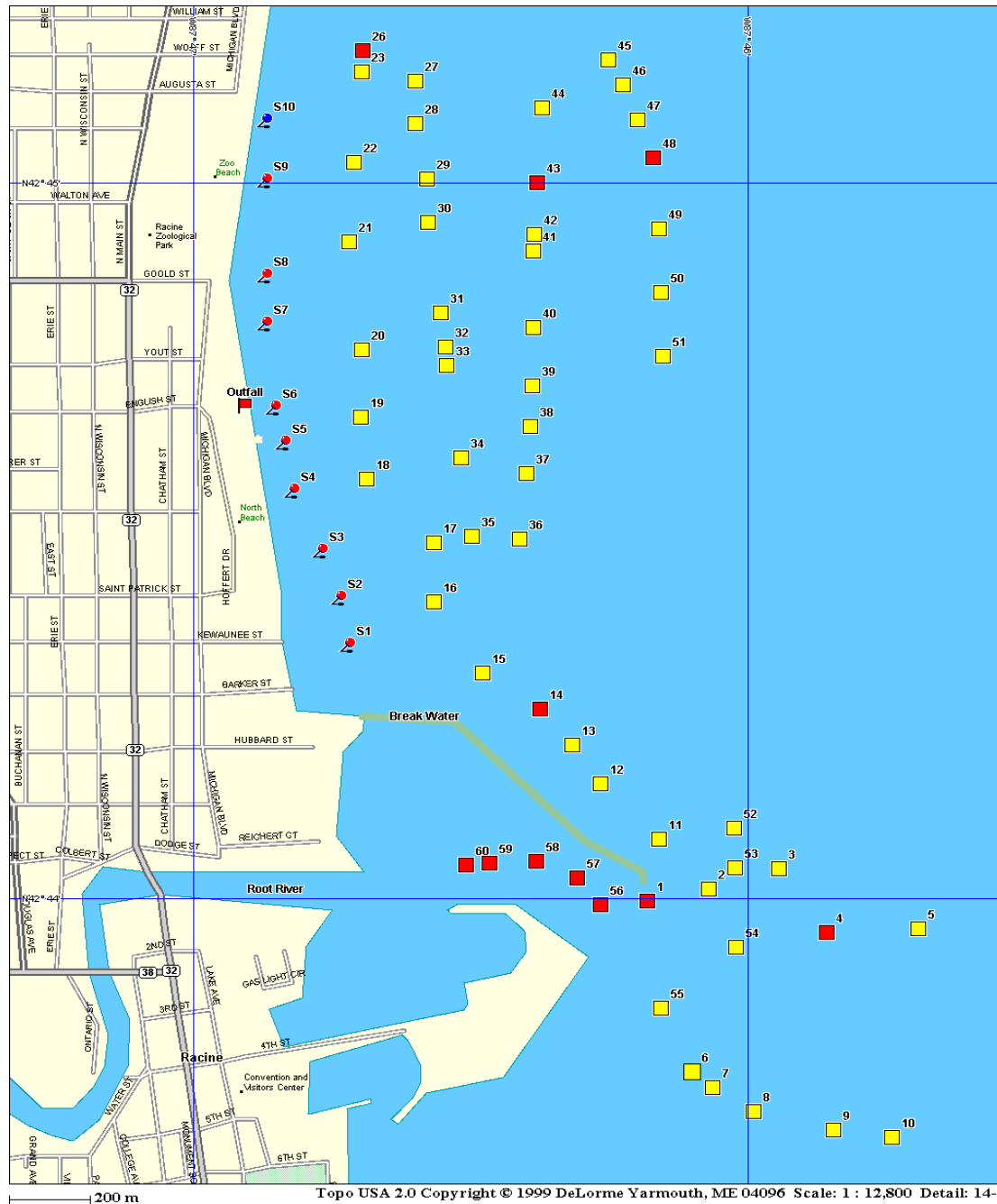


Combined Use of Physical/Morphological, Chemical, and Microbial Parameters to Assess Stream Health

Root River, Racine, WI



**2009 AWRA Annual Meeting
March 5-6, Stevens Point, WI**



2004 Spatial Distribution Study

**80 samples
by wading or boat**

Pre-rainfall, Rainfall, and Post- rainfall samples

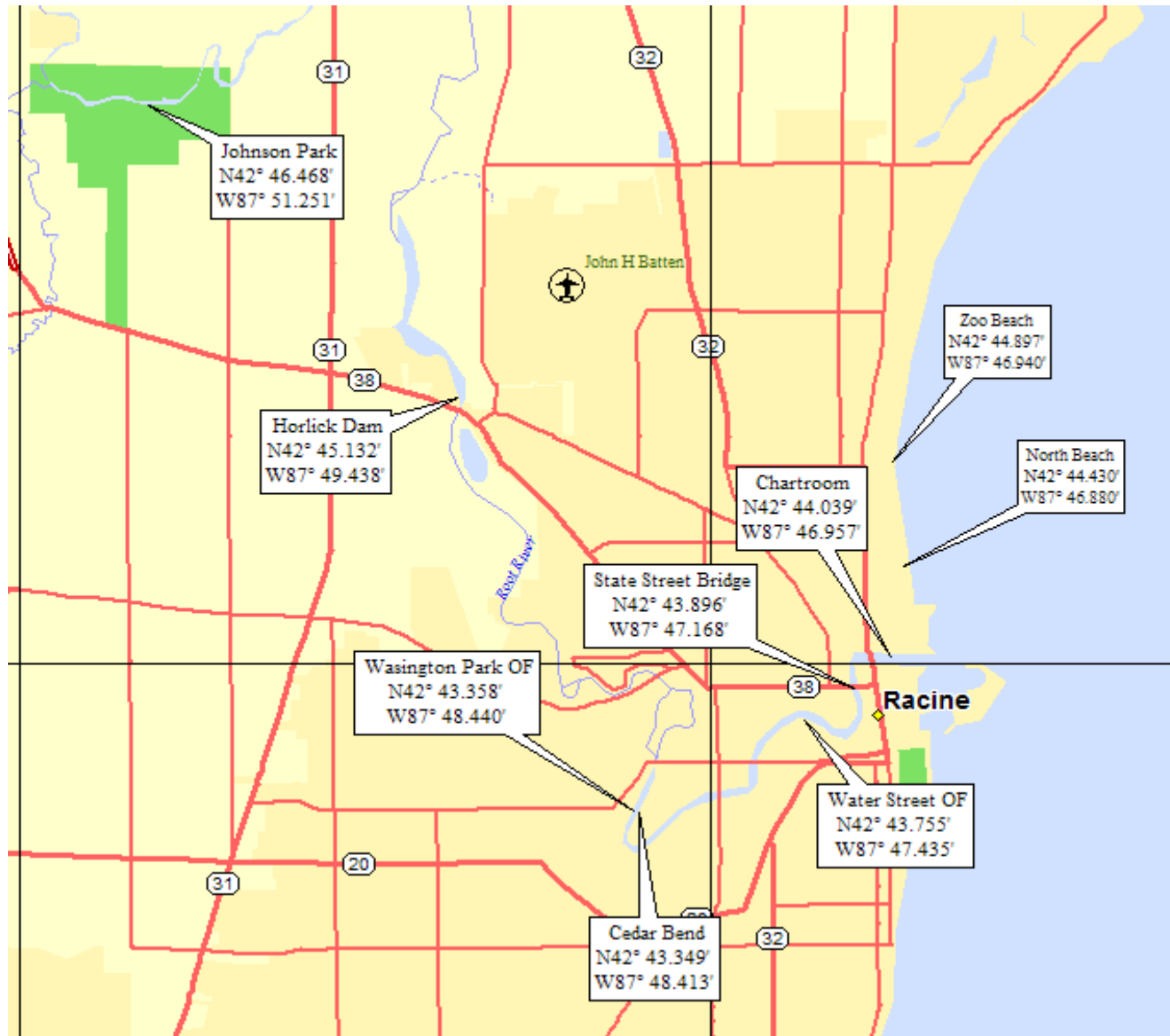
Look for elevated levels of *E. coli*

Definite plume from the Root River



North Beach

Racine had 7 monitoring stations



Root River *E. coli* Densities – 2004

SITE	MEAN <i>E. coli</i> MPN/100 ml	RANGE
Johnson Park (R1)	1518	10 – 14,136
Horlick Dam (R2)	1431	10 – 12,997
Cedar Bend (R3)	3705	0 – 12,997
Washington Park Storm Outlet (R4)	38,856	0 – 198,628
Water Street Storm Outlet (R5)	18,020	100 – 173,287
State Street Bridge (R6)	1372	63 – 11,199
Chartroom (R7)	1098	20 - 9804

the Root River and its Watershed



Over 1.6 million residents from Kenosha, Milwaukee, Racine and Waukesha Counties interact with and impact the watershed on a daily basis

