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An Economic Framework for Evaluating the Benefits and Costs of Biosolids Management Options

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AN ECONOMIC FRAMEWORK FOR EVALUATING THE BENEFITS AND COSTS OF BIOSOLIDS MANAGEMENT OPTIONS

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ABSTRACT AND BENEFITS

Abstract:

The intent of this research is to help wastewater agencies—and other relevant entities and stakeholders—understand the benefits and costs of the biosolids management options that are available to them. As such, this report:

- Describes what an economic benefit-cost analysis (BCA) is
- Discusses why it is important and useful to conduct such economic analyses
- Provides guidance on how to conduct BCAs, and how to document and communicate the inputs and outputs of such analyses
- Offers various tools, resource guides, and templates to help utilities and other interested parties conduct BCAs for biosolids options
- Illustrates how BCAs for biosolids options can be performed and documented, using case studies derived from several utilities

Benefits:

- Helps agencies choose and justify biosolids management options—particularly those that involve beneficial use—that may appear relatively expensive, but that provide important and valuable benefits.
- Provides tools and guidance to help utilities conduct or manage BCAs or related forms of Business Case Evaluation, including the triple bottom line approach.
- Helps utilities communicate more effectively with their decision-makers (utility managers, Board members, public officials) and other stakeholders.
- Provides useful guidance, resources, and case study illustrations, which will help utilities develop better assessments of a broad array of the benefits and costs of biosolids management options, including issues such as energy recovery, climate change and carbon accounting, odors, and program sustainability.

Keywords: Benefit-cost analysis, triple bottom line, biosolids, sustainability, odors, externalities, nonmarket goods and services, carbon accounting, energy recovery, beneficial use, disposal, land application.

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AF	acre-foot
ARES	Advanced Reciprocating Engine System
ASP	aerated static pile
AwwaRF	Awwa Research Foundation
BCA	benefit-cost analysis
BT	benefits transfer
BTU	British thermal unit
BUVD	Beneficial Use Values Database
C	carbon
Ca	calcium
$CBFT^3$	Columbus Biosolids Flow-Through Thermophilic Treatment
CCX	Chicago Climate Exchange
CDM	Clean Development Mechanism
CFR	Code of Federal Regulations
CH_4	methane
CHP	combined heat and power
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalents
CPG	Citizen Participation Group
CPI	Consumer Price Index
CSIRO	Commonwealth Scientific and Research Organization
CWW	Columbus Water Works
DAP	diammonium phosphate fertilizer
DOE	U.S. Department of Energy
dt	dry tons
dtpd	dry tons per day
EDC	endocrine disrupting chemical
EERI	Environmental Economic Report Inventory
EIA	Energy Information Administration
EMS	Environmental Management System
EPM	Environment Programs and Management
EQ	Exceptional Quality
ETS	Emissions Trading Scheme
EU	European Union
EVRI	Environmental Valuation Resource Inventory
FCA	full cost accounting
GHG	greenhouse gas
GJ	gigajoule
GVRD	Greater Vancouver Regional District
GWP	global warming potential
HVAC	Heating, ventilating, and air conditioning
IEC	Industrial Economics, Incorporated
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization

JI	Joint Implementation
K	potassium
km	kilometer
kWh	kilowatt hour
lb	pound
LCA	Life Cycle Analysis
LRMP	long-range management plan
MANA	maximum allowable nitrogen application
Metro	Metro Wastewater Reclamation District
MGD	million gallons per day
mL	milliliter
MMBTU	million BTU
MPCA	Minnesota Pollution Control Agency
MSW	municipal solid waste
Mt	metric ton
MW	megawatt
N	nitrogen
N_2O	nitrous oxide
NBP	National Biosolids Partnership
NETL	National Energy Technology Laboratory
NO_x	nitrogen oxide
NPDES	National Pollutant Discharge Elimination System
NPV	net present value
NRC	National Research Council
O&M	operation and maintenance
OCSD	Orange County Sanitation District
OMB	Office of Management and Budget
P	phosphorous
PAN	plant available nitrogen
PEC	Pathogen Equivalent Committee
PFRP	process to further reduce pathogens
PV	present value
PVNC	present value of net costs
RCID	Reedy Creek Improvement District
RGGI	Regional Greenhouse Gas Initiative
RR&R	Resource Recovery and Reuse
SCWRF	South Columbus Water Resource Facility
SMR	standard mine land reclamation
SO_2	sulfur dioxide
SO_x	sulfur oxide
SRI	Sustainable Region Initiative
STAG	State and Tribal Grant
SWRCB	State Water Resources Control Board
T&E	threatened and endangered

TBL	triple bottom line
TCM	Travel Cost Method
USD	United States dollars
USDA	U.S. Department of Agriculture
U.S. EPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VOSC	volatile organic sulfur compound
WEP	water extractable phosphorus
WEPS	Wind Erosion Prediction System
WERF	Water Environment Research Foundation
WLSSD	Western Lake Superior Sanitary District
WQSID	Water Quality Standards Inventory Database
WWTP	wastewater treatment plant

EXECUTIVE SUMMARY

ES.1 Overview and Motivation

The intent of this research report is to help wastewater agencies and other relevant entities and stakeholders understand the benefits and costs of the biosolids management options that are available to them. As stewards of the environment and public trust, wastewater agencies need to consider the full range of benefits and costs associated with their activities. This means that they need to take into account all the impacts—good, bad, and uncertain—that their activities may impose on the broader community.

This report describes the approaches, methods, and tools available to help utilities take a broad perspective and develop benefit-cost analysis (BCA) of their biosolids management options. This is designed to help agencies understand why it is important to conduct such analyses and why it is important to adopt a broad social accounting perspective when doing so. This report also provides tools and guidance to help utilities conduct such BCAs or related forms of Business Case Evaluation (BCE), including the triple bottom line (TBL) approach.

Conducting BCAs and/or related BCE analyses is a complex and specialized endeavor. In some cases, utilities may need specialized technical expertise to assist in the framing, implementation, and presentation of these analyses. In these instances, this report can be used to help utilities be better-informed managers, reviewers, and users of analyses developed on their behalf.

ES.2 The Challenges Facing Utilities

Wastewater agencies, regulatory bodies, the research community, and other entities have identified and implemented a suite of practices, processes, and regulations that enable the safe and prudent management of biosolids. There are also numerous existing and emerging ways biosolids can be used as a valuable resource (e.g., for energy recovery) rather than as a waste product. Still, numerous significant challenges face wastewater agencies and other interested parties as they consider how to best manage biosolids:

- Biosolids management options tend to require high capital outlays and operating expenses (including energy costs). Managers need to consider whether the benefits warrant the high costs of some of the options available to them.
- Many biosolids management options tend to be controversial due to public concern over various real or perceived risks and inconveniences. These potential negative impacts may include increased local truck traffic, odors, or perceived and real risks to public health. Managers need to weigh a broad suite of biosolids options and the potential outcomes associated with those options.
- Physical or other constraints may limit the viability or impact the cost of some relevant biosolids management options for some locations. For example, a future shortage of land application sites or landfill capacity in reasonable proximity may preclude those options for some agencies. Therefore, these benefit-cost comparisons are highly site- and utility-specific, and the comparison of options can be quite complex.

BCA and related economics-based decision support tools—if conducted with a suitably broad "social" perspective and based on a transparent application of appropriate methods and data—offer a well-established framework for addressing these issues. This report is intended to provide wastewater agencies with a practical way to better recognize and account for the impacts of the biosolids management options they are considering, regardless of who realizes the benefits, or who bears the costs and risks.

ES.3 Navigating a Rapidly Changing Landscape for Biosolids Management

The landscape is changing—often rapidly—with respect to available biosolids management options. Evaluation of these new options poses an additional challenge for agencies with biosolids responsibilities.

Technological advances are making several new processes and options available, or more economically attractive, than in the past. New technological advances:

- Provide an array of offerings that may help enhance energy use efficiency
- Provide ways to generate energy or other useful value-added products from biosolids
- Reduce greenhouse gas emissions associated with global climate change concerns

At the same time, some current options are becoming less feasible from a public acceptance and/or cost-effectiveness perspective. For example, in some parts of North America, land application of Class B biosolids may not remain an option due to public opposition, local bans, or other restrictions. Some Class A processes may become economically cost-prohibitive due to rapidly escalating energy costs.

Given this changing landscape of engineering, economic, and political realities, utility managers face a daunting task of trying to chart a prudent and sustainable biosolids course for their community's future. Among the challenges faced is evaluating multiple options, and trying to develop a rationale for advocating one option over another. This is especially challenging when the attractive options appear relatively expensive and have hard-to-quantify (and often external) benefits and costs. Much of the empirical guidance and several of the case study illustrations provided in this research focus on energy-related benefits and costs, because energy recovery and other aspects of the biosolids-energy nexus have become a paramount issue in biosolids management for many utilities.

ES.4 Recognizing that BCA is Simply One Tool in the Decision Support Toolbox

Although BCA is a valuable tool, it is important to acknowledge its limitations.

1. BCA is one of several tools that wastewater agency managers and public officials need to have in their decision support toolbox to effectively deliberate biosolids management options and decisions in the public policy sphere. And, while BCA can be very informative and useful, it does not necessarily supplant other tools or override other considerations.
2. BCA is not an exact science and should not be seen as providing a firm "rule" to determine what outcomes (e.g., biosolids management options) should be pursued. Rather, BCA is simply a tool to help systematically organize information and illustrate suitable comparisons across options.

3. A good BCA alone is unlikely to carry the day for a manager or public official attempting to update biosolids management practices. Instead, BCA is among a suite of tools and can be used to complement other types of analyses, perspectives, and communication approaches.

Further, BCA is but one type drawn from a suite of related BCE-type economic evaluation approaches that can be adapted to analyzing biosolids management options. Other useful variations include the TBL approach and multi-objective evaluation processes, which also are discussed and illustrated in this report. For example, the TBL is a planning tool developed to help agencies track their progress toward promoting sustainability. In essence, TBL is a streamlined and often qualitative version of a broad social accounting-oriented BCA. The TBL has been popularized through widespread application in Australian utilities, and has been introduced in some North American agencies in the past few years.

ES.5 Identifying Key Environmental and Economic Benefits and Costs to Consider

The types and levels of benefits and costs associated with a specific biosolids management option are highly utility-, location-, and option-specific. However, the researchers' review of the literature and case studies identified several types of benefits and costs that often are important when considering an alternative.

The environmental and other values linked to the beneficial use on other management options for biosolids may include:

- Reduced traditional energy consumption and air pollution, where biosolids options provide or contribute to renewable biofuels, thermal values, and/or reduced energy use. These can reduce dependence on imported and other nonrenewable energy sources, reduce excessive demands on capacity-strained power grid systems, and reduce the carbon footprint of wastewater and biosolids agency operations.
- Improved sustainability and reliability of a biosolids program, by providing the community with a more diversified and viable longer-term set of options for addressing their biosolids needs (i.e., ensuring the community is not burdened in the future with a limited set of options that would increase the costs of managing the biosolids produced, such as by requiring long transport distances to future disposal sites).
- Reduced odor-related issues and concerns, by pursuing options that help control odor and address concerns from neighbors. Odors can be a critical constraint on whether a biosolids option is publicly acceptable (and if not, that option is unlikely to be a sustainable one for the utility). Although odors are a crucial issue to whether an option can be used for any sustained period, there is little information available to quantify or value potential changes in odors across options.
- Increased land productivity and/or restoration values, through soil enhancement from land application practices. Alternatively, this benefit may take the form of reduced use of agricultural chemicals to achieve the same soil nutrient conditions.

On the cost side of the ledger, there are two types of issues that utilities may need to address:

- High direct financial cost of biosolids management options, including the lifecycle costs and operation and maintenance costs of all capital equipment, over the useful economic life of the investment.
- Adverse environmental and public health impacts, and nuisance and aesthetic concerns. These often include (depending on the location and the biosolids option):

    Perceived or real risks due to the possibility of placing very low levels of aerosols, pathogens, metals, and/or trace organic chemicals (e.g., endocrine disrupting compounds) into the environment

    Nuisance and aesthetic issues such as odors, dust, noise, and increased vehicle traffic

ES.6 A Systematic Approach to Conducting BCAs and Related Evaluations

This report provides a straight-forward, systematic framework for how to conduct a BCA or related form of economic evaluation. A series of steps are developed, and guidance, resource materials, and case study illustrations are provided to help utilities and other practitioners through the process. Some of the key steps and issues that arise include:

1. Defining a suitable baseline, that includes a recognition of how future changes will impact a utility that adheres to its "status quo" approach
2. Including impacts that are important, even if they cannot be readily quantified or monetized, so that these important benefits and costs are suitably identified and described qualitatively
3. Recognizing and acknowledging uncertainties and omissions, and considering how these may impact the net benefit results using tools such as sensitivity analyses
4. Including stakeholder involvement at all stages of the process
5. Promoting transparency and communication throughout the process, to enable replication and foster trust in the outcomes

CHAPTER 1.0

INTRODUCTION

This report describes efforts conducted for the Water Environment Research Foundation (WERF), for project 04-CTS-2, "*An Economic Framework for Evaluating the Benefits and Costs of Biosolids Management Options*." As the name of the WERF project and this document imply, the intent of this research is to help wastewater agencies—and other relevant entities and stakeholders—understand the benefits and costs of the biosolids management options that are available to them. As such, this report:

- Describes what an economic benefit-cost analysis (BCA) is
- Discusses why it is important and useful to conduct such economic analyses
- Provides guidance on how to conduct BCAs, and how to document and communicate the inputs and outputs of such analyses
- Offers various tools, resource guides, and templates to help utilities and other interested parties conduct BCAs for biosolids options
- Illustrates how BCAs for biosolids options can be performed and documented, using case studies derived from several utilities

This chapter briefly describes the main rationale and objective of this research report, and also provides a chapter-by-chapter roadmap of what the rest of this document contains.

1.1 Project Objective

Wastewaters, and the solids derived from the treatment of municipal wastewaters, are a fact of life. The safe and prudent management of these liquid and solid "wastes" is of considerable concern because, if not managed suitably, there could be serious public health, welfare, and environmental consequences.

Fortunately, wastewater agencies, regulatory bodies, the research community, and other entities have identified and implemented a suite of practices, processes, and regulations that enable the safe and prudent management of these inevitable byproducts of human existence and economic activity. Furthermore, there are numerous existing and emerging options that enable biosolids to be used as a valuable resource (e.g., for energy production or recovery) rather than as a waste product.

Still, there are numerous significant challenges faced by wastewater agencies and other interested parties as they consider how to best manage biosolids:

- First, biosolids management options tend to be expensive in terms of capital outlays and operating expenses (including energy costs). Therefore, managers need to consider whether there are benefits that warrant the high costs of some of the options available to them.

- In addition, many biosolids management options tend to be controversial due to public concern over various real or perceived risks or inconveniences (e.g., land application may meet with some opposition and local restrictions due to concerns over perceived and real potential impacts such as increased local truck traffic, odors, or risks to public health). Therefore, managers need to be able to weigh a broad suite of outcomes and options.
- Also, there may be physical or other constraints on some relevant biosolids management options for some locations (e.g., a lack of land application sites or landfill capacity in reasonable proximity, air quality restrictions that may preclude some incineration or energy recovery options, limited markets for Class A products). Therefore, a comparison of options can be quite complex, and such benefit-cost comparisons are highly site- and utility-specific.

Given these complex challenges, the intent of this report is to provide some basic tools and guidance to help utility managers and other interested parties better evaluate their various applicable biosolids management options. The goal is to help utility managers better understand the broad range of benefits, costs, and risks associated with their biosolids options. This in turn will enable them to better 1) identify which option(s) are most logical and promising for their agency (i.e., have the highest net social benefits), and 2) communicate and work with their local public officials, customers, and other stakeholders to jointly understand, assess, and select the options best suited for their communities.

1.2 The Rationale for Doing BCA for Biosolids

Issues related to residuals and biosolids have consistently ranked among the top priorities of WERF subscribers over the past decade. There is good reason for this. The cost of solids treatment and handling alone typically compose half of wastewater utility costs (WERF, 2005b). But the challenge facing wastewater agencies is much broader and deeper than simply trying to better manage or reduce costs. There also are fundamental issues about how liquid and solid byproducts of wastewater treatment are perceived and used—either as wastes requiring prudent disposal, or as resources that provide beneficial use values and promote sustainability.

While intuition might point to the inherent advantage of beneficial use options, the issue is complicated by several real and perceived concerns. Each biosolids management option—regardless of whether it reflects a disposal or a beneficial use approach—imposes financial costs on the wastewater agency, and beneficial use options in many instances are relatively expensive and potentially controversial. Further, each biosolids option may also generate benefits, costs, and potential risks that may accrue to people and entities other than the utility. These are called "external" costs, risks, and benefits because they are not borne directly (internally) by the utility, and instead are borne by others. These external benefits and costs typically are difficult to measure and not often systematically included within the internal cost-accounting decision-making framework of wastewater agencies.

Therefore, utilities need a systematic and objective manner to evaluate the full range of costs, benefits, and potential risks associated with their broad array of biosolids management options. They also need to consider who might bear those costs, risks, and benefits. This is because the distribution (incidence) of the impacts raises the matter of fairness (environmental justice) and provides a practical basis for mission-critical dialogue with stakeholders and governing officials (e.g., to constructively engage winners and losers in the deliberations, and to provide an economic basis for cost sharing, rate setting, or risk mitigation efforts).

The objective of this research was to provide a practical, user-friendly, yet reasonably robust tool that wastewater agencies can use to identify and assess the benefits and costs of their biosolids management options. The key is to provide an objective and comprehensive basis for considering all the benefits and costs—both internal and external to the agency—so that utility managers, governing officials, customers, and other stakeholders can better understand the implications of the applicable biosolids options. The benefit-cost framework provided here is intended to be useful as:

1. A tool for project evaluation (i.e., to help guide and conduct the analysis of Master Plan options)
2. A process for information dissemination and stakeholder communication (i.e., to help document and portray key assumptions, findings, and associated sensitivity analyses)

This report is intended to help wastewater districts and other interested parties overcome many of these obstacles. This report, and its associated spreadsheet tools, provide objective, credible, and relatively simple ways to:

- Distinguish between a *financial* analysis and an *economic* analysis, where the latter enables a more complete view of all the benefits (as well as risks and costs) of biosolids management options, and provides a suitable construct for comparing benefits to costs
- *Identify* the full range of potential benefits associated with a biosolids project, and *quantify* and *monetize* these benefits (to the extent feasible), in ways that should be objective and credible
- Assess the *distribution* (or, *incidence*) of benefits and costs so that the beneficiaries of biosolids management options can be identified (as can those who bear the costs), and thereby facilitate equitable cost recovery, provide justification for grants and other external financial assistance, and enable more extensive stakeholder identification and involvement
- Develop a sound economic analysis of biosolids management options—in a transparent, credible, replicable, and helpful manner—by providing an *organizational framework* (including a process, templates, and spreadsheet tools) to systematically conduct, organize, and portray key inputs, assumptions, findings, and sensitivities
- Document, articulate, and *communicate* biosolids BCAs to customers, managers, governing officials, and other important stakeholders

1.3 Roadmap to this Report

There are several key parts to this report. Following this introductory chapter, the following materials are provided:

- Chapter 2.0 contains an overview of issues related to the economics of biosolids management options, describing the motivation for this project, and providing an overview of the types of benefits and costs that may be relevant for biosolids options.
- Chapter 3.0 provides guidance on how to conduct an economic analysis of biosolids management options, structured in a question and answer format, to help users understand the basis for (and how to implement) the economic framework embodied in the spreadsheet tool and associated templates.

- Chapter 4.0 provides hard copy templates of the various tables and forms to guide users through the various steps that are defined for an economic analysis. These paper version templates also parallel what is provided in the spreadsheet tool, to help users gain a visual overview of the steps in the software tool (although the software version differs in some ways, to enhance the value of functions enabled by a computerized approach). The templates also provide a means through which users can implement the economic framework off-line (i.e., without relying on the electronic spreadsheet version).
- Chapter 5.0 provides some useful illustrations, tips, and lessons learned based on case study applications of the framework to wastewater agencies that have participated in this research.
- Chapter 6.0 offers conclusions and identifies an agenda for future research.
- A series of detailed appendices offer technical insights and resource guides to help wastewater agency personnel understand how to develop estimates for several key benefit (and cost) categories, including values associated with energy recovery or generation, carbon sequestration, and land productivity.

CHAPTER 2.0

AN OVERVIEW OF ECONOMIC ISSUES APPLICABLE TO BIOSOLIDS MANAGEMENT OPTIONS

2.1 Overall Objective: A Broad Assessment of Benefits and Costs

Agencies responsible for wastewater treatment can manage their treatment residuals as waste products requiring suitable disposal (e.g., liquids managed as wastewater effluent, and sludges directed to traditional landfills). Or, the agencies can view the liquid and/or solid treatment residuals as resources that can have significant "beneficial use" potential. For example, effluent can be rendered into reclaimed water, and solids can be used beneficially as a soil amendment in land applications and mine site reclamation, or used as a bio-fuel for energy production.

The beneficial use options for biosolids management can generate important benefits to the utility and the community it serves. However, in some instances these beneficial use options also may have the potential to impose additional costs and/or risks. These benefits, costs, and potential risks generally accrue not only to the wastewater agency alone, but also to society as a whole (including the environment).

As stewards of the environment and public trust, wastewater agencies need to consider the full range of benefits and costs associated with their activities. This means that they need to take into account all the impacts—good, bad, and uncertain—that their activities may impose on the broader community.

Likewise, utilities cannot in good faith focus exclusively on the direct financial impacts on their agency alone (i.e., internal cash flow implications of out-of-pocket expenses and incoming revenues). Instead, utilities also need to take account of the "externalities" their activities bestow (or impose) on the broader community.

BCA—if conducted with a suitably broad "social" perspective and based on a transparent application of appropriate tools and data—offers a well-established framework for addressing these issues. Accordingly, the researchers' approach in this report is intended to provide wastewater agencies with a practical way to better recognize and account for the impacts of the biosolids management options they are considering, regardless of who realizes the benefits, or who bears the costs and risks. Their approach also will help agencies consider all benefits and costs regardless of whether they are market-traded and priced, or need to be assessed and perhaps valued as "nonmarket" goods or services (e.g., environmental impacts, odors).

2.2 The Biosolids Challenge Faced by Wastewater Agencies

2.2.1 Identifying and Communicating All the Benefits and Costs

To make prudent decisions about biosolids management options, wastewater treatment agencies need a practical framework that can help them 1) identify and understand the full range of options available to them; 2) assess the full benefits and costs of each option (including any risks, costs, and benefits that may accrue to individuals or organizations external to the agency); and 3) place the benefit-cost results of the options in a suitable comparative framework so that the alternative(s) with the largest net benefits can be identified.

Concurrently, agencies need to communicate effectively—with regulators, governing officials, public interest groups, customers, and other stakeholders—so that risk perceptions and attitudes can be mutually understood and addressed, and so that the comparative advantages (net benefits) of preferred biosolids management options can be explained in an accurate, clear, and effective manner. Therefore, the benefit-cost framework needs to be seen and applied as part of a process that 1) invites stakeholder input and accommodates public perceptions on values and concerns (including risks, costs, and benefits); and 2) serves as a vehicle for helping to communicate with stakeholders and decision-makers in a transparent and effective manner.

The researchers' approach was aimed directly at addressing this need for a clear, objective, comprehensive, yet practical and readily applicable benefit-cost framework. This report attempts to provide a tool (and associated guidance) that wastewater agencies can readily apply to their specific circumstances to help them better understand—and communicate—their range of biosolids management options (including a suitable status quo baseline), and the likely consequences of those options (including the implications of the "do nothing" baseline of making no changes to current practices).

2.2.2 Navigating a Rapidly Changing Landscape for Biosolids Management

An additional challenge faced by agencies with biosolids responsibilities is that the landscape is changing—often rapidly—with respect to what biosolids management options can be considered (and what benefits and costs should be included in the evaluation of these options). Technological advances are making several new processes and options available, or more economically attractive, than in the past. New technological advances are providing an array of offerings that may help enhance energy use efficiency, provide ways to generate energy or other useful value-added products from biosolids, and/or reduce greenhouse gas (GHG) emissions associated with global climate change concerns.

At the same time, some recently viable or current practices are, in some locations, becoming less feasible from a public acceptance and/or cost-effectiveness perspective. For example, in some parts of North America, land application of Class B biosolids may not remain a practical or available option due to public opposition and related politically-imposed constraints (e.g., bans or other restrictions on land application). Further, some Class A processes may become economically cost-prohibitive due to rapidly escalating energy costs.

