Colorado *E. coli* Toolbox: A Practical Guide for MS4s

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Sponsored by
Urban Drainage and Flood Control District
City and County of Denver

Overview

- Introduction
  - Colorado regulations
  - Extent of problem
  - TMDLs
- Finding the sources
- Developing a control strategy
  - Progression of controls
  - Modeling
- Source controls
- Structural BMPs
- Regulatory considerations/site-specific standards

Colorado *E. coli* Toolbox: A Practical Guide for Colorado MS4s (DRAFT)

Prepared by
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Understanding Stream Standards and Impairment

- Fecal indicator bacteria vs. pathogens (e.g., *E. coli* O157:H7)
- EPA 2012 Recreational Water Quality Criteria
- Colorado stream standards
  - Magnitude: 126 cfu/10 mL
  - Duration: Bimonthly
  - Frequency: Geometric mean not allowed to exceed standard
- 303(d) List updated biennially: over 70 segments in Colorado impaired on M&E list for *E. coli*

Colorado Use Classification	*E. coli* (cfu/100 mL)
Class E - Existing Primary Contact	126
Class P - Potential Primary Contact	205
Class N - Not Primary Contact	630
Class U - Undetermined	126

Total Maximum Daily Loads (TMDLs) & Implications for MS4s

TMDL = ΣWLA + ΣLA + MOS

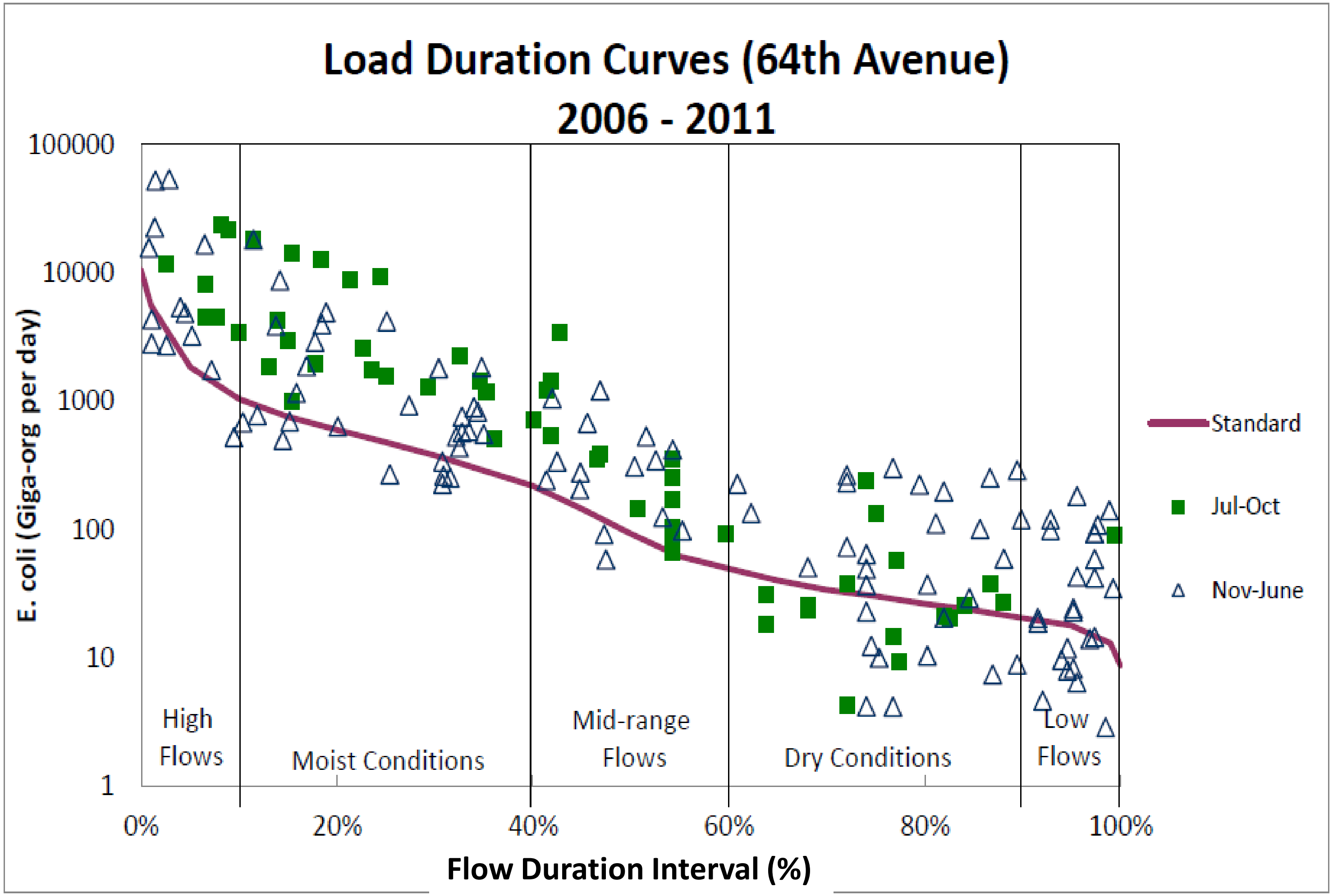
Where:

- WLA =the sum of wasteload allocations (point sources such as permitted wastewater and stormwater discharges)
- LA= the sum of load allocations (nonpoint sources and background)
- MOS=the margin of safety

- WWTPs typically not the source in Colorado
- MS4s likely to have requirements in CDPS permits due to TMDLs
- Nonpoint sources often significant
- Alternatives to TMDL approach being explored on Lower Bear Creek

Load Duration Curves

(a common characterization tool for Colorado TMDLs)



Partners for Developing Effective *E. coli* Control Strategies

Local Goverment

- Wastewater/Utilities
- Water Providers
- Stormwater/MS4
- Parks and Open Space
- Social/Community Services
- Police

State/Federal Government

- Water Quality Control Division
- Parks and Wildlife
- U.S. EPA Region 8

Non-Governmental Organizations/Non-profits

- Watershed Groups
- Environmental Organizations
- Coalitions for Homeless

Community: Businesses & Residents

- Restaurants
- Private Garbage Collection Services
- Recreators (e.g., kayakers)
- Homeowners/ Residents

Long List of Potential Sources

- Leaking sanitary infrastructure
- Pets & wildlife
- Dumpsters/trash
- Mobilizing flows (e.g., irrigation)
- MS4 infrastructure issues (e.g., illegal sanitary connections)
- Hobby farms/horses
- Open Space
- Naturalized sources (e.g., soil, decaying plants)

