Technical Memorandum

Prepared for: Lower South Platte Water Conservancy District

Project Title: South Platte Regional Water Development Concept Feasibility Study

Subject: Evaluation of Nonpoint Source Treatment Options

Date: March 2020

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Executive Summary

The SPROWG nonpoint source treatment study consisted of a conceptual assessment of possible nonpoint source approaches to water quality improvement that could be considered in the future as alternatives or companion programs to conventional water treatment measures. This was a very limited evaluation of the potential for nonpoint source treatment measures to be beneficial to the SPROWG Concept and was intended only to indicate the potential feasibility of this treatment approach for further study.

Nonpoint source treatment BMPs were assumed to be applied at a watershed scale based on land use type (urban/residential, commercial/industrial, farmland, grassland, forest). Data for the type, cost, and effectiveness of a variety of BMPs was taken from published reports and data sources. Data for cost and effectiveness is highly variable for all BMPs, and strongly affects the level of accuracy for any watershed scale BMP assessment.

A range of possible nonpoint source treatment assumptions for improving South Platte River water quality in the SPROWG study area was investigated using a scenario approach. Scenarios were developed assuming application of effective BMPs for each land use type in a buffer area within 5 miles of the South Platte River mainstem (priority area) and in the area tributary to a SPROWG reservoir near Balzac. BMPs applied to each land use type were:

- Urban/residential: detention basins, retention basins, bioretention areas
- Commercial/industrial/transportation: detention basins, retention basins, bioretention areas
- Farmland/agricultural: grass strips and field borders, nutrient management, irrigation water management
- Grassland/rangeland: detention basins, riparian buffer zones, streambank stabilization
- Forest: level terraces, riparian buffer zones, streambank stabilization

The extent of assumed BMP deployment in the priority area varied from 10% to 50% of the tributary area. BMPs for nutrient management and sediment control were also assumed for the watershed upstream of the Balzac storage facility included in SPROWG alternatives 2, 3 and 4 that include direct delivery of water from that reservoir to municipal entities. Typical BMP unit costs per acre and pollutant removal effectiveness in percentage reduction in TSS, iron, total nitrogen, total phosphorus and TDS were estimated for four SPROWG diversion points and three BMP deployment assumptions.

Costs to implement BMPs across all land use types in the nonpoint source study area vary from $21 million to $102 million at the Brighton diversion point and $105 million to $524 million at the Sterling diversion point. These are conceptual, order-of-magnitude cost estimates for 50 years of annual operation, with an accuracy of -50% to +100%. Pollutant removal percentages vary from about 5% to about 30% depending on the constituent and the location.

The cost of nonpoint treatment on a watershed scale could be considered high compared to the level of pollutant removal that could potentially be achieved. However, existing agricultural and urban BMPs have already achieved some level of pollutant reduction, so estimated pollutant removal by new BMPs would be in addition to those past reductions.

The most effective BMPs relative to treatability of South Platte River water for municipal use may be those that manage irrigation practices such that irrigation tailwater return to the river from irrigated lands and recharge of shallow groundwater by excess irrigation water are minimized.

Nonpoint source treatment measures should not be viewed as a substitute for conventional water treatment of SPROWG supplies for municipal water providers, but as a companion strategy to reduce treatment costs and provide environmental benefits.

Best management practices would normally be implemented and funded by private landowners. In the case of agricultural BMPs, there are outside state and federal funding sources available in the form of grants or loans to offset many of these costs. In addition, public agencies participating in the SPROWG Concept could invest in nonpoint source management projects as a pollutant trading approach, in which pollutant reductions to receiving waters through nonpoint source measures would offset required pollutant reductions in wastewater treatment discharges or other point source discharges. In this way nonpoint source treatment would be part of a more holistic, watershed-based approach to water quality management in the SPROWG study area.

Further studies of potential nonpoint source management options related to the SPROWG Concept could include the following.

- Investigation of hot spots for particular constituents of concern (e.g., TDS, nutrients), and the benefits and costs of focusing nonpoint source measures on those areas.
- Analysis of pollutant loads in the lower South Platte River and refined estimates of pollutant reductions achievable by BMPs commonly applied on irrigated agricultural lands.
- Study of the potential reduction in water treatment costs if nonpoint source controls were applied throughout the watershed.
- Study of the relative impact of agricultural and urban land use contributions to South Platte River pollutants in the SPROWG study area to determine where nonpoint controls could have the most benefit.
- Case studies or conceptual outlines of how a pollutant trading approach could benefit SPROWG participants who contribute to implementing nonpoint source programs.

Section 1: Introduction

1.1 Project Objectives

The South Platte Regional Operations Water Group (SPROWG) is investigating the feasibility of a new regional water supply project in the South Platte River basin downstream of the Denver Metro Area. The South Platte Regional Water Development Concept Feasibility Study (Study) is analyzing conceptual alternatives to meet a wide range of potential municipal, agricultural, and environmental/recreational water needs in the region. Municipal water deliveries could consist of raw or treated water.

Conventional treatment options are challenging and expensive due to poor water quality for some constituents important to municipal water users, including TDS. Therefore, the scope of work for the Study included a task to conduct a conceptual assessment of possible nonpoint source approaches to water quality improvement that could be considered in the future as alternatives or supplements to conventional water treatment measures. The scope of the nonpoint source treatment assessment included preparing a list of water quality constituents of concern, collecting information on best managements practices (BMPs) that could be implemented in the study area to reduce constituent concentrations or loads, and assessing the potential effectiveness and cost of applying nonpoint source treatment measures at a variety of scales in the basin. Suggestions were developed for ways to integrate nonpoint source treatment measures into an overall balanced SPROWG water treatment concept.

This Technical Memorandum (TM) presents the results of the nonpoint treatment assessment. Conventional treatment options are discussed in the SPROWG Water Treatment Alternatives TM.

1.2 Study Area

The SPROWG study area includes the portion of the South Platte River Basin extending from the Denver Metro Area to the Colorado-Nebraska State Line. For purposes of treatment evaluations, the study area was limited to the stream reaches in which diversions could be located to supply water for municipal entities needing SPROWG water for direct use (i.e., excluding diversions for entities using SPROWG water to augment depletions from other sources of supply). The study area for the nonpoint source assessment includes the potential diversion areas on the South Platte River mainstem from Brighton (near the Henderson stream gage) to Sterling (near the Balzac stream gage). It also includes the watershed area tributary to a potential off-channel reservoir near Balzac that could be part of a SPROWG Concept, since runoff from that drainage area could affect reservoir water quality and water from the reservoir would be conveyed upstream to the Front Range area for municipal use. Figure 1-1 is a schematic of the SPROWG study area showing potential diversion locations and reservoirs.