Given this changing landscape of engineering, economic, and political realities, utility managers face a daunting task of trying to chart a prudent and sustainable biosolids course for their community's future. Among the challenges faced in evaluating multiple options, and trying to develop a rationale for advocating one or more options (over the other biosolids alternatives), there are numerous impediments that may include:

1. The anticipation of relatively poor financial returns (net cash flows) for many beneficial use biosolids projects, in terms of the utility's expenses (cash outflows) relative to any projected biosolids-generated revenues or cost savings

2. Uncertainty about the relative environmental, social, and economic net benefits (where "net benefits" refers to benefits minus costs) of one biosolids alternative compared to other biosolids management alternatives
3. Public concerns (whether arising from legitimate risks, scientific uncertainties, or misperceptions) about the safety or value of some relevant biosolids management options

This report can help practitioners overcome these obstacles by providing a systemic approach, several case study illustrations, and technical guidance on how to identify and assess benefits and costs.

2.3 Distinguishing Financial Analysis from Economic Analysis

2.3.1 Cash Flows versus BCA

A very important distinction for this report is the difference between financial analysis and economic analysis. This report focuses on the latter, emphasizing benefit-cost comparisons as the applicable form of economic analysis. To make the distinction more clear, consider the discussion and distinctions made below.

1. A *financial* analysis of biosolids management focuses solely on the *cash flows* of expenses paid out and revenues brought into the utility. In other words, a financial analysis focuses on the internal monetary bottom line of the agency, and disregards any impact or values that do not register within the utility as cash transactions.
   a. This means that a financial analysis will reveal how much revenue is collected, and how much money the utility spends (salaries and other operating expenses, and debt service on capital equipment investments).
   b. This comparison of cash outlays (expenses) to cash inflows (revenues) produces the utility's *financial bottom line*—the degree to which cash expenses may exceed inflowing revenues (or vice versa). If the utility were a private sector enterprise, this would indicate whether or not the firm earned a profit (revenues exceeding costs) or a loss (costs exceeding revenues).
2. An *economic* analysis starts with the financial analysis, but then adds external and nonmarket impacts to provide a much broader perspective of the full value (benefits) and full costs of the biosolids-related operation.
   a. In other words, an economic analysis provides a suitable benefit-cost perspective for considering if a biosolids management option is an investment that is worth the expense, given due consideration to all the values provided to (as well as costs imposed on) the broader region and community as a whole.
   b. The comparison of all the benefits generated (regardless of to whom they accrue) to all the costs (including any costs borne outside the utility) indicates whether there are positive net benefits (benefits that outweigh costs) for society as a whole.

2.3.2 Overcoming the Cash Flow Challenge for Beneficial Use Options

Beneficial use options for biosolids management often are relatively expensive in terms of the direct financial cost of installing and operating the required treatment processes and related infrastructure. At the same time, the anticipated revenue stream may appear relatively low. High out-of-pocket costs to the utility, coupled with limited prospects for revenue generation, present utilities with a clear financial challenge that can impede development of beneficial use biosolids management options.

Thus, on a cash flow basis, beneficial use options may appear to be a financial loser: A wastewater district will typically see a relatively high estimate for a total annualized cost per ton of solids managed ($/ton), while at the same time, the utility anticipates limited revenues (if any) from its biosolids program. Thus, it is difficult (and perhaps impossible) to make a "business case" for beneficial use projects based solely on the utility's assessment of its internal financial outcomes.

2.3.3 Adding "Value" to the Equation

While financial analyses are very important and useful in many ways, they typically provide too limited a context with which to evaluate the real social worth of most biosolids projects. This is because a financial analysis focuses strictly on revenue and cost streams internal to the wastewater agency, and these cash flows are not the same as the true worth or *value* of most beneficial use biosolids projects to the community and society as a whole.

The problem is not necessarily that the value of some biosolids management options is too low. Rather, the problem is that a financial analysis provides too narrow a perspective of the "value" of the goods and services provided. For example, a financial analysis focused on the wastewater utility would not typically reflect benefits to the community such as the environmental and social costs avoided when a beneficial use option enables a community to forego or postpone developing a new solid waste landfill (e.g., when land application avoids the accelerated use of limited local landfill capacity). This report and associated tools provide a suitable economic framework within which the benefits ("value") of biosolids management projects can be more fully identified and evaluated, and then properly compared to the full costs of those options.

In economic parlance, an analytical tool is being developed for conducting a *full social cost accounting* of the benefits and costs of biosolids projects (as defined and discussed in greater detail below). Case study illustrations are also provided of the benefit-cost framework to 1) demonstrate how the tool can be used to estimate and portray environmental and other costs and benefits of a biosolids management option (relative to other alternatives) in an objective and comprehensive manner, and 2) reveal how the benefits of specific biosolids projects compare to their costs.

A Simple Graphical Depiction The difference between a financial analysis and an economic analysis is depicted in the contrasting bar charts provided in Figures 2-1 and 2-2. In Figure 2-1, a financial analysis is depicted in which costs are reflected as annual cash outflows to cover debt service on capital investments (e.g., treatment plant facilities, distribution and storage, and so forth) plus the annual operation and maintenance (O&M) outlays for the biosolids management project. The financial analysis depicted in Figure 2-1 also shows the expected cash inflow (i.e., revenue stream), typically based on annual volume of biosolids product sold (if any), times the per unit price charged for biosolids products (though in many utilities, biosolids products such as cake or compost are provided for no charge to users). In this illustration, projected revenues are far less than annual cash outlays.

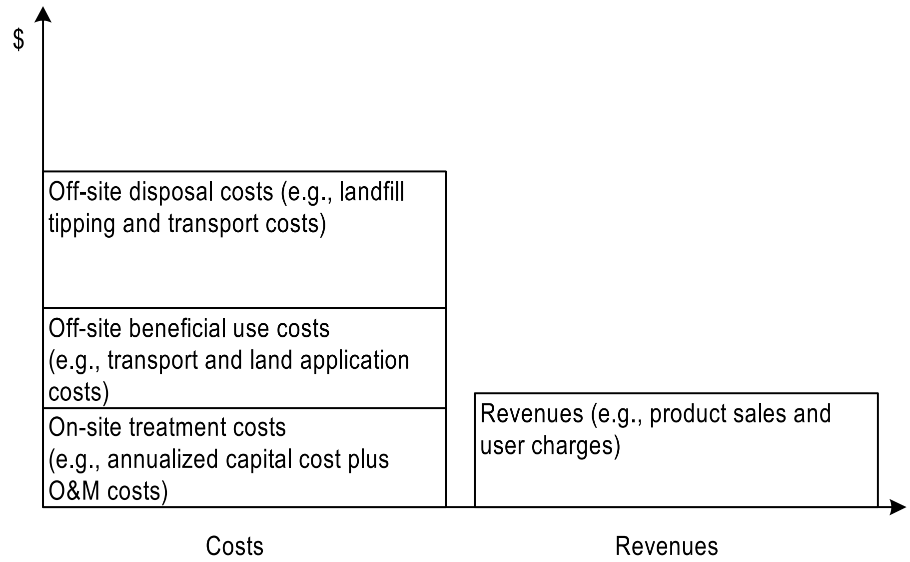

Figure 2-1. Financial Analysis Focuses on Internal Cash Flows.

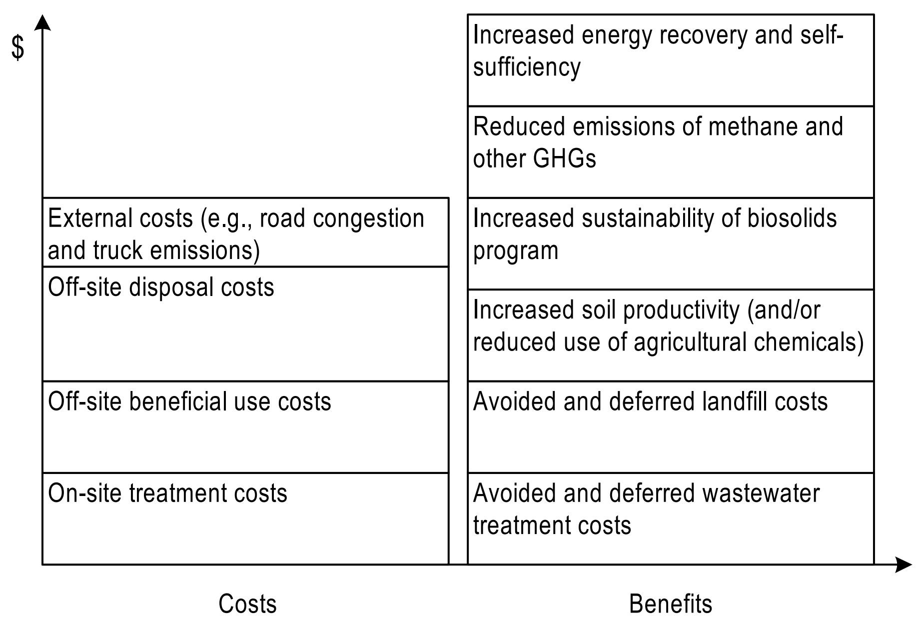

Figure 2-2. Economic Analysis Focuses on Societal Benefits and Costs.

In contrast, Figure 2-2 reveals an economic analysis for a hypothetical beneficial use biosolids project. On the cost side, financial costs can still be depicted in the same manner as in the financial analysis (i.e., either as an annualized total cost, or as a present value of costs over the expected useful life of the project), but also accounted for are some nonfinancial costs beyond the utility (e.g., additional noise and traffic congestion from shipping biosolids to agricultural lands rather than to a landfill). In this figure, the right-hand bar reflects the varied benefits (values) of the biosolids use project (depicted in either an annualized or present value context, to be consistent with how costs are depicted). Here, when all the varied types of benefits are considered and combined, this illustrative depiction shows the benefits of the beneficial use project appear to outweigh costs.

The key to these figures is that in the financial analysis, it is revenues that are contrasted to costs, whereas in the economic analysis, it is benefits that are compared to costs. Another key observation is that it may often require a compilation of several different types of benefits to recognize that the overall benefits may outweigh costs; if some of the benefit categories are overlooked, the project may not appear to be economically justified. Thus, it is important that all the key benefits of a biosolids management project be recognized in some fashion in an economic analysis; this report is intended to help agencies and stakeholders properly identify, describe, and, where feasible, develop some quantitative measure of those key benefits.

2.4 The BCA Framework Needed for Biosolids

Today, wastewater agencies are individually developing their own approaches for comparing alternatives and selecting biosolids management plans. These individual approaches vary in their quality and extent, and are likely to include widely differing approaches with widely differing effectiveness. And, as the public grows increasingly aware of and interested in biosolids management and planning for their communities, the necessity for thorough, acceptable analyses of alternatives continues to grow. A uniform and well-founded approach is needed to ensure quality, reduce utility effort, and promote broader acceptance and usefulness.

To address this need, this project aims at developing an analytical tool for conducting a "full social cost accounting"-based assessment of the benefits and costs of proposed biosolids management options in North America. BCA is a technique that enables program evaluators to undertake structured comparative analyses of alternative approaches to achieving the same general outcome (e.g., to economically and safely manage X wet tons of sewage sludge generated per day). It is widely used, and in some cases federally mandated, in evaluating complex projects that have substantial environmental and social impacts.

2.4.1 Including Internal and External Impacts for Market and Nonmarket Goods and Services

The term "full social cost accounting" refers to the economics perspective of trying to identify and account for *all* the benefits and costs of a potential action or policy, regardless of who bears the impact, or whether the impact can be valued using observed market prices. In other words, the researchers' approach is to try to include benefits, costs, and risks borne "internally" by the wastewater agency as well as those impacts borne "externally" by other parties (households, businesses, plant and field workers, etc.). The researchers also strive to help include, to the greatest degree feasible, "nonmarket" goods and services—meaning impacts that are not typically traded in markets and therefore do not have market-observable values, such as improved public perception. These values are estimated using nonmarket valuation technique, which are described in greater detail in Chapter 3.0.

2.4.2 Considering the "Triple Bottom Line" Approach: A Variant of BCA

There are important roles for both financial and economic analyses in biosolids management agencies. However, given the nature of the public trust aspect of a wastewater agency's role in the communities it serves, it is very important to look beyond the financial bottom line and also include the broader economic perspectives.

A wastewater and biosolids management utility should not be expected to operate exactly like a private sector business in terms making a profit or being self-sustaining financially. Certainly, a utility should still strive to operate efficiently using sound business-like practices such as cost control, asset management, and careful accounting, so that public funds are being spent wisely. However, a wastewater/biosolids management utility is an entity intended to serve a public purpose, i.e., managing the community's wastes in a way that preserves public health and welfare and protects the environment. As such, a utility should not necessarily focus on profit-making, or be evaluated based solely on its financial bottom line.

Instead, utilities need to look beyond the financial bottom line and also consider important social and environmental impacts associated with various biosolids management options. This means considering benefits and costs that are external to the utility, including those that may reflect nonmarket outcomes (i.e., impacts on goods and services that are not traded in markets but may nonetheless be highly valued).

The full social cost accounting-based application of BCA can also be portrayed within a "triple bottom line" (TBL) framework. The TBL is a planning tool developed to help agencies track their progress toward promoting sustainability, and in essence is a streamlined and often qualitative version of a social BCA. The TBL has been popularized through widespread application in Australian utilities, and has begun to see applications in some North American utilities in the past few years. The TBL consists of:

1. A financial bottom line that reflects the cash flow accounting stance of the agency (i.e., internal costs and revenues)
2. A second bottom line to reflect "social" impacts of an agency action (e.g., "helps promote environmental justice by creating employment opportunities for economically disadvantaged members of the community," or "extends the useful lifetime of local solid waste landfills by diverting solids to land application sites")
3. A third, environmental bottom line (e.g., "reduces GHG emissions by reducing methane flaring and electricity purchases," or "reduces likelihood of groundwater contamination")

A more detailed description of how to apply the TBL is offered the next chapter (Section 3.16). Also, as part of the case study illustrations provided in Chapter 5.0, the researchers demonstrate how the TBL can be fashioned and applied to the biosolids management issue, as a simplified first step toward a more full-scale, social benefit-cost assessment (and as an intuitive way to promote better communication with stakeholders, governing officials, etc.).

2.4.3 Accounting for and Portraying Risk and Associated Uncertainties

A critical issue for biosolids management options is the degree to which each may pose risks to human health and/or the environment. Incineration releases air pollutants including GHG emissions, and landfill disposal can generate toxic leachate that may contaminate groundwater. Land application may add endocrine disrupting chemicals (EDCs), metals, or pathogens to soils. This may pose potential risks to humans through ingestion or inhalation pathways, and may pose risks to organisms in the environment.

What is critically important for the benefit-cost framework is that it provides a systematic and objective avenue for accommodating potential or estimated risks, including the often considerable scientific uncertainty surrounding those risks. This is not a simple undertaking, and the researchers' framework includes guidance on how to qualitatively discuss impacts that may be difficult (or impossible) to quantify in a reliable or meaningful manner (including how sensitivity analyses can help reveal whether these types of impacts might alter how a biosolids option ranks relative to its alternatives). The BCA approach also provides a comparative framework, so that a broad range of feasible alternatives—spanning a variety of disposal and beneficial use options—can be assessed relative to each other, and their types and relative levels of risk can be suitably portrayed.

2.4.4 Building on and Complementing Existing Research and Programs

This WERF-sponsored BCA approach tries to avoid re-inventing the wheel. Instead, it builds upon existing information, systems, data, and tools to the degree feasible and suitable. Among these are 1) the Biosolids Partnership and its associated Environmental Management System (EMS); 2) WERF's full cost accounting (FCA) protocol (Epstein et al., 2003); 3) risk assessment reviews and insights by WERF (e.g., Moss et al., 2002), the National Research Council (NRC, 2002), the U.S. Environmental Protection Agency (U.S. EPA, 1993), and other credible entities; and 4) economic framework and benefit-cost guidance documents, including those issued by the U.S. EPA (U.S. EPA, 2000e) and the WateReuse Foundation (Raucher et al., 2006).

2.4.5 Recognizing that BCA is Simply One Tool in the Decision Support Toolbox

Although this report is about developing and applying a BCA framework, it is critical to acknowledge the limitations and appropriate intent of doing a BCA. Accordingly, it is useful to keep in mind the following three interrelated observations:

1. BCA is one of several tools that wastewater agency managers and public officials need to have in their decision support toolbox to effectively deliberate biosolids management options and decisions in the public policy sphere. And, while BCA can be very informative and useful, it does not necessarily supplant other tools or override other considerations.
2. BCA is not an exact science and should not be seen as providing a firm "rule" to determine what outcomes (e.g., biosolids management options) should be pursued. Rather, BCA is simply a tool to help systematically organize information and illustrate suitable comparisons across options.
3. A good BCA alone is unlikely to carry the day for a manager or public official attempting to update biosolids management practices. Instead, BCA is among a suite of tools and can be used to complement other types of analysis, perspectives, and communication

approaches (e.g., a BCA is unlikely to overcome opposition to a project from those who perceive potential health risks due to a proposed beneficial use application, and in most cases complementary approaches in risk communication and public dialogue will be needed as well).

2.5 Engaging Customers, Governing Officials, and Other Stakeholders

In addition to developing a framework to better encompass the environmental and economic implications of biosolids projects, another key function of this economic framework project is to provide a basis that agencies can use to help communicate their key assumptions, inputs, and findings with impacted communities and stakeholders. The tool developed here can (and should) be used to facilitate a process wherein input is invited from relevant individuals and organizations, and through which utilities systematically reveal the key assumptions, input values, sensitivities, and other factors embodied in the analysis.

The framework tool provided here is *not* intended to be used as a "black box" that develops fixed empirical outputs (e.g., dollar values) for all benefits and costs. Instead, it is intended to help organize, document, and communicate benefit-cost information in a transparent manner, to help guide public discourse and policy making.

There are several important reasons for engaging stakeholders throughout the application and interpretation of the economic framework. First, it is important to ensure that the key benefits and costs of a potential biosolids management approach are well recognized. Beneficial use can generate many important types of benefits and costs, but often the full range of benefits or costs is not well recognized because:

- Some benefits (and/or costs) are disbursed across political or district jurisdictional boundaries
- Some beneficiaries (and/or cost-bearers) may not be engaged in the deliberations
- Many benefits (and/or costs) are not realized until many years in future
- Projects often are viewed from a narrow financial perspective (revenues versus costs) rather than a broader context of social benefits and costs

In addition, it is important that analysts applying the framework avoid technical jargon, and instead try to find and apply lay terms (especially to describe the types of benefits to be derived). The key is to use words and concepts that effectively communicate with the key stakeholders. This can be a challenge, because many biosolids-related benefits may be hard to describe in ways that resonate with stakeholders and public officials. This problem may arise because:

- Economic terminology is not always user-friendly, intuitive, or communicative
- The traditional economics labels for key benefit categories (e.g., "passive use" to describe values associated with the motive to preserve endangered species) can foster the impression with some stakeholders that their core issues have not been fully recognized or included in the analysis
- Benefit measurement and estimation methods developed and used by economists may be seen as smoke and mirrors, and lead stakeholders to question the overall credibility of the economic analysis

- There may be a mistrust of BCA, especially where the approach is seen as incomplete (e.g., missing benefits or costs), biased (e.g., generating predetermined outcomes), or part of a broader political agenda (e.g., to undermine the fabric of environmental and health regulations)

Also, it is important to consider stakeholders within the context of equity—what is often referred to as environmental justice. The economic framework encourages utility analysts to identify the key beneficiaries of biosolids projects. This is intended to help all parties recognize (and consider the implications of) who will realize benefits, and who bears the costs or risks associated with a biosolids management project. This is important for biosolids project evaluations because there often are real or perceived equity issues (e.g., who faces a potential risk or bears a cost, versus who receives a benefit from a biosolids option) that can serve to derail a project (e.g., utility customers pay, but large benefits may be generated for other people and entities in locations—such as farmers—beyond the local utility service area or political jurisdiction boundaries).

There are several additional important advantages of applying the broad BCA of the biosolids economic framework. Identifying and describing the full range of benefits, including those that accrue beyond the utility and its customers, will help the wastewater agency:

- Recognize the full range of benefits of each biosolids option, and portray all these benefits to governing/oversight bodies
- Facilitate buy-in and support from utility customers, and help diffuse or offset possible opposition, e.g., by describing green values attributable to beneficial use, such as energy recovery-related reductions in air pollutant emissions (including GHGs), because less electricity production is required from power sector
- Identify beneficiaries beyond the agency's customer base, thereby providing a basis for pursuing broader cost-recovery (i.e., by showing who benefits and how they benefit, there is a more logical and equitable basis for cost allocations that better reflect the distribution of benefits)
- Provide a basis for seeking external funding support, by recognizing and systematically characterizing the external benefits (e.g., when seeking state or federal grants, to recognize how the wastewater district's biosolids choices generate benefits to neighboring communities and/or for the environment in general)

Therefore, the economic framework provided here is designed to help utility analysts think about the distribution of all lifecycle benefits and costs, and also to provide a foundation on which stakeholder interactions can be structured.

2.6 Key Environmental and Economic Benefits and Costs to Include in the Assessment

For some, a major concern regarding the development of some biosolids projects is the potential for adverse environmental or public health impacts, or both. These issues and concerns need to be given due consideration as potential costs of a biosolids management option.

At the same time, comparatively little attention has focused on beneficial use biosolids options as a mechanism for reducing adverse environmental impacts. The environmental and other benefits of biosolids uses may include:

1. Increased land productivity and/or restoration values, through soil enhancement derived from suitable land application (or, reduced use of agricultural chemicals to achieve the same conditions, thereby reducing demands on energy- and petroleum-intensive inputs used in agricultural chemical production, and potentially affording greater protection of surface and groundwater systems from agricultural chemical use).
2. Reduced traditional energy consumption and air pollution where biosolids options provide or contribute to renewable biofuels, thermal values, and/or reduced energy use. These can reduce dependence on imported and other nonrenewable energy sources, reduce excessive demands on capacity-strained power grid systems, and reduce the carbon footprint of wastewater and biosolids agency operations.
3. Improved sustainability and reliability of a biosolids program, by providing the community with a more diversified and viable longer-term set of options for addressing their biosolids needs (i.e., ensuring the community is not burdened in the future with a highly limited set of options that would drastically increase the costs of managing the biosolids produced, such as by requiring extraordinarily long transport distances to future disposal sites).[1]
4. Reduced odor-related issues and concerns, insofar as options are pursued that help control odor and address concerns from neighbors.
5. Reduced risk of negative local and regional economic impacts under alternative biosolids constraints (i.e., changes in local economic sustainability, if biosolids options become too limited and expensive in the future).

In the materials that follow, the researchers describe empirical evidence and provide a framework to enable wastewater agencies to identify and, in many instances, estimate the likely level of relevant benefits and costs associated with biosolids options. The framework uses a regional and community-wide perspective to better capture the full range of potential societal returns and costs from biosolids management investments.

2.7 A Comparative Context, with Careful Attention to Defining the Baseline

One important key to conducting a proper economic evaluation is to place biosolids projects in a comparative context, evaluating these options against a default scenario of continuing current practices (if viable), as well as in comparison to a range of applicable biosolids management alternatives. The key is to set up the economic analysis in a "with versus without" context in which a biosolids option can be compared to a baseline of continuing current practices into a changing future, and/or a context in which one or more options can be compared to other feasible biosolids management alternatives.

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1. This may be viewed as the risk-reducing value associated with developing alternative mixes of biosolids management options within a portfolio approach to biosolids management (i.e., diversifying the types and sources of variability in biosolids volumes covered and/or costs, across the options in a community's biosolids management portfolio).

Baseline issues are described in greater detail in Chapter 3.0. Three key related points about the baseline are:

1. *Biosolids happen.* The baseline needs to acknowledge that the issue is not whether or not to have biosolids to manage. Rather, the critical perspective is to *compare* the relative merits and disadvantages of alternative options for addressing the biosolids issues in a community.
2. *The future will not look like today.* The baseline needs to reflect the future, not today or yesterday. A good economic analysis is suitably oriented to a "with and without" perspective, and this is not the same as "before and after." Maintaining current practices into the future will have different outcomes than those seen with current practices today (e.g., because of changing volumes, increasing costs, present options becoming foreclosed).
3. *Defining the baseline will be a challenge.* Defining the baseline may be the most contentious and difficult part of doing a good economic analysis. Expect stakeholders to hold different views about what the future will (or should) look like for your community; this will impact the assumptions that drive the analysis.