General Category	Source/Activity
Municipal Sanitary Infrastructure (piped)	Sanitary sewer overflows (SSOs)
	Leaky sewer pipes (Exfiltration) (see Sercu et al. 2011)
	Illicit Sanitary Connections to MS4
	WWTPs (if inadequate treatment or upsets)
Other Human Sanitary Sources (some also attract urban wildlife)	Leaky or failing septic systems
	Homeless encampments
	Porta-Potties
	Dumpsters (e.g., diapers, pet waste, urban wildlife)
	Swimmers/bathers, boaters, trail users (e.g., hikers, runners)
	RVs (mobile)
	Trash cans
	Garbage trucks
Domestic Pets	Dogs, cats, etc.
Urban Wildlife (naturally-occurring and human attracted)	Rodents/vectors (rats, raccoons, squirrels, opossums)
	Birds (gulls, geese, ducks, pigeons, swallows, etc.)
	Open space (coyotes, foxes, beavers, feral cats, etc.)
Other Urban Sources (including areas that attract vectors)	Landfills
	Food processing facilities
	Outdoor dining
	Restaurant grease bins
	Bars/stairwells (washdown areas)
	Green waste, compost/mulch
	Animal-related facilities (e.g., pet boarding, zoos, off-leash parks)
Urban Non-stormwater Discharges (Potentially mobilizing surface-deposited FIB)	Power washing
	Excessive irrigation/overspray
	Car washing
	Pools/hot tubs
	Reclaimed water/graywater (if not properly managed)
MS4 Infrastructure	Illegal dumping
	Illicit sanitary connections to MS4 (*also listed above*)
	Leaky sewer pipes (exfiltration) (*also listed above*)
	Biofilms/regrowth
	Decaying plant matter, litter and sediment in the storm drain system
Agricultural Sources (potentially including ranchettes within MS4 boundaries or areas in urban growth boundaries)	Livestock, manure storage
	Livestock, pasture
	Livestock, corrals
	Livestock, confined animal feeding operations (CAFO) (NPDES-regulated)
	Manure spreading, pastures/crops
	Municipal biosolids re-use
	Reclaimed water (if not properly managed)
	Irrigation tailwater
	Slaughterhouses (NPDES-regulated)
Natural Open Space/Forested Areas	Wildlife populations
	Grazing
	Natural area parks, off-leash areas
Other Naturalized Sources	Decaying plants/algae, sand, soil (naturalized FIB)

Prioritizing Sources for Investigation

- Dry vs. wet weather
- Human health risk
  - Human origin (i.e., from the human body)
  - Anthropogenic, non-human origin (resulting from human activities, but not the human body)
  - Non-anthropogenic origin (independent of human activity)
- Magnitude of loading
- Geographical distribution relative to recreational use locations
- Controllability/Ability to Implement (technical/design/fiscal/organizational)
- Potential benefits (beyond bacteria)
- Frequency of standards exceedances

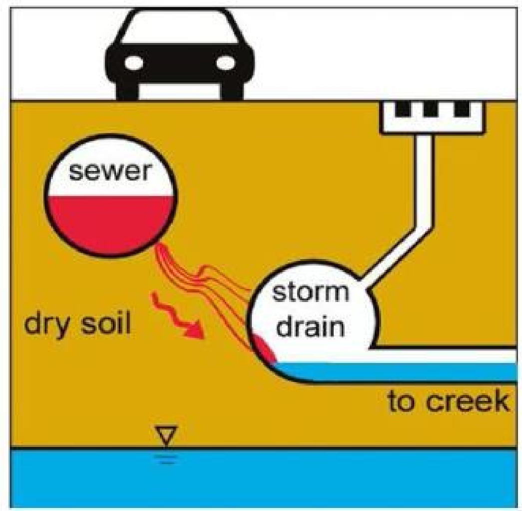
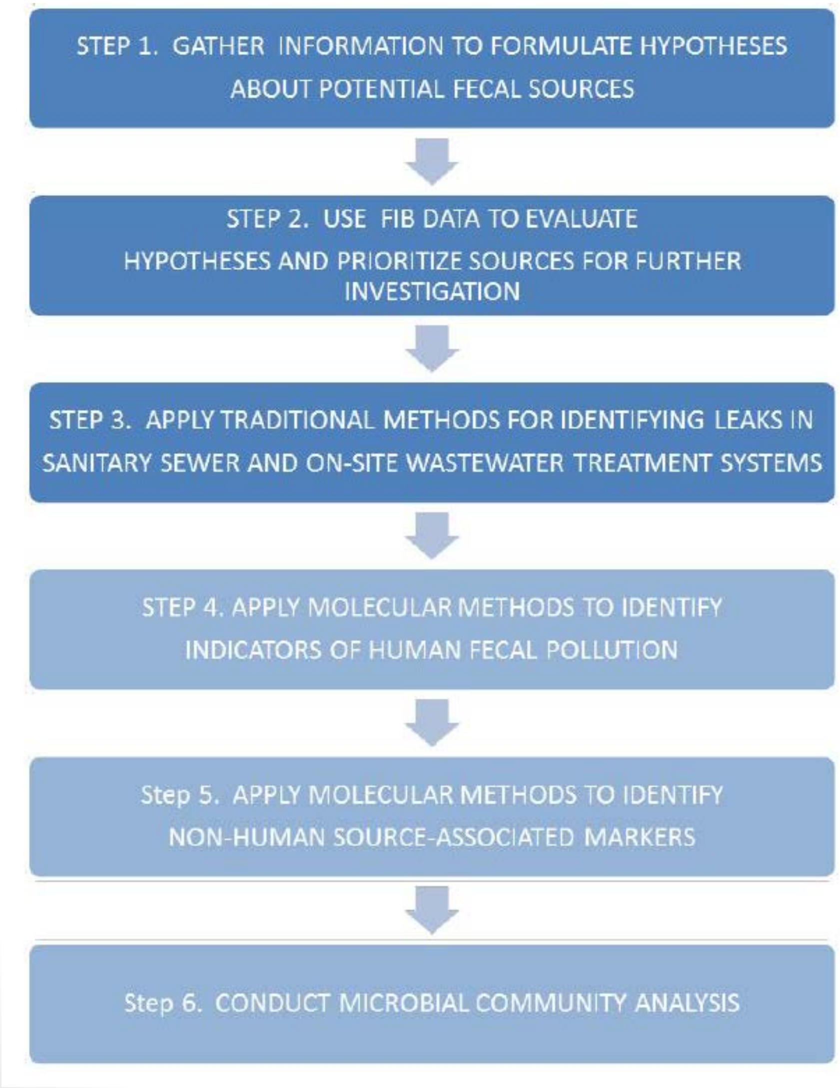
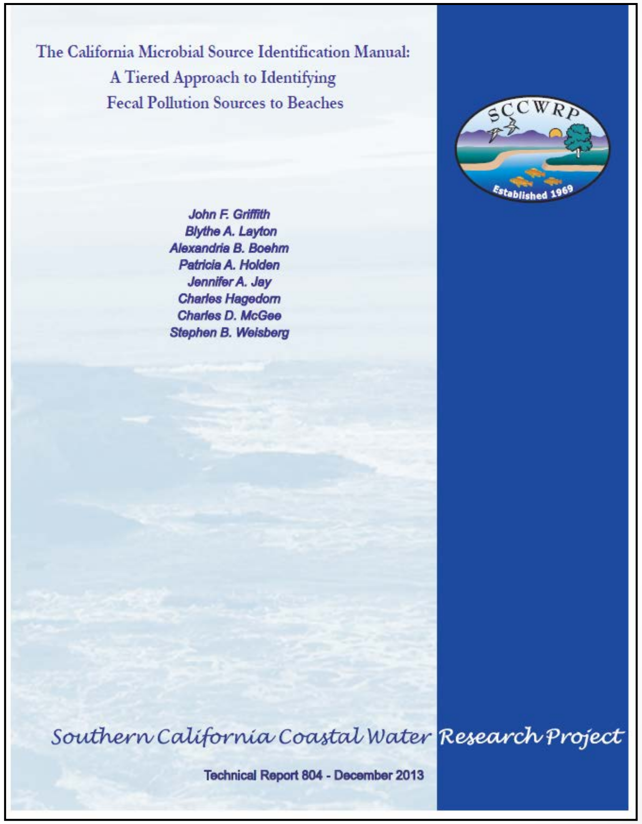


