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Soller Environmental, LLC
Norcal Beach Water Quality Workgroup
1 February 2018

INCIDENCE OF GASTROINTESTINAL ILLNESS FOLLOWING WET WEATHER RECREATIONAL EXPOSURES

REGULATIONS
The Surfer Health Study
Winter 2014 - 2015
For more information and to enroll visit our study website:
www.sccwrp.org/shs
or scan the QR code:
What is the study about?
This will be the first research study to measure the health risks (if any) associated with surfing on the California coast during the winter months.
How can you help?
We are enrolling hundreds of surfers in the San Diego area to parcipate in 5-10 minute online surveys over the 2014-2015 winter. For every 4 weekly surveys you complete, we will give you a $20 gift card to Swell.com.
You can help us by enrolling and by getting the word out!
School of Public Health
SCCWRP
SURFRIDER FOUNDATION
This study is funded by the City and County of San Diego

Motivation

- We started the study to address wet weather bacteria
  - Wet weather bacteria is a chronic problem
- Potential cost for fixing is large
  - Compliance deadlines are looming
- Uncertainty regarding the extent to which wet weather bacteria is a public health risk
  - Wet weather epidemiology study had never been done before

Setting the Stage

- Existing WQSs are generally met during spring, summer, fall
- Existing WQSs are generally met during winter dry weather
- Existing WQSs are not met during winter wet weather– typically SSM exceeded
- Level of public health protection associated with existing WQSs is/was not known

Research Questions

1. Is water contact associated with an increased risk of illness among surfers?

2. Is risk of illness greater from exposure following wet weather compared to dry weather?

3. What is the association between levels of *Enterococcus* and illness following wet weather?

4. What level of *Enterococcus* corresponds to the same risk of illness as current water quality objectives?

Findings of the Surfer Health Study

A three-year epidemiological study examining illness rates associated with surfing during wet weather

School of Public Health
UNIVERSITY OF CALIFORNIA, BERKELEY

SCCWRP
Established 1969

SURFRIDER FOUNDATION

Soller Environmental, LLC

Southern California Coastal Water Research Project

SCCWRP Technical Report 943

Findings of the Surfer Health Study

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American Journal of Epidemiology
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DOI: 10.1093/aje/kwx019

Original Contribution

Acute Illness Among Surfers After Exposure to Seawater in Dry- and Wet-Weather Conditions

Benjamin F. Arnold*, Kenneth C. Schiff, Ayse Ercumen, Jade Benjamin-Chung, Joshua A. Steele, John F. Griffith, Steven J. Steinberg, Paul Smith, Charles D. McGee, Richard Wilson, Chad Nelsen, Stephen B. Weisberg, and John M. Colford, Jr.

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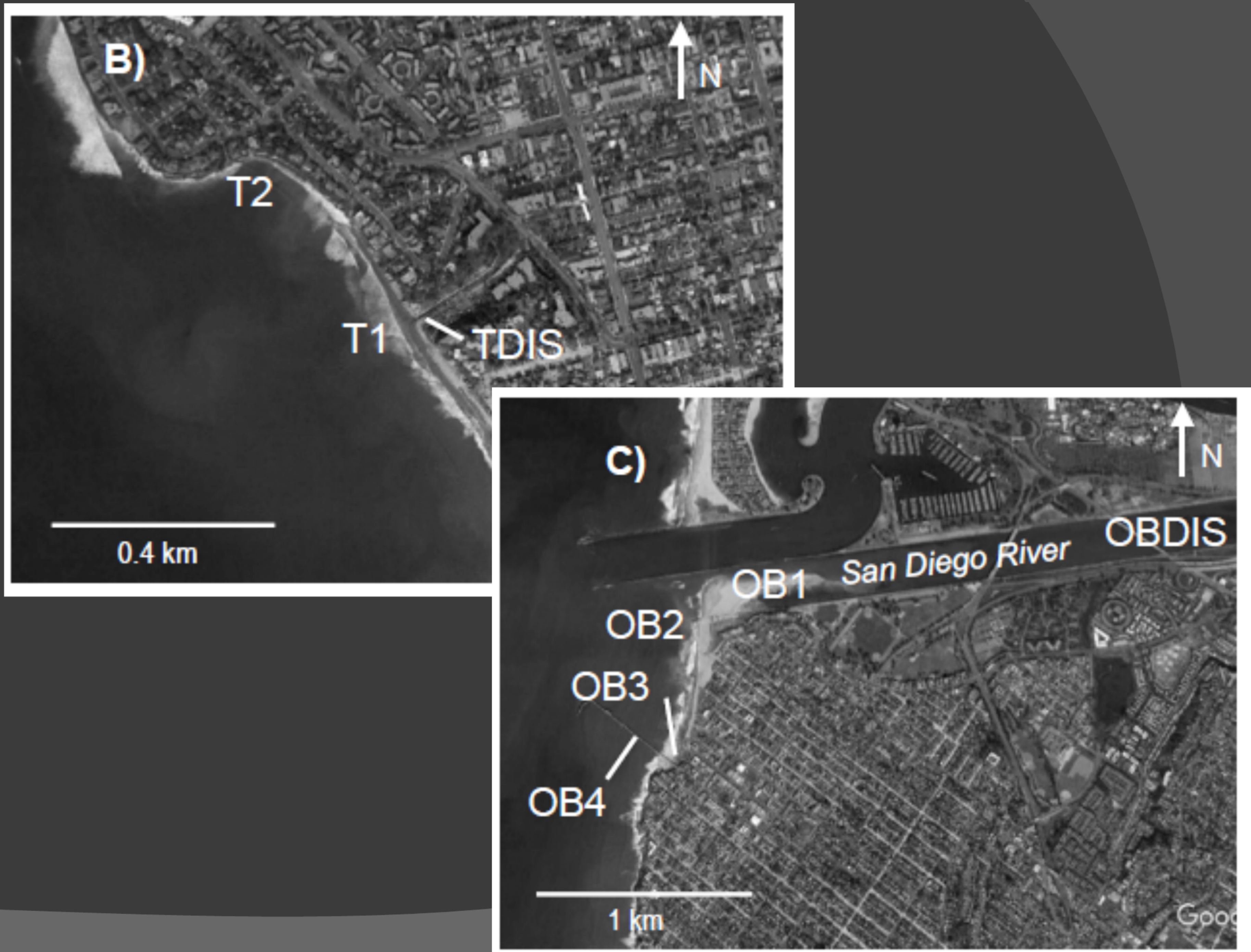
Rainstorms increase levels of fecal indicator bacteria in urban coastal waters, but it is unknown whether exposure to seawater after rainstorms increases rates of acute illness. Our objective was to provide the first estimates of rates of acute illness after seawater exposure during both dry- and wet-weather periods and to determine the relationship between levels of indicator bacteria and illness among surfers, a population with a high potential for exposure after rain. We enrolled 654 surfers in San Diego, California, and followed them longitudinally during the