With regard to the latter point, a challenge to defining the baseline is that the "with and without" context can become a place where hidden agendas or disagreement over core assumptions often arise between stakeholders and the utility or other interested parties. For example, setting the baseline may set off a debate between the utility and stakeholders over future wastewater and biosolids volume projections (e.g., where some members of the community hold alternative views about the size and pace of future population growth, or about the long-term acceptance of land application). Therefore, it is important to carefully define the baseline, be transparent about underlying assumptions, and engage relevant stakeholders at this critical stage of the economic analysis.

Another key aspect of the baseline in a comparative economic framework is that it is important to establish and then carefully *maintain a suitable accounting stance*. For example, if a biosolids project enables a community to forgo (or postpone) capital and/or operating expenditures for alternative wastewater management activities, then these cost savings need to be included in the economic analysis. However, the side of the benefit-cost ledger that this entry gets placed on depends on the baseline scenario and what other biosolids alternatives are included in the assessment. Ultimately, the key is to ensure that cost savings are not double counted as a benefit for one option if it also is shown as a cost for an alternative option (i.e., the cost of option A should not also be shown as a cost savings benefit for its alternative, option B; it needs to be shown as either the cost of A, or a cost avoided benefit of B, but not both).

2.8 Findings of an Economic Framework Workshop

The economic framework was introduced and discussed at length at a dedicated workshop, held at WEFTEC 2006, in Dallas, Texas, in October 2006. Presentations, panel discussions, and breakout sessions provided useful insights that the researchers have incorporated into this report.

This workshop was planned as an interactive forum where the audience could contribute ideas to the WERF project as well as provide feedback on the approach. The workshop was held on October 21, 2006 from 8:30 a.m. to 5:00 p.m. at the convention Center in Dallas, Texas. There were approximately 20 speakers and panelists and 85 people in attendance.

Each speaker was accompanied by a group of panelists who had reviewed the papers before the workshop and were prepared to comment or add emphasis on the papers presented. The proceedings were bound and distributed at the workshop.

The audience was very participatory and engaged and seemed to enjoy the opportunities for networking and for discussions. During the breakout sessions ideas were captured on flip charts and each group was asked to report on the highlights of their discussion. Important insights and perspectives gained from the workshop participants include the following:

- There are many items (i.e., impacts that are benefits and/or costs) that are not typically included in how an agency assesses its biosolids options, and many of these omitted items warrant more serious consideration and inclusion. In particular, utilities need to think “beyond the fence” to take account of the benefits and costs borne by facility neighbors and others who are impacted—for better or worse—by biosolids programs. This broader view of accounting for benefits and costs—looking not just at those borne internally by the utility—can lead to better and more widely accepted biosolids management practices.
- The nexus between energy and biosolids is complex and vitally important for biosolids managers to consider. Given energy prices, concerns over GHG emissions, and other factors, energy recovery and other options that reduce demands on nonrenewable energy resources can have significant benefits. These benefits include potentially large energy cost savings (or offsets) for wastewater agencies, as well as social and environmental benefits (including reduced emissions of air pollutants). Energy recovery may also promote greater public acceptance of the biosolids program.
- Innovative processes offer considerable promise for biosolids management agencies. There are many potential benefits, including energy recovery or energy savings, as well as improved product (e.g., moving from Class B to Class A). At the same time, innovative processes also pose some unique challenges, including operational uncertainties and the expense and calendar duration of regulatory review and permit approval.
- Understanding and addressing stakeholder concerns is a critically important component of any biosolids management effort. Real and perceived health and safety risks and disamenities (e.g., odor, truck traffic, noise, and dust) can derail a project. Utilities need to do more than talk and listen; they also need to be willing and able to act on stakeholder input, and take stakeholder perspectives into account as they consider which options to pursue.
- There is increased pressure for utilities to look at biosolids management from a short-term business planning perspective (e.g., controlling costs, seeking rapid payback periods), rather than from a broader, municipal agency perspective. There is often considerable resistance to anything that might induce rate hikes. This creates a significant challenge in terms of trying to develop options that provide for greater community benefits, because such beneficial use options are often relatively expensive.

- Sustainability means having multiple options for biosolids products, because markets and/or the availability of related beneficial use options are subject to sometimes rapid change. Biosolids managers operate in a very dynamic setting, where options and process are frequently changing, creating a lot of uncertainty and fiscal risk as they consider long-lived capital investments in processes and approaches to managing their biosolids.

2.9 What the Framework Tool and Guidance Offer

The framework and its associated tools have been developed with the objective of providing wastewater and biosolids agency professionals with a way to:

- Provide a technically sound, objective basis for identifying, quantifying, and monetizing benefits and costs (and net benefits)
    - Include and describe all the relevant benefits and costs of biosolids options
    - Adhere to principles of economics for professional integrity and rigor
    - Reveal how to address benefits that cannot be readily quantified or valued
- Work with stakeholders and public officials—and wastewater agency professionals—to develop a "common parlance" for benefits (and costs)
    - Ensure that technicians (economists and engineers) do not talk past public officials, customers, constituencies, and stakeholders
    - Embrace and integrate stakeholder perceptions and value systems
    - Ensure broader recognition of all the applicable benefits and costs of biosolids management options

The economic framework is intended to be generic, since each biosolids project and location has its unique properties. Thus, the framework tool should not be seen as a "plug and play" or "one size fits all" model. Rather, it is a practical tool to organize, develop, and communicate credible analyses of benefits and costs. The framework tool and associated user guidance are provided in the chapters and appendices that follow.

CHAPTER 3.0

HOW TO CONDUCT AN ECONOMIC ANALYSIS FOR BIOSOLIDS MANAGEMENT OPTIONS

This chapter provides overall guidance on what an economic analysis for biosolids management options is, what questions need to be addressed and considered, and what steps need to be executed. A question and answer format is used here, and the guidance is supplemented through cross references to supplemental materials (e.g., technical appendices, resource guides, and a spreadsheet tool) provided as part of this project report.

3.1 What is Economic Analysis and How Does it Differ from Financial Analysis?

Financial analysis and economic analysis are both used in the planning and development of wastewater and solids management projects. However, there is an important distinction between the two analyses, as discussed previously in Chapter 2.0.

- *Financial analysis* considers only direct costs to the agency, and project revenues. It is typically used by the utility or agency as a cash flow analysis. The purpose of the financial analysis is to determine if a biosolids project can be financed and what the debt service, O&M, and other recurring costs will be over time.
- In contrast, an *economic analysis* is a more comprehensive investigation of potential projects and management decisions. Economic analysis takes into account not only the financial costs and revenues accounted under the financial analysis, but also the wider range of benefits and costs of a project, from all perspectives including the customer and society (i.e., the broader community) as a whole. These can include direct benefits such as avoided cost of the development of a new landfill disposal site as well as nonmarket benefits and costs (e.g., environmental impacts from a beneficial use project).

The focus of this report and the associated framework tool is on economic analysis.

3.2 Why is Economic Analysis Appropriate for Biosolids Management Projects?

Beneficial use biosolids projects typically produce a wide range of benefits to society, many of which may not be fully acknowledged or appreciated, in part because they are of a less tangible, less quantifiable nature. All of these benefits need to be considered to determine if a project makes economic sense. Omitting some benefits may lead erroneously to a conclusion that benefits are outweighed by costs, when in fact the opposite might be true.

Although it may not seem to the layperson that some categories of benefits are suitable for quantification or monetization, there is a well-established toolkit of economic valuation approaches that can be used in many cases. In addition, a wealth of economic literature provides experience and examples of the use of these techniques, and some provide useful empirical information on the potential magnitude of the values. Even if a specific site or project has not been previously analyzed, it is often the case that similar or equivalent issues have been addressed in a different context, but one from which some insights may nonetheless be "transferable" to a given biosolids context.

3.3 Why Look at the Full Range of Internal and External Benefits and Costs?

Economic analysis allows for a comparison of the full range of costs associated with the project to the full range of benefits. Unless all the benefits and all the costs are recognized and considered, policy makers may make inefficient decisions (e.g., projects with positive net social benefits may mistakenly be considered economically inefficient).

In choosing between project alternatives, the alternatives can be ranked according to their net present values (NPVs), which represent the present value of net output that will be generated over the life of the project (present values and discounting are described in greater detail later). The project with the highest NPV (assuming the same discount rate) is more desirable (all else equal).

In addition, economic analysis can also be applied to determine the allocation of costs and funding responsibility on an equitable basis. This can be supported by identifying the proportion of total project benefits a stakeholder is expected to enjoy (i.e., it can help identify who bears the costs versus who receives the benefits).

3.4 How Can the Framework Help Examine Beneficial Use Options for Biosolids?

Outside of the benefit-cost framework, comparatively little attention has focused on beneficial use as a mechanism for reducing adverse environmental impacts (or providing positive environmental impacts) relative to its alternatives. The environmental and other benefits of beneficial use need to be viewed from the standpoint of what costs and risks may be avoided by steering biosolids away from disposal options.

An example of environmental and health risks avoided by beneficial use is air pollution from incineration, including emissions with adverse human health and welfare impacts, and GHGs associated with global warming. Landfill alternatives pose a risk of groundwater contamination, and accelerate the pace at which regionally limited landfill capacity is consumed. In contrast, properly managed land application improves soil conditions (e.g., adding nutrients, moisture retention); helps sequester carbon (rather than generate GHG emissions); and promotes the binding of metals in the soils (so that potential human and ecosystem exposures are reduced).

There also are important costs that need to be included in a balanced assessment of biosolids options. These include all the lifecycle costs borne internally by the utility as related to their biosolids operations, including biosolids-relevant aspects of wastewater treatment as well as costs for the post-wastewater treatment elements of the biosolids management program (e.g., storage and transport of cake). These internal costs should include all relevant capital outlays as well as all operating expenses, over the expected lifetime of the equipment (for additional detail and guidance, see WERF 00PUM7, Epstein et al., 2003). External costs also need to be taken into account, to the extent feasible. These external costs include adverse impacts as may potentially be borne by the general public and other stakeholders. External costs may arise due to odors, transport-related traffic congestion and risks, and potential concerns about human health and/or environmental risks as may be associated with some biosolids management options in some locations.

The key point is that each utility needs to consider which option (or mix of options) makes the most sense, given their location and other agency-specific factors. This requires a comparative assessment that factors in costs, odors, net energy use (or production), transportation costs and risks, and a host of other considerations that need to considered within the framework.

3.5 How Does the Benefit-Cost Framework Differ from an Environmental Management System?

Over the past few years, the industry has created a significant nationwide effort to further improve biosolids management programs—the National Biosolids Partnership (an alliance of the Water Environment Federation, the Association of Metropolitan Sewerage Agencies, and the U.S. EPA). The main focus of the partnership is establishing a comprehensive program to implement EMS for biosolids.

An EMS is a rigorous management system that ensures biosolids recycling is done in accordance with legal requirements and best management practices and is constantly improved. This progressive environmental program requires extensive public input and independent audits of biosolids programs. The EMS mandates compliance with all regulatory requirements, but includes third-party verification and public input as key additional elements. EMS implementation may therefore impose some additional internal costs on utilities, but should help allay public fears and thus offset the potential for some citizens to implicitly assign inflated risks to some biosolids options. In the balance, the public's perceptions of risks have significant weight. EMS efforts to provide additional information and assurance can help to keep options open and therefore allow a better overall optimization of biosolids management.

In terms of how the BCA differs from an EMS, an EMS is geared towards "continuous improvement" in the day-to-day operations of a biosolids management agency. In contrast, a BCA typically focuses on longer-term capital investment planning, with the objective of helping a utility evaluate its options to identify which ones provide the greatest net benefits. Thus, a BCA might most typically be used to help decide what process changes and overall biosolids management approaches the utility might adopt going into the future, and an EMS would then help the utility operate and manage the selected options in the best manner possible.

Both the BCA framework and the EMS are geared toward promoting sustainability, engaging stakeholders, and building confidence and trust in the utility. These common foci should serve as a useful nexus through which EMS and BCA efforts can be interrelated and mutually reinforcing. Ultimately, both tools are parts of a process intended to help identify and implement biosolids management practices that create the greatest value to the utility and the community it serves.

3.6 What Are the Steps that Make up this BCA Framework?

There is a series of steps that should guide an economic analysis of biosolids (or other water and wastewater-related) projects. A recently completed report for the WateReuse Foundation (Raucher et al., 2006) provides the general framework and steps that apply generically to any water or wastewater-related BCA, and these are adopted here for biosolids as well. These steps provide a logical and consistent process through which the analyst can proceed through the assessment.

The framework tools provided here also provide a way for the analyst to document each step and thus offers a structured basis for communicating with utility managers, governing officials, customers, and other stakeholders. These steps can be documented via the spreadsheet tool, and/or in the comparable paper-version templates provided in Chapter 4.0 and on the accompanying CD.

The following steps make up the economic framework for analysis of biosolids management projects, and are summarized in Figure 3-1. This material is based on Raucher et al.

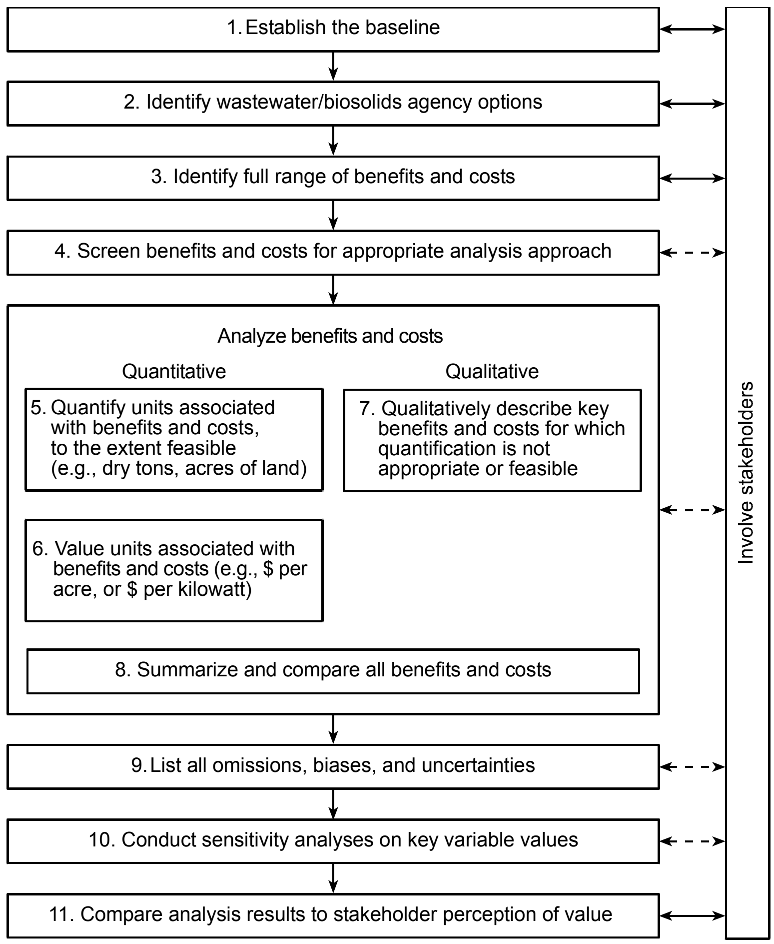


Figure 3-1. Steps in an Economic Analysis Framework.

(2006), as published by the WateReuse Foundation, and other source material cited therein. Additional guidance on how to implement each step is provided later in this report.

3.6.1 Step 1. Establish the Baseline

Define the outcomes associated with the "no action" status quo [i.e., what would happen "without" the biosolids option(s) being considered]. This base case may entail doing nothing different (i.e., not pursuing a different biosolids management project), or undertaking already planned actions. The baseline is the mark against which changes resulting from the biosolids management alternative(s) are measured. It is important to define the scale and timing of the impacts of the baseline, articulate what problems the proposed project (or range of project alternatives) is intended to resolve, be explicit about assumptions, and engage stakeholders about their perspective of what happens under a no action, status quo baseline. (Additional discussion and guidance is provided in Section 3.7 of this chapter.)

3.6.2 Step 2. Identify Wastewater Agency Options for Biosolids Management

Identify and develop all the relevant utility options that will be compared to the baseline, and to each other. It is useful to scale project options to a common size or objective (e.g., to meet projected minimum water delivery requirements). For options available at different scales, it is helpful to consider staging or combinations of options. (Additional discussion is provided in Sections 3.8, 3.9, and 3.10 of this chapter.)

3.6.3 Step 3. Identify the Full Range of Relevant Benefits and Costs for the Selected Option

Develop a thorough inventory of all likely costs and benefits associated with each of the project alternatives (options). Include costs and benefits beyond those faced by the utility alone or customers alone. In other words, try to identify all the benefits and costs, regardless of to whom they may accrue, or where they might be realized. (Additional discussion is provided in Sections 3.11, 3.12, and 3.13 of this chapter.)

3.6.4 Step 4. Screen Benefits and Costs for Appropriate Analysis Approach

In the screening step, the analyst determines which costs and benefits can and should be analyzed quantitatively, which should be described only qualitatively, and which are insignificantly small and can be eliminated from further analysis. (Additional discussion is provided in Sections 3.13 and 3.14 of this chapter.)

3.6.5 Step 5. Quantify Units Associated with Benefits and Costs, to the Extent Feasible

In the first step of valuing a benefit or cost, the amount (quantity) of the outcome should be established. These quantity outcomes may be a volume of biosolids delivered [e.g., wet or dry tons (dt) of class A product], amount of energy produced by a bio-fuels option [e.g., kilowatt hours (kWh)], or whatever units the outcomes are most readily and meaningfully measured. It is important to match the quantity units of measurement to whatever metric is available for the corresponding dollar values (e.g., if the valuation in Step 6 uses a $/kWh measure, then the quantification in Step 5 should be aimed at estimating the number of kWh generated or saved by an option). Ranges of quantity estimates (rather than a single point estimate) may be used to better represent variability or uncertainty associated with resource use estimates.

3.6.6 Step 6. Value Units Associated with Benefits and Costs in Monetary Terms

Once the quantity of resource use has been estimated, a per unit dollar value often can be assigned to the benefit or cost, to reach a total value (quantity times per unit value). The per unit values can be expressed as dollars per unit of product [e.g., dollars per dry ton ($/dt) of class A bagged product] or dollars per unit of resource use or value added [e.g., dollars per change in cropland yields, ($/bushel)]. Ranges of values may be used to better represent per unit resource valuations. Annual benefit or cost values should be projected over the project life (either annualized, or as a NPV, as per Step 8). (Additional discussion is provided in Sections 3.17 and 3.18 of this chapter.)

3.6.7 Step 7. Qualitatively Describe Key Benefits and Costs for Which Quantification is Not Appropriate or Feasible

It may not be feasible or desirable to express some types of benefits or costs in quantitative or monetary terms (as per screening in Step 3). However, it is always important to describe these nonquantified benefits and costs in a meaningful, qualitative manner. One way to do this, in part, is by using a simple scale indicating the likely impact on net project benefits. Impacts can be qualitatively ranked on a 5-point scale, ranging from -2 to +2, to reflect unquantified relative outcomes that span from very negative to very positive (e.g., a "-1" may signify an outcome with moderate unquantified costs, and a "+2" may represent a high unquantified benefit). Qualitative ratings should be accompanied by descriptions of the impact, and should be explicitly carried through the analysis. (Additional discussion is provided in Section 3.15 of this chapter.)

Also, if the analyst does not wish to pursue quantitative estimates of benefits, he or she might opt to portray the analysis at this stage as a TBL analysis (described in Chapter 2.0). This would in essence skip Steps 5 and 6 above, and instead focus on a systematic effort of portraying the benefits and costs in a qualitative framework. (Additional discussion is provided in Section 3.16 of this chapter.)

3.6.8 Step 8. Summarize All Present Value (or Annualized) Costs and Benefits, and Compare Benefits to Costs

Quantitative benefit or cost projections over time (from Step 6) should be discounted to present value at an appropriate discount rate (the discount rate, which is similar to an interest rate, is described in detail in Section 3.20). The NPV of monetized benefits and costs should be summarized in one location (i.e., a summary table), along with the listing and ranking of those benefits described only qualitatively (from Step 7). It is important that one summary table include both the monetized benefits and costs, as well as a listing and some qualitative assessment of the nonquantified benefits and costs, so that reviewers do not overlook potentially important outcomes when reviewing the empirical results (additional discussion is provided in Chapters 4.0 and 5.0). Distributional aspects also should be presented (see Section 3.20 of this chapter).

3.6.9 Step 9. List and Assess All Omissions, Biases, and Uncertainties

All omissions, biases, and uncertainties associated with the estimated benefits and costs should be explicitly documented. The impact that these may have on the final outcome of the analysis (e.g., in terms of their likelihood of increasing or decreasing net benefits, or an uncertain direction of change in net benefits) should be noted. (Additional discussion is provided in Chapters 4.0 and 5.0.)

3.6.10 Step 10. Conduct Sensitivity Analyses on Key Values

Sensitivity analyses should be conducted on key variables or benefit and cost estimates, to explore and communicate the impact of assumptions, uncertainty, or natural variability. Use sensitivity analyses to identify which assumptions or uncertainties have the largest impact on the outcome of the analysis (e.g., identify which assumptions might change the net benefits of an option from positive to negative, or alter the ranking of options in terms of their relative net benefits). (Additional discussion is provided in Sections 3.21 and 3.22 of this chapter.)

3.6.11 Step 11. Compare Analysis Results with Values from Stakeholder Perspective

The quantitative and qualitative values that result from the analysis and from the various sensitivity analyses should be compared with stakeholder expectation of values. This comparison of expected values to the values derived in the analysis can be informative both as a check on the reasonableness of the analysis results and as a process for working with stakeholders to realize (or at least better articulate) the values that the biosolids project provides to stakeholders. This understanding of values may become the basis for cost-sharing agreements with stakeholders to share costs for a project according to the relative shares of benefits derived from the project.

The vertical box on the right side of the diagram illustrating the steps in an economic analysis (Figure 3-1) emphasizes that stakeholder involvement should be sought throughout the project identification and valuation process, with stronger involvement (represented by the solid-line arrows as opposed to the dashed-line arrows) recommended at certain portions of the process (e.g., especially at the outset, and again to review and discuss findings).

3.7 How and Why is the Baseline Defined?

Defining the baseline is a very critical step, not just because it establishes the accounting stance within which beneficial use (and/or other biosolids management alternatives) are evaluated and compared, but also because it establishes the problem-solving context within which the biosolids management option (and, possibly, other alternatives) are being considered by the agency and the community as a whole. Thus, the baseline needs to be defined carefully, explicitly, and in a manner suitable for local circumstances. The baseline is the pivotal foundation for not just the BCA itself, but also for framing the policy-making dialogue with governing officials, customers, and other stakeholders.

Accounting Stance Issues From the technical perspective of establishing the suitable accounting stance for the economic analysis, the baseline should typically be defined as the "status quo" or "do nothing" alternative to a potential biosolids project (and/or other alternatives) being considered. For example, in a relatively simple circumstance under which an agency is considering whether or not to move beyond a current disposal option (e.g., a current practice of landfill disposal without methane recovery) and instead pursue a beneficial use project (e.g., to pursue land application), then the baseline should reflect the *future* biosolids situation for the community if it continues with its current approach (i.e., a future with continued landfill disposal, and *without* the beneficial use option adopted by the agency). The beneficial use option (e.g., land application) is then the alternative that is compared to the disposal baseline.

One important aspect of defining the baseline, even in relatively simple contexts, is that it must reflect the future. The baseline is *not* the same thing as the "current" situation. Even though the baseline may entail retaining the current set of biosolids practices, it is looking at the implications of retaining those practices into the future.

Defining the baseline means looking into the years ahead, and since the useful lifetime of most biosolids-related capital investments typically is 20 or more years, a matching long-term timeframe needs to be applied for the baseline and alternative options. Thus, developing the baseline in most circumstances means considering the projected increases in wastewater loads and biosolids volumes over the coming decades, and assessing how those future loads compare to the region's long-range capacity to absorb the biosolids generated. For example, the local landfill capacity may adequately cover biosolids disposal demands in the present, but in the future, demand may be expected to accelerate the consumption of remaining local landfill capacity (e.g., lead to a nearer-term closure of the landfill). In this example, the projected long-term shortfall in local landfill capacity (and the time path to that shortfall) should be used in defining the baseline.

