“who doesn’t swim in the Limmat? Limmat is life!”

survey response

RiverWatch: ‘nowcasting’ recreational water quality in urban estuaries using Bayesian Networks

Simon Lloyd, Guido Carvajal, Nerida Taylor,
Paul Osmond , David Roser , Stuart Khan

UNSW SYDNEY

Sydney WATER

RIVER WATCH

URBAN PLUNGE

2025 - swimmablilty

Image source: Our living river, https://www.facebook.com/ourlivingriver/

PRCG, Parramatta River Catchment Group (2018): Ten Steps To A Living River. The Parramatta River Masterplan. www.ourlivingriver.com.au

Wet weather overflows

Image source: Coogee beach, dailytelegraph.com.au

Image source: portbotany.wordpress.com/about/

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Risk management

- Indicator = Enterococci
- Physical sampling -> 24hr turnaround
- Predictive modelling -> supporting tool (WHO, 2021)

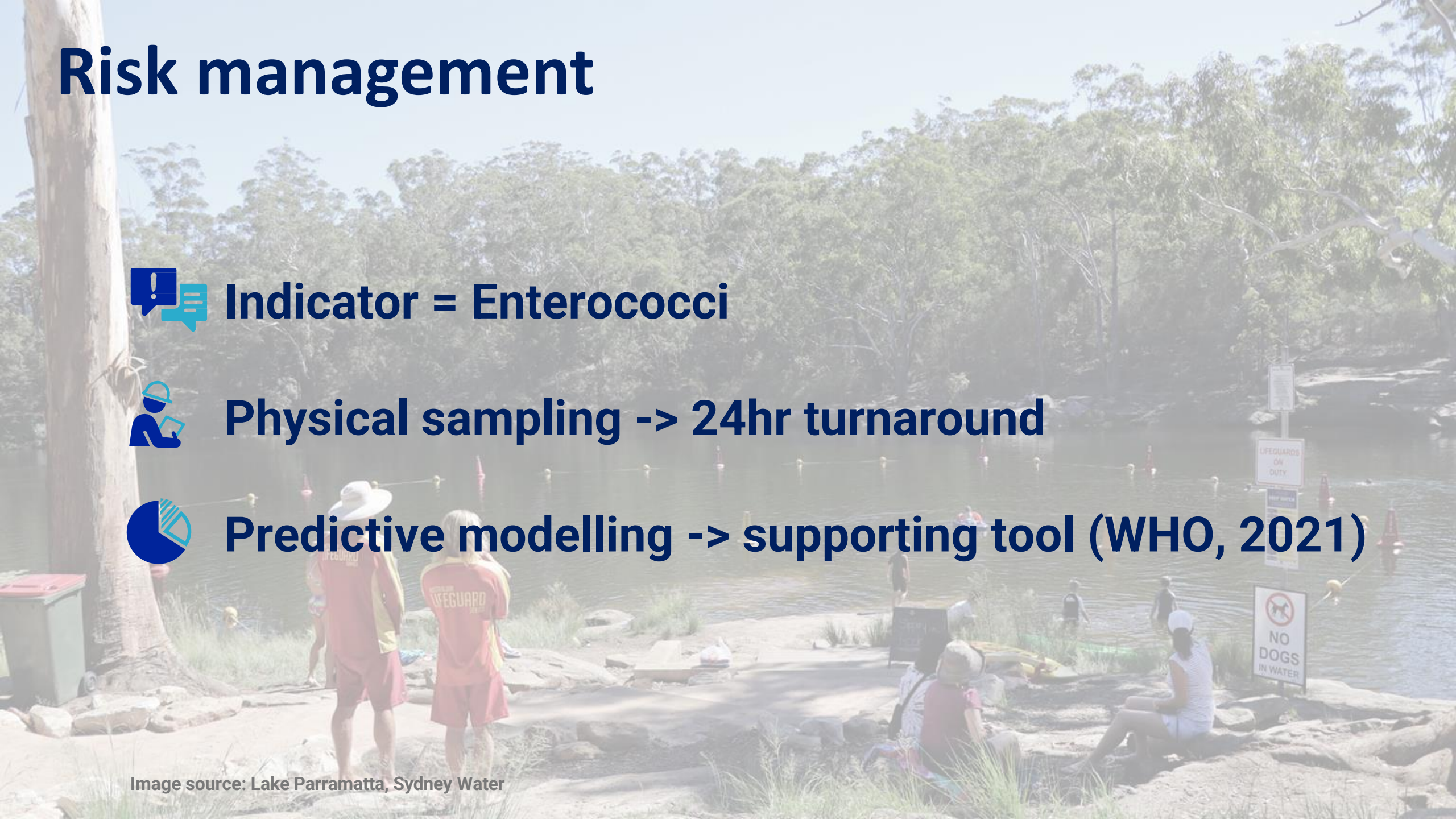

Image source: Lake Parramatta, Sydney Water

Aims

Develop a Bayesian Network and trial as a method to ‘nowcast’ and forecast enterococci concentrations in nominated swimming sites

Evaluate performance in comparison to current water quality pollution forecasting method

