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Design Limitations to Low Impact Development: Observing the Site Conditions that Lead to Stormwater Bypass

TRIECA

21 March 2019

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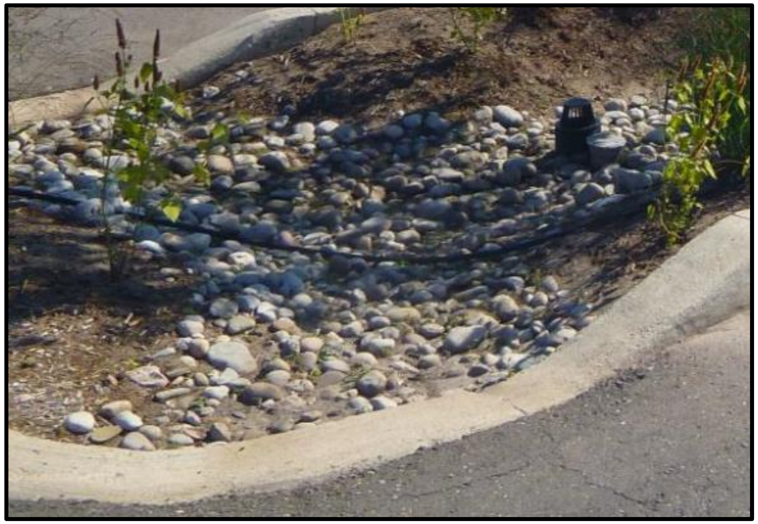
Overview

- Bioretention swales are often designed with an overflow, allowing water to bypass water quality treatment
- Purpose of our presentation is to review factors that lead to overflow, and water quality implication of these events
- Study site is the IMAX head office parking lot in Mississauga, Ontario



Introduction

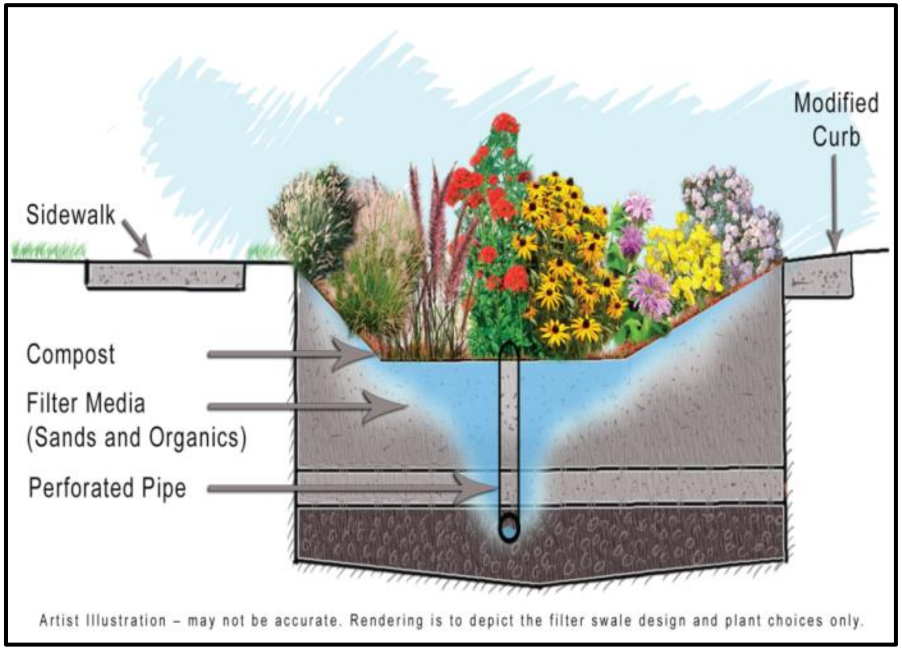
- Low Impact Development (LID) is an alternative to traditional stormwater management
- Engineered landscape features that infiltrate, filter, and store stormwater runoff
- A major barrier to LID implementation is a lack of performance data

LID Performance Monitoring - IMAX

- In 2013, IMAX redeveloped the parking lot at their head office in Mississauga
- The asphalt -> catchbasin parking lot was transformed to one using a variety of different LID features
- Focus today will be on the three bioretention swales

IMAX Bioretention Swales

- The three swales are designed to treat storm events up to 25 mm
- Water infiltrates through the engineered media to an underdrain below
- An overflow in each cell leads directly to the underdrain (to avoid ponding on the parking lot)



(Picture credit: TRCA/STEP)

Why do we care about overflow?

- Overflow water isn't treated
- Water quality implications
- May indicate need for maintenance activities

- Understanding conditions that lead to overflow can inform design

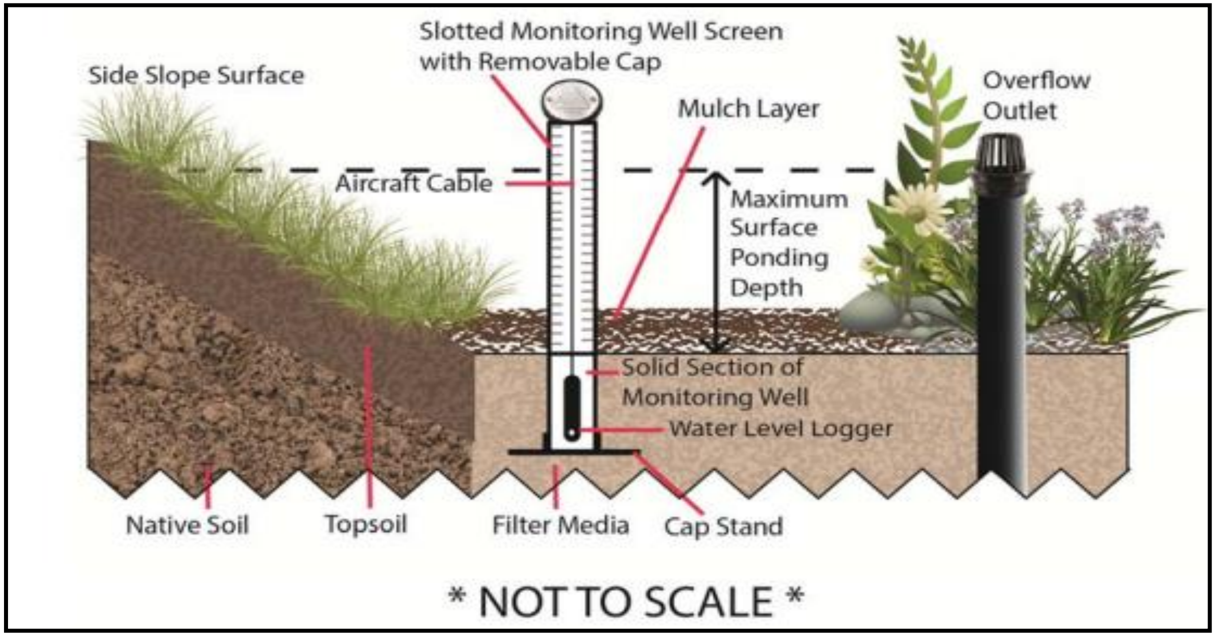
Performance Monitoring and Overflow Events