Wastewater agencies typically develop forecasts that embody different regional growth scenarios, and these should be reviewed and used as applicable to define the "without project" baseline. The assumptions underlying these future projections should also be clearly stated, and may become a focal point for discussions with stakeholders (and/or serve as a basis for sensitivity analyses), as discussed later in this chapter.

BCA is Comparative and Biosolids Happen BCA is a comparative approach, meaning that it requires a comparison of a biosolids management option to one or more alternatives (with the baseline serving as one vital comparative option). And, because biosolids are an inevitable byproduct of wastewater treatment, it is only useful and appropriate to apply a BCA for options (baseline included) that all recognize that biosolids will be present in some volume and at some quality. BCA cannot be applied to any single option in isolation—there needs to be at least a viable and realistic baseline option that recognizes the existence of biosolids, to which the option can be compared.

Policy Framing and Public Discourse Issues Presumably, a wastewater agency or community is considering beneficial use biosolids options because they are seen as a possible solution to a current or anticipated problem, and/or because it is seen as a way to promote or enhance values that are important to the community (e.g., embracing a recycling ethic, or providing a way to ease energy demands). Thus, in defining the baseline for the economic analysis, it is critical that the baseline be defined in a manner that helps articulate what problem and/or value enhancements the biosolids project alternatives would address. By specifying the problem to be solved, the economic analysis is then suitably framed to compare how well beneficial use (and/or other options) serve as vehicles to solve the problem and provide the community with outcomes it values.

As noted above, different stakeholders may have different views about the size or nature of the problem, and may even argue whether the problem exists. An example would be where a wastewater agency sees a relatively expensive or contentious biosolids option (e.g., a high cost partnership with a distant private sector entity to develop energy from biosolids) as a potential solution to a future shortfall in landfill and/or land application capacity that is forecast. Such constraints of future landfill or land application capacity might arise due to anticipated growth in local population and associated changes in local land use patterns and economic activity. Some local stakeholders may question whether that future growth is inevitable or desirable, and thus argue about the very premise for why the agency is considering the biosolids alternative.

This illustrative baseline-associated issue may boil down to a debate between developers who seek to stimulate local growth (e.g., converting farms to suburbs), utility managers who more neutrally see a need to serve the community by accommodating growth, and no-growth advocates wishing to limit growth. Biosolids planning then often becomes a de facto vehicle through which various stakeholders may try to promote a desired land use planning perspective (in lieu of using zoning and other land use planning tools). This obviously creates headaches for wastewater agency managers, yet it is important to recognize these underlying issues at the outset, rather than proceeding blindly with a presumption that the community views the problem the same way that the agency does. For all these reasons, the baseline should be defined with care, and in concert with public discourse.

3.8 What Biosolids Management Options Should be Considered?

This economic framework is designed primarily to address a situation in which one or more biosolids management options are being considered. However, the approach is very generalizable, and its most suitable use is in looking at multiple biosolids management options that may be feasible for a utility and the community it serves. Thus, the approach can be used for a wide range of circumstances, including 1) a baseline that might reflect what is likely to happen in the future if the agency does nothing to enhance its biosolids portfolio, and 2) one or more biosolids management alternatives that might be pursued by the agency in the future. Obviously, the more relevant options considered, the more complex the analysis will become, but the results will also be most valuable if all the relevant feasible options are evaluated.

Also, it typically is most useful to limit the analysis to options that are technically, politically, and legally feasible. For example, if a biosolids option is not viable because of restrictions imposed by state or federal regulation (e.g., land application bans, Endangered Species Act issues), then that option is probably not worth including in the economic analysis. If options that are not feasible are included, they should clearly be labeled as such and the cause (technical, ethical, legal) should be articulated.

3.9 How Does One Evaluate the Benefits and Costs of a New, Innovative Process?

Given the dynamic nature of biosolids management, many agencies are looking to innovative processes as potential approaches for addressing the many challenges they face. Innovative processes are often sought for ways to reduce energy demands and cost (either by enabling energy recovery, and/or by using less energy to achieve an outcome) and/or to improve the quality of the product generated (e.g., moving from Class B to Class A, and/or reducing odors).

As more biosolids-related processes are developed and made available to wastewater agencies, the utilities face a challenge in how to evaluate such “innovative” biosolids processes and approaches in terms of their likely costs and benefits. There is considerable interest in innovative approaches (including energy-related and other value-added processes), but the evaluation of innovative/emerging processes is very difficult because there is often limited (if any) information and perhaps no sustained in-the-field utility experience to review. In addition, there may need to be regulatory reviews and approval steps that could take considerable time and expense, and out of which the desired permitting outcome may not ultimately be reached.

In brief, there often are considerable uncertainties about what some innovative processes can and will actually cost to acquire and operate, what performance and benefits will actually be realized, and whether they will be considered permit-worthy by regulators. Accordingly, a BCA of such options is quite difficult. In Appendix G, a more detailed discussion is provided to help wastewater agencies better evaluate innovative processes, so that they are less likely to overlook factors or outcomes that may not be apparent at first glance (e.g., the need and cost of acquiring and bring additional blending materials on-site, additional permit requirements, retrofit needs and process incompatibilities, or key operating cost drivers such as energy demands). Appendix G also provides a utility-based illustration of the challenges (and potential rewards) of pursuing an innovative process.

3.10 What Biosolids Options Are “Beneficial Use” and Which Are “Disposal?”

There are no firmly established definitions or categorizations about which biosolids options should be labeled as “disposal” and which constitute “beneficial use.” However, there are some common sense criteria that can be applied to various options.

For example, disposal may be used to refer to any option in which no value or no use is recovered from how the materials are managed. Thus, shipping biosolids to a landfill in which there is no methane recovery would be viewed as disposal. However, if that same landfill captured a portion of the methane produced by the decomposing biosolids, and made productive use of that gas as an energy source, then that would be considered a beneficial use.

There may be different levels of beneficial use in which biosolids may be employed. Some options may tap a relatively low level of beneficial values (e.g., limited amounts of soil conditioning or energy recovery), while other options may garner a considerable level of beneficial value. A key advantage of the BCA approach is that it provides a framework for identifying and portraying the full range (and level) of beneficial values that a specific biosolids application may generate.

Options that may be considered as “disposal” include landfilling without gas collection or use of biosolids as cover material, incineration without energy capture, and surface disposal (e.g., in a monofill or surface impoundment). The central theme here is that “disposal” pertains to approaches in which no attempt is made to derive any beneficial value from the product; instead, the biosolids are viewed and managed strictly as waste.

Beneficial use options include the following:

- Agricultural land applications of Class B or Class A liquid and solids
- Land reclamation (e.g., mine sites, forests) using Class B or Class A materials
- Horticultural uses of Class A materials (e.g., in compost, soil blending, or as a fertilizer bulking agent)
- Energy production using Class B or Class A materials (e.g., direct combustion of cake, anaerobic digestion with gas recovery, gasification)
- Making bricks or other construction material

3.11 What Are the Benefit and Cost Categories that Apply to Biosolids Management Options?

There are numerous types or categories of benefits and costs that may apply to biosolids management options. Natural resource economists have developed a general taxonomy of benefits categories, but it does not provide a very intuitive way for wastewater agencies or their stakeholders to assess or communicate their biosolids program situations. Therefore, the researchers offer the following general view of broad benefit (and cost) categories.

Note that there may be overlap across several categories described below (e.g., energy use has implications for air quality and climate change). The categories are presented to help users identify potentially important impacts (benefits or costs), and users will need to be alert not to double-count impacts that may arise due to linkages and overlaps across the categories described here.

3.11.1 Internal Financial (Cash Flow) Impacts

The out-of-pocket costs borne by the wastewater agency are the direct financial costs associated with the proposed biosolids management option. These should reflect lifecycle costs and, thus, include capital equipment or construction costs, O&M costs, input acquisition costs, transport and distribution costs, administration and permit fees, and the agency's additional administration costs. If a subsidy or cost share is provided by an outside source (e.g., the state), these should be considered as part of the economic analysis of costs. A recent WERF publication provides considerable detail on how to account for lifecycle costs for biosolids (WERF 00PUM7; Epstein et al., 2003).

A biosolids option may also mean that some alternative wastewater treatment or biosolids management costs can be avoided, compared to the baseline. The biosolids option may avoid a) wastewater or solids capital costs, b) treatment plant or wastewater plant expansion capital costs, or c) variable costs associated with the baseline or alternate options (e.g., by reducing the amount of energy to be purchased). These cost savings, or avoided costs, should be considered as a benefit of the biosolids option, as long as the baseline scenario reflects the alternative projects.

3.11.2 Environmental (Air, Land, and Water Resources) Impacts

The manner in which biosolids are managed can have impacts on various environmental resources, including water, land, and air quality.

Water and Land Resources Land disposal or land application impacts on water resources should be negligible, if the applicable operations and facilities are managed properly (e.g., land application at agronomic rates, landfills with suitable liners and leachate collection). However, infiltration and runoff may result in some adverse impacts to groundwater or surface waters, if suitable practices are not followed. Alternatively, land resource restoration promoted by biosolids applications at mine sites and other such facilities can significantly reduce erosion and the associated adverse impacts from sedimentation and runoff.

Land resource impacts should generally be positive, including improved soil conditions, nutrient enhancement, and metals binding at sites with suitable land application practices. However, there may be concern in some circumstances about the potential risks that may arise from possible pathogens, metals, and/or trace organics in land applied biosolids. Appendices A and B provide additional discussion and guidance on land and water impacts from biosolids practices.

Air Quality Biosolids management options may have many types of impacts (positive or negative) on air quality. Emissions of air pollutants are associated with operations of many biosolids-related processes that may be adopted at the wastewater treatment plant (WWTP; e.g., methane and other gaseous pollutants from digesters). Also, many biosolids operations at wastewater plants require a considerable amount of energy, and the generation of the required energy at regional power plants will create air pollutant emissions as well.

The transport of biosolids to their ultimate point of use or disposal also will typically involve the emission of pollutants in the exhaust of hauling trucks, especially when large volumes of solids are involved and considerable distances need to be traveled between the wastewater plant and the final biosolids location (e.g., landfill, incinerator, land application site). Airborne emissions (particles and odors) at land application sites may also pose aesthetic problems and/or raise concern about possible respiratory or other health risks to field workers and neighbors.

The air pollutant emissions associated with the various aspects and stages of biosolids management alternatives can create risks to human health, cause damage to physical materials and natural resources, impose a loss of aesthetic values (e.g., smog, reduced visibility, odors), and can contribute to global warming and its associated impacts. These damages need to be accounted for, to the degree feasible.

Note that for some biosolids options, there will be an expected net *decrease* (compared to baseline) in the level or form of air pollutant emissions. This means that there will be air pollution reduction benefits (i.e., reduced damages, relative to the impacts at baseline) to include in the analysis. Appendix C provides some guidance on how to do so.

Finally, odors are a considerable air pollution-related concern related to biosolids. A more expansive discussion of odor-related issues is provided later in this chapter (Section 3.13.2), and in Appendix F.

3.11.3 Energy (Use, Recovery, and/or Generation)

As noted above, biosolids options can have significant energy implications, including both how much energy is consumed and how much energy might be captured or generated. Energy costs amount to approximately 35% of wastewater operating expenses, and much of that energy use is also associated with biosolids operations (WERF, 2006). Thus, energy-related impacts of biosolids options may have implications for either (or both) the cost and benefits side of the BCA ledger.

On the cost side, many biosolids options and processes are relatively energy-intensive. This includes energy consumed at the wastewater and biosolids utility through the separation, digestion, or drying processes, as well as by transport to a final use or disposal location (e.g., fuel consumed by transport trucks and land application equipment). Energy consumption creates a direct, internal financial cost (e.g., the costs borne by the utility for purchasing power for the treatment plant, and for fuel for its transport vehicles). Energy consumption also creates adverse environmental impacts (i.e., damages, or negative benefits), typically of the nonmarket, external variety. These negative external impacts arise from the emission of air pollutants at the power generation facility from which the wastewater agency acquires its power, and from tailpipe emissions from biosolids-related vehicle use. These costs often can be quantified (e.g., pounds of pollutant X emitted per year due to biosolids-related energy use for a given option), and many also can be expressed in monetary terms (e.g., based on estimated dollar damages per ton of air pollutant emitted), as described in Appendix C.

Biosolids options can also provide opportunities to generate benefits, either by reducing energy consumption (e.g., providing a more energy-efficient option) and/or by providing new ways to capture or generate energy (e.g., methane gas recovery and use as fuel, or using the solids themselves as a fuel source in an incineration process, or using land application as a way to promote/enhance production of bio-fuels). The benefits realized from such positive impacts include internal financial gains for the utility because the utility saves money by offsetting energy purchases. There also may be external nonmarket benefits, such as reducing damages by reducing emissions of air pollutants, and decreasing reliance on energy imports. Several case studies in Chapter 5.0 and in Appendices C and D reveal how these energy-related impacts can be identified and, as feasible, monetized.

3.11.4 Climate Change (Carbon Footprint) Impacts

Because of the energy implications of biosolids management, there are many biosolids-related potential impacts on GHG emissions and, hence, the pace and severity of climate change impacts. One approach to reflect the way in which a biosolids options can have a positive or negative effect on potential climate change impacts is to use a "carbon accounting" approach. This approach entails tracking and quantifying the net increase (or decrease) in carbon-equivalent emissions (e.g., tons of carbon per year, or pounds of carbon per ton of managed biosolids), when comparing one biosolids option to another. Using a carbon accounting approach, one can assess how some biosolids management options will reveal a smaller "carbon footprint" than others.

Carbon accounting can reflect changes in air pollution emissions of GHG (e.g., from methane flaring versus methane recovery) and/or carbon sequestration (e.g., from increasing soil productivity via land application). Case study illustrations (Chapter 5.0) and Appendices C and D provide guidance and examples for how this approach can be applied and interpreted.

3.11.5 Public Health (Risk of Illness or Premature Mortality)

This category reflects any change in the risks of illness (morbidity) or of premature death (mortality) due to changes in exposure to any harmful substances when one biosolids option is compared to an alternative. For example, some land application options or treatment plant process alternatives may pose greater or lesser degrees of exposure to air- or water-borne microbial agents, chemical contaminants, and soil particulates. To the extent that options are associated with changes in potential exposures (and, hence, risks), these should be articulated and included in the analysis. Quantifying and valuing changes in risks to public health are challenging exercises, but at a minimum the potential changes need to be described in an informative qualitative manner. For a further discussion of challenges and options available to quantify or value changes in health risks, the Awwa Research Foundation (AwwaRF) report *Quantifying Public Health Risk Reduction Benefits* provides useful summaries and examples (Raucher et al., 2002).

There remains considerable disagreement in some circles about the potential of some biosolids management options to pose risks to human health. These often focus on land application at agricultural sites. Concerns are expressed about pathogens, metals, trace organics, and/or wind-blown fine particles that may find a pathway to human exposure (e.g., ingestion or inhalation) and, hence, pose a risk. This is a complicated topic that has been addressed in considerable depth by U.S. EPA regulators in 1993, and by several other researchers and organizations, including the NRC (2002), as summarized in Table 3-1. The complexity is compounded by the fact that the debate also encompasses disagreement about which risks are "real" as opposed to "perceived" (and whether or how perceived risks should be given due merit in policy discourse), and about which issues are scientifically resolved and which remain areas of scientific uncertainty. Additional discussion is also provided in Appendix E.

For the purposes of this report, these complex issues of scientific uncertainty and debate cannot be resolved. However, the researchers suggest that users try to include health risks in their BCAs, to the extent that these risks appear legitimate or, at a minimum, are important to some key stakeholders. Uncertainty about the presence or level of these risks can be accommodated through sensitivity analyses, as discussed later in this chapter.

Table 3-1. U.S. EPA Regulation of Biosolids and Potential Risks to Public Health.

In 1993, U.S. EPA issued "Standards for the Use and Disposal of Sewage Sludge" that appear at 40 *Code of Federal Regulations* (CFR) Part 503. The "503 rule" defines management practices and numerical criteria for land application, incineration, and surface disposal of biosolids.
Class A biosolids contain very small levels of indicator pathogenic organisms and can be land applied without restriction if Exceptional Quality (EQ); they can also be pelletized or composted and sold to the public as a soil amendment. Class A status must be obtained through treatment processes involving either heating, composting, digestion, pasteurization, or increased pH to assure reduction of pathogens to acceptable levels.
Class B biosolids are also required to be treated by either digestion, composting, air drying, lime stabilization, or equivalent process. Class B biosolids may contain higher levels of pathogens than Class A, but they are still reduced to levels that are intended to protect public health and the environment in view of the restrictions placed on crop production, grazing, and public contact.
The NRC reviewed the Part 503 regulations in a July 2002 report entitled, *Biosolids Applied to Land: Advancing Standards and Practices* (NRC, 2002). They concluded that there is no documented scientific evidence that sewage sludge regulations have failed to protect public health, but there is persistent uncertainty on possible adverse health effects. The NRC noted that further research is needed and made about 60 recommendations for addressing public health concerns, scientific uncertainties, and data gaps in the science underlying the sewage sludge standards.
Based on public comments and research priorities from a WERF-sponsored Biosolids Research Summit, held in July 2003, the U.S. EPA developed a final action plan that has four main objectives: 1) determine potential risks of select pollutants, 2) measure pollutants of interest, 3) characterize potential volatile chemicals and bioaerosols from land application sites, and 4) understand the effectiveness of water/sludge treatment and risk management practices.

3.11.6 Sustainability

The term "sustainability" can mean different things to different people, but in general the meaning is applied to practices or options that promote or enable long-term continued operation of an activity. Sustainability implies an ability to maintain a high level of performance or operation over a long time horizon (decades, or even across generations), based on maintaining a suitable balance between resources consumed by an activity and the resources provided by that activity (i.e., a practice that consumes or diminishes resources at a pace such that those inputs can be replenished or replaced at an equal or greater pace).

Sustainability is typically considered according to specific perspectives or targeted assets. For example:

- Sustainability in the context of physical capital (i.e., infrastructure) implies a need to invest suitable amounts of funding into infrastructure rehabilitation and replacement, such that the physical assets do not decline to a point where service is compromised. This "asset management" in turn requires adequate revenues are raised to financially support infrastructure renewal efforts at the level necessary to maintain service at the targeted levels. Sustainability thus implies a level of revenue generation (or other fiscal support), and an associated level of fiscally supported infrastructure investment, to keep the utility operating at a targeted level of service.
- Sustainability in the context of natural resources and the environment (i.e., natural capital) implies maintaining a balance in terms of limiting resource consumption and providing enough environmental protection such that natural systems can continue to support flora, fauna, and economic activity at levels that are at least as great as found currently. For example, a wastewater utility helps assure a sustainable watershed by

returning the water extracted and used by the community back to the river as suitably treated effluent that supports the river's designated uses and other community values.

- Sustainability in the context of an organization or enterprise implies the ability of a utility to continue to remain effective and functional despite emerging large-scale changes (or random shocks) in its operating environment. In this context, sustainability captures the ability to maintain effective business continuity despite changes in human systems (social, economic, and political disruptions), or natural disasters. Sustainability here includes the ability to perform despite volatility in the prices of key inputs (e.g., energy, construction) or rapid and significant changes in regulatory constraints (e.g., new bans or limitations on some biosolids options such as land application).

In the management of biosolids, the term sustainability can be invoked in each of these different contexts. For example, the agricultural land application of biosolids can be seen as contributing to a more sustainable and closed cycle of enhanced land productivity, which leads to better crop yields, human consumption and, ultimately, the creation of more biosolids. This is a natural resource context for viewing sustainability.

In this report, the researchers use sustainability in a broad context that, in addition to natural resource preservation and infrastructure asset management, also considers organizational sustainability by embodying societal influences, preferences, and choices. In this broader view, sustainability refers to the ability of a utility to maintain a viable biosolids management program well into the future (e.g., for decades), so that the utility can continue to operate in a manner that continuously meets (or exceeds) community needs and desires, is consistent with sound environmental stewardship, and adheres to all applicable regulations and standards.

This broad view of biosolids "program sustainability" includes consideration of cost control (i.e., moderating rate increases for customers), as well being able to meet broader societal goals as may be reflected through a TBL perspective (e.g., to avoid odors, and/or to promote development and use of domestic renewable energy resources). Perhaps most important, given the rapidly changing biosolids landscape, program sustainability means developing the foresight and flexibility to navigate changing operating landscapes—for example, developing a portfolio of biosolids management options so that the agency can continue to effectively manage the community's biosolids in the face of potential bans or other limitations on future land application or other changes in operating conditions.

3.11.7 Economic, Social, and Equity Considerations

Social, equity, and economic development issues may include consideration of the location of impacts, resource access issues, aesthetics, or cultural values. They also include the impact of the project on the local economy, whether considered in a positive light such as helping to build or sustain community economic development, or considering the negative impacts that may be associated with growth. Overall, the objective is to identify who the likely beneficiaries are, who is likely to be affected by the impact, and whether they will be impacted in a manner they will consider negative or positive. This enables the utility to better frame its stakeholder outreach efforts (e.g., to identify and listen to potential concerned citizens and identify beneficiaries), and to consider possible ways to compensate or offset potential negative outcomes.

3.12 How Do the Benefit Categories Correspond to Different Types of Biosolids Options and Project Impacts?

The above types of benefits (or damages, costs) may be generated in numerous ways by a biosolids project. In considering options and their associated benefits (and costs), it is important to recognize the feedback loop that exists between the issues or context in which a utility operates in defining which options may be most viable and attractive, and between the context and the benefits that may be derived. This is depicted by the triangular relationship depicted in Figure 3-2.

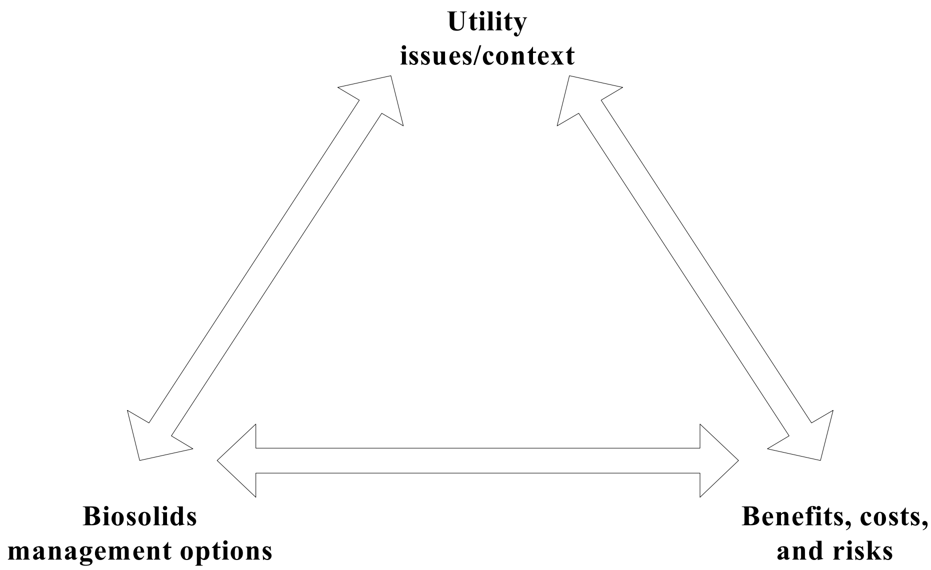


Figure 3-2. Reverse Engineering Perspective Recognizes Interrelationships between Utility Issues, Options, and Benefits.

The triangle diagram was developed to reveal the three-way linkage of between "options," "benefits," and "issues" faced. The figure indicates how each potential biosolids management option is integrally related to the benefits of relevant options, and issues facing wastewater agencies in their biosolids management programs. For example:

- One needs to consider what biosolids management options to consider in order to know what types of benefits, costs, and potential risks to evaluate within the framework.
- Further, the options that an agency should consider depends on what issues it faces. These "issues" include regulatory and policy pressures, costs, regional market realities, land use patterns and availability, local climate, existing practices and infrastructure, and public sentiment in their area.

This indicates the need for biosolids agencies to adopt a "reverse engineering" perspective when considering their options. This means considering and evaluating biosolids options within the context the utility's local conditions/issues, and then selecting options based on the option's ability to address/fit within the issues faced (rather than picking a suite of technical options first, and then evaluating them to see what outcomes might occur).

