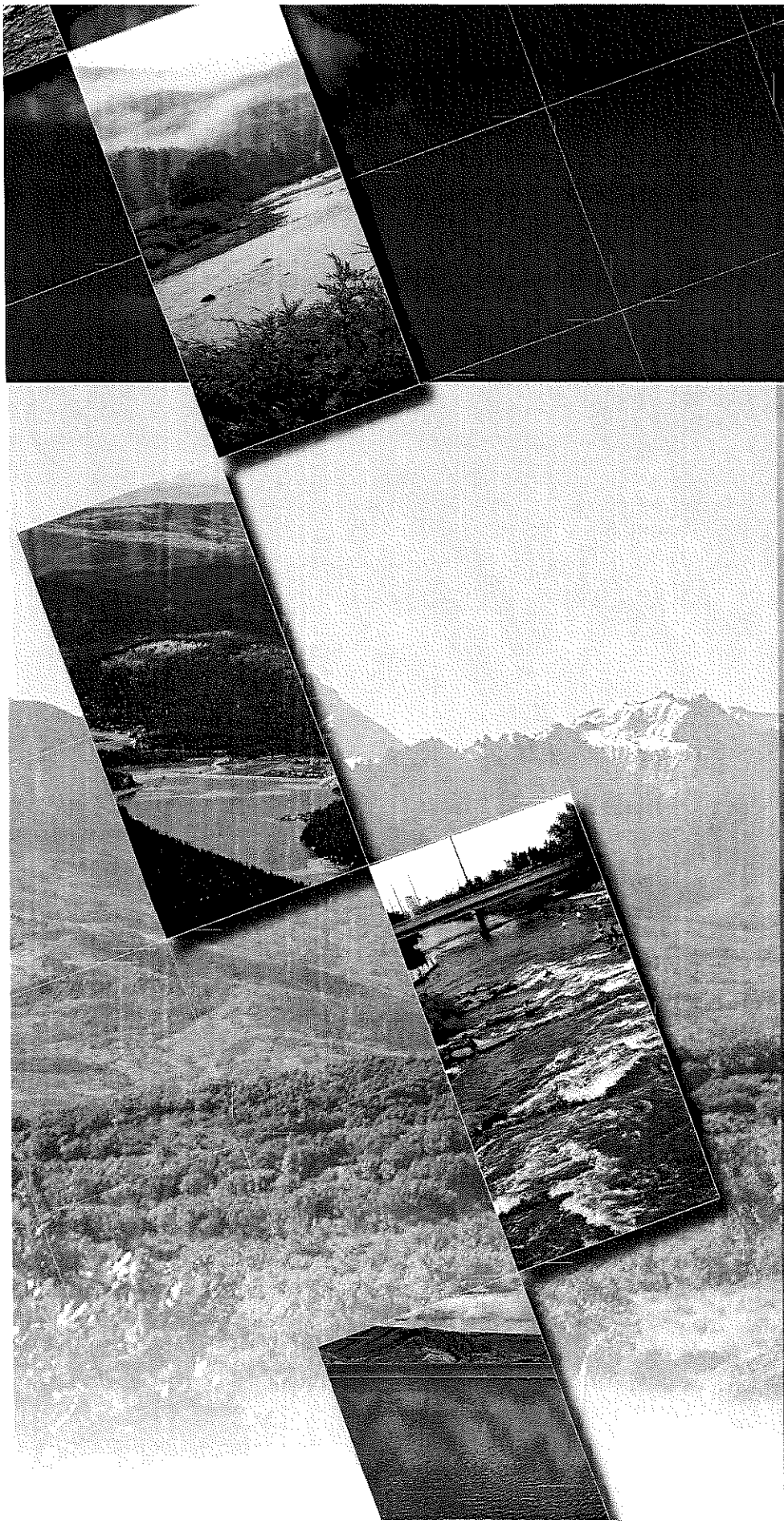


Report

Cost/Benefit Study of the Impacts of Potential Nutrient Controls for Colorado Point Source Discharges

December 2011

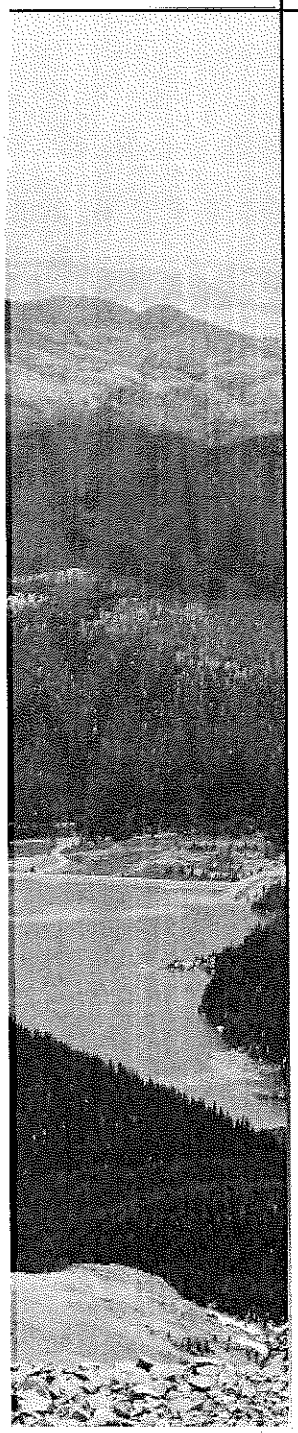
CDM Smith

RISK SCIENCES

On behalf of

Colorado Department of Public Health and Environment

Colorado Water Resources & Power Development Authority



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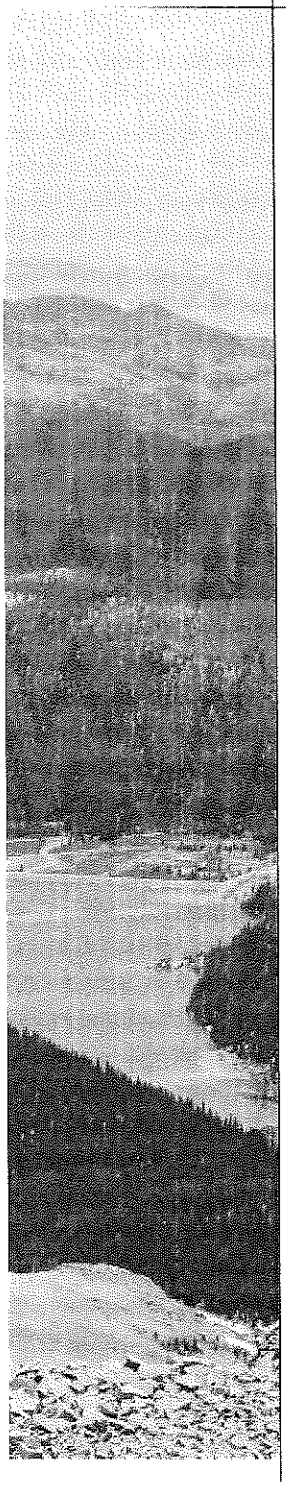
Acronyms

µg/L	micrograms per liter
ADF	average daily flow
AOP	Advanced Oxidation Processes
Authority	Colorado Water Resources and Power Development Authority
BMP	best management practice
BNR	biological nutrient removal
BOD	biochemical oxygen demand
CDOT	Colorado Department of Transportation
CDOW	Colorado Division of Wildlife
CDPHE	Colorado Department of Public Health and Environment
CDPS	Colorado Department of Public Safety
CH_4	methane
CO_2	carbon dioxide
Commission	Water Quality Control Commission
CSC	Colorado Stormwater Council
CWA	Clean Water Act
CWNS	Clean Watershed Needs Survey
CWQF	Colorado Water Quality Forum
CWWUC	Colorado Wastewater Utility Council
D/DBP	Disinfection/Disinfection Byproduct
DADR	Discharge Assessment Data Report
DBP	Disinfection Byproduct
Division	CDPHE Water Quality Control Division
DOLA	Department of Local Affairs
DUWS	Direct Use Water Supply Lakes and Reservoirs
EDU	Environmental Data Unit
EMC	Event Mean Concentration
ENR	Engineering News Record
EPA	Environmental Protection Agency
ESRI	Environmental Systems Research Institute
GHG	Greenhouse Gas
GIS	geographic information system
gpd	gallons per day
gpd/sf	gallons per day per square foot
GWP	global warming potential
HAA5	five haloacetic acids
HUCs	Hydrologic Unit Codes
IFAS	integrated fixed-film activated sludge
kWh	kilowatt hour
kWh/lb	kilowatt hour per pound
LGOP	Local Government Operations Protocol
LRAA	locational running annual average
MBBR	moving bed-bioreactor

