[section three]

Baseline Conditions & Impairments to Denver's Urban Waterways

3.1 Overview

As explained in previous sections, urbanization can contribute to increased pollutant loading to lakes, streams and rivers and cause impairment of their beneficial uses (i.e., aquatic life, water supply, recreation, agriculture). In keeping with the Clean Water Act, Colorado's list of impaired waterbodies ("the 303(d) list") is updated biennially with waterbodies that are not meeting their designated uses, including those located within Denver. The Colorado Water Quality Control Commission assigns designated uses and associated stream standards to waterbodies in Colorado, and these standards are approved by the U.S. Environmental Protection Agency (EPA). For purposes of this plan, Denver generalizes these standards into a "swimmable and fishable" goal for all Denver waterbodies.

Once a water body has been listed as "impaired", then a plan must be developed for the stream to attain its designated uses. This is typically accomplished through completion of a Total Maximum Daily Load (TMDL), which calculates the pollutant load that the water body can absorb and still realize its full beneficial use. TMDLs must consider all dischargers to a receiving water body, as well as establish background concentrations/loads and a margin of safety. The South Platte River through Denver currently has TMDLs for nitrate and *Escherichia coli* (E. coli). CDPHE's nitrate TMDL assessment document[1] indicates that municipal wastewater treatment facilities are the primary point source dischargers of nitrate to the South Platte River and further states that stormwater runoff from non-point source dischargers do not contribute significantly to the nitrate impairment. Therefore, nitrate was not considered in this analysis.

CDPHE's Bacteria TMDL Assessment[2] for the South Platte River specifically identifies dry weather flows from MS4 outfalls as potential bacteria sources. Dry weather flows are those flows not associated with surface runoff from rain or snow melt events but include flows associated with irrigation overspray, illicit discharges from the sanitary system, or groundwater flows into the storm drain system. The TMDL further states that once dry weather flows are eliminated future updates to the TMDL shall consider wet weather measures. Wet weather flows are those flows associated with melting snow or stormwater runoff over impervious surfaces and is the number one cause of surface water impairment in urban areas.

In addition to TMDL-related requirements, Denver is also required to minimize pollutant loading to the maximum extent practicable under its municipal stormwater discharge permit. Through implementation of best management practices, which include green infrastructure, other urban pollutants such as nutrients (e.g., phosphorous, nitrogen), metals (e.g., copper, zinc), and sediment (e.g., TSS) are also addressed. For purposes of this plan, phosphorous, nitrogen, TSS and E. coli have been selected as the primary pollutants of interest. Because metals in urban areas are often associated with particulates, TSS is used as a proxy for these pollutants. Phosphorus and nitrogen were selected because Colorado has recently adopted nutrient-related regulations and standards.

The GI Implementation Strategy seeks to not only build green infrastructure facilities that meet current regulations and treat dry weather discharges, but also be proactive in meeting future regulations by treating wet weather flows. Reducing both dry and wet weather pollutant loads is necessary to improve the health of the South Platte River.