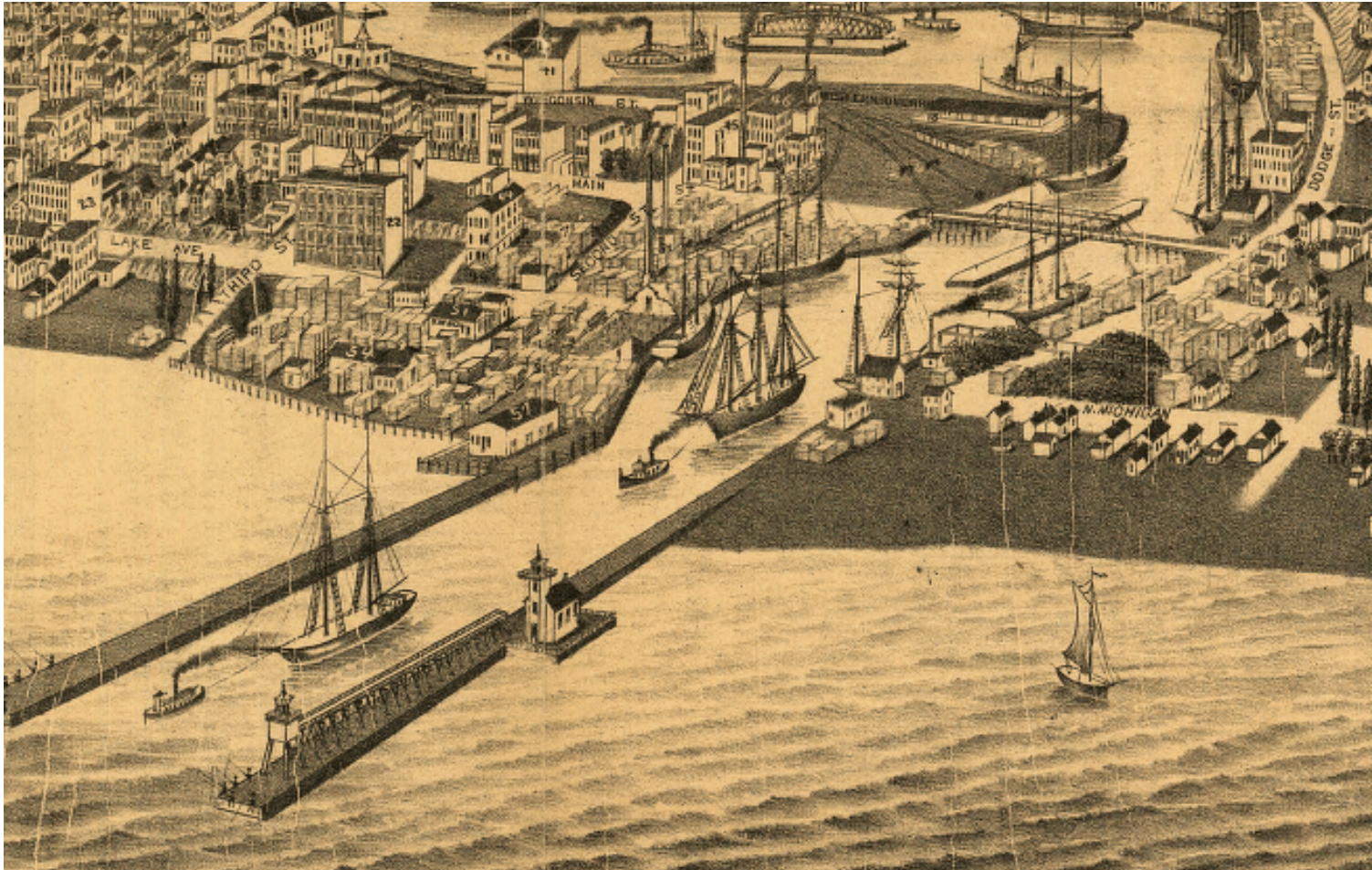
Root River Facts

- Origin, New Berlin (Waukesha County)
- Part of the Root-Pike Watershed
- Approximately 35 miles long
 - 117 mi of combined tributaries/streams
- City of Racine reach
 - Approximately 5 miles long
 - Horlick Dam to mouth at Lake Michigan

History of the Root River

- Historic names:
 - Chippecotton, Chipperooton
 - KipiKawi
- French explorer's first landed at the Root River in 1699
- Racine means "root" in French
- Racine's harbor & the Root River were important to the shipping industry in the late 1800's
- Also used recreationally

Mouth of Root River c. 1883



Racine Heritage Museum

Mouth of Root River - 2007



Is the Root River Impaired?

- WI Lutheran College Study (Ortenblad et al., 2003)
 - Biotic Integrity rating for fish species ranged from very poor (Milwaukee/Racine Co. line) to good (Colonial Park)
 - Family Biotic index of macro invertebrates ranged from good (upstream) to poor (downstream)
- WI DNR 303d list (2006)
 - Impaired for PCBs, low priority, no TMDL

Water Quality Impacts

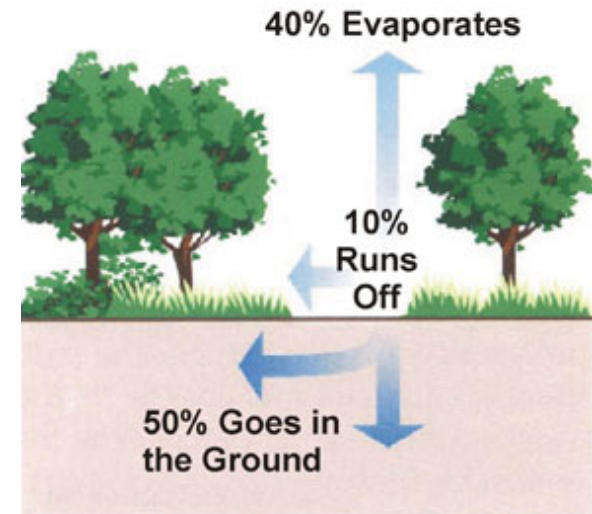
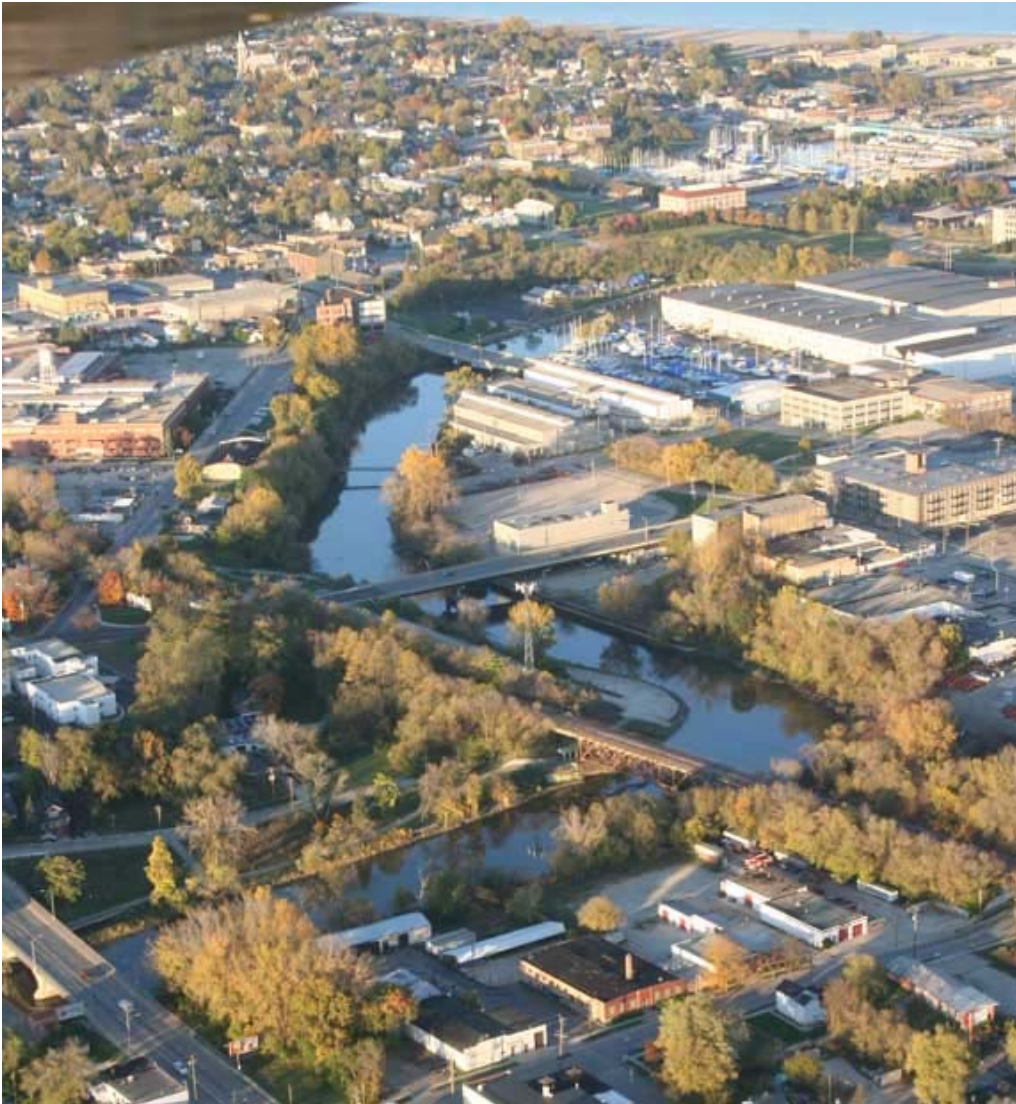
- Rock/soil/water interactions (the dissolution of rocks and minerals in water)
- Human activity
 - Residential
 - Industrial sources
- Climate
 - Precipitation (or lack thereof)
 - Temperature



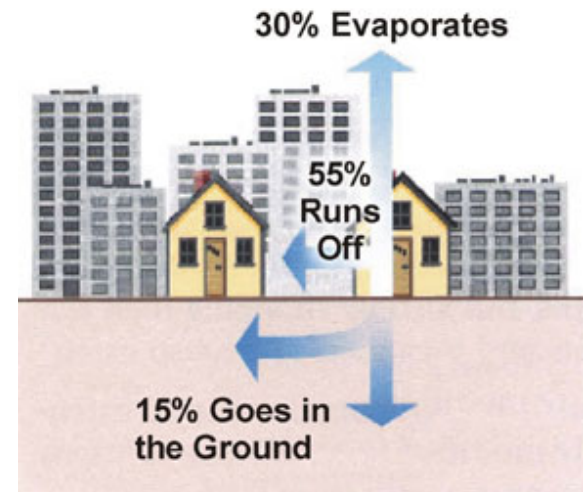
Non-point Source Pollution

- “polluted run-off”
 - pesticides, bacteria, oil, and other chemicals
- Impacts an estimated 40 percent of the WI streams
- Leading cause of water quality problems in WI today
- Can impact Great Lakes beaches, harbors and coastal waters
- Origins of NPS can be hard to identify

What Happens When it Rains?

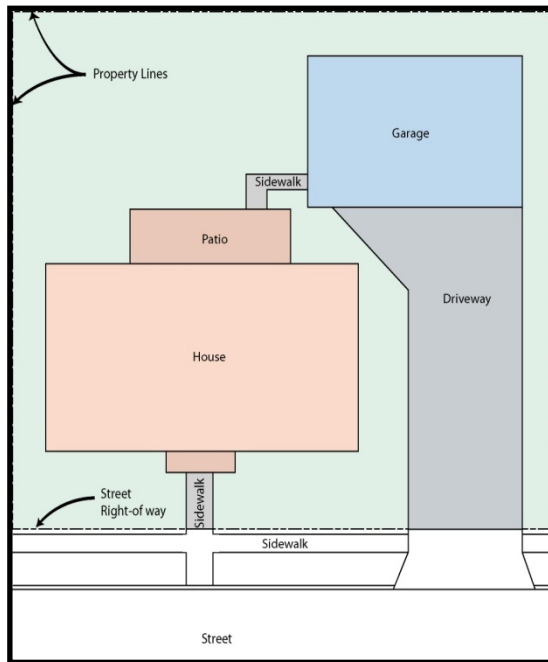


The Federal Interagency Stream Restoration Working Group



The Federal Interagency Stream Restoration Working Group

Racine Storm Water Utility



Residential Average
Impervious Area =
2,844 square feet
(or 1 Equivalent
Residential/Runoff
Unit (ERU))



