

Pathogen Transport in Coastal Environments: Case Studies of Urban Runoff in Southern California

*A presentation to the Center for Water Sciences MSU
Pathogens Workshop, April 20, 2007*

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Talk Outline

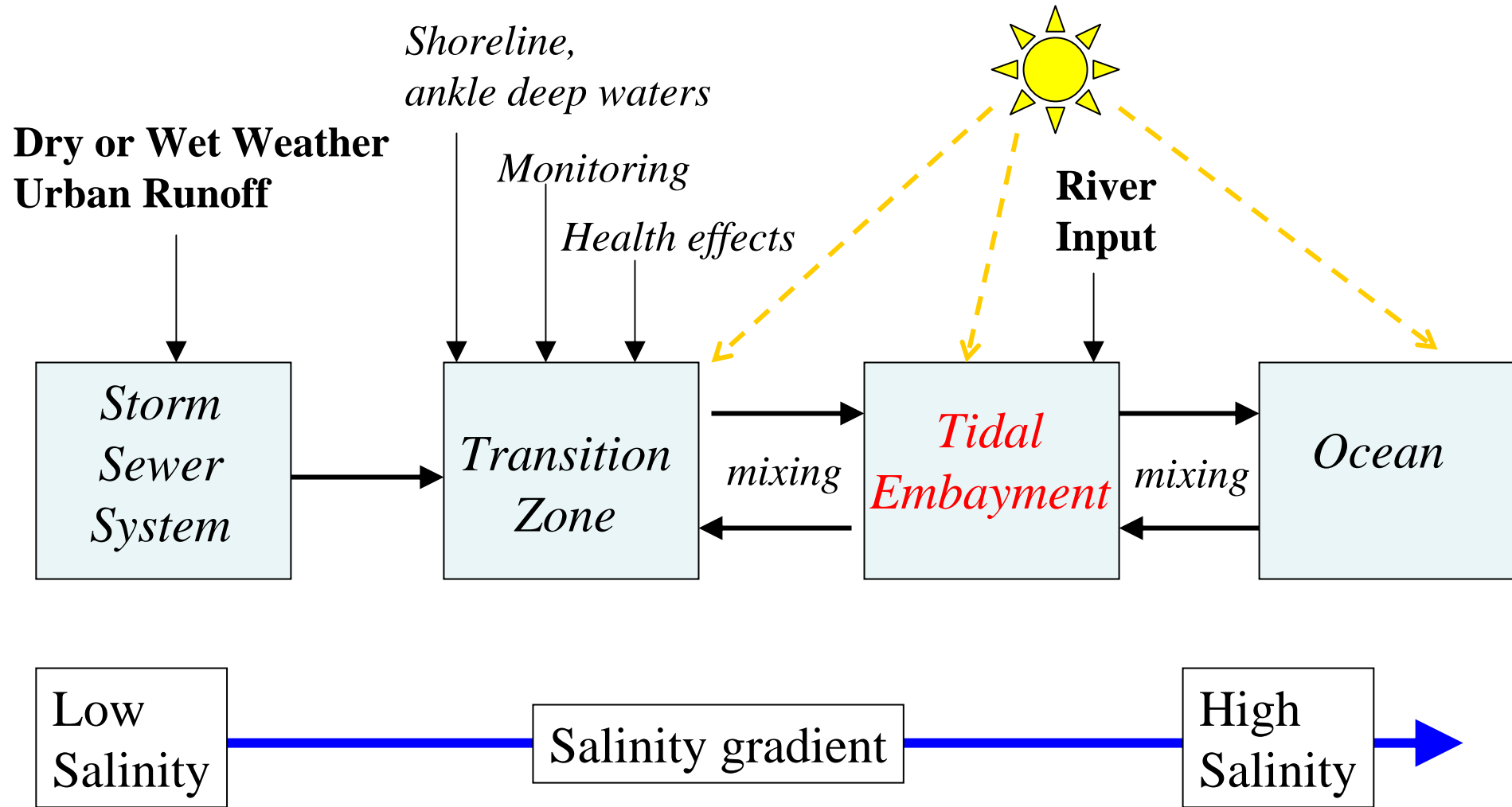
- Motivation and Big Picture
- Case Study 1: Urban runoff impacts on an open coastline (Huntington Beach)
- Case Study 2: Urban runoff impacts on a tidal embayment (Newport Bay)
- Conclusions

Motivation

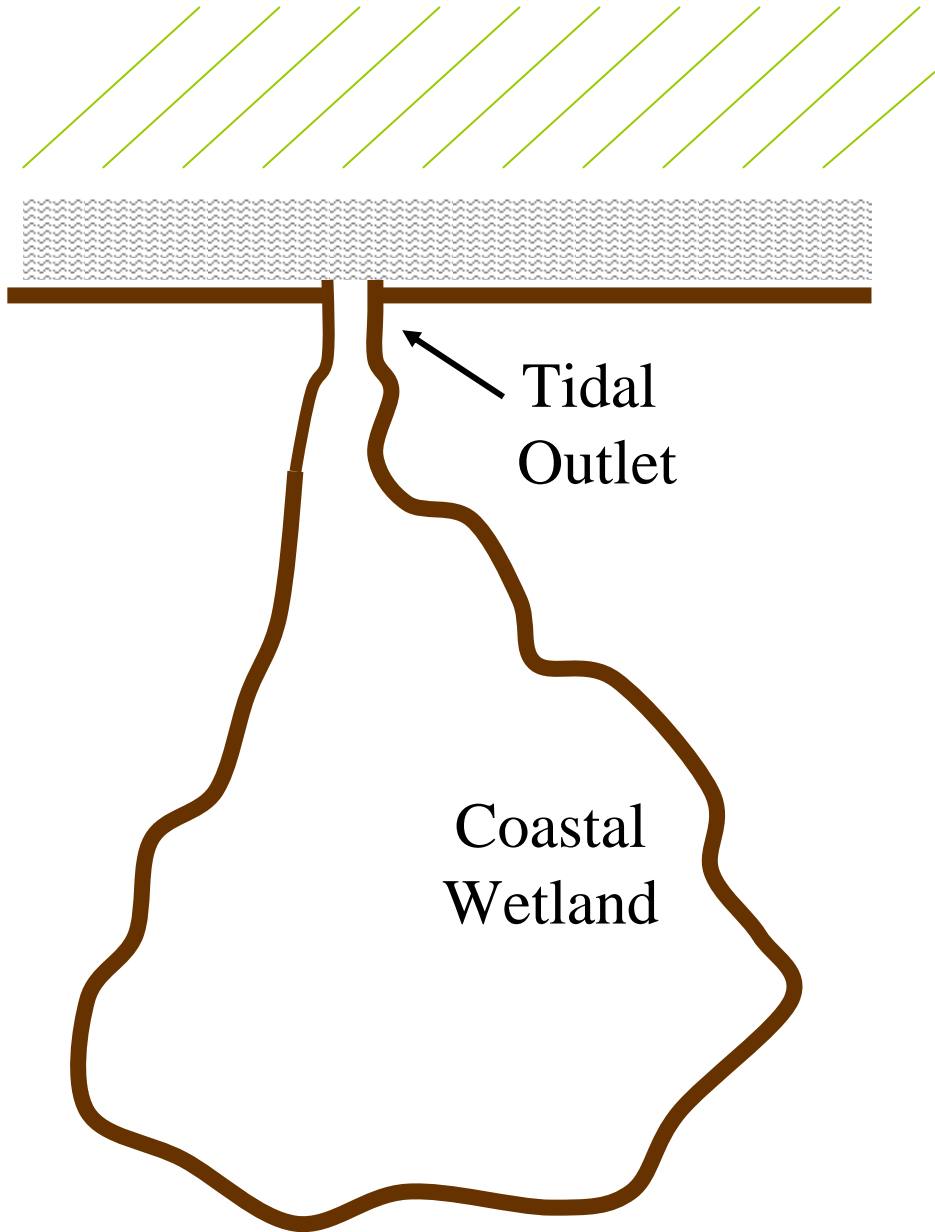
- 238 million people visit California's ocean beaches every year
- Potential health effects of exposure to contaminated marine waters
- Beachgoers spend over \$9.5 billion annually
- Number of beach postings and closures on the rise; 3,985 in 2004