LID Performance Monitoring - IMAX

- CVC's monitoring program includes both water quantity and quality monitoring
- Rain gauge and level logger data used to determine when overflow events occurred

LID Performance Monitoring - IMAX

- Level loggers used to measure height of water ponding on swales (to determine if overflow occurs)
- Monitored from 2014 to 2017, logger removed during the winter to avoid freezing

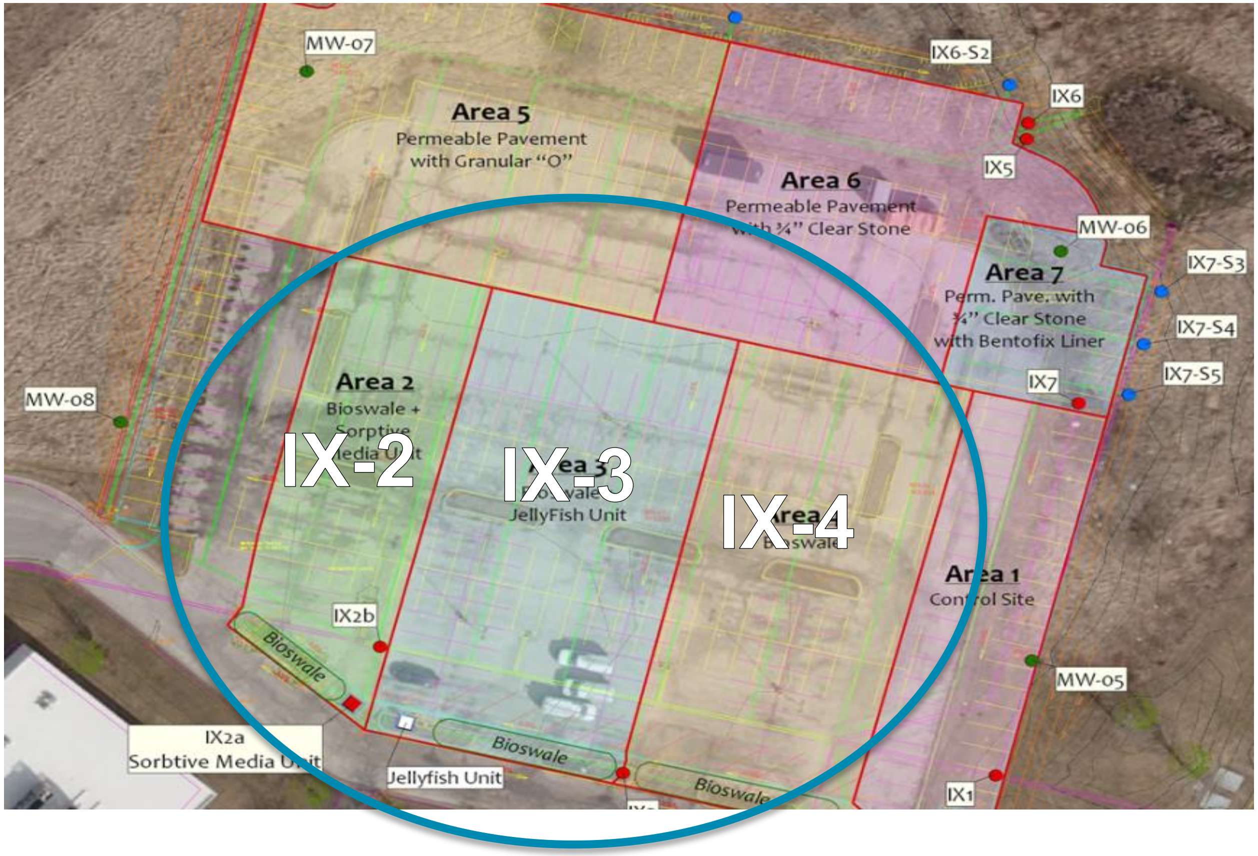


(Picture credit: TRCA/STEP)