Figure 3-1. Leaking Sanitary Sewer Exfiltrating to Storm Sewer
(Source: Sercu et al. 2011[4])

Investigating Sources: 6-Step Process
(following "SIP" by Griffith et al. 2013)




The California Microbial Source Identification Manual:
A Tiered Approach to Identifying
Fecal Pollution Sources to Beaches

John F. Griffith
Blythe A. Layton
Alexandria B. Boehm
Patricia A. Holden
Jennifer A. Jay
Charles Hagedorn
Charles D. McGee
Stephen B. Weisberg

Southern California Coastal Water Research Project

Technical Report 804 - December 2013

Source Identification Tools: Simple [$] to Complex [$$$$]

- Visual Surveys of Potential Sources
- GIS
- Dry Weather Outfall Screening FIB (E. coli)
- Chemical Indicators (Basic Flow Fingerprinting)
- Chemical Indicators (Advanced Markers)
- Canine Scent Tracking
- CCTV
- Electric Current Flow Method
- Basic Dye Test
- Smoke Test
- Dye with Rhodamine Probe
- Automated continuous flow gauges and autosamplers
- Temperature Probes
- Human-specific waste markers (DNA)
- Other Emerging Advanced Technique (e.g., phylochip)

Raccoons in an urban storm drain manhole. Photo Courtesy: Andy Taylor, City of Boulder, CO.

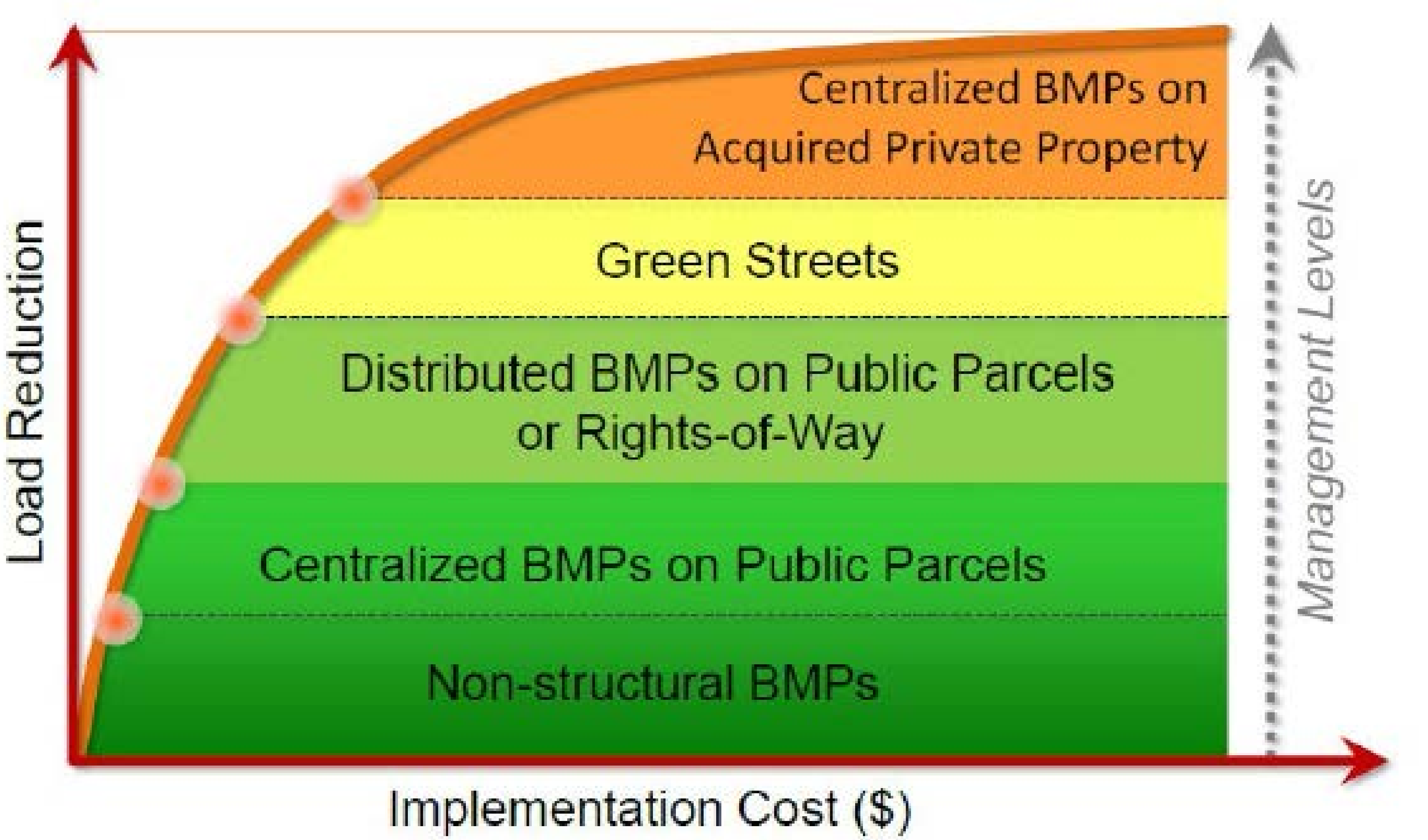
Fecal waste in a storm drain (Geosyntec Consultants)

Developing a Control Strategy

General Themes:

- Address human source first, then other sources
- Address dry weather first, then wet weather
- Implement nonstructural/source controls, then structural

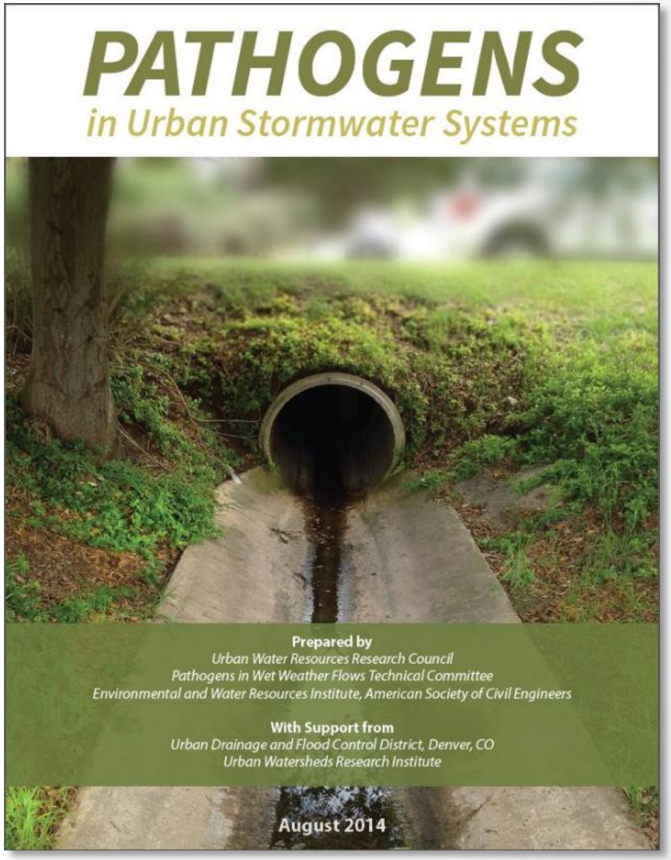
Conceptual Progression of Costs and Management Levels