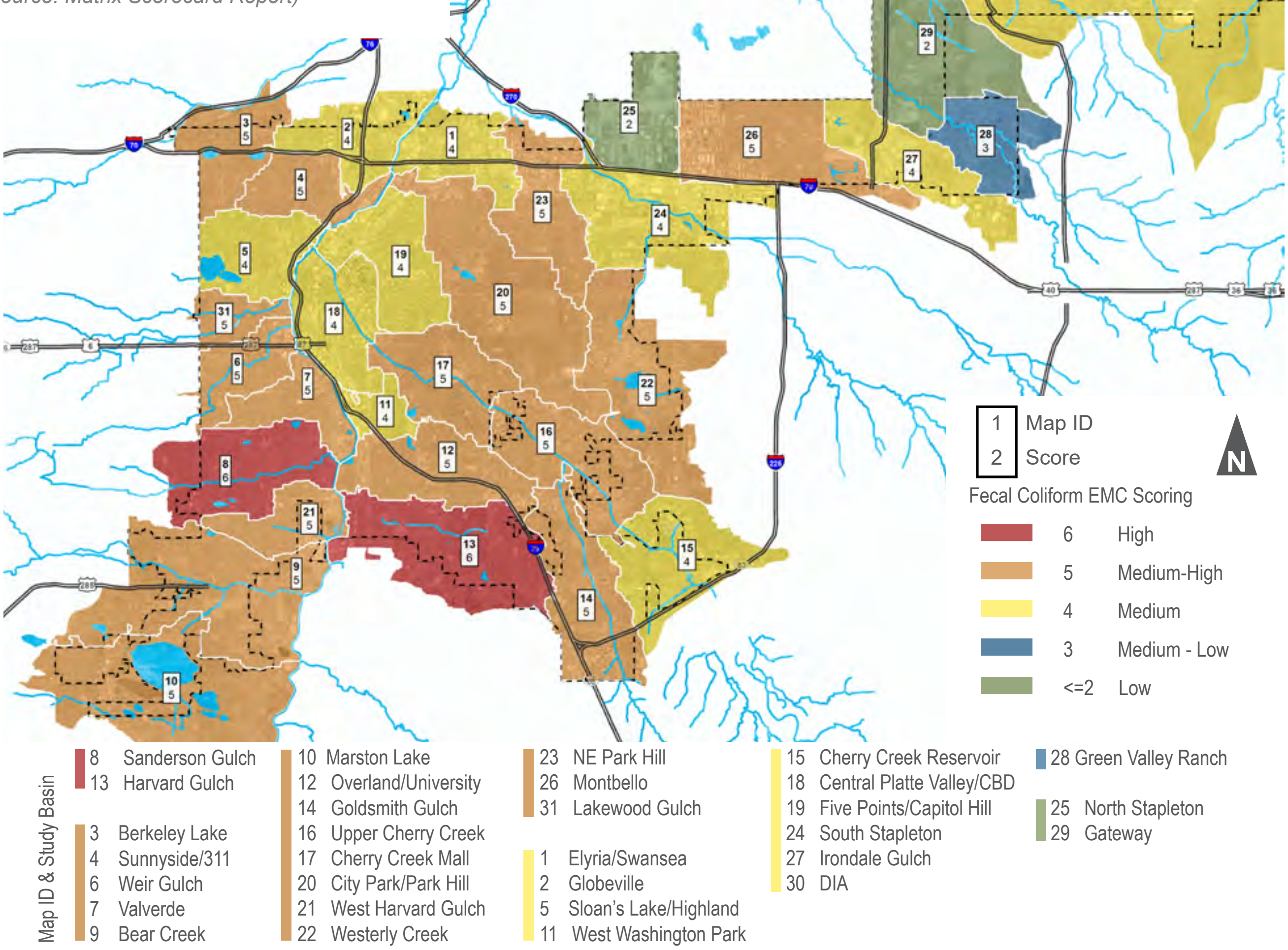
Pollutant load reduction benefits from green infrastructure BMPs are based on treatment processes incorporated into their designs, as well as the volume reduction enabled by the BMP. The BMPs processes discussed in this section focus primarily on sedimentation, filtration, adsorption, and biological uptake. Sedimentation allows for sediment and sediment bound pollutants (e.g., metals, phosphorus) to settle out of the fluid in which they are entrained; filtration physically traps pollutants/particulates in soil media; adsorption binds pollutants to media surfaces; and biological uptake allows for pollutants to be absorbed by plants and roots.

3.2 Fecal Indicator Bacteria including *Escherichi coli* (E. coli)

Fecal indicator bacteria such as E. coli top the list of impairments to streams nationally, with nearly 180,000 miles of streams identified as impaired for recreational use.[3] While most strains of E. coli are harmless, these bacteria are used as an indicator of pathogens associated with fecal contamination that can make people sick. Currently, the State of Colorado considers water quality at swim beaches to be ‘safe for swimming’ when E. coli levels are less than 235 colony forming units per 100 milliliters (cfu/100 mL). Primary contact stream standards are attained when the geometric mean concentration of E. coli samples over a two-month period is below 126 cfu/100 mL.

The Department of Public Health and Environment (DDPHE) uses these standards as guidance and has studied E. coli levels in Denver’s streams to determine what factors might be used to predict when E. coli levels are higher than what is safe for contact due to potential

Figure 3.1: *E.coli* Scores for Basins
(Source: Matrix Scorecard Report)



ingestion of water. DDPHE monitors two locations that are used heavily for swimming and boating including Confluence Park and Bear Creek near the picnic shelter in Bear Valley Park. Monitoring efforts show that E. coli levels increase as the South Platte River passes through Denver. E. coli levels are higher in the summer and fall, which may be influenced by environmental factors such as more frequent storm events, warm temperatures and other factors that affect persistence, growth, and die-off.[4]

Identifying and controlling bacteria sources present significant and costly challenges for municipalities. Sources vary and include human, animal and environmental sources. A few representative examples include leaking sanitary sewers, illegal connections to storm sewer systems, homeless encampments, urban wildlife, domestic pets, and persistent naturalized sources such as biofilms in storm drains and sediment. Stormwater runoff and irrigation overspray can transport bacteria deposited on the ground into the storm drain system. Because human pathogens typically present greater health risks of illness, the first priority for source identification and control is human sources of E. coli. Consistent with these principles, Denver's efforts to date have focused on identifying and controlling dry weather, human related sources, which are generally considered to be the most controllable sources. Denver also works to address stormwater-related sources through implementation of best management practices that can include non-structural measures like pet waste ordinances and structural measures such as green infrastructure and other stormwater BMPs.