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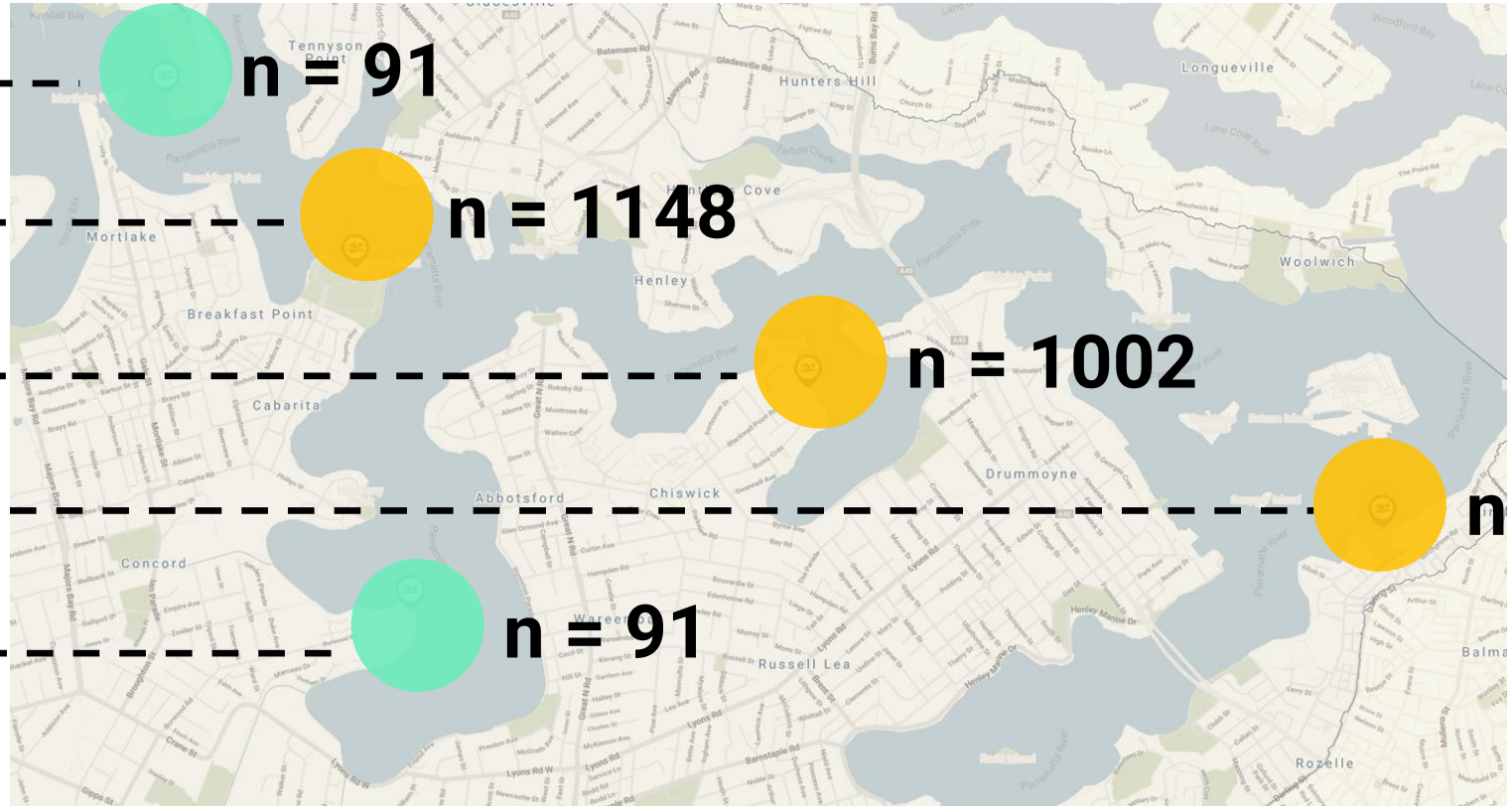
Swimming sites

enterococci timeseries datapoints, 1994 - 2021



Beachwatch

Daily pollution bulletin uses rainfall trigger values

If rainfall in the previous 0-48 hrs was:

<12mm pollution is UNLIKELY

12 - 20mm pollution is POSSIBLE

>20mm pollution is LIKELY

* Refer OEH, 2011 *'protocol for assessment and management of microbial risks in recreational waters',* for more detail