B)
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T2
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TDIS
0.4 km
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San Diego River
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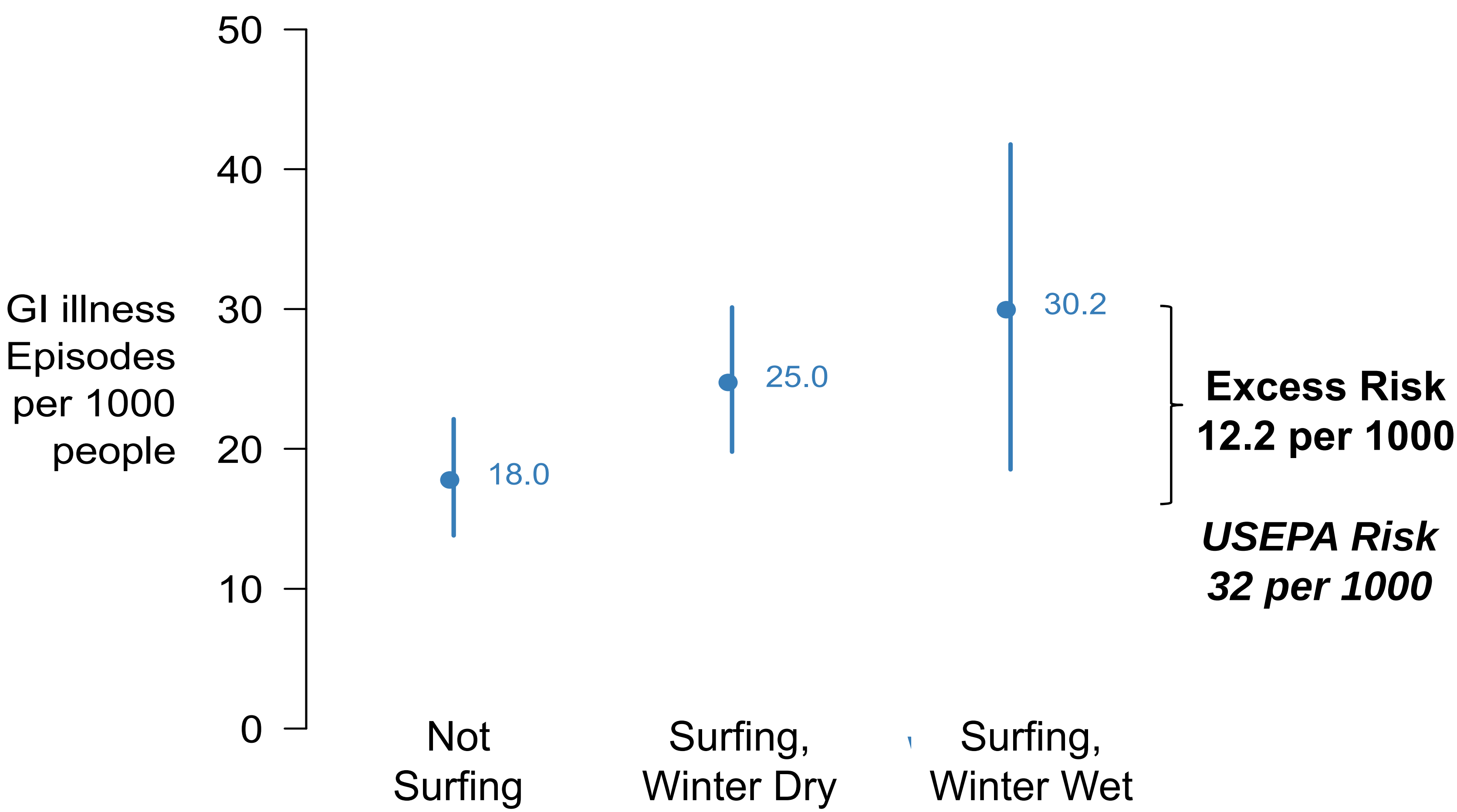
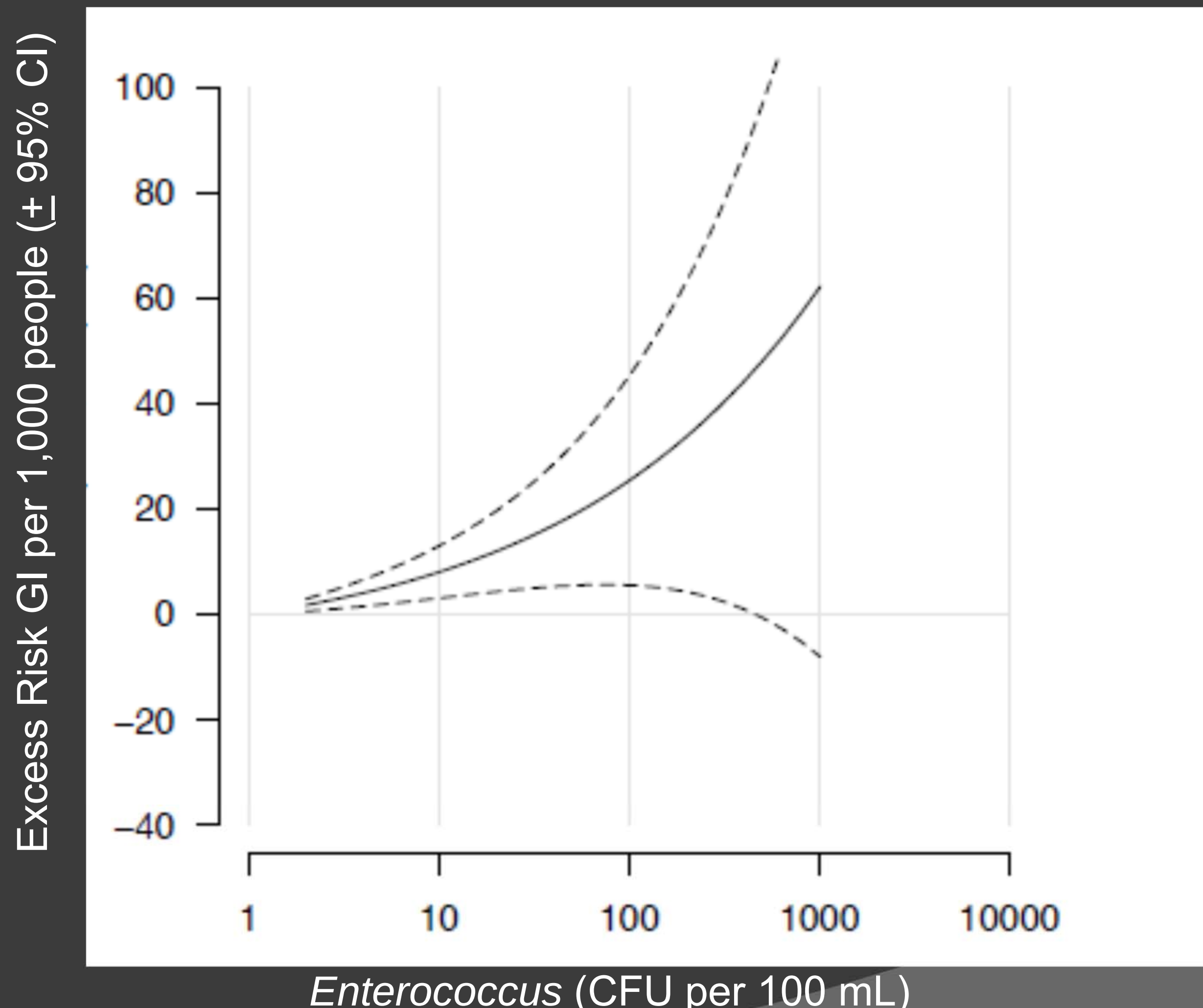
OB2
OB3
OB4
1 km