Mitigation

To control human sources, Denver will continue to implement dry weather source controls that are already in place including practices such as inspecting, maintaining and repairing the sanitary and storm sewer systems. Programs to address homeless encampments along the river are an important priority for Denver for social reasons, but are also important for water quality and protection of the health of those recreating in the South Platte River.

Trash management programs are in place which help to reduce both human and non-human sources of E. coli such as diapers and animals like raccoons and rats that are attracted to garbage. Denver Solid Waste is phasing out use of dumpsters and replacing these with rolling trash cans with hinged lids that can reduce exposure to rainfall and animals, as well as reduce leakage often associated with dumpsters. Water quality monitoring in other parts of the country has shown that fecal indicator bacteria concentrations can be quite elevated from dumpster leakage.[5] Street sweeping is also conducted by Denver, which can help to reduce waste transport to the storm drain system.

Proper pet waste disposal and geese management can be a challenging issue in Denver parks. Enforcement of leash laws and pet waste pickup can be better implemented. Parks staff also implement various management strategies to control resident geese populations.

A partnership is being developed with Denver Water and the City of County of Denver to develop neighborhood-scale water conservation programs that reduce irrigation overflows, which is a significant source of dry weather flows into the storm sewer system. Chronic irrigation runoff can contribute to formation of biofilms in storm sewers that can be an on-going source of bacteria discharged from the storm sewer system.[6]

Green infrastructure best management practices (BMPs) help to reduce bacteria loading to the storm drain system by reducing surface runoff volumes through infiltration and by reducing bacteria concentrations to various degrees. Examples of factors that help to reduce bacteria concentrations include solar irradiation, predation or competition from other microorganisms, sedimentation and filtration.[7] Sorption to filter media, physical straining, and other chemical/biological processes may also be important removal mechanisms. Because concentrations of E.coli are difficult to remove, volume reduction strategies can be effective at reducing pollutant loads, even if concentrations are not significantly reduced. Out of the practices considered in the Scorecard evaluation, bioretention and streetside planters are expected to provide higher load removals for E. coli than practices such as extended detention basins.

Table 3.1: General Urban Sources of *E. coli* and Strategies for Bacteria Reduction

Sources		Strategy
Municipal Sanitary Infrastructure (piped)	• Leaky sewer pipes (exfiltration) and broken tap connections • Illicit sanitary connections to MS4 • Sanitary sewer overflows (SSOs)	• Conduct investigations to identify leaking sanitary sewer line sources and implement repairs • Implement an illicit discharge detection and elimination (IDDE) program to identify and remove illicit connections
Other Human Sanitary Sources	• Homeless encampments • Porta-Potties (at construction sites & outdoor events) • Dumpsters (e.g., diapers, pet waste) • Garbage trucks • Leaky or failing septic systems	• Support city shelters and services to reduce homelessness • Periodic cleanup of homeless camps near streams • Providing public restrooms • Fencing to prevent access to frequently used encampment areas • Partnering with non-governmental organizations to address homelessness • Converting dumpsters to trash carts
Domestic Pets	• Dogs, cats, etc.	• Provide signage to pick up dog waste, providing pet waste bags and disposal containers • Adopt/enforce pet waste ordinances • Place dog parks away from environmentally sensitive areas • Protect riparian buffers and provide un-manicured vegetative buffers along streams to dissuade stream access
Urban Wildlife (naturally-occurring & human attracted)	• Rats, mice, raccoons, and squirrels • Birds (geese, pigeons, swallows, etc.) • Parks/open space (coyotes, foxes, beavers, etc .)	• Reduce food sources accessible to urban wildlife (e.g., manage restaurant dumpsters/grease traps, residential garbage, feed pets indoors) • Identify areas with high bird populations and evaluate deterrents, population controls, habitat modifications and other measures that may reduce bird-associated fecal indicator bacteria loading • Consult with state wildlife offices (CPW) on strategies to reduce food, shelter and habitat for overpopulated urban wildlife • Implement and enforce urban trash management practices
Other Urban Sources (including areas that attract vectors)	• Food processing facilities • Outdoor dining • Restaurant grease bins • Bars/stairwells (wash-down areas) • Landfills • Green waste, compost/mulch • Animal related facilities (e.g. pet boarding, zoos)	• Inspection of commercial trash areas, grease traps, wash-down practices, along with enforcement of ordinances
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)	• Encourage site designs that minimize directly connected impervious areas (e.g., Green Infrastructure, Low Impact Development) • Implement public education programs to reduce dry weather flows from storm sewers related to lawn/park irrigation practices, car-washing, power-washing and other non-stormwater flows • Provide irrigation controller rebates • Implement and enforce ordinances related to outdoor water waste and/or collaborate with water utilities to promote water-wise landscapes and irrigation practices
MS4 Infrastructure	• Illegal dumping • Illicit sanitary connections to MS4 • Leaky sewer pipes (exfiltration) • Biofilms/regrowth • Decaying plant matter, litter and sediment in the storm drain system	• Implement a reporting hot-line for illegal dumping and educate the public/industries that dumping to the storm sewer system is illegal • Proper maintenance of the storm sewer system and water quality BMPs is needed for proper functioning of the system. For example, sediment, organic deposits and biofilms in stormwater facilities can be sources of elevated fecal indicator bacteria
Recreational Sources	• Bathers and/or boaters • RVs (mobile) dumping to storm drains	• Provide public education materials on proper waste disposal • Mark or stencil storm drain inlets with “no dumping” markers
Other Naturalized Sources	• Decaying plants, algae, sand, soil (naturalized fecal indicator bacteria)	• Clean the storm drain system and maintain BMPs