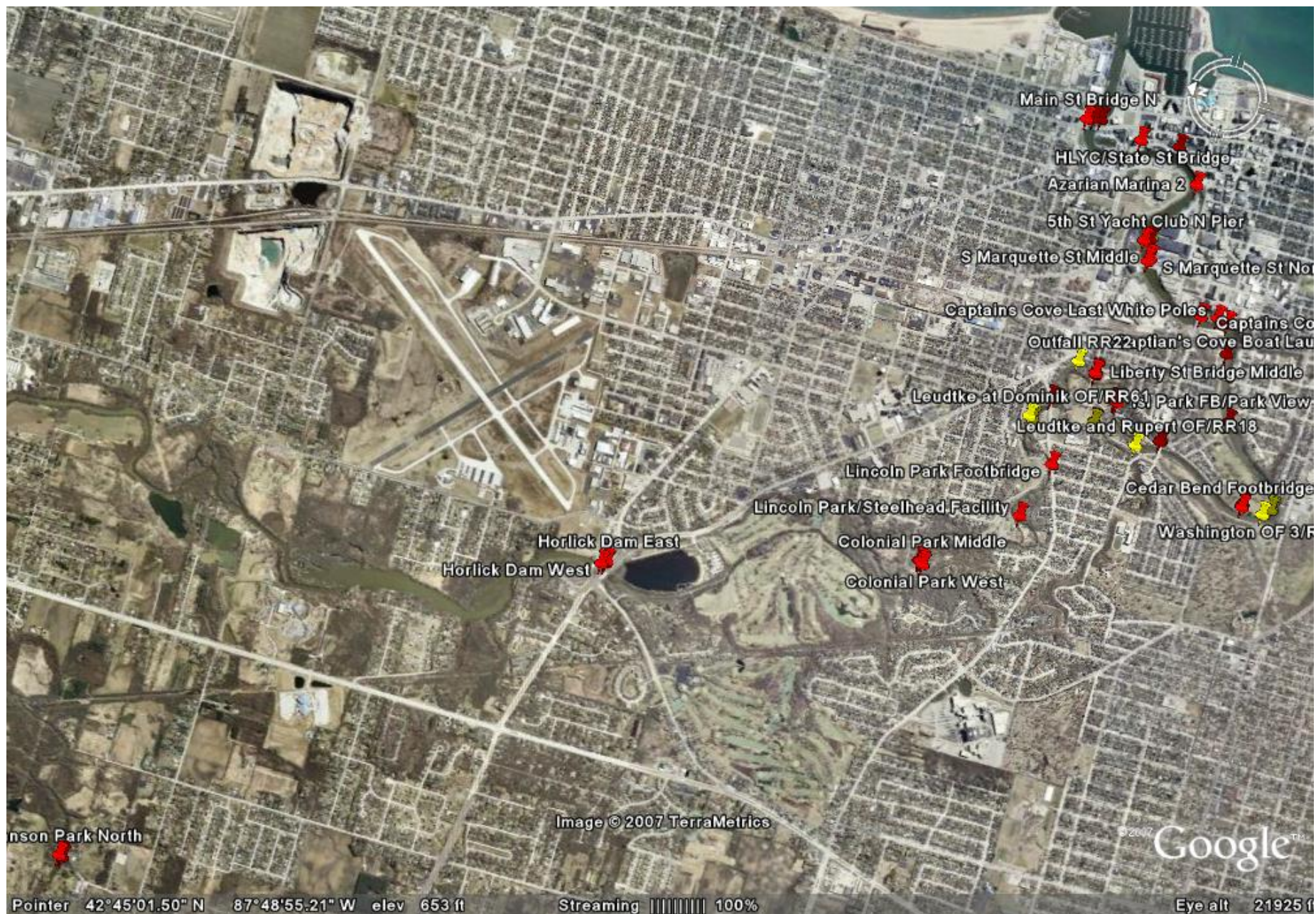
Downtown
Customer Example



Industrial Customer
Example

Purpose of Current Study

- Expand upon historic Root River monitoring conducted by the Racine Health Department
- Assemble a comprehensive database of water quality data which could be used as a baseline from which to gauge improvements as redevelopment and revitalization of the Root River corridor occurs
- Provide science to target remediation



Mitigation

- Watershed approach
 - Use Natural boundaries not manmade ones
- Base decisions on sound science
 - Strong scientific data, tools and techniques will enhance the process and aid in targeted remediation
- Public Involvement and Partnerships
 - Involving concerned individuals, agencies and organizations
 - Provide public education (kids & adults)
 - Communicate

Best Management Practices

- Riparian buffers
- Eliminate phosphorous fertilizers
- No dumping (anything) into the storm sewer system
- Install a rain garden
- Wash your car on the grass or at a car wash
- Direct your downspouts over the lawn
- Discourage wildlife like geese

Root River Stream Bank Stabilization Projects



Island Park, 2005



Island Park, 2006

Root River Average *E. coli* Densities (MPN/100 ml)

SITE	2004 (Rainfall = 9.23")	2007 (Rainfall = 19.45")
Johnson Park (R1)	1518	483
Horlick Dam (R2)	1431	460
Cedar Bend (R3)	3705	815
Washington Park Storm Water Outfall (R4)	38,856	529 – 5,469
Water Street Storm Water Outfall (R5)	18,020	4392
State Street Bridge (R6)	1372	840
Chartroom (R7)	1098	805

Local Initiatives

- Root-Pike WIN
 - Rain garden initiative
- Historic Sixth Street Association (HSSA)
 - Have proposed comprehensive design plans
- UW-Parkside
 - Expand urban environmental education and recreation
- River Alliance of Wisconsin
 - Comprehensive Root River Plan
 - Uses best elements of existing plans to ensure, among other key principles, that the water quality in the Root River is improved and the environment protected

2007 Study Sites

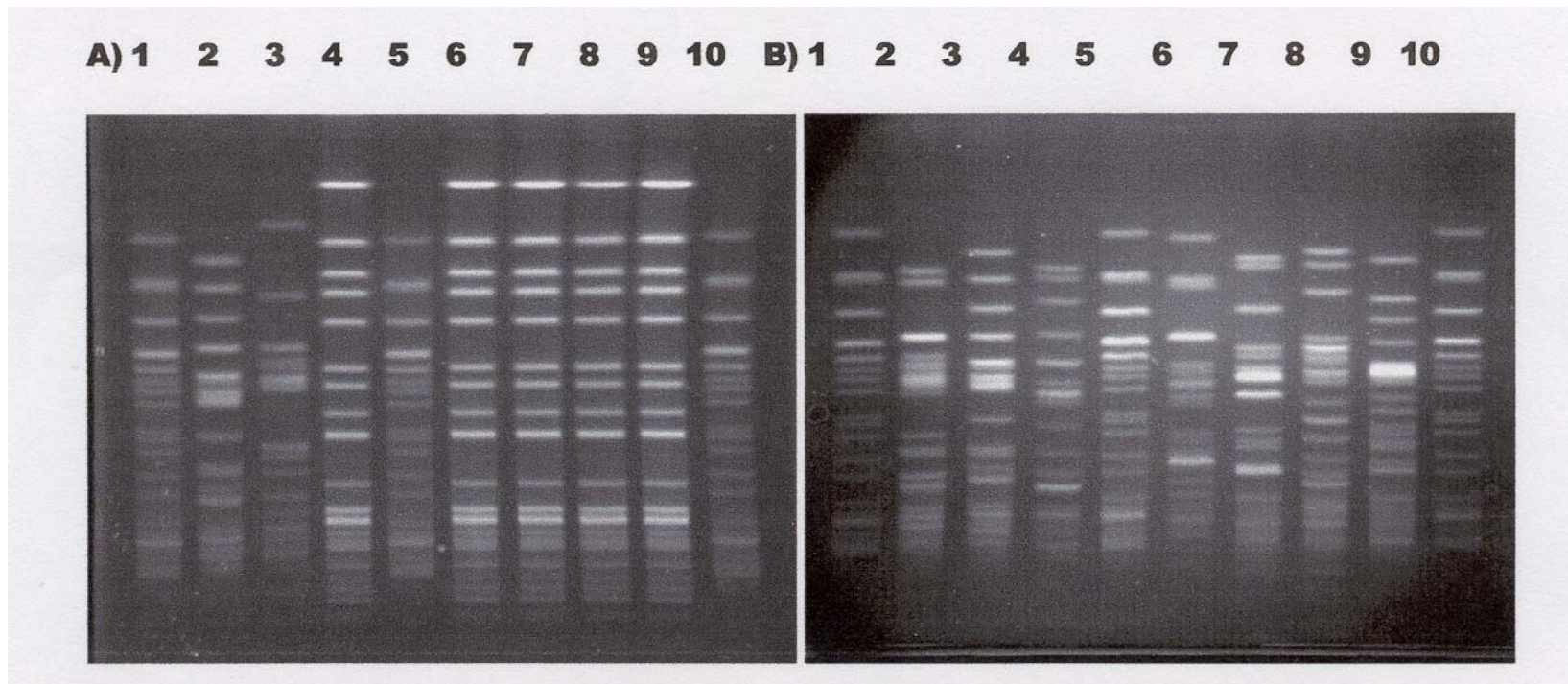
- Johnson Park (3)
- Horlick Dam (3)
- Colonial Park (3)
- Lincoln Park (2)
- Spring St/Domanik (1)
- Island Park/Glen St (3)
- Horlick Dr/Liberty St (3)
- Parkview Dr (3)
- W. 6th St/Rupert (2)
- Riverside/Cedarbend (3)
- Clayton Park (1)
- Barbee Park (1)
- REC Center (3)
- S. Marquette St. (2)
- 5th St. YC/Azarian (2)
- Azarian – downstream (3)
- State St. Bridge (1)
- Main St. Bridge (3)
- Chartroom (1)

- Leudtke Ct/Domanik
- Leudtke Ct/Spring
- Glen St
- Rupert/Leudtke
- Washington Park (3)
- Water Street/Azarian (2)



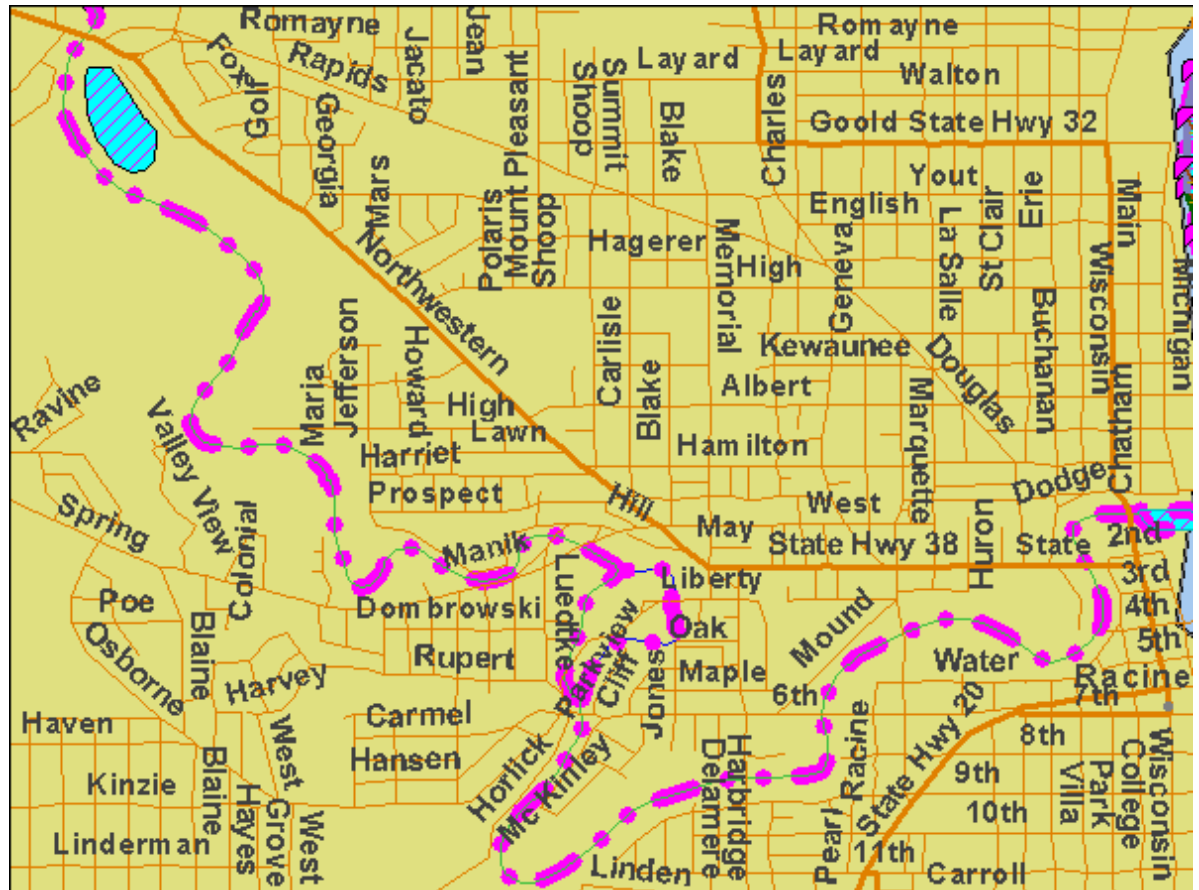
Biological Indicators

- *E. coli*
- Human specific *Bacteroides*



Chemical Indicators

- pH
- Temperature
- Turbidity
- Conductivity
- Detergents
- Chlorine
- Copper
- Phenols