➔ *How can information on pathogen transport help?*

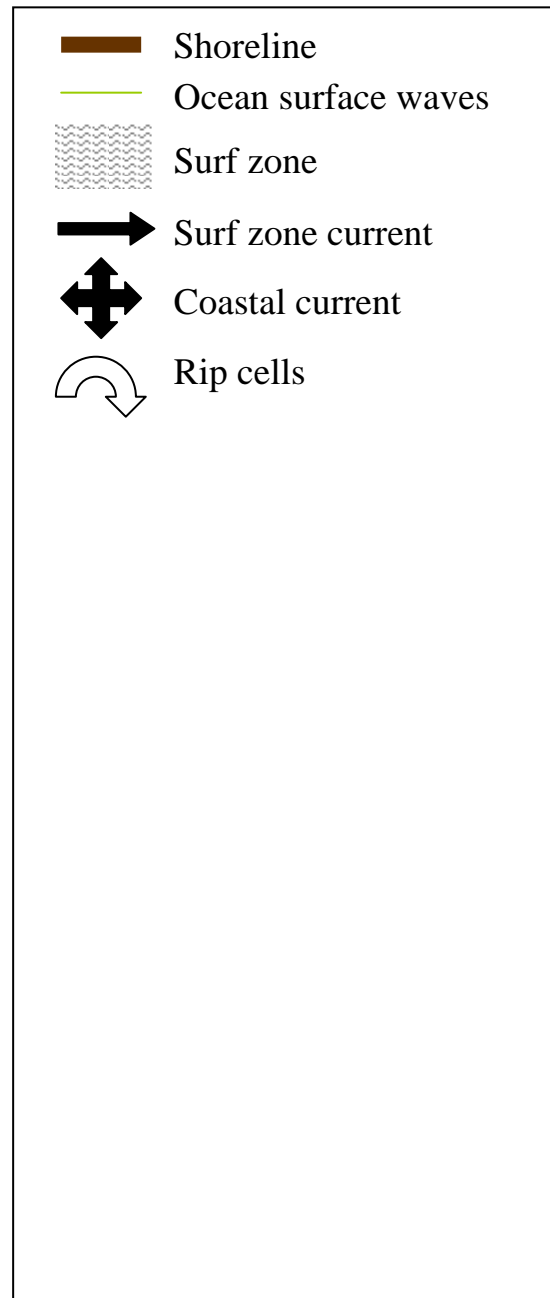
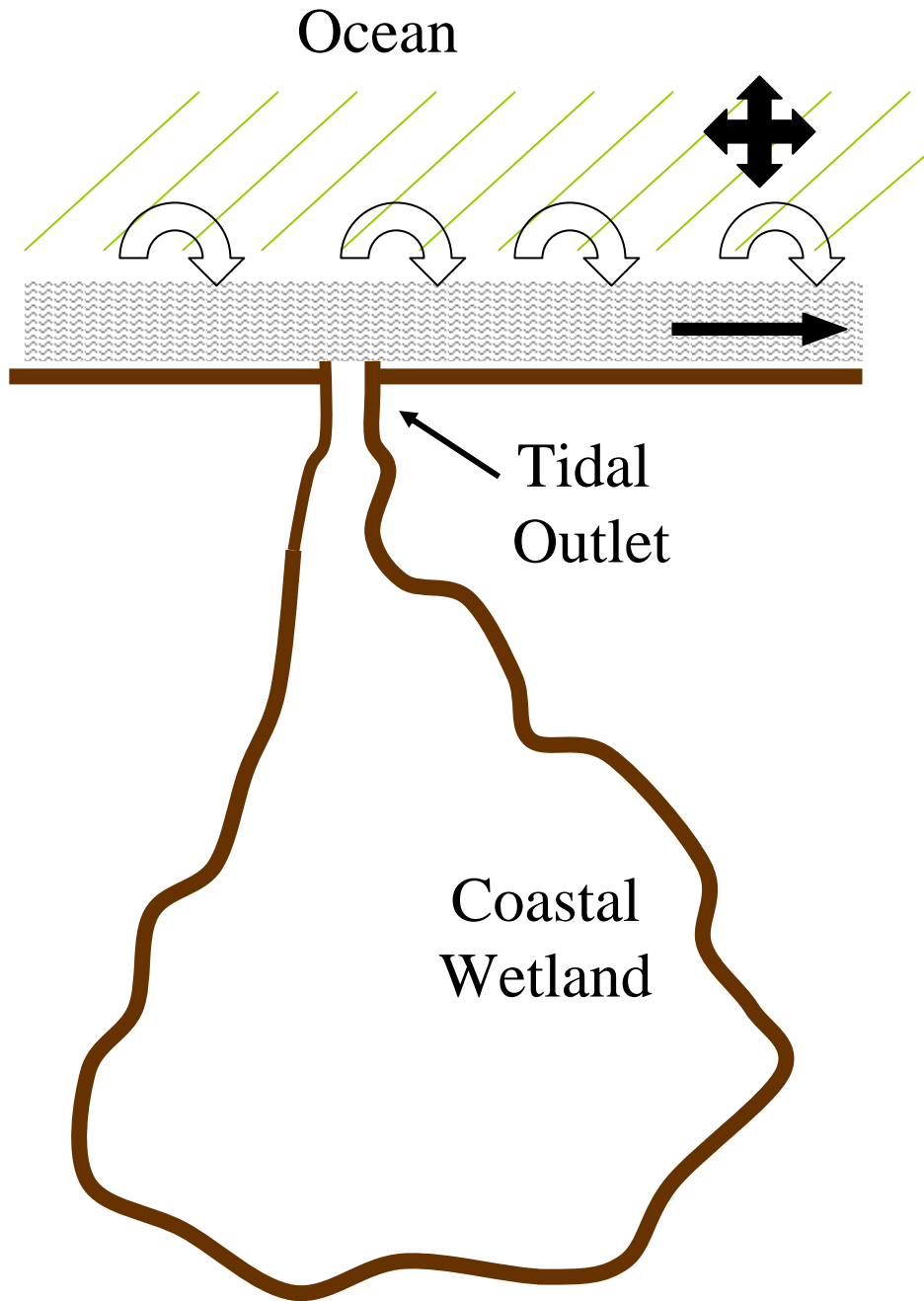
Big Picture

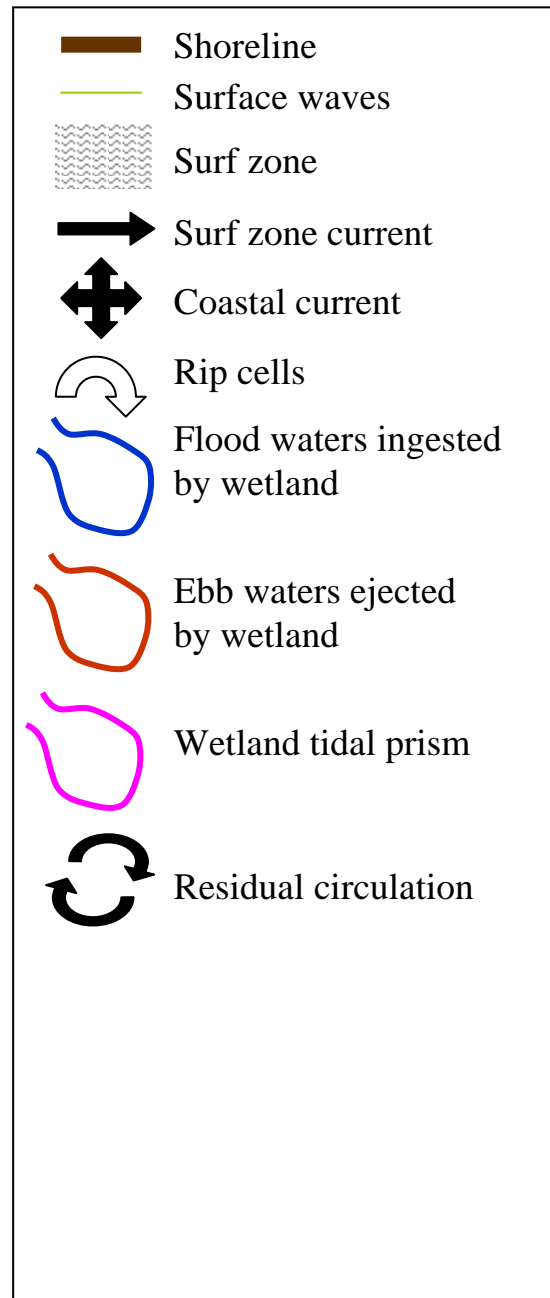
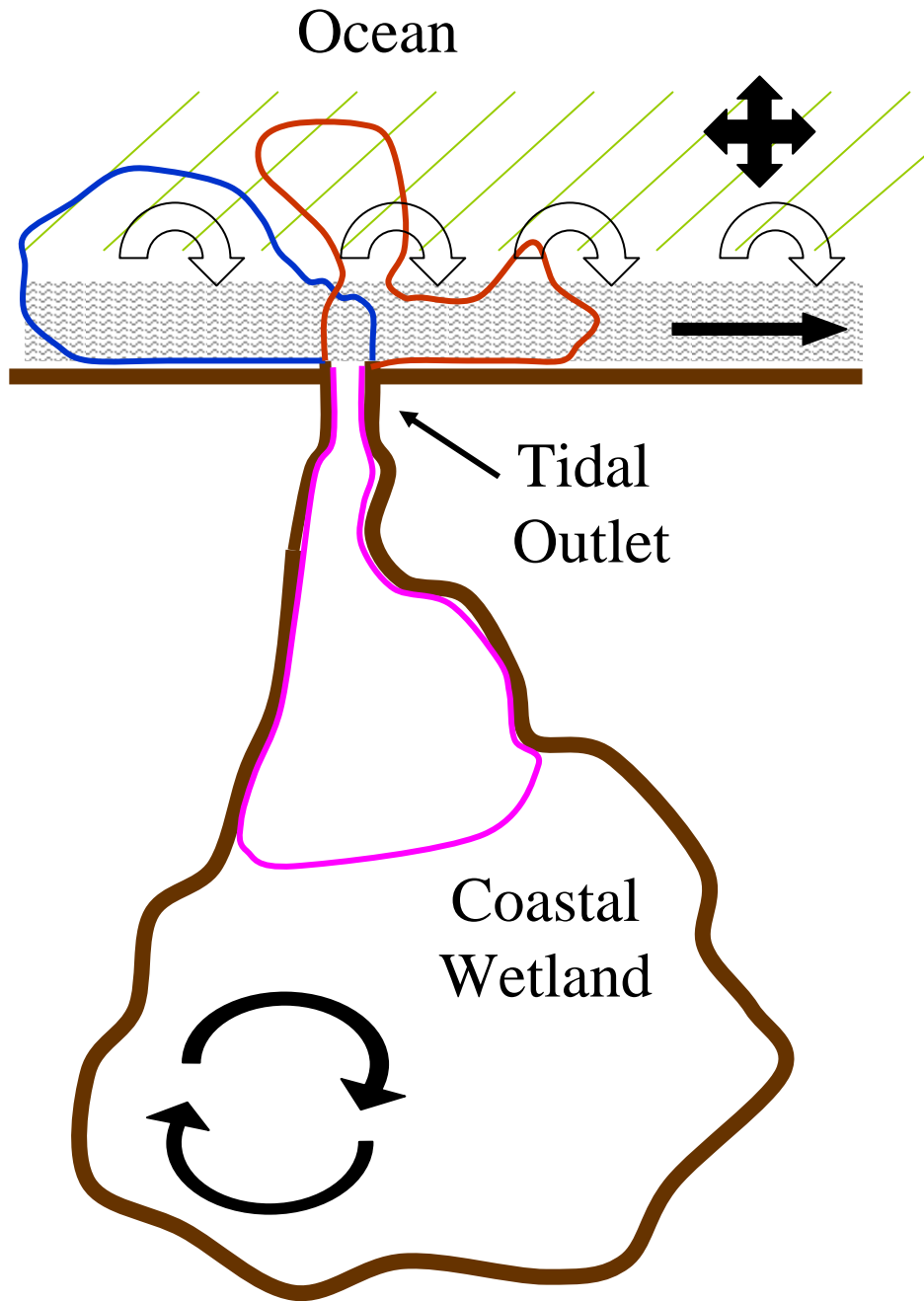