3.3 Total Suspended Solids (TSS)

Total suspended solids (TSS) include a variety of particles in water such as clay, sand, sediment, silt, and decaying plant and animal matter. Although TSS occurs naturally in streams, elevated TSS can adversely impact aquatic life, habitat, stream aesthetics and raw water treated for public water supply. Nutrients, metals, and bacteria are often attached to TSS particles, so controlling TSS loading can help to reduce loading of other sediment-bound pollutants.

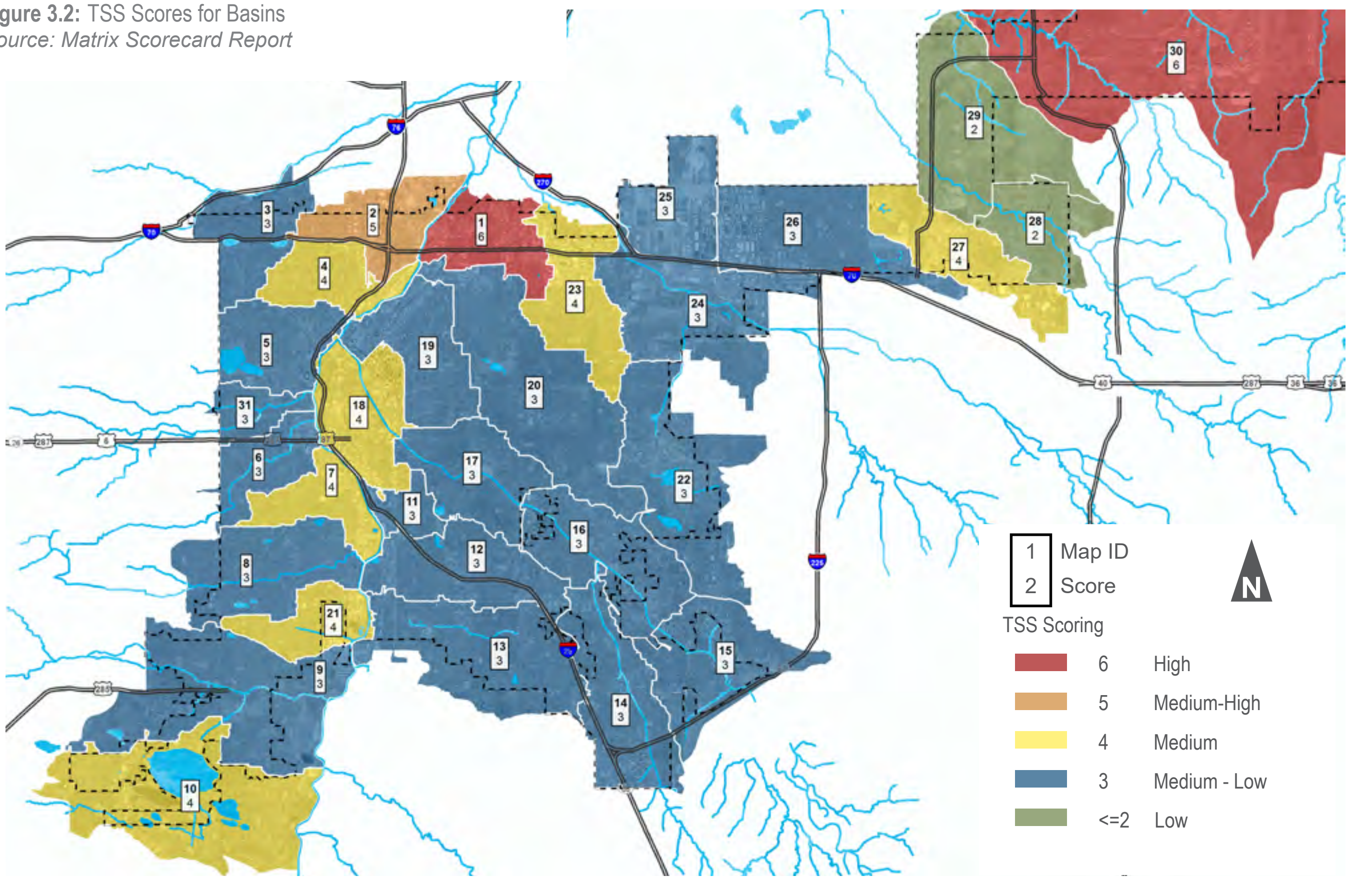
Contributers

Construction activities, road sanding, decaying leaves, metallic brake dust from cars and engines, erosion of bare landscapes or hill slopes, and dust from atmospheric deposition are common sources of TSS in runoff from urban areas.[8] Land uses within urban areas that produce the highest sediment loads include industrial and commercial areas and freeways.[9] In-stream sources of elevated TSS from channel erosion can also be exacerbated by increased runoff associated with increased imperviousness urban areas. When runoff is not managed through appropriate stormwater BMPs, stream channel erosion can be accelerated due to higher flow rates, durations, and volumes compared to predevelopment flows.

Mitigation

TSS loading from urban areas can be reduced through source controls and through structural stormwater BMPs such as green infrastructure practices. Source controls include street sweeping and storm sewer maintenance such as cleaning inlets and sumps. Enhanced street sweeping schedules in priority basins are being explored

Figure 3.2: TSS Scores for Basins
Source: Matrix Scorecard Report



Map ID & Study Basin

- 8 Elyria/Swansea
- 30 DIA
- 2 Globeville
- 4 Sunnyside/311
- 7 Valverde
- 10 Marston lake
- 18 Central Platte Valley
- 21 West Harvard Gulch
- 23 NE Park Hill
- 27 Irondale Gulch
- 3 Berkeley Lake
- 5 Sloan's Lake/Highland
- 6 Weir Gulch
- 8 Sanderson Gulch
- 9 Bear Creek
- 11 West Washington Park
- 12 Overland/University
- 13 Harvard Gulch
- 14 Goldsmith Gulch
- 15 Cherry Creek Reservoir
- 16 Upper Cherry Creek
- 17 Cherry Creek Mall
- 19 Five Points/Capitol Hill
- 20 City Park/Park Hill
- 22 Westerly Creek
- 24 South Stapleton
- 25 North Stapleton
- 26 Montbello
- 31 Lakewood Gulch
- 28 Green Valley Ranch
- 29 Gateway

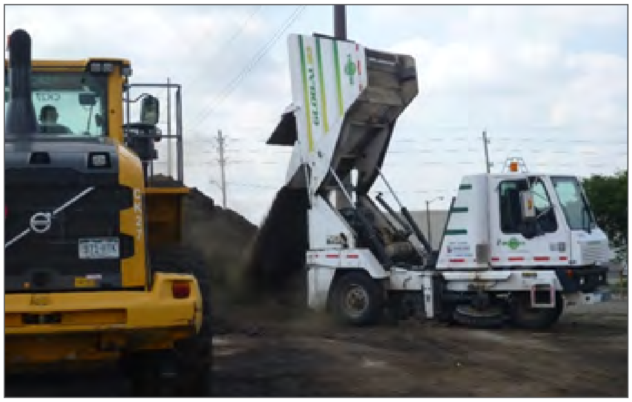


Figure 3.3: Denver's street sweepers collect about 41,386 tons of sediment, litter and other pollutants annually.
(Annual estimates from 2012-2015)

by Denver Public Works, particularly in high priority sub-basins that have limited room for green infrastructure practices.