Results

pH

(Normal range: 6.0 – 8.5)

- Of the 43 open water sites five had pH values which exceeded the recommended level once ($\text{pH} > 8.5$):
 - Johnson's Park – Middle (6/20/07)
 - Horlick Dam – Middle (8/1/07)
 - Main Street Bridge – South (6/18/07)
 - Clayton Park (10/9/07)
 - Captain's Cove/REC Center – Sampling Point #1 (7/23/07)
- One site, Captain's Cove/REC Center – Sampling Point #3, exceeded the recommended pH level on four occasions (7/2, 7/9, 7/23, and 7/30/07)
-
- All exceedances were on the high end ($\text{pH} > 8.5$) and none were associated with a rain event.

Results

Water Temperature:

- The water temperature remained fairly stable at all sampling points
- Average deviation being ± 5.9 °F between the highest and lowest readings at each of the respective 43 sites (minimum ± 4.2 °F, maximum ± 7.2 °F)
- Mean water temperature overall was 71.0 °F
- Upstream segments generally had cooler water temperatures, by approximately one to two degrees

Results

Turbidity

(Normal range ≤ 29 NTU above natural background levels):

- Of the 41 sites tested all but Clayton Park had turbidity levels exceeded 29 NTU at least once.
- The average number of elevated turbidity values associated with precipitation was 2 per site.
- Some sites had elevated turbidity without rainfall
 - Johnson's Park
 - Horlick Dam
 - Colonial Park
 - Lincoln Park at the DNR Steelhead Facility
 - Spring St./Domanik Drive, Captain's Cove/REC
 - W. Sixth St. – Middle
 - Azarian Marina – sampling point #2

Results

Conductivity

(Normal range: 50 – 1500 $\mu\text{mhos/cm}$ or 50% above baseline levels):

- The highest conductivity measurement recorded during this study was 5.82 $\mu\text{mhos/cm}$
- This value only reflects the summer months and may very well be higher during the winter and spring when road salt may be transported to the Root River

Results

E. coli

(Normal range: depends on use, recommended up to 394 MPN/100 mL):

- All sites exhibited elevated *E. coli* levels after some rain events. For some sites this was exclusive
 - Colonial Park – east
 - Lincoln Park/Spring St.
 - Azarian Marina/#1
 - Harbor Light Yacht Club
- Most sites also had elevated *E. coli* levels in the absence of precipitation
- For two of the sampling sites there was little correlation between the sampling points (either bank, middle of stream, or both)
 - Island Park/Liberty Street
 - Island Park/Park View Drive
- *E. coli* values were generally correlated to turbidity except at the Island Park footbridge behind Lutheran High School (all three sites), Island Park footbridge to Park View Drive – East, and Island Park bridge to Liberty St. – East

Occurrence of E. coli w/o Rain

- 6%: Main St. Bridge, Johnson Park, Chartroom, State St. Bridge, Lincoln Park/Steelhead, Azarian Marina/#2
- 6-19%: Horlick Dam, depending on sampling location
- 6-25%: W. 6th St., depending on sampling location
- 6-31%: Island Park/Liberty St., depending on sampling location
- 12.5%: Colonial Park – west, middle
- 12.5-19%: Marquette St., depending on sampling location
- 19%: Island Park/Park View Dr.
- 25%: Island Park/Lutheran HS
- 25-31%: 5th Street Yacht Club, depending on sampling location
- 31%: Clayton Park, Barbee Park, Spring St./Domanik Dr.
- 31 – 37.5%: Captain's Cove/REC, Cedarbend

Other Chemical Parameters

- **Detergents (Normal range: ≤ 0.50 mg/L):**
Detergents were detected frequently (80 – 100% of sampling events) except at Washington Park Outfall #3 (RR37-c, 31%)
- **Total Residual Chlorine (Normal range: < 0.01 mg/L):**
Total residual chlorine was detected in the Water Street Outfall (#RR36-1W, #RR36-2E) 25% of the time. Values ranged from 0.1 – 0.15 mg/L.
- **Copper (Normal range: ≤ 3.7 $\mu\text{g/L}$): None detected**
- **Total Phenols (Normal range: < 1.0 $\mu\text{g/L}$):**
Washington Park Outfall #2, #RR37-b, had detectable phenols once (0.15 $\mu\text{g/L}$) but they were within acceptable limits.

Missing Information

- Phosphorus levels
- Current & depth measurements
- Dissolved oxygen
 - Fish community assessments
- Seasonal variation in measured parameters
 - Impacts of snow melt
 - Impacts of heavy spring rains, flooding

Next Steps

- Applied to WI Coastal Management Program for an additional year of funding
- Includes educational programming for general public and REC Center
- Continues collaborative effort with River Alliance, Root-Pike WIN
- Provides for citizen-based training opportunities

SEWRPC (2007) – Plan Update

- Update includes major plan elements addressing:
 1. Land Use
 2. Surface Water Quality
 - Point source pollution abatement
 - Non-point source pollution abatement
 3. Groundwater Management

Planning Objectives

- Water quality management objectives
 - Development of facilities, programs, and policies to serve the regional development pattern
 - Development of policies and practices to meet water use objectives
 - Enhancement of the quality of natural and man-made environments
 - Reduction of sedimentation, other water pollution, and eutrophication

Water Quality Management Plan

Land Use Plan Element

- Fundamental and basic
- Future land use will determine the character, magnitude, and distribution of NPS
 - Ultimately the quality of surface water in the watersheds
 - Tributaries
 - Lake Michigan

Urban NPS Abatement

- Control stormwater pollution from existing and planned development, redevelopment, and infill
- Implement coordinated programs to detect and eliminate illicit discharges
 - Enhance stormwater OF monitoring (wet/dry)
 - Molecular tests for human specific markers
 - Upstream dry weather screening of OF when human specific markers are present

Auxiliary Measures

- Long-term trend lake monitoring programs
- Maintain or expand current public health monitoring programs at public beaches
- Coastal zone management
- Household hazardous waste and PCP collections
- Standardized agency water quality monitoring of surface water
 - Utilize citizen-based water monitoring programs

History of the Root River

- Historic names:
 - Chippecotton, Chipperooton
 - KipiKawi
- French explorer's first landed at the Root River in 1699
- Racine means "root" in French
- Racine's harbor & the Root River were important to the shipping industry in the late 1800's
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the Root River and its Watershed



Root River Watershed

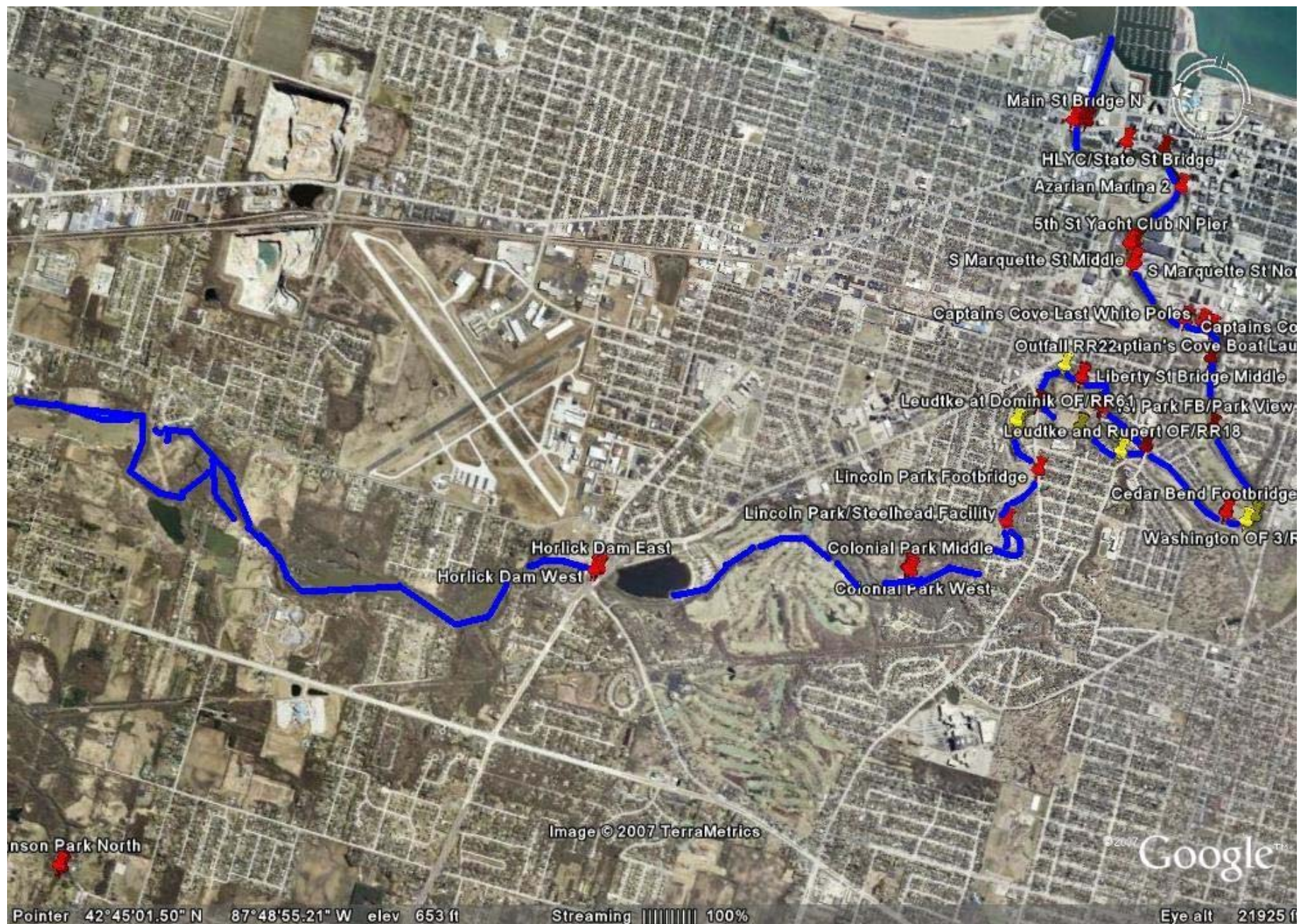
- Significant downward trend in bacterial indicators from upstream to downstream
- Improved water quality in bathing beaches (at mouth of river)
- Pesticides and herbicides detected, many below USEPA draft aquatic life criteria
- 10 fish species not seen since 1986, also 10 new species