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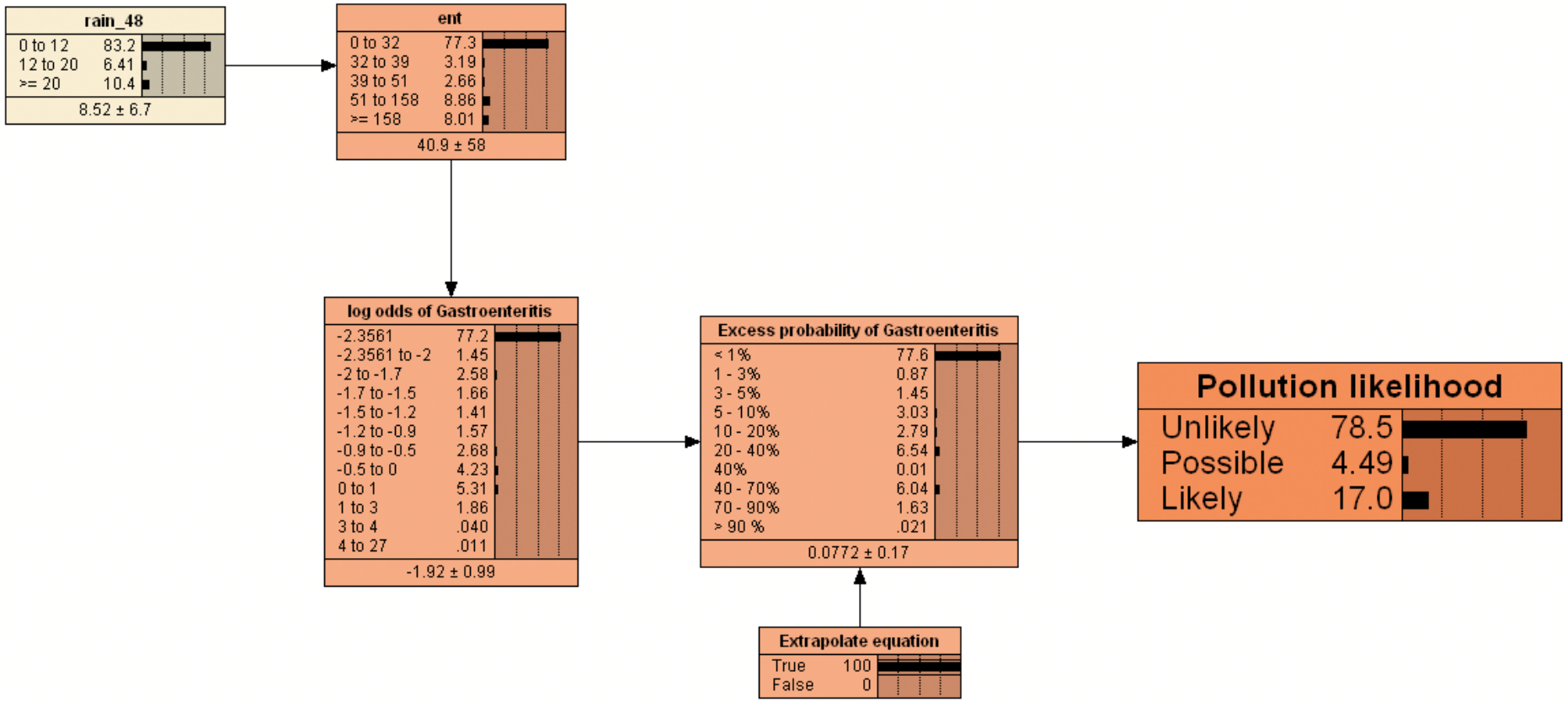
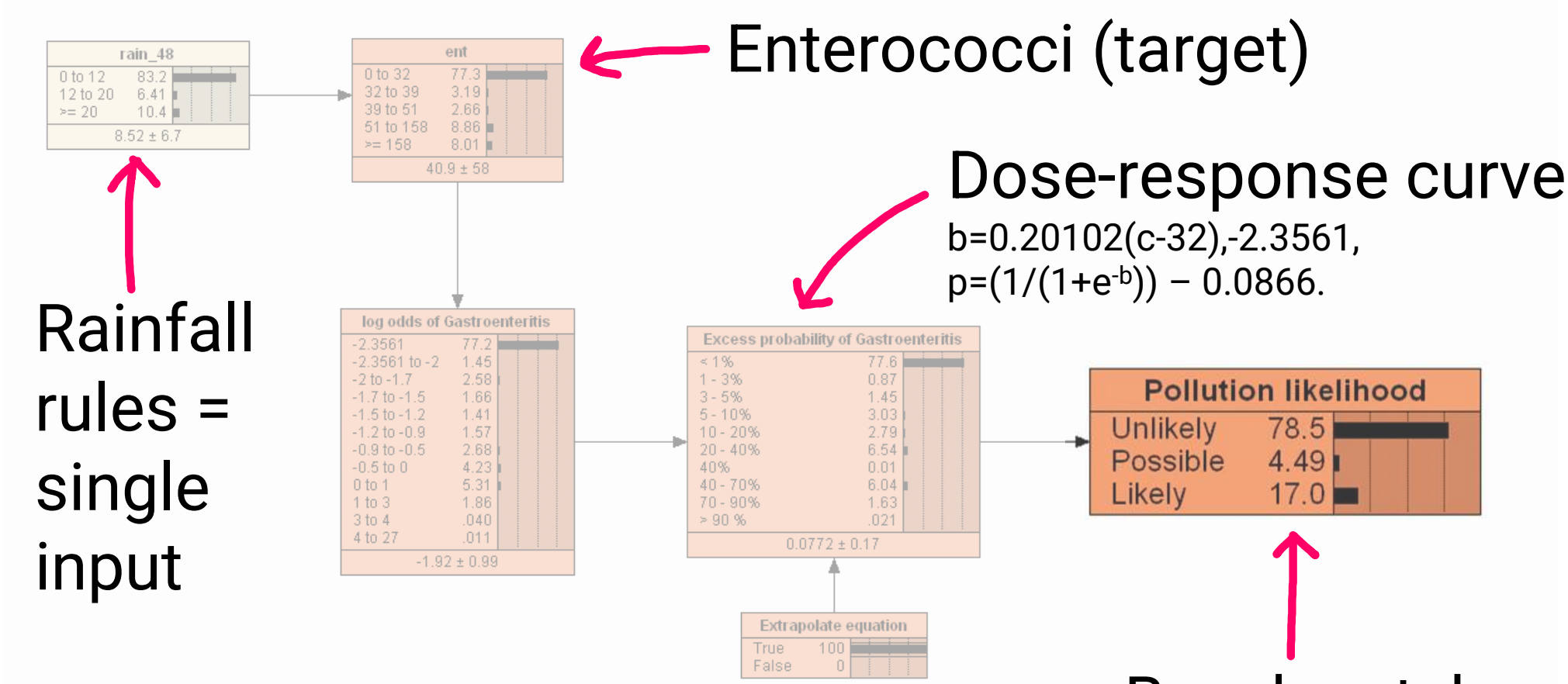
Model construction

Translate Beachwatch rules into a bayes net…



Model construction

Translate Beachwatch rules into a bayes net…



Enterococci (target)

Dose-response curve[1]

b=0.20102(c-32),-2.3561,

$p=(1/(1+e^{-b})) - 0.0866.$

Rainfall rules = single input

Beachwatch terminology

1. Kay D, Bartram J, Prüss A, Ashbolt N, Wyer MD, Fleisher JM, Fewtrell L, Rogers A, Rees G. Derivation of numerical values for the World Health Organization guidelines for recreational waters. Water Res. 2004

