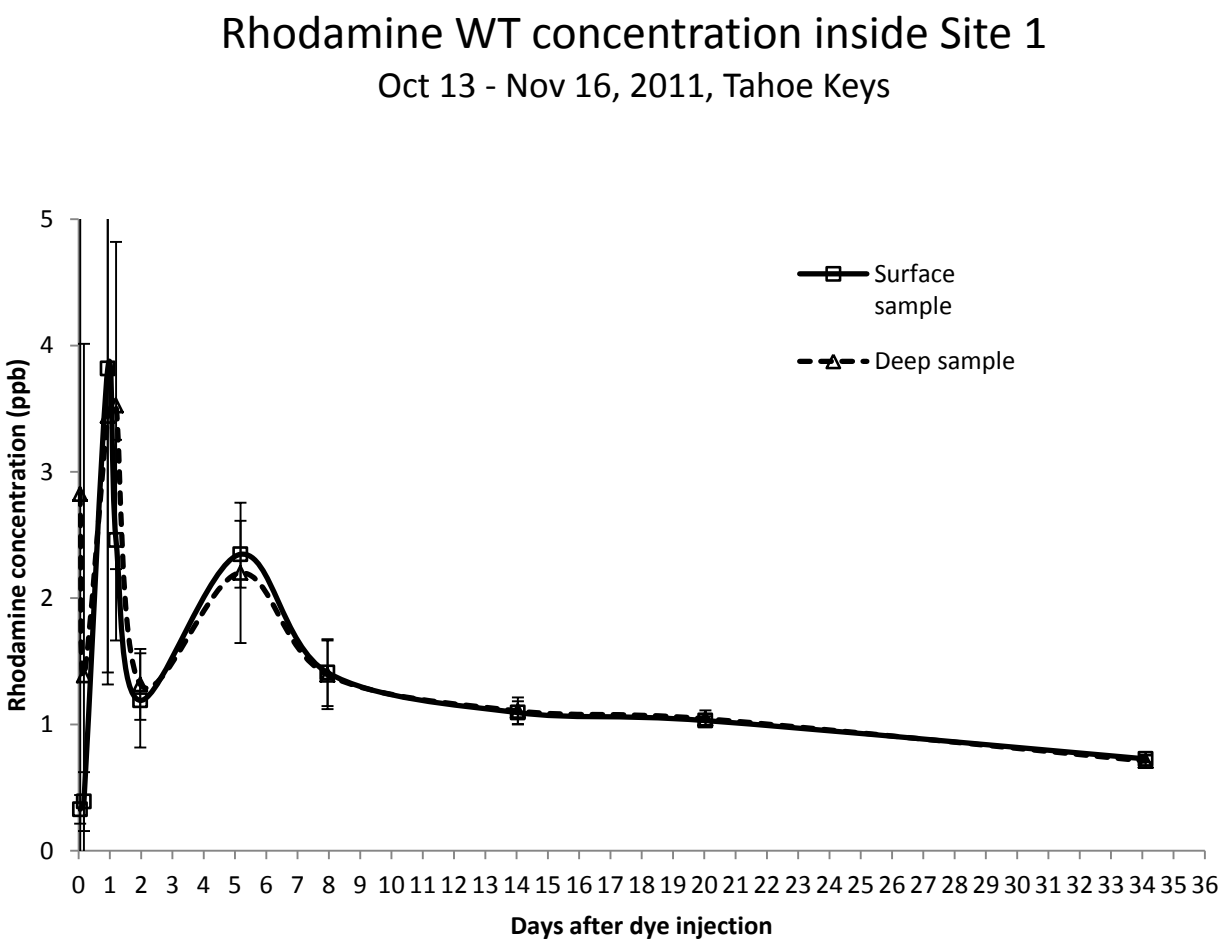
> 5 ppb

>1 <5 ppb

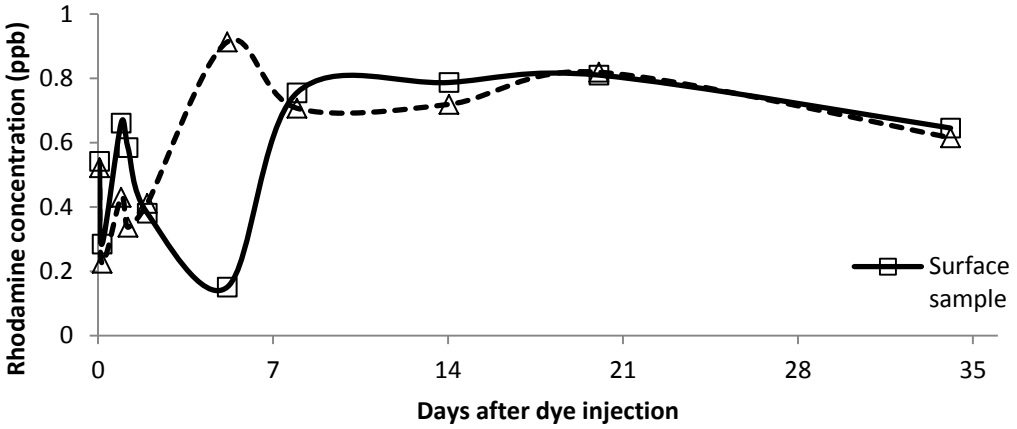
>.25 <1 ppb

>0 <0.25 ppb

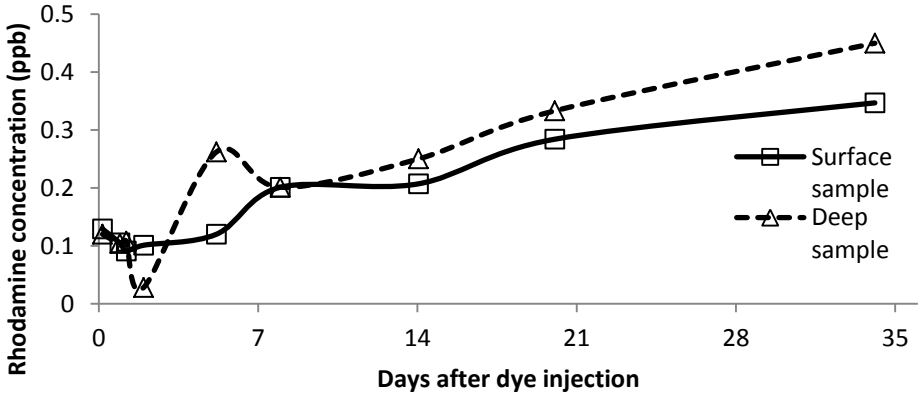
Dead- End Site



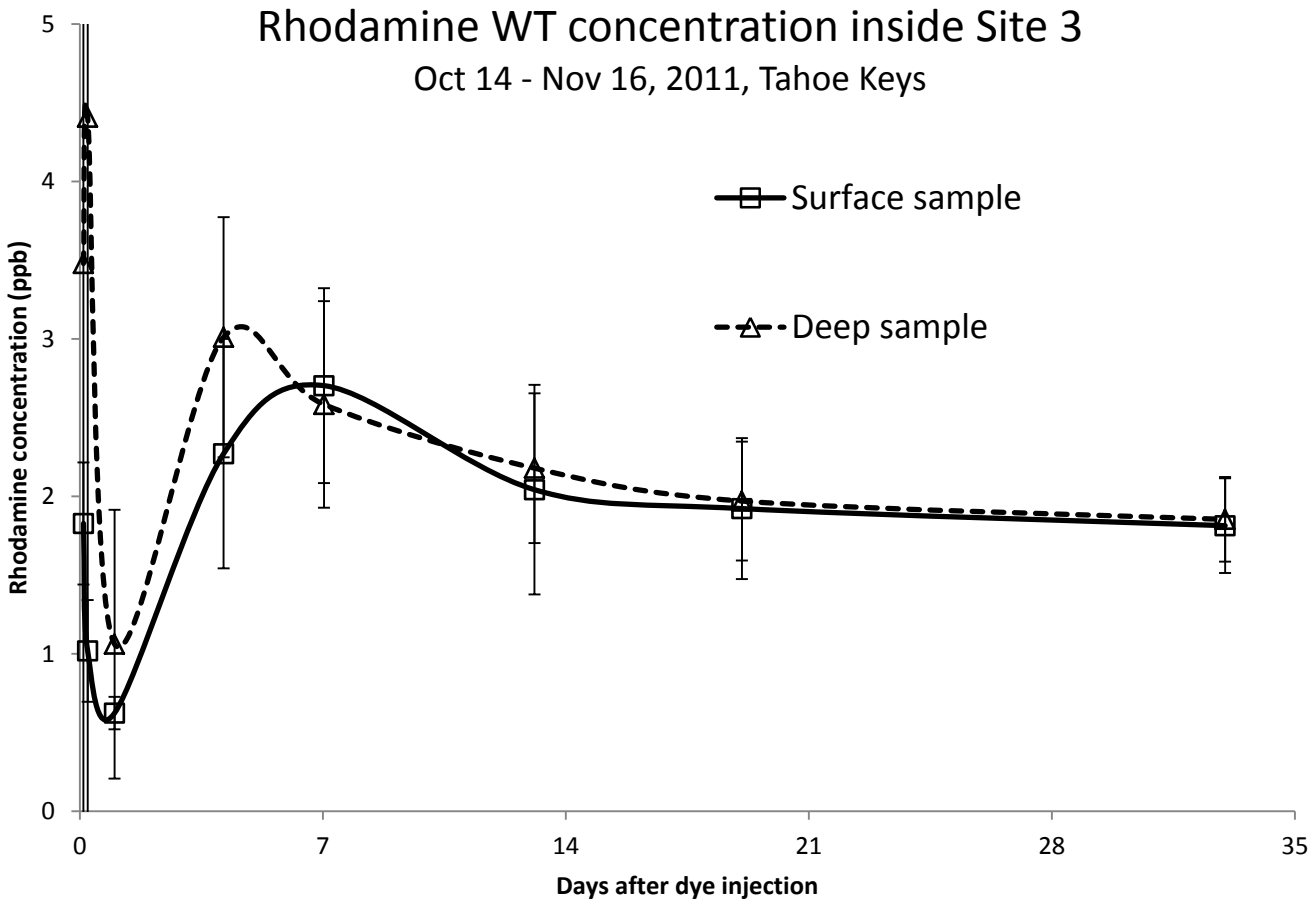
Rhodamine WT concentration outside Site 1 @ South buoy
Oct 13 - Nov 16, 2011, Tahoe Keys



Rhodamine WT concentration outside Site 1 @ West buoy
July 18 - Sept 1, 2011, Tahoe Keys