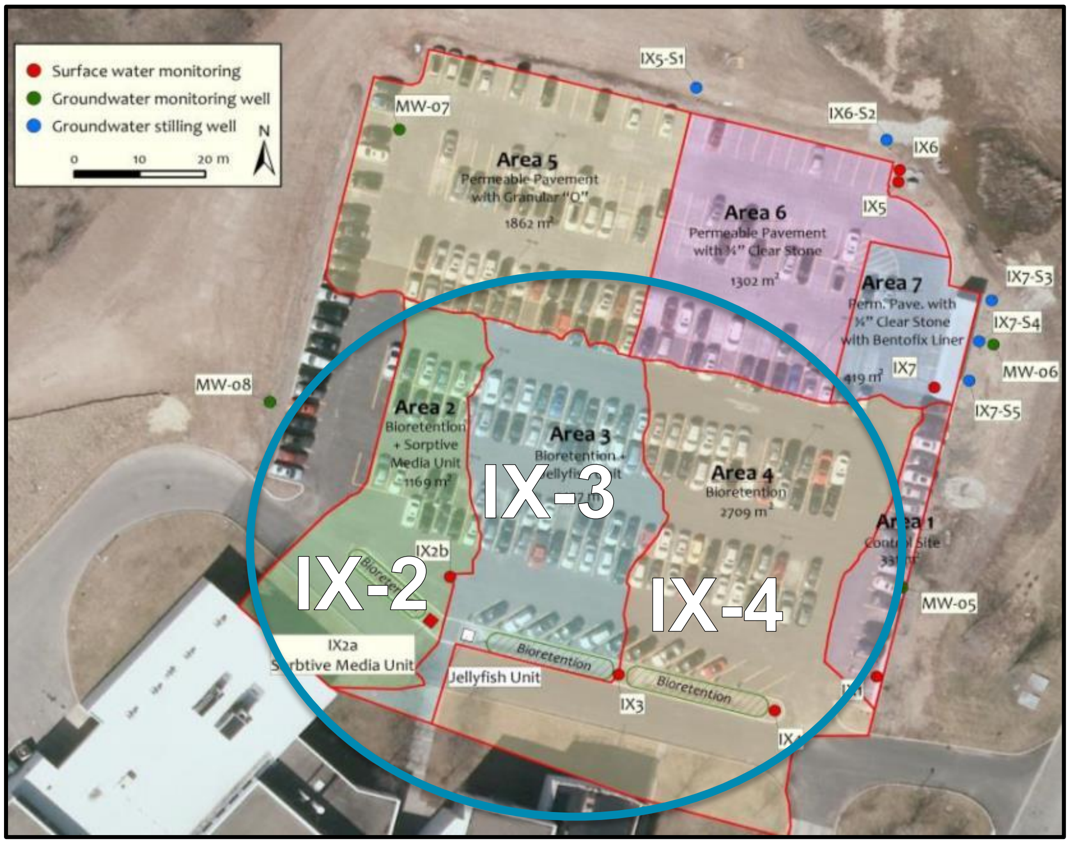
Parameters that may contribute to overflow

1. Design Considerations
2. Precipitation Depth
3. Precipitation Intensity
4. Antecedent Soil Conditions
5. Event Duration
6. Age of the Bioretention Media

IMAX Bioretention Swales



IMAX Bioretention Swales



Site	IX-2	IX-3	IX-4
Ratio of impervious drainage area/ feature area	22:1	22:1	**30:1**
Number of events	146	156	153
Percent of events with overflow	3%	2%	**32%**

Precipitation depth(mm) and chance of overflow

Precipitation Depth	Percentage of Overflow			
	IX-2	IX-3	IX-4	All Sites
Count:	146	156	153	455
0 to 5 mm	0%	0%	0%	0%
5 to 10 mm	0%	0%	41%	12%
10 to 15 mm	0%	0%	64%	16%
15 to 20 mm	15%	8%	79%	36%
20 to 25 mm	0%	0%	86%	27%
25 to 30 mm	17%	13%	83%	35%
>30 mm	20%	13%	70%	36%
Total:	3%	2%	32%	13%

Data is from 2014 to 2017, excluding winter.

Legend	0%	1-20%	20-40%	40-60%	60-80%	80-100%

Peak intensity(mm/h) and chance of overflow

Peak Precipitation Intensity	Percentage of Overflow			
	IX-2	IX-3	IX-4	All Sites
Count:	146	156	153	455
0-5 mm/h	0%	0%	0%	0%
5-10 mm/h	2%	0%	5%	2%
10-20 mm/h	3%	0%	48%	16%
20-30 mm/h	5%	0%	94%	32%
30-40 mm/h	0%	0%	100%	33%
40-50 mm/h	25%	33%	100%	54%
> 50 mm/hr	0%	0%	100%	33%
Total:	**3%**	**2%**	**32%**	**13%**

Data is from 2014 to 2017, excluding winter.

Legend	0%	1-20%	20-40%	40-60%	60-80%	80-100%

Average precipitation intensity (mm/h) and chance of overflow

Average Precipitation Intensity	Percentage of Overflow			
	IX-2	IX-3	IX-4	All Sites
Count:	**146**	**156**	**153**	**455**
0-0.5 mm/h	0%	0%	3%	1%
0.5-1 mm/h	0%	0%	10%	3%
1-1.5 mm/h	0%	0%	45%	15%
1.5-2 mm/h	7%	5%	39%	17%
2-3 mm/h	8%	0%	47%	21%
3-5 mm/h	5%	7%	59%	24%
5-10 mm/h	9%	9%	50%	22%
> 10 mm/hr	0%	0%	80%	25%
Total:	**3%**	**2%**	**32%**	**13%**

Data is from 2014 to 2017, excluding winter.

Legend	0%	1-20%	20-40%	40-60%	60-80%	80-100%

Antecedent conditions and chance of overflow

Antecedent Conditions (Past 3 Days of Rain)	Percentage of Overflow			
	IX-2	IX-3	IX-4	All Sites
Count:	**146**	**156**	**153**	**455**
0 mm	3%	2%	30%	11%
0-5 mm	2%	2%	32%	13%
5-10 mm	10%	9%	40%	20%
10-15 mm	0%	0%	14%	4%
15-20 mm	0%	0%	50%	19%
20-25 mm	0%	0%	25%	9%
25-30 mm	0%	0%	40%	14%
>30 mm	0%	NA	NA	0%
Total:	**3%**	**2%**	**32%**	**13%**

Data is from 2014 to 2017, excluding winter.