Cumulative Incidence of Gastrointestinal Illness



Gastrointestinal Illness, Wet Weather



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American Journal of Epidemiology
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Original Contribution

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Incidence of gastrointestinal illness following wet weather recreational exposures: Harmonization of quantitative microbial risk assessment with an epidemiologic investigation of surfers

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A R T I C L E I N F O

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A B S T R A C T

We modeled the risk of gastrointestinal (GI) illness associated with recreational exposures to marine water following storm events in San Diego County, California. We estimated GI illness risks via quantitative microbial risk assessment (QMRA) techniques by consolidating site specific pathogen monitoring data of stormwater, site specific dilution estimates, literature-based water ingestion data, and literature based pathogen dose-response and morbidity information. Our water quality results indicated that

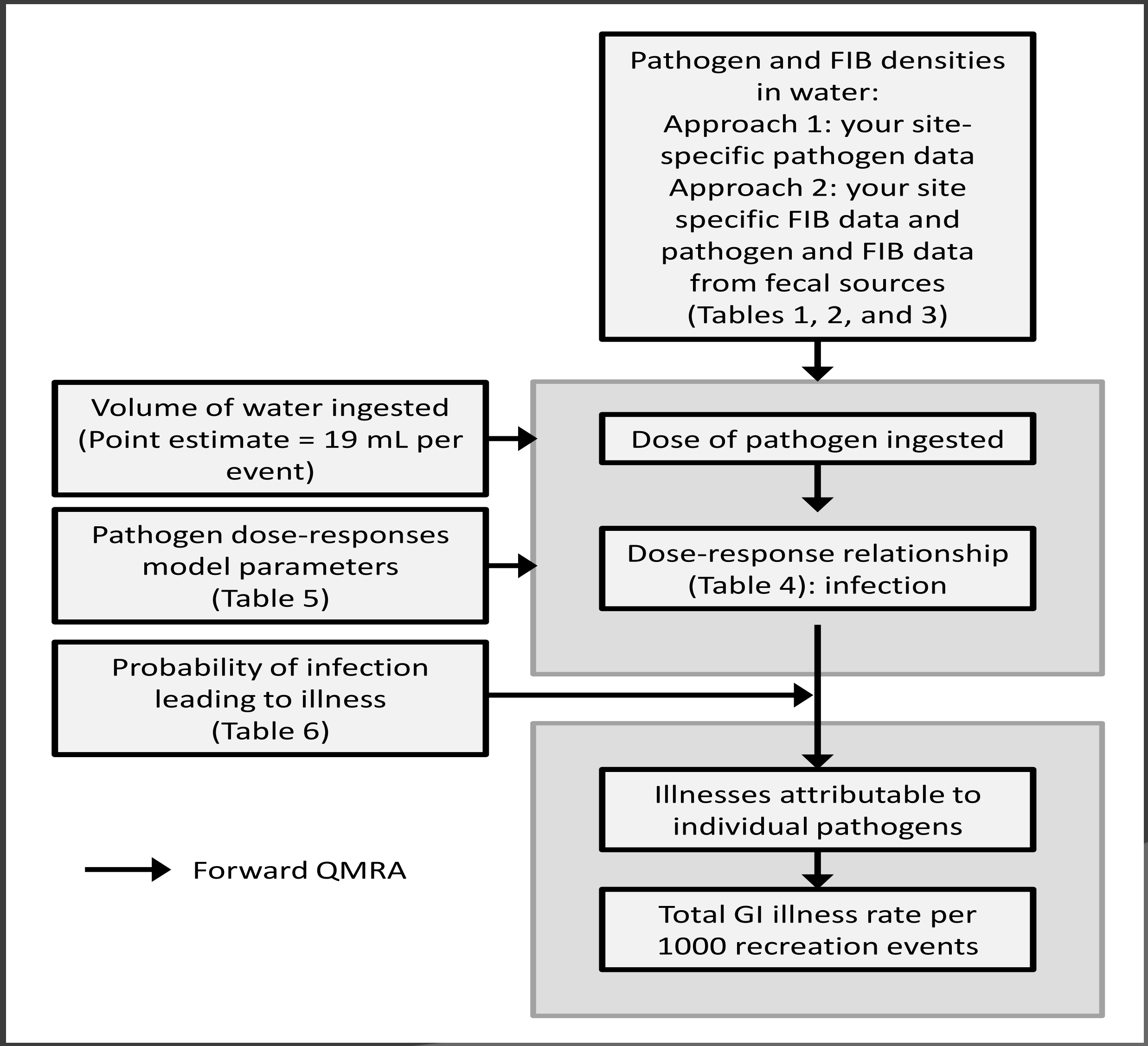
QMRA Overview

- Tool that is specifically recommended by EPA in the 2012 RWQC
- The model predicts average risk
- QMRA has advantages for estimating risk in unmeasured scenarios
  - Different source control applications
  - Potential for extrapolation

QMRA Risk Modeling Summary

- QMRA requires
  - Pathogen concentration at exposure point
  - Volume of water ingested
  - Mathematical relationship between the number of pathogens ingested and adverse health effect
  - Proportion of infections that result in illness
- Uncertainty and variability in each of these
  - We evaluate impacts of variability and uncertainty in each of these on our study results
- Output – pathogen-specific and cumulative probability of illness

Generic QMRA Conceptual Model



SHS QMRA Assumptions

- Surfing and recreation (*i.e*. swimming) result in similar levels of water ingestion
- Exposure happens in the ocean
  - No adjustment for % recovery of pathogens
  - Paired enterococci data can be used to estimate “dilution” from the discharge to standard monitoring sites
  - No die off of pathogens between discharge and exposure
- Pathogen densities in units of genome copies/100mL represent
  - viable and infectious pathogens
  - strains/genogroups that are consistent with dose response relationships
  - *C. jejuni* and *C. coli* are infectious to humans, other strains of Campylobacter are not

Data collection: Discharge FIB concentrations

INDICATOR SUMMARY

Pilot and Full Scale Wet Weather Study – Indicator Data Summary (cfu/100mL, MPN/100mL. copies/100mL)

Indicator	Site	N	# < MDL	# > TNTC	Median	Mean	Max
Fecal Coliform	Ocean Beach Discharge	32	1	0	520	1456	6000
	Tourmaline Discharge	29	1	0	800	1547	6000
Total Coliform	Ocean Beach Discharge	57	0	15	24196	45415	280000
	Tourmaline Discharge	57	3	22	24196	78726	560000
E. coli	Ocean Beach Discharge	28	0	0	2940	2818	6131
	Tourmaline Discharge	30	0	1	5271	5534	24196
Enterococcus	Ocean Beach Discharge	60	1	1	3665	5385	26000
	Tourmaline Discharge	60	2	4	7717	10385	50000
HF183	Ocean Beach Discharge	35	4	0	213	706	3363
	Tourmaline Discharge	35	7	0	310	1165	12440