MCLs	Maximum Contaminant Levels
mg/L	milligrams per liter
mg/m^2	milligram per square meter
mgd	million gallons per day
MLSS	mixed liquor suspended solids
MMI	Multi-Metric Index
MRLC	Multi-resolution Land Characteristics Consortium
MS	Municipal Screener
MS4	municipal separate storm sewer system
MWRD	Metro Wastewater Reclamation District
N_2O	nitrous oxide
NDMA	N-Nitroso-Dimethylamine
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NO_2	nitrite
NO_3	nitrate
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
O_3	ozone
PF	peaking factor
ppd	pound per day
RAS	Return Activated Sludge
RBC	rotating biological contactors
RFP	Request for Proposal
RO	reverse osmosis
SBR	sequencing biological reactors
SCORP	Statewide Comprehensive Outdoor Recreation Plan
SDWA	Safe Drinking Water Act
SIC	Standard Industrial Code
SRT	solids retention time
STORET	EPA Storage and Retrieval
Study	Cost Benefit Study
SVI	Sludge Volume Index
SWAP	Source Water Assessment and Protection
SWSI	Statewide Water Supply Initiative
TDS	total dissolved solids
TIN	total inorganic nitrogen
TKN	total kjeldahl nitrogen
TMDL	Total Maximum Daily Load
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
TTHM	total trihalomethanes
UCCWA	Upper Clear Creek Watershed Association
USACE	U.S. Army Corps of Engineers

USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UV	ultraviolet
WAS	Waste Activated Sludge
WERF	Water Environment Research Foundation
WLA	Waste Load Allocation
WPCR	Watershed Protection Control Regulation
WPCRF	Water Pollution Control Revolving Fund
WTP	willingness-to-pay
WWTFs	wastewater treatment facilities

Section 1
Executive Summary



1.1 Study Goals and Objectives

The Colorado Department of Health and Environment (CDPHE) Water Quality Control Division (Division) is developing an approach to manage nutrients in Colorado waters. The primary driver for this effort has been an Environmental Protection Agency (EPA) directive to reduce nutrients in waters under jurisdiction of the federal Clean Water Act (CWA). Originally, the Division developed a nutrient management approach based solely on the establishment of numeric criteria to protect uses. In 2010, the Division revised its approach to shift its emphasis from the adoption of numeric criteria to the establishment of technology-based controls on facilities that discharge nutrients to Colorado waters.

The Division's proposal to control the discharge of nutrients relies largely on a technology-based control regulation that would establish effluent limits for both total phosphorus (TP) and total inorganic nitrogen (TIN) for many domestic and some nondomestic wastewater treatment facilities (WWTFs). WWTFs that become subject to the control regulation will have to invest in capital improvements and ongoing operation and maintenance (O&M) costs.

The Colorado Water Resources and Power Development Authority (Authority) and the Division are co-administrators of the Colorado Water Pollution Control Revolving Fund (WPCRF), a state revolving fund that provides low interest capital funding to governmental agency sponsors of water quality improvement projects. Because adoption of the proposed regulations would impact the WPCRF, for strategic planning purposes, the Authority and the Division wanted to quantify future infrastructure needs and future loan demands on the WPCRF related to potential future nutrient controls. The Authority requested and the Division agreed to prepare a statewide cost-benefit analysis (Study) related to the potential promulgation of regulations for nutrient control in order to provide the information necessary to better understand the merits of the proposed regulation and potential requirements that would be placed on the WPCRF. The Study results will be used as part of the evidence examined by the Water Quality Control Commission (Commission) when it holds a rule-making hearing to evaluate the Division's regulatory proposal.

Therefore, the goal of this Study is to inform the Division, Authority, Commission, and other interests of the statewide implications of the Division's proposed nutrient control regulations. To achieve this goal, the Study focused on three objectives:

- Estimate the statewide aggregate costs resulting from the potential implementation of a range of statewide regulations to address nutrients and impacts from any requirements for stormwater monitoring;
- Estimate the environmental benefit of implementation of those nutrient regulations; and
- Estimate the benefit to drinking water quality and any reduced treatment costs for drinking water.

The state might have selected a number of different types of impact studies to evaluate the proposed regulations, but the pursuit of a cost-benefit analysis is the appropriate study type, given the questions at hand and the present stage of deliberation. This Study attempts to answer threshold questions that are pertinent at this point in the deliberative process: (1) Are the potential public health and environmental benefits sufficient to justify the likely costs for establishing nutrient controls; and (2) Are there other levels of regulation that would be more justified?

1.1.1 Regulatory Proposal

The Division proposes to manage nutrients being discharged from point sources on a statewide basis, through adoption of a new regulation (5 CCR 1002-85 ["Regulation #85"]) and amendment of an existing regulation (5 CCR 1002-31 ["Regulation #31"]) through the addition of Sections 31.13 (d) and 31.17. The Division published the first draft of these proposed regulations on February 2, 2011. Following continuing discussions with stakeholders, the Division released revised regulatory proposals on July 5, September 30, and November 2, 2011. The Division's current proposal was published on November 21, 2011 as part of the Notice of Public Rulemaking Hearing. This proposal provides the basis of this Study.

Proposed Regulation #85 establishes effluent limitations for certain existing domestic and non-domestic WWTFs and new WWTFs (collectively referred to as "non-exempt WWTFs") (Table 1-1). These limitations would only apply where existing information indicates that the facility's effluent discharge contains nutrients at concentrations in excess of the effluent limitations. Some WWTFs are excluded from the effluent limitations presented in Table 1-1. The Study did not include any existing domestic WWTF that meets at least one of the following exclusions:

- WWTFs with a design capacity of less than or equal to 1.0 million gallons per day (mgd) that use waste stabilization pond (lagoon) technology as its means of treating wastewater
- Any WWTF owned by a disadvantaged community
- WWTFs with a design capacity of less than or equal to 0.5 mgd

Table 1-1: Summary of Proposed Effluent Limits (mg/L) for Domestic and Non-Domestic WWTFs Subject to Proposed Regulation #85 (Novembe 21, 2011 Regulatory Proposal)

Facility Type	Discharge Status	Parameter	Annual Median[1]	95th Percentile[2]
Domestic WWTFs	Existing (discharging prior to May 31, 2012)[3]	Total Phosphorus	1.0	2.5 mg/L
		Total Inorganic Nitrogen as N[4]	10.0	20 mg/L
	New (discharging on or after May 31, 2012)	Total Phosphorus	0.7	1.75 mg/L
		Total Inorganic Nitrogen as N[4]	7.0	14 mg/L
Non-Domestic WWTFs	Existing (discharging prior to May 31, 2013)	Total Phosphorus	1.0	2.5 mg/L
		Total Inorganic Nitrogen as N[4]	10.0	20 mg/L
	New (discharging on or after May 31, 2013)	Total Phosphorus	0.7	1.75 mg/L
		Total Inorganic Nitrogen as N[4]	7.0	14 mg/L

[1] Running Annual Median: The median of all samples taken in the most recent 12 calendar months
[2] The 95th percentile of all samples taken in the most recent 12 calendar months
[3] Including WWTFs for which a complete request for preliminary effluent limits has been submitted to the Division prior to May 31, 2012
[4] Determined as the sum of nitrate as N, nitrite as N, and ammonia as N

1.1.2 Study Questions

A cost-benefit study is, by its very nature, a high level planning analysis. Its primary use is to provide comparative data to evaluate the justification for various policy alternatives. In this Study, the costs and benefits associated with the combined implementation of both TP and TIN technology-based controls formed the basis of the comparison. This approach was required given that the proposed regulations, which form the basis for this Study, would require both TP and TIN controls to be implemented in tandem, not separately. Accordingly, for the purposes of this Study, the project team assumed that compliance with both TP and TIN effluent limitations would be required.

The Division's November 21st regulatory proposal provides the baseline for this Study. As described above, these proposed regulations establish two potential tiers of nutrient effluent limits – one for existing WWTFs (Tier 1) subject to the proposed regulation; the other for new WWTFs (Tier 2). The Division requested the inclusion of a third tier (Tier 3) in the analysis to provide a contrast between the effluent limitations proposed in Regulation #85 and effluent limitations that could be required if the Commission were to adopt numeric nutrient criteria to protect classified uses (as originally proposed for adoption by the Division in 2010). This Study included analysis of all three tiers, with the assumption that all non-exempt WWTFs would need to comply either with Tier 1, Tier 2, *or* Tier 3 effluent limitations (Table 1-2).

Table 1-2. Effluent Limitation (Tiers 1, 2, or 3) that Provide the Baseline for the Cost-Benefit Study

Parameter	Tier1[1] (Annual Median)	Tier2[2] (Annual Median)	Tier3[3] (Quarterly Average)
Total Phosphorus	1.0 mg/L	0.7 mg/L	0.11 (Cold) 0.16 (Warm)
Total Inorganic Nitrogen as N	10 mg/L	7 mg/L	0.4 (Cold) 2.0 (Warm)

[1] November 21, 2011 Division proposal for existing WWTFs subject to the proposed regulations
[2] – November 21, 2011 Division proposal for new WWTFs subject to the proposed regulations
[3] Criteria based on Division analysis of nutrient water quality data; similar to criteria originally considered for adoption to protect classified uses in Colorado waters.