Legend	0%	1-20%	20-40%	40-60%	60-80%	80-100%

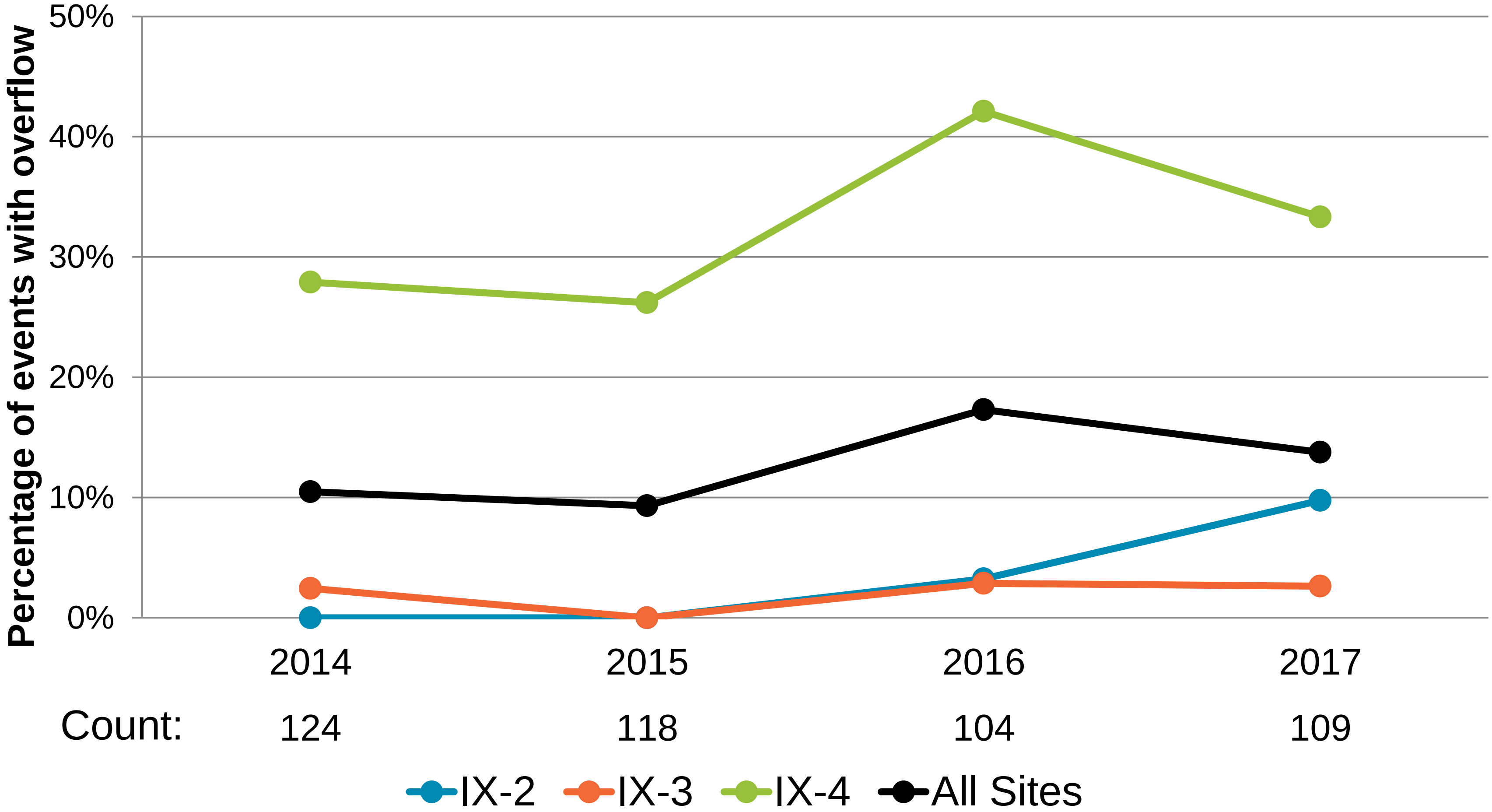
Event duration and chance of overflow

Precipitation Duration	Percentage of Overflow			
	IX-2	IX-3	IX-4	All Sites
Count:	**146**	**156**	**153**	**455**
0-5 hours	3%	2%	23%	10%
5.1-10 hours	0%	0%	31%	10%
10.1-15 hours	5%	4%	52%	20%
15.1-20 hours	0%	8%	27%	12%
20.1-25 hours	17%	0%	80%	24%
25.1-30 hours	0%	0%	25%	9%
>30.1 hours	25%	0%	50%	19%
Total:	**3%**	**2%**	**32%**	**13%**

Data is from 2014 to 2017, excluding winter.