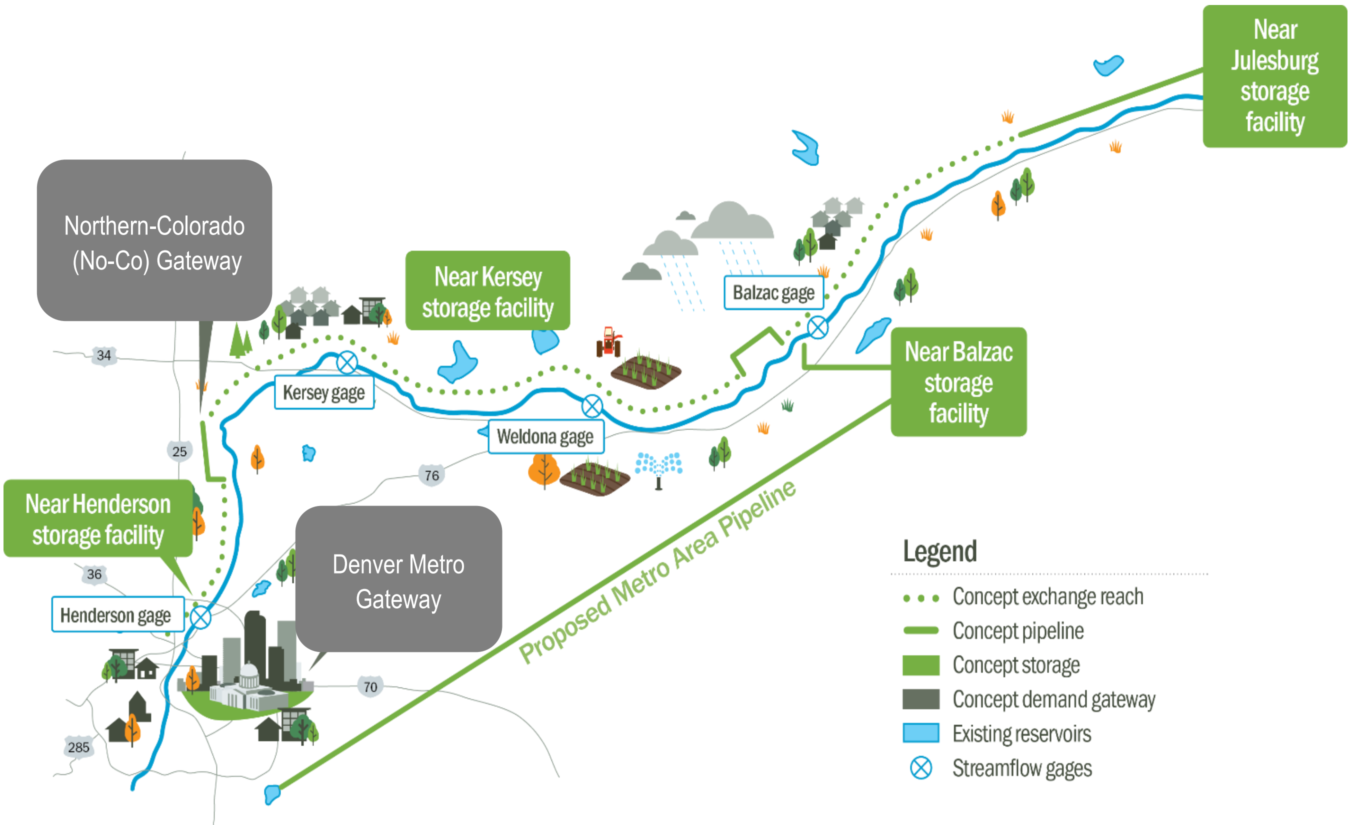

Figure 1-1. SPROWG Conceptual Alternative Facilities and Diversion Points

Section 2: Study Methodology and Data

2.1 Water Quality Concerns

The SPROWG Water Treatment Alternatives TM included a review of key water quality constituents in the study area. Based on a review of available data, constituents of most concern for treatment to meet primary and secondary drinking water standards are Total Dissolved Solids (TDS), turbidity, iron, manganese, Total Organic Carbon (TOC), and bromide. Because all SPROWG concepts include operation of new surface reservoirs, nutrient management (nitrogen and phosphorus) in South Platte source water is also a concern. Planned updates to Colorado Water Quality Control Commission Regulation 85 will eventually require nutrient standards for surface water, which could affect use of SPROWG reservoirs. Future management of emerging contaminants could also be a concern.

2.2 Study Approach

Based on budget limitations and the very generalized nature of the SPROWG concept at this stage of project development, the nonpoint source treatment assessment was conducted at a very conceptual level. The main steps in the study approach are shown below.

2.3 Potential Nonpoint Source Treatment Methods

Nonpoint source treatment methods are typically categorized based on best management practices associated with types of land uses. **Error! Reference source not found.** summarizes common BMPs and their applicability to land uses common to the South Platte watershed – urban and residential; commercial, industrial and transportation corridors; farmland and agriculture; forest; and grassland and other natural vegetated areas. Applicability to land uses is based on a general consensus of BMP literature and nonpoint source management plans (Colorado Department of Public Health and Environment 2012a; Colorado Department of Public Health and Environment 2012b; International Stormwater BMP databases 2016; CSU 2011).

Table 2-1. Applicability of Best Management Practices to South Platte Basin Land Uses

Best Management Practice	Urban / Residential	Commercial / Industrial / Transportation	Farmland / Agriculture	Forest	Grasslands / Herbaceous / Rangeland
Bioretention (Rain Garden)	X	X			
Detention Basin	X	X	X		X
Filter Strip/Field Borders			X		X
Grass Swale	X	X	X		X
Low Impact Development	X	X			
Media Filter	X	X			
Porous Pavement	X	X			
Retention Pond	X	X	X		X
Wetland Basin	X	X	X	X	X
Wetland/Retention Pond	X	X	X	X	X
Wetland Channel	X		X		X
Nutrient Management	X		X	X	X
Level Terraces			X	X	X
Diversions around Erodible Soils			X	X	X
Grade Stabilization	X	X	X		
Animal Waste Storage			X		X
Livestock Exclusion (fencing)			X		X
Riparian Buffer Zones	X	X	X	X	X
Irrigation Water Management			X		

Streambank Stabilization	**X**		**X**	**X**	**X**

2.4 BMP Effectiveness and Cost

Data for BMP effectiveness is highly variable due to a number of factors including inconsistent BMP design standards, different installation conditions, inconsistent maintenance, and highly variable inflow water quality. BMP monitoring studies show wide differences in pollutant removal effectiveness, and differences in study methods, site conditions, watershed conditions, and many other factors make it difficult to determine a theoretical range of pollutant removal effectiveness by BMP type. For purposes of this study, several published sources of BMP effectiveness research were combined to develop a range of assumed pollutant removal effectiveness for the main types of BMPs appropriate for the land uses in the study area (Novotny 2011; International Stormwater BMP Database 2016; CSU 2011; CDPHE 2012b; Urban Drainage and Flood Control District 2010). Data is summarized in the table in Attachment A. The top three performing BMPs for selected pollutants are listed in **Error! Reference source not found.**.