1.2 Project Methodology

As noted above, this cost-benefit analysis is a high level planning Study to guide policy makers on the adoption of statewide nutrient control alternatives for simultaneous implementation of both TP and TIN controls. It is not intended to be a facility-specific analysis and does not evaluate costs or benefits of implementation of only TP or TIN controls at any one facility. The Study does not evaluate financial impact, funding availability, or ability-to-pay. Instead, the Study estimates the direct statewide cost (including both capital and O&M costs) to upgrade existing WWTFs. It does not address the issue of how any given community would pay for such improvements or the expected effect on future sewer rates. As such, this Study is not an economic impact analysis. Indirect effects, such as impacts to the tourism industry, effects of reduced disposable income, or potential for construction stimulus were not examined. Finally, this Study only evaluated potential benefits of the implementation of point source controls at domestic and non-domestic WWTFs. Potential benefits of nutrient reductions from nonpoint sources were not analyzed. The proposed nutrient management program does not mandate nonpoint source controls.

1.2.1 Methodology Framework

The starting point for cost-benefit studies is the adoption of an accounting stance. That is, will benefits and costs be considered at the national, state, or local level? Because the regulatory decision occurs at the state level, that is the accounting stance adopted in this Study. Therefore, all costs and all benefits occurring

within state boundaries are estimated as closely as possible. Any potential benefits from the nutrient regulations potentially experienced by downstream users in other states are not included in this Study.

Figure 1-1 illustrates the methodology framework applied to this Study, beginning with the establishment of Manageable Units. These geographic units were devised by the project team to facilitate development of region-specific cost-benefit models that provide an opportunity to account for regional differences, including differences in degree of urbanization, WWTF facility type and size, opportunities for recreation and enjoyment of the environment, and socio-economic status. One immediate benefit of this approach is increased accuracy of aggregated statewide results. Benefits and costs are estimated first at the Manageable Unit level and then aggregated to the river basin and state level. This approach provides the opportunity to demonstrate the range in benefit-cost relationships that exist throughout the State of Colorado.

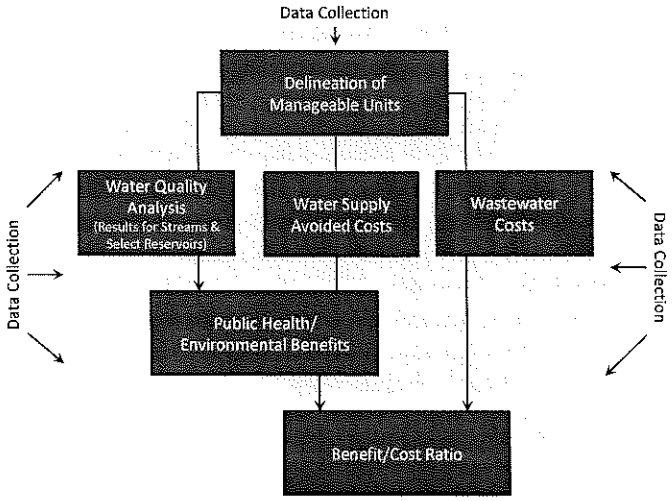


Figure 1-1. Framework for Development of Costs and Benefits

Potential secondary benefits of this approach include illustration of geographic differences in costs and benefits and having information presented in a format that can inform regional decision-making, in particular with regards to basin planning. For each of the framework components, e.g., wastewater costs or public health/environmental benefits, a specific methodology was developed, tested, and refined through the use of pilot tests before it was applied statewide.

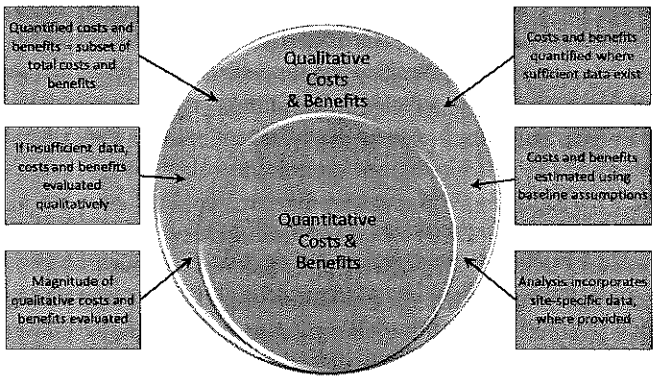


Figure 1-2. Quantitative Results are a Subset of Overall Costs and Benefits

Study results include both quantitative and qualitative components (Figure 1-2). Quantitative results were developed only where sufficient data exist to support the analysis. Where data were insufficient, results were expressed qualitatively. The lack of quantification of a particular cost or benefit element does not diminish the importance of the element. Instead, the findings of this Study should be viewed within the following context: Quantified costs and benefits, presented in the form of a benefit-cost ratio, represent a subset of the larger universe of combined quantitative and qualitative benefits.

1.2.2 Project Data Sources

This Study largely relied on data existing at the time that the Study was initiated. The project team compiled water resources data and digital data layers from state and federal agencies to support key project elements, e.g., delineation of Manageable Units, characterization of WWTFs, location of water supply facilities, and preparation of water quality analyses. State and federal data, especially WWTF data, were supplemented by information provided by the Colorado Wastewater Utility Council, wastewater survey data collected as part of this Study, and site-specific information provided by stakeholders. Additional data sources incorporated, where appropriate, included information obtained from the published literature and industry trade information. Information to support benefits analyses were obtained primarily from the published literature and reports prepared by state agencies.

1.2.3 Manageable Units

The primary purpose for delineating Manageable Units was to create watershed areas small enough to reduce the complexity of cost-benefit analyses. The Manageable Unit delineation process began with the division of the state into its eight major basin areas: South Platte, North Platte, Arkansas, Rio Grande, Southwest, Gunnison, Colorado, and Yampa-White (Green). Given the small size of the North Platte River Basin, this basin was joined with the South Platte River Basin to create a Platte River Basin, resulting in a total of seven basins for further delineation. Each river basin was sub-divided as appropriate into Manageable Units based on factors such as the locations and numbers of point source discharges and the location of water supply intakes. In total, the Study delineated 27 Manageable Units (see Figure 3-2, for example).

The use of Manageable Units as the foundation for data analysis provided the opportunity to perform pilot tests on the methodology. Early in the Study two Manageable Units were selected for pilot tests: One along the Front Range (East Slope watershed) and one West Slope watershed. Based on the pilot test outcome and stakeholder comments, the methodology was refined before it was universally applied.

1.2.4 Water Quality Analysis

The project team completed analyses of existing water quality in each of the 27 Manageable Units. This effort estimated expected changes in water quality (both TP and TIN) if the proposed regulations were implemented at all non-exempt WWTFs and compliance with Tier 1, 2, or 3 effluent limits was achieved. Water quality analyses relied on available water quality data using standard modeling practices. Where insufficient data were available to estimate water quality benefits, no attempt was made to quantify expected water quality benefits. This outcome was common for many reservoirs and lakes, due to the paucity of data. Where the team could not quantify water quality benefits for lakes or reservoirs downstream of a non-exempt WWTF, these benefits are considered within the context of qualitative benefits.

1.2.5 Wastewater Costs

There are over 400 domestic and non-domestic WWTFs located throughout Colorado; accordingly, the project team developed an approach that involved creating a baseline "typical" WWTF that could be "adjusted" and "modified" to account for different types of existing WWTF categories and site conditions. An important key to the understanding of this approach and the reported results is that the "typical" facility defined by this Study does not represent any one facility within the state. Instead, the use of a "typical" facility provides a high level cost analysis for comparison to an equally high level benefit analysis. Actual costs for a specific facility would require an independent, site-specific engineering analysis.

Figure 1-3 presents the systematic methodology used for development of WWTF costs for "typical" facilities in each Manageable Unit to meet the three effluent quality tiers analyzed for this Study. The body of the report provides detailed assumptions associated with each of these steps. Consistent with the proposed regulations, this analysis assumed that both TP and TIN controls would be required at each "typical" facility. The outcome from this effort for each effluent tier was used as input to the cost-benefit comparison, as described below.

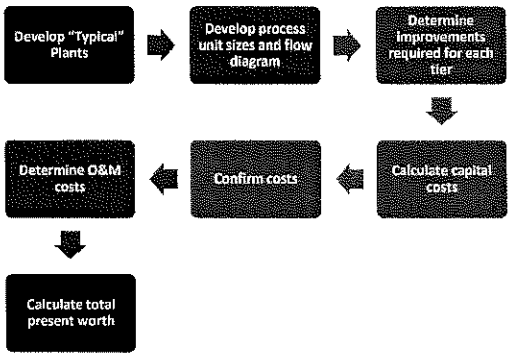


Figure 1-3. Methodology for Wastewater Treatment Cost Development

1.2.6 Public Water Supply Benefits

Where public water supply facilities are downstream of non-exempt WWTFs, reductions in source water nutrient concentrations could provide benefits. For example, benefits could occur because potable water utilities might be able to reduce their future water treatment capital investment costs as a result of reduced nutrients, or if potable water utilities made no such future investments, reduced nutrients in the drinking water supply might improve public health (e.g., reduced Disinfection Byproducts (DBP) and the aesthetic attributes of drinking water, i.e., appearance, odor, and taste.