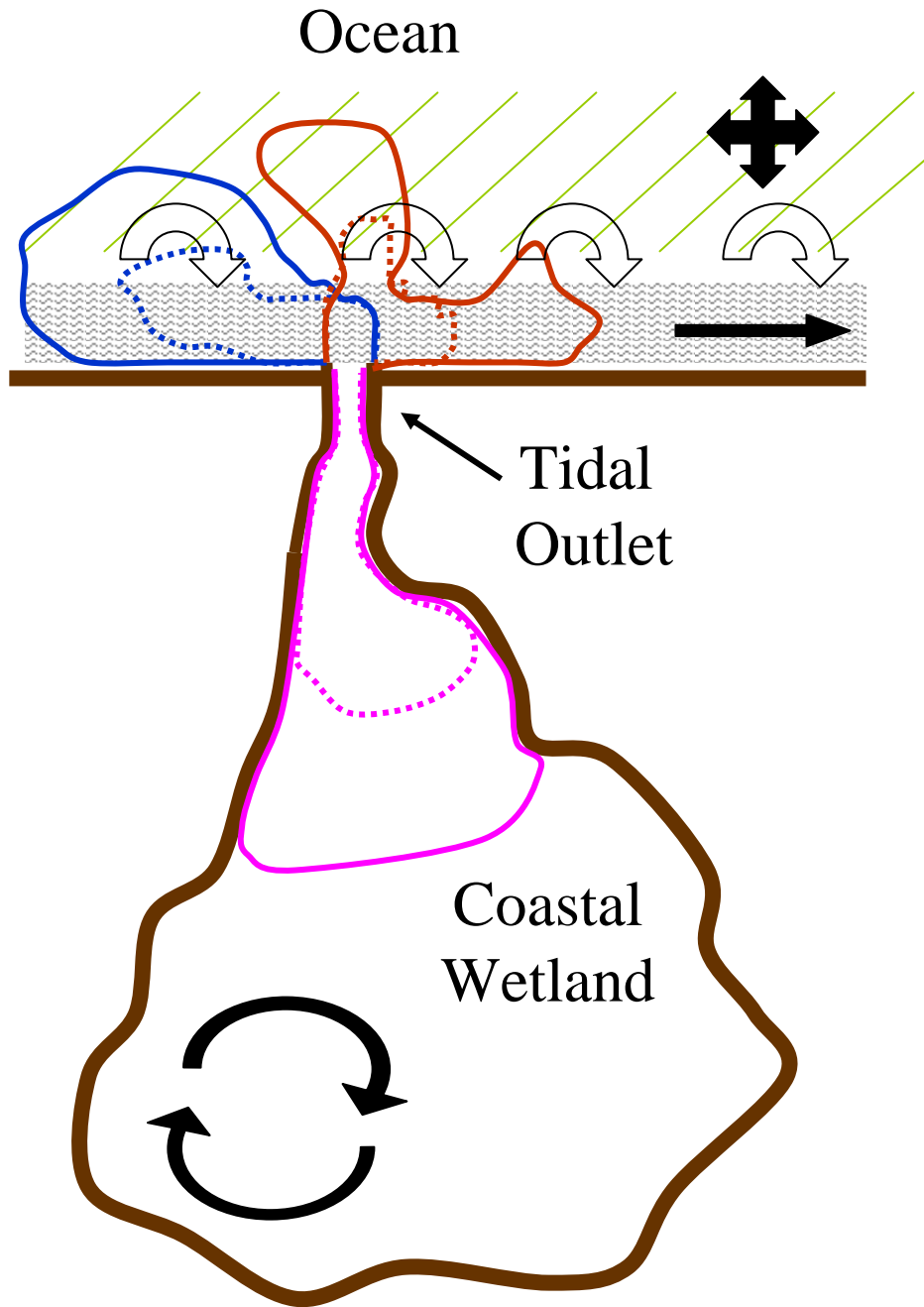
Ocean













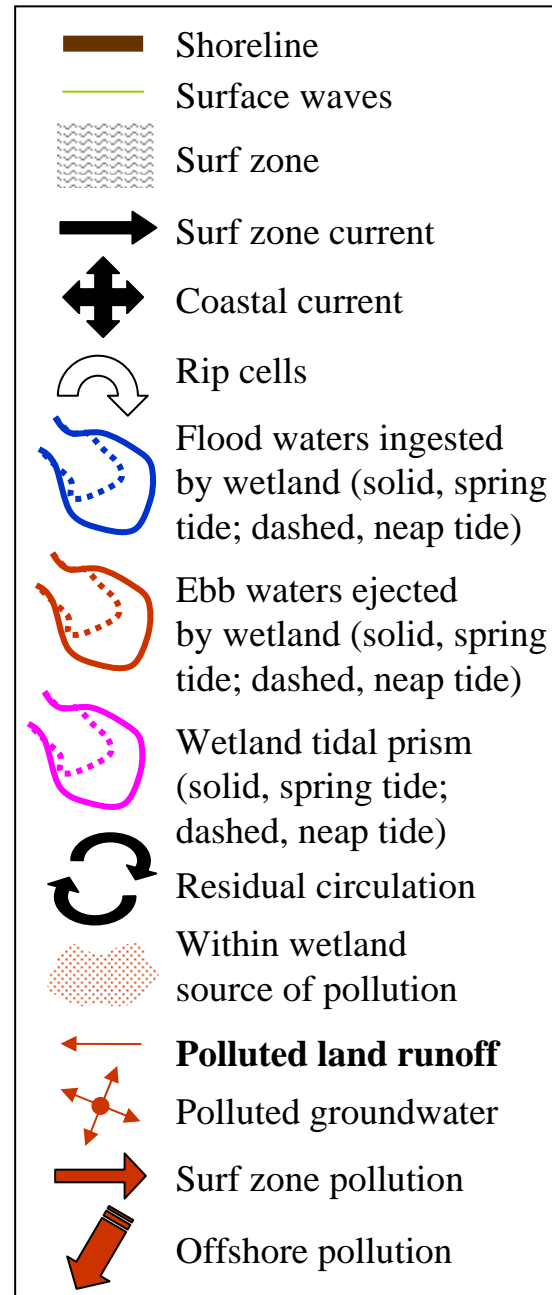
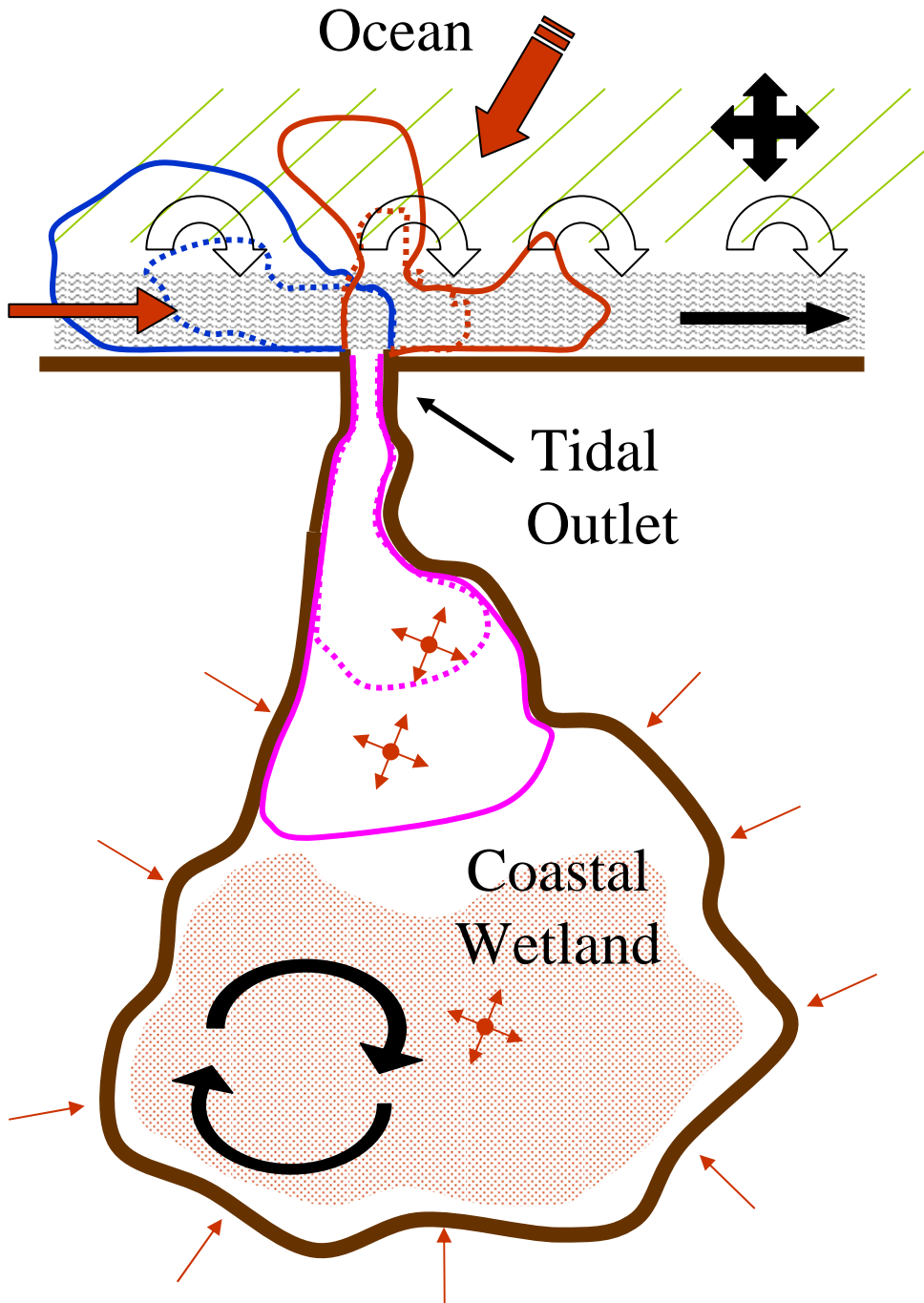
- Shoreline
- Surface waves
- Surf zone







-  Shoreline
-  Surface waves
-  Surf zone
-  Surf zone current
-  Coastal current
-  Rip cells
-  Flood waters ingested by wetland (solid, spring tide; dashed, neap tide)
-  Ebb waters ejected by wetland (solid, spring tide; dashed, neap tide)
-  Wetland tidal prism (solid, spring tide; dashed, neap tide)
-  Residual circulation