3.13 What Types of Benefits May Be Most Important for Biosolids Projects?

The type of benefits that apply to a particular biosolids management project or practice, and the potential magnitude of those benefits, will be very site- and circumstance-specific. However, in reviewing several biosolids management projects around the United States, there are several types of benefits that often appear to be among the most important motives for adopting beneficial use forms of biosolids management. These types of important benefits are not always amenable to quantitative analysis (i.e., often it has not been feasible to assign monetary values to these benefits). Nonetheless, they often are stated as key reasons for backing the biosolids option. If any or all of these issues are central values for why a utility is considering a biosolids option, then it is important to identify the applicable benefit categories and carry them through the analysis. Even if some or all of these benefits cannot be readily valued in monetary terms, they may represent important values that should at a minimum be described quantitatively in the final summary of results.

3.13.1 Sustainability

As described in the previous section, sustainability here is often viewed in the multi-layered context of how a biosolids option (or, a portfolio of various options) can help a utility 1) promote better environmental and/or infrastructure sustainability (i.e., maintain or enhance natural and physical capital), and also 2) better ensure the utility can continue to properly manage biosolids well into the future, even if and when there are significant changes in operating environments (such as regulatory or political constraints such as land application bans).

In this work with participating utilities, the researchers found a growing appreciation by utility managers for developing a suite of options so that more than one biosolids management approach would be available. The intent is to develop the nimbleness to move biosolids into different management avenues, in case one practice becomes less viable in the future. This dynamic flexibility, as developed from a diversification of the biosolids management portfolio developed by an agency, is one way to better assure business continuity into the changing future. This is in contrast to a more static view in which sustainability might be viewed as selecting a single option in the hope that it would remain feasible and acceptable over the long term (e.g., for one or more decades).

Thus, many utilities have recognized an emerging need (and value) to developing a "portfolio" of biosolids management approaches. The concept is that agencies will be better positioned to adjust to changing circumstances (e.g., potential prohibitions of local land application options, or increased competition for limited markets for bagged products) if they pursue a suite of options rather than putting all their eggs in one basket. The value of a diversified suite of biosolids options cannot be readily quantified or monetized, but it can be considerable because an agency is not wholly at risk if one option is pursued and then circumstances change to render that option less viable or far more costly than initially thought.

3.13.2 Odor Control

One of the most prominent challenges faced by biosolids operations is the public concern and complaint about odors from biosolids processes and cake. Many utilities consider processes or controls to minimize nuisance odors at the relevant property boundaries. Such options can be costly. However, the benefit to the utility of having reduced odors is that it will then enjoy a better rapport with its neighbors, and the reduction in public complaints and opposition. The benefits of odor control are thus realized both by the odor-impacted neighbors (who now endure less odor) and also the utility (because an agency with continuing public opposition due to odors will not be able to sustain its operations). Thus, odor control may be seen as providing sustainability benefits.

As described in greater detail in Appendix F, it is not feasible to quantify or assign a monetary value to odor control benefits. Nonetheless, the benefits of odor controls may be quite significant for many utilities.

3.13.3 Community Acceptance

Increased public acceptance (or reduced public opposition) to biosolids management practices is vitally important to wastewater agencies. Public acceptance issues can be far-reaching and diverse. They can arise from nuisance issues such as odors (see above) or truck traffic associated with hauling operations, and they can also arise from concerns over public health and environmental quality (e.g., concerns associated with trace organics in cake or compost materials). Many utilities actively engage in EMS (or EMS-type) programs and/or other activities that strive to reach out to the public and other stakeholders, and build a better rapport. The benefit of these outreach and community relations activities are not readily measured in dollar terms, but they are essential to keeping the utility operating in a manner that can be sustained (e.g., provide an operating environment of local politically acceptability).

3.13.4 Energy Management and Recovery

The researchers' work with participating utilities revealed a considerable interest and active engagement in options that enable them to improve energy management by reducing power consumption and/or tapping the fuel value of the biosolids to generate power. As noted above and in supporting appendices, there are relatively straightforward ways to estimate the benefits of energy savings and/or beneficial use of biosolids-generated energy. These include reduced power purchasing expenses, as well as values that can be assigned for reducing emissions of various air pollutants.

3.13.5 Land Productivity

For land application options, the use of biosolids provides nutrient and other beneficial values related to soil conditions and productivity. These benefits can be measured as increased crop yields and/or as cost savings due to the substitution of biosolids for purchased fertilizers. These and other benefits from land applications are discussed in greater depth in Appendices A and B.

At the same time, there are some concerns about possible negative impacts on land productivity and associated ecosystems, as might result in some instances due to the cumulative impact of long-term application at the U.S. EPA limits, or from spreading unregulated EDCs into the soil environment. These concerns reflect some of the uncertainty about the possible risks of land application, in some settings and circumstances.

3.13.6 Environmental Improvements

Biosolids projects can generate appreciable value by improving local or regional environmental conditions. For example, accelerated and enhanced soil and vegetation reclamation from land application of biosolids at mine-impacted sites will generally lead to decreased soil erosion. This in turn will reduce adverse nonpoint source pollution impacts on neighboring watersheds. The reduced loadings of sediment (and any associated contaminants such as metals or agricultural chemicals) in turn can improve instream water quality and provide better habitat for aquatic species of ecological, recreational, and/or commercial value.

The types and magnitudes of these benefits will be very dependent on the specific circumstances to each location and biosolids project. However, in some cases, the estimable monetary value associated with ecological benefits (e.g., helping to preserve critical habitat for threatened or endangered species), or recreational benefits (improving fishing or boating experiences along rivers and streams) may be very sizable (e.g., see Appendices H and I).

3.14 How Do I Screen the Various Outcomes to Determine Which Benefits and Costs Require Detailed Quantitative Analysis, and Which Should Be Described Qualitatively?

It is useful to screen the list of potential costs and benefits for a project to determine which impacts are so small (or mitigated) that they can be dropped from the analysis, which must be qualitatively described (because quantification is not generally feasible), and which impacts can and should be quantified. The three screening criteria used in this step are described below. Figure 3-3 shows the screening analysis process as a flow chart. Note that the screening process described here reflects a way to assess how much effort should be devoted to estimating the various different benefits and costs, and the process assumes that a previous screen would separate out options that were infeasible either because of technical/physical limitations or institutional constraints (e.g., regulatory, political, or legal barriers that in effect “veto” an option and thus remove it from the choice set).

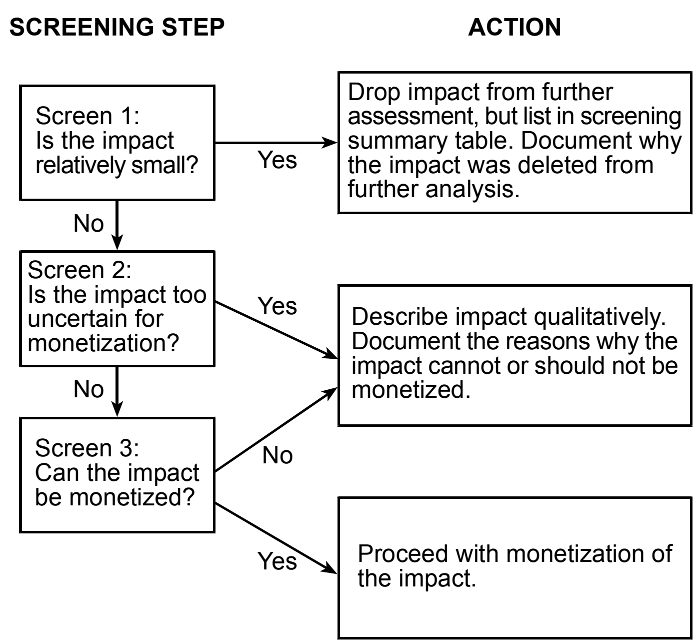


Figure 3-3. Screening Analysis Flow Chart.

3.14.1 Screen 1: Is the Impact Relatively Small?

This screen considers whether the cost or benefit will be very small in absolute terms, or in relative terms compared to the other impacts. If the impact is so small as to be insignificant, then perhaps it can be eliminated from the analysis in an effort to save or focus resources. This is a matter of judgment, and it is important to document the reasons behind such a decision.

Some impacts can be dropped from the assessment, even if they are not small, when the impacts are going to be mitigated through some activity embedded in the project design and cost. For example, if a biosolids option may adversely impact some wetlands, but as part of the project there will be restoration or creation of other nearby wetlands, then the wetland impact will be mitigated and does not belong in the analysis. However, it will be important to carefully assess and document that the impacts are indeed mitigated (e.g., that the newly restored wetlands will provide the same or better ecological services than those that may be adversely impacted). Further, the mitigation should then not be counted as a project benefit (since it was used to offset a non-included project cost).

3.14.2 Screen 2: Is the Impact So Uncertain or Changing as to Resist Economic Quantification?

This screen considers the situation where the impact is so changing or uncertain (e.g., due to scientific uncertainty or time lags in natural processes) or sensitive (e.g., due to political considerations, legal uncertainties, or cultural sensitivity) that any attempt at economic assessment would be impossible or not useful. In this case, it is important to explicitly recognize that economic valuation may not be possible or useful, but that continued recognition of the impact is important through qualitative characterization.

3.14.3 Screen 3: Can the Impact Be Quantified in Economic Terms?

This screen considers whether available data and methods are sufficient for monetization of the impact. If the data and methods are available, then the analyst can proceed with quantifying the impact and then converting the impact into monetary terms. If monetization is not possible, it is important to continue recognition of the impact through qualitative characterization.

In some instances, it will be feasible to quantify the impacts in physical terms (e.g., acres of restored lands, added bushels of crop yield, reduced tons of air pollutant emissions), but not all these physically quantified outcomes can then be portrayed in monetary terms. In these instances, the analyst should provide results in quantified physical units, even though monetization may not be feasible.

3.15 For Benefits or Costs that Are Not Readily Quantifiable or Monetizable, How Do I Describe Them Qualitatively?

If an important benefit or cost cannot be quantified in a reliable or readily feasible manner, it is still very important to make sure that impact remains a visible part of the analysis, and is routinely included in any summary table or results sections. It is more important to keep a focus on "what counts" rather then to focus only on what may be "countable."

In developing qualitative descriptions, it generally is useful to have short but clearly stated descriptions of what type of benefit value is generated, and why it is important to the community. Also, even where it may not be feasible (or desirable) to monetize some benefits, one often can nonetheless portray whether the benefit (or cost) is likely to be of *relatively* high importance and value.

Thus, using some indication of relative magnitude can be very useful when summarizing the benefit-cost findings, including the qualitative outcomes. The researchers suggest using a 5-point scale, ranging from a negative 2 to a positive 2, wherein a "+2" signifies a very high relative benefit, and a "-2" represents a large relative negative value (a high cost), and "-1" and "+1" represent the intermediate outcomes of relatively smaller costs or benefits, respectively (and zero represents a very small relative impact of little consequence in either direction). Other options include using a "+" or "-" sign.

Also, the one useful approach to help systematically describe the broad array of benefits (financial, environmental, and social) in a qualitative fashion is the TBL. The TBL does not require that results be quantified or valued (although some results can be). The TBL is described below and in illustrated in a case study provided in Chapter 5.0.

3.16 How Can I Apply a TBL Approach?

As described in Chapter 2.0, the TBL provides one way to examine a full social cost accounting-based application of BCA. The TBL is a planning tool developed to help agencies track their progress toward promoting sustainability, and in essence is a streamlined and often qualitative version of a social BCA. The TBL has been popularized through widespread application in Australian utilities, and has begun to see applications in some North American utilities in the past few years. The TBL consists of:

1. A financial bottom line that reflects the cash flow accounting stance of the agency (i.e., internal costs and revenues)
2. A second bottom line to reflect "social" impacts of an agency action (e.g., "helps promote environmental justice by creating employment opportunities for economically disadvantaged members of the community," or "extends the useful lifetime of local solid waste landfills, by diverting solids to land application sites," or "reduces concerns held by neighbors of the land application site about bearing impacts of sludges imported from outside their community")
3. A third, environmental bottom line (e.g., "reduces GHG emissions by reducing methane flaring and electricity purchases," or "reduces likelihood of groundwater contamination")

The identification and valuation of factors contributing to an agency's social and environmental bottom lines is, for the most part, less straightforward than for the financial bottom line. There is no "hard rule" that defines which elements of an agency's program contribute to its social bottom line and/or its environmental bottom line. While it is likely that the specific components of a TBL for one agency will differ from those of another agency, Table 3-2 below identifies several potential components of a TBL. An agency may find that many of these elements have already been incorporated into management decisions, though often in an informal or implicit manner. Addressing the social and environmental impacts of a management program in the context of the TBL enables an agency to evaluate these externalities in a systematic way, and may help an agency measure its progress towards sustainability.

Table 3-2. Potential Elements of a TBL Analysis.

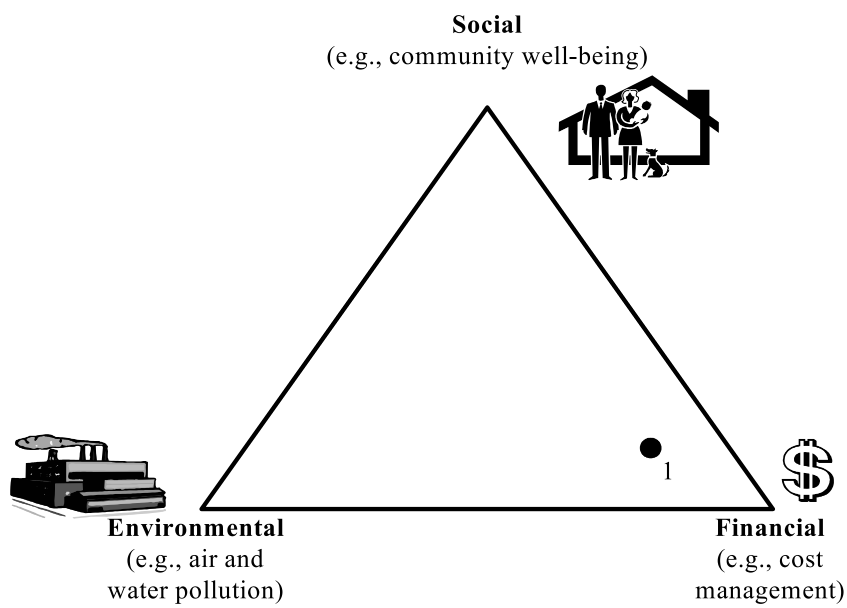
Financial Bottom Line	Social Bottom Line	Environmental Bottom Line
Planning, permitting, design cost	Public perception	Air quality
Construction cost	Nuisance impacts (odors, noise, traffic)	Water quality
Capital equipment cost	Aesthetics	Soil/land quality
Operations and maintenance cost	Recreation	Wildlife species
System upgrade costs	Human health and safety	Ecosystem functions
Cost savings	Employment impacts	Habitat
Revenues	Equity considerations	

In an attempt to create a framework to help water utilities get started using the TBL, AwwaRF and Australian researchers at the Commonwealth Scientific and Research Organization (CSIRO) have partnered to develop a "Guide to Triple Bottom Line Reporting." The guidebook, which is scheduled for completion by 2008, will discuss sustainability and the TBL in the context of a "sustainably managed utility" as well as provide step-by-step instructions for developing a TBL report.

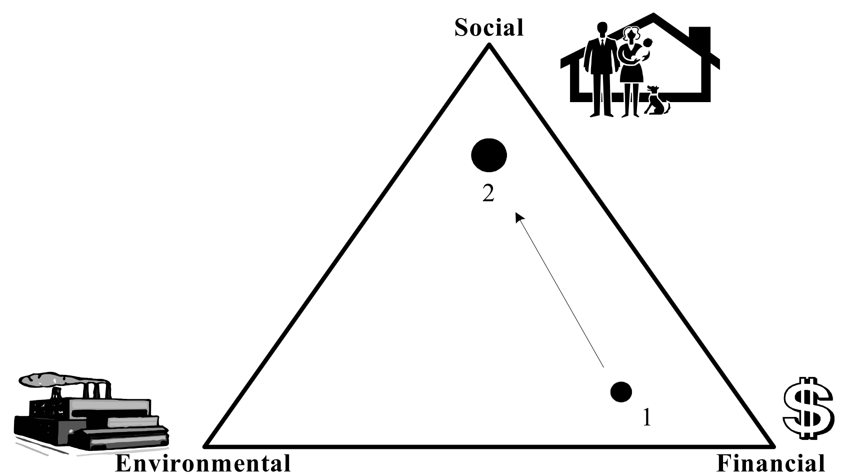
As part of the case study illustrations provided in Chapter 5.0, the researchers demonstrate how the TBL can be fashioned and applied to the biosolids management issue, as a simplified first step toward a more full-scale, social benefit-cost assessment (and as an intuitive way to promote better communication with stakeholders, governing officials, etc.).

While the TBL approach provides a useful way to systematically identify and describe the range of benefits and costs, it can also be somewhat uninformative and subjective if users do not provide some well-articulated and systematic descriptions of progress or outcomes in each bottom line. That is, because the TBL is largely conceptual rather than empirical, it does not necessarily help measure progress towards a goal or help develop a clear comparison between alternative biosolids management options.

One method devised to help utilities understand and apply the TBL concept is to visualize each of the bottom lines as the corner of a triangle, as depicted in Figure 3-4. The area inside the triangle thus represents the choice set of the utility. If the utility opts for a biosolids management option that minimizes its net financial cost, but that option does not provide much to the social or environmental bottom lines, then the option can be represented by a dot in the financial corner of the triangle (dot 1 in Figure 3-4a). If the agency then considers adopting an alternative biosolids approach (option 2) that provides some important social and environmental benefits relative to option 1, then that may be depicted in Figure 3-4b as dot 2. In this depiction, option 2 is shown as a larger dot than option 1, to reflect that the total net benefits across all three bottom lines is larger for option 2 than for option 1 (i.e., the size of the dot can be used to represent the anticipated relative size of the combined benefits for each option). The TBL triangle thus provides a way to visually depict how different biosolids options might vary in terms of what types (and what levels) of values they provide to the community, and thus enable managers and stakeholders to better understand the tradeoffs across options.



(a)



(b)

Figure 3-4. Depicting TBL (Size of Dot Indicates Relative Total Social Benefits of an Option).

3.17 What Methods Can Be Used to Determine Monetized Values for the Benefit Categories?

There are numerous approaches for developing estimates of the monetary value of many of the benefits and costs associated with a biosolids project.

3.17.1 Market Price

Where there is a well-functioning market for a good or service that is impacted by a biosolids project, one can use the observed market price as the dollar value to insert in the benefit-cost framework. Market prices typically are used for the direct costs of the project (or its alternatives), such as the cost of capital equipment, labor, and so forth. These market prices are sufficient to cover the needs of a financial analysis. However, for an economic assessment of benefits and costs, many of the important outcomes pertain to "nonmarket" goods and services. This means that there are no market prices to observe for many key outcomes (e.g., for a day enjoying an outing in a wetland, or fishing on flow-enhanced streams). Thus, nonmarket valuation approaches are required for many benefits and costs.

3.17.2 Nonmarket Valuation

Because many of the important benefits provided by biosolids management involve nonmarket goods and services, monetary values need to be derived using various well-established methods developed by economists for "nonmarket valuation." These nonmarket valuation approaches can help develop dollar estimates for some important types of biosolids-related benefits and, thereby, help decision-makers and the public better recognize the value of a biosolids option. These nonmarket valuation methods are summarized below.

3.17.2.1 Primary Methods

Many goods and services associated with biosolids-related impacts are not traded in markets. For example, rarely are there well-defined markets for many water-based recreational activities. There are two main approaches that economic researchers can use to estimate nonmarket values via primary research. These are known as *stated preference* methods, and *revealed preference* methods. Stated preference methods are survey-based and include contingent valuation and conjoint analysis, and revealed preference methods include travel cost and hedonic modeling (see summaries in Table 3-3).

Table 3-3. Primary Economic Valuation Methods for Nonmarket Goods and Services, Comparative Advantages and Disadvantages.

Travel cost	
+	Uses observed tourist and recreation trip-taking behavior
-	Measures use values only, often expensive and time-intensive to collect adequate data
Hedonic pricing	
+	Uses observed housing, property, or labor market behavior to infer values for environmental quality changes
-	Measures use values only, requires extensive market data, assumes market prices capture the environmental good's value
Contingent valuation	
+	Only method that can estimate nonuse values, also can estimate use values
-	Time-intensive and expensive to implement, challenges in framing survey questions to elicit valid responses, potential response biases
Conjoint/stated choice	
+	Similar to contingent valuation, except respondents are surveyed about a set of choices instead of a single willingness-to-pay question
-	Time-intensive and expensive to implement, challenges in framing survey questions to elicit valid responses, potential response biases

Revealed preference methods are based on observing individuals' behavior and associated voluntary cost bearing to infer the value of a nonmarket good or service. While there may not be active markets to buy and sell days of outdoor recreation, there are often costs that individuals incur to undertake direct use activities. For these types of uses, often incurred costs can be applied to develop proxy "prices" for the activity, and that information is used in developing the demand curve, and thus value, of recreation-related services. This approach uses observations on people's behavior, or their associated expenditures, as indications of "revealed preferences" for the good. Methods have been developed, and are discussed below, that use these revealed preferences to develop estimates of the value of nonmarketed goods and services such as many water uses.

For other activities, where there is no direct use of the resource, and thus no behaviors or expenditures available as a measure of people's preferences, methods have been developed to directly elicit preferences and estimate value. These direct methods are often described as stated preference methods because they most commonly elicit value through direct statements on value rather than using observations on behavior or expenditures to infer value.

The most common revealed preference methods are the hedonic pricing method and the travel cost method. The travel cost method is used to value recreational uses of natural and environmental resources. The hedonic pricing method can be used to value a wide variety of factors that influence observed prices, and is often used to infer the value of environmental goods.

Two common stated preference methods are the contingent valuation method and the conjoint/stated choice method. The contingent valuation method can value not only direct use values, but also nonuse (e.g., existence and bequest) values for natural and environmental resources. The conjoint/stated choice method asks for a ranking of choices instead of an answer to one willingness-to-pay question, and can also be applied to derive estimates of either use or nonuse values.

3.17.2.2 Secondary Methods

Primary research is often expensive to execute correctly, and often not feasible due to budgeting, scheduling, and the other constraints. It is often more practical to turn to secondary methods (described below), and to use an approach that helps identify the critical values in the BCA. If a particular value is identified as critical, then perhaps it will become desirable to invest in a primary research study to more definitively determine that value.

Benefits Transfer (BT) An expeditious method for valuing nonmarket environmental resource services is known as BT. The BT approach involves taking the results of existing valuation studies and transferring them to another context, e.g., a different geographic area or policy context. Under suitable circumstances (as described below), estimates for use or nonuse values may be derived, for example, using BT by applying an annual willingness-to-pay estimate per household to all the households in the geographic area in question with the same use or nonuse motives for the resource.

There are numerous challenges and cautions to consider when using BT. While it is relatively simple to develop a BT-based value monetary estimate of many types of benefits (e.g., there is a large literature on user day values for recreational experiences associated with improved surface water or wetland conditions), there are numerous ways in which the approach can generate potentially inaccurate (and misleading) results, even when a well intentioned and objective analysis is being attempted. The most significant challenges to the accuracy and credibility of BT-generated findings are that there often are important differences between what type of natural resource conditions were studied in the primary empirical research (i.e., the study context for the published monetary estimate), and the biosolids context and site to which an analyst may wish to transfer the results.

One such challenge in the BT approach is defining the appropriate "market" for the impacted site (e.g., what are the boundaries for defining how many households are assigned a BT-based value, such as dollars per year to preserve wetland habitat?). Another challenge arises due to the frequent need to attribute a BT estimate for a large outcome (e.g., avoiding a species extinction in a state) to the fractional contribution to the whole (e.g., the marginal additional protection for the endangered species provided by a single biosolids project in a single location). These and other challenges are illustrated in the case studies provided in Chapter 5.0, and reflect various challenges associated with properly matching the primary research scenario to the site and impacts in question.

Well-developed literature is available to guide those applying BT in the choice and use of appropriate studies (e.g., Desvousges et al., 1992), and the key steps are described below. When implemented correctly, the BT approach is accepted as a suitable nonmarket estimation method for estimating the use and nonuse benefits of changes in the level or quality of environmental resources, especially when used cautiously and transparently, and with a recognition that the estimates are not intended to be precise. However, primary research is broadly considered a far better alternative, when time and resources allow.

The advantages of using BT include time and financial savings, as conducting original research can be time consuming and expensive. The disadvantages of using BT include decreased accuracy as compared to primary research specifically tailored to the issue and site at hand, and the potential difficulty in obtaining relevant, high-quality existing studies.