Potential public water supply benefits were divided into quantitative and qualitative elements. Quantified elements focused on where a direct link could be made between a known water quality concern and the potential for avoided future water supply treatment costs. This linkage could only be demonstrated for requirements to comply with Safe Drinking Water Act (SDWA) regulations, specifically requirements to comply with Stage 1 and 2 Disinfection/Disinfection By-product (D/DBP) regulations.

This Study documents a number of potentially important benefits from reduced nutrients in source waters for public water supply facilities located downstream of non-exempt WWTFs that could not be quantified for various reasons. These qualitative benefits include:

- Nutrient reduction and related reductions in the volume/types of algae (particularly those types known to be toxic) might reduce adverse health effects in people particularly sensitive to those substances.
- Odor, taste, and appearance of water might be improved as a result of lower concentrations of nutrients in waters. Although this is a perceptual issue, it can be very important to water utilities and their customers
- N-Nitroso-Dimethylamine (NDMA) has been identified as an emerging contaminant that can be a DBP associated with water treatment processes. Reductions in nutrients in source water can reduce the likelihood of DBP formation, which would be an important benefit to water supply facilities.

1.2.7 Environmental Benefits

The environmental benefits analysis identifies and estimates, to the extent possible within the Study framework, each of the benefits that could accrue from nutrient reduction in Colorado waters as a result of the proposed regulation. This Study assumes that a reduction in nutrients in waterbodies would result in reduced algae growth, increased dissolved oxygen, betterment in the ecological functions of waterbodies

and their appearance, odor, and taste. By lessening these biological effects, a reduction in nutrients would create a set of avoided costs or benefits associated with the utilization of those waterbodies.

The types of benefits likely to accrue from nutrient reduction include the following:

- *Public Water Supply Benefits* – Public water supply benefits from nutrient reduction would conceivably occur because potable water utilities might be able to reduce their future water treatment capital investment costs as a result of reduced nutrients in their source water. These avoided costs, where they could be quantified, were treated as a benefit.

- *Active Recreational Benefits* – Active uses of Colorado's waterbodies include recreation of different types. With reduced nutrient levels and associated biological processes, direct water recreational uses, e.g., swimming, fishing, and boating activity, would potentially increase. Other recreational endeavors, such as picnicking, scenic drives, and watchable wildlife could also benefit.

- *Passive Benefits* - Passive benefits occur as reduced nutrients result in improved environmental conditions (Figure 1-4). With reduced nutrients, habitat is improved which, in turn, benefits animals, fish, and aquatic invertebrates and may improve the health of the aquatic community.

- *Intrinsic Benefits* – Intrinsic benefits can occur when Colorado residents perceive a value in preserving or enhancing the environment for present or future generations. These values are above and beyond the specific values quantified as passive benefits.

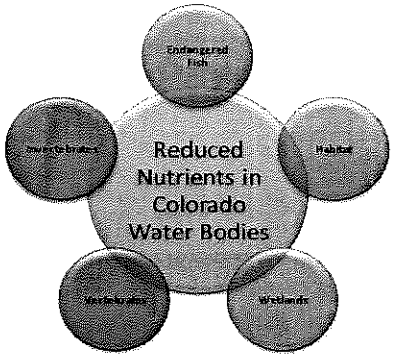


Figure 1-4. Examples of Passive Benefits from Nutrient Reduction

- *Agriculture Benefits* - Additional active water uses include irrigation and animal watering. Potential relationships between nutrient levels in water and agriculture water uses include drinking water quality for livestock, nutrient concentrations in water used for crop irrigation, and vegetation growth in irrigation water conveyances.

Information about the general impacts of nutrients, the specific benefits of nutrient reduction, and the methodological approaches for valuing these benefits were obtained from a search of the relevant literature. This literature review resulted in information being gathered on the following topics:

- The impacts of nutrients in waterbodies upon public health, environmental resources (i.e., water quality, aquatic habitat) and recreational activity;

- Methodological approaches to estimating environmental and recreational benefits, as well as other social or public benefits;

- The potential benefits resulting from the reduction of phosphorus and nitrogen, including studies describing the general benefits of nutrient reduction as well as the benefits of improvements in water quality to specific resources or activities (i.e., fish habitat or swimming activity);

- Methodology for estimating environmental benefits via the application of contingent valuation, or willingness-to-pay (WTP) for environmental improvements;

- Data about current recreational and other economic and demographic activity in Colorado; for example, the number of anglers, boaters, and swimmers; activity days for each; and expenditure data for each activity.

A number of studies were obtained, ranging from qualitative descriptions of the general impacts of nutrients to detailed academic research studies quantifying the benefits of nutrient reduction to specific resources (i.e., recreational activity, property values). Each study was reviewed and screened for usefulness based on factors such as the specific nutrients discussed, the types of recreational activities or environmental resources addressed, geographic location, and currency of the research. In addition to a review of the published literature, this Study also relied on state and federal baseline demographic data (e.g., population, household and income data) from the U.S. Census Bureau and Colorado Department of Local Affairs and various state and county level reports detailing recreational activity.

The project team faced several challenges when gathering data for use in estimating the benefits of the proposed nutrient regulations:

- Although the literature search uncovered a large number of reports, studies, and other types of information regarding the impacts of nutrients and nutrient reduction, there was a lack of applicable studies focusing on Colorado. Where appropriate, the project team made adjustments to the available data from the most relevant studies to better reflect conditions in Colorado.
- Few studies were found that directly link nutrient levels or nutrient reduction to changes in recreational activity. The project team used the available studies to the extent possible, but a number of assumptions were relied upon to estimate recreational benefits.
- Data on recreational activity days for fishing, boating, and swimming were available only at the statewide level (boating and swimming) or the county level (fishing); these data were distributed among the Manageable Units based on a number of reports and assumptions.

1.2.8 Present Worth Analysis

The time period for calculating benefits and costs is an important consideration in this Study. The capital costs of complying with the proposed regulations will occur during the construction years, but the annual WWTF operating costs and benefits will occur after the WWTFs are completed and will continue annually into the future. For the purposes of calculating benefits and costs, it is assumed that the proposed regulations would begin to be implemented within a Manageable Unit by the year 2015, design for WWTF improvements would take place in 2016, and construction would begin in 2017. This Study assumes the operating costs and benefits would last for 20 years. After that time, machinery and equipment at the WWTFs would be nearing the end of their useful life and would need to be replaced or upgraded, which would require additional capital costs.

Since construction costs take place at a different time than benefits, comparison of the two requires a discount back to present value for both benefits and costs. A discount rate is the interest rate that would be required to make a future dollar value equal to a present dollar value. The discount rate applied in this Study brings costs and benefits back to 2010 constant dollars. The discount rate derived for this Study is based upon the long-term Treasury bond yield, the long-term Treasury Inflation Protected Series bond yield, and the long-term Authority bond yield. Table 1-3 shows the derivation of the discount rate using a baseline date of July 1, 2011. The Colorado-specific discount rate of 1.4 percent was adopted for this Study.

Table 1-3. Derivation of the Discount Rate for the Cost Benefit Study (Baseline July 1, 2011)

Step	Procedure	Result
1	Obtain 20-Year Treasury Bond Yield for July 1	4.12%
2	Obtain 20-Year TIPS Bond Yield for July 1	1.47%
3	Calculate Long-Term Inflation Expectation *(Step 1 minus Step 2)*	2.65%
4	Obtain 20-Year Authority Bond Yield for July 1	4.05%
5	Input Long-Term Inflation Expectation *(from Step 3)*	2.65%
6	Calculate Discount Rate *(Step 4 minus Step 5)*	1.40%

1.2.9 Stormwater Monitoring Costs

The Study included an evaluation of potential stormwater monitoring costs associated with implementation of Regulation #85 (based on previous drafts of the regulation, e.g., the July 5th proposal). The current proposed regulation (November 21, 2011) requires municipal separate storm sewer system (MS4) permit holders to develop a Discharge Assessment Data Report (DADR) that documents existing program information and will help determine the need for additional future monitoring. The current regulatory proposal does not obligate MS4 dischargers to conduct stormwater monitoring for nutrients unless a regulatory determination is made that such monitoring is necessary.