Model construction

Additional inputs into a semi-naïve structure

Rain events

Intensity
Distribution
Duration

Solar radiation

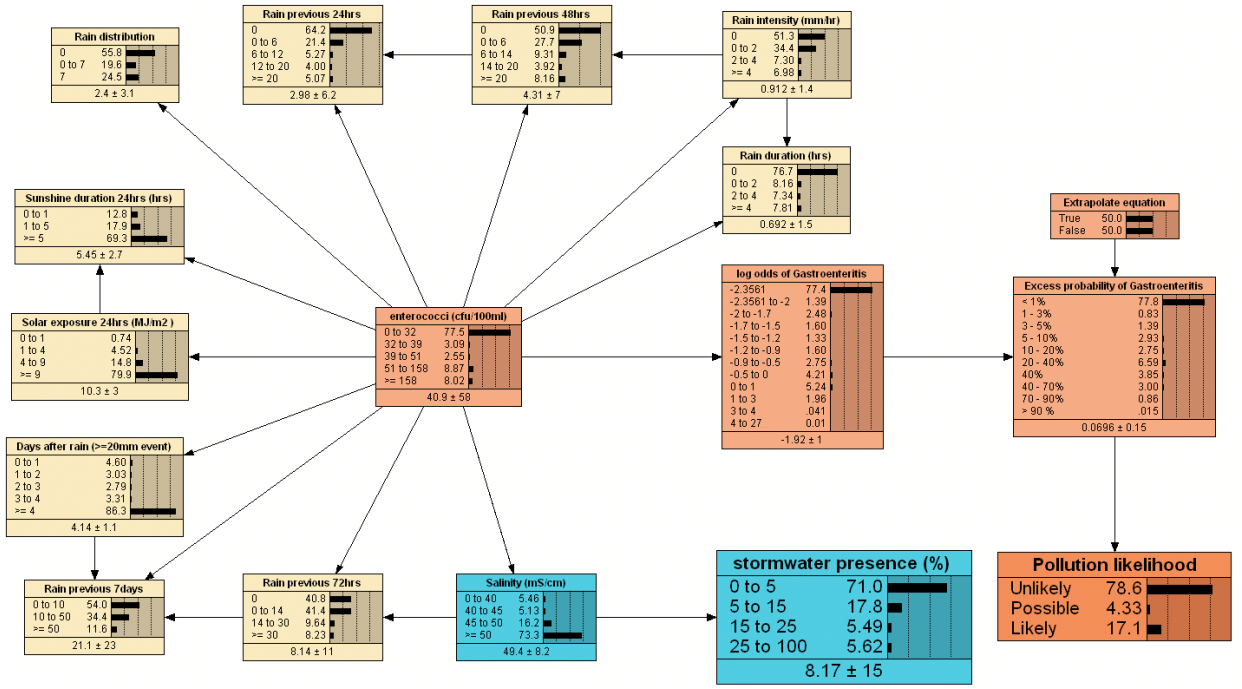
Dry spells
J/m^2

Salinity

Salinity change
Stormwater %

X
Data excluded

Tide
Wind
Bather numbers
Overflow events



Model performance

Compare training data, *1994 – 2018 (n=1291)*

	Beachwatch	
UNLIKELY (True negative)	93 % 955 days	93 % 956 days
POSSIBLE	15 % 8 days	10 % 4 days
LIKELY (True Positive)	43% 92 days	66 % 142 days

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Model performance

Compare training data, *1994 – 2018 (n=1291)*

	Beachwatch	
UNLIKELY (True negative)	93 % 955 days	93 % 956 days
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Model performance

Compare testing data, *2019 – 2021 (n=100)*

	Beachwatch	
UNLIKELY (True negative)	97 % 88 days	92 % 83 days
POSSIBLE	0 % 0 days	0 % 0 days
LIKELY (True Positive)	**75%** **6 days**	**100%** **8 days**

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Model transferability

Transfer structure to proposed sites with limited data…

	Bayview Park n = 91	Putney Park n = 91
UNLIKELY (True negative)	**100 % 68 days**	**93 % 61 days**
POSSIBLE	**25 % 2 days**	**16 % 1 days**
LIKELY (True Positive)	**80% 12 days**	**63% 12 days**