When conducting BT, one should make certain that each of the following steps is carefully done (as stated in U.S. EPA, 2000e):

- Describe the issue (including characteristics and consequences) and the population impacted (e.g., will impacts be felt by the general population or by specific subsets of individuals such as users of a particular recreation site?).
- Identify existing, relevant studies through a literature search.
- Review available studies for quality and applicability. The quality of the study estimates will determine the quality of the BT. Assessing studies for applicability involves determining whether available studies are comparable to the issue at hand. Below are several guidelines for evaluating usefulness of a particular study for BT for a particular situation (based on guidance provided in U.S. EPA, 2000e):
    - The technical quality of the study should be assessed. The original studies must be based on adequate data, sound economic and scientific methods, and correct empirical techniques.
    - The expected changes in site conditions should be similar in magnitude and type in the project being appraised and on those projects from which the data are obtained.

- If possible, studies that analyze locations and populations similar to those of the project being evaluated should be used.
- The cultural differences between project location and the source of data should be carefully considered.

♦ Transfer the benefits estimates. This step involves the actual transfer of benefits over the affected population to compute an overall benefits estimate. The transfer may simply involve applying a user day value as derived from the primary study, or a more complex transfer of the benefits function derived empirically by the original researchers or from a meta analysis of multiple studies.

♦ Address uncertainty. Because BT involves judgments and assumptions, the researcher should clearly describe all judgments and assumptions and their potential impact on final estimates, as well as any other sources of uncertainty inherent in the analysis.

Societal Revealed Preference Nonuse values may be deduced (under limited circumstances) using voluntarily incurred restoration-based costs as a proxy for the value of the change in resource conditions. For example, for threatened or endangered species, the costs of voluntary or consensus-driven restoration programs and the costs imposed by various widely endorsed resource use restrictions may indicate the revealed preference value of restoring species populations to sustainable levels.

Avoided Costs (Cost Offsets) Avoided costs may be an important part of valuing the range of benefits likely to be generated by biosolids projects. These benefits accrue from reducing or eliminating expenditures related to power purchases (e.g., from energy recovery) or reduced purchases of fertilizer (e.g., from land application). These costs can also be deferred to later years. Use of NPV analysis will allow comparison of benefits accrued in different years to be made on an apples-to-apples basis.

However, there are potential issues to be alert to when using avoided costs as a proxy for benefits values. Avoided costs can be used as measures of benefits when they would actually be incurred in the absence of the biosolids project. Thus, and as noted previously, there is a potential for double-counting avoided costs in a BCA, and analysts need to be alert to this possibility when defining the baseline (and determining that costs of some options do not simultaneously appear as cost savings benefits of their alternatives).

Replacement Costs In some cases, a lower bound value for a lost resource can be estimated according to the costs necessary to replace the resource. For example, with loss of wetlands, an estimate can be derived for the cost to replace that habitat. Using cost-based measures as proxies or lower bounds for values can be tricky, however. Costs should only be used in this manner if they have been incurred voluntarily or through a consensus-based process. Otherwise, it is inappropriate to assume that costs also reflect values.

Response Cost: Averting or Mitigating Behavior The averting behavior approach examines the expenditures people make to avoid damages that result from environmental degradation. The mitigation approach examines the expenditures people make to correct a problem after the potential impact has occurred. This could include measures such as installing water air purification or filtering devices in the home in order to avert biosolids odors from a neighboring site. Averting costs are those costs associated with avoiding impacts from environmental degradation.

3.17.2.3 Analysis Strategies

Values are often not available for many benefit categories. A useful strategy in conducting an economic analysis when one or more key types of benefits is not measurable is to conduct an initial analysis that makes use of readily available data for the other categories of benefits and costs. Once the results are available for the existing data, then the analyst can attempt to determine whether or not valuation of other, omitted benefit or cost categories would influence the final outcome.

This approach, sometimes referred to as *implicit valuation* or a *"break-even" analysis*, attempts to determine what value for an unknown benefit would be needed to make the NPV of the analysis turn from negative to positive. For example, if monetized benefits exceeded costs by $10 million, then a nonmonetized benefit would need to be worth at least $10 million for the BCA to "break even." It may be quite obvious that the omitted benefit is (or is not) likely to be worth this amount of money. If values are available for comparison in the literature, this value can then be compared to values in the literature to determine how realistic that implied value might be—whether or not it passes the "laugh test."

Another similar method to help ascertain the relative importance of values is to conduct *sensitivity analyses* on key variables, or variables with large uncertainty, to help understand the effect of changes in those variables on the performance measures being used (e.g., NPV). Additional discussion is provided in Section 3.21, "What is sensitivity analysis and how does it help?" and Section 3.22, "How Should Uncertainty Surrounding this Analysis Be Handled?"

3.17.2.4 Finding a Common Metric

In some cases an analyst may be able quantitatively describe a set of cost and benefit categories but not monetize those categories. Often, the most intuitive metric for describing one benefit or cost category will be different than the metric for describing another category [e.g., total electricity consumed by a WWTP may be measured in kWh and total emissions may be measured in tons of carbon dioxide (CO_2) and other air pollutants]. Comparing these numerical, but nonmonetized results, may be instructive, but it will not necessarily be clear which benefit and cost categories are of the greatest concern or value. One approach is to "normalize" these values and create a common metric, such as the impact that each benefit or cost category has on the average person (this could be the average person in the community, state, or country, depending on what information is available). For example, if the electricity consumption at the WWTP is known (but cannot be monetized), this can be normalized by dividing the total annual electricity consumption at the WWTP (kWh) by the average annual electricity consumed per person in that state. If the analyst is able to do this for each quantified benefit or cost category, then a comparison of these nonmonetized variables can be made on the basis of the impact per person. An example of this approach is described in the case study for Greater Vancouver Regional District (GVRD) in Chapter 5.

3.18 What Are the Values for These Categories that Are Available in the Literature?

Many of the direct financial cost and benefits will likely be available based on engineering cost studies that have been performed for the utility. These values may include items such as the capital and O&M costs of constructing and operating biosolids-related facilities.

For nonfinancial benefits and costs associated with biosolids projects (i.e., the benefits and costs beyond financial, cash flow impacts, and often entailing nonmarket goods and services), there is a significant amount of literature available to help derive values for several potentially applicable benefit and cost categories. A summary of the literature is presented in several appendices to this document for key areas including recreation, environmental, cultural and aesthetic, and water supply reliability values. An outline of those benefit and cost areas, and associated subcategories is listed below.

- Land Application
  - Agricultural lands (Appendix A)
  - Reclaimed lands (Appendix B)
- Energy Recovery and Management
  - Energy recovery and generation (Appendix C)
  - Carbon accounting and climate change (Appendix D)
- Public Health Risks and Concerns (Appendix E)
- Odors (Appendix F)
- Innovative Processes (Appendix G)
- Water-Based Recreation (Appendix H)
  - In-water recreation (e.g., fishing)
  - Near-water recreation (e.g., hiking, picnicking)
- Environmental (Appendix I)
  - Water quality
  - Groundwater-related
  - Habitat for threatened and endangered (T&E) species
  - Habitat in general (for species that are neither threatened or endangered)
  - Coastal ecosystems
  - Wetlands

3.19 Distributional Perspectives (Equity Concerns)—Who Benefits? Who Pays?

There are several perspectives to consider when analyzing benefits and costs of a biosolids project. These include the wastewater agency perspective, the customer perspective, the government regulatory perspective, and the societal perspective. A benefit from one perspective may be a cost from another perspective. For instance, providing biosolids product for free to farmers is a reduced cost to the farmer (relative to fertilizer purchases), but is a cost to the water agency (foregone revenue) and, ultimately, a cost to the utility customers (who bear the cost of the biosolids program in their rates, thus subsidizing the farmers). Understanding and tracking all of these perspectives is the key to understanding motivations for possible support and opposition to biosolids projects, and possibilities for cost-sharing arrangements.

A key intent of exploring the different perspectives is to help examine the equity (i.e., fairness) implications of who pays versus who benefits from a biosolids project. Equity concerns are important to identify as part of a policy discourse, and may include explicit consideration of "environmental justice" as described below. In addition, understanding the distributional incidence of benefits and costs can serve a useful basis for considering how to pursue a more equitable distribution of project costs (e.g., to seek cost sharing from neighboring jurisdictions that may benefit from a biosolids project but not otherwise bear any of the costs), or to justify a state or federal subsidy (to reflect external benefits provided to a broad area). As a general principle, fairness considerations suggest that parties should bear costs in proportion to the extent they receive benefits.

Environmental justice is a term used more specifically (especially under federal mandated analyses) to explore the fair treatment of people of all races and incomes with respect to actions that affect the environment. Here, fair treatment implies that no group bears a disproportionate share of the negative impacts of an action. A group can be defined by race, ethnicity, income, community, or other relevant characteristics. In evaluating biosolids projects, a qualitative assessment of potential environmental justice impacts should be considered as part of the broader processes of policy evaluation, decision-making, and public discourse.

3.20 What is Discounting, and How Does It Relate to Cost Escalators Used in Financial Analysis?

Benefits and costs from biosolids management projects often occur as a stream of values over time. That stream may change in magnitude over time. Most biosolids options usually have large upfront capital costs that are paid for either up front or more likely over an amortization period at the beginning of a project, whereas benefits may accrue over the economic life of the project, which for some projects can be substantially longer than the amortization period. Values that occur in different time periods need to be adjusted to their comparable "present values" to compare them or make calculations with them.

There are two interrelated factors to consider when comparing values from different times—inflation and the "time value of money." When inflation is accounted for in recording or projecting values over time, then the values are said to be in "nominal" terms. Many financial analyses are conducted in nominal dollars. However, for economic analyses, benefits and costs are normally *not* entered in inflation-adjusted dollars. Instead, the use of "real" (i.e., not inflation-adjusted) dollars makes analyses easier and keeps inflation-related projections from clouding the analysis. In real dollars, a dollar today has the same purchasing power as a dollar 10 years from now.

The second factor to account for in comparing values over time is the fact most people prefer a dollar today more than an inflation adjusted dollar available in the future. Most prefer to have a real dollar today instead of a real dollar in the future because they prefer to use that dollar to consume today or they prefer to invest that dollar today to yield a future return. This preference for near-term consumption over deferred consumption is referred to as the "social rate of time preference" or the "time value of money." This social rate of time preference is the real (i.e., inflation free), net of tax, and risk free rate of interest that would need to be paid to a person to entice them to consider delayed receipt of a real dollar.

The annual rate at which present values are preferred to deferred values is known as the discount rate (and is similar to an interest rate). The greater the preference for immediate benefits (time preference), or the greater expected rate of return on other investments today (known as the opportunity cost of capital), then the greater the discount rate. The discount rate can be expressed in nominal or real terms. A real discount rate is the nominal discount rate with the inflation rate subtracted out. The key is to use a real discount rate when analyzing dollars in real terms, and a nominal discount rate when analyzing values in nominal terms.

Economic theory suggests that in a world with no taxes, no financial transaction costs, and zero risk, there would be a clear signal about what discount rate to use. If consumption today would come at the expense of investments in the future, then the opportunity cost of capital should be used to discount the stream of future benefits and costs. In that case, the discount rate should be equal to the rate of return that could be earned by investing the money. If inflation is expected to be 4% in the future, and there is a 3% risk free real return on capital, then the real discount rate would be 3%, and the nominal discount rate should be 7% (3% + 4%). If instead the use of funds or resources today predominantly displaces future consumption (instead of investments), then a social rate of time preference is more suitable as the discount rate.

There are philosophical and practical aspects to the choice of discount rate, and there is not always general agreement among economists or policymakers about the correct discount rate to apply to evaluating projects. For BCAs of biosolids and other wastewater management projects, which are generally investments made for broad public benefit, it may be most appropriate to use a real, net of tax, social rate of time preference as a real discount rate to convert all values to their present worth. However, justifications can be made for a range of rates, from a zero discount rate to a discount rate reflecting the private cost of capital.

- The argument for a zero discount rate is that discounting distorts project benefits that may occur far into the future and thus affect future generations, or that include irreversible outcomes (e.g., species extinctions).
- Others suggest that the discount rate should reflect prevailing interest rates on low-risk bonds because such risk-free, net of tax rates best reflect the rate of social time preference. This might be reflected by the real cost of capital to municipal agencies in raising capital through bonds, or the cost of long-term federal government bonds.
- Another argument is that for projects that will be paid for through wastewater rates, the cost of capital to ratepayers is the appropriate measure. This cost of capital might reflect an average of credit card debt rates, home and automobile finance rates, and other consumer rates—and may average around 8 to 10% in nominal terms.
- The argument for using the private cost of capital is that the project’s funds might be otherwise invested in private ventures, and therefore reflects the true opportunity cost.

Various governmental entities have specified discount rates to be used in analyses. The federal Office of Management and Budget (OMB) regularly updates discount rates in Appendix C to its Circular Number A-94 on *Guidelines and Discount Rates for Cost Benefit Analyses of Federal Programs* (OMB, 1992). OMB recommends using real interest rates on Treasury notes and bonds matched to the project time period for the real discount rate. The real interest rate on a 30-year note as of February 1994 was 3.5%.

OMB also mandates that federal agencies apply a 7% real rate of discount when evaluating the costs and benefits of federal regulatory actions (U.S. EPA, 2000e), although other rates often are used in sensitivity analyses (and a 3% real rate is typically used by the U.S. EPA to reflect the social rate of time preference). Finally, federal water resource agencies also are directed to use specific rates to evaluate water project alternatives by the Federal Code of Regulations, Plan Formulation and Procedures (for federal fiscal year 2006, the general planning rate is 5.125%).

To compare streams of value over time from different projects, the stream of values for each project is discounted to "present value" using the discount rate. If both benefits and costs are involved, the present value of the costs is subtracted from the present value of the benefits to get the NPV of the project. If the NPV of a project is greater than zero, then the present value of the benefits is greater than the present value of the costs. The NPV of different projects can be compared if they are adjusted to be in the same year's dollars. Comparison of NPV of projects allows apples-to-apples comparisons of project values regardless of possible differences in the timing of benefits and costs for each project.

3.21 What is Sensitivity Analysis and How Does It Help?

In many cases it will be useful to explore the impact of uncertainties or key assumptions (such as the choice of discount rates, or the use of BT-based estimates) through the use of sensitivity analysis. Sensitivity analysis involves systematically changing the value of some key input variable to see how it affects the outcome of the analysis. The change in results with the change in inputs can illuminate how important the impact is of uncertainty in a particular variable to the outcome. Sensitivity analysis is often performed by varying a particular input by equal amounts greater to and less than the current value.

For example, if a discount rate of 9% has been chosen for the main analysis, that value might be varied in increments of 3 percentage points from 0 to 15% for the sensitivity analysis. Table 3-4 shows an example of a sensitivity analysis for the discount rate applied in this fashion to the biosolids example.

Table 3-4. Sensitivity Analysis Applied to Discount Rate (Thousands of Dollars).

Discount Rate	Monetized Benefit	Cost	Monetized Net Benefit (NPV)
0%	49,000-51,500	30,000	19,000-21,500
3%	39,500-41,700	26,000	13,500-15,700
6%	29,500-34,000	22,000	7,500-12,000
9%	15,950-21,300	16,000	(50)-5,300
12%	8,500-14,000	11,000	(3,500)-3,000
15%	2,500-8,000	8,000	(5,500)-0

3.22 How Should Uncertainty Surrounding this Analysis Be Handled?

In an ideal situation, data would be available to statistically estimate confidence intervals for benefit or cost estimates. When this is possible, confidence intervals for estimates should be noted on the framework templates as the analysis is being conducted. However, statistically estimated confidence intervals are most often not possible. When it is possible with available data, ranges should be developed for an estimate by stating the upper and lower bounds. When bounding of an estimate is not possible, one can at least characterize uncertainty qualitatively by describing the sources of uncertainty and stating whether an estimate developed is likely to over- or under-estimate the true value (see omissions, biases, and uncertainty, which is Step 9 of the framework process, as described earlier in this chapter, in Section 3.6.9).

3.22.1 Imprecision in Estimates

It should be noted that are two main sources of imprecision in estimates of values. One is *variability*—the natural variations in an estimate due to its properties or the forces acting on it (e.g., rainfall can vary by season and from year to year). The other is *uncertainty* about an estimate due to a lack of knowledge on the part of the analyst about the true value (e.g., is the value of improved land reclamation $25 per dt applied, or is it $250 per dt?). Both variability and uncertainty can lead to imprecision of estimates, and are both reasons why estimates typically should be represented with a range of values instead of just a single value. A single "best estimate" or mean value can be used, but the range of possible values should be identified and explored using sensitivity analysis. Using a range of values instead of only a single estimate can avoid giving any impression that the analysis is tilted toward a desired outcome.

3.22.2 Risk and Uncertainty

A related concept to uncertainty is *risk* which, for the purposes of this discussion, can be thought of as reflecting the probability and consequences of an event. For example, prolonged rain storm events carry risks in terms of the reliability of access to land application sites. Drought and storm events reflect variability in precipitation from year to year (i.e., there is variation in the level and pattern of rainfall over the years), and there are uncertainties about when the next drought or extreme wet period will occur or how severe it will be. The risk associated with a highly wet period is that there is some probability that in a given future year(s), there will not be enough access to agricultural lands to apply all the biosolids produced, and the consequence is that in those years (or weeks) there may be a strain on on-utility storage capabilities or a need to divert biosolids to other options such as landfill disposal. Not all biosolids management options bear the same types and/or levels of risk, and these differences are important to articulate in the analysis. In some instances, monetary values may be assignable to differences in risks across options (but in many cases, monetary measures of differences in risk will not be readily monetizable using available literature).

3.22.3 Sensitivity and Scenario Analysis (Monte Carlo Simulation as an Example)

Scenario analysis or sensitivity analysis is an important tool to help in understanding the effect of uncertainty. By examining different scenarios with different values from the range of uncertainty for key variables, the analyst can examine whether the uncertainty in the underlying variables is important to the ultimate outcome of the analysis. Knowledge of whether uncertainty regarding key variables is likely to affect the outcome of analysis or the decisions to be made can help focus future research efforts on the most productive topics. One useful approach to scenario analysis is to conduct a Monte Carlo simulation. A brief summary of this approach is described here, and a more thorough description and illustration is provided in Appendix K.

3.22.3.1 Applicability

Monte Carlo simulation is useful in situations where there are multiple sources of variability or uncertainty that can have profound impacts on estimates of benefits, risks, and/or costs. The approach can be applied where the range and likelihood of plausible values for the key variables are understood well enough to be characterized by a probability distribution. The approach can be especially useful when there are multiple variables that may interact with each other to establish the true character of the risk being studied.

3.22.3.2 Procedure

Using data and knowledge developed through experience, the analyst characterizes probability distributions for key input variables. For first approximations, it is often sufficient to assume relatively simple distributions for many types of phenomena (e.g., uniform, triangular, normal, or log normal distributions). It is important that the distributions of any two variables are independent of each (if the variables always move together—in either the same or opposite direction—then the variables may not be independent and the analysis needs to account for their joint relationship). Monte Carlo simulation uses computers to draw a large number (e.g., more than 1,000) random sample draws for each possible combination of variable values. The random draws are guided by the probability distributions, such that more probable outcomes are drawn more frequently than low probability outcomes. The result is a probability distribution of the final output, based on the combined probabilities of each of the underlying input values. This can provide decision-makers with very useful insights about the likelihood of a given outcome, e.g., what the probability is that a project's NPV will be positive, when the NPV outcome is influenced by several variables whose values are uncertain or variable.

3.22.3.3 Illustration

In the example below a utility is considering the benefits and costs of implementing an energy recovery system. Key variables that will determine if the benefits outweigh the costs include the cost and timing to complete the project, the amount of electricity produced, and the value of the power generated (in terms of the cost of power that would otherwise be purchased from the grid).

- Using the expected values for these key variables, the project is estimated to have a positive NPV of $2 million. However, there are possible delays in completing construction or in obtaining necessary operating permits.
- If there are delays, the result will be escalated construction costs as well as postponed power generation benefits. This cost escalation and delay in benefits would result in a NPV that indicated the project was a losing proposition (e.g., a negative NPV of -$4 million).
- Then again, another highly plausible scenario is that real energy prices escalate more rapidly than currently anticipated. Under this scenario, the estimated NPV would be positive and large (e.g., a positive NPV of $4 million).

Rather than trying to make sense of each of the several possible scenario outcomes for the energy recovery facility, a Monte Carlo analysis compiles all the scenarios together in a single statistics-driven analysis. The Monte Carlo simulations are used to develop an estimate of the likelihood of a particular outcome (e.g., the probability that the NPV of an energy recovery system will be greater than zero). This information could be extremely useful to a decision-maker dealing with multiple sources and levels of uncertainty (e.g., regarding future electricity prices, potential construction cost escalations, and the likelihood and duration of permitting delays). For the energy recovery project, an example of the kind of outcome generated by a Monte Carlo analysis is provided in Figure 3-5, which shows the probability that the NPV will be greater than zero. From this distribution, it is clear that while there is a chance that the NPV of net benefits will be less than zero, the probability that the NPV will be greater than zero is approximately 80% [this is represented in Figure 3-5 by the area under the curve defined by the solid line (to the right of the vertical line)].

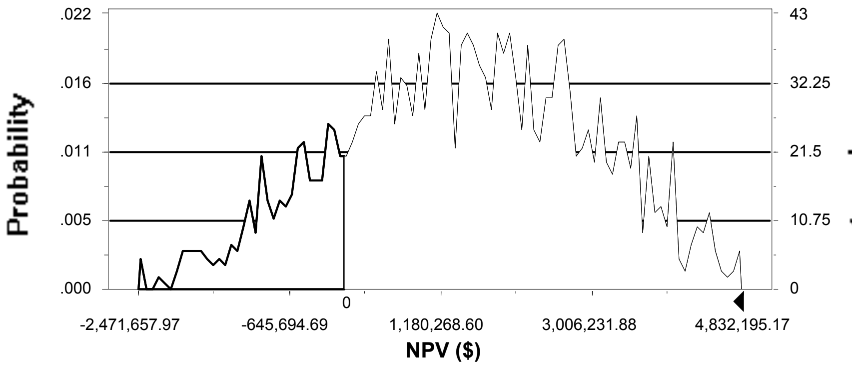


Figure 3-5. Probability Distribution of the NPV of Monetized Benefits over 20 Years. There is over 80% probability that NPV > 0.

3.23 How Does this Analysis Relate to the Impact on Wastewater Rates from Projects?

The net financial utility costs for a biosolids project from the agency perspective, minus the financial utility benefits (revenues, if any, are generated by the biosolids option) are net costs. These net costs must be covered from several possible funding sources, one of which is likely to be wastewater user rates. The impact that a biosolids management option will have on the rates charged to wastewater utility customers will depend on several utility-specific circumstances. These include the agency's access to and approach to financing for capital improvement projects (e.g., bond issues, potential public sector loans and subsidies, and so forth). The manner in which a utility garners the additional cash flow required to cover the added cost of a new biosolids program is a local public policy decision, and the cash flow needs may be covered by any one of a number of sources that may include grants, loans, connection fees, and increases in wastewater rates.

3.24 How Can this Analysis Be Used to Explore/Understand Potential Cost-Sharing Arrangements for Proposed Facilities?

Estimates of how much each stakeholder benefits from the project that is made using an economic analysis can be used as a basis for a fair cost-sharing arrangement. The key is to have buy-in from stakeholders on the values estimated (or at least to have stakeholders acknowledge the types of benefits realized). If stakeholders do not understand the estimates, or the estimates do not match well with stakeholders' understanding or expectation for the value of their benefit from the project, then it will be more difficult to suggest the results of the economic analysis as a basis for cost sharing. Results of the analysis should be discussed with stakeholders, with adjustments made to either better align the results with expectations or to educate stakeholders on the valuation process. This tool and analysis can be used as a learning process to educate all parties, and help lead to an equitable arrangement based on sound analysis.

3.25 What's Next?

This chapter has described what an economic (benefit-cost) analysis is, and has provided guidance on how to develop one. Chapter 4.0 provides the templates that can be used to implement the economic framework (a spreadsheet version of the tool is available on the CD provided with this report). Case studies are also provided, in Chapter 5.0, to offer illustrations of how the templates can be completed.