Costs for potential future monitoring requirements (if determined necessary) were estimated using compiled information from MS4s, input through the assistance of the Colorado Stormwater Council, selected literature sources, and cost quotes from equipment vendors and environmental laboratories. Estimated costs for stormwater requirements incorporated several cost elements:

- *DADR Costs,* which included costs to develop documentation that identifies existing stormwater monitoring information and the need for additional monitoring to be conducted in the future to determine the approximate nitrogen and phosphorus contribution to receiving waters due to MS4 discharges.
- *Planning Costs,* which included costs associated with locating monitoring stations, site characterization of outfalls, and research and documentation of hydrology and characteristics of the surrounding area.
- *Implementation Costs,* which developed costs for a range of monitoring options (e.g., ranging from grab samples to renting samplers or purchasing automated samplers) and the costs associated with laboratory analyses. Costs were developed on a per outfall/per sampling event basis.

1.3 Project Results

Project results are presented in three parts: (1) cost-benefit results for each Manageable Unit; (2) cost-benefit results aggregated by river basin and statewide; and (3) estimated stormwater monitoring costs.

1.3.1 Manageable Unit Results

Quantified Costs and Benefits

Figure 1-1 illustrated the relationship between cost and benefits evaluated as part of this Study and how this relationship is expressed as a benefit-cost ratio. Costs and benefits are assumed to occur between the year 2014 and the year 2038 and all costs and benefits were discounted back to 2010 present value dollars. Benefit-cost ratios were developed for each Manageable Unit based on the assumption that all non-exempt WWTFs in each Manageable Unit would have to comply simultaneously with Tier 1, 2, or 3 effluent limits (see Table 1-2). A ratio greater than one indicates that, as quantified, the expected benefits are greater than costs of implementation of the proposed regulations. A ratio less than one indicates that the costs are greater than the benefits.

Figure 1-5 illustrates the variability observed in benefit-cost ratios for Tier 1 implementation across the 27 Manageable Units analyzed for this Study (see Section 7 of the report for illustrations of Tier 2 and 3 results). Key reasons for variability among Manageable Units include:

- Location of non-exempt WWTFs within a Manageable Unit, specifically:
  - The higher geographically a non-exempt WWTF is located in a watershed, the greater potential there is for more river miles to accrue benefits from improved water quality. This effect was particularly significant when comparing Manageable Units with significantly different areas. An example comparison of two Manageable Units with significantly different sizes illustrates this effect. GRN-01 in northwest Colorado is much larger in area than COL_03 (see Figure 1-6). Benefits of improved water quality accrue downstream of the non-exempt WWTFs. The larger the area, the greater potential there is for having more river miles with accrued benefits (Figure 1-6).
  - Location of non-exempt WWTF discharges relative to public water supply intakes influences the potential for avoided treatment costs for a public water supply. For example, in some Manageable Units no non-exempt WWTFs discharge upstream of public water supply intakes; as a consequence there is no potential for avoided water treatment costs to count as benefits.
- The number and size of non-exempt WWTFs within a Manageable Unit influences the potential for point source loading of nutrients to downstream waters. In many Manageable Units, especially on the West Slope, there are relatively few non-exempt WWTFs (as compared to the Front Range) and these WWTFs tend to be small in terms of effluent volume discharged (Table 1-4). As a result, the expected water quality improvements are relatively low. This outcome, coupled with the geographic considerations described above, affects the calculated benefits.
- The volume of WWTF discharge relative to the instream flow is an important variable. Where the potential for significant dilution of effluent is high, (e.g., the effluent discharge is of low volume compared to typical instream flows) the expected improvement in water quality downstream of the WWTF will be relatively small compared to locations where the WWTF effluent comprises a relatively high proportion of the typical instream flow. Given that the quantified benefits are directly linked to percent changes in water quality, if the dilution effect is high, the estimated water quality benefits will be relatively low and thus the accrued benefits will also be relatively low.

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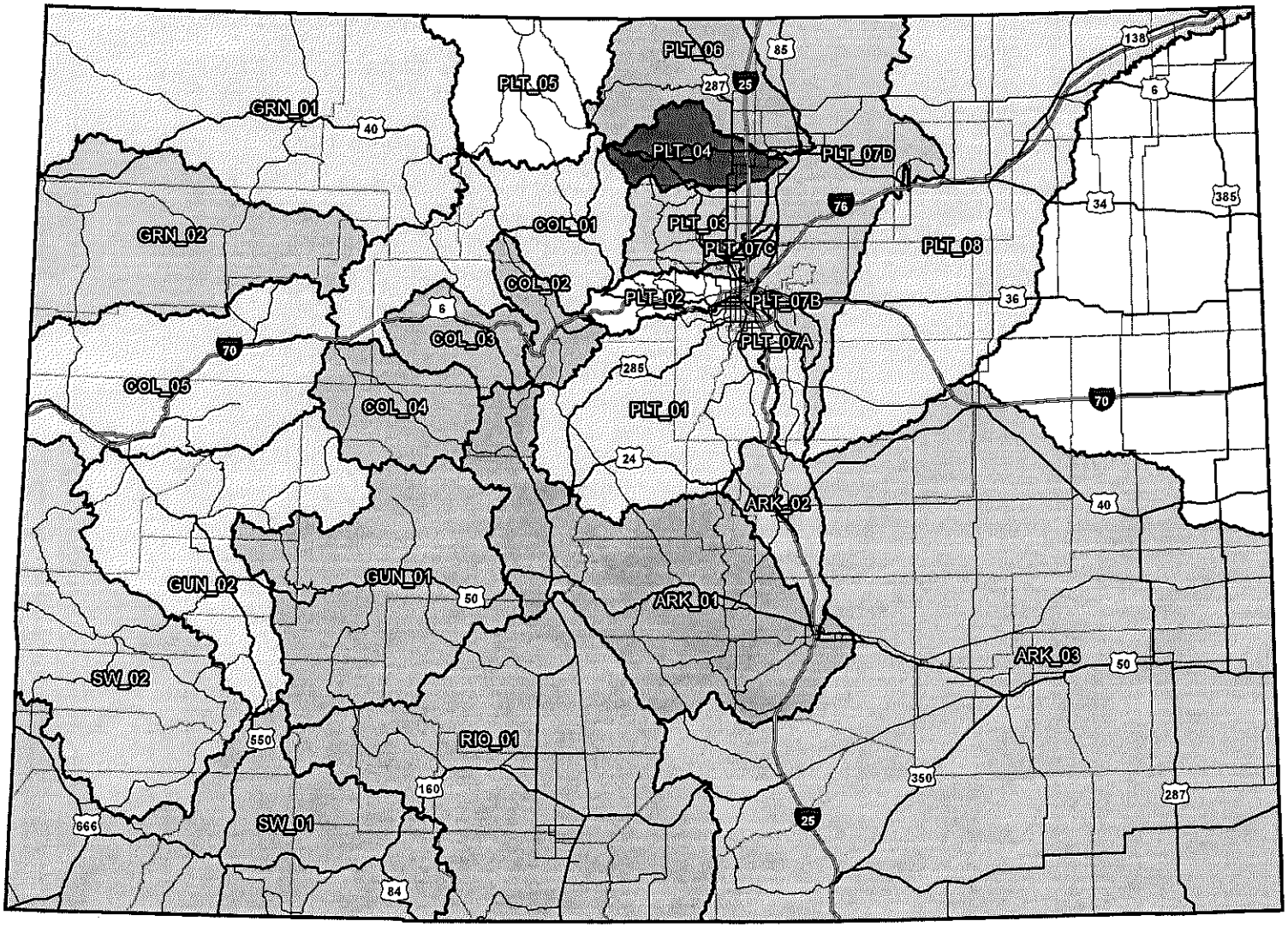


Range of Tier 1 Benefit-Cost Ratios

- >0:1 - 0.5:1
- 0.5:1 - 0.75:1
- 0.75:1 - 1:1
- 1:1 - 1.5:1
- 1.5:1 - 2:1
- 2:1 - 2.5:1
- 2.5:1 - 3:1