2005 Streambank Erosion & OF Study

- Commissioned by City of Racine
- Evaluate condition of storm sewer OF
- Streambank condition
- Erosion potential
- Develop baseline data
- Identify problems associated with hydromodifications

Additional Studies

- 2007 baseline assessment of Root River water quality
- 2008 expanded Root River study
 - Seasonal variation
 - Educational component
 - DO, phosphorous
- 2009 predictive modeling study
 - Combine land use & coastal models



Main St Bridge N

HLYC/State St Bridge

Azarian Marina 2

5th St Yacht Club N Pier

S Marquette St Middle

S Marquette St Nor

Captains Cove Last White Poles

Captains Co

Outfall RR22, aptian's Cove Boat Lau

Liberty St Bridge Middle

Leudtke at Dominik OF/RR6, 1 Park FB/Park View

Leudtke and Rupert OF/RR18

Lincoln Park Footbridge

Lincoln Park/Steelhead Facility

Cedar Bend Footbridge

Washington OF 3/F

Horlick Dam East

Horlick Dam West

Colonial Park Middle

Colonial Park West

inson Park North

Image © 2007 TerraMetrics

Google

Pointer 42°45'01.50" N 87°48'55.21" W elev 653 ft

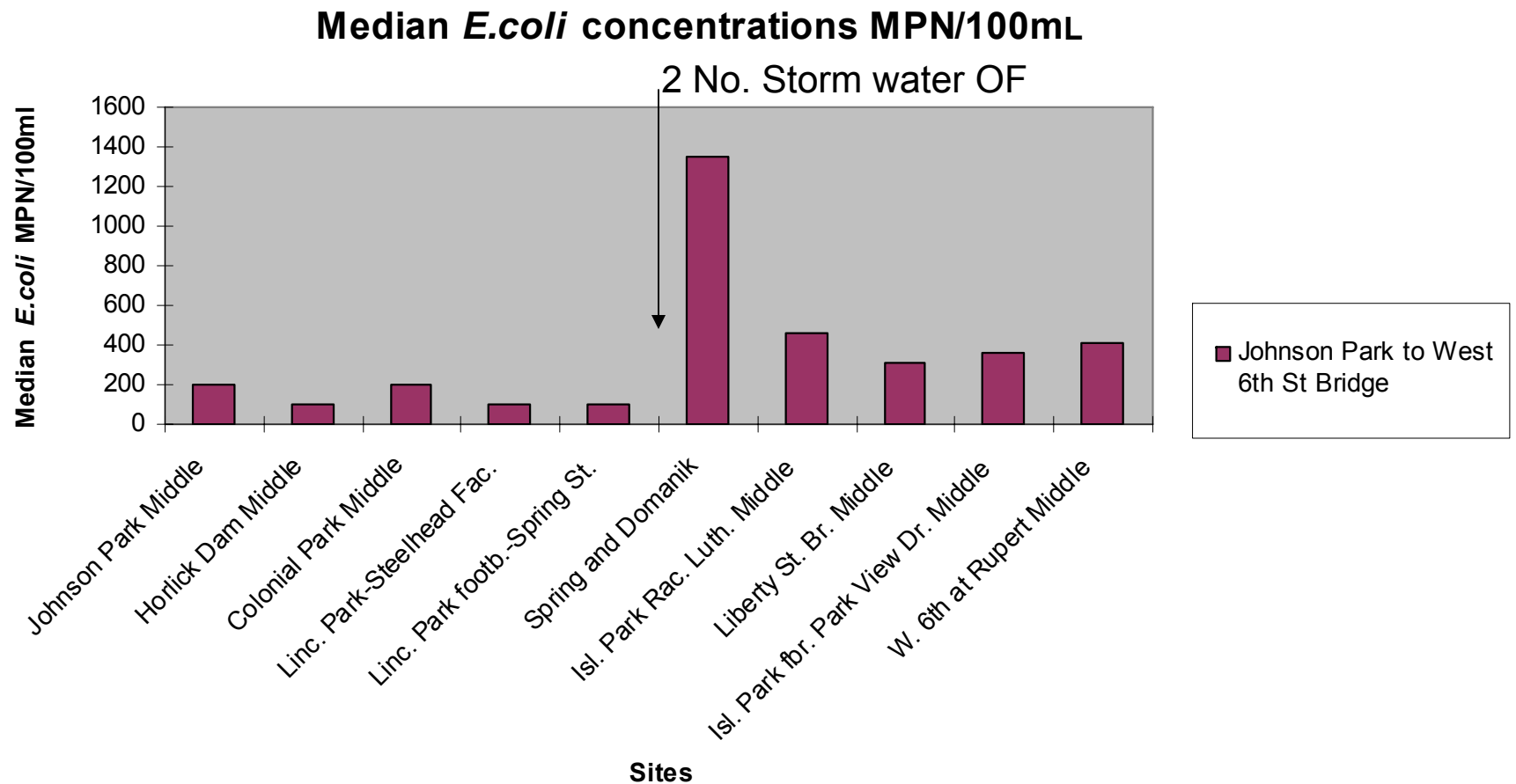
Streaming 100%

Eye alt 21925 ft

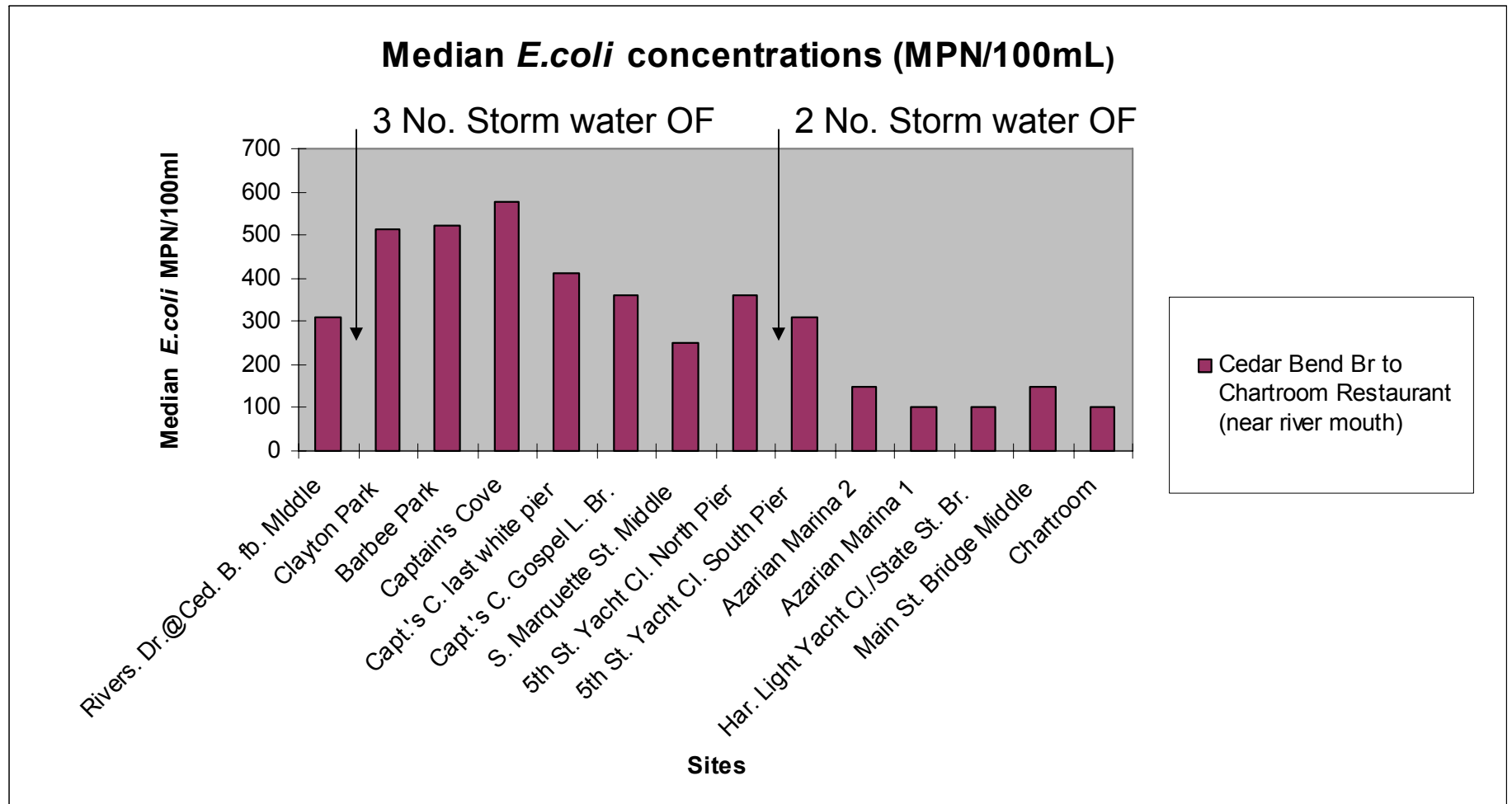
Summary of storm water outfall results using chemical and microbiological source tracking parameters (2008)