Table 2-2. Top BMPs for Removing Selected Pollutants

Constituent	Top Three Performing BMPS		
Total Suspended Solids	**Streambank Stabilization**	**Level Terraces**	**Media Filter**
Fecal Coliforms	**Detention Basin**	**Retention Pond**	**Wetland/Retention Pond**
Total Iron	**Detention Basin**	**Retention Pond**	**Media Filter**
Total Zinc	**Bioretention (rain garden)**	**Porous Pavement**	**Media Filter**
Total Nitrogen	**Nutrient Management**	**Riparian Buffer Zones**	**Animal Waste Storage**
Total Phosphorus	**Nutrient Management**	**Riparian Buffer Zones**	**Livestock Exclusion**

BMP effectiveness data was combined and simplified for five key constituents for which a fair amount of information is available. The pollutant removal effectiveness assumed in this analysis for those five key constituents is shown in **Error! Reference source not found.**. BMP effectiveness is expressed as a percentage of the pollutant load removed by the BMP when properly maintained. Total Suspended Solids was used as a surrogate for TOC or other solids-based constituents because there is considerable available data for TSS removal rates. Iron was used as a surrogate for manganese and other metals. There is little data available for removal of TDS in common BMPs; this is unfortunate because it is perhaps the most important constituent driving water treatment requirements for municipal use in the SPROWG study area. TDS removal rates were assumed based on the removal rates for other dissolved constituents. In some cases, there was little pollutant removal data available for some BMP-constituent combinations. In these cases, a conservative value of 10% removal was assumed.

Data on the cost of implementing BMPs is even more variable and difficult to compare than data on BMP effectiveness. BMP size, maintenance requirements, ownership (public or private), and a host of other factors strongly influence the cost of BMP construction and operation. For purposes of this project, publications and websites[1] containing BMP cost estimates were used to estimate a range of potential BMP unit costs (e.g., $/AF or $/acre) or lump sum costs. BMP cost data and sources of that data are listed in Attachment B.

[1] www.lid-stormwater.net; nrcsolutions.org; *Construction Site Erosion and Sediment Controls: Planning, Design and Construction,* Robert Pitt et al., www.epa.gov/sites/production/files/2015-09/documents/urban_guidance; secure.in.gov/indot/files/Cost_and_Pollutant_Removal_of_Storm_Water.pdf; coagnutrients,colostate,edu/ag-best-management-practices/nutrient-fertilizer-management; www.nrcs.usda.gov/internet/FSE_DOCUMENTS/nrcs143_012400.pdf; www.extension.iastate.edu/agdm/livestock; extension.colostate.edu/topic-areas/water; Novotny, 2011; bmpdatabase.org

Table 2-3. Pollutant Removal Efficiency for Selected BMPs					
	Percent Pollutant Removal by Constituent				
Best Management Practices	TSS	Iron	TN	TP	TDS
Bioretention (Rain Garden)	80%	70%	10%	0%	10%
Composite	80%	65%	20%	50%	20%
Detention Basin	60%	50%	5%	20%	20%
Grass Strip/Field Borders	50%	40%	40%	20%	30%
Grass Swale	10%	10%	0%	0%	10%
Low Impact Development	20%	10%	10%	10%	10%
Media Filter	80%	60%	20%	40%	50%
Porous Pavement	60%	70%	10%	40%	50%
Retention Pond	70%	60%	20%	50%	50%
Wetland Basin	60%	50%	30%	20%	50%
Wetland/Retention Pond	70%	50%	30%	40%	50%
Wetland Channel	30%	30%	30%	10%	30%
Nutrient Management	10%	10%	30%	30%	10%
Level Terraces	90%	10%	40%	40%	40%
Diversion Structures around Erodible Soils	40%	10%	30%	30%	30%
Grade Stabilization	20%	10%	10%	10%	10%
Animal Waste Storage	60%	10%	40%	30%	20%
Livestock Exclusion	60%	10%	10%	60%	0%
Riparian Buffer Zones	80%	10%	60%	50%	10%
Irrigation Water Management	50%	10%	10%	10%	50%
Streambank Stabilization	80%	10%	60%	40%	10%

To estimate BMP costs for this study, the average of the upper and lower range of costs was adopted from Attachment B for each BMP. These costs were then converted to a unit cost in $/acre for the most effective BMPs in each land use category. In addition, a conservative estimate of the percentage of total acreage occupied by the BMP was developed. This allowed BMP cost to be tied to total land acreage in a particular land use in subsequent calculations. The BMP cost data assumed for this Study is summarized in **Error! Reference source not found.**.

BMP costs are capital costs, except for nutrient management and irrigation water management. Costs for these BMPs are recurring annual costs. To put them on a similar basis as capital costs, the net present worth of these annual costs was computed for a 50-year period. This is consistent with the period used to estimate life-cycle costs for SPROWG conceptual infrastructure facilities.

BMP cost estimates at this level are very speculative and order-of-magnitude only. Unit costs vary widely, and the geographic areas over which BMPs should be applied are unknown at this stage of project development. Thus, the BMP costs developed for this study are very conceptual and are intended to be conservative. Cost estimates for SPROWG infrastructure were reported to have a level of accuracy of -50% to +100%. The BMP cost estimates developed for this study have a similar level of accuracy.

Table 2-4. Unit Cost and Acreage Data for Selected BMPs by Land Use					
	Land Use Type				
BMP Parameter	Urban / Residential	Commercial / Industrial / Transportation	Farmland / Agriculture	Forest	Grasslands / Herbaceous / Rangeland
BMP #1	Detention Basin	Detention Basin	Grass Strip/ Field Borders	Level Terraces	Detention Basin
Cost ($/acre)	$25,000	$25,000	$5,200	$80,000	$25,000
% of Total Acreage Required for BMP	1%	1%	2%	3%	1%
BMP #2	Bioretention	Bioretention	Nutrient Management	Riparian Buffer Zones	Riparian Buffer Zones
Cost ($/acre)	$152,000	$152,000	$300/yr	$184,000	$184,000
% of Total Acreage Required for BMP	3%	3%	50%	1%	1%
BMP #3	Retention Pond	Retention Pond	Irrigation Water Management	Streambank Stabilization	Streambank Stabilization
Cost ($/acre)	$25,000	$25,000	$300/yr	$50,000	$50,000
% of Total Acreage Required for BMP	3%	3%	75%	1%	1%

2.5 Priority Nonpoint Source Treatment Areas

Nonpoint source BMPs could be applied anywhere in the South Platte Basin, but their effectiveness in improving water quality in the stream reaches from which SPROWG diversions could occur would vary widely based on several factors including distance from the South Platte River; contribution of the area where BMPs are applied to base flows and stormwater flows; and potential of water that could be treated by the BMPs to cause water quality impairments in the River. The areas where nonpoint source treatment would be most effective would be areas with:

- Shallow alluvial groundwater contributing return flows to the South Platte River
- Irrigated agriculture generating tailwater return flows and high groundwater levels
- Close proximity to the South Platte River mainstem channel

GIS data from state databases was collected for the boundaries of shallow alluvial groundwater and irrigated lands in the South Platte Basin. Two buffer areas around the South Platte River mainstem channel were delineated assuming widths of 5 miles on both sides of the channel and 20 miles on both sides of the channel. These buffer areas were based on the study team's professional judgment of the areas most likely to provide significant water quality improvements to the South Platte mainstem if BMP treatments were applied. Figure 2-1 is a map showing areas of shallow groundwater, areas of irrigation, and the two buffer zones. The highest priority areas for nonpoint source BMP application would be on lands within 5 miles of the main South Platte River channel that have irrigated agriculture and shallow groundwater basins.