Roads

- Interstate Highway
- US Highway
- State Highway
- County Boundary

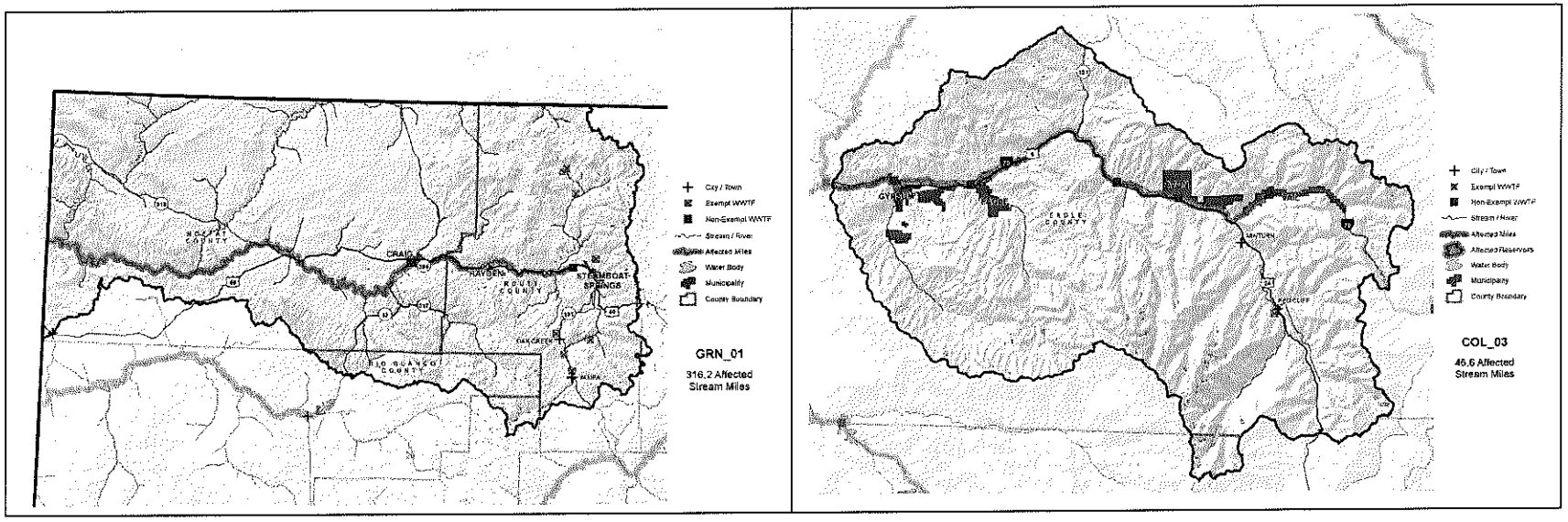
N
W E
S

0 12.5 25 50
Miles

Colorado Nutrient Cost/Benefit Study

Figure 1-5

CDM



Yampa River *Eagle River*

Parameter	Manageable Unit	
	GRN_01	COL_03
Primary Stream/Rivers	Yampa River	Eagle River
Total Stream Miles	9014.2	1002.7
Affected Miles	316.2	46.6
% Change in Water Quality	14.28%	19.30%
Base Level Recreational Activity Days	735,448	432,231
Recreational Benefits	$6.1M	$6.7M

Figure 1-6. Example Comparative Statistics for Manageable Units of Significantly Different Area

Table 1-4. WWTFs and Associated Flows by Manageable Unit

MU	MU Name	Tier 1 Benefit:Cost	Total Number of Facilities	Total Flow (mgd)	Total Exempt*	Percent Exempt	Exempt Flow (mgd)*	Percent Exempt Flow
ARK_01	Upper Arkansas River	2.12 : 1	25	38.3	17	68%	2.7	7%
ARK_02	Fountain Creek	0.83 : 1	12	101.7	2	17%	0.1	0%
ARK_03	Lower Arkansas River	1.41 : 1	26	13.0	21	81%	5.2	40%
COL_01	Colorado River Headwaters	0.57 : 1	18	9.8	14	78%	1.7	17%
COL_02	Blue River	0.34 : 1	8	10.4	2	25%	0.1	1%
COL_03	Eagle River	0.33 : 1	6	12.6	1	17%	0.1	1%
COL_04	Roaring Fork	0.26 : 1	20	12.0	15	75%	1.7	14%
COL_05	Lower Colorado River	0.66 : 1	18	21.0	12	67%	1.2	6%
GUN_01	Upper Gunnison River	0.39 : 1	11	6.6	9	82%	1.2	18%
GUN_02	Lower Gunnison River	0.6 : 1	16	10.3	14	88%	5.2	51%
PLT_01	Upper South Platte River	0.74 : 1	29	52.3	22	76%	1.6	3%
PLT_02	Clear Creek	**	12	12.0	8	67%	0.7	6%
PLT_03	St Vrain River	0.81 : 1	24	59.9	14	58%	1.3	2%
PLT_04	Big Thompson River	2.97 : 1	12	16.6	7	58%	1.4	8%
PLT_05	North Platte River	No Non-Exempt Facilities	2	0.4	2	100%	0.4	100%
PLT_06	Cache La Poudre River	0.09 : 1	15	60.1	6	40%	0.5	1%
PLT_07A	Cherry Creek	0.67 : 1	6	227.9	1	17%	0.2	0%
PLT_07B	Sand Creek	1.17 : 1	5	11.0	3	60%	0.6	5%
PLT_07C	Big Dry Creek	0.86 : 1	3	30.4	0	0%	0.0	0%
PLT_07D	Middle South Platte River	0.88 : 1	21	23.7	14	67%	3.6	15%
PLT_08	Lower South Platte River	0.56 : 1	15	10.3	11	73%	2.0	19%
PLT_09	Republican River	No Non-Exempt Facilities	9	1.8	9	100%	1.8	100%
RIO_01	Rio Grande River	0.15 : 1	17	13.0	12	71%	2.9	22%
SW_01	San Juan and Animas Rivers	0.23 : 1	34	13.3	31	91%	4.9	37%
SW_02	San Miguel and Dolores Rivers	0.98 : 1	11	3.6	10	91%	1.5	42%
GRN_01	Yampa River	0.73 : 1	11	11.1	9	82%	1.2	10%
GRN_02	White River	1.17 : 1	5	2.6	4	80%	1.6	61%
TOTAL	**STATEWIDE**	**0.79 : 1**	**391**	**786**	**270**	**69%**	**45.4**	**6%**

* Based on the following exemptions - mechanical plants ≤ 0.5 mgd, lagoons ≤ 1.0 mgd, and disadvantaged communities

**All Non-Exempt Facilities in the Clear Creek Basin (PLT_02) have provided site-specific effluent data to indicate they are discharging below Tier 1 levels in agreement with the Stanley Lake Water Rights. Therefore, there were no costs and benefits associated with Tier 1.

Qualitative Costs and Benefits

As noted above, the overall costs and benefits of the implementation of the control regulations must consider both quantitative and qualitative elements. The quantified costs and benefits, described above, represent only a subset of the overall costs and benefits (see Figure 1-2). Qualitative effects are no less important and they apply to all Manageable Units. These effects are qualitative only because the project team was not able to obtain sufficient data or derive sufficient supportable assumptions in order to quantify the costs or benefits.

Table 1-5 summarizes the qualitative cost and benefit findings from this Study. Each of these qualitative elements represents an important consideration for policy makers in interpreting the conclusions of this Study. The following sections summarize the key cost or benefit issues associated with each element.

Table 1-5. Summary of Qualitative Costs and Benefits

Qualitative Factor	Cost or Benefit	Magnitude of Effect
Greenhouse Gas Emissions	Cost	Potentially Substantial
Potable Water Supplies	Benefit	Substantial
Private Property Values (streamside and lakeside)	Benefit	Potentially Substantial
Additional Recreational Activities (hiking, picnicking, wildlife watching)	Benefit	Moderate
Intrinsic Values	Benefit	Unknown
Agriculture (livestock source water, conveyance vegetation, crop irrigation)	Benefit/Cost	Minimal

Greenhouse Gas Emissions

The wastewater industry contributes to Greenhouse Gas (GHG) emissions primarily through combustion of fuels from mobile and stationary sources, through consumption of electricity, and from fugitive and process emissions unique to wastewater treatment. While it is possible to estimate GHG emissions from sources, these results are typically in units that cannot be readily converted into quantifiable costs. Accordingly, the potential costs associated with GHG must be viewed from a qualitative perspective.

For scope 1 type emissions (direct GHG emissions from within the operational boundary of a WWTF) the analysis of implementation of Tier 1 and 2 effluent limits showed a decrease in GHG emissions (approximately 25 to 35 percent), while Tier 3 implementation showed a decrease of about 60 to 70 percent. These decreases area associated with the types of wastewater treatment processes expected to be employed. In contrast, for scope 2 emissions (GHG emissions from outside the operational boundary of a WWTF as a result of energy purchased by the WWTF) the analysis suggests implementation of any of the effluent quality tiers will increase GHG emissions by 3 to 14 times. This increase occurs because of the expected increased electricity usage by WWTFs. The conclusion from this analysis is that the potential costs associated with GHG emissions are potentially substantial.

Potable Water Supplies

Improvements to potable water quality as a result of nutrient control might be a substantial benefit, but the project team was only able to quantify certain effects associated with reduced phosphorus and specific regulations of that element for potable water utilities. Areas where additional potential benefits should be considered include reductions in certain types of algae that might be toxic, which might reduce adverse health effects in people particularly sensitive to those substances; odor, taste, and appearance that affect perceptions of the quality of water used for drinking, and potential concerns associated with emerging contaminants, such as NDMA.

Private Property Values

Evaluations of expected improvements in water quality in a number of lakes and reservoirs were not possible given the minimal water quality data and variable, complex sources of in-lake flows. Accordingly, the private property value benefits to water quality in some of these waterbodies are likely understated by this Study. In addition, the potential exists changes in water quality will also impact property values along streams and rivers; however, insufficient data was available to quantify this potential benefit.