Case Study 1

Dry and wet weather runoff
impacts on open coastlines

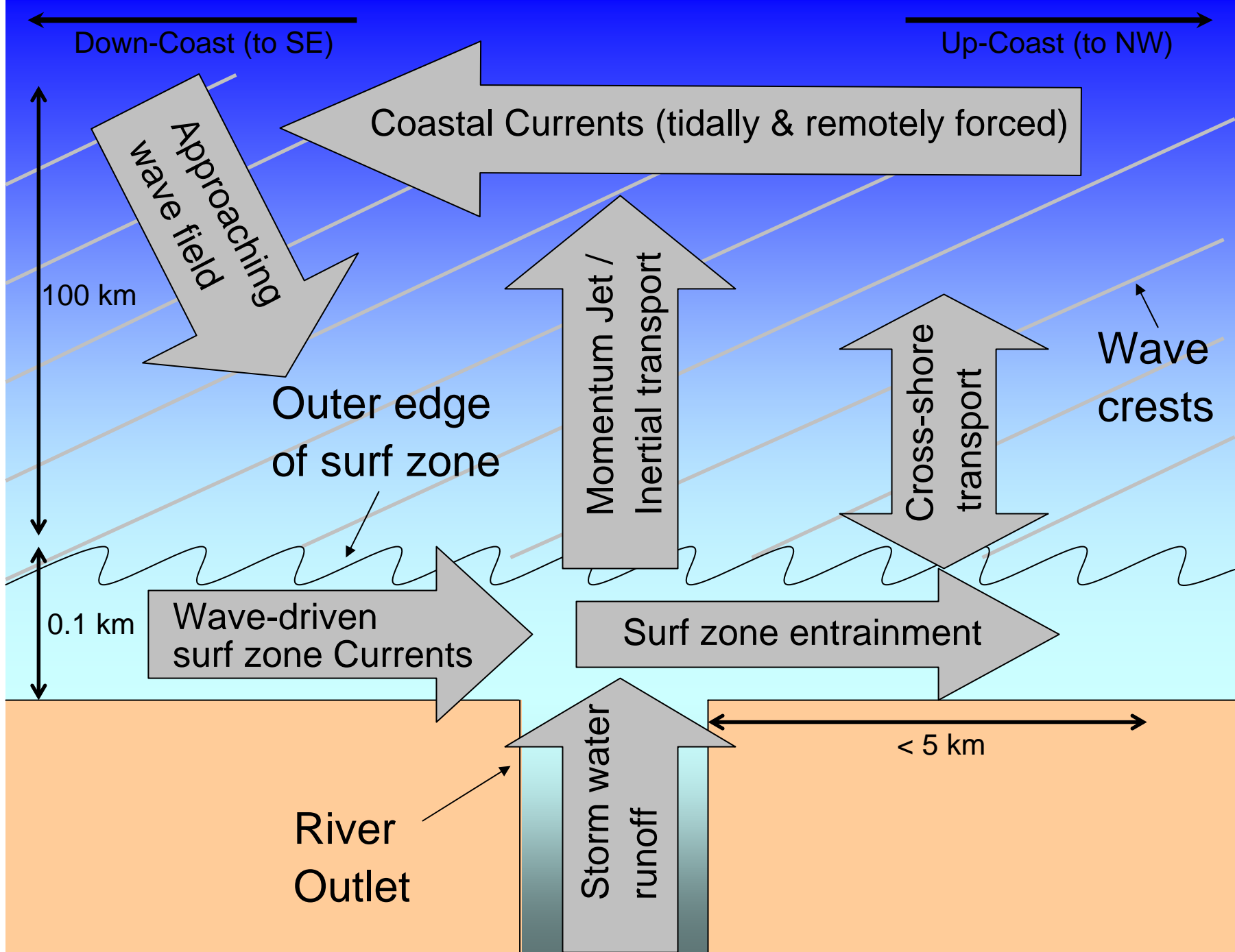
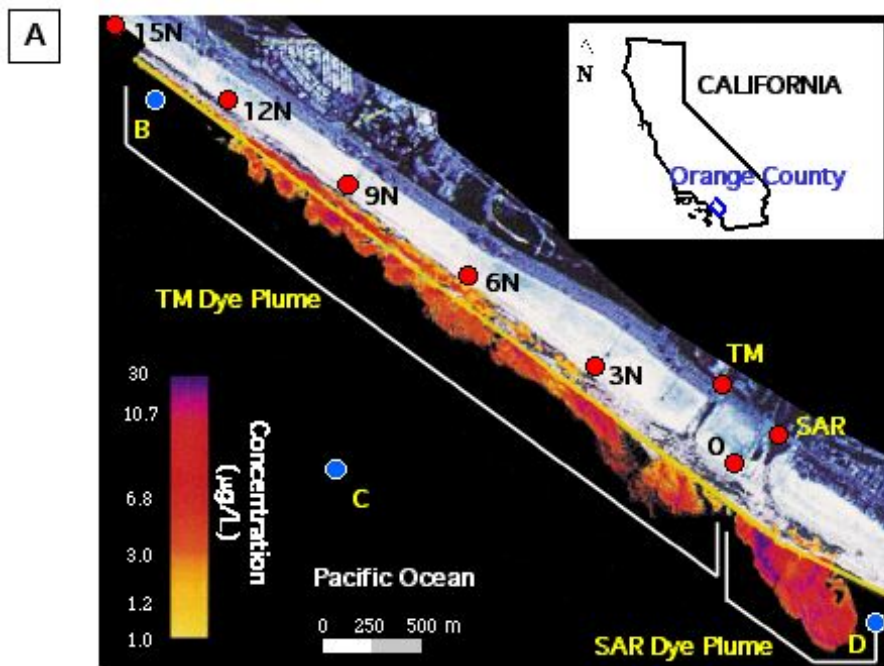
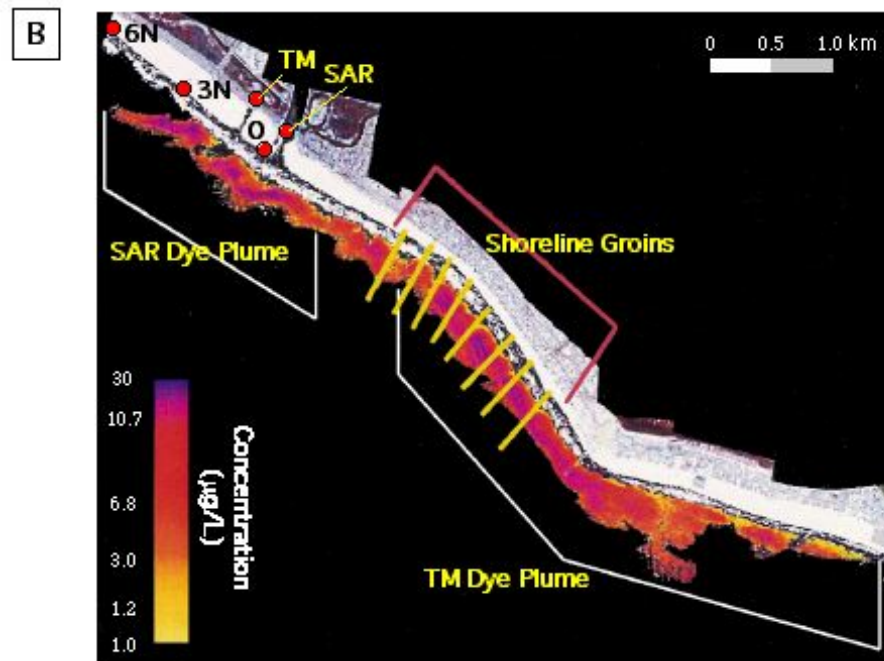


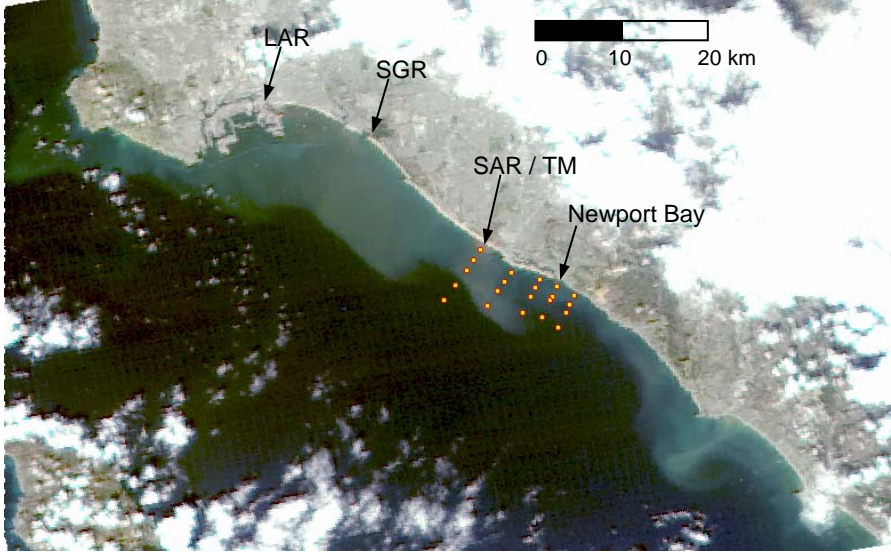
Figure 9A



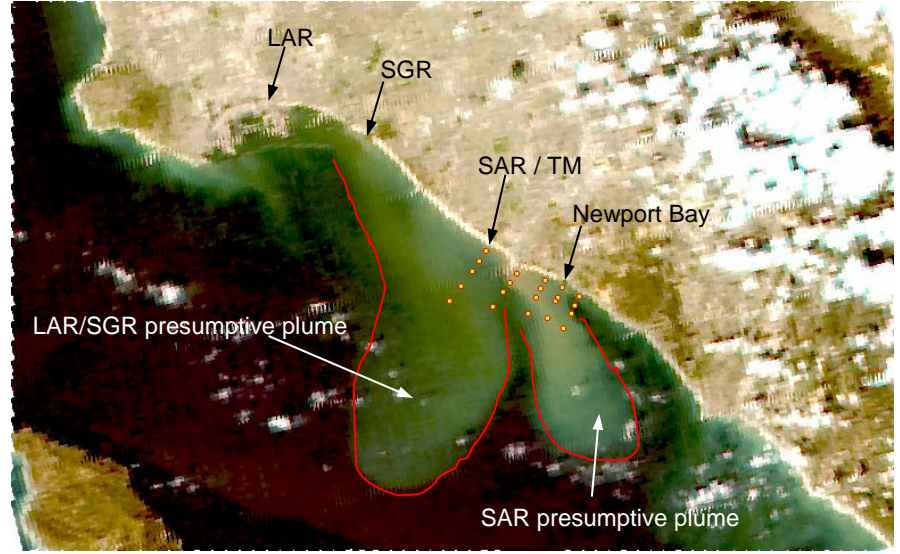
TM - Talbert Marsh outlet, SAR - Santa Ana River outlet
B & D - Acoustic Doppler Current Profilers, C - S4ADW wave sensor