Figure 2-1 also shows the location of the Balzac reservoir site. Nonpoint source measures applied in the tributary watershed could be effective in minimizing impacts of stormwater runoff or shallow groundwater on reservoir water quality. Managing inputs of nitrogen, phosphorus and TOCs could be beneficial in maintaining water quality and minimizing potential for eutrophication if the reservoir is operated with significant year-to-year carryover storage.

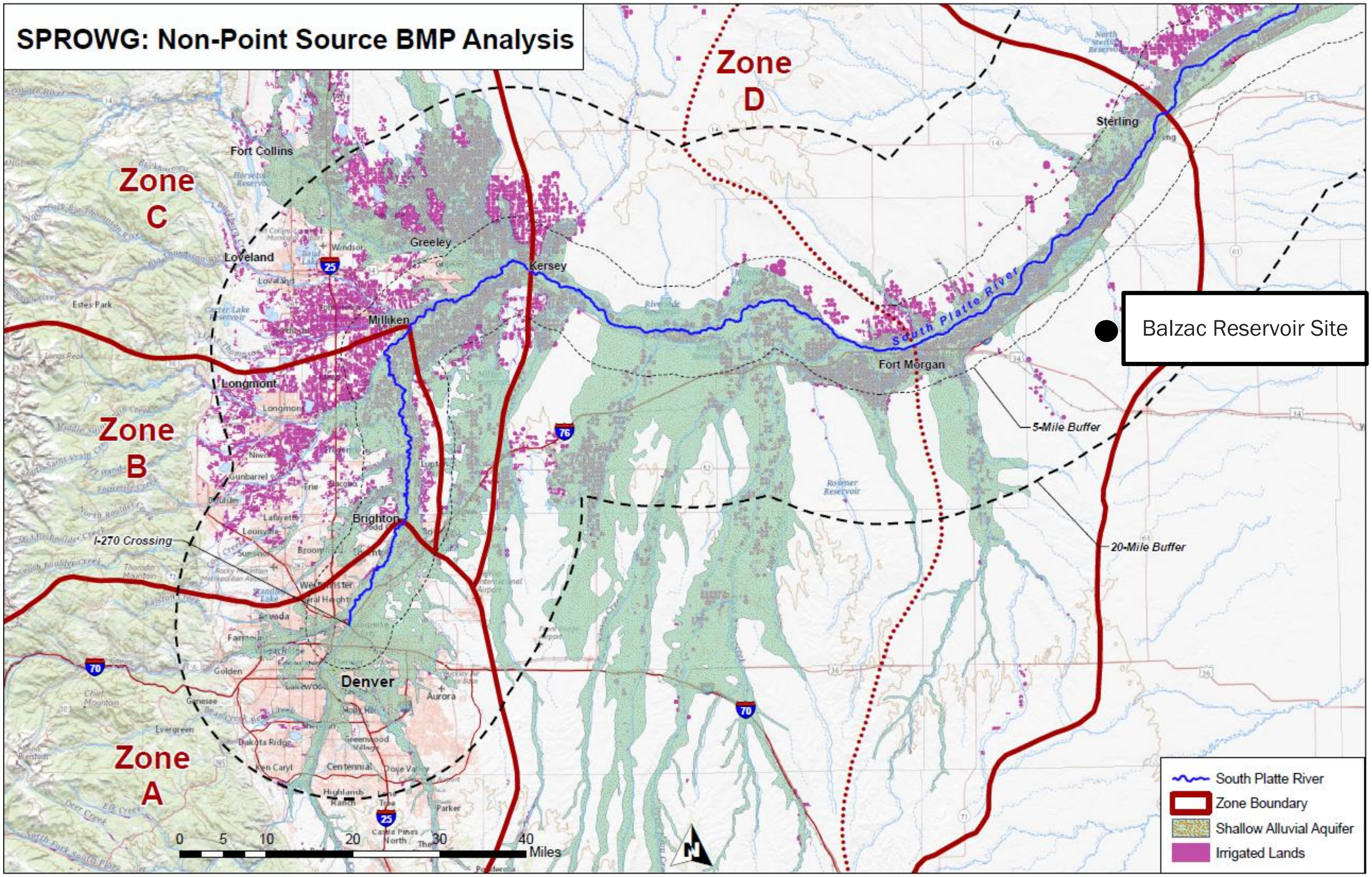

Figure 2-1. Priority Areas for BMP Applications

Section 3: Nonpoint Source Treatment Scenarios and Results

3.1 Nonpoint Source Treatment Scenarios

A scenario approach was adopted to estimate a range of possible nonpoint source treatment costs and effectiveness. Nonpoint source treatment scenarios were developed based on the following assumptions:

- Selection of BMPs for each major land use type
    - Three effective BMPs for each land use type were selected for each scenario. See **Error! Reference source not found.**.
    - The three BMPS were assumed to be equally distributed across the relevant land use types.
- Percentage of tributary watershed area treated with one of the BMPs
    - The extent of deployment of BMPs throughout a tributary area is dependent on many factors including compliance with environmental regulations (e.g., for urban stormwater controls), financial incentives provided to landowners by public agencies, education of landowners on the benefits of nonpoint source control, etc. Future deployment in the study area is unknown, so was addressed through a scenario approach.
    - Many agricultural landowners have already implemented BMPs on their irrigated lands as part of their commitment to stewardship and responsible land management. This may include nutrient management measures, irrigation practices, etc. In addition, urban development in the Denver Metro area since the early 1990s has been required to have construction site and permanent BMPs in response to stormwater permit requirements. BMP scenarios are intended to explore a range of additional BMP application beyond the BMPs already in place.
    - BMPs were assumed to be implemented in the portion of the tributary watershed within 5 miles of the South Platte River mainstem.
    - Three levels of BMP application throughout tributary watershed were investigated: Low = 10%, Midrange = 25%, High = 50%. These percentages represent the additional watershed area to be addressed with BMPs beyond the area covered by BMPs already in place, or land areas on which enhanced BMPs would be implemented.
    - For any scenario the percentage of BMP application was assumed to be the same for all land use types.
- Diversion point and watershed areas
    - Diversion points were assumed based on the preliminary diversion locations envisioned for the SPROWG alternative concepts as described in the Concept Refinement Alternatives Modeling TM.
    - Assumed diversion points were near Brighton, near Milliken, near Kersey, and near Sterling. The distribution of land uses in the 5-mile buffer area upstream of each diversion point is shown in **Error! Reference source not found.**.
    - Tributary watershed area for each scenario was based on the South Platte Basin area upstream of each diversion point and within 5 miles of the South Platte River mainstem.
    - The area tributary to the Balzac reservoir site was addressed separately in this analysis from the South Platte River diversions.