Additional Recreational Activities

Besides the quantified recreational benefits, other recreational activities might benefit from the proposed regulation, e.g., scenic drives, picnicking, and watchable wildlife. To some extent, these might be positively affected by improved water quality in the state's streams and lakes, but there is insufficient information to substantiate or quantify this benefit.

Intrinsic Values

It is possible that water quality improvements might have an existence bequest value to Colorado citizens. The project team was not able to distinguish such a value from the passive values already accounted for in the benefit-cost analysis. Even so, if such benefits exist, based upon studies in other regions of the country, these benefits may be substantial.

Agriculture Activities

Several studies acknowledge the potential benefits to cattle and other livestock as a result of nutrient reduction in drinking water. In addition, reduced nutrients in irrigation water might reduce the rate and volume of vegetation growth in the irrigation conveyance canals, which may provide a small benefit. The project team could not quantify these potential agricultural related benefits. However, to the extent they exist, they are expected to be minimal.

Potential reduction of nutrients in agricultural source waters has been noted as a potential cost as the presence of nutrients in irrigation water potentially reduces the need to apply nutrients directly to the growing crops. While these costs could not be quantified, it is believed to be minimal given that farming interests do not typically rely on source water nutrients to substitute for standard fertilization practices.

1.3.2 River Basin and Statewide Aggregate Results

The project team aggregated the benefit-cost ratios developed for each Manageable Unit into a benefit-cost ratio for the seven river basins (Table 1-6). This presentation of benefit-cost ratios does not include any new data or analyses. The aggregate values are the combined benefit and cost values for each Manageable Unit shown as a combined benefit-cost ratio. Benefit-cost ratios at the river basin level are lower overall simply because the variable Manageable Unit results are being averaged across the river basin. Similar to the Manageable Unit results the highest ratios are found for Tier 1.

The Manageable Unit values were also aggregated together to establish a statewide benefit-cost ratio for each effluent tier (Table 1-7). Similar to above, no new data or analyses were done. The final statewide numbers represent the combined costs and benefits for all Manageable Units presented as a total benefit-cost ratio. Similar to the river basin aggregation, aggregating all Manageable Units has the effect of averaging the wide range of benefit-cost ratios observed across the state. The highest benefit-ratio continues to be associated with the implementation of Tier 1 effluent limits.

Table 1-6. Aggregate Benefits and Costs by River Basin

Aggregate (River Basin or Statewide)	Component	Tier 1*	Tier 2*	Tier 3*
Arkansas	Benefits	$679,062,000	$808,956,000	$1,056,414,000
	Costs	$545,429,000	$1,121,448,000	$5,910,796,000
	Benefit-Cost Ratio	1.25 : 1	0.72 : 1	0.18 : 1
Colorado	Benefits	$103,315,000	$154,851,000	$279,996,000
	Costs	$226,322,000	$393,719,000	$2,840,746,000
	Benefit-Cost Ratio	0.46 : 1	0.39 : 1	0.1 : 1
Gunnison	Benefits	$24,043,000	$31,798,000	$43,075,000
	Costs	$46,947,000	$96,172,000	$447,136,000
	Benefit-Cost Ratio	0.51 : 1	0.33 : 1	0.1 : 1
Platte	Benefits	$1,068,108,000	$1,278,498,000	$1,854,325,000
	Costs	$1,473,367,000	$3,152,796,000	$14,286,950,000
	Benefit-Cost Ratio	0.72 : 1	0.41 : 1	0.13 : 1
Rio Grande	Benefits	$10,561,000	$12,206,000	$16,980,000
	Costs	$68,185,000	$94,131,000	$502,522,000
	Benefit-Cost Ratio	0.15 : 1	0.13 : 1	0.03 : 1
Southwestern	Benefits	$22,418,000	$33,428,000	$55,024,000
	Costs	$63,657,000	$98,692,000	$542,752,000
	Benefit-Cost Ratio	0.35 : 1	0.34 : 1	0.1 : 1
Yampa-White	Benefits	$31,882,000	$36,204,000	$49,229,000
	Costs	$40,990,000	$77,461,000	$461,614,000
	Benefit-Cost Ratio	0.78 : 1	0.47 : 1	0.11 : 1

* Expressed in Present Value 2010 Dollars

Table 1-7. Aggregate Benefits and Costs Statewide

Aggregate (River Basin or Statewide)	Component	Tier 1*	Tier 2*	Tier 3*
Statewide Aggregate	Benefits	$1,939,389,000	$2,355,941,000	$3,355,043,000
	Costs	$2,464,897,000	$5,034,419,000	$24,992,516,000
	Benefit-Cost Ratio	0.79 : 1	0.47 : 1	0.13 : 1

* Expressed in Present Value 2010 Dollars

1.3.3 Stormwater Monitoring Cost Results

The current regulatory proposal (November 21, 2011) does not obligate MS4 dischargers to conduct stormwater monitoring for nutrients unless a regulatory determination is made that such monitoring is necessary. Costs associated with the development of a DADR will depend on the MS4s capabilities to perform the work in-house versus contracting the work to a consultant, the size of the existing monitoring program, and the volume of available data for analysis and documentation. Table 1-8 summarizes the results from the analysis of potential stormwater monitoring costs should future monitoring be required by the Division. Overall, the estimated costs to MS4 permitted jurisdictions for potential monitoring range from approximately $9,000 - $20,000 per outfall and sample event based on the sampling method. Total costs are dependent on the number of outfalls sampled and the number of sampling events per year.

Table 1-8. Estimated Stormwater Monitoring Costs per Outfall/Event

MS4 Monitoring Component		Cost	Notes
Planning		$4,000	Background research, site characterization, documentation
Implementation – Sampling Method	Grab Sampling	$7,000	N/A
	Rented Automated Sampler	$11,000	N/A
	Purchased Automated Sampler	$17,000	Initial cost – subsequent years would be significantly less
Implementation - Laboratory	Lab Costs	$450	N/A

1.4 Study Limitations and Uncertainties

A study of this type, which relates implementation of a proposed nutrient control regulation to expected water quality improvements and associated benefits, has never been performed for the State of Colorado. Costs and benefits of water quality improvements have been examined previously by EPA and by others for the states of Iowa, New Hampshire, Minnesota, Maine, Florida, and other locations. In addition, costs and benefits of certain water quality issues have been studied in Colorado, but these studies had a different and more limited focus than the present effort described in this Study. To the extent practicable, the project team drew methodological elements from other existing cost-benefit studies; these methodological elements were modified as appropriate to fit the goals and objectives of this Study. However, we have been careful to not quantify elements for which sufficient data are lacking. Moreover, we have been careful to note the non-quantifiable elements and indicate their probable magnitude of effect so that policy-makers can properly consider them as part of the regulatory decision-making process.

There are specific sources of uncertainty and limitations associated with this Study that have been noted by the project team or by the various Colorado stakeholders, who participated in workshops, reviewed interim work products, provided comments, or interacted directly with the project team to better understand the project methodology. These uncertainties or limitations are described below.

1.4.1 Manageable Unit Framework

From the outset, it was agreed that Study analyses would occur at a low enough level to reflect key geographic differences across the State of Colorado (e.g., Front Range vs. West Slope). This requirement was addressed through the establishment of Manageable Units. Study results show substantial differences in benefit-cost ratios across these Manageable Units. A question that still can be asked is, are there substantive differences in benefit-cost ratios within Manageable Units? For example, do the expected benefits of increased recreational activity as a result of improved water quality occur in a dispersed fashion throughout the Manageable Unit, or are there specific areas where such activities tend to primarily occur? While the Study did not allow for analyses at this level, it is important to note that based on literature and data reviewed, such data are not generally available at small geographic scales. However, the lack of such data does not discount the potential for benefits to occur in some areas of Manageable Units more than others. Further understanding of this issue would require implementation of site-specific analyses.

1.4.2 Development of Wastewater Costs

Planning Level Costs - By its nature this Study could only provide "order of magnitude" estimates (estimates range from +50 percent to -30 percent), which, per industry practice, is the acceptable level typically done for a facility or master plan. While appropriate for a study of this type, this range of uncertainty should be kept in mind when interpreting benefit-cost ratios.

Cost Validation - The Study found that the Tier 1 and 2 costs fell within acceptable ranges, based on other studies; however, significant uncertainty underlies the Tier 3 costs primarily the result from the analyses associated with brine disposal. This Study assumed brine disposal would be addressed by deep well injections; however, the use of this method and associated cost will vary significantly around the state. Further evaluation requires site-specific information on potential disposal locations and geotechnical conditions. Accordingly, the typical facility Tier 3 costs may be high relative to what could actually be incurred by some facilities following a facility-level investigation and design process.