Data collection: Discharge pathogen concentrations

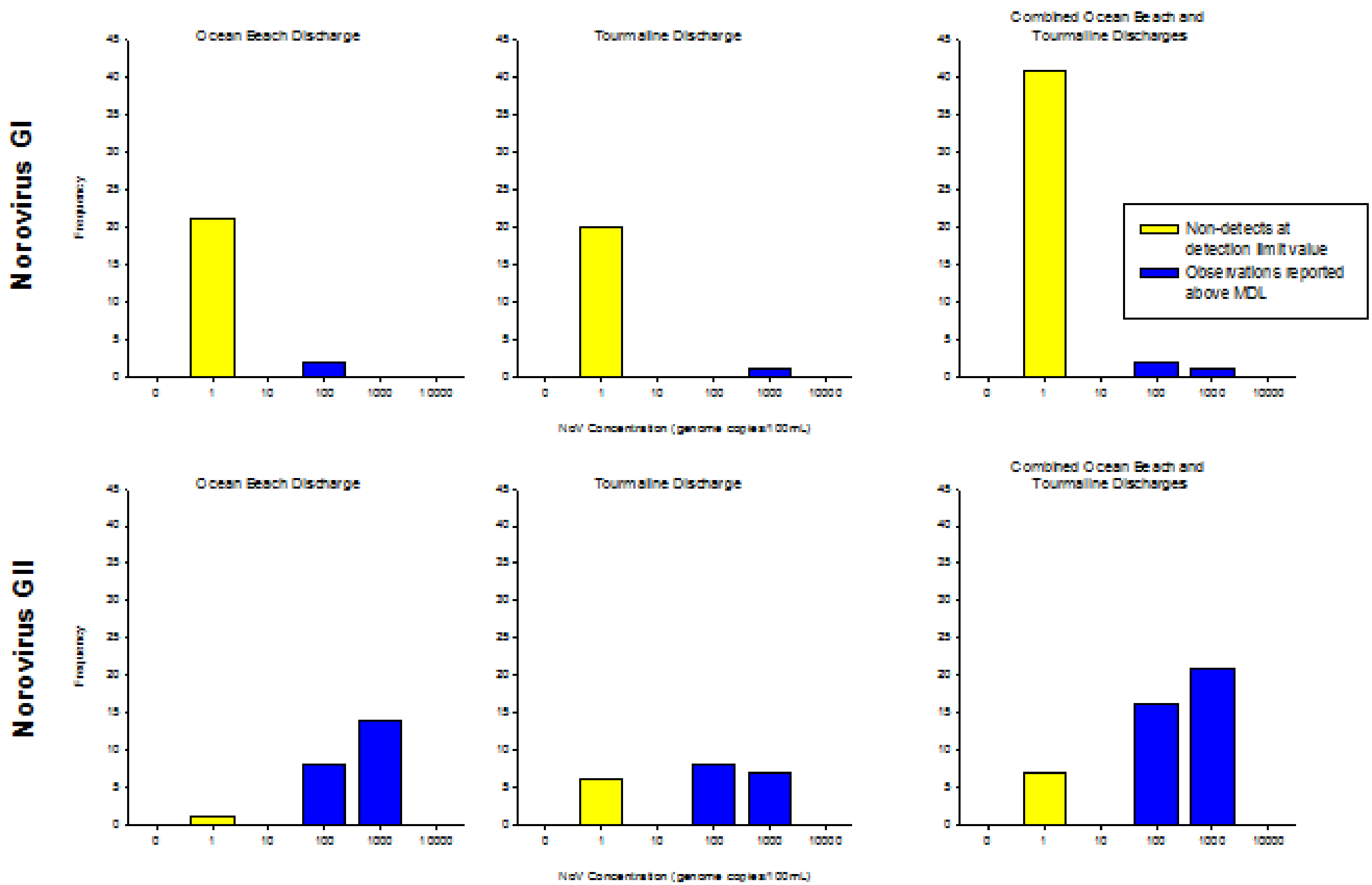
PATHOGEN SUMMARY – STUDY DISCHARGE POINTS

Pilot and Full Scale Wet Weather Study – Pathogen Data Summary (copies / 100mL)

Pathogen	Site	N	# <MDL	Median	Mean	Max
Norovirus G1	Ocean Beach Discharge	23	21	1.0	3	32
	Tourmaline Discharge	21	20	1.0	23	465
Norovirus G2	Ocean Beach Discharge	23	1	135.0	158	495
	Tourmaline Discharge	21	6	70.0	77	231
Enterovirus	Ocean Beach Discharge	23	23	1.0	1	1
	Tourmaline Discharge	21	21	1.0	1	1
Adenovirus	Ocean Beach Discharge	23	18	1.0	6	42
	Tourmaline Discharge	21	18	1.0	3	16
Campylobacter	Ocean Beach Discharge	23	0	320	457	1136
	Tourmaline Discharge	21	11	1.0	283	3072
Salmonella invA	Ocean Beach Discharge	23	17	1.0	3	14
	Tourmaline Discharge	21	19	1.0	6	90
Salmonella ttr	Ocean Beach Discharge	23	23	1.0	1	1
	Tourmaline Discharge	21	19	1.0	6	83

Note: For summary purposes, values <MDL computed at 1 copies/100mL

Pathogen Occurrence Distributions



Exposure

- Fate and transport - What happens to concentration between monitoring point and exposure point
  - Used paired enterococci data to estimate pathogen attenuation (dilution)
- Exposure = concentration x volume

Volume Ingested

- Calculated from a study observing 53 recreational swimmers in an outdoor community swimming pool (Dufour et al., 2006)
  - Assume that surfers ingest similar amounts of water that occurred during swimming in swimming pools
  - The pilot study found children ingested significantly more than adults
- A statistical distribution for the volume of water ingested was derived based on the study data (Soller et al, 2007)
  - The best-fit volume distribution lognormal
  - The median value of this distribution is ~19mL
  - The ingestion volume distribution is based on data from adults and children combined
  - Truncated at 60mL

Fate and Transport

- Four options for estimating dilution
  - No dilution
  - Simple model
  - Complex model
  - Back-calculate dilution based on epi study results
- Used Paired Enterococci to estimate “dilution”
  - Range of “dilution” values that correspond to the predicted median values derived from the fitted lognormal distributions across all of the exposure sites evaluated
  - These dilution values range from 25 -150
  - These values in the QMRA represent the lower and upper bounds of a triangular distribution, with the most likely value of 85
  - Use of the fate and transport data in this manner is most consistent with the use of water quality data in the epidemiological component of the study

Fate and Transport

- Paired enterococci data

Site	N	Median	Min	Mean	Max
Ocean Beach Discharge	23	1200	20	3389	26000
FM010	27	400	28	1063	5800
PL110	27	40	2	119	1200
PL100	27	20	2	27	140
OB PIER	27	12	2	17	76
Tourmaline Discharge	21	2600	120	10807	50000
Tourmaline South	27	50	2	896	9400
FM030	27	18	2	127	1200

- Enterococci-based dilution estimates

		Dilution Estimates		
Beach	Site	10th %ile	50th %ile	90th %ile
Ocean Beach	FM010	<1	3	30
	PL110	2	25	400
	PL100	5	60	800
	OB Pier	7	90	1000
Tourmaline	Tourmaline South	4	80	2000
	FM030	15	150	1200

Dose response relationships

- Peer reviewed from the literature
- Accepted within field of QMRA
- Probability of infection increases with increasing number of pathogens ingested
- Sigmoidal (bounded by 0 and 1)
- Relative level of infectiousness