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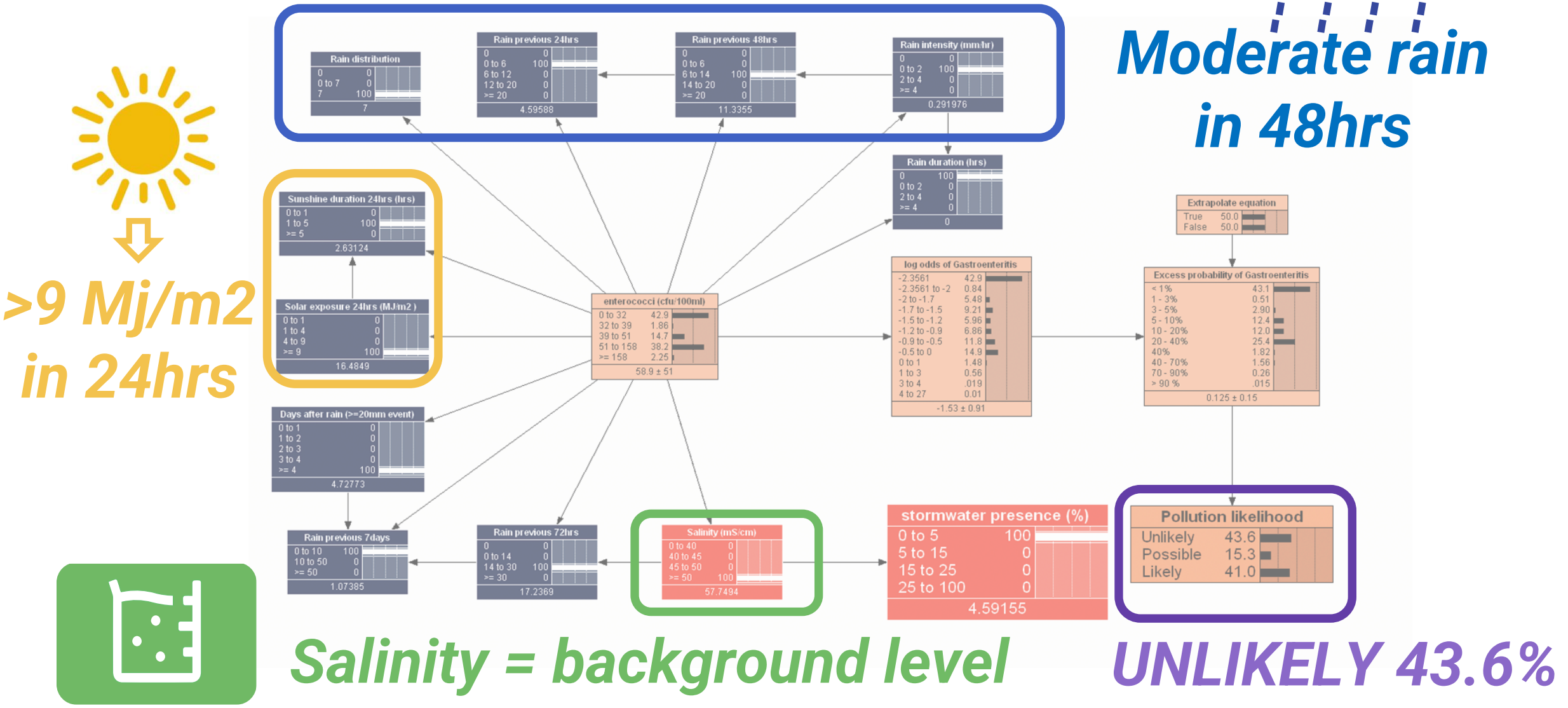
Improved user accessibility

Scenarios with stakeholders



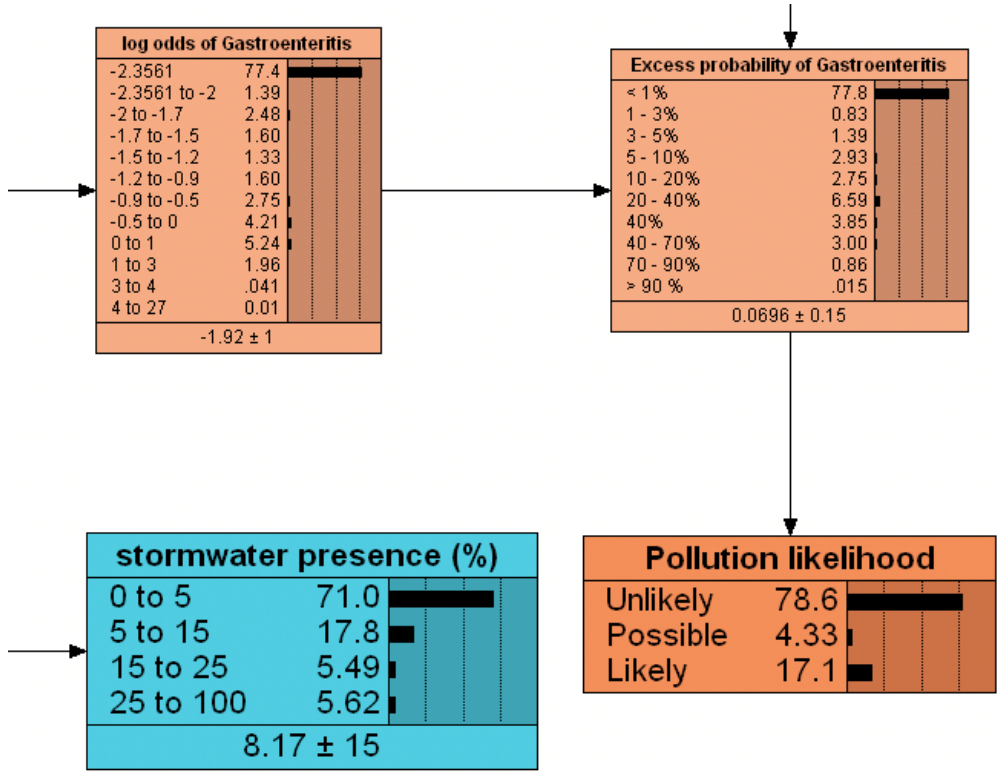
Conclusions

Improved model for swimmability

Transferability - multiple sites

Walk-fwd validation

Improved understanding of system dynamics



Offering additional decision support regarding bathing suitability

Next steps…

- Operationalise model
- Salinity - real time ?
- Predict 2 states – communicate 3
- Forecast +2 days