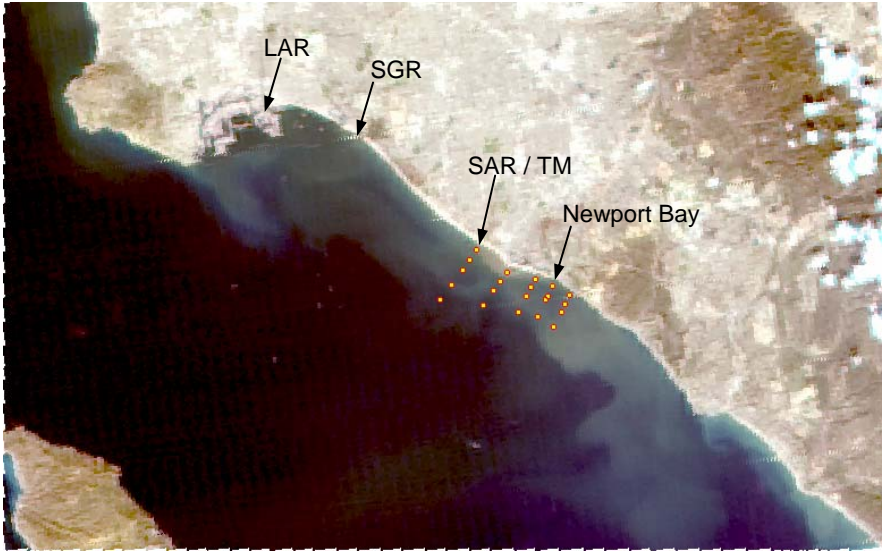
A 23 Feb. at 13:00



B 27 Feb. at 12:35



C 28 Feb. at 13:20



D 29 Feb. at 10:50

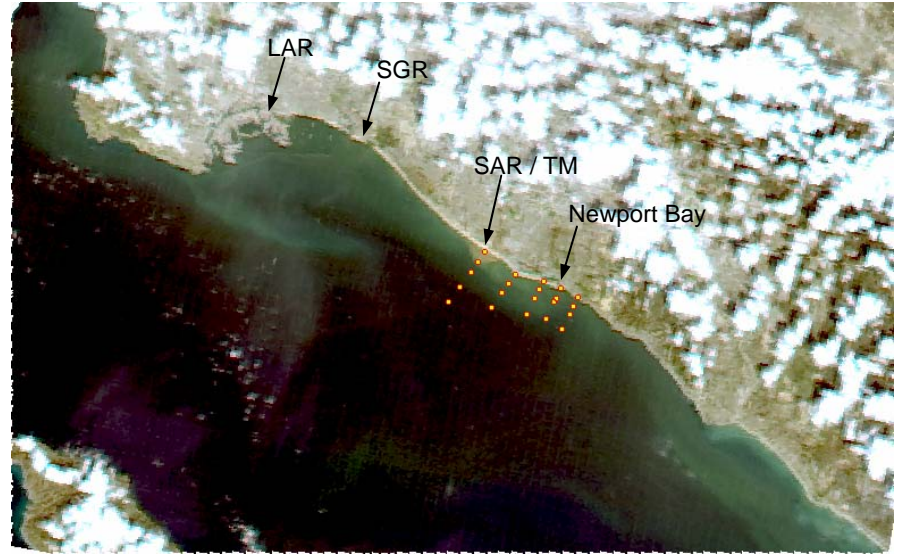


Figure 3

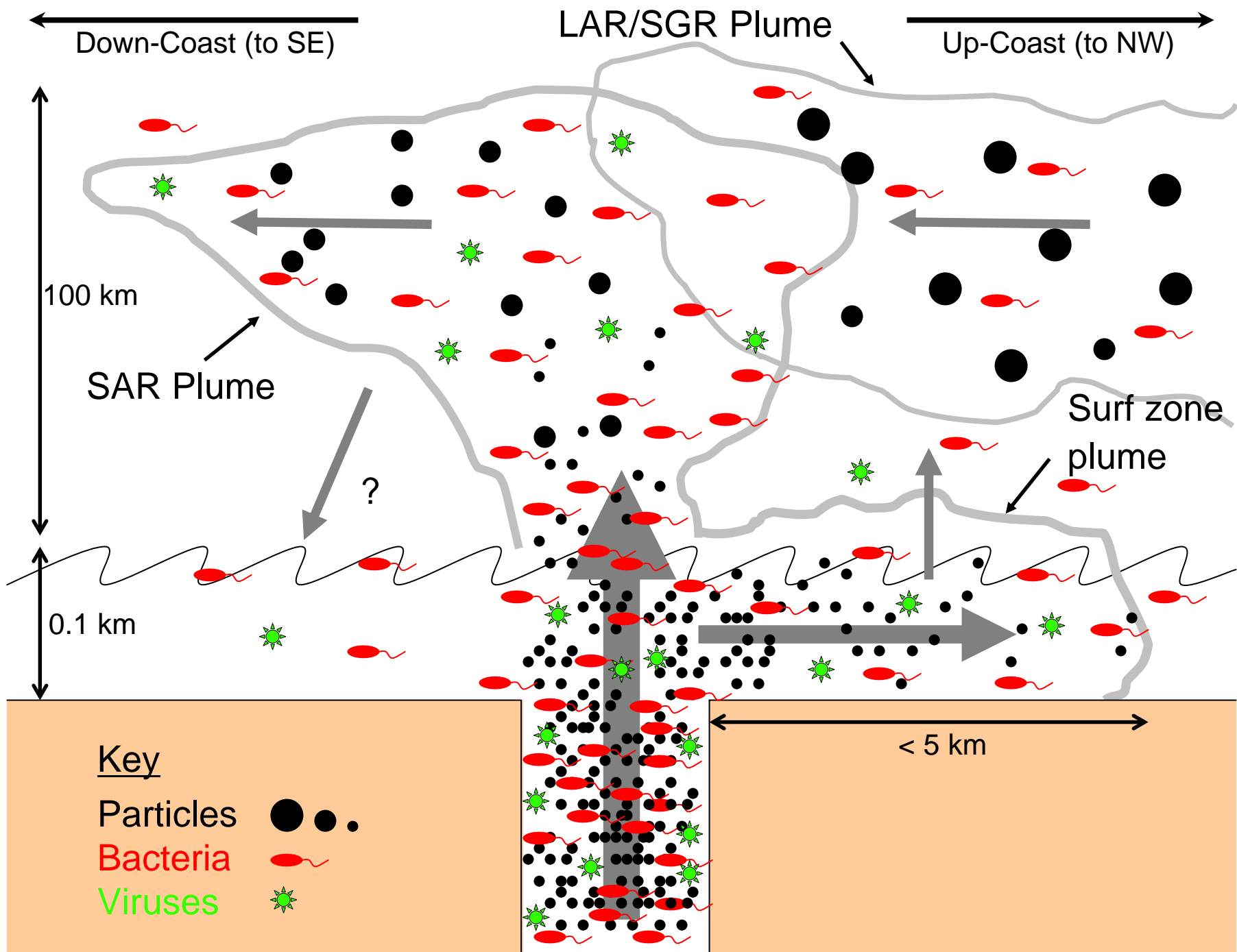


Figure 9B

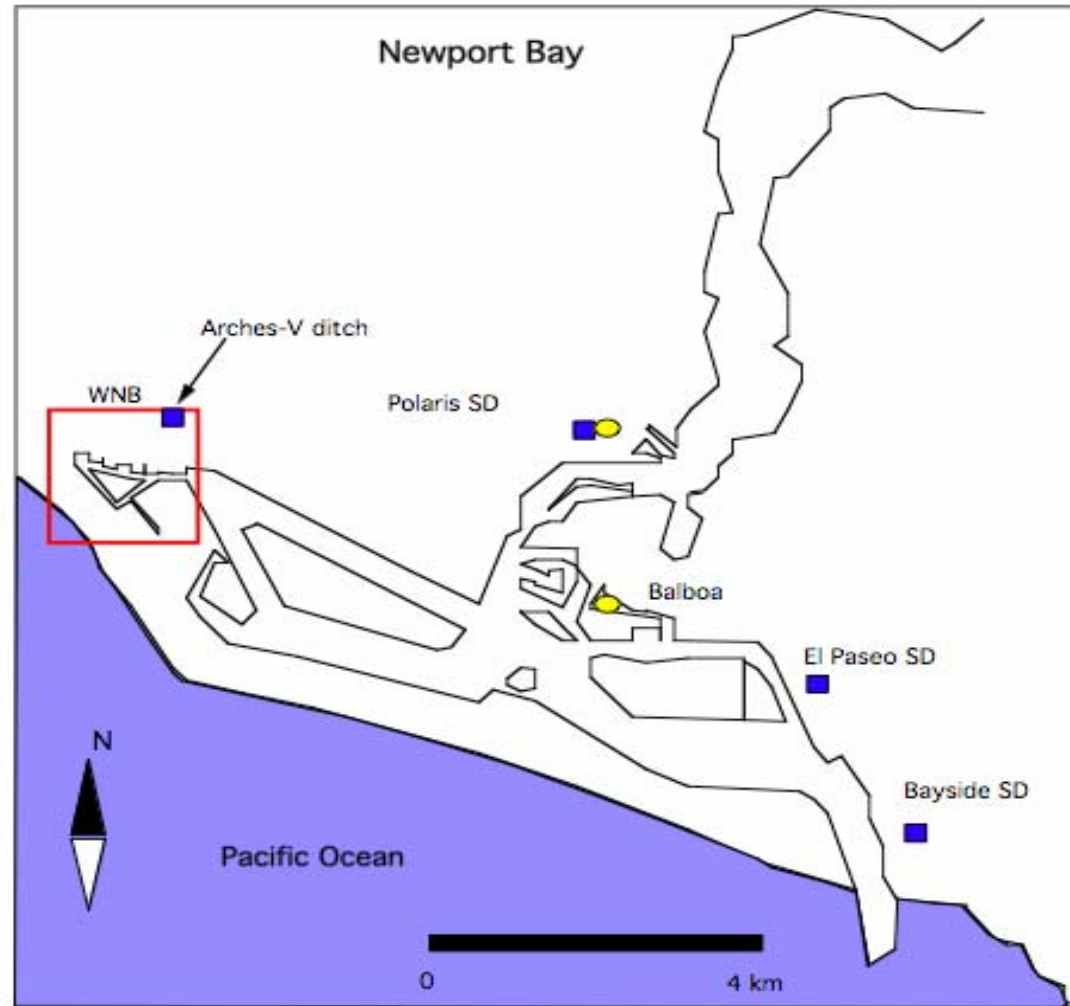
Case Study 1: Summary

- Dry weather:
 - Tidal flow at river outlets
 - Significant surf zone entrainment
 - Runoff plumes elongated parallel to shore (~0.1 km cross-shore; >5 km along-shore)
- Wet weather:
 - River flow at river outlets
 - Some surf zone entrainment
 - Runoff plumes extend far offshore (~20 km cross-shore; <5 km along-shore)

Case Study 2

Dry weather runoff impacts on a coastal embayment

West Newport Bay (WNB)