Source: Source: San Diego River Watershed Comprehensive Load Reduction Plan Phase II [TetraTech 2013])

Use of Models to Support BMP Implementation

- "What is the best way to solve this water quality problem?" --Daren Harmel, USDA-ARS
  - What are the important contributors to this problem?
  - What are the best practices to implement?
  - Where are the best locations to install these practices?
  - How can practice effectiveness be evaluated (post-implementation)?
- Understanding the limits of models and accounting for uncertainty are fundamental to developing a model useful for management decisions.
- Model outputs should include estimates of uncertainty and should be treated as a planning resource, subject to change as more is learned.



Source Control BMPs

- Education and Outreach
- Repair of Aging Infrastructure and Correcting Illicit Connections
- Maintenance of Storm Sewers and Stormwater Controls
- Street Cleaning
- Downspout Disconnections/MDCIA
- Pet Waste Disposal and Pet Control Ordinances & Enforcement
- Animal Facilities Management (Doggy Daycares, Hobby Farms)
- Bird Controls

Drawing upon existing Fact Sheets in UDFCD's Volume 3, Colorado Stormwater Council, Others

- Urban Wildlife (Mammals)
- Irrigation, Car Washing, Power Washing
- Good Housekeeping/Trash Management (Dumpsters, Restaurants, Garbage Cans)
- Mobile Sources of Human Waste: Portable Toilets and RV Dumping
- Septic Systems /OWTSs
- Homeless Encampment Outreach and Enforcement
- River Cleanup

Sanitary Sewer Lining

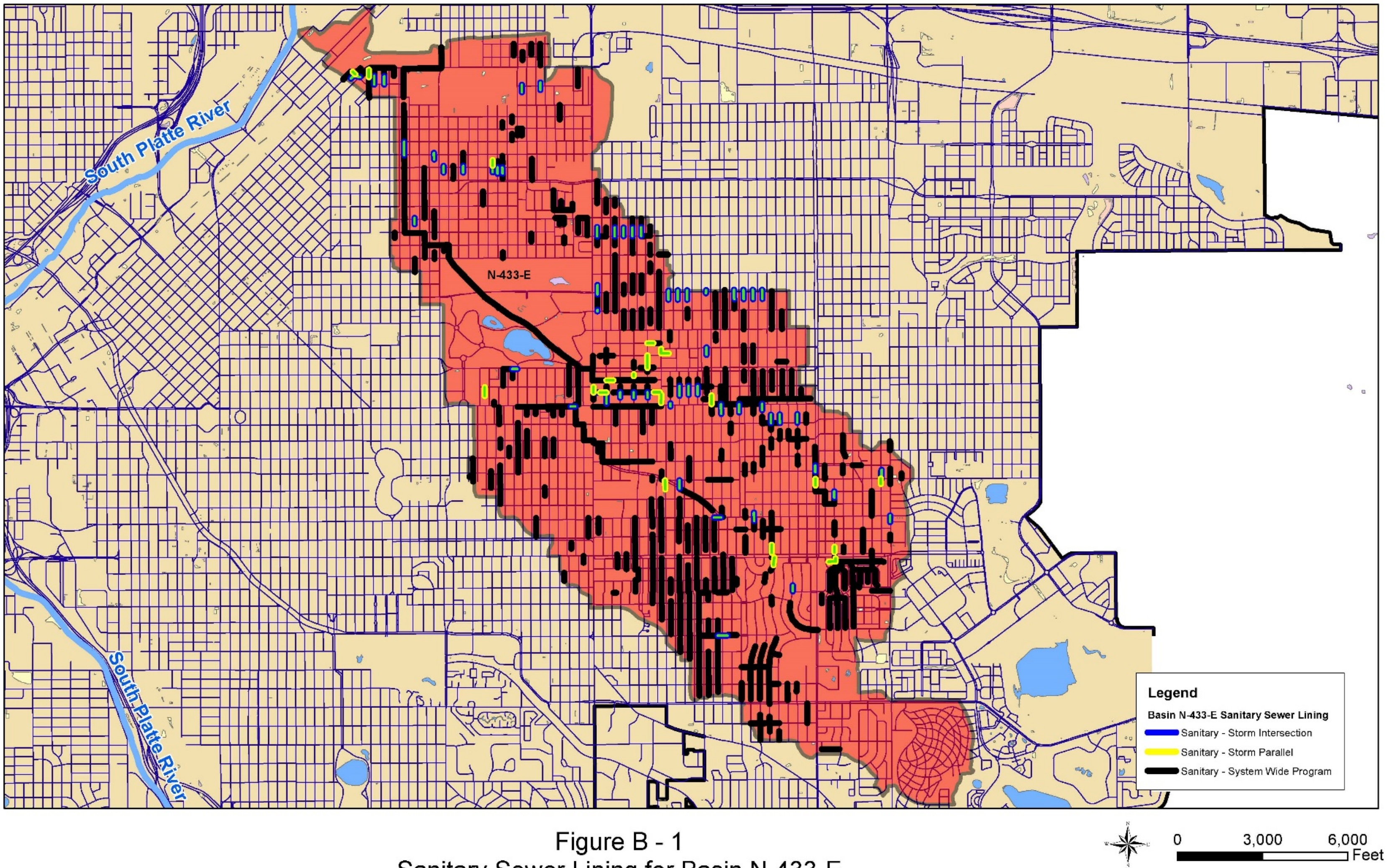
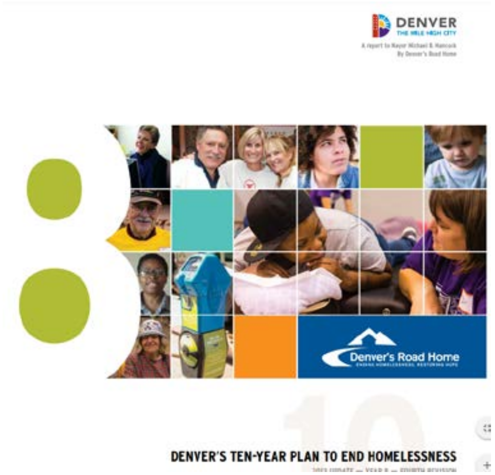


Figure B - 1
Sanitary Sewer Lining for Basin N-433-E

Other Examples of Source Controls

Public education campaigns.