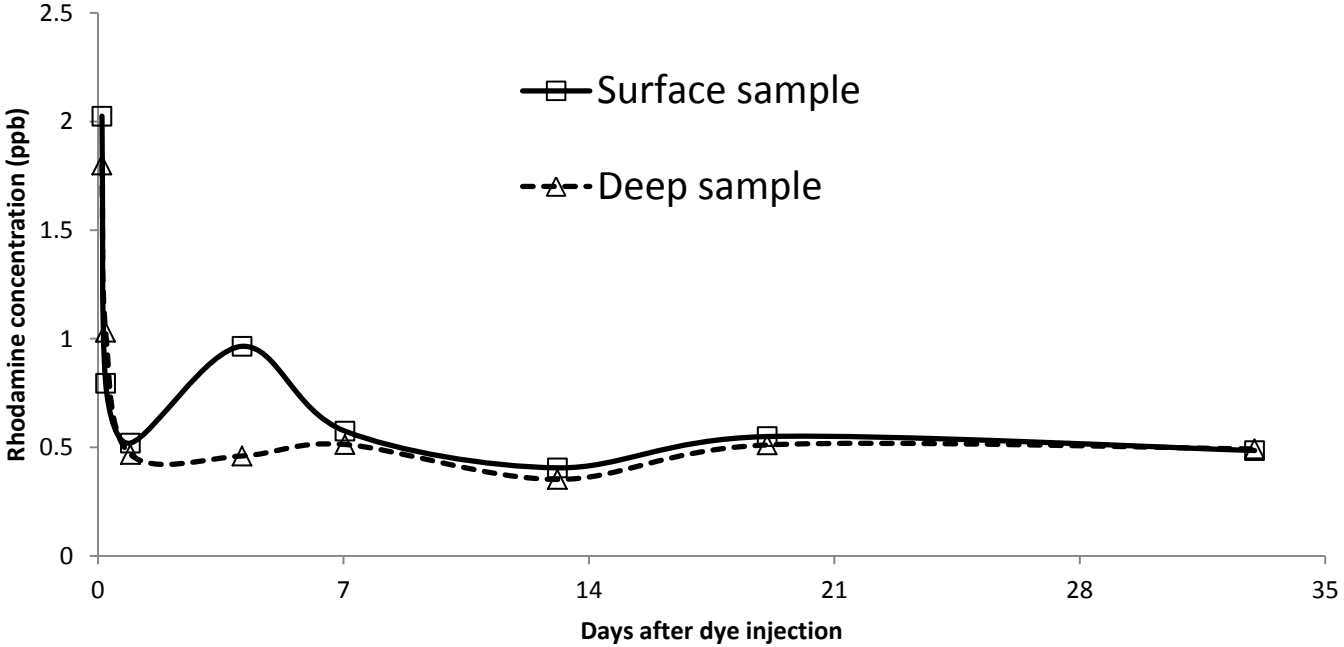


Dead- End Site

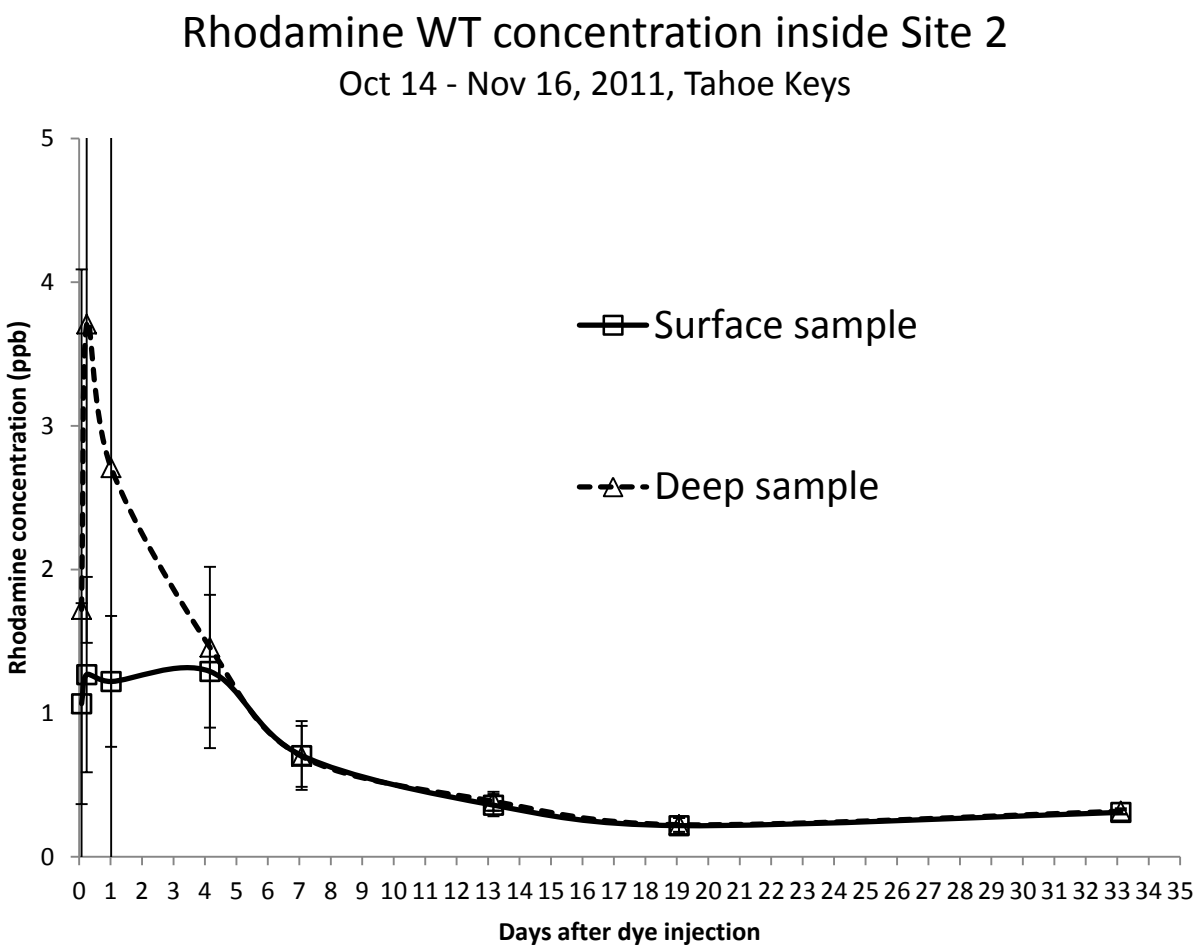


Rhodamine WT concentration outside Site 3 @ West buoy

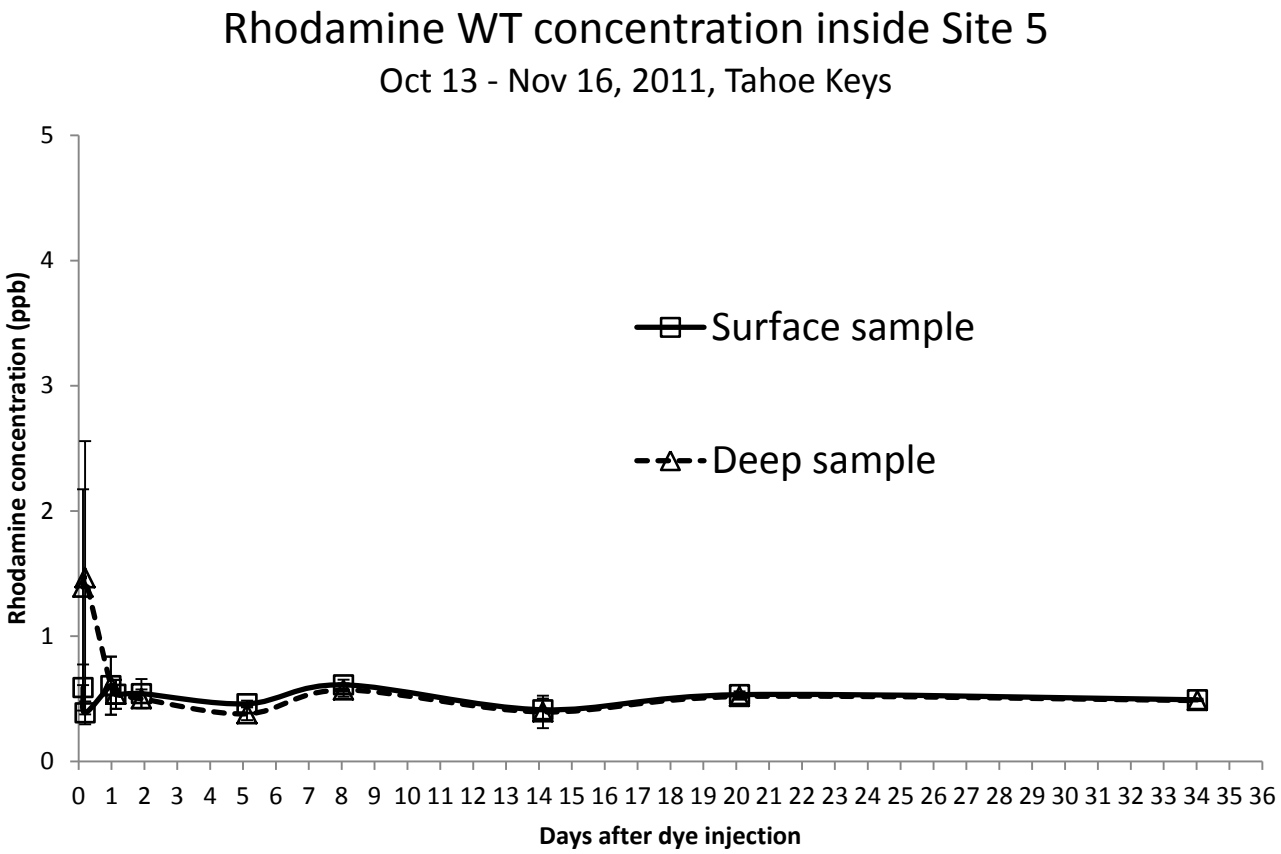
Oct 13 - Nov 16, 2011, Tahoe Keys



Open Site

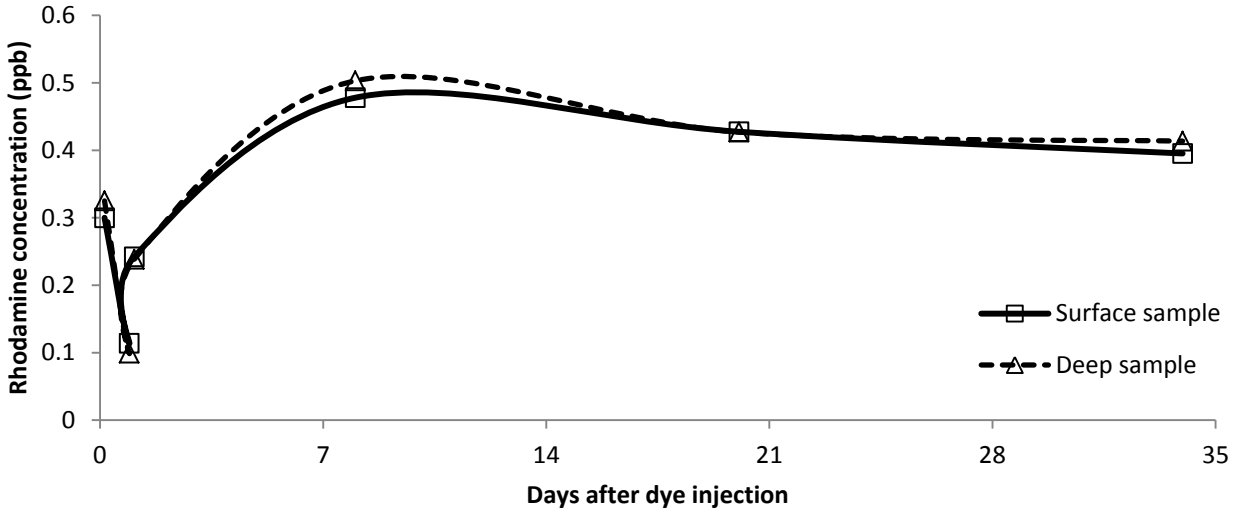

Rhodamine WT concentration inside Site 2
Oct 14 - Nov 16, 2011, Tahoe Keys
Rhodamine concentration (ppb)
Days after dye injection
Surface sample
Deep sample
0
1
2
3
4
5
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35