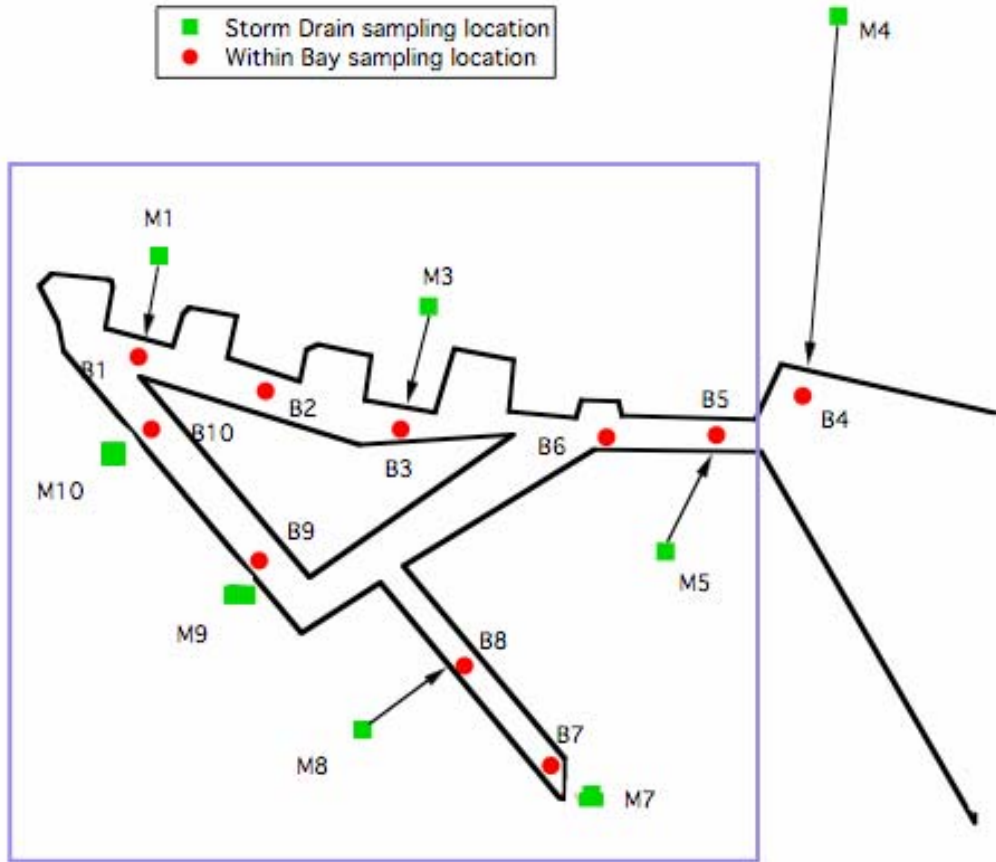


Lower Bay: Marina



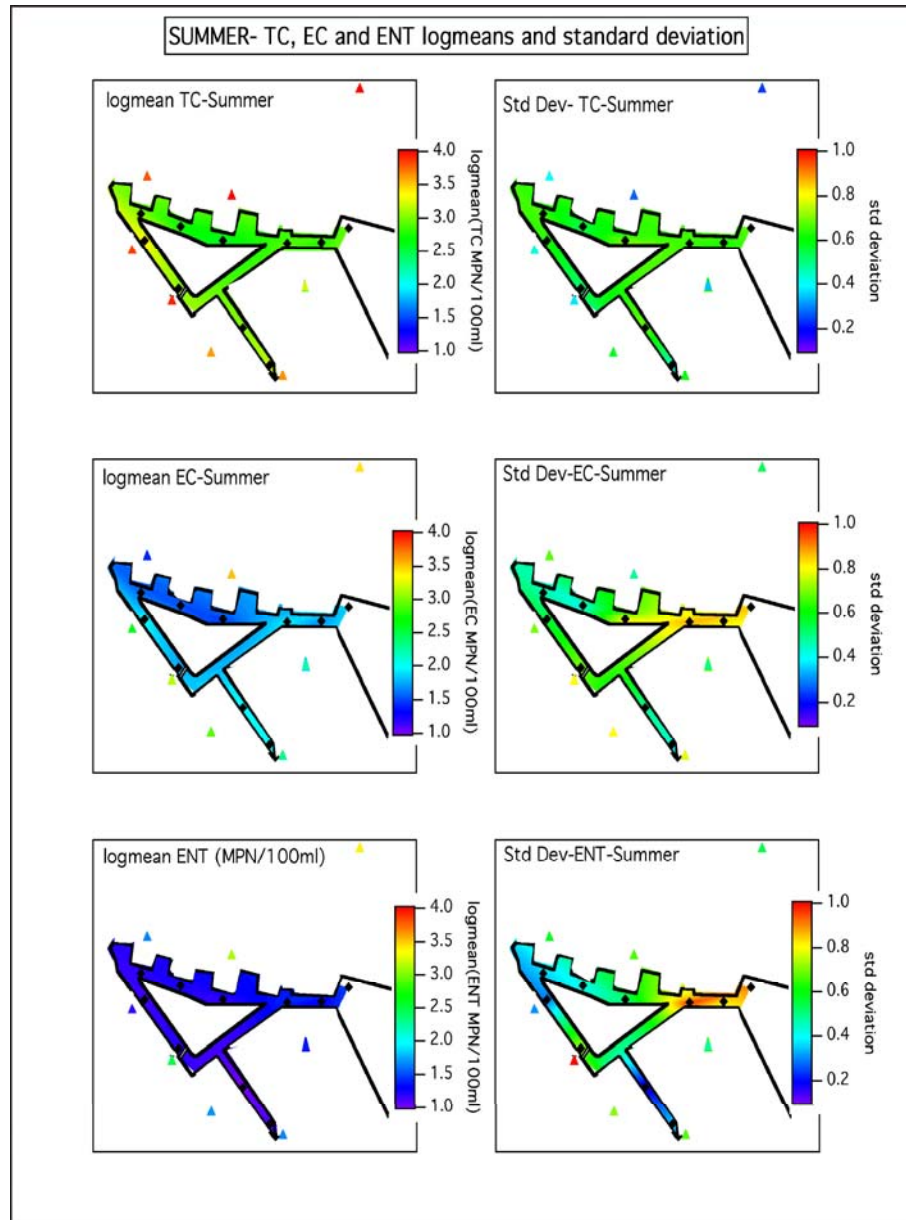
West Newport Bay (WNB)

- Storm Drain sampling location
- Within Bay sampling location



0 1 km

Boat and Storm Drain Sampling: Summer



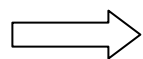
Results

- **Storm Drains Sites:**

- FIB concentrations highly variable (median values vary by 3 orders of magnitude)
- Depending on drain, between 10 and 52% of samples exceed marine bathing water standards

- **Within Bay Sites:**

- FIB concentrations relatively homogeneous (median values within one order of magnitude)
- Depending on site, between 7.5 and 8% of samples exceeded marine bathing water standards (typical for so. Cal embayments)

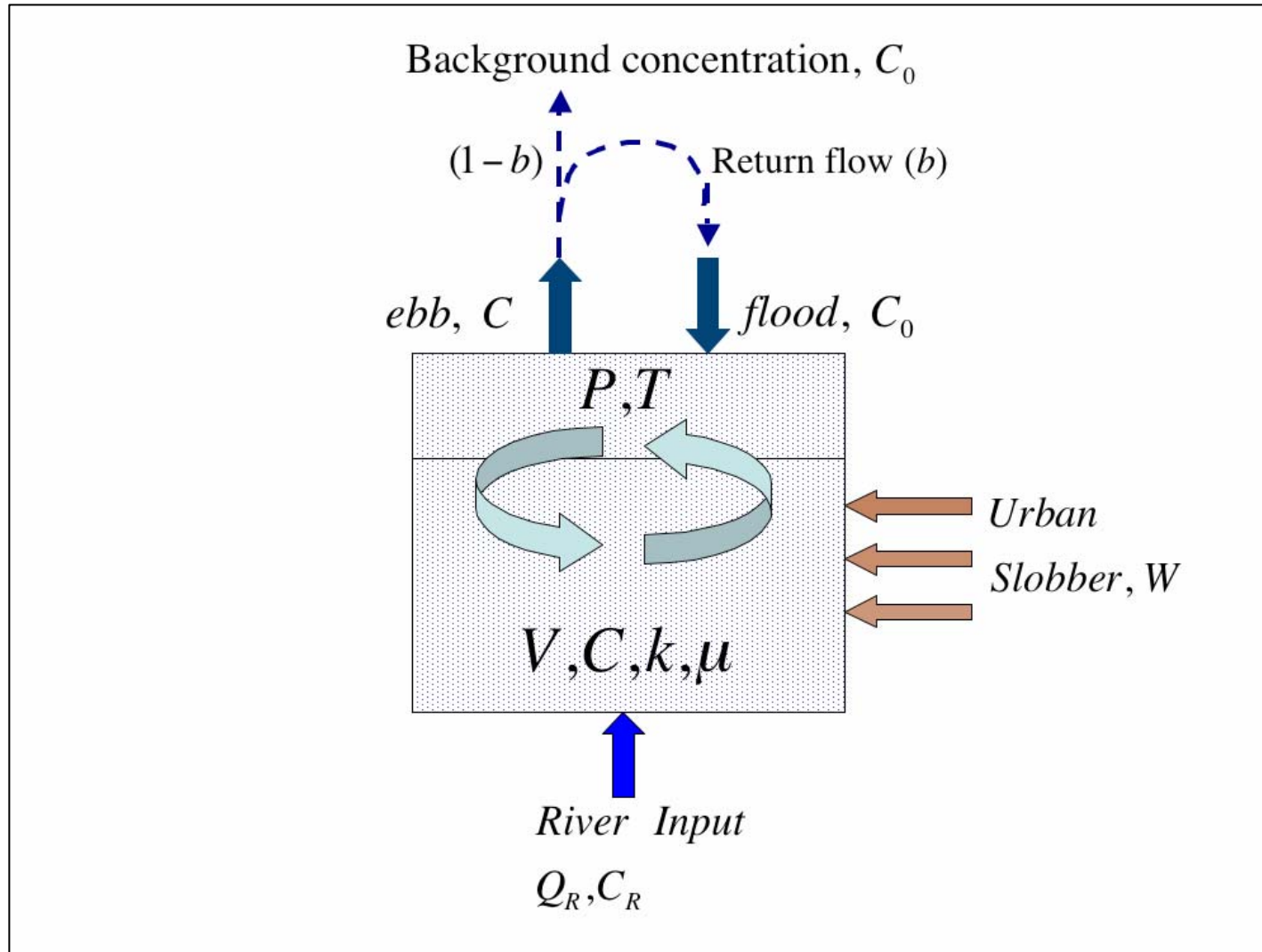


WNB is well mixed with respect to FIB

Possible BMP Strategies

- **Load reductions:** intercept or treat runoff before it reaches embayment
- **Circulation enhancement:** “mixing is the solution to dilution”
- **Volume alteration:** dredging or infilling
- **Die-off enhancement:** manipulate environmental conditions (e.g., control turbidity, salinity, nutrients) to enhance die-off of FIB and pathogens after they enter the Bay

Box model of *tidal embayments*



Model Input Parameters

- P: Tidal Prism Volume
- V: Volume of embayment at low tide
- W: Loading of FIB into embayment (bacteria/time)
- k: Die-off rates as a function of solar irradiance (1/time)
- b: Return flow factor (dimensionless)
- C_0 : Background concentration (bacteria/volume)
- T: Tidal Period (time)

Steady state: “Urban Slobber” case.