    Viruses > Protozoans > Bacteria

Dose Response Relationship Summary

Reference Pathogen	Distributional Form	Parameter of Distribution	Parameter Values	Units	Reference	Morbidity
Norovirus (GI & GII) (upper bound)	Hypergeometric	alpha beta	0.04 0.055	Genome copies	Teunis et al., 2008a	0.6
(lower bound)	Fractional Poisson	P u	0.72 1106	Genome copies	Messner et l. 2014 Atmar et al., 2008,2013	0.6
Adenovirus	Exponential	r	0.4172	PFU	Crabtree et al., 1997	0.5
Campylobacter jejuni	Beta-Poisson	alpha beta	0.145 7.59	CFU	Medema et al. 1996	0.28
Salmonella enterica	Beta-Poisson	alpha beta	0.3126 2884	CFU	Haas et al., 1999; Fazil, 1996	0.2

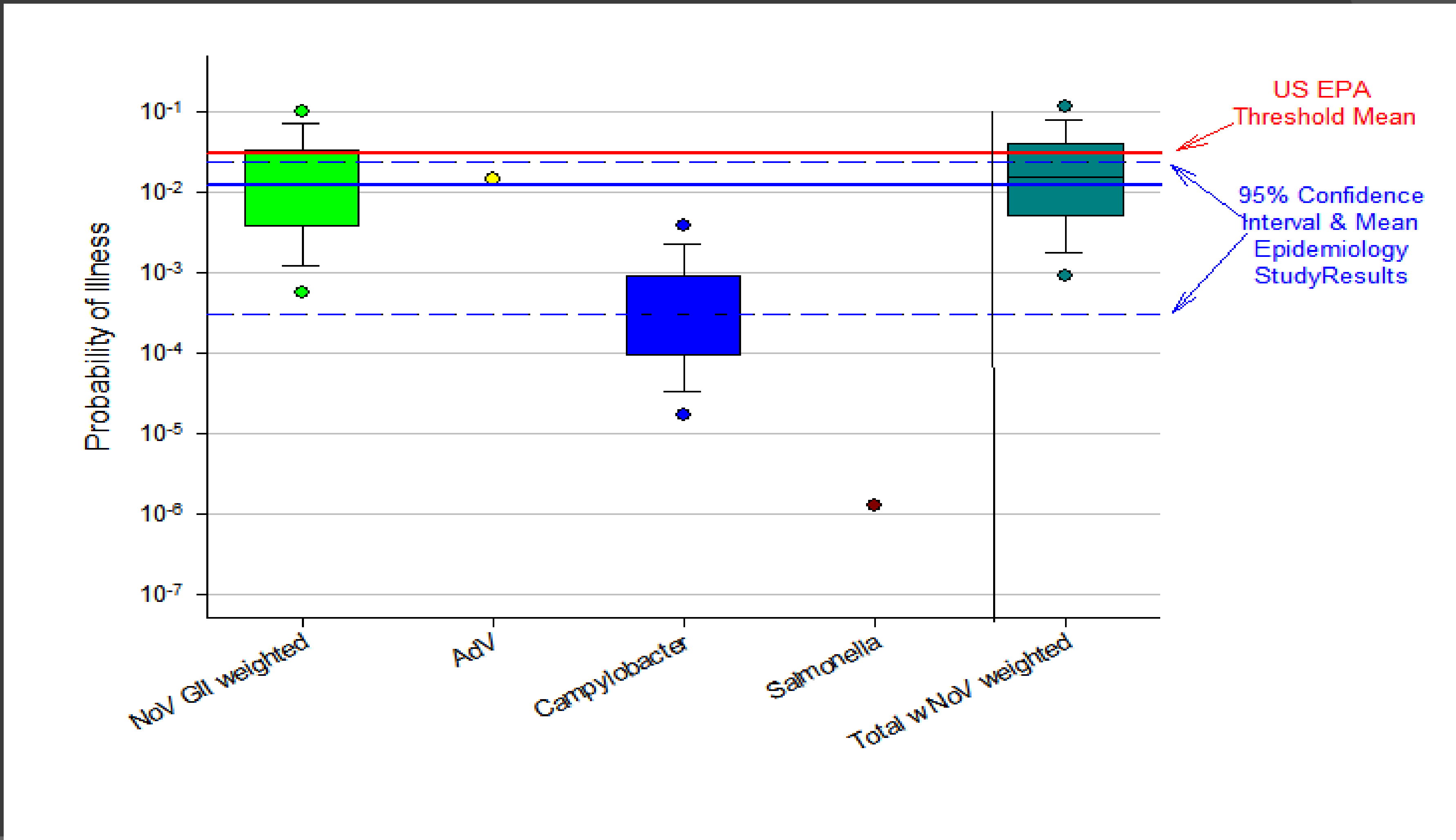
Risk Characterization

- Modeled exposure to stormwater impacted ocean using the “combined dataset”
- The fitted pathogen distributions include infectious Campylobacter only
- Lognormal ingestion distribution truncated at 60mL
- Used a triangular dilution distribution for dilution with lower and upper bounds of 25 and 150
- Evaluated a series of approaches to model uncertainty associated with the NoV dose-response relationship