Open Site


Rhodamine WT concentration inside Site 5
Oct 13 - Nov 16, 2011, Tahoe Keys
Rhodamine concentration (ppb)
0
1
2
3
4
5
Surface sample
Deep sample
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Days after dye injection

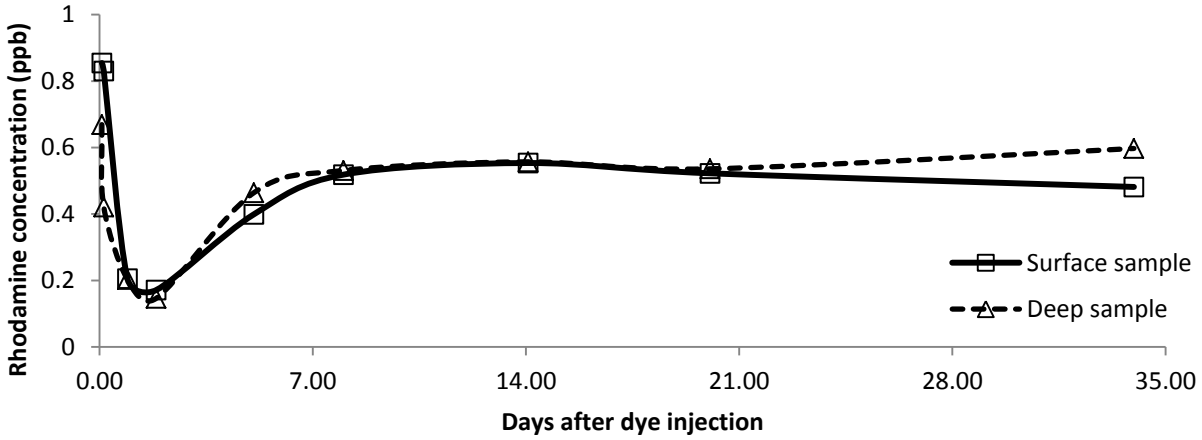
Rhodamine WT concentration outside Site 5 @ South buoy #2