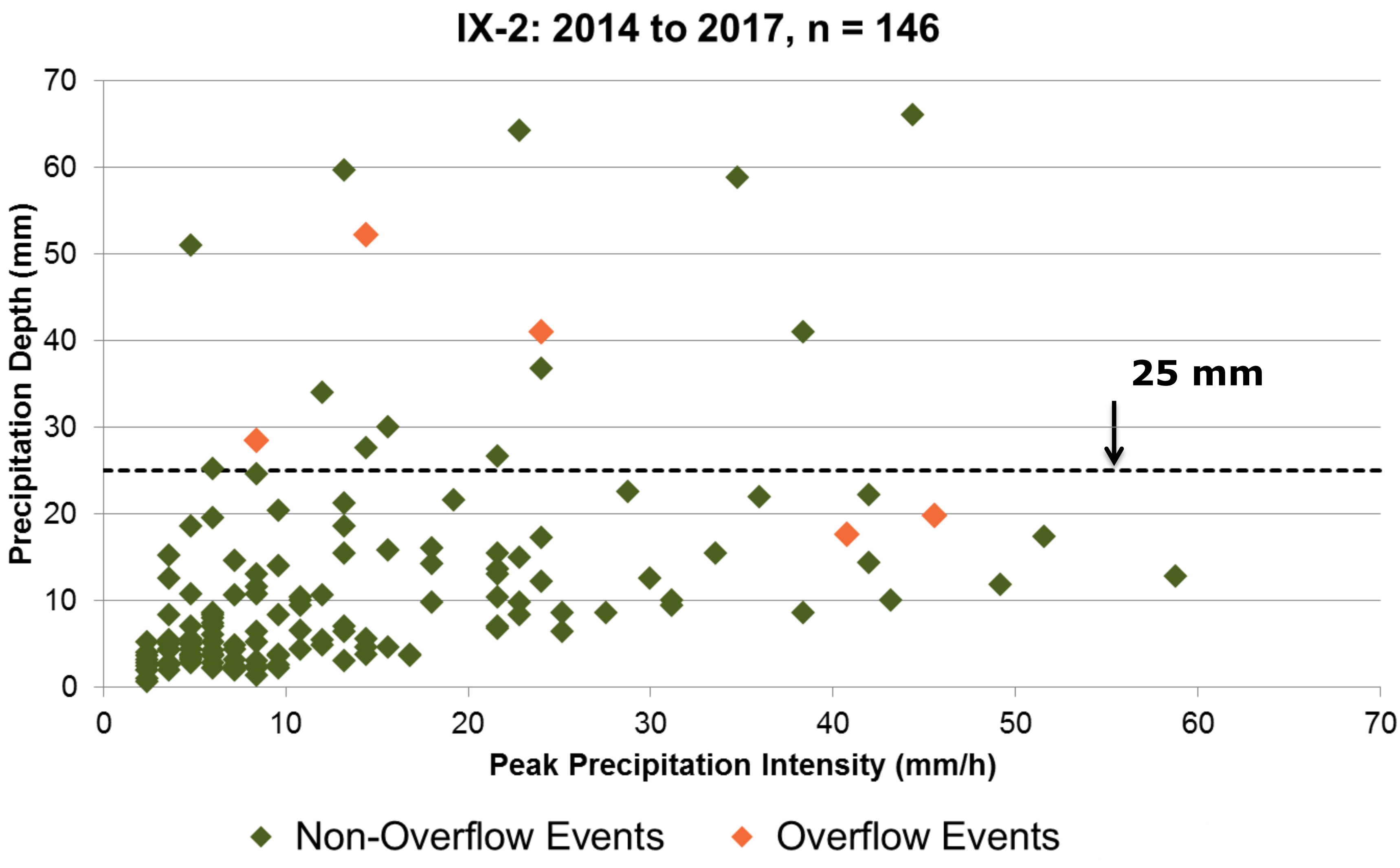
Legend	0%	1-20%	20-40%	40-60%	60-80%	80-100%

Frequency of overflow events each year



Data is from 2014 to 2017, excluding winter.

Precipitation depth (mm) and peak precipitation intensity (mm/h)



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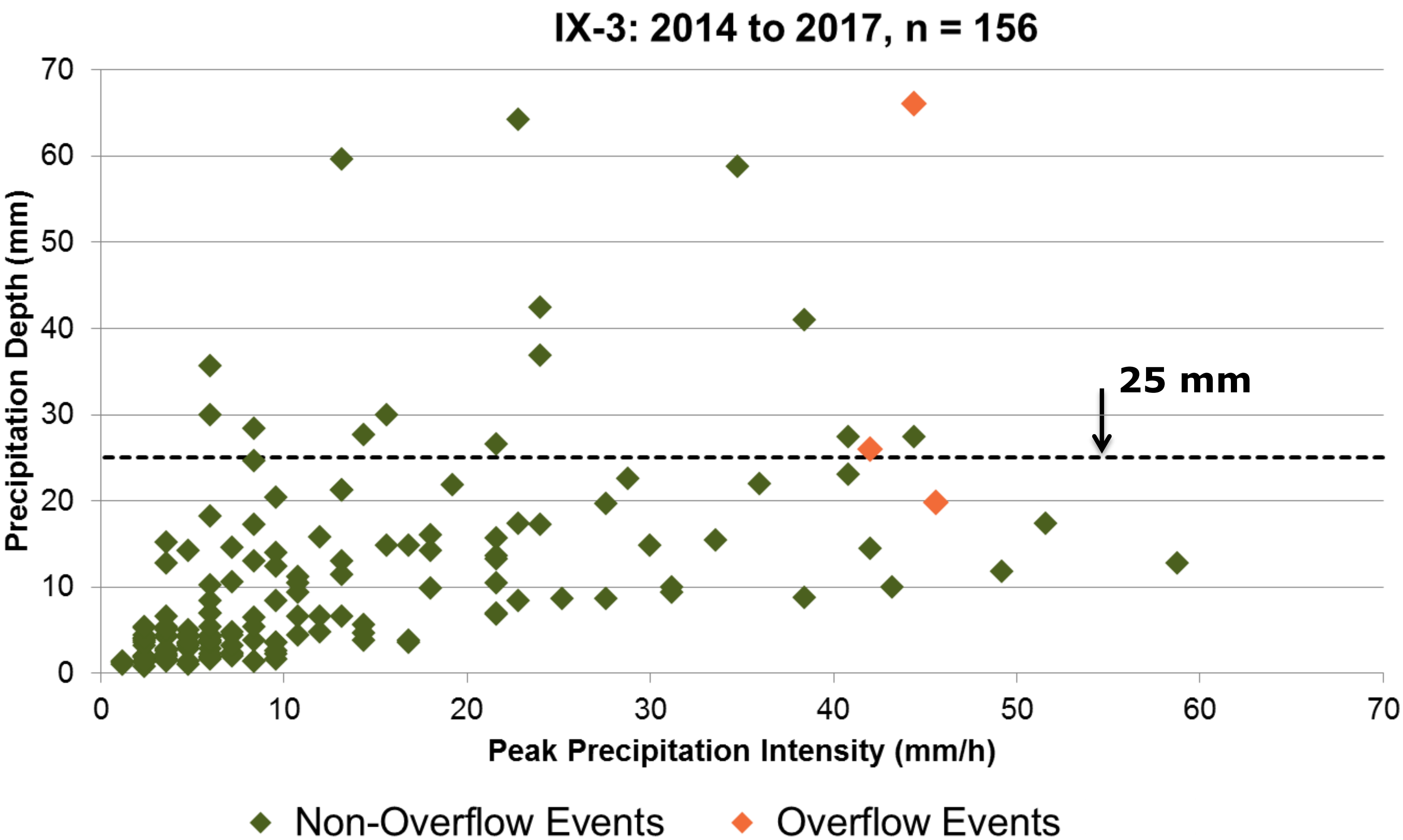