Program to end homelessness.

Remote controlled goose hazing device, “Goosinator,” used to deter resident waterfowl in Denver Parks.

Waste management/trash collection programs, City and County of Denver.

Pet waste stations in parks.

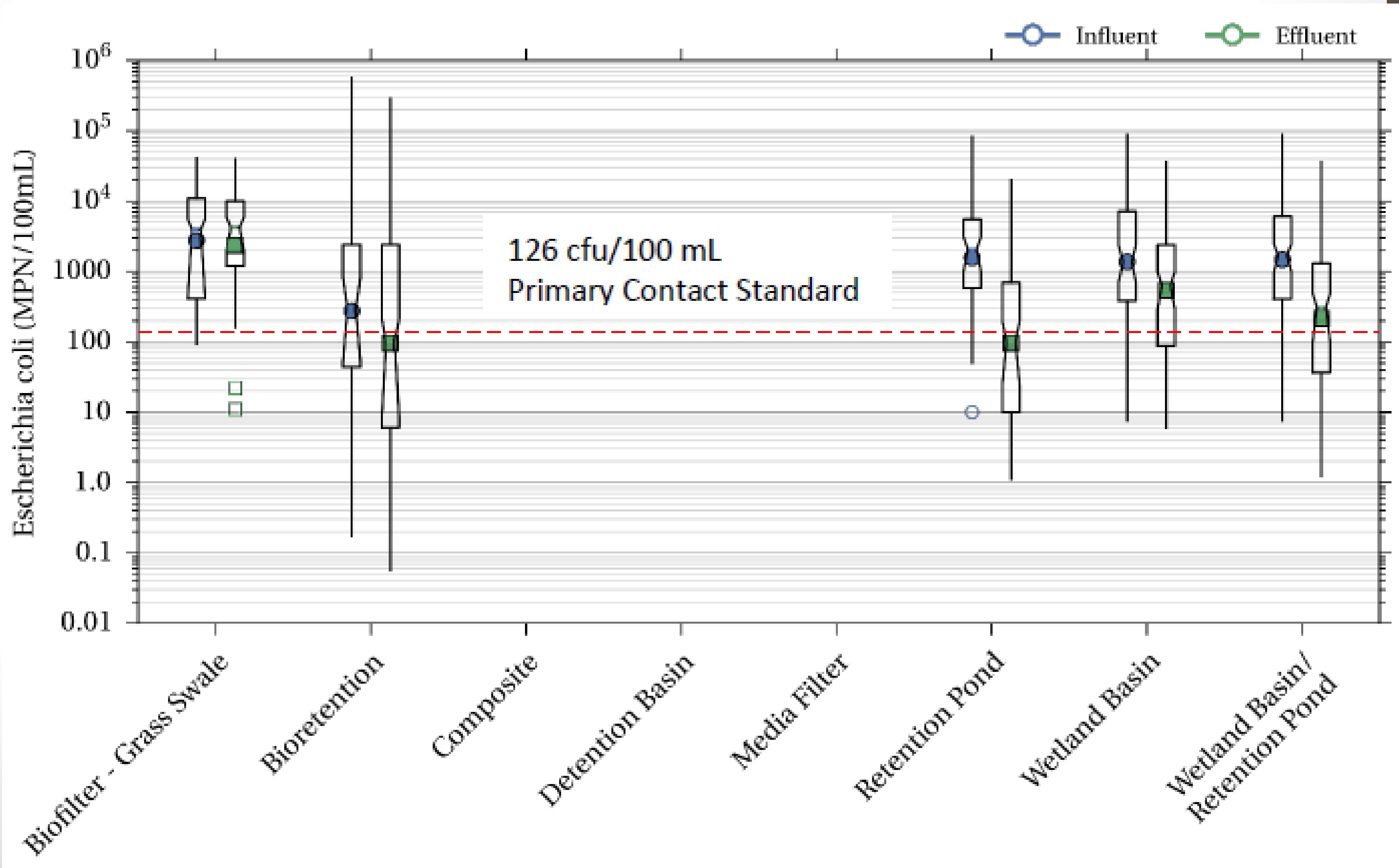
Retrofitted storm drain inlet, City of Boulder, CO

Structural Control Practices

- Passive Stormwater Structural BMPs
  - Urban Stormwater BMPs and Expected Effectiveness for Bacteria
  - BMP Performance Findings from the International Stormwater BMP Database
  - Optimizing BMP Designs to Enhance Bacteria Removal
- Considerations for Evaluating Proprietary Devices
- Low-Flow Diversions for Dry Weather Flows to Sanitary
- Active Disinfection Practices

Treatment Systems Being Pilot Tested in Denver

International Stormwater BMP Database: E. coli



International Stormwater BMP Database: E. coli (tabular results)

BMP Type	Count of Studies and EMCs		25th Percentile		Median (95% Conf. Interval)*		75th Percentile	
	In	Out	In	Out	In	Out	In	Out
Biofilter - Grass Strip	NA	NA	NA	NA	NA	NA	NA	NA
Biofilter - Grass Swale	5; 39	5; 39	411	1200	3998 (411, 5600)	4201 (1200, 5900)	11000	10000
Bioretention***	4; 61	4; 61	44.0	6.0	295 (52, 820)	**100 (8, 213)****	2400	2400
Composite	NA	NA	NA	NA	NA	NA	NA	NA
Detention Basin	NA	NA	NA	NA	NA	NA	NA	NA
Media Filter	NA	NA	NA	NA	NA	NA	NA	NA
Porous Pavement	NA	NA	NA	NA	NA	NA	NA	NA
Retention Pond	4; 69	4; 65	582	10	2069 (988, 3106)	**99.6 (20, 200)****	5500	697
Wetland Basin	5; 60	5; 59	383	88	1379 (690, 2346)	**636 (279, 988)****	7169	2376
Wetland Basin/Retention Pond	9; 129	9; 124	403	36	1713 (988, 2433)	**311 (100, 485)****	6100	1300
Wetland Channel	NA	NA	NA	NA	NA	NA	NA	NA