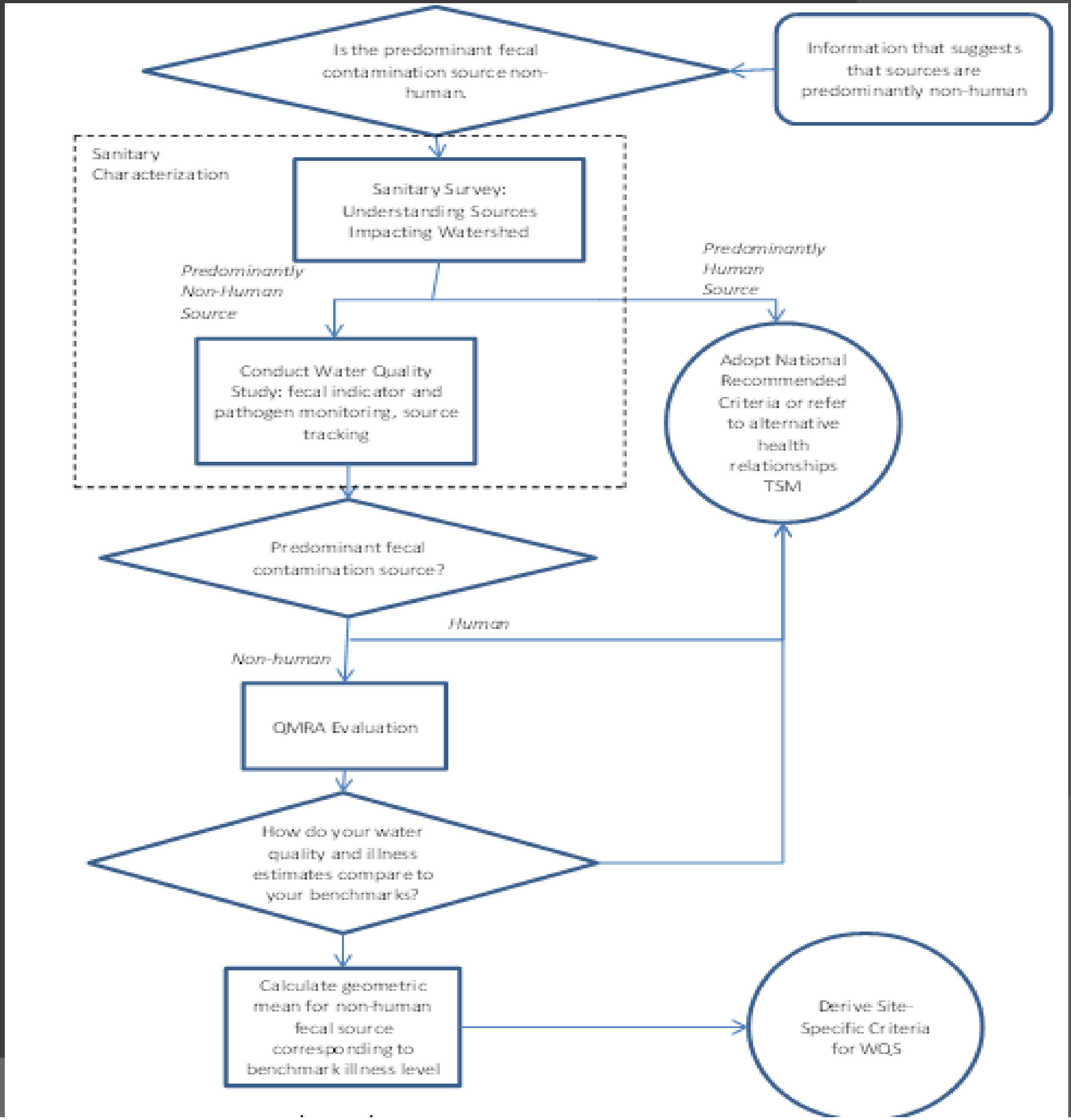
Risk Characterization Results

	Predicted or Observed Illnesses / 1000		
Approach	5th %ile	Median	95th %ile
Epidemiology results	0.3	12.2	24.0
Lower bound NoV	0.0	0.6	25.2
Randomly weighted NoV	0.5	15.5	146.2
Log uniform Risk NoV	0.0	2.3	77.3