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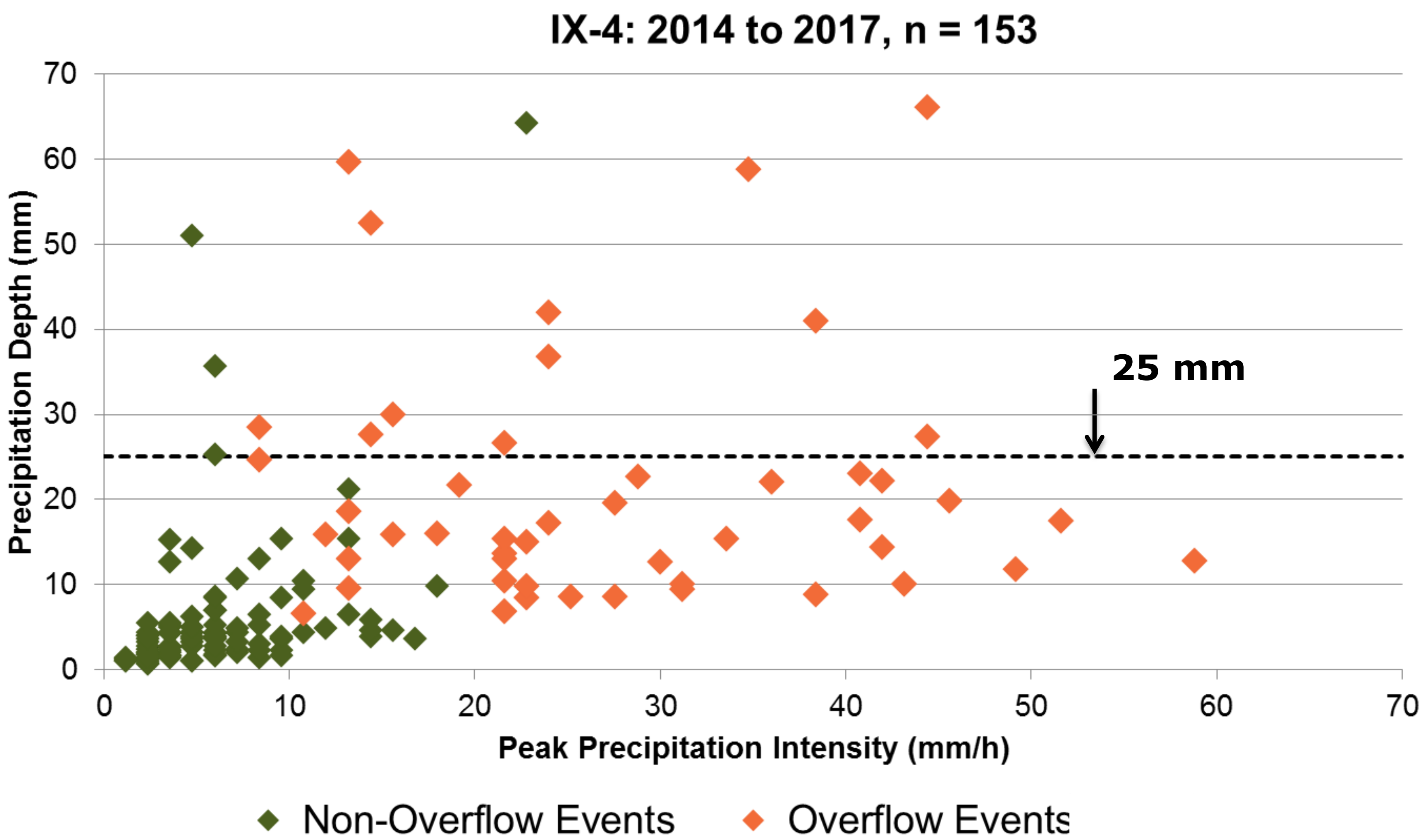