Implementation of Facility Upgrades to Comply with Effluent Quality Tiers - This Study assumed that treatment upgrade costs to meet any of the effluent tiers was the sole capital cost incurred. This assumption assumes that no other effluent quality issues emerge related to the requirements to comply with the nutrient control regulation. For example, increased chemical use to remove phosphorus could cause other effluent quality issues that could require mitigation and therefore increased treatment costs. This uncertainty would be site-specific, and thus could not be evaluated as part of this Study.

1.4.3 Water Quality Analyses

Data Limitations – The benefits analysis relies on estimated percent changes in water quality expected from Regulation #85 implementation. This effort relied on the use of a simple mass balance approach that required assumptions regarding effluent quality of existing WWTFs. While this approach is valid for making general estimates of water quality changes, a certain degree of uncertainty exists given the assumptions and data availability. Where the uncertainty was considered too high, e.g., lakes and reservoirs, the project team relied on a qualitative approach rather than developing expected concentrations with substantial uncertainty.

The November 21, 2011 regulation does not include exceptions for nondomestic facilities; however, due to the limited information available for nondomestic facilities (in particular determining which facilities would actually be subject to the regulations) and the expected limited effect on receiving water quality by small dischargers, nondomestic facilities discharging less than 0.5 mgd were excluded from the quantification of costs and benefits.

Water Quality Improvements – Unless site-specific information was provided, this Study relied on median instream TP and TIN values and specific wastewater effluent discharge parameters (concentration and flow volume). Use of median values removes the normal seasonal variability inherent in flows in most waterbodies, which may underestimate the water quality benefits during periods of low instream flow, but overestimate the benefits during periods of high flow, e.g., during snowmelt. Use of general facility effluent parameters also may over- or underestimate downstream water quality improvements. While these assumptions simplified the water quality analysis (a necessity given data availability and project resources); the uncertainties created seem to work in both ways, i.e., to under- or overestimate water quality improvements.

Other Water Quality Factors - This Study adopted an "all other factors being equal" approach, meaning that the Study estimated water quality changes attributable solely to changes in TP and TIN in WWTF effluent discharge; however, water quality may improve or decline for a host of reasons unrelated to the proposed regulations. Such cumulative changes in water quality were beyond the scope of this Study.

1.4.4 Benefits Analyses

Relationship of Nutrient Changes to Changes in Biologic Processes – To simplify benefits analyses, this Study assumes a direct and consistent relationship between percent changes in nutrient levels and changes in the biological processes which occur in Colorado's streams and lakes. However, while the literature demonstrates that higher concentrations of TP and TIN in waterbodies leads to algae growth and adverse algae growth leads to declines in dissolved oxygen and reduced water clarity; the exact incremental response of those adverse conditions to changes in nutrient levels is unknown for Colorado waterbodies. Understanding such cause and effect relationships is a site-specific endeavor.

Elasticity Response of Active Recreation to Water Quality Changes - The Study assumed a linear response of visitor days to changes in water quality, whereas it is quite possible that the actual relationship is non-linear. If such non-linearity exists, then the change in recreational visitor days could be higher or lower than the figures derived in this Study. Even so, since no relevant studies were found that provided any reliable information regarding the potential non-linearity of this relationship, it was assumed to be linear.

Willingness-to-Pay Issues - The passive benefits identified and quantified in this Study relate to the full spectrum of environmental improvements and the value Colorado residents place on those benefits. This application of WTP relies on the proposition that, when given a choice, Colorado residents would expend monies to improve water quality. No specific Colorado survey was conducted as part of this Study; instead, literature values were applied. However, give the hypothetical applicability of these values to Colorado, based on a review of literature regarding application of adjustments, the project team attempted to reduce uncertainty by applying adjustments to the WTP estimates. For example, studies in other areas have found that WTP survey values are inflated by two to three times. Accordingly, the baseline WTP value for this Study was reduced by 2.5. In addition, the WTP was further adjusted to take into account household income differences across Manageable Units to account for differences in WTP based on available resources.

Future Values versus Current Values - This Study assumes that the WWTFs would be modified or reconstructed by the year 2018 and project benefits and operating costs would begin in the year 2019 and run into the future. However, this Study focuses on current water quality conditions, point source dischargers, recreational visitation patterns, and current estimates of WTP as compared with those conditions that might exist in 2019 and beyond. Clearly, there will be changes to these elements in the future. However, given the many factors that will influence the future trends, to avoid greater uncertainty, this Study assumed current conditions, which likely interjects some conservatism to the results.

Lack of Consideration of Nonpoint Discharges - This Study focused only on the costs and benefits associated with application of the proposed regulations to point source discharges. Nonpoint source discharges and their effects on the water quality of Colorado's waterbodies were not evaluated. The water quality analysis took this into account by estimating water quality changes associated with changes in the quality of effluent discharges. Therefore, excluding nonpoint sources did not create a bias in the water quality results. However, not including potential costs and benefits associated with the control of nonpoint sources does not provide a complete picture of the overall costs and benefits of alternative nutrient reduction strategies that could be applied, for example, at the Manageable Unit level.

1.5 Study Conclusions

To the extent data were available and within a prescribed framework, this Study quantified the costs and benefits associated with the implementation three different tiers of effluent quality for the nutrients TP and TIN. These costs and benefits were developed at a Manageable Unit level, which shows the range of benefit-cost ratios across the State of Colorado. Among the three effluent quality tiers examined, the highest benefit-cost ratios were associated with implementation of the Tier 1 effluent limitations, which are consistent with the nutrient controls proposed for existing WWTFs in Colorado that are not subject to a

regulatory exclusion. The Tier 2 effluent quality limits, which are consistent with the Division's regulatory proposal for implementation of nutrient controls on new WWTFs, showed lower benefit-cost ratios.

Geographically, the highest benefit-cost ratios, regardless of tier, were typically observed in the Manageable Units along the Front Range in the Platte River and Arkansas River basins. Where quantification was not possible because of a lack of relevant data, the Study identified additional potential costs and benefits from a qualitative perspective. Policy makers should consider these statewide qualitative elements alongside the quantified benefit-cost ratios.

This Study only focused on first order effects associated with implementation of any of the three effluent quality tiers. Studies such as this one do not take into account indirect or induced (second or third order) effects. For example, this Study did not evaluate the beneficial effect on the tourist economy in counties, Manageable Units, and the state as a whole. Similarly, from a cost perspective, this Study did not evaluate availability of capital, cost of debt service, or how the total costs are likely to affect wastewater utilities and their ratepayers. While all of these issues are important, they are not part of a cost-benefit study. Instead, such studies focus on first order effects so that the final comparison of benefits and costs is provided on an "apples to apples" basis. Second and third order effects would typically be evaluated at a more local or regional level and be part of studies such as economic impact analyses.

The Study findings are intended to provide input to deliberations by the Commission regarding adoption of the Division's proposed statewide nutrient control regulations. It has been noted by a number of stakeholders that the findings presented may not be applicable to their specific facility or may not accurately reflect local conditions below the Manageable Unit level. Examples of the specific issues identified include:

- What is the location where benefits will be accrued within a Manageable Unit relative to where the WWTF discharge occurs?
- What is the impact of a specific WWTF effluent discharge on downstream water quality?
- What is the relationship between reduced TP or TIN and the expected specific biological response in any given waterbody?
- Is there a need for both TP and TIN controls to meet downstream uses in a particular waterbody?
- What are the potential differences in the costs or benefits associated with implementation of only TP or TIN controls separately rather than in combination as evaluated in this Study?

These are appropriate questions, but they could not be addressed given the Study's original framework, schedule, and available resources. This Study is inextricably tied to the specific provisions contained within the Regulation #85 proposal. For the most part, the above concerns could be dealt with through site-specific or watershed-specific analyses. However, in many cases, the data required for more local studies, especially with regards to potential benefits (e.g., local recreational activity levels, willingness to pay by local populations, or waterbody-specific biological outcomes) are not typically available.

From the outset, the purpose of this Study was to explicate and provide a rigorous comparative analysis of all of the benefits and costs associated with implementation of the proposed nutrient control regulations. The threshold question for this Study was whether nutrient control under Tier 1, Tier 2, or Tier 3 will be a net benefit or a net cost to each of the Manageable Units and to the state as a whole? Additional statewide or regional economic and implementation considerations will have to be addressed in the future. Facility-specific or watershed-specific issues certainly will arise during the regulatory implementation phase.

This cost-benefit Study provides quantified benefit-cost ratios to support further discussion and analysis of the threshold question. However, these quantified outcomes are just part of the overall picture. Information contained in this Study regarding qualitative costs and benefits, as well as information developed outside the framework of this Study, e.g., through efforts of the Colorado Water Quality Forum Nutrient Workgroup, provide a substantial body of information for consideration, as well. In addition, as noted above under the discussion of uncertainties and limitations, a number of site-specific factors could not be taken into account given the high level purpose of this analysis. Some of these factors including eligibility of facilities for variances, exceptions, and compliance schedules would be investigated if the proposed regulations are adopted and implemented through Colorado Discharge Permit System permits.