Oct 13 - Nov 16, 2011, Tahoe Keys

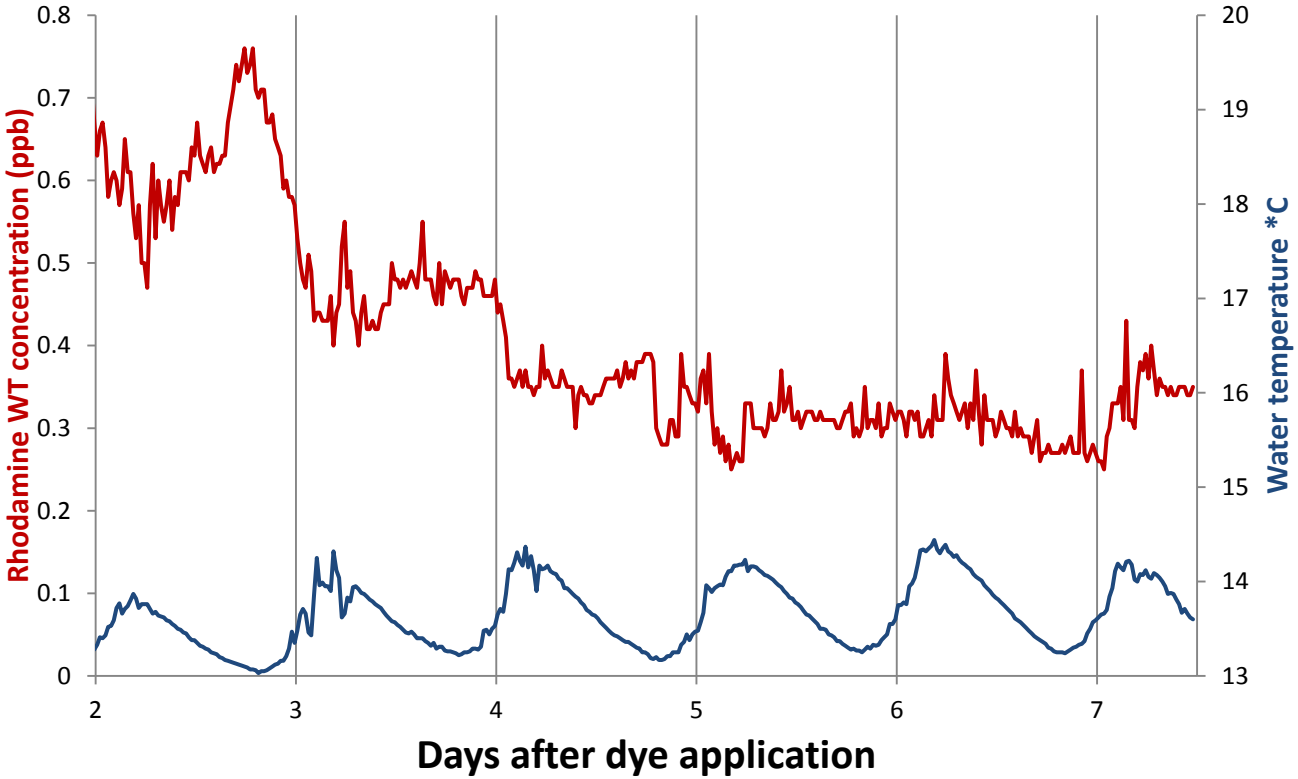


Rhodamine WT concentration outside Site 5 @ South buoy #1

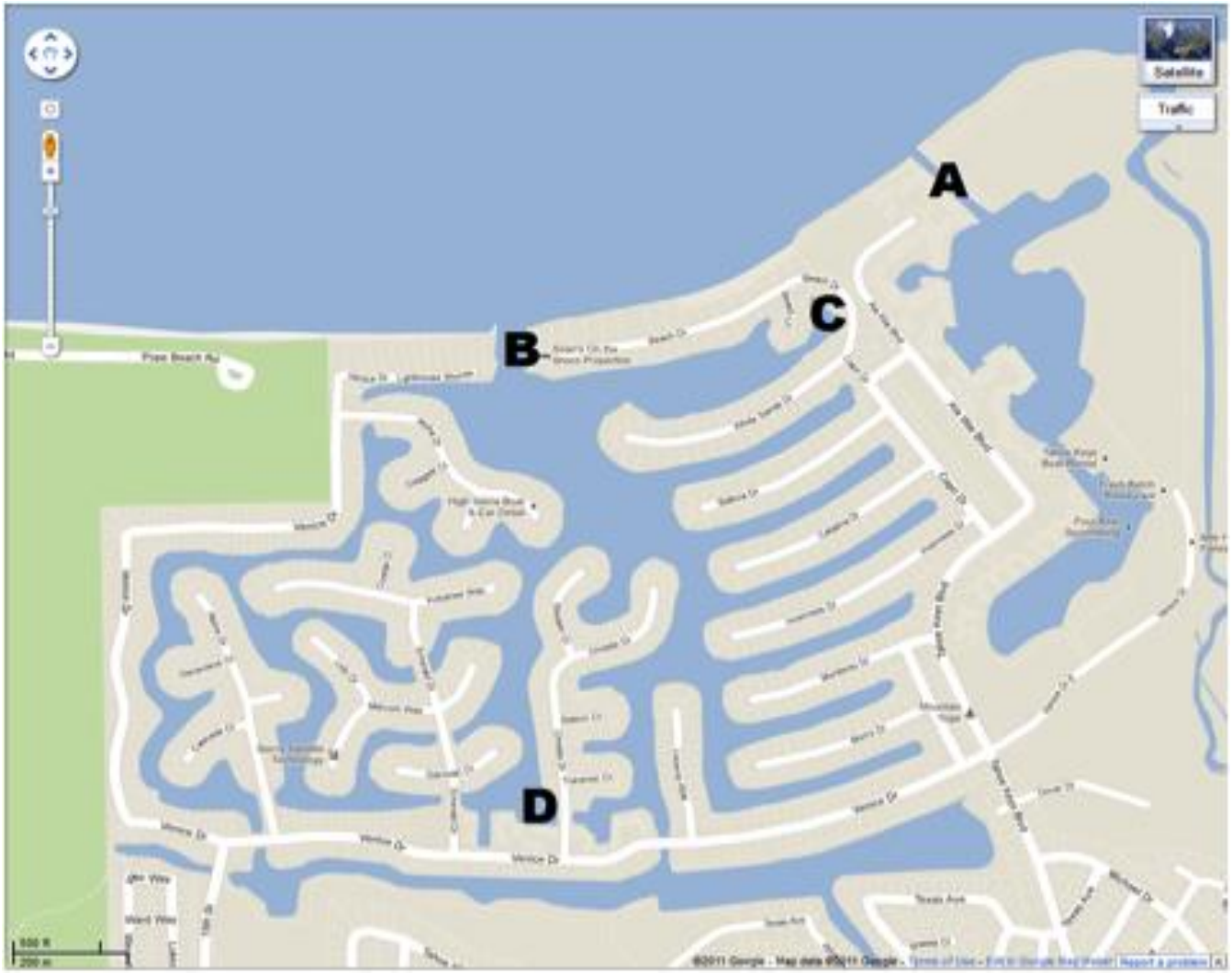