Water Quality Impacts of Overflow

Water Quality Monitoring

- A weir and level logger are used to measure the water leaving the swales

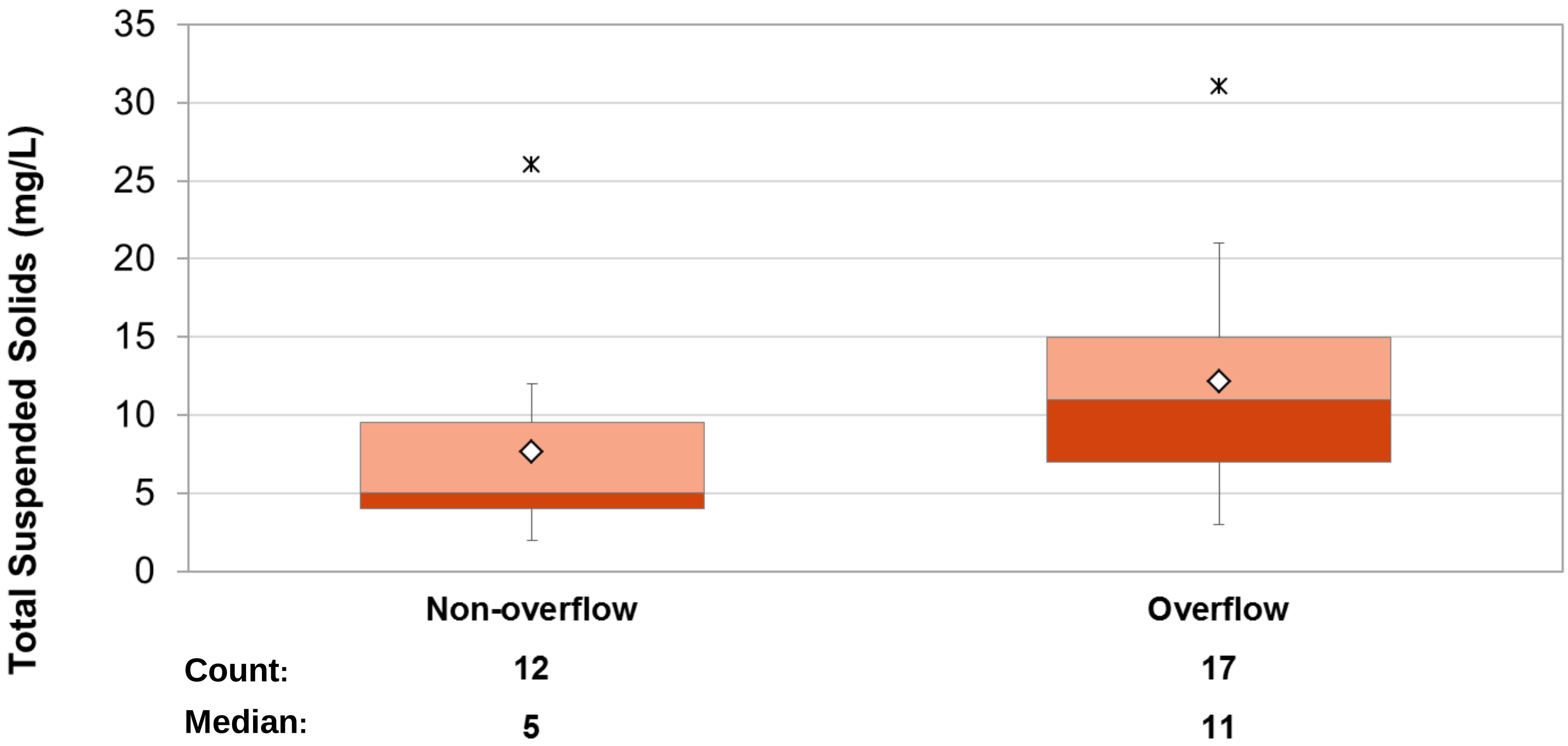
Water Quality Monitoring

- An autosampler is installed to collect water during a storm event

- Flow-proportioned composite samples are collected after events

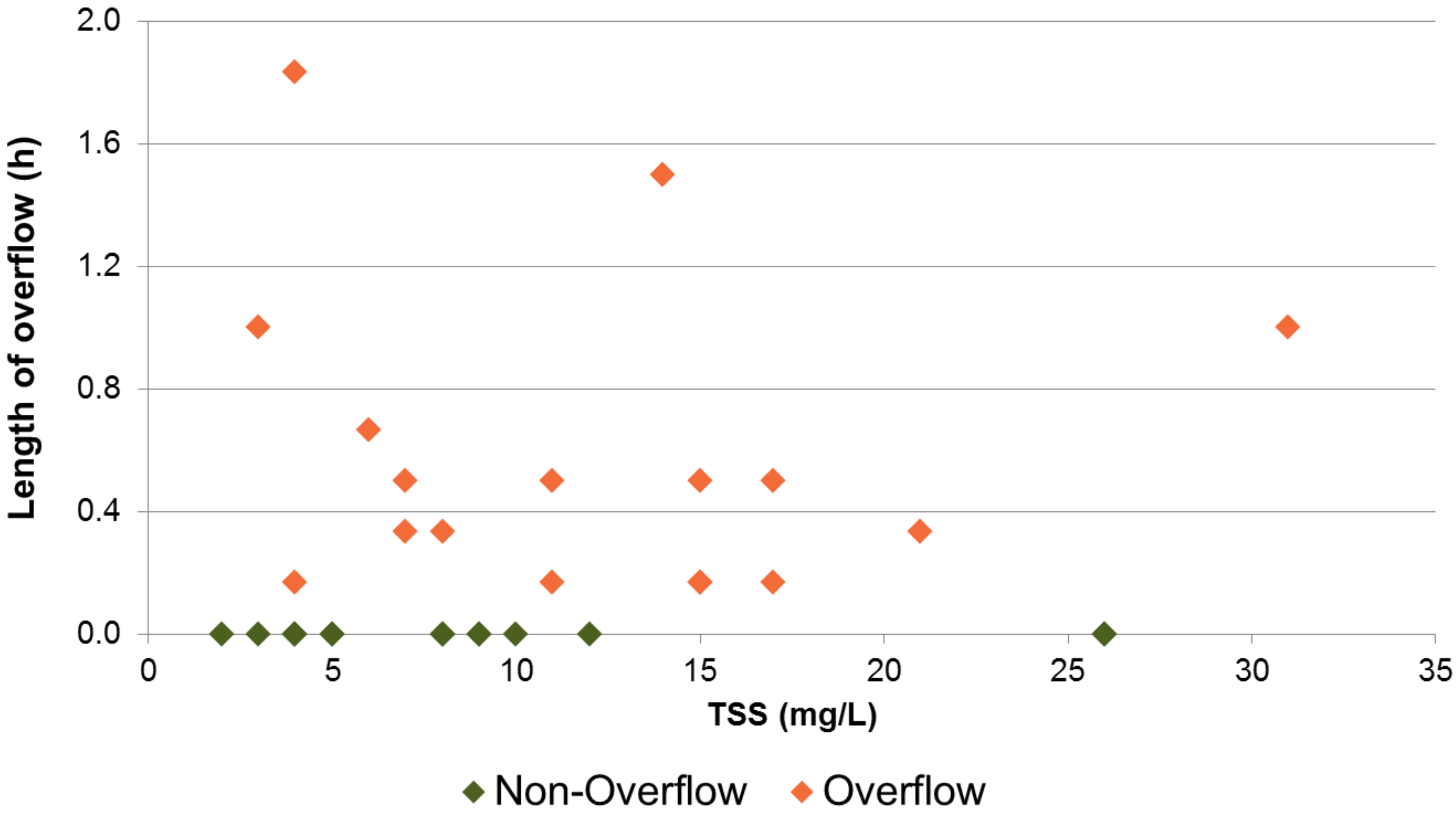
- This leads to event-mean concentrations (EMCs)