Based on these scenario definitions, scenarios varied by the diversion location and the percentage of area treated by BMPs. Other assumptions described above were the same for each scenario.

Table 3-1. Distribution of Area by Land Use Type In the 5-mile Buffer Area Upstream of SPROWG Diversion Points

Land Use Type	Area of Land Use Types Upstream of SPROWG Diversion Points (acres)			
	Near Brighton	Near Milliken	Near Kersey	Near Sterling
Commercial/Industrial/Transportation	11,000	12,000	15,000	17,000
Farmland	15,000	87,000	167,000	342,000
Forest	19	96	110	110
Grasslands/Herbacious/Rangeland	22,000	42,000	62,000	252,000
Urban/Residential	15,000	20,000	28,000	32,000

3.2 Scenario Results

For each scenario (combination of diversion point and BMP application percentage), the cost of BMP implementation and the effectiveness of pollutant removal were estimated.

The cost of BMP implementation was estimated based on the unit BMP costs and percentage of land area required for a BMP in **Error! Reference source not found.**. Calculations took the following form for each combination of land use type and BMP:

Total Area x % of Land Use Type x BMP area x Unit Cost = Total Cost per BMP

The total cost for BMP implementation was then computed as the sum of the costs of implementation all the BMPs for all the land uses upstream of the diversion point.

Similarly, the pollutant removal effectiveness was the weighted average of the combined pollutant removal effectiveness of the BMPs assumed to be applied to each land use type. The BMP effectiveness is different for each of the five key constituents and is expressed as a percentage of the pollutant removed from the surface and subsurface flow from the portion of the watershed within 5 miles of the South Platte River mainstem (i.e., the priority area).

Results of the scenario analysis are shown in **Error! Reference source not found.**. The BMP costs and percent pollutant removal at each diversion point account for all the area upstream of the given diversion point within the 5-mile buffer area.

In addition to BMPs upstream of the South Platte River diversion points, SPROWG nonpoint source management plan scenarios include BMPs for nutrient management and sediment control in the watershed upstream of the Balzac storage reservoir. A budget of $1,000,000 was included in the total BMP cost estimate for these reservoir watershed management strategies.

Table 3-2. Results of Nonpoint Source Treatment Scenario Analysis									
				Percent Pollutant Load Removed from Tributary Area(3)					
Diversion Point	Total Watershed Area in 5-mile Buffer (acres)	Percent of Watershed Treated(1)	BMP Implementation Cost(2)	Total Suspended Solids	Iron	Total Nitrogen	Total Phosphorus	Total Dissolved Solids
Near Brighton	63,000	10%	$21,000,000	6%	3%	3%	3%	2%
		25%	$51,000,000	16%	7%	7%	7%	6%
		50%	$102,000,000	32%	14%	14%	14%	11%
Near Milli-ken	160,000	10%	$32,000,000	5%	3%	3%	3%	3%
		25%	$78,000,000	13%	8%	8%	7%	7%
		50%	$157,000,000	26%	16%	16%	14%	14%
Near Kersey	270,000	10%	$46,000,000	5%	3%	3%	3%	3%
		25%	$113,000,000	13%	8%	8%	7%	7%
		50%	$226,000,000	25%	16%	16%	14%	14%
Near Sterling	641,000	10%	$105,000,000	5%	3%	3%	3%	3%
		25%	$262,000,000	13%	9%	9%	8%	8%
		50%	$524,000,000	27%	17%	17%	15%	16%

(1) Percentage in addition to areas already managed with BMPs.
(2) BMP costs estimates are order-of-magnitude only; -50% to +100%
(3) Percent removal averaged over entire upstream area within the 5-mile buffer

As a point of cost comparison, Colorado State University studied nutrient management BMP implementation in irrigated agricultural lands throughout Colorado, and estimated the cost of implementing measures on agricultural lands without nutrient management measures in place (CSU 2011). The cost estimate for the lower South Platte Basin was $2 million - $8,5 million per year just for nutrient management BMPs. The net present worth of that level of investment over 50 years would be $44 million - $186 million. The estimates in Table 3-2 are higher, because they include other types of BMPs for agricultural lands (not just nutrient management) and BMPs for all land use types, not just irrigated acreage.

Several high-level conclusions may be drawn from this conceptual assessment of nonpoint treatment options.

- The cost of nonpoint treatment on a watershed scale could be considered high compared to the level of pollutant removal that could potentially be achieved. However, existing agricultural and urban BMPs have already achieved some level of pollutant reduction, so estimated pollutant removal by new BMPs would be in addition to those past reductions.
- The cost of nonpoint treatment increases in the downstream direction along the South Platte River because the contributing watershed increases.
- The most effective BMPs relative to treatability of South Platte River water for municipal use may be those that manage irrigation practices such that irrigation tailwater return to the river from irrigated lands and recharge of shallow groundwater by excess irrigation water are minimized.
- Nonpoint source treatment measures should not be viewed as a substitute for conventional water treatment of SPROWG supplies for municipal water providers, but as a companion strategy to reduce treatment costs and provide environmental benefits.

Best management practices would normally be implemented and funded by private landowners. In the case of agricultural BMPs, there are outside funding sources available in the form of grants or loans to offset many of these costs. Examples are the Natural Resources Conservation Service Environmental Quality Incentives Program (NRCS EQIP) and Colorado's Water Supply Reserve Fund. In addition, public agencies participating in the SPROWG Concept could invest in nonpoint source management projects as a pollutant trading approach, in which pollutant reductions to receiving waters through nonpoint source measures would offset required pollutant reductions in wastewater treatment discharges or other point source discharges. In this way nonpoint source treatment would be part of a more holistic, watershed-based approach to water quality management in the SPROWG study area.

There are substantial limitations to the level of analysis that could be performed within the scope and budget constraints of the SPROWG feasibility study contract.