CHAPTER 4.0

TEMPLATES FOR CONDUCTING AN ECONOMIC ANALYSIS

Chapter 3.0 described the various steps involved in conducting an economic analysis of biosolids projects, and provided background information and guidance related to each of the steps. This chapter provides a series of forms or “templates” that are useful for helping to systematically organize and transparently document information as an analyst works through each step. The templates also are designed to be useful for communicating the contents and findings of the analysis to decision-makers, customers, governing officials, and other stakeholders.[1]

There are two versions of the templates—one set (presented in this chapter) that is provided as paper versions, and the other set that is built into the software version of the economic framework. In this chapter (and in Chapter 5.0), the researchers focus on the paper (hard copy) versions that can be used by analysts. These paper versions generally replicate what is on the spreadsheet (though in a more paper-friendly manner), and provide a way that utility analysts can implement the economic framework off-line (i.e., without relying on the electronic spreadsheet version). This chapter provides the blank versions along with some guidance, and Chapter 5.0 provides some case studies in which many of the templates are partially filled in so that they can serve as useful illustrations of how to use them. These blank templates are also available in electronic form (in MS Word) on the CD that accompanies this report, so that users can download them and use them as needed.

In addition to the hard-copy templates provided here, the researchers also have developed a spreadsheet version of the economic framework that embodies the same logic and approach. Each tab in the spreadsheet version represents a step-specific template. The software version of the templates in the MS Excel-based software tool do not exactly correspond to their hard-copy counterparts, because the software version is designed to enable use of the functionalities the spreadsheet offers. However, the software tool replicates the same logic and intent as the hard copy versions shown here. Appendix J helps users gain a visual overview of the software tool, by providing a hard copy version of the spreadsheet tool. The electronic version of the software tool is provided on the accompanying CD.

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1. These templates are not unique to this WERF project, and have been developed and applied in various other efforts produced by the research team. These include Awwa Research Foundation report 91068F, *The Value of Water: Concepts, Estimates, and Applications for Water Managers* (Raucher et al., 2005), and the WateReuse Foundation report 03-006-02, *An Economic Framework for Evaluating the Benefits and Costs of Water Reuse* (Raucher et al., 2006).

4.1 Overview of the Steps

In Section 3.6 of Chapter 3.0, an overview was provided of the steps for conducting an economic analysis of a biosolids project. The flow diagram that summarizes these steps is repeated here (Figure 4-1), to provide a visual roadmap to users as they examine the accompanying templates and spreadsheet tool materials.

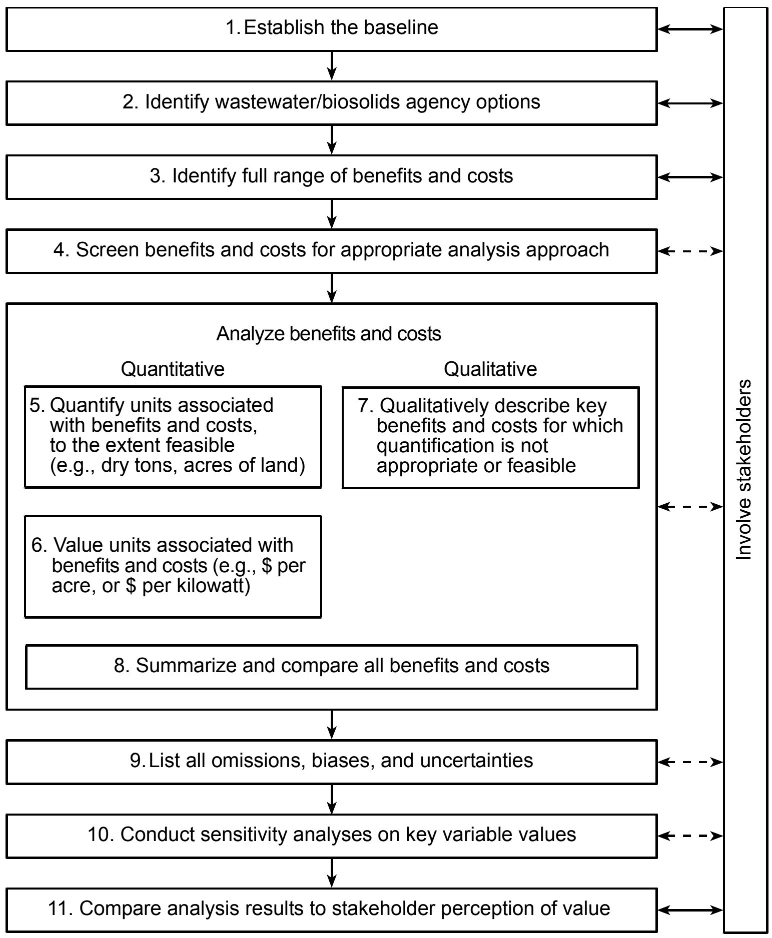

Figure 4-1. Steps in an Economic Analysis Framework.

Note too that the economic analysis embodied in the steps portrayed in Figure 4-1 is only one part of the broader decision-support toolkit that wastewater agency planners and decision-makers will need to deploy in the public policy context of biosolids management decisions. An economic analysis is only one tool, and the application of complementary tools in the decision support arsenal will also be necessary.

4.2 Paper Versions of Framework Templates

The following templates are intended to help guide users and provide a systematic way to organize and present information. A formal template is not provided for every "step" in the economic evaluation process, as some steps do not necessarily entail the need for a formal assessment. However, a user should follow the process steps from Figure 4-1, regardless of whether worksheet templates are provided here.

Step 1 has no formal worksheet, but entails defining and recording baseline information. This typically will entail considering what the future will look like in terms of biosolids generated (quantities, qualities, and cost) and future demands (embodying one or more possible regional growth and changing land use scenarios). It is good practice to explicitly state key assumptions and to provide a clear statement of what problem(s) the potential project is intended to help address (and/or state what desired objectives the project would help the utility and community attain).

Step 2 also has no formal worksheet template, but is the step in which the analyst defines the biosolids-related options that the agency considers feasible for its biosolids management portfolio. This is a place to record information regarding the biosolids option(s) to be evaluated. This includes information on the type of project (e.g., land application, energy recovery), the type and number of other entities (e.g., farmers, landfill operators) associated with a project option, other entities associated with the project, key project dates, and key project stakeholders.

Step 3 includes a template (next page) to help users with the identification of benefits and costs for the biosolids management option(s), and includes columns for multiple alternative projects (each option has its own column). This is a simple checklist, to get the process rolling, in which the user should place a check into the rows for which a benefit or cost (relative to the baseline) would probably apply.

Step 4 includes a template for summarizing and reporting the findings of the screening analysis—separating the various identified benefits and costs into three categories: 1) those for which some level of quantitative analysis is feasible and pursued; 2) those which are not amenable to quantified analysis, but which are nonetheless important and require/deserve a meaningful qualitative discussion; and 3) benefit and cost impacts that exist but are deleted from further analysis because they are likely to be too insignificant to be of relevance, or because they are impacts mitigated by other actions embodied in the project. In the second category, a simple relative scoring scheme is useful to apply (e.g., the +2 to -2 scale described earlier or, as shown in the example template below, a simple + or - sign).

Steps 5 and 6 are summarized in a single template offered below, which provides space to indicate the types and levels of physical units used to quantify the benefit outcomes, as well as the dollar value is applied to each unit. The user can thus enter the relevant quantity and units of measurement associated with a given type of benefit. As noted in Section 4.3, these quantification units might be represented in dry tons of biosolids managed per year (dt/yr), kWh generated, acres of land to which biosolids will be applied, or number of recreation days. The guiding principle is that the units will depend on what physical outcomes are most relevant and for which dollar values may be most reasonably be applied. The monetary units would then be shown as ranges of $/unit values associated with that item (e.g., $/dt land applied, or $ per kWh generated from energy recovery). If the units and/or values are expected to change over time (e.g., the volume of biosolids applied grows, or their use does not become available until x years in the future), this can and should be described in these entries as well, since projection of the potentially changing units and $/unit values over time should be used to calculate total benefits and costs over time.

Template for Step 3
Checklist overview of benefit, cost and risk categories across biosolids management options

Category	Option 1	Option 2	Option 3	Option 4	Option 5
Costs to wastewater/biosolids management agency (internal financial costs, relative to baseline)					
Capital					
Land					
Electricity					
Heat					
Labor					
Transportation					
Other operating costs					
Storage					
Administrative fees					
Avoided wastewater and biosolids management costs (relative to baseline)					
Electricity					
Heat					
Storage					
Transportation					
Labor					
Land					
Administrative fees					
Program sustainability and reliability					
Storage capacity					
Adequate land available					
Adequate landfill capacity					
Regulations/permitting					
Public health and safety					
Change in real risk of illness (morbidity)					
Change in perceived risk of illness (morbidity)					
Change in risk of premature fatality (mortality)					
Environmental and related impacts					
Groundwater					
Revegetation					
Habitat					
Carbon sequestration/offsets					
Air pollution emissions					
Commercial fertilizer production and use					
Beneficial use applications					
Fertilizer value					
Soil amendment value					
Fuel source					
Synergies with other utilities					
Economic, social, and equity impacts					
Economic development/growth					
Odors					
Visibility/aesthetics/dust					
Noise					
Traffic					
Distributional effects					
Public opposition/support					

✓ indicates that the category of impact exists for the given supply option.

Template for Step 4
Summary screening analysis

Benefits and costs receiving full or partial economic valuation

❍
❍
❍
❍
❍
❍
❍
❍
❍
❍

*Benefits and costs requiring qualitative assessment**

(+)
(+)
( )
(-)
(-)

Impacts deleted from further analysis: Impacts that are relatively small or mitigated

❍
❍
❍
❍
❍
❍
❍
❍
❍
❍
❍
❍

* Place “+” or “-” in parenthesis for positive benefits or costs (negative benefits), respectively.

Template for Steps 5 and 6
Detail on benefit value derivation for biosolids management project

Benefit category	Annual quantity	Unit value used	Comments

Finally, the "comments" column should be used to document the information sources (e.g., citations) for the quantified values selected for each impact, as well as some indication of the confidence (or lack thereof) held in the values applied. Overall, this template is intended to provide clear documentation of the basis for each quantified outcome used in the analysis, so that the analyst and reviewers can retrace the information and defend or critique it later, if warranted.

Step 7 entails considering the qualitative benefits and costs identified in Steps 3 and 4. In using the suggested template, users are encouraged to 1) develop short but meaningful qualitative descriptions of the important qualitative outcomes, 2) convey a sense of relative ranking of whether the benefit (or cost) is likely to be of high or low relative importance compared to other benefits and costs in the analysis, and 3) identify who are the likely beneficiaries.

The relative ranking aspect can be done using (for example) a five-point scale to indicate the likely impact on net benefits (net benefits are the monetized benefits minus the monetized costs for the project). This rating scale can use +2 (or ++) for showing a very positive impact on net benefits, -2 (or --) showing a very negative impact on net benefits, and 0 showing a neutral impact on net benefits. Users can also insert a +1 (or a single + sign) or -1 (-) for modest positive (or negative) impacts on net benefits, respectively.

Step 8 is a template for summarizing all the benefit and cost findings, including both quantified and qualitative information on all the benefits and costs of significance associated with the project. This page shows a summary of net benefits for the project along with the qualitative assessments developed in previous steps. This summary of benefits and costs is likely to be a table that is often used by those considering the project, therefore it is very important that the qualitative benefits and costs be included in every table that also contains the monetized benefit and cost findings (otherwise, there is a tendency for too much focus to be placed on the numeric results, and too little attention—or none at all—on the qualitative outcomes that may be of considerable importance.

Step 9 is a template listing the various omissions, biases, and uncertainties associated with all values in the analysis—both quantitative and qualitative. Here, "omissions" refer to possibly important benefits or costs that could not be explicitly included in the analysis. "Biases" refer to quantified outcomes that the analyst knows are likely to be skewed to be lower bound or upper bound (rather than "most likely") estimates, as may occur due to data limitations or other unavoidable reasons (note that the term "bias" here does *not* imply any intentional intrusion of opinion over fact, and instead refers to empirical outcomes arising from data limitations). "Uncertainties" reflect results that quite possibly are inaccurate, but for which it is not clear whether they may be too low or too high.

Step 10 provides a template for conducting and reporting the results of sensitivity analyses. The template was shown earlier (Table 3-4) in a simple version in which the sensitivity analysis is based on how the NPV benefits (present value benefits minus present value costs) are impacted under alternative discount rates. However, sensitivity analyses can (and generally should) be based on multiple variables (not just the discount rate), and often are helpful if alternative scenarios or assumptions for multiple variables can be conducted simultaneously.

Template for Step 7
Qualitative benefits description

Type of benefit	Relative importance*	Brief description	Key beneficiaries

* Expected relative impact on project net benefits: ++ (or +2) for relatively large positive addition to net benefit, + (or +1) for moderate added benefit, - (or -1) for moderate negative impact, and -- (or -2) for relatively large negative impact on net benefits.

Template for Step 8
Costs and benefits of biosolids management project
(present values, x% discount rate, <enter year> dollars)

	Dollar amount	Stakeholder accruing cost or benefit
Cost components *Total costs*		
Benefit components *Total monetized benefits*		
*Benefits requiring qualitative assessment**		
Monetized net benefits (monetized benefits minus costs)		

* (+) indicates positive benefits anticipated, but not monetizable with readily available data; and (-) indicates costs anticipated, but not monetizable with readily available data. Or, use +2 to -2 five-point scale.

Template for Step 9
Omissions, biases, and uncertainties and their effect on the project NPV

Benefit or cost category or variable	Likely impact on net benefits*	Comment

*Direction and magnitude of effect on net benefits:
++ = Likely to increase net benefits significantly.
+ = Likely to increase net benefits relative to quantified estimates.
- = Likely to decrease benefits.
-- = Likely to decrease net benefits significantly.
U = Uncertain, could be + or -.

Template for Step 10
Sensitivity analysis applied to <specified variable/parameter>
(thousands of dollars)

Variable/ scenario	Monetized benefit	Cost	Monetized net benefit

4.3 Units of Measurement

Using the appropriate units to quantify benefit and cost categories is a critical part of a meaningful economic analysis. Selecting the physical units to quantify benefits and determining the corresponding dollar value is not always straightforward. The units of measurement for quantifying benefits, and the corresponding dollar values to monetize those benefits, depend on the particular benefit categories selected for the analysis and the type information available to the analyst.

For example, where a benefit is energy recovery in the form of electrical production, then the logical and appropriate unit of measurement is likely to be quantified in terms of kWh generated or saved per year. Likewise, if a land application option provides increased agricultural productivity, then this specific type of benefit is likely to be quantified in terms of increased crop yields (e.g., additional bushels harvested per acre, or some similar measure). Alternatively, if the land application of biosolids is used in lieu of applying agricultural chemicals, then there may be no expected change in crop yields. In this case, the benefit cannot be meaningfully quantified in terms of added crop yields, but may instead be measured in terms of tons of chemical fertilizers purchases that were avoided (e.g., local farmers were able to forgo purchases of X tons of chemical fertilizer per year).

It also is important for some types of benefits that the quantification units are applied that best correspond to the available monetary valuation information. If a biosolids option improves recreational opportunities, and the available economics information for valuing this benefit is cast in terms of $ per added recreational activity outing, then the analysis should strive to quantify the benefit in terms of increased numbers of recreational outings (e.g., added recreational angling or bird watching days).

The bottom line is that the units of measurement for biosolids-related benefits are often very situation specific. Accordingly, there are no units of measurement specified in the template provided for Steps 5 and 6. Instead, analysts will need to use good judgment to select the most suitable units of measurement for the specific benefit categories and circumstances that apply to their situation. Careful attention to the types of information available for each benefit (or cost) category will help the analyst ensure that he is using appropriate physical units (and corresponding dollar values) in Steps 5 and 6.

In some cases, it will be very evident to the analyst what physical units (and the associated range of per unit monetary value dollar value) to assign to a particular benefit. For example, if the benefit category is "avoided electricity purchases" resulting from the implementation of a specific energy recovery technology, then the analysis should obviously focus on the amount of electricity that will be produced, and that amount may be explicitly stated in kWh. The monetary value of the electricity can then be derived from the price that the agency typically pays in purchasing power off the grid (in $/kWh). In this case, it is clear that the analyst should record the amount of electricity produced by the new technology in kWh, and the dollar value assigned to that benefit should be listed in $/kWh.

In other situations, however, the choice may not be as clear. If an agency land applies biosolids at reclaimed mine sites, for example, the physical units used to describe "avoided fertilizer purchases" could refer to the volume of biosolids applied at a site (dt) or to the size of the site (acres). The analyst may have to compile estimates from various sources in order to determine which physical units are most appropriate and which dollar values are the most relevant. For example, a manager at a reclaimed mine site may inform the biosolids program manager that he typically spends $1,500 on fertilizer at a 20-acre site, thus providing the information necessary for the analyst to determine the $/acre value of "avoided fertilizer purchases" (in this case, $75/acre). The analyst may choose to quantify the benefit in terms of the size of the reclaimed mine sites to which biosolids will be applied (acres), in which case the information he has regarding the dollar value ($/acre) is sufficient. If however, the analyst ultimately wants to assign a dollar value to the volume of biosolids that are put to this beneficial use ($/dt), then the volume of biosolids applied at a reclamation site (dt/acre) will need to be determined, and simple division ($/acre divided by dt/acre) will provide the analyst with the metric of interest ($/dt).

4.4 Conclusions

This chapter has provided several templates that can be used to help guide and document the economic analysis, and some guidance on the use of these templates also has been provided. The economic analysis framework (and these templates) are illustrated in a series of case studies, in Chapter 5.0. In addition, a software tool (a spreadsheet model) also is provided with this report (see the accompanying CD and Appendix J), which generally replicates these templates and provides a computerized and interlinked alternative method for applying the economic framework.

CHAPTER 5.0

CASE STUDY ILLUSTRATIONS

Previous chapters have described why it is important and useful to conduct economic analyses of biosolids management options, and also provided guidance on how to perform such BCAs. This chapter provides some illustrations and lessons learned based on case study applications of the framework to several wastewater agencies that have participated in this research project.

It is important to note that it is not typically a straightforward or simple task to develop a credible economic (benefit-cost) analysis of a biosolids project. Many of the important benefits (and some of the important costs) are not readily quantifiable or monetizable. Further, some of the streamlined valuation methods that can be applied, such as BT, are often not as straightforward as may initially appear. This raises the possibility that unintended errors may be introduced that could yield misleading results and/or cast the credibility of the analysis in doubt. Therefore, the illustrations provided here are intended, in part, to help reveal some of the challenges and potential pitfalls that users need to be alert to and try to avoid, and concurrently to offer suggestions for how to best approach these issues.

The case studies below are not, in and of themselves, comprehensive evaluations of any single biosolids project. The researchers have selected illustrative elements from the various projects so that they can provide some focused discussion and examples, and highlight some lessons learned and associated tips for practical application. They have extracted from the case studies the benefit-cost estimation issues that appear to be important in many biosolids situations. A summary overview of the case studies and associated benefit types explored is provided in Table 5-1.

Finally, because these case studies are intended to be useful as illustrations, they have taken some liberties with simplifying some of the facts, and in some instances may have glossed over some important details. The intent is to provide illustrations, not to offer up materials that might be misconstrued as comprehensive or fully accurate depictions of any particular biosolids project or wastewater utility. All monetary figures cited here reflect 2005 price levels, and are stated in United States dollars (USD), unless otherwise specified.

5.1 Illustration 1: Applying the TBL Approach to Biosolids Management: Vancouver, British Columbia

5.1.1 Introduction and Overview

The GVRD is a partnership of 21 municipalities and one electoral area that make up the metropolitan area of Greater Vancouver, British Columbia. The GVRD is responsible for planning growth and development in the region as well as providing utility services to over two million Lower Mainland residents. This includes managing the region’s five WWTPs, which have a combined treatment capacity of over 300 million gallons per day, as well as the roughly 70,000 metric tons (Mt) of biosolids produced annually.

Table 5-1. Overview of Case Illustrations.

Case Study	Benefits Illustrated	Comments and Key Lessons
Greater Vancouver Regional District, BC	TBL approach illustrated, to compare land application, incineration, and landfilling. Energy recovery is a feature of all three options.	The TBL approach used to reveal that the option with the lowest financial cost is not the most preferred option, when environmental and social outcomes also are considered.
King County, WA	A carbon accounting framework is illustrated, comparing land application alternatives (forest versus agricultural lands), and landfilling (with and without energy recovery).	The carbon accounting framework enables agencies to understand the lifecycle net impact of their biosolids management options on the carbon balance in the atmosphere (linked to climate change), through carbon sequestration and emissions of greenhouse gases.
Columbus Water Works, GA	Issues and benefits associated with developing and piloting an innovative pathogen reduction process are illustrated. The level of value of energy recovery benefits from the innovative process also are illustrated.	The benefits of energy recovery are quantified and monetized, and a spreadsheet tool to do so is illustrated. These benefits can be sizeable, including reductions in power purchases from the grid as well as the value of reducing air pollutant emissions.
Reedy Creek Improvement District, FL	A multi-objective evaluation process is illustrated to compare the baseline (composting) to thermal drying, in-vessel composting, and landfill disposal.	The multi-objective evaluation process provides a semi-quantitative (but nonmonetized) approach to weigh different types of benefits and costs across the biosolids options. This approach develops a score to rank the options according to the criteria and weights assigned by the utility.
Metro Wastewater Reclamation District, Denver, CO	Energy recovery and associated reduced air pollution benefits, derived from methane and heat capture at the digesters, are quantified and valued. (A more detailed case study, covering a broader array of issues at Metro, is provided in Appendix L.)	Quantified and monetized values are developed for avoided electricity and thermal heat purchases, and for reducing power plant emissions of GHG and other air pollutants. This illustrates the spreadsheet tool that is explained in greater detail in Appendix C.
Western Lake Superior Sanitation District (WLSSD), Duluth, MN	Tradeoffs are evaluated between expanding land application for mine site reclamation and land application at agricultural sites. (A more detailed case study, covering a broader array of issues at WLSSD, is provided in Appendix M.)	The types and levels of benefits associated with both land application alternatives (mine site reclamation and agricultural soil conditioning) are illustrated. Issues include tradeoffs between added distance to reach mine sites, versus the higher volume and potential value of applications at those sites
Orange County Sanitation District (OCSD), CA	An innovative energy recovery approach, in partnership with a private vendor, is evaluated and contrasted to traditional land application options in the southern CA context. A graphical TBL approach is illustrated for depicting the choice set for OCSD.	Given increased restrictions and transport costs associated with land application, and limited (saturated) regional markets for composted materials, a range of novel options are required to enable OCSD to continue to have sustainable options for the biosolids it produces. Energy recovery provides one such option that, while relatively costly, provides renewable energy values and helps assure longer-term program sustainability.

The GVRD expects biosolids production in the region to more than double over the next 50 years as a result of population growth. The volume of biosolids that can be put to beneficial use via land application will remain roughly the same in future years, which means there is a need for alternative uses for the increasing volumes of biosolids that will inevitably be produced (GVRD, 2006).

Since 2001, the GVRD has been promoting its Sustainable Region Initiative (SRI)—a program established to identify and pursue regional sustainability based on the following principles:

- Balance consideration of present and future generations
- Care for economic prosperity, community well-being, and ecological integrity
- Identify and protect assets and resources (GVRD, 2006)

Based on what the GVRD considered to be the most common end uses of biosolids, the agency assessed three possible scenarios for the management of biosolids produced at two hypothetical WWTPs. The agency's evaluation of these hypothetical scenarios served as a means to illustrate how the TBL can be used as a tool to evaluate various elements of biosolids management options in the context of a long-term, sustainable program. The GVRD uses these scenarios as illustrations, and does not necessarily intend to select one of these management options for their biosolids program.[1]

5.1.2 Potential Biosolids Management Scenarios

The three scenarios evaluated were:

- Land application (anaerobically digested biosolids)
- Incineration (undigested sludge)
- Landfilling (undigested sludge)

Each scenario included some form of energy recovery and examined the effects of the management program at the WWTPs, during transportation, and at the end use. The evaluation assumed that there were two WWTPs (one large plant and one small plant) that together serve roughly 1 million people.

Land Application In this scenario, sludge is digested (using thermophilic digesters) and dewatered, producing Class A biosolids that are applied to land for mine site reclamation and agricultural fertilization. Digester gas is used for power production and waste heat generation (cogeneration).

Approximately three-quarters of the biosolids are used for mine reclamation and the remainder are used as fertilizer in various agricultural applications. In both cases the nutrient value of the biosolids offsets the cost of commercial fertilizer that would otherwise be used.

Landfilling In this scenario, undigested sludge is co-disposed with municipal solid waste (MSW) at an existing landfill. The landfill gas is recovered and used for energy. The portion of landfill capital and O&M costs attributed to the sludge disposal was determined based on the total wet weight of the material. Tipping fees for the sludge are considered to be significantly higher than for MSW. The hypothetical landfill is designed to maximize gas production and capture efficiency (65%). The landfill gas production potential specifically attributed to the undigested sludge was assumed to be 40% based on the volatile solids content of the sludge and typical values for landfill gas production from volatile solids.