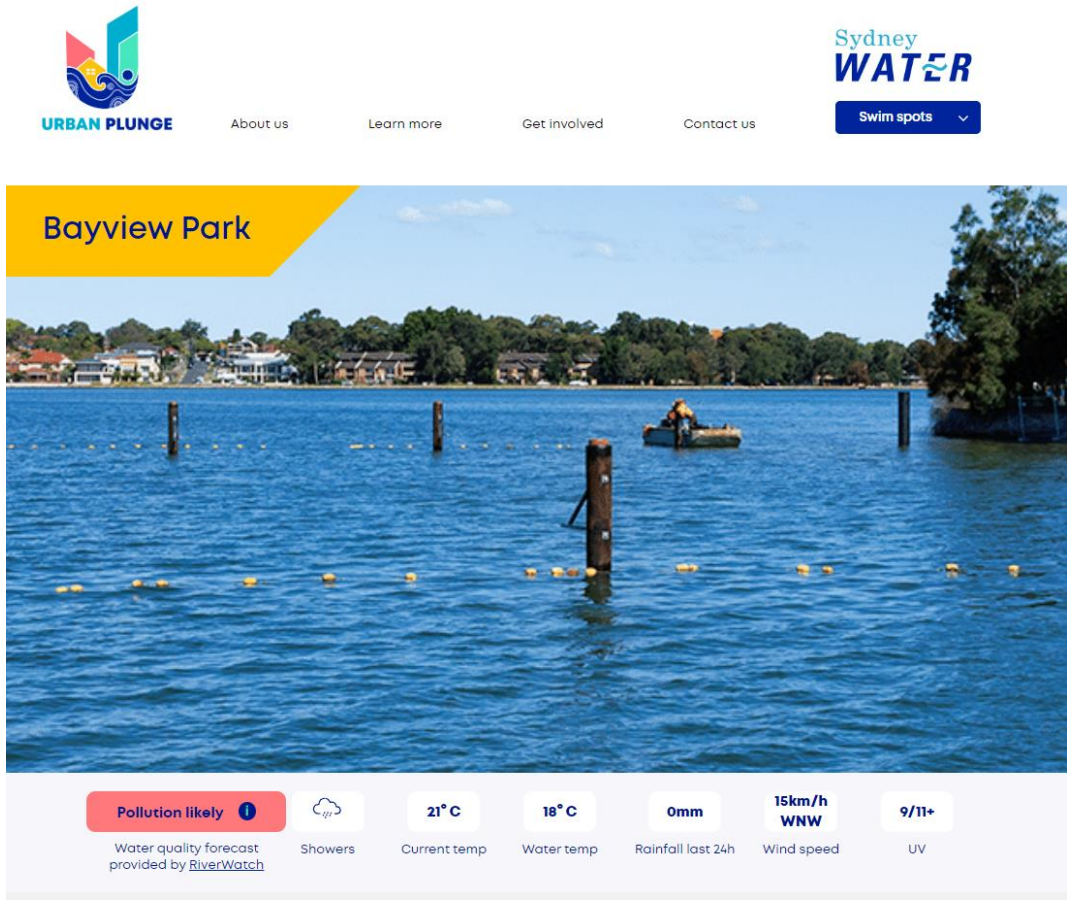


Image source: urbanplunge.sydneywater.com.au

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Questions?

Acknowledgements

BeachWatch
Meridth Campey, Courtney May

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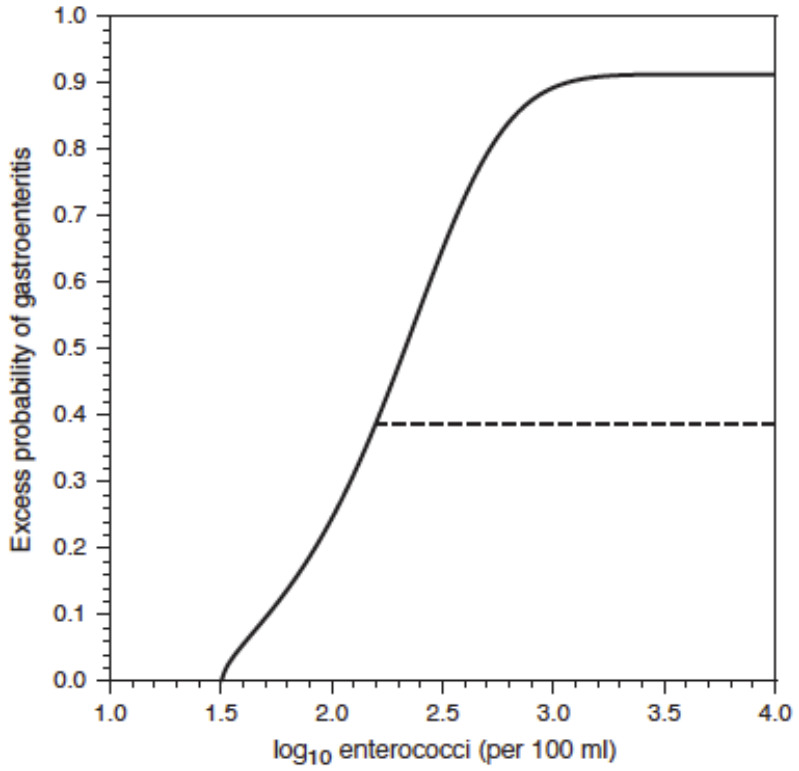
Paul Osmond, David Roser, Stuart Khan

Other
Richard Lugg, Guido Carvajal

Epidemiology

Dose-response



Kay D, Bartram J, Prüss A, Ashbolt N, Wyer MD, Fleisher JM, Fewtrell L, Rogers A, Rees G. Derivation of numerical values for the World Health Organization guidelines for recreational waters. Water Res. 2004

Guidelines

Category	95th %	GI illness
A	≤40	<1%
B	41-200	1-5%
C	201-500	5-10%
D	>501	>10%

National Health and Medical Research Council (2008): Guidelines for Managing Risks in Recreational Water. National Health and Medical Research Council (NHMRC).