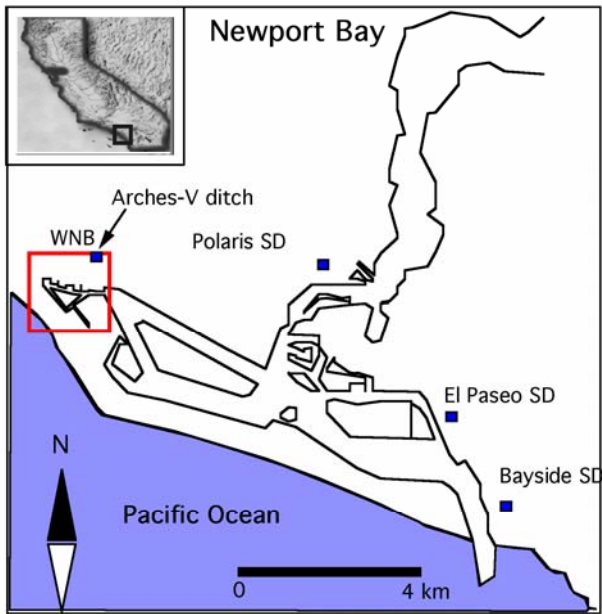
Because there is no fresh water inflow

$$C_{slobber} = \left[\frac{WT + P(1-b)C_0}{kT(V + P) + P(1-b)} \right]$$

Model Input Parameters

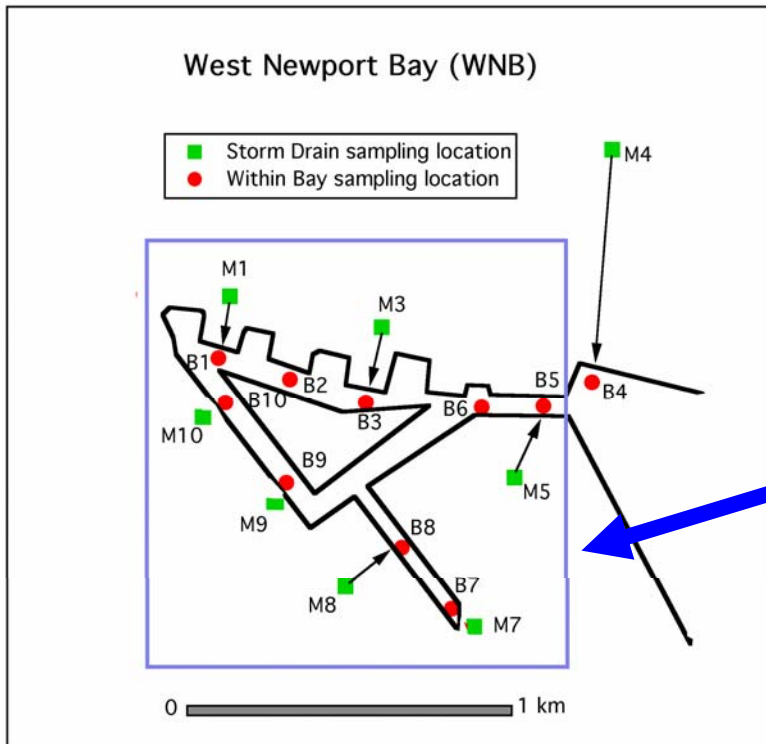
- To account for the extreme variability associated with many model input parameters, we:
 - Estimated probability distributions for each of the input parameters,
 - Performed a Monte Carlo simulation to determine the corresponding probability distribution of predicted FIB concentrations in WNB
 - Compared the probability distribution of predicted and measured FIB concentrations in WNB

A

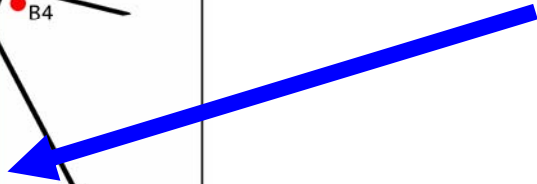


Field test of the model: West Newport Bay (WNB)

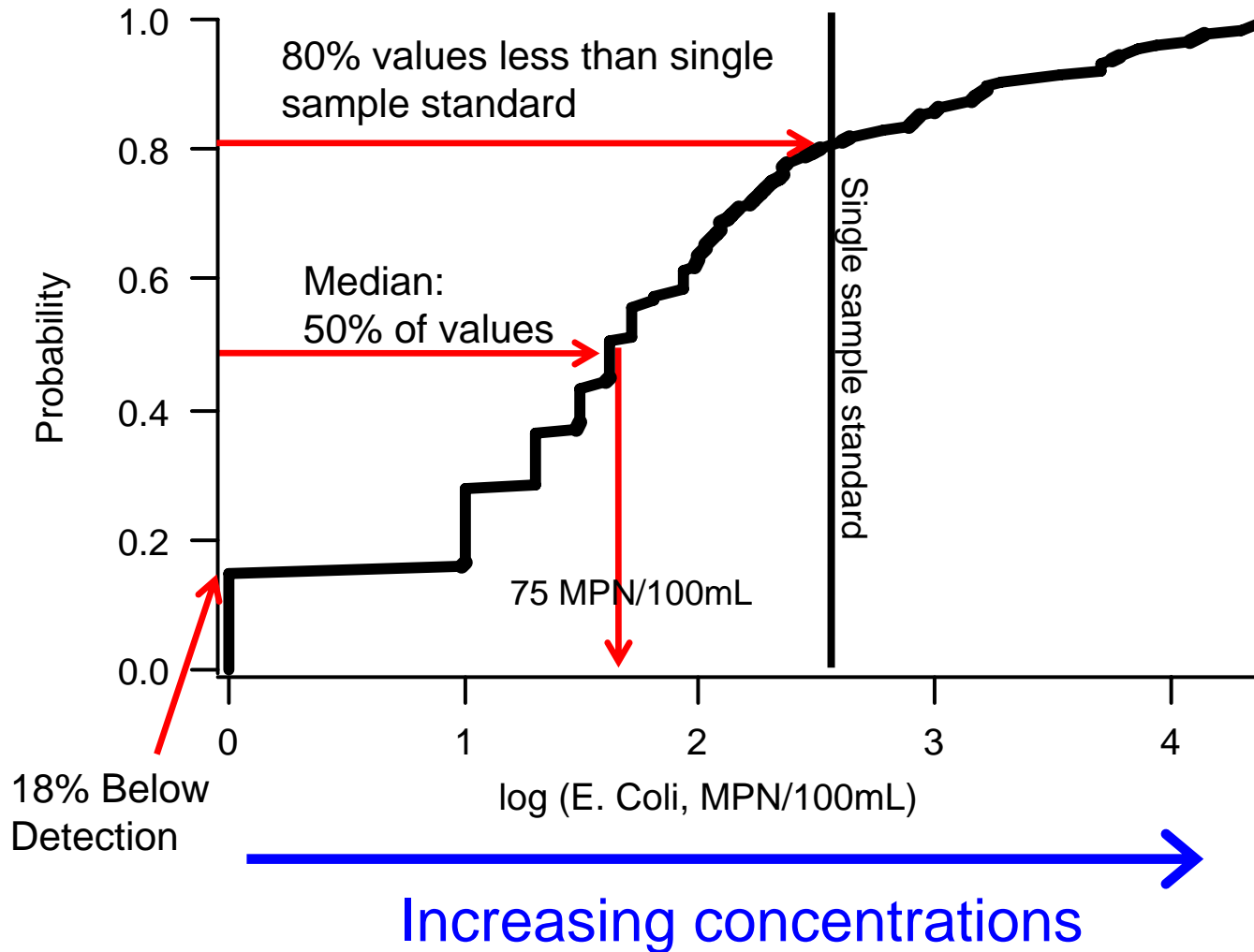
B



Region modeled



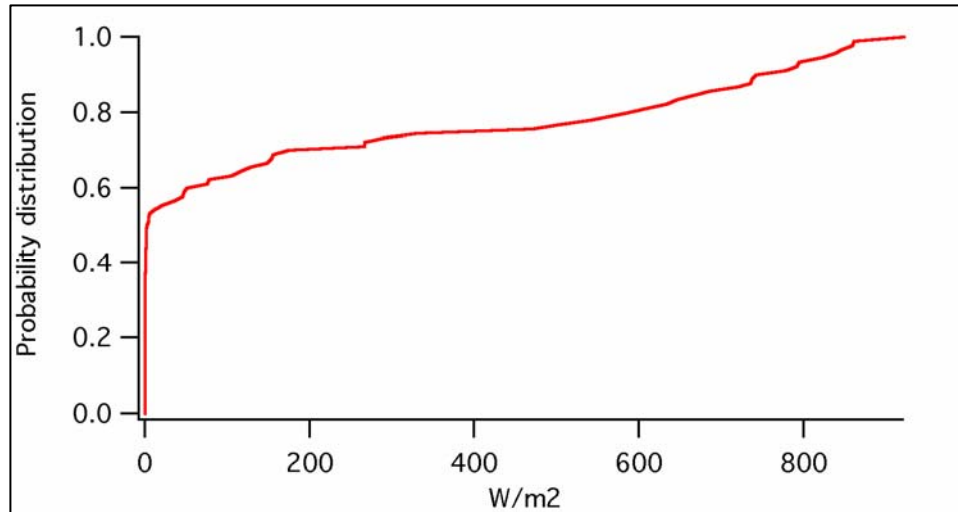
Cumulative Distribution Plots



Volume Comparison

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

FIB Die-off (Single-hit Model)

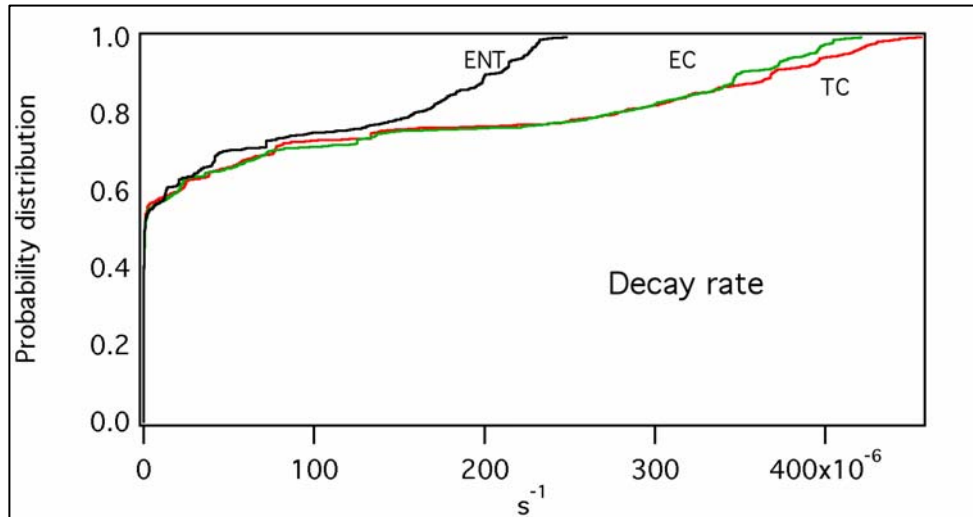


Sinton et al rate constants:

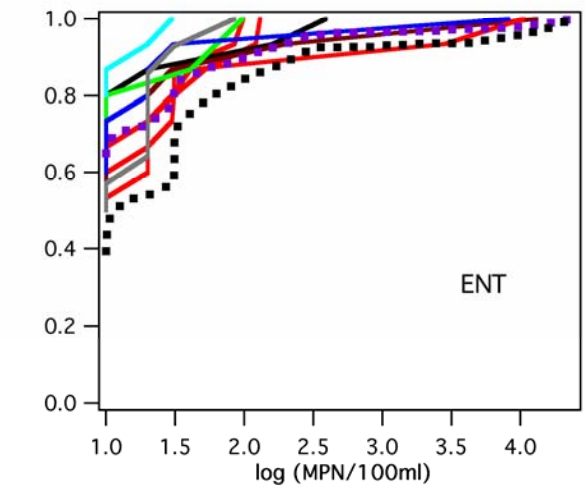
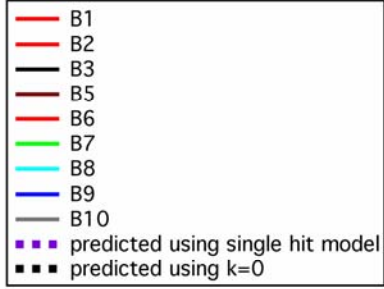
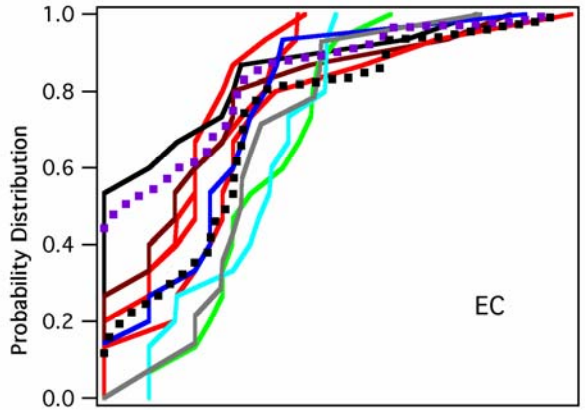
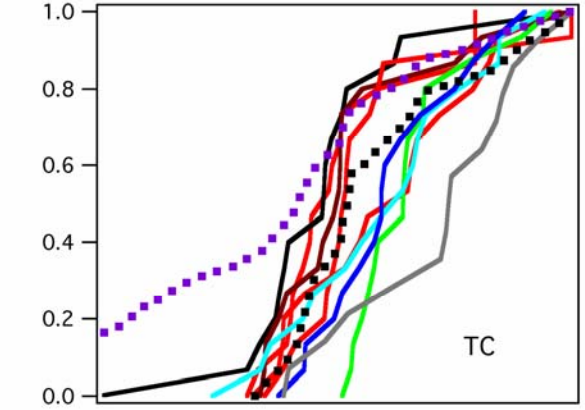
$$k(\text{TC})=5\text{E-}07 \text{ m}^2/\text{Ws}$$

$$k(\text{FC})=4.7\text{E-}07 \text{ m}^2/\text{Ws}$$

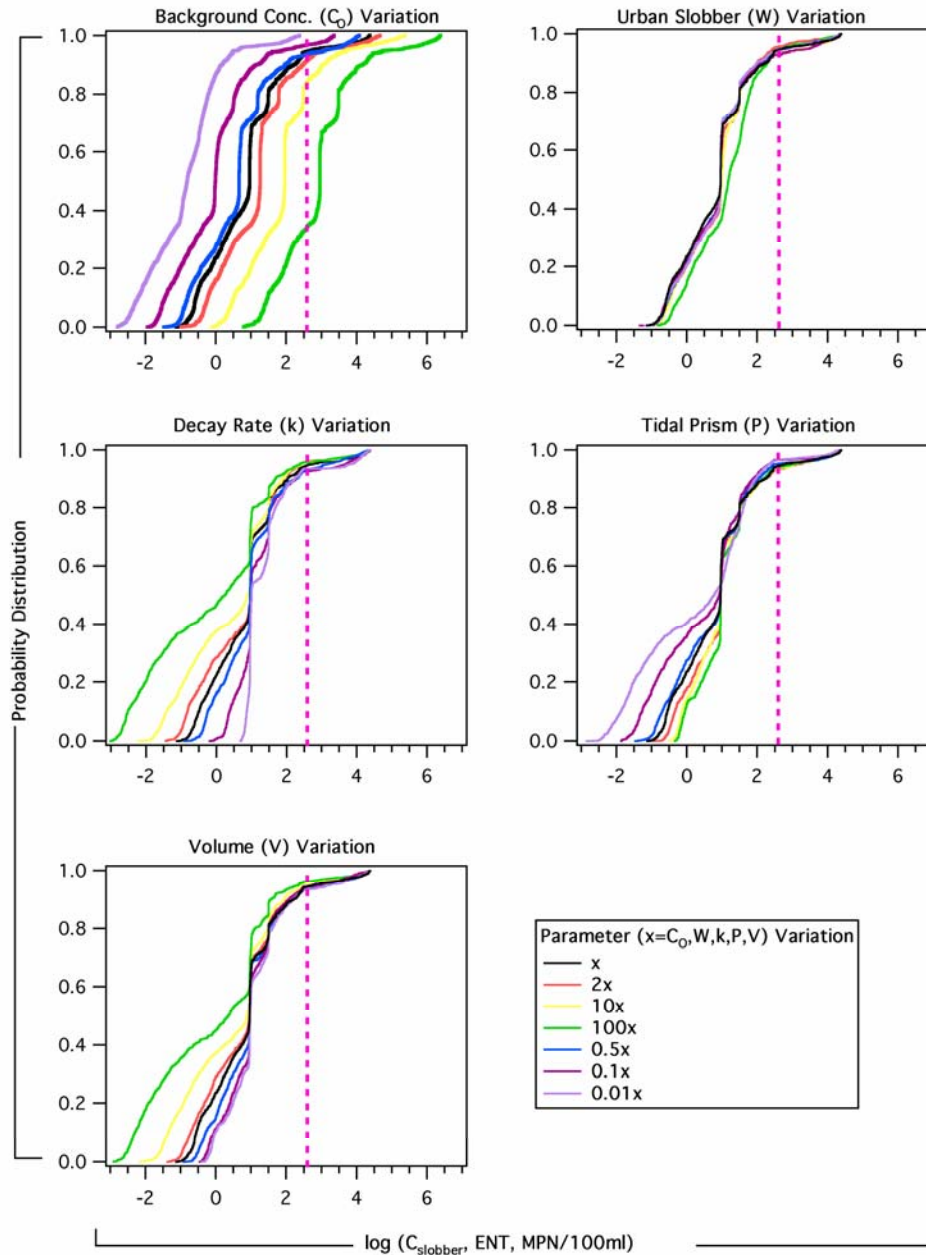
$$k(\text{ENT})=2.7\text{E-}07 \text{ m}^2/\text{Ws}$$



Model Output



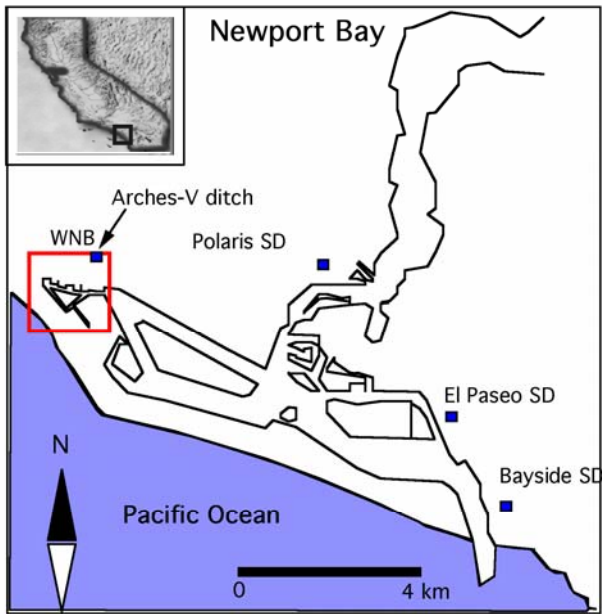
What is the best BMP?



Case 2: Summary

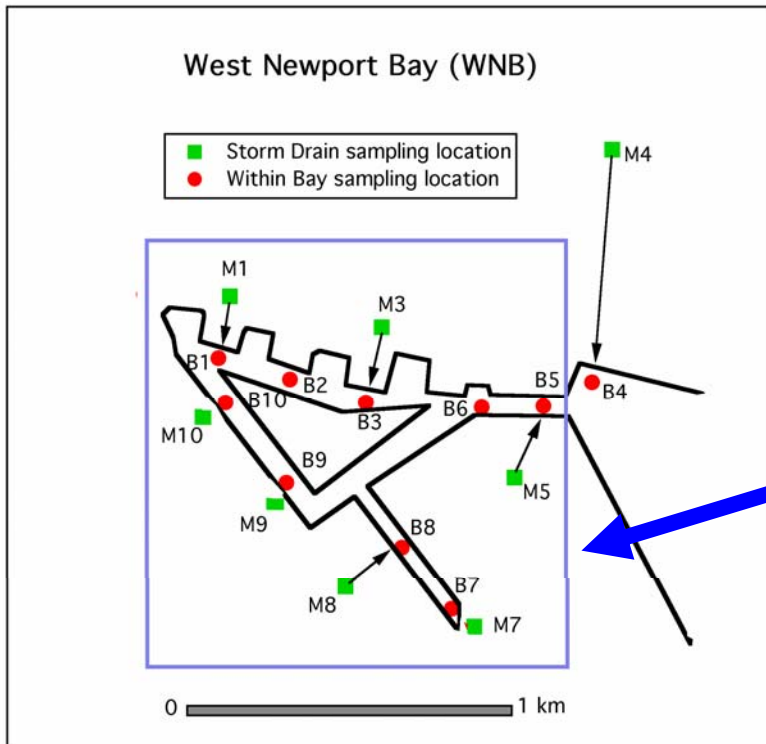
- Box model predictions of FIB in WNB match measurements (dry weather)
- Box model results suggest:
 - FIB are coming from the portion of Newport Bay outside the “WNB box”
 - FIB from runoff are very stable after entering the Bay
 - Recommended BMP: Reduce the background concentration of FIB (e.g., by diverting Arches Drain)

A



Field test of the model: West Newport Bay (WNB)

B



Region modeled

Overall Conclusions

- Some understanding of pathogen transport pathways crucial for source identification and BMP evaluation
- Along the open coast, different physical transport processes dominate during dry and wet weather
- Simple models (e.g., that take into account tidal mixing and FIB die-off) can be useful for identifying optimal BMPs

Questions?