- Pollutant loads have not been estimated, as that would require a detailed analysis of surface and groundwater inflows to the South Platte, including its tributaries, and analysis of all available water quality monitoring data.
- Impacts of specific industries or agricultural sites have not been quantified. The presence of feedlots and other intensive agricultural operations such as processing plants in the study area could have a significant impact on South Platte River water quality, and addressing pollutant contributions from these sites could have a substantial beneficial effect on river water quality if they are not already addressed through water quality management plans. These types of sites typically have their own environmental permits from Colorado Department of Public Health and Environment that require management of surface water and/or groundwater flows from the site. Costs of any ongoing management practices at these sites have not been included in the BMP cost analysis in this TM.
- The entire Denver Metro Area contributes stormwater runoff to the study area. The impact of stormwater discharges on river water quality from this large urban area, most of which is outside the 5-mile buffer adopted for this analysis, was not assessed. Runoff from this area is managed under the Municipal Separate Storm Sewer System (MS4) permits for Denver Metro Area municipalities, which implement stormwater quality management practices in their jurisdictions. The impact of those measures on South Platte River water quality as far downstream as the potential SPROWG diversion points is not known.
- High-level conceptual assumptions have been made for extent of BMP deployment, BMP implementation costs, and pollutant removal effectiveness.

Section 4: Summary

Nonpoint source control methods were considered at a conceptual level and evaluated for their potential costs and benefits related to addressing water quality concerns for SPROWG municipal water providers. Nonpoint source BMPs applied to agricultural, urban, and range land in the South Platte basin could play a part in managing water quality for key constituents at potential SPROWG diversion points and in SPROWG reservoirs. While likely not capable of being a cost-effective or technically reliable substitute for the level of water treatment required by municipal water users, nonpoint source programs could be an effective companion strategy that reduces treatment costs and improves environmental conditions in the South Platte River. Although implementation, maintenance and funding of nonpoint source measures is traditionally the responsibility of private landowners, financing programs are available at the state and federal level to offset some of these costs. In addition, pollutant trading strategies allowed in Colorado could provide an incentive for public agencies participating in the SPROWG Concept to invest in nonpoint source BMPs in lieu of investing in additional wastewater treatment or other point source treatment.

Further studies of potential nonpoint source management options related to the SPROWG Concept could include the following.

- Investigation of hot spots for particular constituents of concern (e.g., TDS, nutrients), and the benefits and costs of focusing nonpoint source measures on those areas.
- Analysis of pollutant loads in the lower South Platte River and refined estimates of pollutant reductions achievable by BMPs commonly applied on irrigated agricultural lands.
- Study of the potential reduction in water treatment costs if nonpoint source controls were applied throughout the watershed.
- Study of the relative impact of agricultural and urban land use contributions to South Platte River pollutants in the SPROWG study area to determine where nonpoint controls could have the most benefit.
- Case studies or conceptual outlines of how a pollutant trading approach could benefit SPROWG participants who contribute to implementing nonpoint source programs.

References

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Urban Drainage and Flood Control District, *Urban Storm Drainage Criteria Manual: Volume 3 Best Management Practices*, November 2010*,*

Attachment A: BMP Effectiveness Table

BMP	Contaminant	% Removal Lower Range	% Removal Upper Range	Score Low Range	Score High Range
Bioretention (rain garden)	Total Suspended Solids	78%	90%	4	5
	Fecal Coliforms	N/A	N/A	#N/A	#N/A
	Total Iron	0%	0%	1	1
	Total Zinc	76%	80%	4	5
	Total Nitrogen	8%	16%	1	2
	Total Phoshorus	0%	0%	1	1
Composite	Total Suspended Solids	80%	85%	5	5
	Fecal Coliforms	20%	43%	2	3
	Total Iron	67%	91%	4	5
	Total Zinc	62%	63%	4	4
	Total Nitrogen	12%	48%	2	3
	Total Phoshorus	47%	66%	3	4
Detention Basin	Total Suspended Solids	56%	80%	4	5
	Fecal Coliforms	41%	85%	3	5
	Total Iron	N/A	N/A	#N/A	#N/A
	Total Zinc	55%	72%	4	4
	Total Nitrogen	0%	6%	1	1
	Total Phoshorus	17%	21%	2	2
Grass Strip/Field Borders	Total Suspended Solids	50%	60%	4	4
	Fecal Coliforms	N/A	N/A	#N/A	#N/A
	Total Iron	24%	54%	2	4
	Total Zinc	71%	77%	4	4
	Total Nitrogen	30%	90%	3	5
	Total Phoshorus	0%	50%	1	4
Grass Swale	Total Suspended Solids	0%	32%	1	3
	Fecal Coliforms	9%	23%	1	2
	Total Iron	0%	33%	1	3
	Total Zinc	5%	44%	1	3
	Total Nitrogen	0%	0%	1	1
	Total Phoshorus	0%	0%	1	1
LID	Total Suspended Solids	6%	49%	1	3
	Fecal Coliforms	N/A	N/A	#N/A	#N/A
	Total Iron	N/A	N/A	#N/A	#N/A
	Totoal Zinc	N/A	N/A	#N/A	#N/A
	Total Nitrogen	N/A	N/A	#N/A	#N/A
	Total Phoshorus	N/A	N/A	#N/A	#N/A
Media Filter	Total Suspended Solids	81%	84%	5	5
	Fecal Coliforms	44%	73%	3	4
	Total Iron	58%	67%	4	4
	Total Zinc	78%	82%	4	5
	Total Nitrogen	8%	84%	1	5
	Total Phoshorus	40%	43%	3	3
Porous Pavement	Total Suspended Solids	59%	78%	4	4
	Fecal Coliforms	N/A	N/A	#N/A	#N/A
	Total Iron	N/A	N/A	#N/A	#N/A
	Total Zinc	71%	89%	4	5
	Total Nitrogen	N/A	N/A	#N/A	#N/A
	Total Phoshorus	42%	44%	3	3
Retention Pond	Total Suspended Solids	71%	80%	4	5
	Fecal Coliforms	59%	83%	4	5
	Total Iron	61%	75%	4	4
	Total Zinc	55%	61%	4	4
	Total Nitrogen	0%	75%	1	4
	Total Phoshorus	52%	56%	4	4
Wetland Basin	Total Suspended Solids	55%	64%	4	4
	Fecal Coliforms	69%	93%	4	5
	Total Iron	39%	60%	3	4
	Total Zinc	58%	66%	4	4
	Total Nitrogen	23%	69%	2	4
	Total Phoshorus	19%	30%	2	3
Wetland/Retention Pond	Total Suspended Solids	68%	73%	4	4
	Fecal Coliforms	63%	87%	4	5
	Total Iron	N/A	N/A	#N/A	#N/A
	Total Zinc	56%	63%	4	4
	Total Nitrogen	23%	63%	2	4
	Total Phoshorus	42%	44%	3	3
Wetland Channel	Total Suspended Solids	23%	59%	2	4
	Fecal Coliforms	0%	51%	1	4
	Total Iron	N/A	N/A	#N/A	#N/A
	Total Zinc	32%	50%	3	4
	Total Nitrogen	23%	69%	2	4
	Total Phoshorus	9%	14%	1	2