Oct 13 - Nov 16, 2011, Tahoe Keys

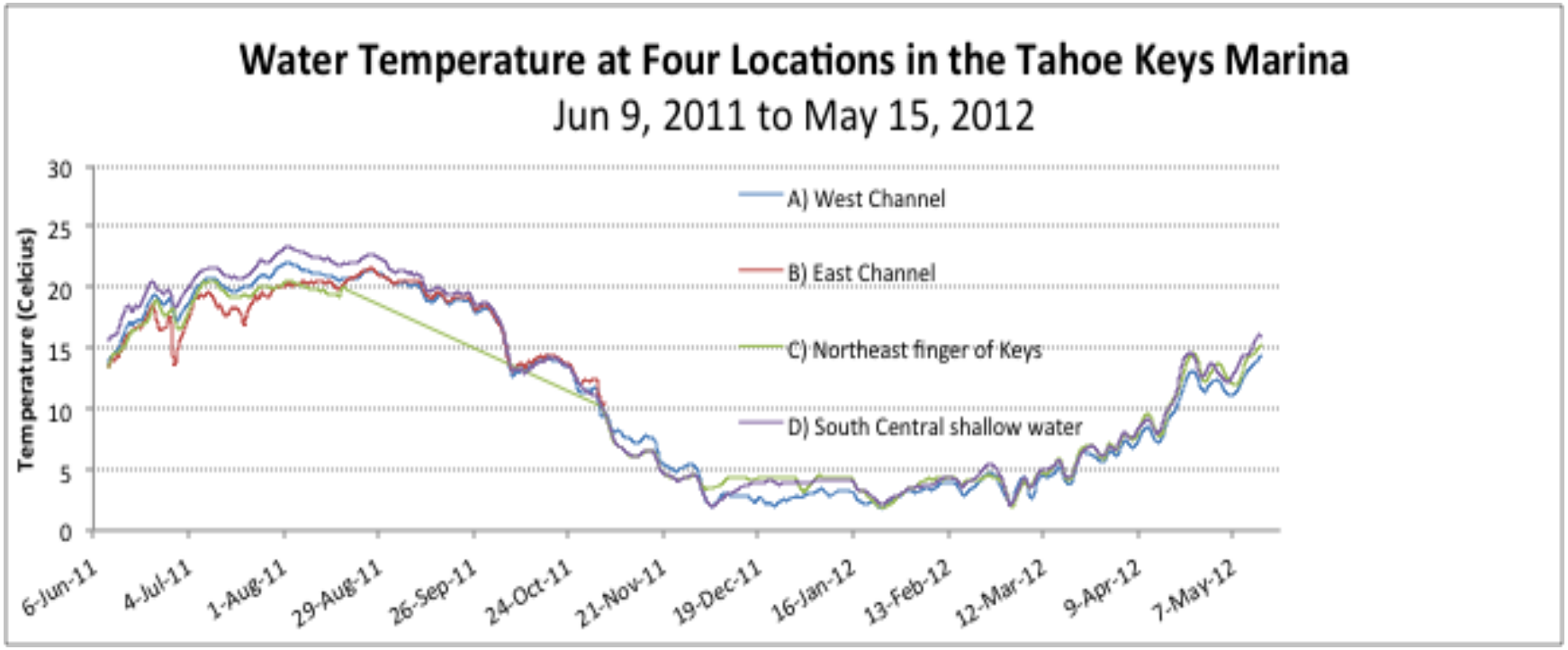


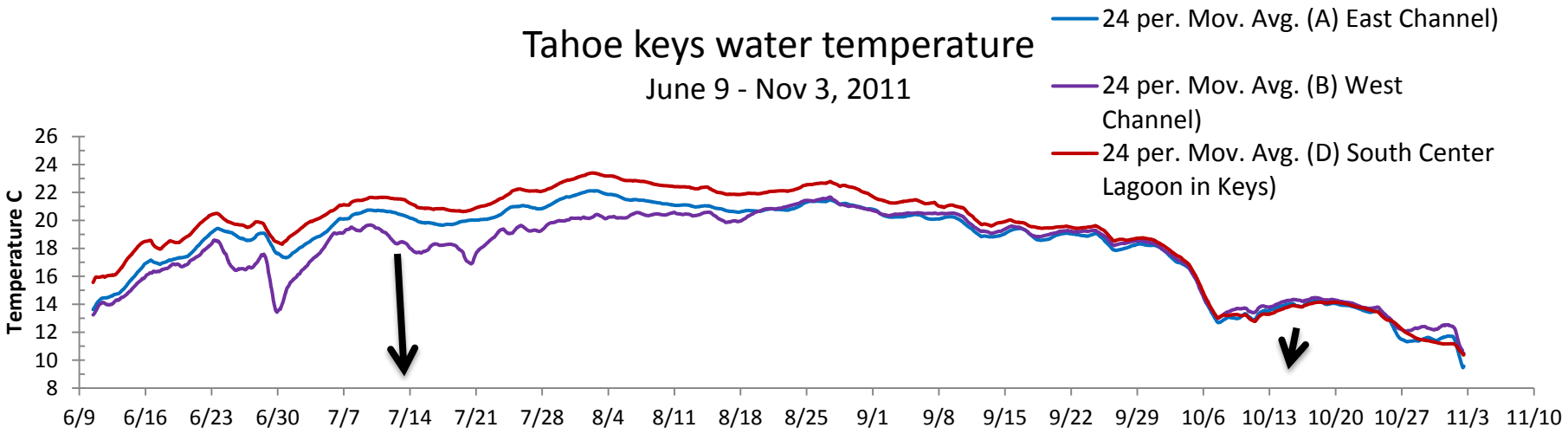
Site 3: Diurnal Temperature and RWT Concentrations (Fall Application)