Sample Weighted /Loguniform	0.0	7.0	121.2
Sample Lower/Upper	0.0	7.1	120.6
Sample 4	0.0	6.8	157.7
Upper Bound NoV	1.9	36.0	226.2

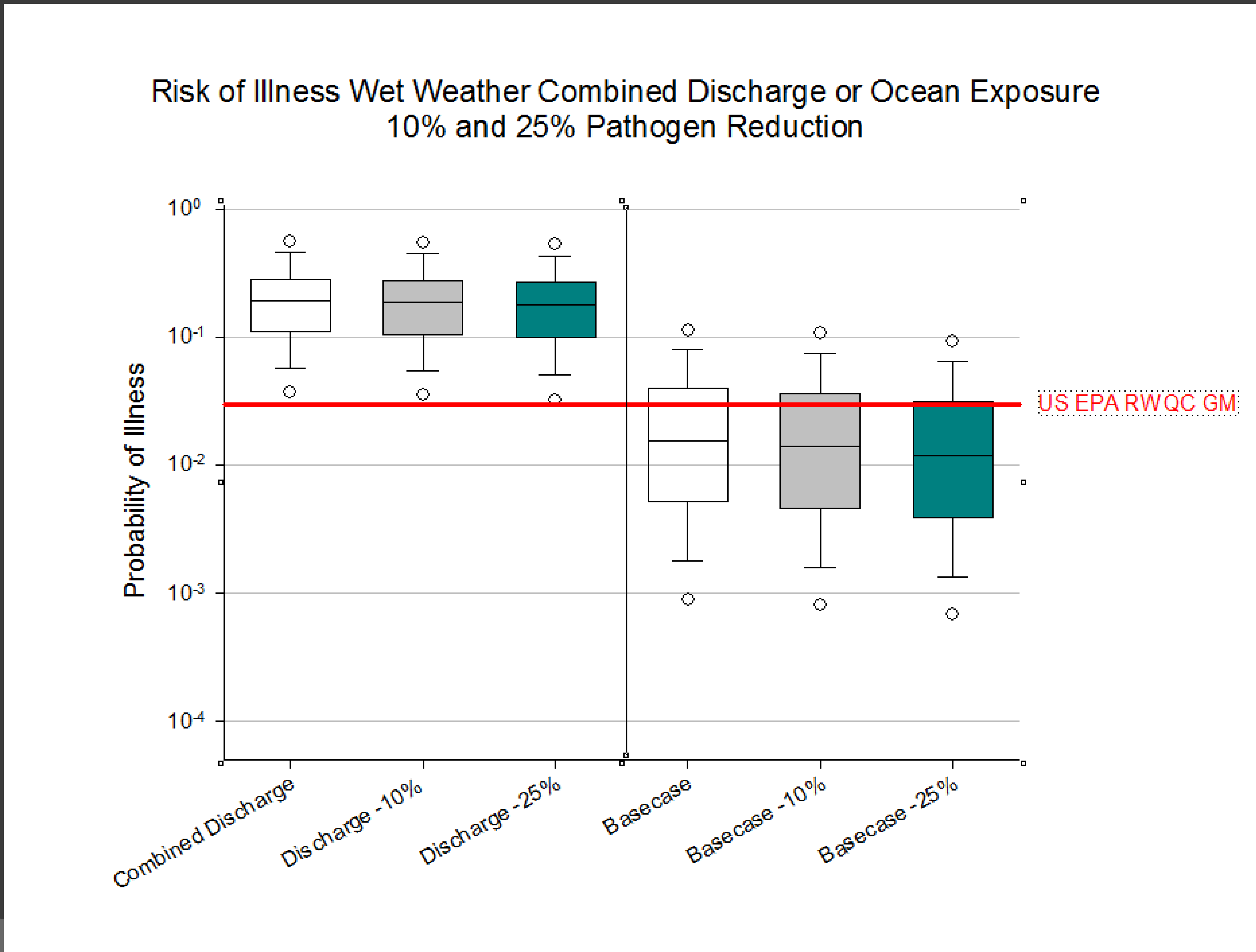
QMRA Results match epidemiology results closely and NoV is the pathogen of public health concern