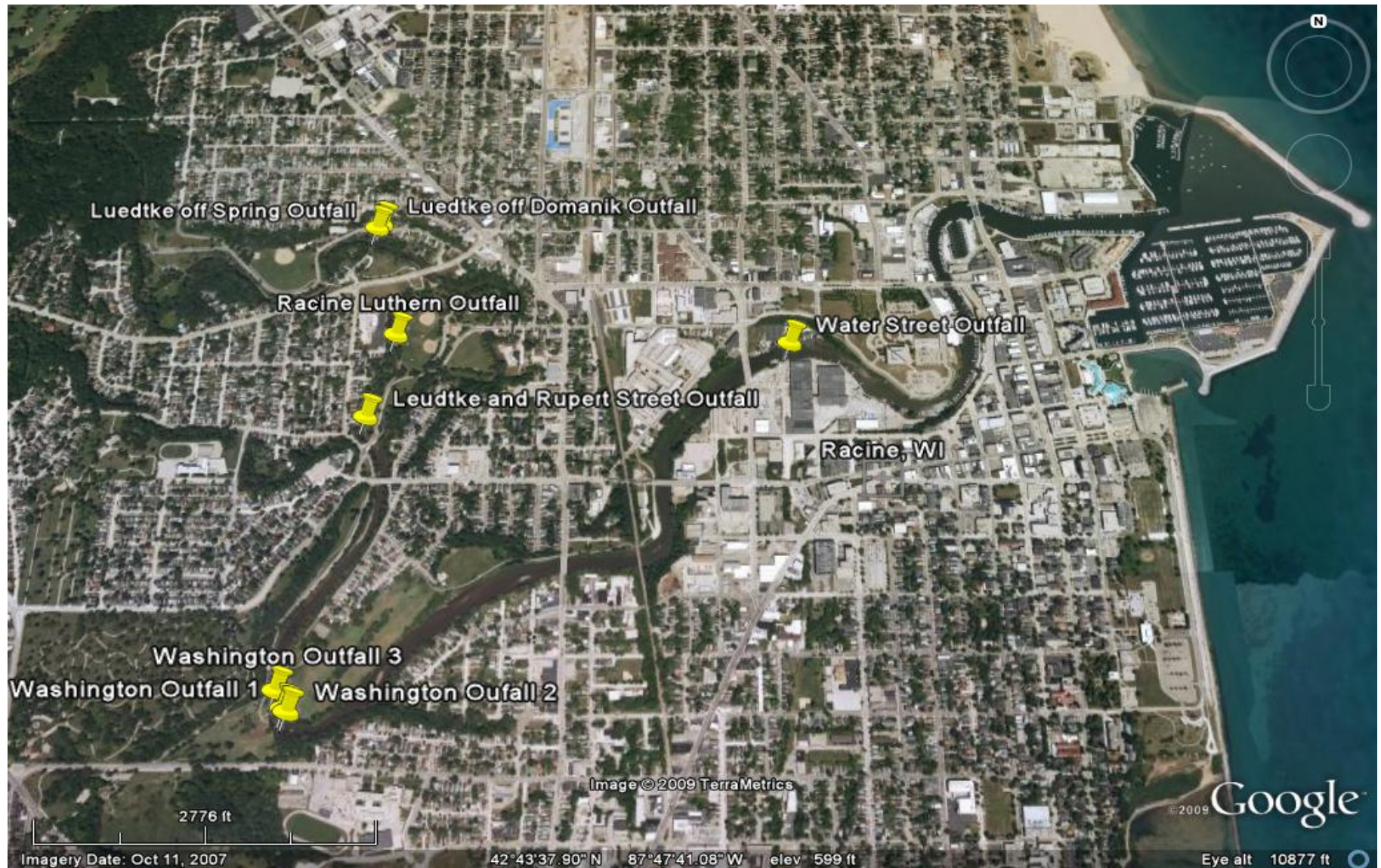
Outfall	Percentage exceedance of total samples	Percentage exceedance in dry weather	Mean <i>E. Coli</i> MPN/100 mL	Max <i>E. Coli</i> MPN/100 mL	Mean Chlorine (mg/L)	Mean Detergents (mg/L)
Behind Racine Lutheran High School	95	52	30,248	141,360	0.002	0.2
Water St. East	93	60	11,611	173,287	0.061	0.2
Leudtke/Domani k.	93	52	25,212	241,917	0.006	0.2
Leudtke/Rupert	88	42	14,396	141,360	0.002	0.2
Water St. West	83	45	27,951	241,920	0.098	0.14

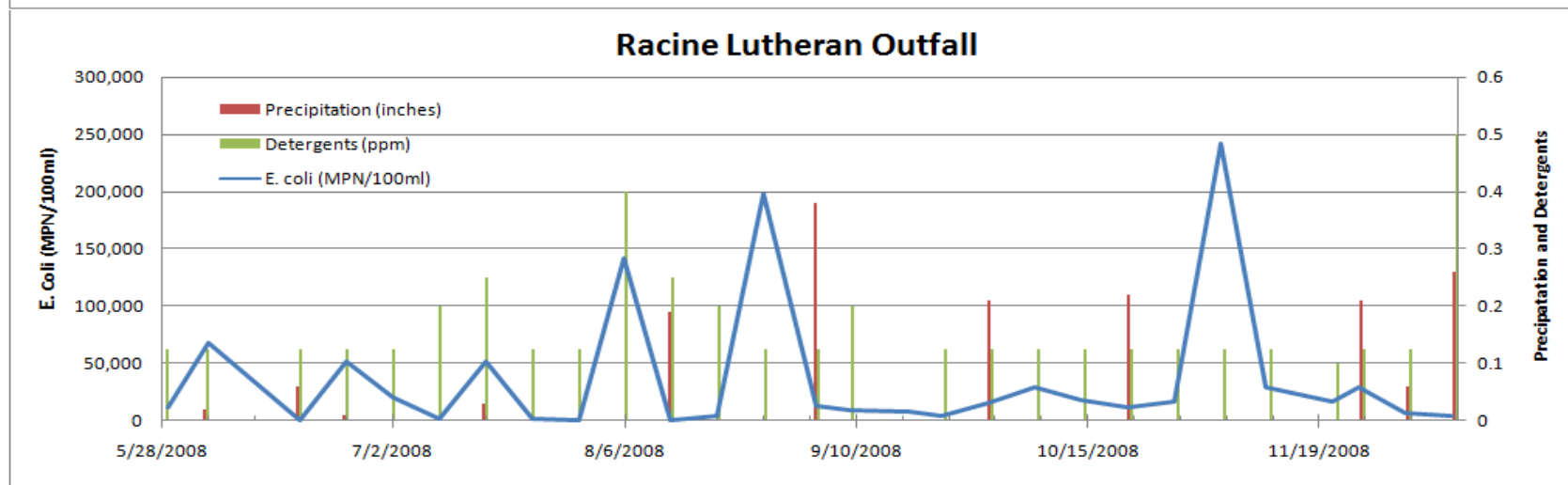
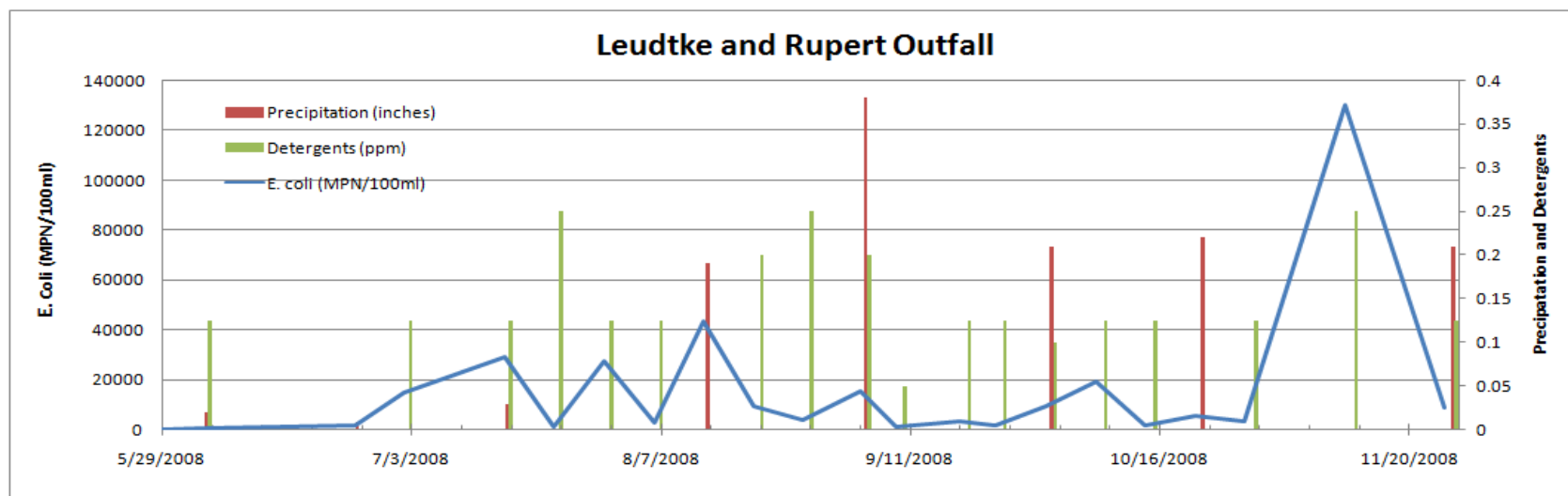
Median *E. coli* concentrations from Johnson's Park to West 6th Street