Green infrastructure BMPs that provide sedimentation, filtration, and volume reduction processes help to reduce TSS loading. Features that increase ease of maintenance to remove accumulated sediment such as concrete forebays, trickle channels, or Denver bays can improve long-term performance of these practices. For bioretention facilities, pretreatment that captures sediment prior to infiltration through the bioretention media, can prolong the permeability of the media. According to BMP performance studies submitted to the International BMP Database, many BMP types demonstrate significant reductions in TSS concentrations including bioretention which can achieve particularly low TSS concentrations.[10]

Figure 3.4: Example of a Denver bay at Huston Lake
Denver Bays are systems that utilize standard right-of-way infrastructure (curbs, gutter, and parking areas) to create forebays that capture sediment and trash. These forebays are easily maintained by standard city practices and equipment. Stormwater then passes through small orifices in the curb into an adjacent treatment facility.

3.4 Nutrients (Total Nitrogen & Phosphorous)

Nutrients, including nitrogen and phosphorus, occur naturally and are essential for plant and animal growth; however, overabundance of nitrogen and phosphorus in surface waters can cause adverse effects. Elevated levels can lead to excessive growth of aquatic plants and filamentous algae, which can smother habitat needed for fish and other aquatic life. This also creates aesthetic nuisances. According to the EPA's Fiscal Year 2014 National Water Program Guidance, "nitrogen and phosphorus pollution is one of the most serious and pervasive water quality problems" in the United States. Because of this, the EPA is encouraging all states to accelerate efforts to develop water quality standards for nutrients based on numeric limits. In 2012, the Water Quality Control Commission adopted interim values for total nitrogen, total phosphorus and chlorophyll-a as part of Colorado's water quality stream standards; however, these values do not yet apply as enforceable stream standards for many streams, particularly those downstream of wastewater treatment plant discharges. The Commission also adopted a Nutrient Management Control Regulation (Regulation 85) to reduce nutrient loading to Colorado waterbodies. Numeric limits are required for wastewater treatment plant discharges and municipalities are required to implement best management practices under their municipal stormwater permits to reduce nutrient loading. Additionally, the metro Denver area is located upstream of Barr Lake and Milton Reservoir, which have a Total Maximum Daily Load that requires phosphorus load reductions from upstream land areas, including Denver.