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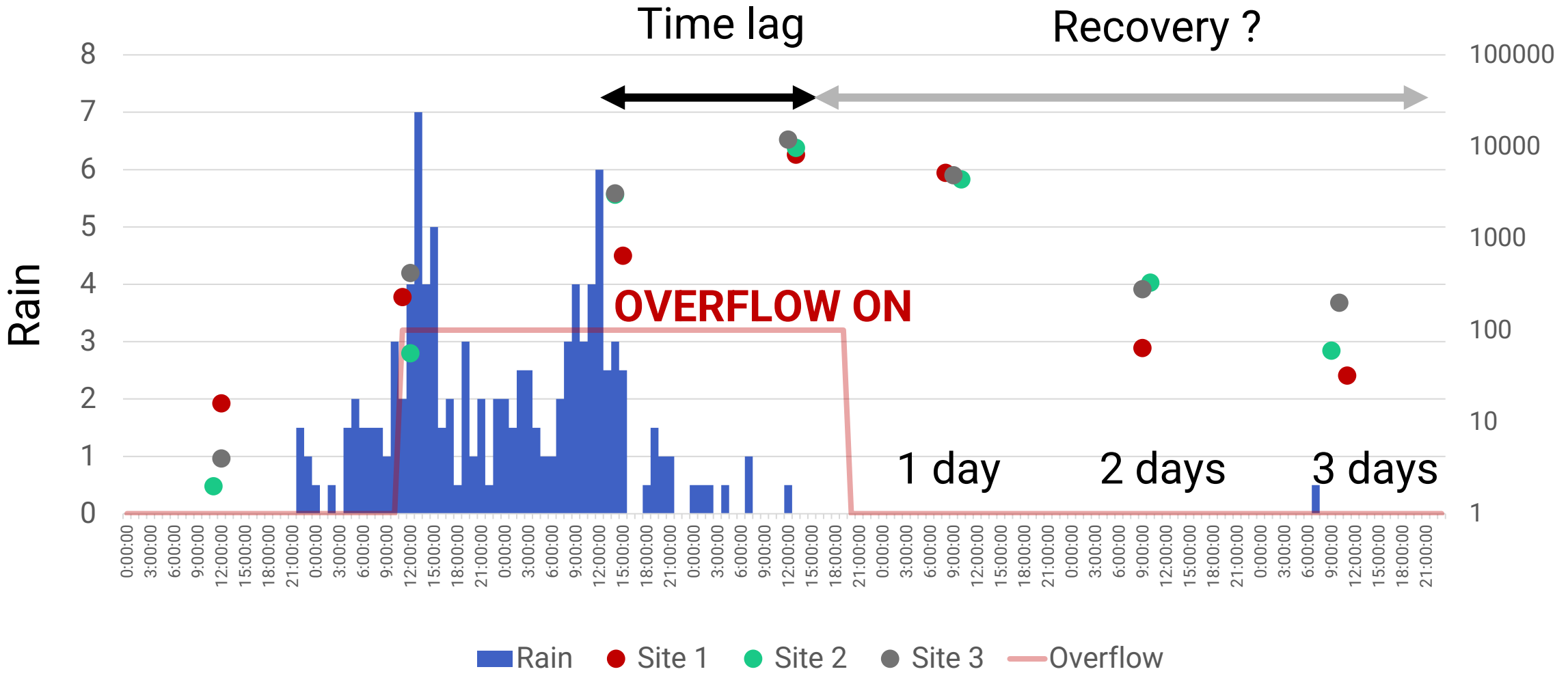
Field data


Time lag
Recovery ?
OVERFLOW ON
1 day
2 days
3 days
Rain
Enterococci cfu/100ml
Rain
Site 1
Site 2
Site 3
Overflow