Median *E. coli* concentrations from Cedarbend Bridge to mouth of Root River

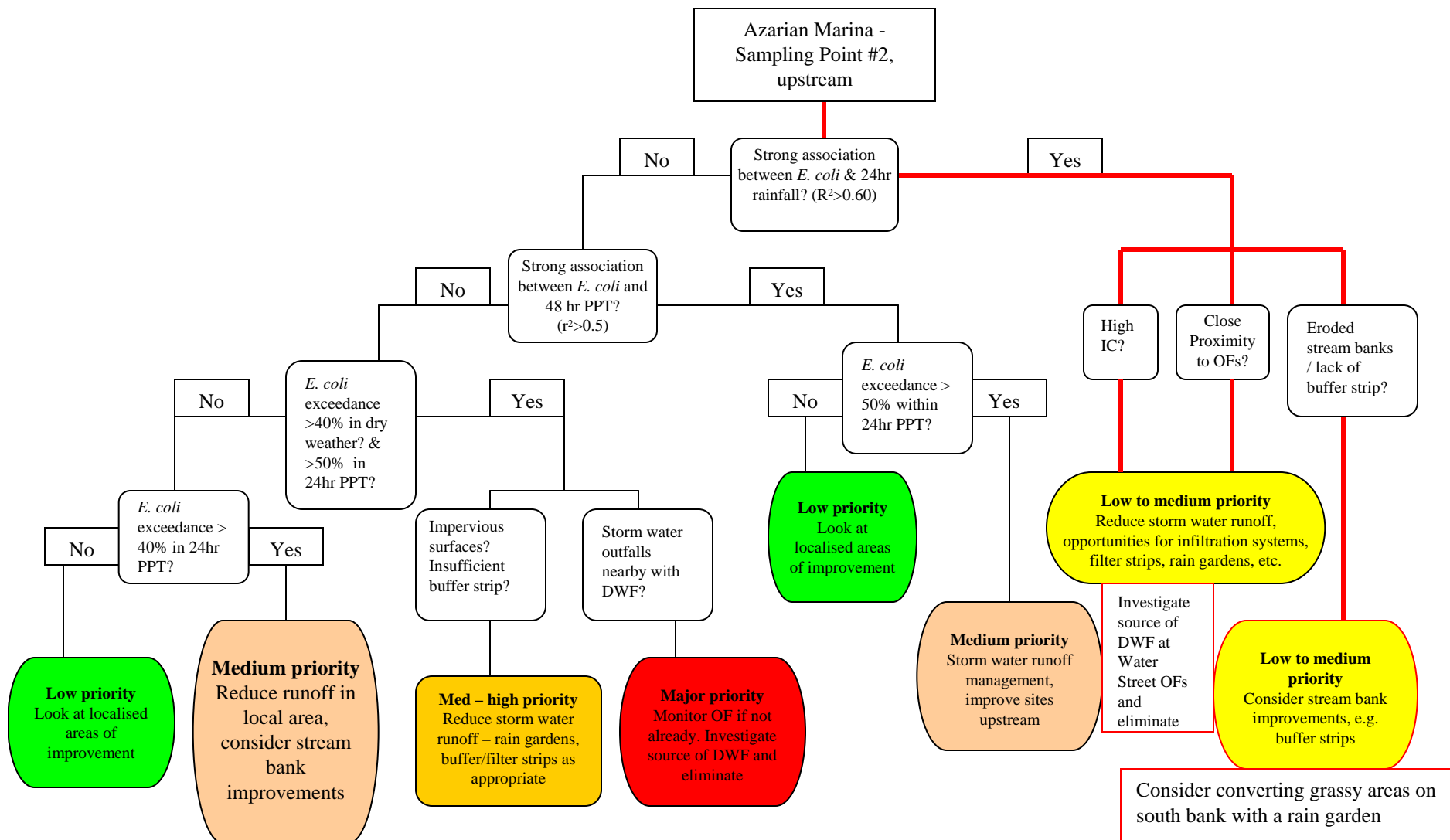


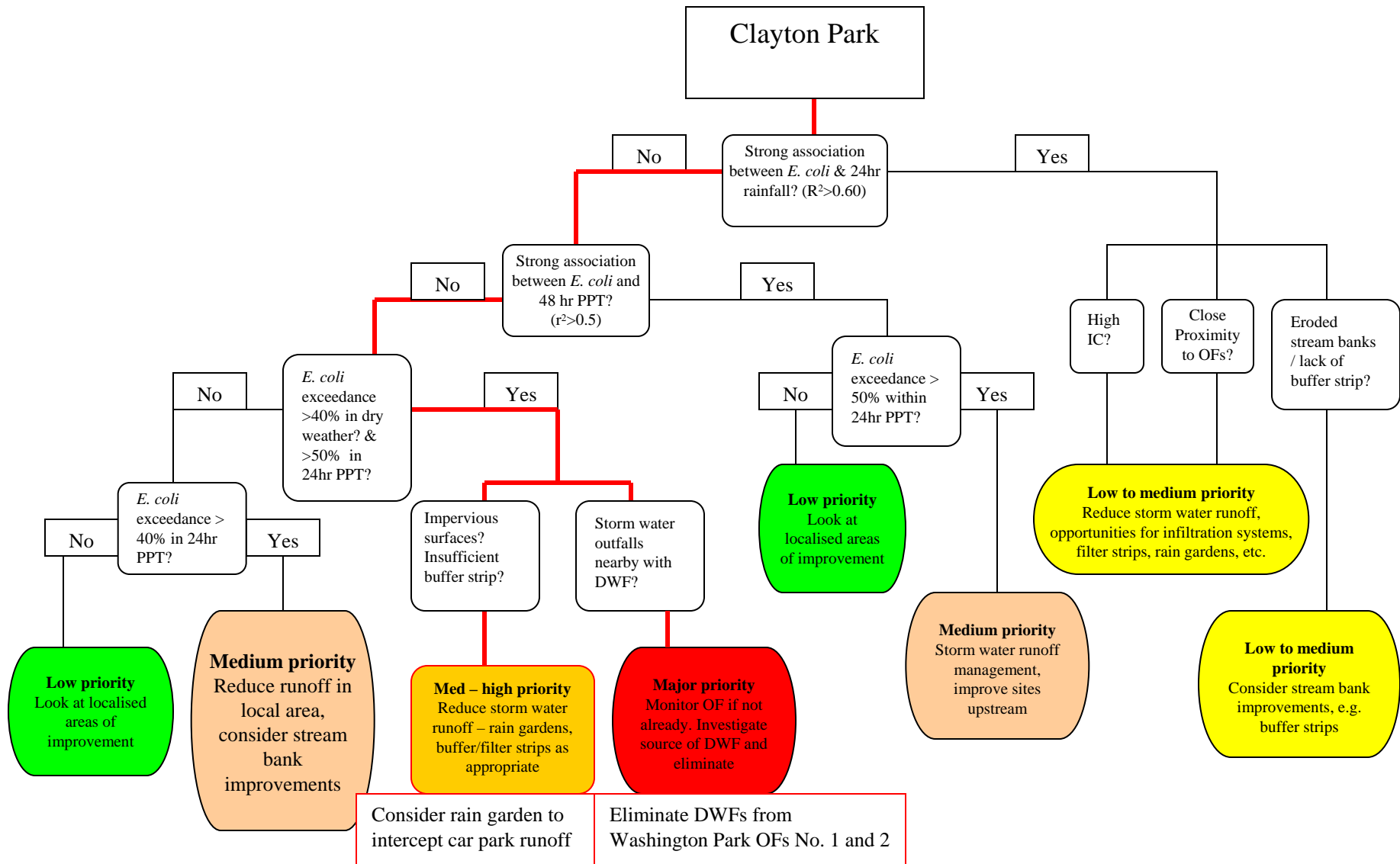


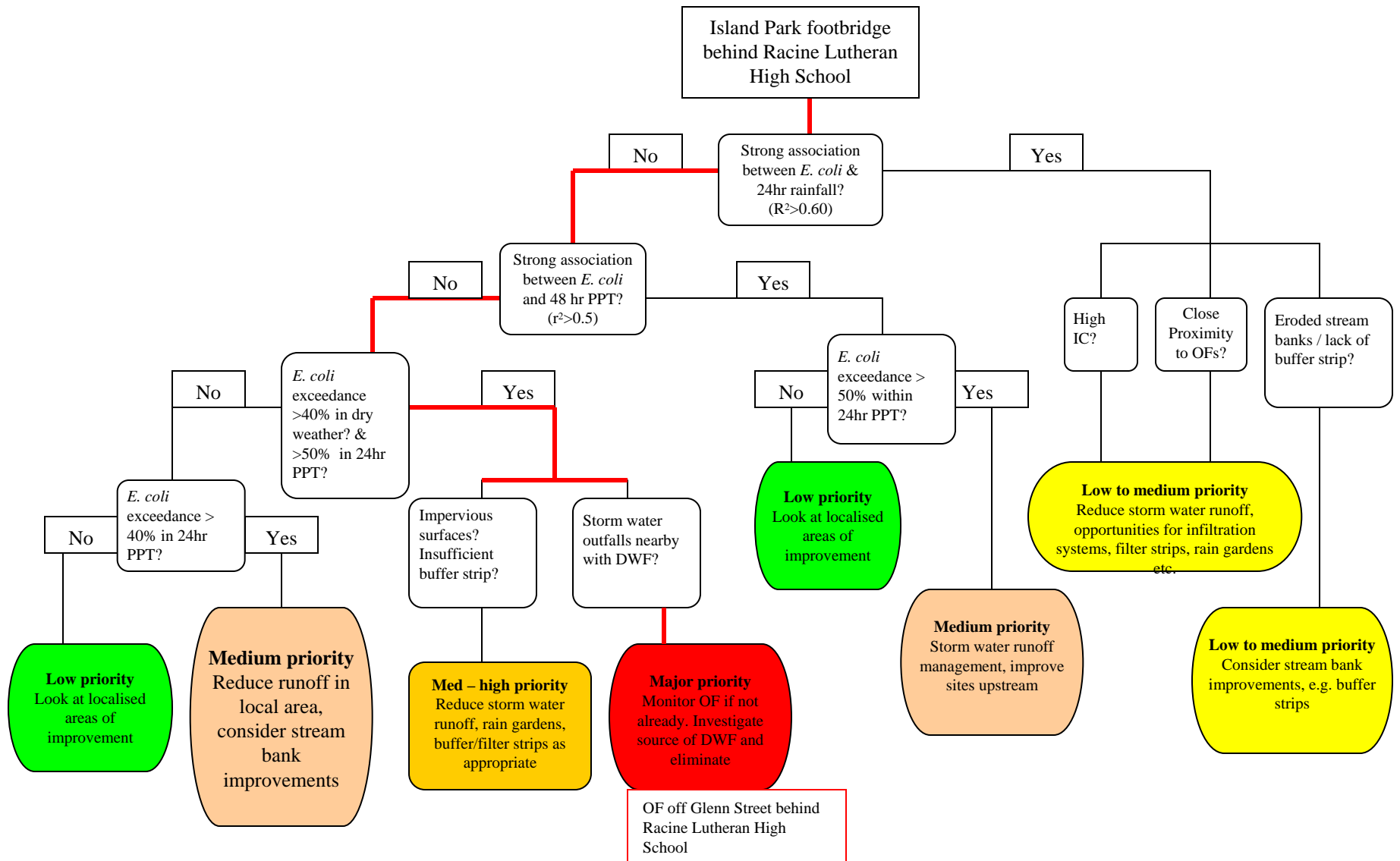


Location	Average E. Coli (MPN/100ml)	Average Dry Weather E. Coli (MPN/100ml)	Average Wet Weather E. Coli (MPN/100ml)	Average Detergent concentration (ppm)	Average Dry Weather Detergent Concentration (ppm)	Average Wet Weather Detergent Concentration (ppm)	n _{Dry}	n _{Wet}
Leudtke and Rupert	15200	15700	14300	0.12	0.14	0.08	14	8
Racine Luther Outfall	36200	44500	23400	0.16	0.15	0.18	17	11
Racine Luthern West	2100	1500	3100				18	11
Racine Luthern East	1500	600	3000				18	11









2008 Site Survey

Site: Island Park footbridge behind Racine Lutheran High School

Location and surrounding area:

Located on the western branch of the river which splits around Island Park. Land to the west is residential and to the east is open space/parkland (mainly grass).

Stream bank conditions

Stream banks are in good condition with recent restoration work undertaken on the east bank adjacent to site and approximately 120m u/s (after 2005 Earth Tech stream bank assessment)

Infrastructure

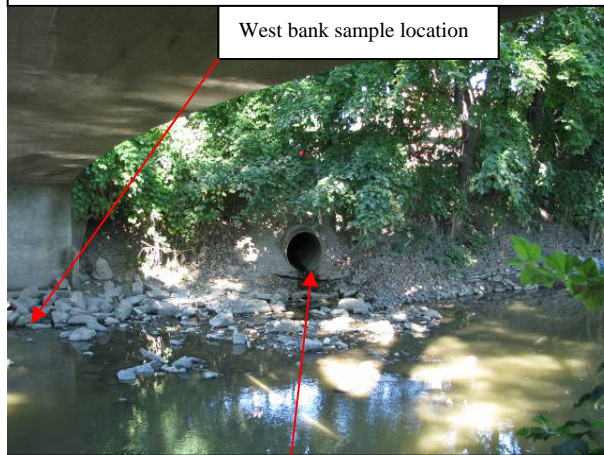
Outfall (RR17) off Glenn Street adjacent to footbridge and sample locations exhibits a constant DWF.

Other comments:

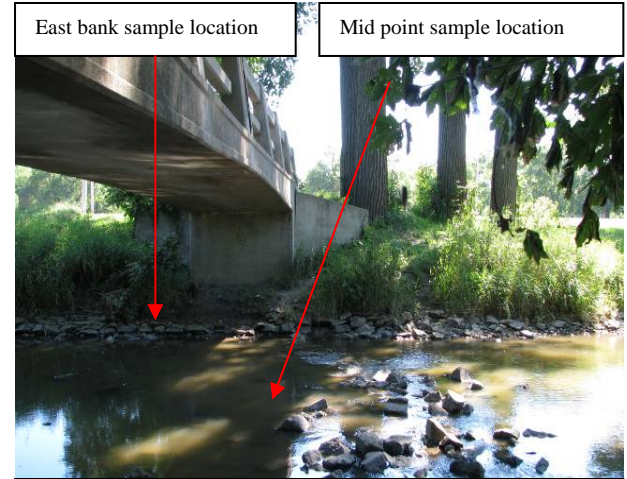
This outfall is suspected of contributing to the high levels of *E. coli* at the sample site.