Contributers

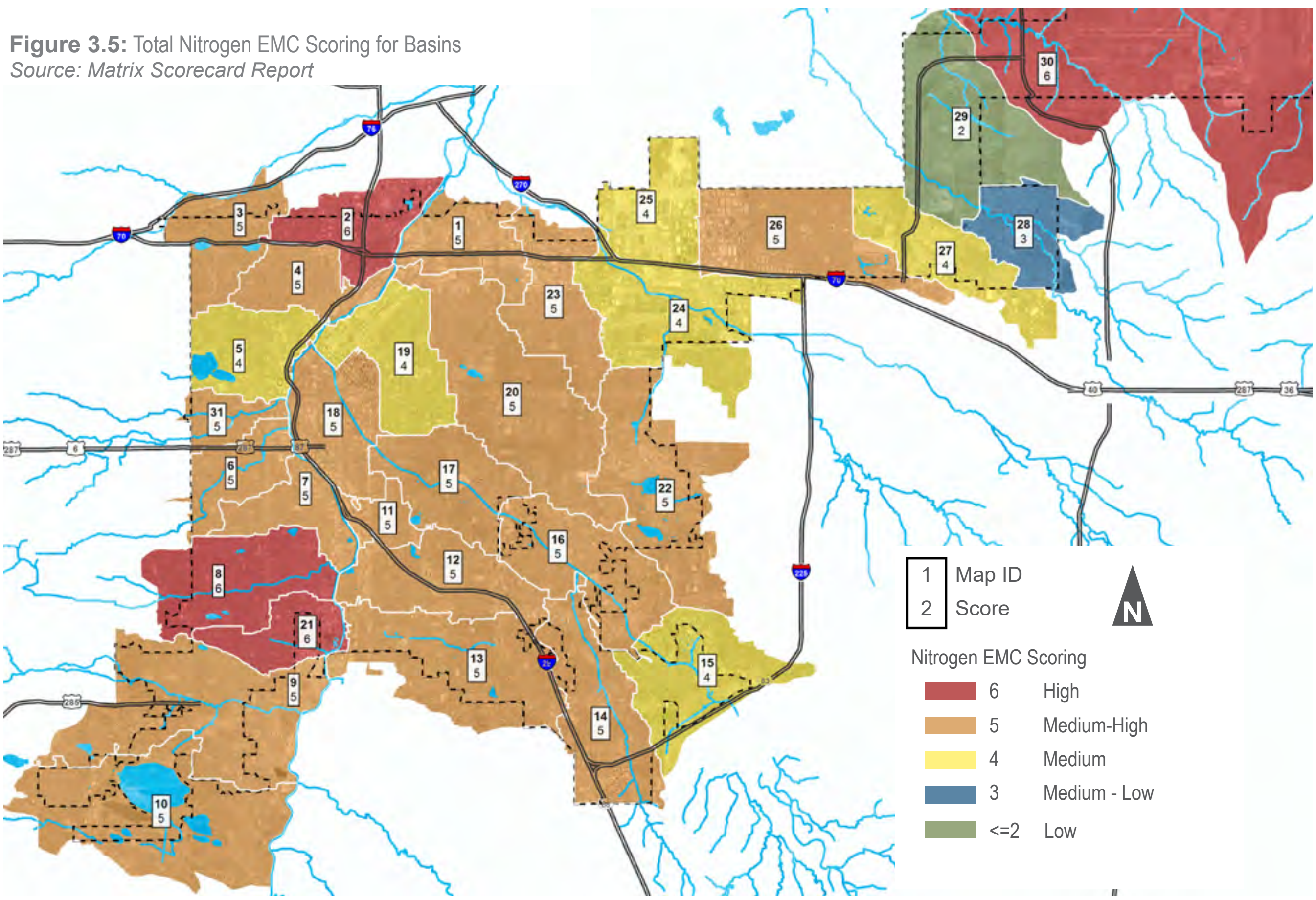
Nutrients occur naturally in streams in lakes and are an essential part of natural ecosystems; however, elevated nutrient loading occurs as a result of human activity. In urban areas, municipal and industrial wastewater discharges, fossil fuel combustion, landscape management practices such as improper fertilizer application rates and irrigation practices, animal waste, sanitary sewer leakage, and stormwater runoff can cause elevated nutrient in urban streams.[11] Sediment associated with channel erosion can also contribute phosphorus to streams.