BMP	Contaminant	% Removal Lower Range	% Removal Upper Range	Score Low Range	Score High Range
Nutrient Management	Total Suspended Solids	N/A	N/A	#N/A	#N/A
	Fecal Coliforms	N/A	N/A	#N/A	#N/A
	Total Iron	N/A	N/A	#N/A	#N/A
	Total Zinc	N/A	N/A	#N/A	#N/A
	Total Nitrogen	20%	90%	2	5
	Total Phoshorus	20%	90%	2	5
Level Terraces	Total Suspended Solids	90%	90%	5	5
	Fecal Coliforms	N/A	N/A	#N/A	#N/A
	Total Iron	N/A	N/A	#N/A	#N/A
	Total Zinc	N/A	N/A	#N/A	#N/A
	Total Nitrogen	30%	70%	3	4
	Total Phoshorus	30%	70%	3	4
Diversion Structures around erodable soils	Total Suspended Solids	30%	70%	3	4
	Fecal Coliforms	N/A	N/A	#N/A	#N/A
	Total Iron	N/A	N/A	#N/A	#N/A
	Total Zinc	N/A	N/A	#N/A	#N/A
	Total Nitrogen	20%	45%	2	3
	Total Phoshorus	20%	45%	2	3
Grade Stablization	Total Suspended Solids	5%	75%	1	4
	Fecal Coliforms	N/A	N/A	#N/A	#N/A
	Total Iron	N/A	N/A	#N/A	#N/A
	Total Zinc	N/A	N/A	#N/A	#N/A
	Total Nitrogen	N/A	N/A	#N/A	#N/A
	Total Phoshorus	N/A	N/A	#N/A	#N/A
Animal Waste Storage	Total Suspended Solids	64%	64%	4	4
	Fecal Coliforms	74%	74%	4	4
	Total Iron	N/A	N/A	#N/A	#N/A
	Total Zinc	N/A	N/A	#N/A	#N/A
	Total Nitrogen	32%	91%	3	5
	Total Phoshorus	10%	69%	1	4
Livestock Exclusion	Total Suspended Solids	50%	90%	4	5
	Fecal Coliforms	30%	70%	3	4
	Total Iron	N/A	N/A	#N/A	#N/A
	Total Zinc	N/A	N/A	#N/A	#N/A
	Total Nitrogen	N/A	N/A	#N/A	#N/A
	Total Phoshorus	50%	90%	4	5
Riparian Buffer Zones	Total Suspended Solids	80%	90%	5	5
	Fecal Coliforms	N/A	N/A	#N/A	#N/A
	Total Iron	N/A	N/A	#N/A	#N/A
	Total Zinc	N/A	N/A	#N/A	#N/A
	Total Nitrogen	60%	90%	4	5
	Total Phoshorus	50%	75%	4	4
Irrigation Water Management	Total Suspended Solids	50%	50%	4	4
	Fecal Coliforms	N/A	N/A	#N/A	#N/A
	Total Iron	N/A	N/A	#N/A	#N/A
	Total Zinc	N/A	N/A	#N/A	#N/A
	Total Nitrogen	N/A	N/A	#N/A	#N/A
	Total Phoshorus	N/A	N/A	#N/A	#N/A
Streambank Stabilization	Total Suspended Solids	80%	80%	5	5
	Fecal Coliforms	N/A	N/A	#N/A	#N/A
	Total Iron	N/A	N/A	#N/A	#N/A
	Total Zinc	N/A	N/A	#N/A	#N/A
	Total Nitrogen	60%	90%	4	5
	Total Phoshorus	30%	90%	3	5

Attachment B: BMP Cost Data

BMP	Assumptions	Approximate Cost (Lower Range)	Approximate Cost (Upper Range)2	Units	Conversion to Acres	Additional Notes	Sources	Cost Per Acre	Application (% of Total Acreage)
Bioretention (rain garden)	average density of plants in typical rain garden	$ 3.00	$ 4.00	$ per square foot	43560	vary depending on soil conditions, density and types of plants used Bioretention should not be used in areas: — With mature trees; — With slopes greater than 20 percent; — With a water table within 6 feet of the land surface; — With easily erodible soils; — Below outfalls; — Where concentrated flows are discharged; or — Where excavation or cutting will occur.	www.lid-stormwater.net	$ 152,460.00	3.0%
Composite	Assume an average of diversion structures, riparian buffer zones, and grass swale	$ 12.00	$ 23.40	$ per cubic yard	4840	Assume 1 yd deep	Same sources as the BMPs referenced in the assumptions	$ 85,668.00	5.0%
Detention Basin	According to EPA, cost for wet detention pond range from .50-1.00$ per cubic foot and dry detention basins cost .15$-.30$ per cubic foot	$ 0.15	$ 1.00	$ per square foot	43560		nrcsolutions.org	$ 25,047.00	1.0%
Grass Strip/Field Borders	dollar range is from seeding to turf	$ 0.06	$ 33.00	$ per square foot	43560		seeding promatcher.com & home depot	$ 5,227.20	2.0%
Grass Swale	Shallow trench with back hoe not requiring dewatering for 5-6$ per cubic yard of removed material. Assuming no disposal costs, an additional; 3$ cubic foot is added for fine grading, soil treatment, and grassing (RS Means); assume average flow depth of 1 ft/sec +1$ per square foot for installation	$ 7.00	$ 8.00	$ per cubic yard	4840		Construction Site Erosion and Sediment Controls: Planning, Design, and Construction by Robert Pitt et al	$ 36,300.00	2.0%
LID	Assuming an average of Grass/Fields Borders, Porous Pavement, and bioretention	$ 2.70	$ 16.00	$ per square foot	43560		Same sources as the BMPs referenced in the assumptions	$ 407,286.00	3.0%
Media Filter	Organic media filter: two types peat/sand filter and a compost filter; increase cation exchange capacity; aassume 3" of topsoil, followed by a 50/50 peat & sand mixture, and the followed by 6" of sand. Lastly the bottom layer will be 6" of perforated pipe & gravel underdrain system. (See bottom from schmatic used for this cost estimate by the EPA). Filters can handle up to 5,500 (m3) in water volume for a particular storm event or up to approximately 100 acres	$ 5,000.00	$ 7,000.00	per unit (assuming use for 100 acres^2)	1	Intermittent media filters might become clogged as the pore space between the grains of the medium begins to fill with excessive amounts of inert biological materials. Resting the filter for several months in warm weather will restore hydraulic conductivity (Tyler et al., 1985). Free access filters should be checked every three to four months to prevent surface problems. So there will be	EPA: https://www.epa.gov/sites/production/files/2015-09/documents/urban_guidance_0.pdf pages:335-361 https://secure.in.gov/indot/files/Cost_and_Pollutant_Removal_of_Storm_Water.pdf	$ 6,000.00	5.0%
Porous Pavement	average materials used; implementation and material considered in this cost	$ 3.50	$ 7.00	$ per square foot	43560		wisconsin transportation synthesis report	$ 228,690.00	1.0%
Retention Pond	Assume same as detetnion pond. According to EPA, cost for wet detention pond range from .50-1.00$ per cubic foot and dry detention basins cost .15$-.30$ per cubic foot	$ 0.15	$ 1.00	$ per square foot	43560		nrcsolutions.org	$ 25,047.00	3.0%
Wetland Basin	5-6$ excavation per cubic yard for soil not needing dewatering (RS Means) and 700$per acre for water based seeding (RS Means)	$ 5.50	$ 6.50	$ per cubic yard	4840		Construction Site Erosion and Sediment Controls: Planning, Design, and Construction by Robert Pitt et al; RS Means	$ 29,040.00	4.0%
Wetland/Retention Pond	5-6$ excavation per cubic yard for soil not needing dewatering (RS Means) and 700$per acre for water based seeding (RS Means)	$ 5.50	$ 6.50	$ per cubic yard	4840		Construction Site Erosion and Sediment Controls: Planning, Design, and Construction by Robert Pitt et al; RS Means	$ 29,040.00	3.0%
Wetland Channel	5-6$ excavation per cubic yard for soil not needing dewatering (RS Means) and 700$per acre for water based seeding (RS Means)	$ 5.50	$ 6.50	$ per cubic yard	4840		Construction Site Erosion and Sediment Controls: Planning, Design, and Construction by Robert Pitt et al; RS Means	$ 29,040.00	1.5%