View south, downstream, from the footbridge. Both banks are in good condition.



View of the outfall off Glenn Street exhibiting DWF.



View from the west bank across to the east bank sample location.

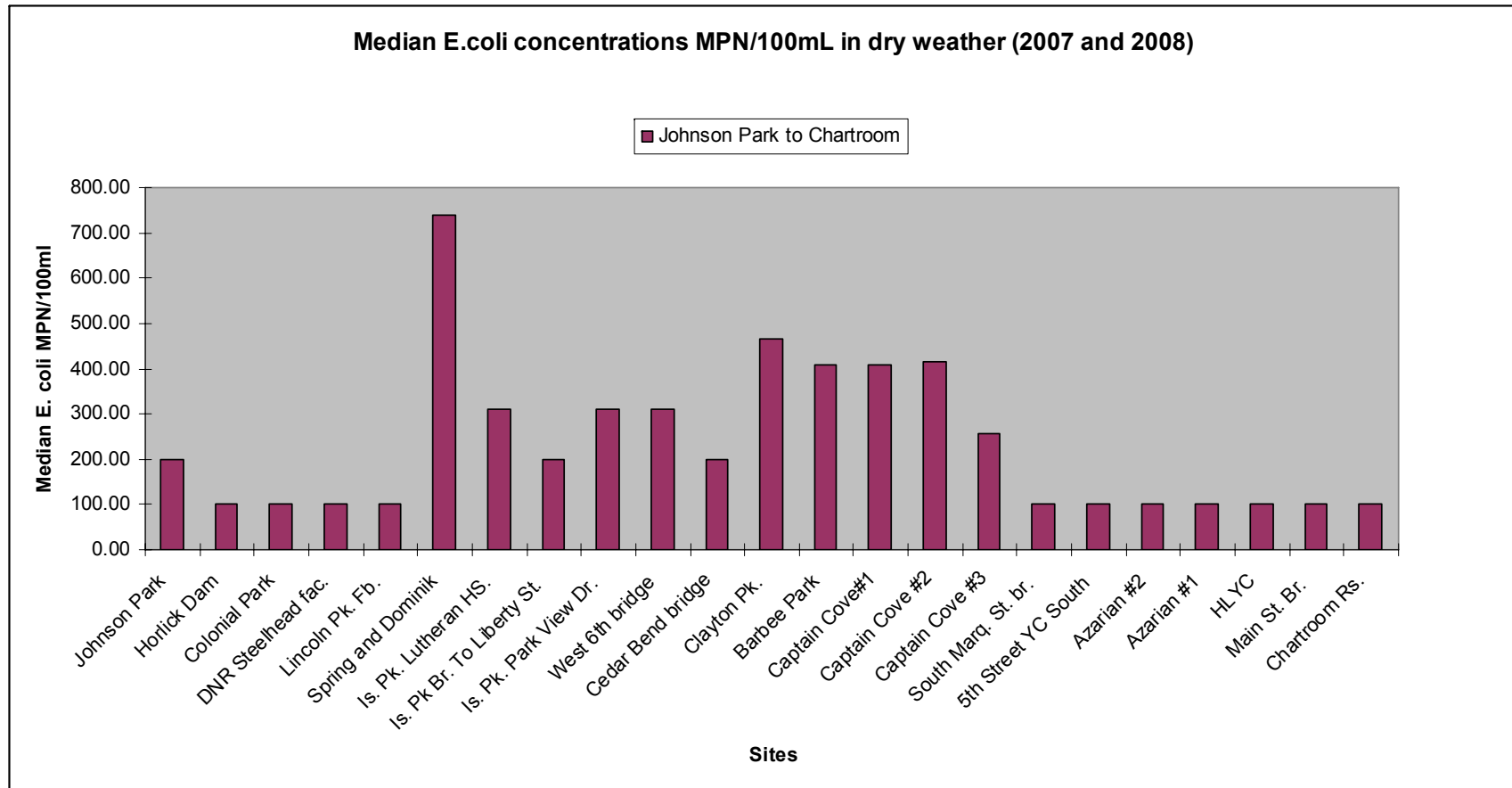


View looking north from footbridge at east bank. Conditions = high grass and little sign of erosion.

Turbidity as a Function of Location, by Group, Johnson's Park to the Mouth

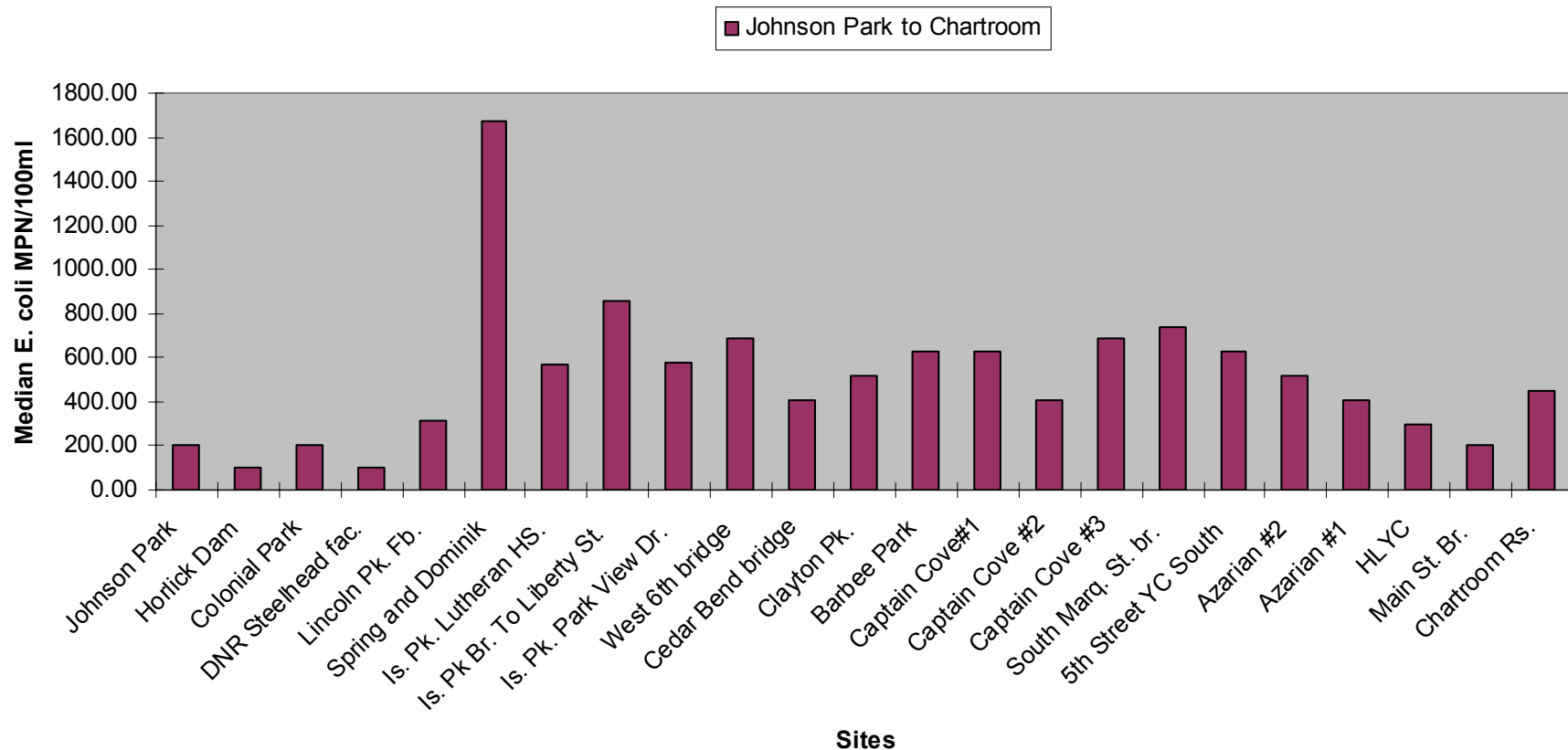
Between Group Turbidity – 2007 and 2008			
2007		2008	
Group	Mean Rank (NTU)	Group	Mean Rank (NTU)
1	191.58	1	230.47
2	186.53	2	227.55
3	163.55	3	211.86
4	156.18	4	171.61
	p = 0.07		p = 0.003

Dry Weather *E. coli*



Wet weather *E. coli*

Median *E. coli* concentrations MPN/100mL in wet weather (2007 and 2008)



Turbidity vs. Precipitation, 2007-2008						
	Coefficient of determinations [(R ²) left column] and correlation coefficients [(r) right column] for combined and wet weather data					
PPT	Group 1 and 2		Group 3		Group 4	
24 hr	0.12	0.11	0.56	0.47	0.56	0.75
48 hr	0.28	0.53	0.60	0.44	0.61	0.78



Turbidity vs. Flow Rate, 2007-2008			
	Group 1 and 2	Group 3	Group 4
R²	0.65	0.90	0.90
r	0.81	0.95	0.95

Summary of recommended ranges/limits for chemical and microbial parameters

	Turbidity	pH	DO	Water Temperature	<i>E. coli</i>
Recommended range/limit	No greater than 25 NTU (Mulla, D 2002)	6.0-8.5 (USEPA, 2000)	Not less than 5 mg/l (WI DNR, 2008)	No greater than 31.7 °C (WI DNR, 2008)	385 MPN/100ml recommended threshold for primary contact limit (75% CI) (USEPA, 2000)

Conclusions

No statistical difference was noted between multiple sample points at any of the 11 sites for turbidity, specific conductance, and pH. This demonstrates that in terms of these parameters there is a relatively high level of dispersion of material within the river making cross-sectional sampling of little scientific value while driving up project costs.



While there was no significant difference in seasonal mean *E. coli* density, with one exception, there was variation in the daily concentrations of this microbial indicator. This information is important as an additional source tracking tool since it may serve to pinpoint the actual locations where water quality exceeds acceptable standards, giving an indication of potential sources of pollution.

Conclusions

A number of associations were identified between environmental conditions, assessed chemical and microbial parameters, and physical characteristics (morphology, stream bank erosion, and presence/quality of infrastructure) along the Root River. These associations were consequently used in order to determine sources of pollution to the river and to develop a means of prioritising effective mitigation at individual sites along the river

The strength of association between *E. coli* concentrations and precipitation at a monitored site may be explained by the physical characteristics of the site and surrounding area. These characteristics may determine how the site responds to rainfall, including what deters or enhances runoff. Sites which exhibit different strengths of association to one another may lead to the identification of common pollution sources, factors which impact the level of association, and what incurs the variability between sites. Differences in association between 24 and 48 hour rainfall events may also be explained by the same physical characteristics.