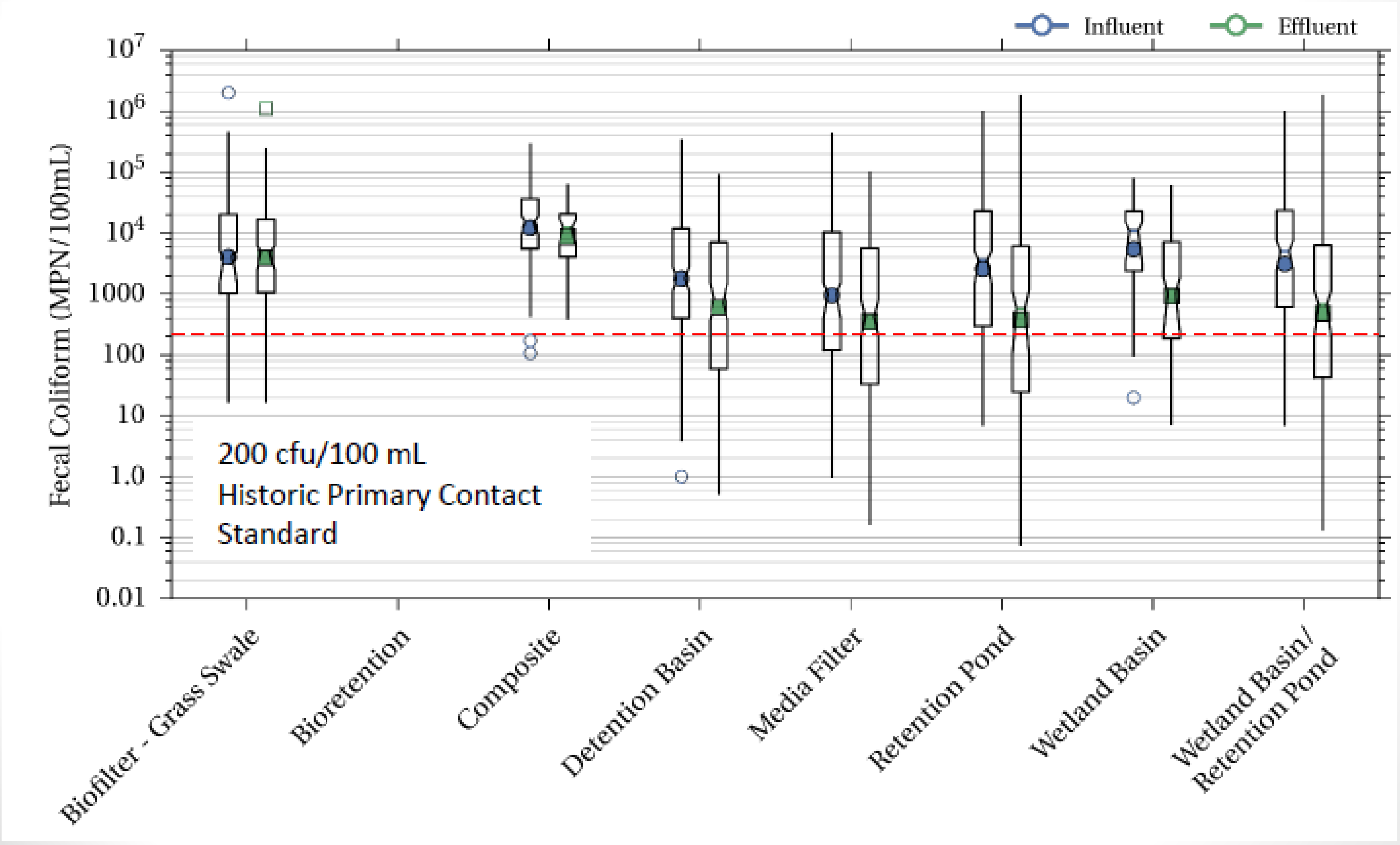
NA – not available or less than 3 studies for BMP/constituent.

*Computed using the BCa bootstrap method described by Efron and Tibishirani (1993).

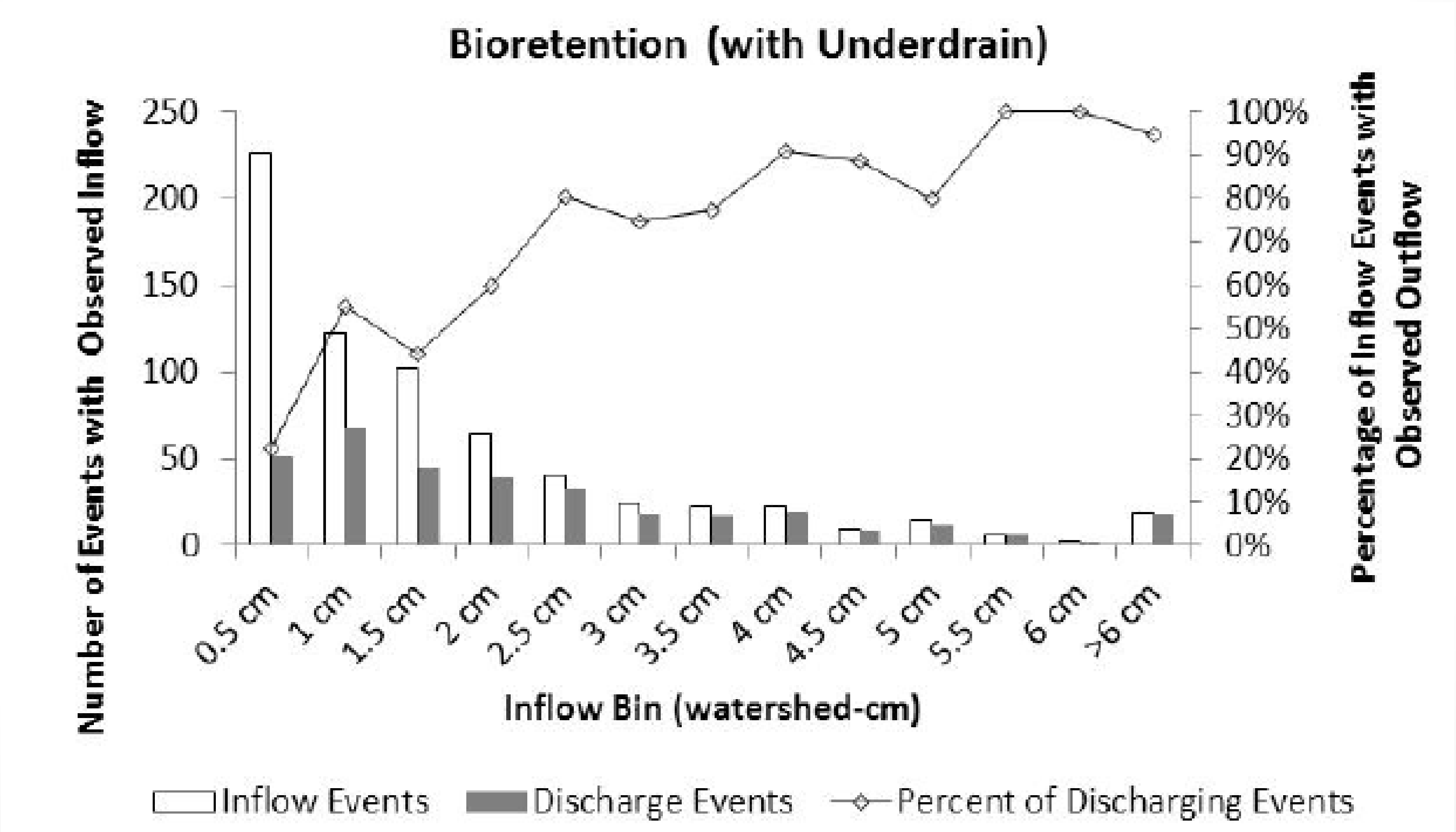
**Hypothesis testing in Geosyntec and WWE (2014) shows statistically significant decreases for this BMP category.

***Due to the unusually low influent concentrations for the bioretention data set, additional results from more studies are needed to draw conclusions regarding statistically significant *E. coli* reductions from bioretention.