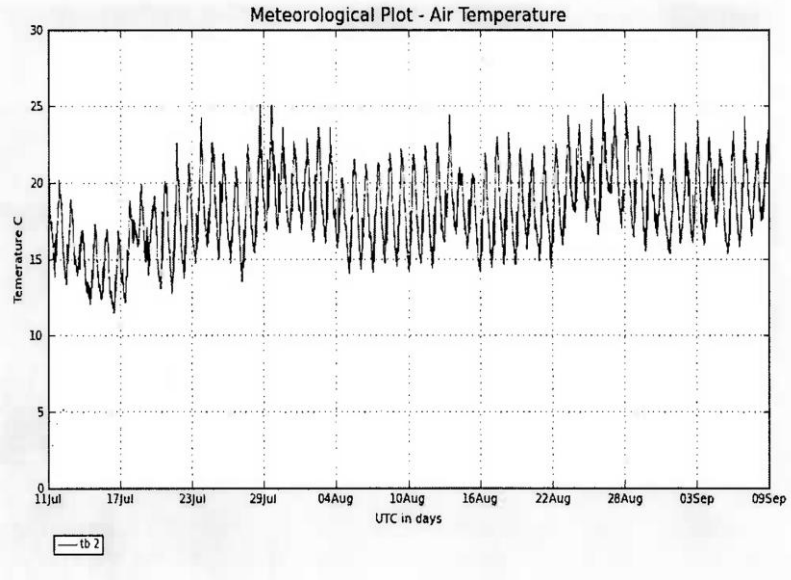


Temperature Loggers :Tahoe West Basin (Summer 2011 -Spring 2012)

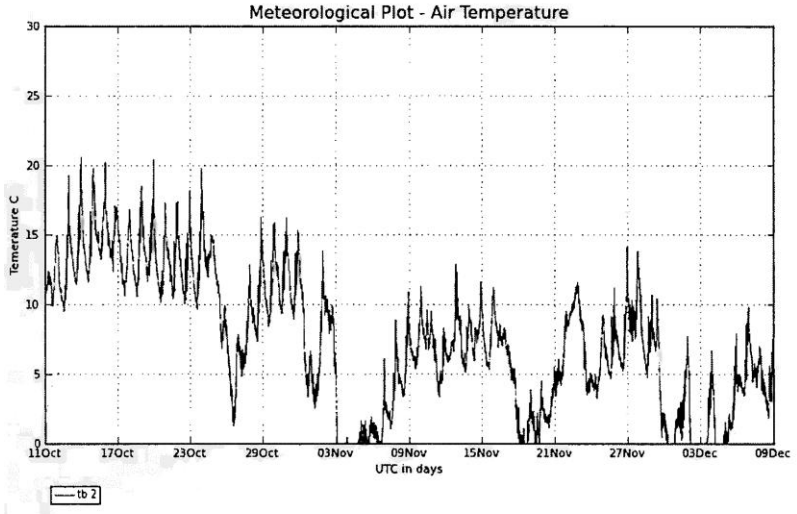



Water Temperature at Four Locations in the Tahoe Keys Marina
Jun 9, 2011 to May 15, 2012
Temperature (Celcius)
30
25
20
15
10
5
0
A) West Channel
B) East Channel
C) Northeast finger of Keys
D) South Central shallow water
6-Jun-11
4-Jul-11
1-Aug-11
29-Aug-11
26-Sep-11
24-Oct-11
21-Nov-11
19-Dec-11
16-Jan-12
13-Feb-12
12-Mar-12
9-Apr-12
7-May-12