BMP	Assumptions	Approximate Cost (Lower Range)	Approximate Cost (Upper Range)2	Units	Conversion to Acres	Additional Notes	Sources	Cost Per Acre	Application (% of Total Acreage)
Nutrient Management	This practice is source removal, and not a treatment. Regulation 85 from the state of Colorado will begin enforcing nutrient pollution from point sources in 2022. (Not farmers yet). Classes are available for the public on BMPs to use through the CSU Extention Office. Possible costs to consider may be if the client would like to sponsor farm managers in area to take the classes.	$ 12.00	$ 15.00	$ per acre	1	Enforceability is something to be considered; and if a cost is to be applied or is reasonable. Cost is from Colorado Nutrient Management Practices: 1997-2011 publication	http://coagnutrients.colostate.edu/ag-best-management-practices/nutrient-fertilizer-managment/ "Colorado Nutrient Management Practices: 1997-2011", Colorado State University, October 2011	$ 13.50	50.0%
Level Terrances	Breaking up steep continuous 2:1 slope with a series of flat 10' wide vegetated steps (700$ per acre for water based seeding (RS Means) therefore $0.02/SF) with an assumed 1' thick 5' high concrete wall ($75/SF); Grading Cost ($40/CY = $1.50/CF) average excavation/fill 5'	$ 385.00	$ 385.00	$ per linear foot	208 linear feet per acre		concretenetwork.com	$ 80,080.00	3.0%
Diversion Structures around erodable soils	Small canal; Shallow trench with back hoe not requiring dewatering for 5-6$ per cubic yard of removed material. Assuming no disposal costs, an additional; 2$ cubic foot is added for fine grading, soil treatment, and overall construction costs	$ 7.00	$ 8.00	$ per cubic foot	43560		Construction Site Erosion and Sediment Controls: Planning, Design, and Construction by Robert Pitt et al; RS Means	$ 326,700.00	1.0%
Grade Stablization	Riprap in Northern Colorado area; material as well as installation	$ 69.00	$ 86.00	$ per square yard	4840		CEI cost calculation sheet for Tollgate creek project	$ 375,100.00	2.0%
Animal Waste Storage	Storage Volume large enough to store manure over winter. Assume SOLID waste from non poultry with 180 days of storage. Animal Storage Waste volume = [avg. # livestock per farm in NoCo* avg. vol waste aquired per cow per day*180 days]* safety factor of 1.5 For a 150-AU herd, the relative size of a solid storage pad would be 1,600 square feet. The storage cost for a typical storage house was based on a 1,600 square foot timber shed with end bays, push walls, and a concrete floor.(includes minor grading and shaping required, forming, cost of concrete, and labor) Cost per ton = 3.50$ for non-poultry.	31562.5	Base cost=12400$ for shed, + 3.50$per ton	per facility	1 unit per 3 acres	If farmer has additional land they are applying the stored manure to, they can get a more precise calculation of storage volume needed and save money by subtracting the amount that is needed to be applied (or that is sold), from the yearly storage volume (safety factor included). Farms that would like to handle waste in liquid or slurry form, (best for larger farms) for conveyance and application, pumps and conveyance costs may need to be considered, where operational costs are low excluding fuel for pumps, whereas maintenence costs may vary and can be high if there is poor management present. Pumps can be rented for approximately 17.50$ an hour if desired. For poultry, storage costs double per ton becasue the required storage period doubles. Assuming average feed lot of 300 animals with each animal producing 100 lbs of waste per day for 1 year. Base cost=12400$ for shed, + 3.50$per ton. Each facilty is 3 acres.	https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_012400.pdf	$ 31,562.50	20.0%
Livestock Exclusion	For grazing livestock only; Woven/barbed wire fencing: 1.63$/ foot (labor equipment included);portable fencing: 18-32$/foot	$ 1.63	$ 32.00	per foot	210	can use permanent or temporary fencing	https://www.extension.iastate.edu/agdm/livestock/html/b1-75.html	$ 3,531.15	
Riparian Buffer Zones	Seed, mulch, plantings, willow matts for Northern Colorado pricing	$ 22.00	$ 54.00	per cubic yard	4840		Robinson Gulch Stream Stabilization Contractor Bid Form	$ 183,920.00	1.0%
Irrigation Water Management	This practice is source removal. Includes irrigation scheduling, weather meters and tracking, soil water testing, etc. Classes as well as online tools are offered through the CSU extention office for those interested in learning the BMPS or Irrigation Water Management	$ 10.00	$ 15.00	per acre per year	1	Cost is a guesstimate based on nutrient management nonstructural costs.	https://extension.colostate.edu/topic-areas/water/	$ 12.50	75.0%
Streambank Stabilization	Willow matts and brush toe implementations for small to medium stream systems. Northern colorado price estimates from construction of the Tollgate Streambank stabilization project in Denver= 3,028,000$ (including materials, construction, permits, and implementation) over 2.4 miles of stream.	$ 238.00	$ 238.00	per foot of stream (Width, length, and depth)	208 linear feet per acre	Cost will be significantly lower due to the tollgate creek project being in urban area which inflates some prices 2-3 times their original prices due to complications in implementation in an urban area	CEI cost calculation sheet for Tollgate creek project	$ 49,504.00	1.0%