Sydney: 3 city vision

- Parramatta = Central **River** City
- Estuaries = transient environments

3 cities vision, Greater Sydney Commission, landscapeaustralia.com

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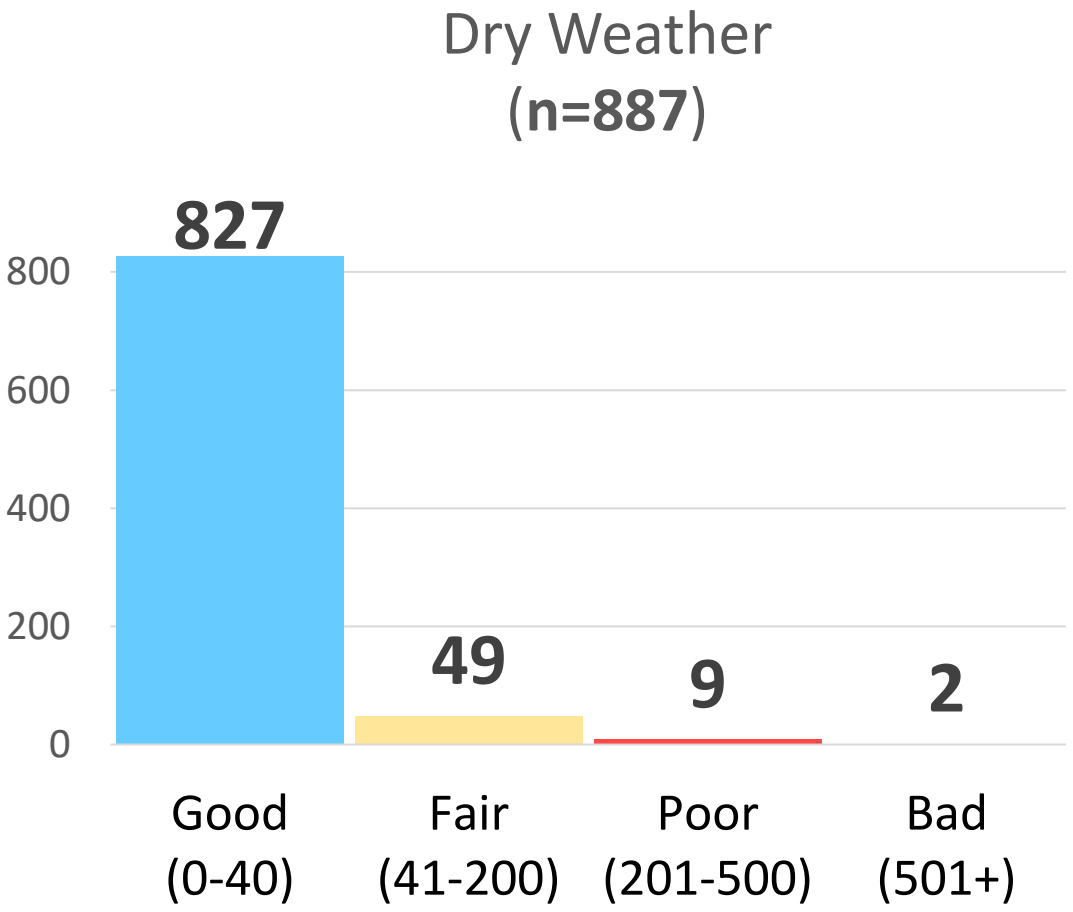
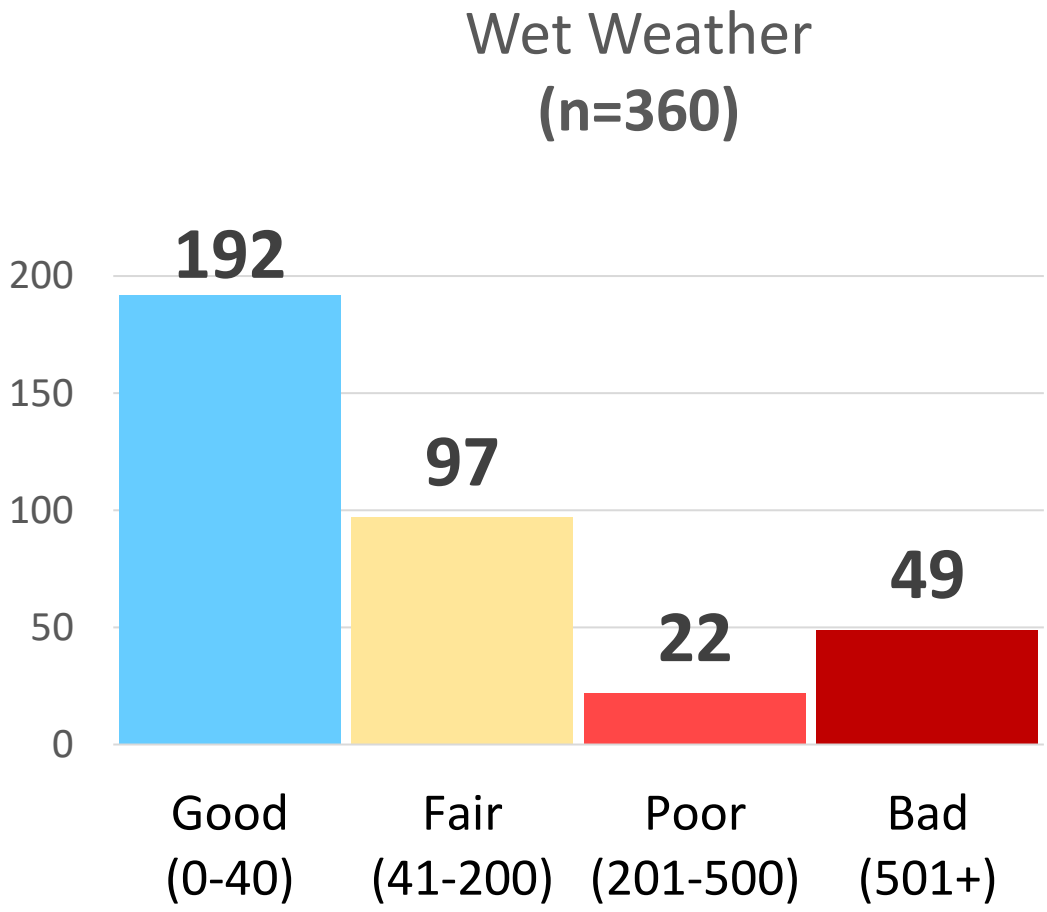
Datasets: enterococci 1996 -2019





True Positives and True Negatives *(n = 1291)*

	Unlikely	Likely
Beachwatch	93 % **955 days**	43 % **92 days**
UNSW SYDNEY	93 % **956 days**	66 % **142 days**

BW method – *1291 observations*

prediction

UNLIKELY < 3% GI RISK	POSSIBLE 3 - 10% GI RISK	LIKELY > 10% GI RISK	
955	46	24	UNLIKELY <3% GI RISK
31	8	13	POSSIBLE 3 - 10% GI RISK
89	33	92	LIKELY > 10% GI RISK

reality

nb/ preliminary results not for dissemination outside this working group. Beachwatch do not use three output states to validate their method and therefore return different results to those shown here. These results categorise the observed data (reality) into the three output states used by the Riverwatch model to enable a like for like comparison between the two methods.

2% False Positives = 24 days unnecessary swim site closure

***False positive** = predicted pollution, but in reality it was was safe…*

prediction

UNLIKELY < 3% GI RISK	POSSIBLE 3 - 10% GI RISK	LIKELY > 10% GI RISK	
955	46	24 **False Positive**	UNLIKELY <3% GI RISK
31	8	13	POSSIBLE 3 - 10% GI RISK
89	33	92	LIKELY > 10% GI RISK

reality

42% False Negatives = 89 days public health risk

***False negative** = predicted no pollution, reality pollution was present…*

prediction

UNLIKELY < 3% GI RISK	POSSIBLE 3 - 10% GI RISK	LIKELY > 10% GI RISK	
955	46	24 **False Positive**	UNLIKELY <3% GI RISK
31	8	13	POSSIBLE 3 - 10% GI RISK
89 **False Negative**	33	92	LIKELY > 10% GI RISK

reality