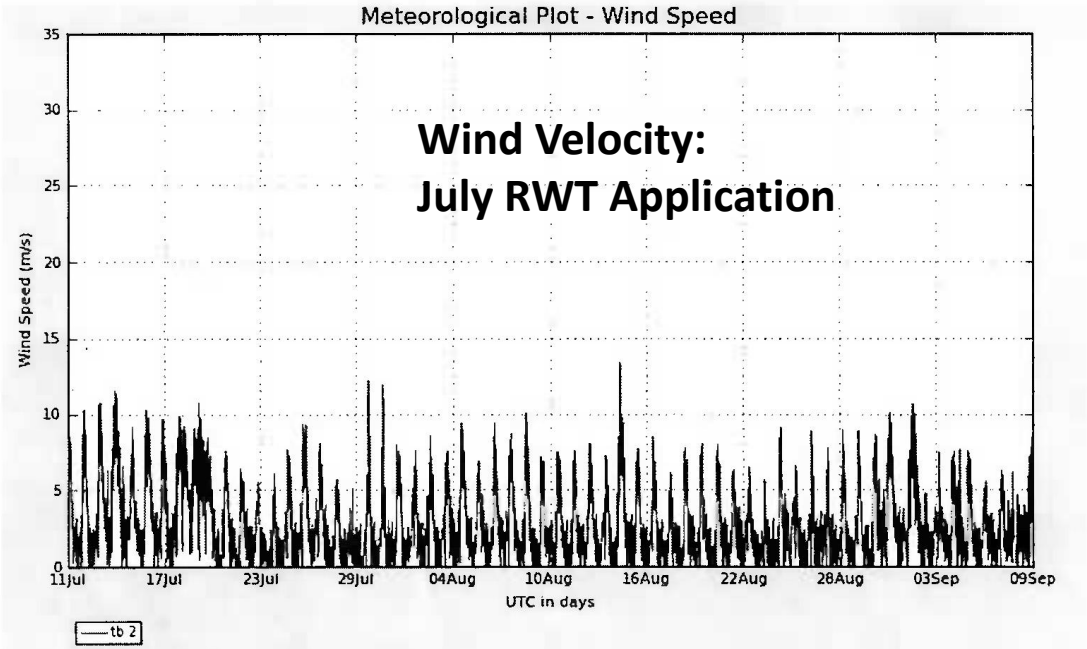


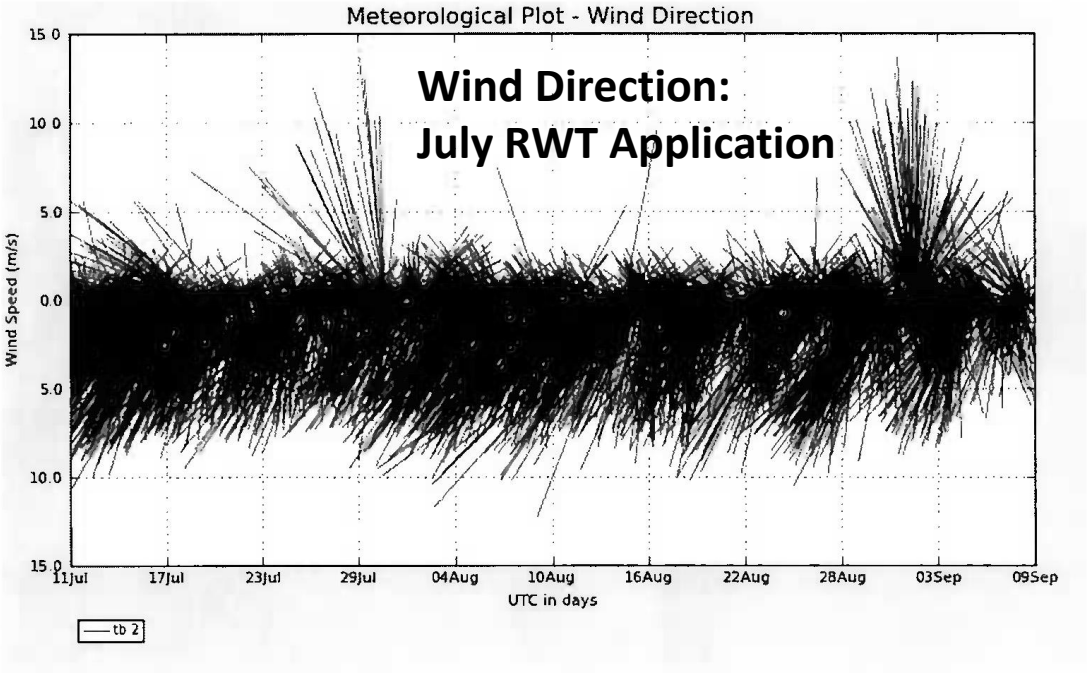


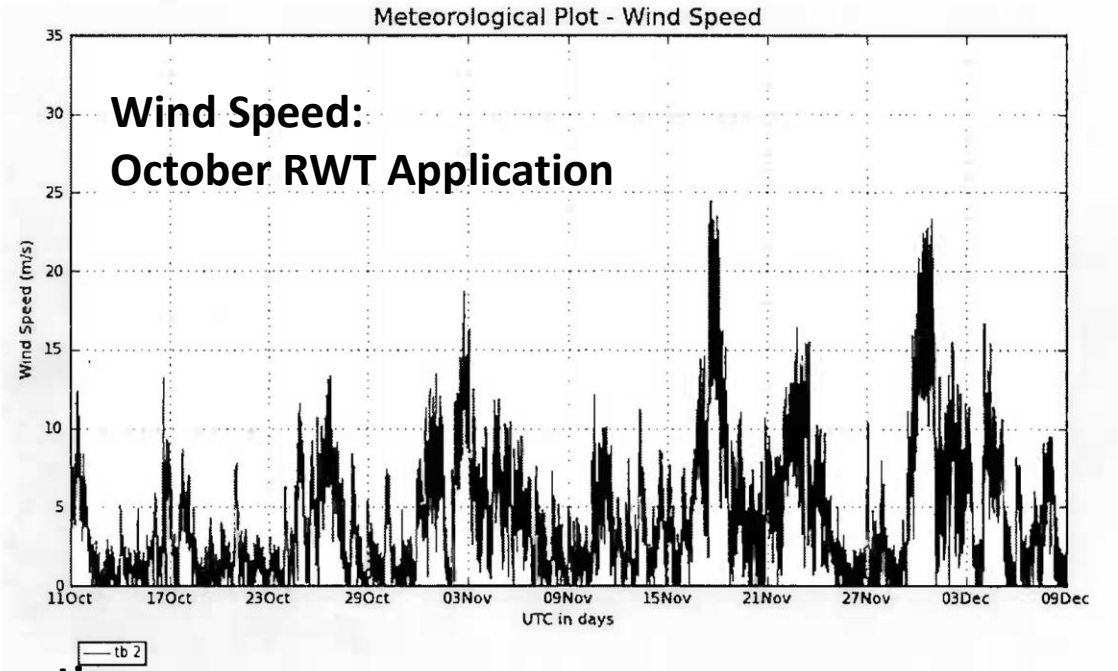
Air Temperature:
July RWT Application



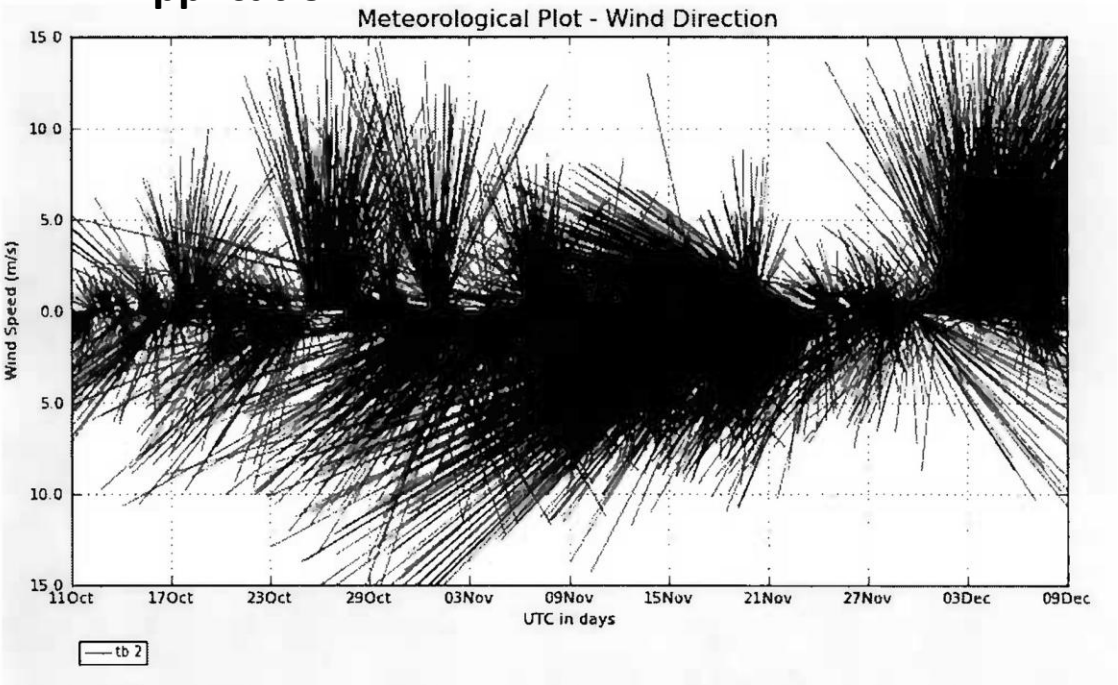
Air Temperature:
October RWT Application


Meteorological Plot - Wind Speed
Wind Velocity:
July RWT Application
Wind Speed (m/s)
35
30
25
20
15
10
5
0
11Jul
17Jul
23Jul
29Jul
04Aug
10Aug
16Aug
22Aug
28Aug
03Sep
09Sep
UTC in days
tb 2

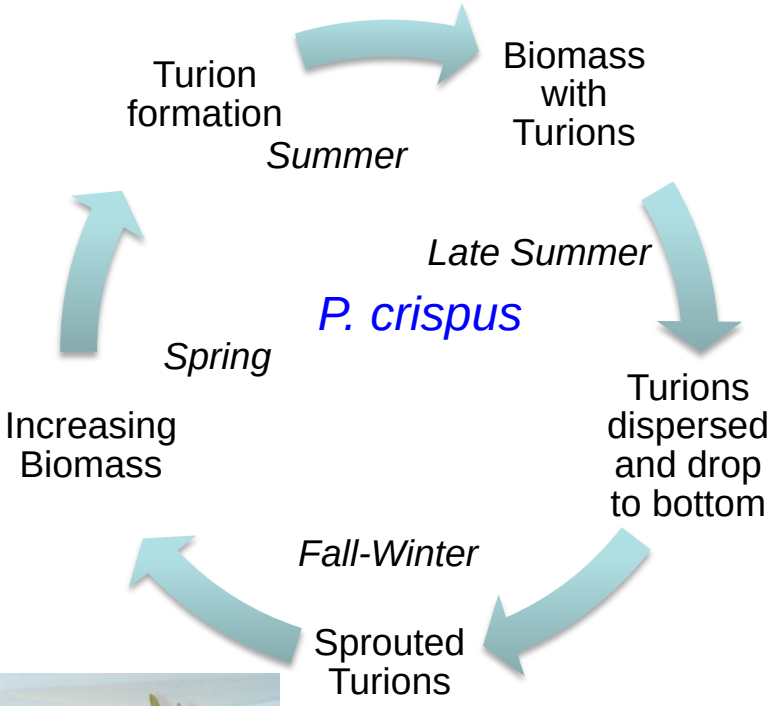

Meteorological Plot - Wind Direction
Wind Direction:
July RWT Application
Wind Speed (m/s)
15.0
10.0
5.0
0.0
5.0
10.0
15.0
11Jul
17Jul
23Jul
29Jul
04Aug
10Aug
16Aug
22Aug
28Aug
03Sep
09Sep
UTC in days
tb 2