Mitigation

Control of nutrients is necessary to protect aquatic life and to maintain safe drinking water. Nitrogen in stormwater runoff is predominately in the form of organic nitrogen and nitrate. The City and County of Denver's rigorous street sweeping program not only removes total suspended solids, but also aids in reducing nutrient loads. In 2015, Denver estimated that street sweeping efforts removed an average of 175,000 lbs. of total nitrogen and 54,000 lbs. of total phosphorus. Nutrients were calculated using a percentage of total street solids which includes the street dirt (sediment) and the street detritus (organics) measured from street surface, catch basin, or sweeper hopper.

Phosphorus in stormwater runoff is generally highly particulate-bound. As a result, BMPs with treatment processes for removing particulates (i.e., sedimentation and filtration), will generally provide good removal for total phosphorus. BMPs with permanent pools such as wetland basins and retention ponds appear to be effective at reducing the major forms of phosphorus. Infiltration-oriented practices such as bioretention will help to reduce phosphorus loads through surface runoff reduction. However, leaching of phosphorus from soils/ planting media and resuspension of captured particulate phosphorus may be a cause of phosphorus increases observed in vegetated BMPs such as bioretention, swales, and filter strips. Vegetated BMPs should be designed with adequate inlet protection, dense vegetation, and drop structures or check dams to minimize resuspension of particulates. The use of virgin compost or chemical fertilizers should be avoided and planting media within

Figure 3.5: Total Nitrogen EMC Scoring for Basins
Source: Matrix Scorecard Report