International Stormwater BMP Database: Fecal Coliform



Reducing Loads through Volume Reduction



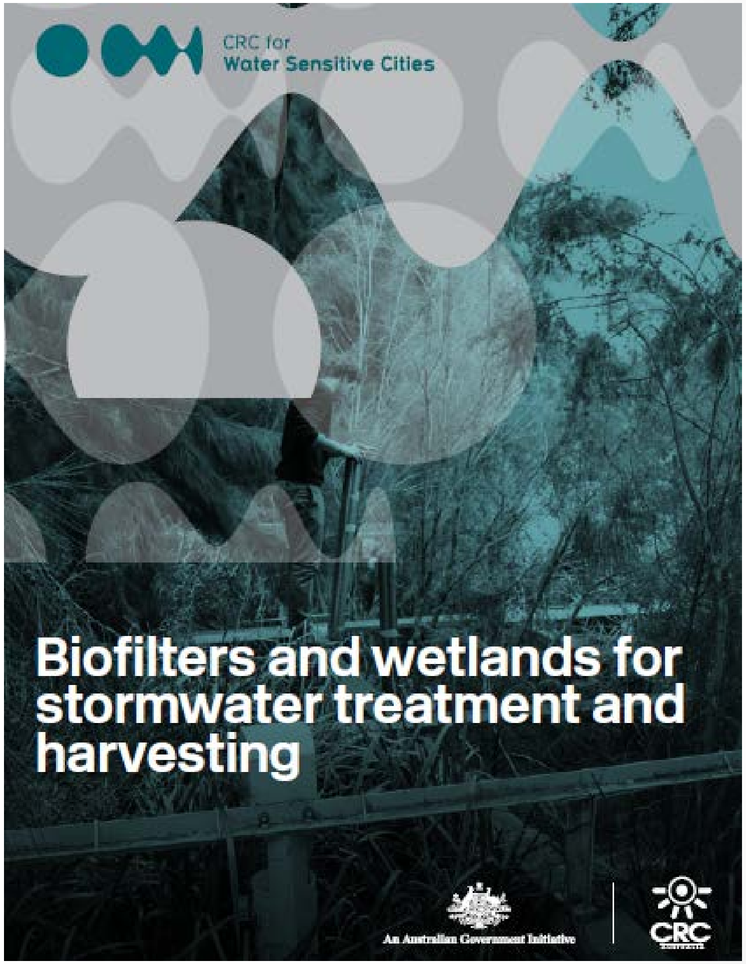
Source: Geosyntec and WWE 2011, www.bmpdatabase.org

Volume 3 BMPs: Expected Performance for Bacteria

UFFCD Vol. 3 BMP	Expected Effectiveness	Dominant Removal Processes
Grass Buffer	Poor	Infiltration
Grass Swale	Poor	Infiltration
Bioretention	Moderate to High	Infiltration, Filtration Biological Processes
Green Roof	Not Well Characterized	Evaporation, Filtration Biological Processes
Ext. Detention Basin	Poor to Moderate (variable)	Sedimentation Infiltration (limited)
Sand Filter	Moderate	Filtration
Retention Pond	Moderate	Sedimentation Biological Processes
Constructed Wetland Pond	Moderate	Sedimentation Biological Processes
Const. Wetland Channel	Poor to High, depending on design	Sedimentation Biological Processes
Permeable Pavement	Not Well Characterized	Infiltration Filtration
Underground/ Proprietary	Variable	Device-dependent

Improving BMP Performance for Bacteria: Optimizing Filtration Media and Design

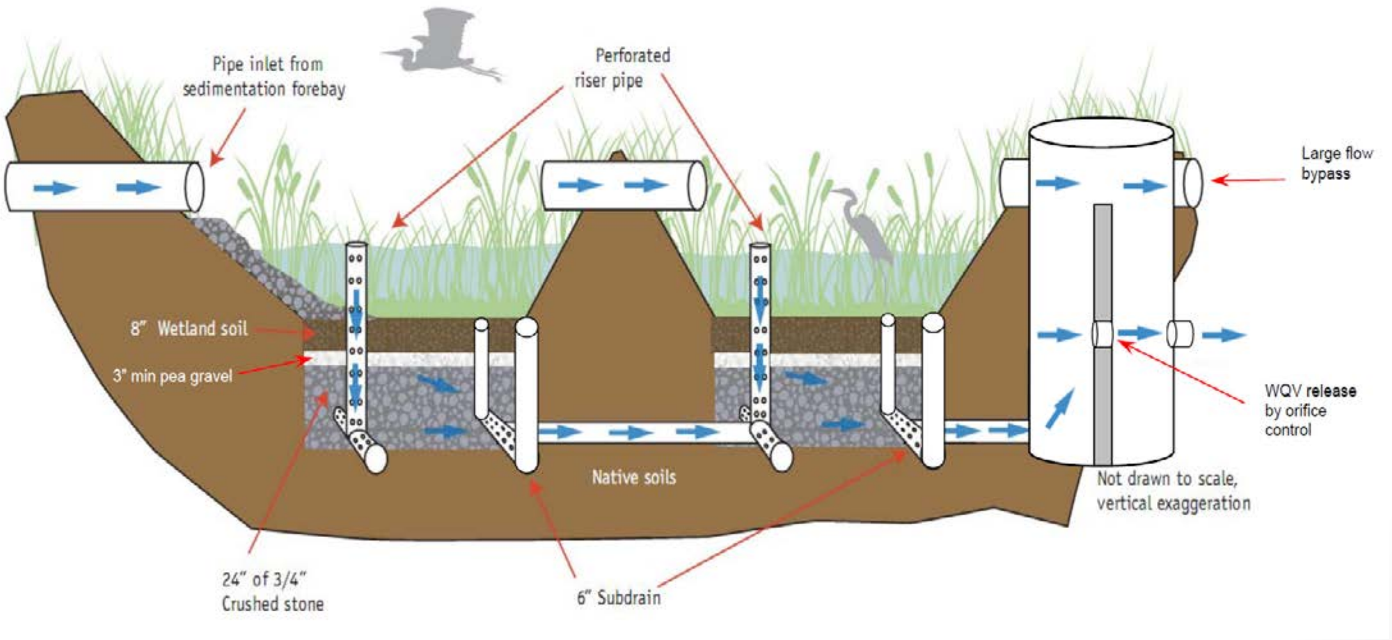
- Media amendments such as biochar and zeolite.
- Vegetation with specific root structures to promote pollutant removal and infiltration.
- Outlet control with sufficient contact time.
- Presence of a saturated zone. ("internal water storage zone")