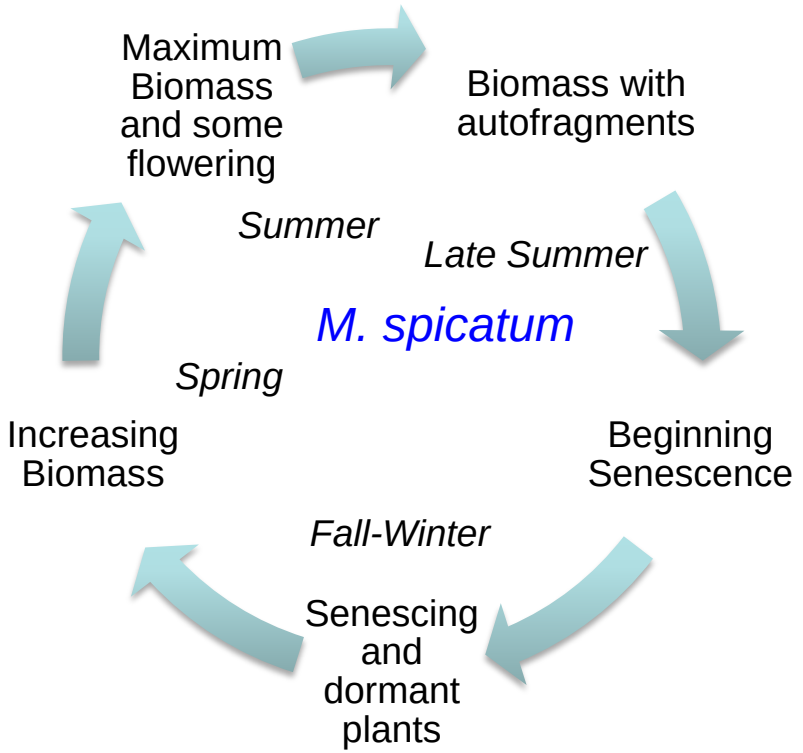


Wind Direction:
October RWT Application

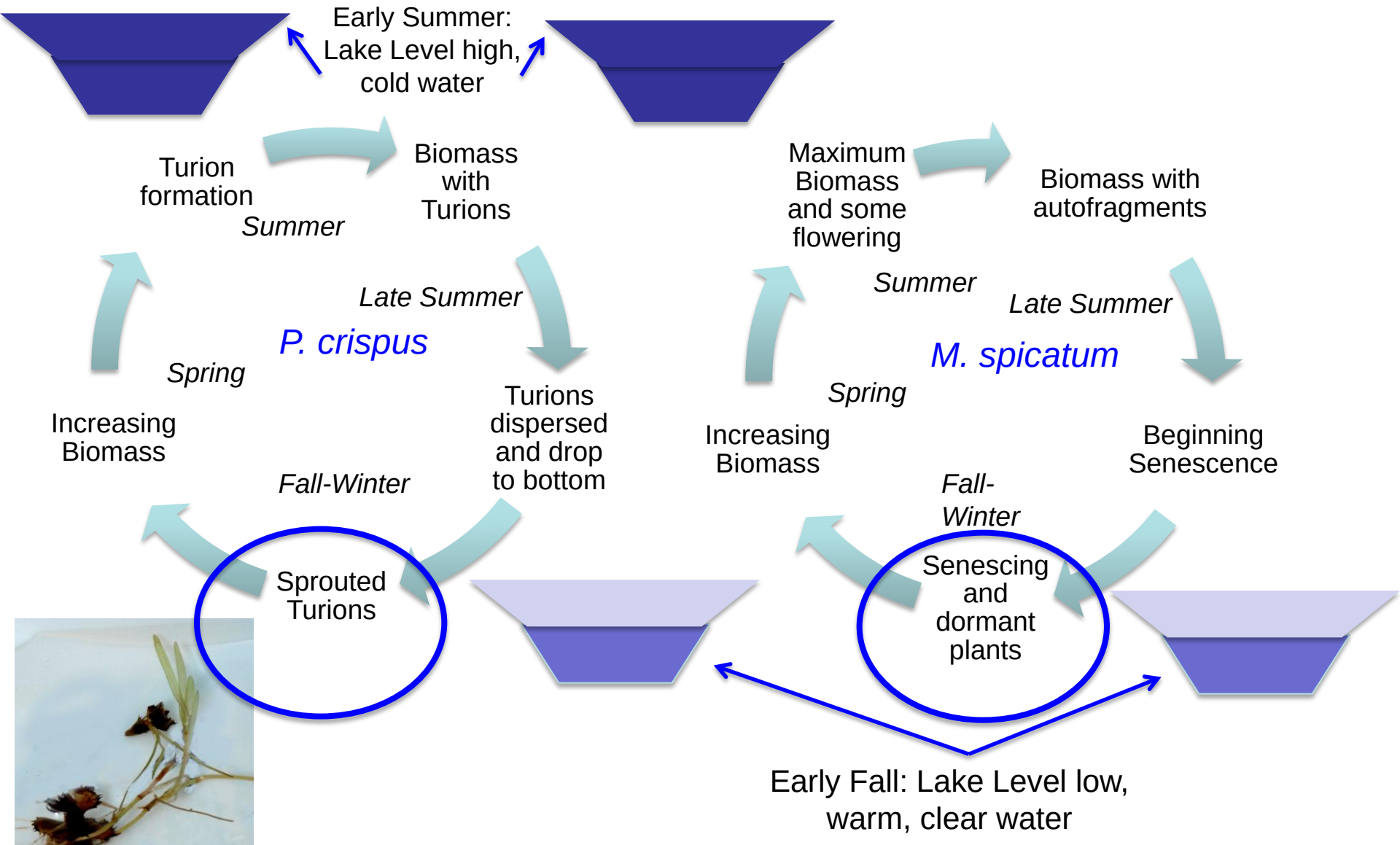


P. Crispus and M. spicatum Phenology





P. Crispus and M. spicatum Phenology



Summary: **Summer** Rhodamine WT Applications

- Dead-end sites had long residence time: >30 days
- Dead-end sites had diurnal vertical mixing
- Open site have very short residence time: Few hours
- Cold water influx from lake probably generated a southern and western flow
- Multiple dead-end sites could be used to compare efficacy of herbicides if approved for use. **These sites comprise ca. 70% of open water**.

Summary: **Fall** Application

- Dead-end sites had long residence time:
  >30 days- Similar to summer characteristics
- Dead-end sites had diurnal vertical mixing-but more rapidly mixed than summer
- **<u>Open sites had much longer residence time than in the summer (less water movement)</u>**
  Residence time: *weeks*, not a few hours
- Water appears to exiting the Keys very slowly- the opposite of summer conditions
- **Results suggest that fall is best time to sustain herbicide concentrations in "open sites" (ca. 30% of the Keys).**

Any *Wicked* Questions?

Native *Elodea canadensis*- December 2011

Tahoe Keys- December 2011