Water chemistry results – TSS at IX-4



- Comparing events of at least 5 mm

IX-4 Chemistry Results



Water chemistry results – IX-4

	Median concentration for non-overflow events	Median concentration for overflow events	Difference
Count	12	17	
Copper (µg/L)	4.55	8.8	↑
Iron (µg/L)	111	117	↑
Nitrate+Nitrite (mg/L)	0.87	0.46	↓
Total Phosphorus (mg/L)	0.11	0.13	↑
Total Suspended Solids (mg/L)	5	11	↑
Zinc (µg/L)	8.85	12.2	↑

Load reductions

- Water quality impact of LID installations can also be measured as load reduction
  - Combination of volume reduction and concentration changes
- Load reduction- difference between influent and effluent loads (masses)

Influent load = Estimated inflow volume x Estimated inflow concentration

Effluent load = Measured discharge x Measured outflow concentration

Load reduction – Overflow vs non-overflow events at IX-4

	Total load reduction for non-overflow events	Total load reduction for overflow events	Difference
Count	104	49	
Copper	87%	64%	↓
Iron	92%	88%	↓
Nitrate+Nitrite	52%	50%	↓
Total Phosphorus	79%	54%	↓
Total Suspended Solids	96%	89%	↓
Zinc	95%	87%	↓

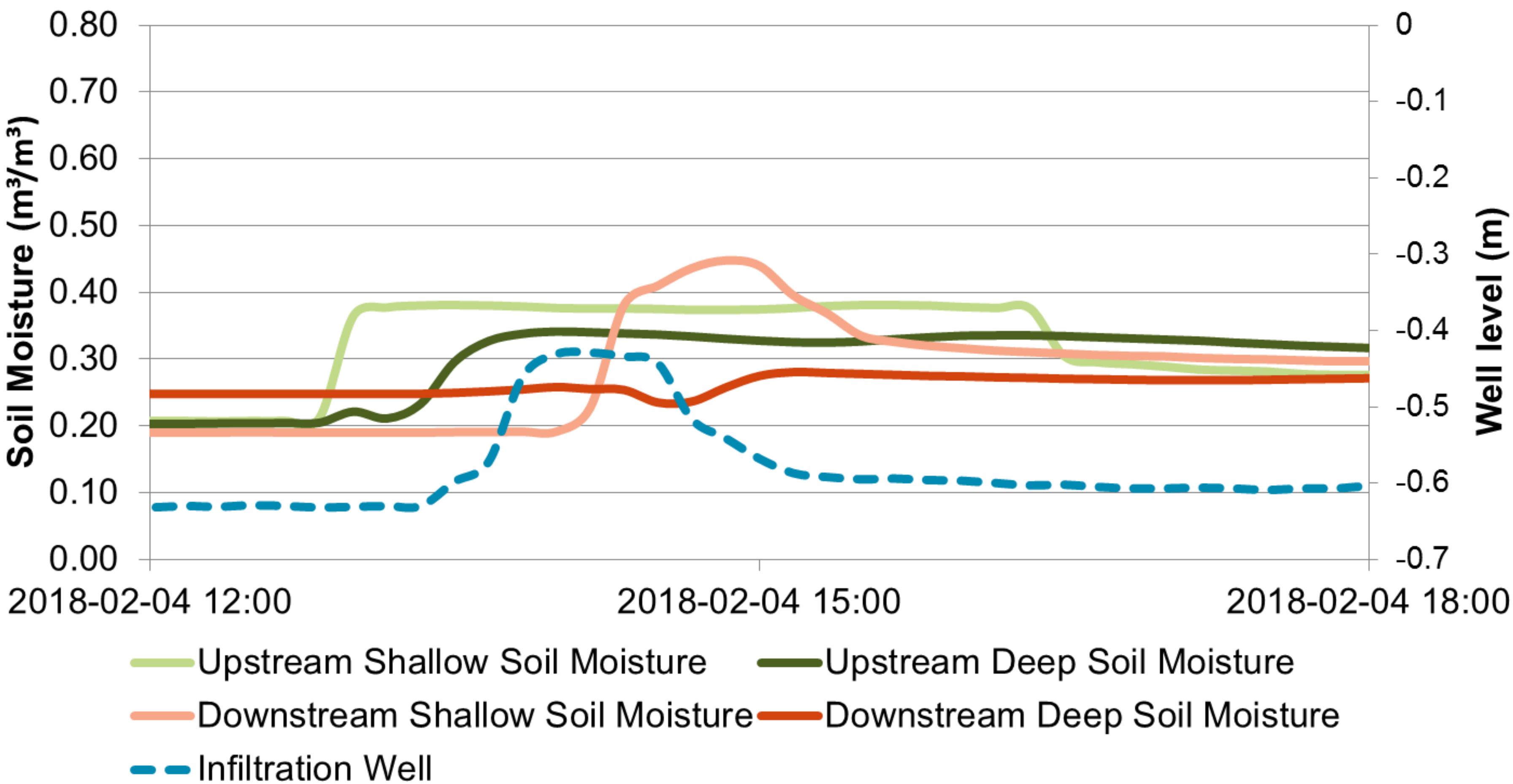
- Overflow events lead to a lower load reduction
- For most parameters there still is a load reduction

Seasonal impacts – Winter monitoring

Next Steps - Winter Data Collection

- Interested in how effective these features are at infiltration in the winter
- Soil moisture probes recently installed to help with winter monitoring

Next Steps - Winter Data Collection



Conclusion

Using monitoring data to inform design:

- Ensure the ratio of drainage area to feature area is not too high for the design
- Carefully grade parking lots when directing stormwater to multiple features
- Consider precipitation depth and peak precipitation intensity, instead of average intensity, when designing LID features
- Consider water quality implications of overflow events

Thank you!

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inspired by nature