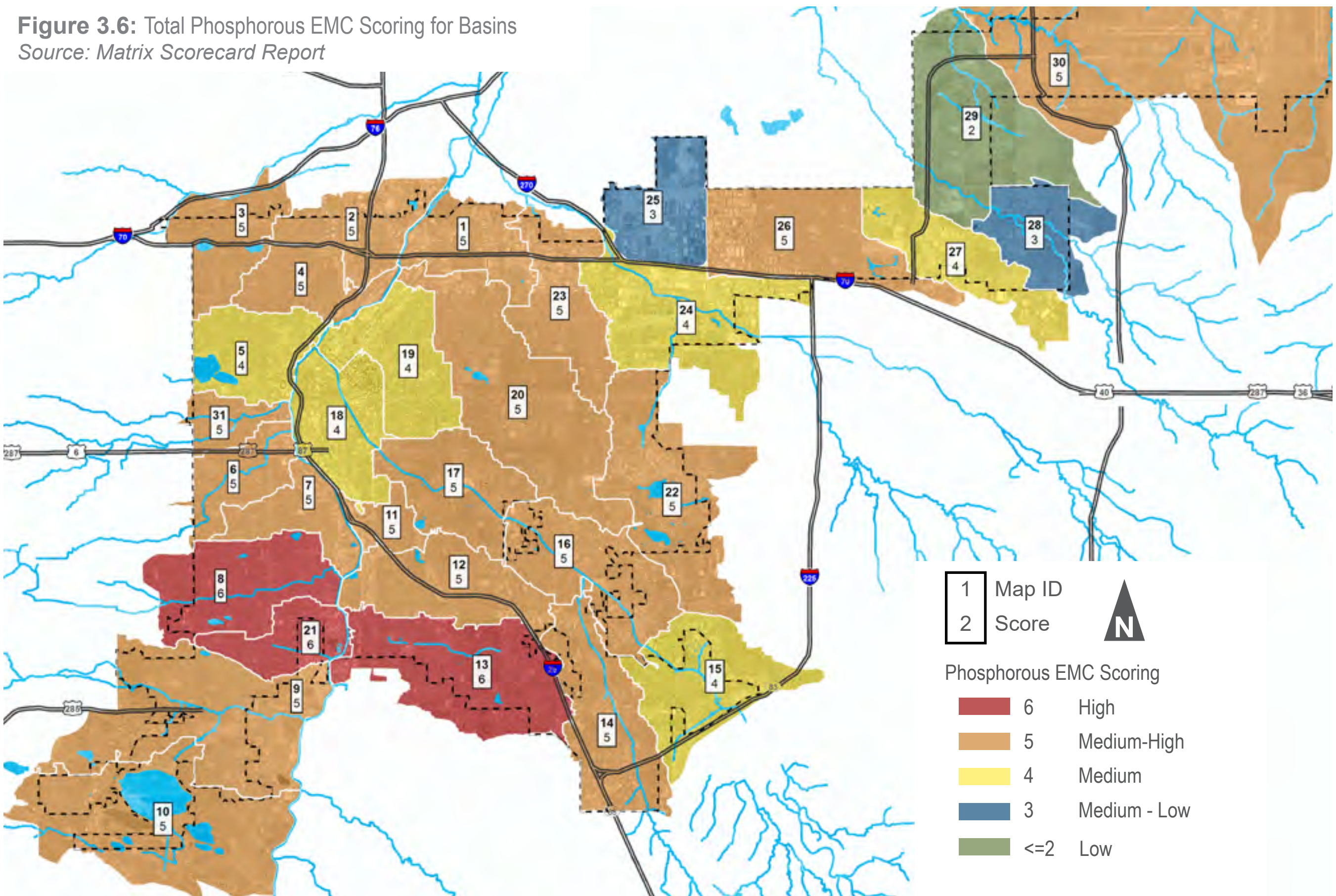
Map ID & Study Basin

2 Globeville	4 Sunnyside/311	13 Harvard Gulch	23 NE Park Hill	24 South Stapleton
8 Sanderson Gulch	6 Weir Gulch	14 Goldsmith Gulch	26 Montbello	25 North Stapleton
21 West Harvard Gulch	7 Valverde	16 Upper Cherry Creek	31 Lakewood Gulch	27 Irondale Gulch
30 DIA	9 Bear Creek	17 Cherry Creek Mall		
	10 Marston Lake	18 Central Platte Valley/CBD	5 Sloan's Lake/Highland	28 Green Valley Ranch
1 Elyria/Swansea	11 West Washington Park	20 City Park/Park Hill	15 Cherry Creek Reservoir	
3 Berkeley Lake	12 Overland/University	22 Westerly Creek	19 Five Points/Capitol Hill	29 Gateway

BMPs should be tested for phosphorus content if phosphorus is a constituent of concern.[12]

Total nitrogen is the sum of nitrate/nitrite plus total Kjehldal nitrogen (TKN), which represents organic nitrogen plus ammonia. BMPs with permanent pools (i.e., retention ponds and wetlands) appear to be able to reduce nitrate concentrations, but may increase organic nitrogen. The opposite appears to be true for biofilters and media filters. Based on relatively high TKN removal and low nitrate removal for media filters, inert filtration appears capable of capturing nitrogenous solids, but the conditions are not as conducive for significant denitrification or nitrogen uptake as compared to bioretention or BMPs with permanent pools (retention ponds and wetland basins). Therefore, a BMP designed for permanently reducing nitrogen may include a permanent wet pool followed by a vegetated swale or media filter. Alternatively, a bioretention cell designed with an upturned underdrain “elbow” may provide aerobic and anaerobic zones for nitrification/denitrification processes, improving nitrogen removal. Harvesting of vegetation and removal of captured sediment may also be key maintenance practices for reliable removal of nitrogen.[13]

Figure 3.6: Total Phosphorous EMC Scoring for Basins
Source: Matrix Scorecard Report



Map ID & Study Basin

- 8 Sanderson Gulch
- 13 Harvard Gulch
- 21 West Harvard Gulch

- 1 Elyria/Swansea
- 2 Globeville
- 3 Berkeley Lake
- 4 Sunnyside/311
- 6 Weir Gulch
- 7 Valverde
- 9 Bear Creek
- 10 Marston Lake
- 11 West Washington Park
- 12 Overland/University
- 14 Goldsmith Gulch
- 16 Upper Cherry Creek
- 17 Cherry Creek Mall
- 20 City Park/Park Hill
- 22 Westerly Creek
- 23 NE Park Hill
- 26 Montbello
- 30 DIA
- 31 Lakewood Gulch

- 5 Sloan’s Lake/Highland
- 15 Cherry Creek Reservoir
- 18 Central Platte Valley/CBD
- 19 Five Points/Capitol Hill
- 24 South Stapleton
- 27 Irondale Gulch

- 25 North Stapleton
- 28 Green Valley Ranch

- 29 Gateway

SOURCES:
1. Nitrate TMDL assessment document (CDPHE 2004)
2. CDPHE's Bacteria TMDL Assessment (CDPHE 2007)
3. EPA 2014 (I CANNOT FIND THIS REFERENCE)
4. Urban Water Resources Research Council, Environmental and Water Resources Institute, American Society of Civil Engineers. 2014. Pathogens in Urban Stormwater Systems. Eds. J. Clary, R. Pitt and B. Steets.
5. Weston Solutions, Inc. San Diego County Municipal Copermittees 2007-2008 Urban Runoff Monitoring. Prepared for the County of San Diego. January 2009
6. Ferguson et al. 2011
7. Kadlec, R. and Wallace, S. Treatment Wetlands. 2009. Second Edition. CRC Press.
8. International BMP Database Pollutant Category Summary, Solids (TSS, TDS, and Turbidity).
9. State of Wisconsin Department of Transportation. Facilities Development Manual. 2012
10. International BMP Database Pollutant Category Summary, Solids (TSS)
11. International Stormwater BMP Database website: www.bmpdatabase.org
12. International Stormwater BMP Database website: www.bmpdatabase.org; Nutrients Paper
13. BMP Database, Nutrients paper, 2010).