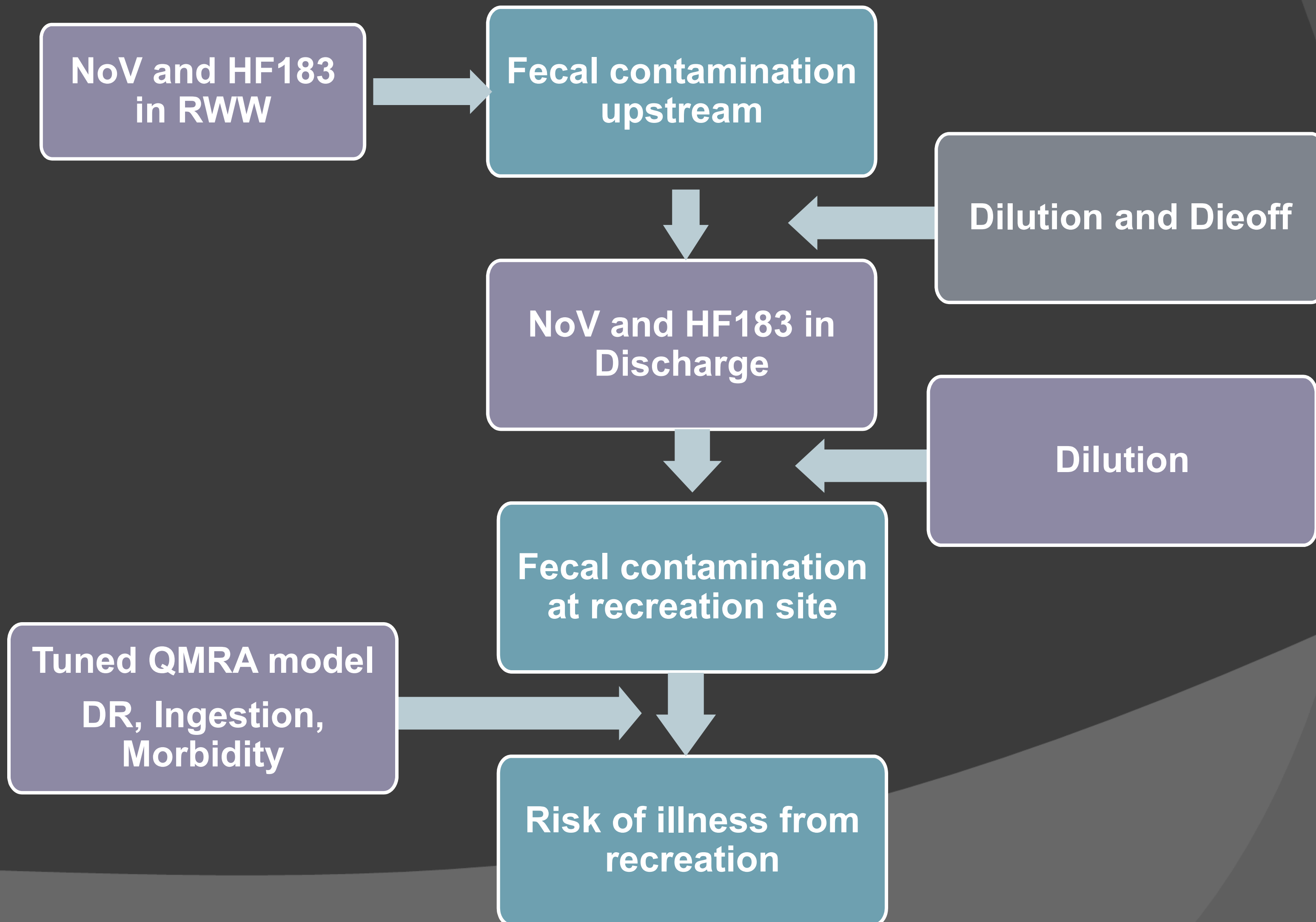
Utility: Using QMRA for Developing Site Specific Alternative Water Quality Criteria



Utility: Management Action Evaluation
Reduce Pathogen Levels in Discharge



Utility: Extrapolation beyond what was observed in SHS



Concluding Thoughts

- 2012 RWQC opens new doors to managing recreational waters
- CA SWRCB seems to be following (mostly) 2012 RWQC approach
- QMRA may be useful tool depending on location, sources of contamination, etc.
- Implementation of alternative WQS is a risk management activity
- SHS QMRA has set an important precedent for QMRA to be one part of those RM considerations