Deletic et al. 2014, Monash University

Subsurface Flow Wetlands

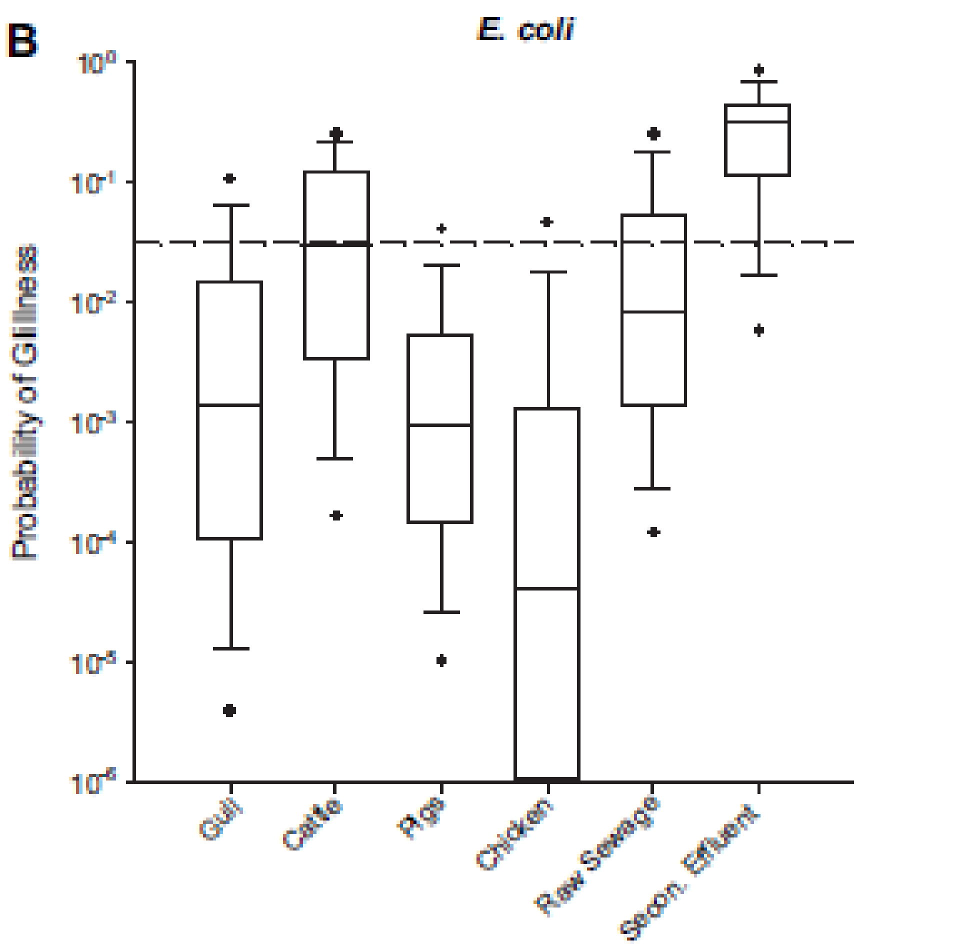
- Often recommended in California CLRPs.
- Have been successfully used for wastewater.
- Various constraints in Colorado (e.g., consistent supply of water (& water rights) to maintain aerobic conditions and support vegetation, adequate land area for equalization basins).



Conceptual Subsurface Flow Wetlands (Source: Geosyntec 2015)

Regulatory Considerations/Site-Specific Standards (EPA 2012 RWQC)

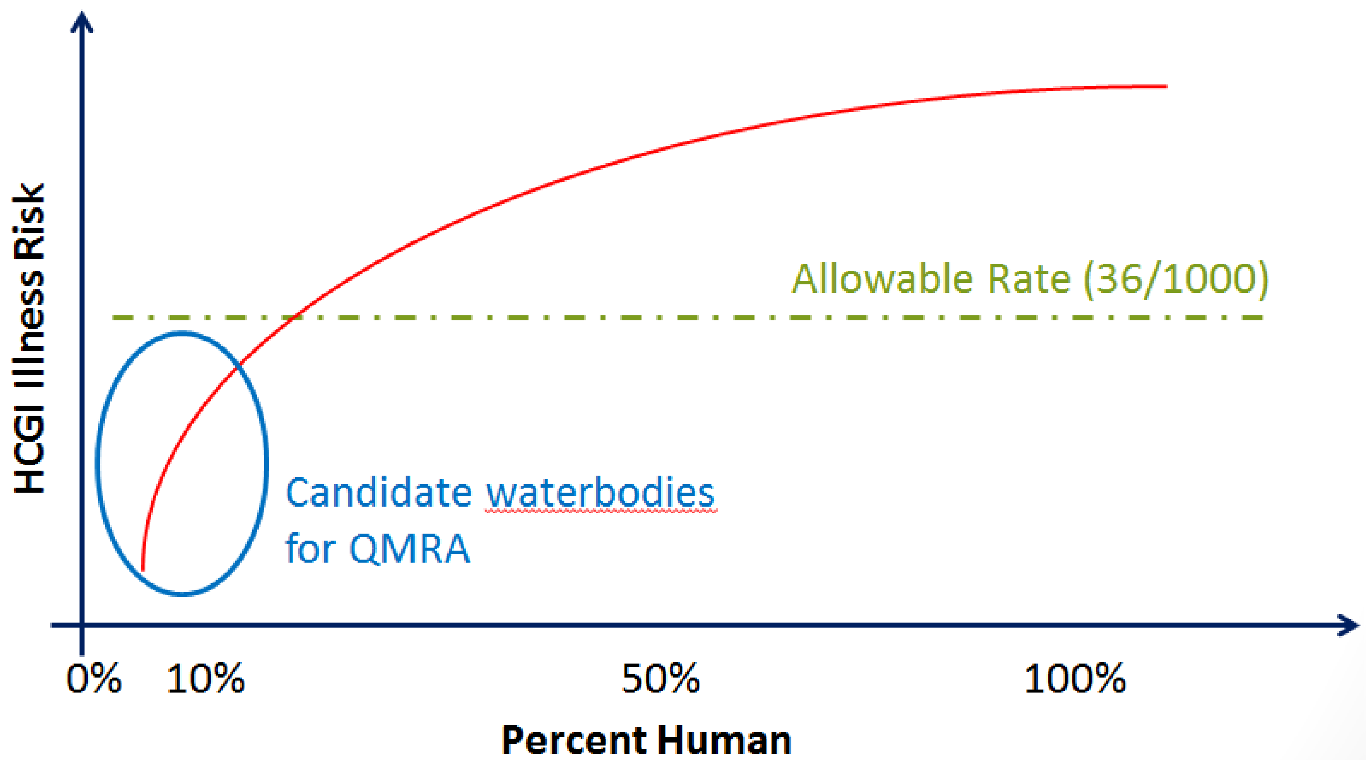
1. Epidemiological studies
2. Quantitative Microbial Risk Assessment (QMRA)
   - EPA's Framework for Use of QMRA for Developing Site-Specific Standards
   - Practical Considerations for Monitoring to Support QMRA
3. Alternative Indicators or Methods



Source: Soller et al. 2010

QMRA/Site-specific Standard Candidates

At 126 MPN/100mL *E. coli*:



Conclusions

- An *E. coli* TMDL is likely coming soon to a community near you!
- *E. coli* issues are complicated, not easily solved and potentially very expensive for local governments.
- The Toolbox is a resource intended to support strategies to identify sources and work towards control of *E. coli*.
- The Toolbox can provide a common foundation to support discussions and planning among multiple municipal departments and organizations.
- Additional monitoring of source area runoff and BMP performance for *E. coli* is needed in Colorado.

Questions?

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