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1. These hypothetical options do not reflect existing GVRD programs that develop a range of soil products with Class A cake.

Landfill gas is assumed to be used for power production and waste heat generation using reciprocating engine generator sets (cogeneration). Emissions from this equipment are assumed to be the same as the emissions from the engines operating at the Maxim cogeneration facility in Delta, BC.

Incineration In this scenario, undigested sludge is incinerated, with energy recovery. The incinerator is located on-site at the large WWTP. The dewatered sludge from the small plant is delivered via truck to the incinerator. The incinerator uses fluidized bed combustion (best available technology as of 2005) and includes a waste heat recovery boiler followed by a condensing turbine for power production.

The air pollution control equipment is designed to meet regulations (also using best available technology) and minimize potential impacts on air quality. The incinerator ash is nonhazardous waste; 100% of which would be used beneficially as daily cover at a landfill.

5.1.3 GVRD Approach to the TBL

The GVRD's approach to the TBL involves addressing each element of the TBL (financial, social and environmental) in a systematic way. The GVRD's TBL consists of:

1. **A financial bottom line**, evaluated as the present value of net costs (PVNC).[2]

   The PVNC of each scenario is calculated as the sum of the costs minus the sum of the benefits, discounted to reflect when they occur and the time value of money (Equation 5.1.3-1, below). Only those costs and benefits that can be monetized are included.[3]

$$PVNC = \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} - \sum_{t=0}^{n} \frac{B_t}{(1+i)^t} \qquad (5.1.3\text{-}1)$$

2. **A second bottom line to reflect "social" impacts** of a particular scenario at three different stages in the biosolids management process (as outlined in Table 5-2), evaluated qualitatively.

Table 5-2. Social Bottom Line: Affected Parties.[a]

Process Category	Potentially Affected Parties
WWTPs	Operators and community members within close proximity to the two facilities
Transportation	Truck drivers and community members along the routes between the WWTPs and the end-use locations (e.g., landfill or land application site)
End use	Operators and community members within close proximity to site(s) where biosolids and/or incinerator ash are used

[a]Adapted from GVRD (2005).

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2. Readers may be more familiar with the term NPV, which is the present value of the benefits minus the costs. The GVRD selected to use PVNC rather than NPV because a large number of benefits in these scenarios could not be monetized and are included in the social or environmental component of the TBL analysis, rather than the financial component. The PVNC provides the same information about the scenarios as NPV, but all PVNC values will be positive where costs outweigh the monetized financial benefits (whereas NPV would be negative under such a scenario).

3. C_t and B_t are the costs and benefits in year t, respectively, i is the social discount rate (in this case 6%), and n is the period over which costs and benefits are calculated (in this case, 50 years).

The social effects were estimated by drawing upon information gathered from:

- ♦ Literature reviews of biosolids management texts and studies
- ♦ Discussions with experts on land application, landfilling, and incineration, from other regions and within the GVRD
- ♦ GVRD workshops with biosolids managers from across North America

3. **A third, environmental bottom line** to reflect resource consumption and the overall "environmental burden" of a particular scenario, evaluated using Life Cycle Analysis (LCA).

   LCA is a methodology used to identify, evaluate, and quantify potential environmental impacts (e.g., net electricity use, GHG emissions) associated with the entire lifecycle of materials and services. In the GVRD's analysis, the "entire" lifecycle included: facility construction, manufacturing of equipment, chemicals and vehicles, system operations, transport of biosolids and ash, generation of digester and landfill gas, as well as energy recovery from incineration. In order to develop a common metric to compare the range of environmental impacts included in the analysis, the GVRD evaluated each scenario on the basis of "the average person's impact" in each category (e.g., net electricity output is divided by the average Canadian electricity consumption). In other words, the elements of the environmental bottom line are compared on a normalized per person basis.

   A full description of the development and application of LCA is beyond the scope of this report. Readers are directed to the International Organization for Standardization (ISO), specifically the ISO 14000 series, for more information.[4]

5.1.4 Assumptions Made to Apply TBL to Three Potential Biosolids Management Scenarios

As with many methodologies, applying the TBL approach often requires making numerous assumptions. Although the assumptions necessary for applying TBL will vary from one agency to the next, depending on the management options being evaluated and the amount of information available at the time of the evaluation, the researchers have highlighted a few of the key assumptions made by the GVRD to illustrate the type of thinking that may be required by decisions makers. Table 5-3 summarizes some of the key assumptions made by the GVRD.

5.1.5 Results of the GVRD's TBL Analysis

Financial Bottom Line The PVNC associated with each scenario was calculated over a 50-year planning horizon. Only the costs and benefits that could be monetized were included in the GVRD's financial analysis, nearly all of which would be incurred by or accrue directly to the utility. Only costs and benefits that differ between the three scenarios were included in the analysis (this focus on differences between option reflects how the analysis accounts for the "baseline" in this illustration). The present value (PV) of total benefits is greatest for the land application scenario, but the PV of total costs is lowest for the incineration scenario. Table 5-4 provides a summary of the GVRD's financial bottom line, and the option with the lowest PV net

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4. The document used by GVRD, *Environmental Management—Life Cycle Impact Assessment—Examples of Application of ISO 14042*, is available at the ISO Website: http://www.iso.org/ (ISO, 2003).

Table 5-3. Key Assumptions Made by the GVRD in Their TBL Assessment.

Assumptions	Applicable Biosolids Management Scenario
Economic life of	
Civil structures: 50 years	All
General electrical components: 15 years	All
Major mechanical components: 20 years	All
Value of electricity: $0.07/kWh	All
Hauling distance (biosolids and/or undigested sludge): 350 kilometers (km)	All
Real costs of inputs and real value of outputs are assumed constant over the 50-year planning horizon	All
Net heat produced is used for space heating and displaces natural gas as a fuel source [natural gas value: $10.50/gigajoule (GJ)]	All
Costs of trucks with enhanced odor controls are 20% more to buy and operate than those suitable for hauling digested sludge	Landfilling Incineration
Net production of electrical energy:	
-0.52 megawatt (MW)	Landfilling
1.74 MW	Incineration
2.11 MW	Land application
End-use costs	
$66.16 per metric ton of sludge	Landfilling
$10 per metric ton of biosolids applied to mine sites	Land application
$2 per metric ton of biosolids applied to agricultural lands	Land application
Fertilizer offset value of biosolids:	
Mine site reclamation: $3.11 per metric ton	Land application
Agricultural application: $8.20 per metric ton	Land application

Table 5-4. The Financial Bottom Line: PVNC of Three Biosolids Management Scenarios (Millions 2005 USD)

	Land Application	Incineration	Landfill
Costs			
Secondary upgrade (capital costs)	$286.69	$127.73	$127.73
Secondary upgrade O&M	$78.97	$30.07	$30.07
Polymer cost	$13.47	$16.00	$16.00
Hauling cost	$36.75	$7.94	$104.54
Program administration	$11.19	$2.24	$2.24
Land application costs	$11.02	$0.00	$0.00
Landfill costs	$0.00	$0.00	$164.67
Ash handling fee	$0.00	$0.53	$0.00
Incinerator (capital costs)	$0.00	$80.39	$0.00
Incinerator (O&M)	$0.00	$39.67	$0.00
Subtotal	**$438.09**	**$304.57**	**$445.25**
Benefits			
Net electricity production	$21.62	$17.80	-$5.35
Net heat production	$7.81	$0.00	$5.46
End uses (fertilizer offsets)	$4.60	$0.00	$0.00
Subtotal	**$34.03**	**$17.80**	**$0.11**
PV of net costs (million 2005 USD)	**$404.06**	**$286.77**	**$445.14**

Adapted from GVRD (2005).

cost (PV costs minus PV benefits) is the incineration option (note that the bottom line of this analysis is PV of net *costs,* rather that net benefits, but the most attractive scenario in terms of the financial economic bottom line is also the one with the highest NPV—the least negative PV net benefits is still the incineration option).

Many of the costs and benefits that were identified by the GVRD but could only be quantified or described qualitatively contribute to either the social or environmental bottom line and, as such, are addressed in the appropriate section of the TBL (and discussed in subsequent sections of this case study).

Social Bottom Line Depending on the available data, the population served, and the agency's specific goals/mission statement, the elements contributing to the social bottom line may vary. The social factors evaluated by the GVRD are instructive of the general types of factors that an agency may want to consider. These include:

- Visibility/aesthetics
- Odors
- Noise
- Health concerns
- Regulations
- Land use
- Security and reliability
- Operations and maintenance considerations
- Quality and quantity considerations

As previously mentioned, the GVRD evaluated the impact of each biosolids management scenario (land application, incineration and landfilling) at each of three process "locations" (at the WWTP, during transportation, and at the final end-use location). Impacts for each of the above elements contributed to the social bottom line. As an example of the level of detail involved, Table 5-5 summarizes the GVRD's qualitative assessment of each scenario's impact on odors.

The GVRD found that there are both positive and negative social effects of all three scenarios, but the location (e.g., at the WWTP or at the end-use location) may differ depending on the scenario. The qualitative assessment led the GVRD to the following conclusions regarding the components with the greatest influence on the social bottom line:

- Odors have the greatest potential impact on all three scenarios
- Security and reliability are likely to have the greatest social influence on the land application scenario
- Noise may be a key social issue for the incineration scenario
- Health concerns may arise in the landfilling scenario

Table 5-5. One Element of the Social Bottom Line: Qualitative Assessment of Odors.[a]

"Location" of Effects	Land Application	Incineration	Landfill
WWTPs Operators and community members within close proximity to the two facilities.	Standard odor control required for digestion, dewatering, storage, and truck loading processes	Enhanced odor control required for dewatering, storage, and truck loading processes at the small WWTP due to presence of volatiles in undigested sludge Fugitive odors during truck unloading at the incinerator; tipping area can be designed to eliminate escape of odors (i.e., indoor tipping floor with outside-in air flow) Fugitive odors from feed storage area at incinerator area can be designed to eliminate escape of odors (i.e., outside-in air flow)	Enhanced odor control required for dewatering, storage, and truck loading processes due to presence of volatiles in undigested sludge
Transportation Truck drivers and neighbors along routes between the WWTPs and the end-use locations.	Standard odor control required during trucking	Enhanced odor control required during trucking from small WWTP due to presence of volatiles in undigested sludge	Enhanced odor control required during trucking due to presence of volatiles in undigested sludge
End use Operators and community members within close proximity to site(s) where biosolids and/or incinerator ash are used.	Odors from stockpile: need to consider maximizing separation distance between stockpile area and neighbors and/or minimize time of storage Truck unloading—consider maximizing separation distance between tipping area and neighbors and/or time tipping to coincide with favorable weather conditions During application: consider maximizing separation distance between application area and neighbors and/or immediately incorporate into soil	Negligible odors from ash residual	Fugitive odors while sludge is uncovered—may need to cover more frequently than MSW Truck unloading—consider maximizing separation distance between tipping area and neighbors and/or time tipping to coincide with favorable weather conditions

[a]Adapted from GVRD (2005).

Environmental Bottom Line As a measure of the environmental bottom line, the GVRD evaluated the resource consumption and overall "environmental burden" associated with each biosolids management scenario. Using the LCA framework, the GVRD quantified the impact of several factors contributing to the "environmental burden" of each scenario. These include:

- Net electricity production/use (e.g., electricity requirements for dewatering sludge)
- Petroleum consumption (e.g., fuel consumption for transportation)
- GHG emissions (e.g., CO_2 emissions from natural gas combustion)
- Smog formation (e.g., emissions from cogeneration engines)
- Criteria air contaminants [e.g., particulates, nitrogen oxide (NO_x), and sulfur oxide (SO_x) emissions]

In order to compare all of the above contributors to the environmental bottom line, each element was divided by the average person's impact to that particular category. For example, the total GHG emissions of each scenario was divided by the total GHG emissions per person in Canada and the net electricity output of each scenario was divided by the average Canadian electricity consumption. The result is a comparison of each scenario's "environmental burden" on a "per capita" basis, as shown in Figure 5-1, below. The figure illustrates that each scenario considered in the GVRD study has at least four non-negligible negative environmental impacts. This approach to evaluating environmental impacts enables decision-makers to systematically compare the environmental effects of different projects.

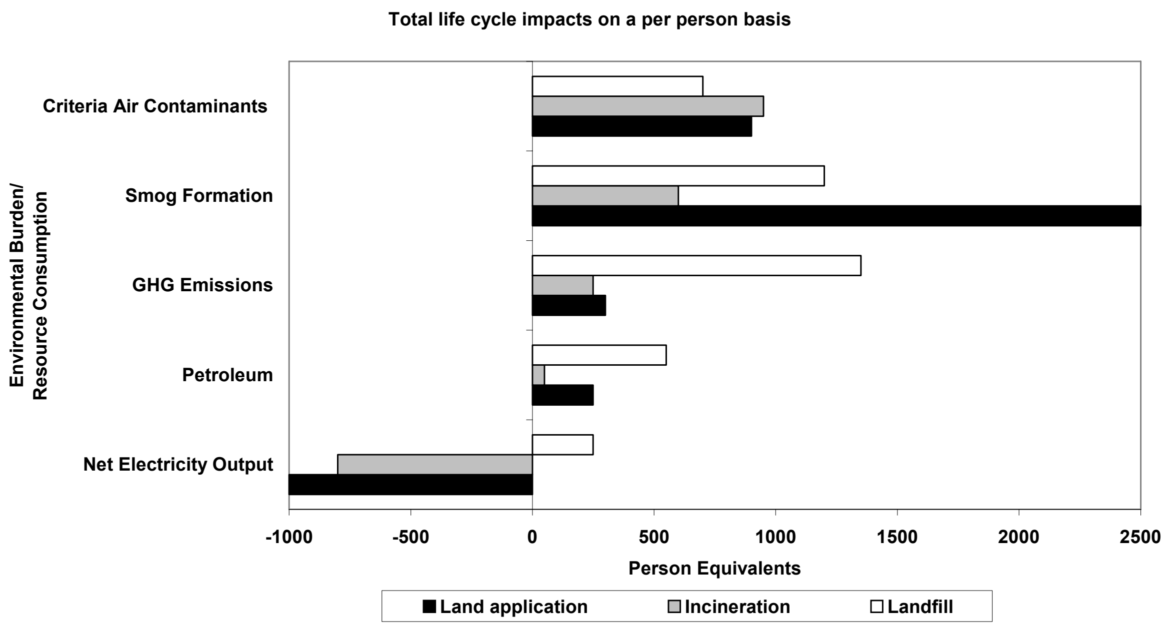

Figure 5-1. The Environmental Bottom Line: Life Cycle Impacts of Three Biosolids Management Scenarios. Note: since this is figure summarizes the "environmental burden" or resource consumption associated with each scenario, a negative value actually represents a benefit.

5.1.6 Conclusions

Applying the TBL approach enabled the GVRD to compare the impacts of three potential biosolids management scenarios on the agency's financial bottom line as well as evaluate the potential social and environmental impacts of those scenarios. As a decision-making tool, the TBL provides a systematic way of assessing and articulating some of the impacts of potential management scenarios that cannot be readily monetized (which, at least in this case, includes many of the social and environmental components of the biosolids management scenarios under consideration). For example, while in this illustration the incineration option is the most attractive option from a financial standpoint (the PVNC is the lowest of the three scenarios), it also has the potential for the greatest negative visual/aesthetic impact near the WWTP and contributes the most to human health concerns related to criteria air contaminants.

Although these hypothetical management scenarios were selected for illustration purposes and do not reflect existing GVRD programs, the development and application of the TBL approach to evaluating potential management programs has provided a useful starting point for future program evaluation, particularly with regard to measuring their progress towards developing a more sustainable biosolids program. As the TBL approach to decision-making gains momentum among utilities, the GVRD's study provides some basic guidance from which other agencies may be able to develop and evaluate their own financial, social, and environmental bottom lines.

5.2 Illustration 2: Carbon Accounting: A Case Study in King County, WA

5.2.1 Overview of Carbon Accounting

Carbon accounting is simply a way to keep track of the amount of GHGs (gases that trap heat in the atmosphere) released or stored as a result of human activities. The primary GHGs of concern relative to biosolids production, disposal, and beneficial use are: CO_2, methane (CH_4), and nitrous oxide (N_2O). Carbon "credits" are accrued by sequestering carbon or offsetting GHG emissions and "debits" result from generating GHGs.

Carbon accounting needs to reflect the fact that in terms of heat absorption, not all GHGs are created equal. Methane, for example, is currently estimated as having 23 times the warming effect of CO_2 (U.S. EPA, 2002b). In order to keep track of the effects of all three of these gases (i.e., to compare apples to apples), the "accounting" is done in terms of carbon equivalents. A carbon equivalent is equal to one Mt of CO_2 (i.e., the carbon equivalent of carbon dioxide is simply 1 Mt of CO_2 and the carbon equivalent of methane is estimated to be 23 Mt of CO_2).[5] To put this in perspective, a typical midsize car emits roughly 4.5 Mt of CO_2 per year (ENS, 2006).

5.2.2 Biosolids and the Carbon Balance

Carbon accounting applied to a biosolids management program applies a lifecycle approach. It begins with biosolids processing[6] and includes both the transportation and disposal or beneficial use of the final biosolids product. Various components of a biosolids management program may potentially lead to carbon debits (by emitting GHGs) or create opportunities for carbon credits (by sequestering carbon or offsetting GHG emissions).

Carbon Debits Many biosolids processing technologies are energy intensive and may involve burning fossil fuels. The CO_2 released from fossil fuel consumption during biosolids processing as well as during transport from the treatment facility to another location for end use is included in carbon accounting as a debit. When biosolids are landfilled, the organic material (which makes up approximately 50% of most biosolids) produces CH_4 and N_2O as it decomposes. Both

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5. This reflects an atmospheric lifetime of 100 years. Methane is not as long-lived in the atmosphere as CO_2, however, so given an atmospheric lifetime of 500 years, the carbon equivalent of methane is 6.5 Mt of CO_2 (U.S. EPA, 2002b).

6. The carbon naturally present in treated municipal wastewater and released to the atmosphere as CO_2 is part of the biological carbon cycle and is not considered to be a contributor to global warming. It is not included in carbon accounting. There is potential for N_2O emissions during wastewater treatment but that was not included in the evaluation of King County's biosolids program (Sally Brown, Associate Professor, University of Washington, personal communication, January 2007).

CH_4 and N_2O (in terms of their carbon equivalents) are included in carbon accounting as debits if the gases are released to the atmosphere.

Carbon Credits Some biosolids processing technologies (such as anaerobic digestion with CH_4 gas recovery) may provide an opportunity for accruing carbon credits by reducing dependence on conventional energy sources that burn fossil fuels. The CH_4 gas generated at a landfill can also be harvested and used as a source of energy. The volume of GHG emissions offset by using recovered energy instead of energy produced by fossil fuel consumption counts towards carbon credits. By utilizing alternative fuel sources (e.g., biodiesel) for the trucks used to transport biosolids, an agency may reduce its CO_2 emissions,[7] thereby reducing its carbon debits. When used in lieu of commercial fertilizers, which are generally energy intensive to produce, biosolids provide another opportunity to offset energy use and GHG emissions. Land application of biosolids may also increase the carbon content of soil (a major carbon sink), creating an additional opportunity to accrue carbon credits.

5.2.3 Carbon Accounting in King County, WA

At the suggestion of King County, which treats roughly 200 million gallons of wastewater per day, the University of Washington conducted a carbon accounting of the municipality's biosolids management program. In their 2004 article for *BioCycle*, Dr. Sally Brown (research associate professor at the University of Washington) and Peggy Leonard (manager of the Biosolids Program for the Wastewater Treatment Division of King County, Washington), discussed this study and their own findings related to the impact of a few of King County's possible biosolids management alternatives on GHG emissions and carbon sequestration (Brown and Leonard, 2004a).

By no means an exact science, carbon accounting can be a complicated process and involves making numerous assumptions. The assumptions made to calculate the net carbon stored or released as a result of one agency's biosolids program may not necessarily apply to a different agency's program. Examining King County's program as a case study, however, sheds some light on the overall carbon balance associated with biosolids management and highlights several opportunities for earning carbon credits and reducing carbon emissions.

Table 5-6 summarizes the net impact, in terms of carbon credits (or debits), of four end-use options for King County biosolids: land application (both on agricultural sites and on forest lands) and landfilling (both with and without energy recovery). The findings of the King County case study indicate that the components of possible biosolids end-use programs that are major contributors to carbon debt are transportation and decomposition of the organic matter in the landfilled biosolids. The components that are major sources of potential carbon credits are CH_4 recovery at the landfill and land application. The calculations (and associated assumptions) used to determine the carbon debits or credits per dt of biosolids produced by King County for each of these components are described in further detail below.

7. According to the U.S. Department of Energy (DOE), biodiesel production and use, in comparison to petroleum diesel, produces 78% less CO_2 emissions (U.S. EPA, 2005).

Table 5-6. Comparing Total Carbon (C) Credit (or Debit) of Each Component of Four Biosolids Management Options for King County, WA.[a]

Component of Biosolids Program Contributing to C Credits (Debits)	Biosolids Management Option: Land Application: Forest Sites	Land Application: Agricultural Sites	Landfilling: Without Energy Recovery	Landfilling: Methane Captured for Energy Recovery	Notes
	CO_2 Equivalent (Metric Tons CO_2 per dt Biosolids)		CO_2 Equivalent (Metric Tons CO_2 per dt Biosolids)		
Transportation (diesel fuel consumption)	(0.03)	(0.12)	(0.13)	(0.13)	Round-trip distance to landfill: 500 miles Round-trip distance to forest sites: 110 miles Round-trip distance to agricultural sites: 410 miles
Gas generation as biosolids decompose at landfill:					
N_2O	–	–	(0.25)	(0.25)	100% of N_2O generated is released to atmosphere
CH_4					
CH_4 currently flared	–	–	–	0.73	15% of CH_4 generated is currently flared; this is not included in C accounting for landfilling without energy recovery, but could be harvested for energy recovery
CH_4 released	–	–	(3.12)	3.12	64% of CH_4 generated is released to atmosphere (or harvested for energy recovery)
Land application [using biosolids instead of commercial nitrogen (N) and phosphorus (P) fertilizers]	0.22	0.22	–	–	Producing the chemical equivalent of 1 unit of N or 1 unit of P (as P_2O_5 fertilizer) requires 1.4 or 3 units of C, respectively
Total C credit (or debit) per dt of biosolids	0.19	0.10	(3.50)	3.47	

[a]Brown and Leonard, 2004a.

Transportation According to the University of Washington's analysis, approximately 3.6 pounds (lbs) (0.0016 Mt) of CO_2 is released per mile traveled by a King County truck. Since the average roundtrip distances from the treatment facility to the sites are:

- Land application for forestry—approximately 110 miles
- Agricultural land application—approximately 410 miles
- Landfill—approximately 500 miles

The amount of CO_2 emissions associated with the delivery of 1 dt of biosolids to each of these sites is roughly 0.03 Mt, 0.12 Mt, and 0.13 Mt, respectively. These estimates were calculated based on the following assumptions: 1) gas mileage of a typical King County truck is 6 miles per gallon of diesel; 2) on average, per gallon of diesel consumed, 21.6 lbs of CO_2 is released; 3) each truck can haul 30 wet tons of biosolids; and 4) the solids content of King County's biosolids is approximately 21% (i.e., one wet ton of King County biosolids is roughly equal to 0.21 dt).

Gas Generation According to the University of Washington's analysis, approximately 170 lbs (0.08 Mt) of CH_4 and 2 lbs (0.0009 Mt) of N_2O are released to the atmosphere per dt of biosolids sent to the landfill. In terms of their carbon equivalents, that translates to roughly 3.12 Mt of CO_2 per dt of landfilled biosolids due to the release of CH_4, and 0.25 Mt of CO_2 per dt of landfilled biosolids due to the release of N_2O. These estimates were calculated based on the following assumptions:

- ♦ The organic component of biosolids is approximately 50%
- ♦ Approximately 95% of the organic fraction of biosolids generates CH_4 as it decomposes and the remaining 5% generates N_2O
- ♦ 100% of the N_2O produced is released to the atmosphere
- ♦ The CH_4 generation capacity is in the middle of the CH_4 generation range for food wastes and grass clippings, which is 250 milliliter (mL) of CH_4 per gram (Eleazer et al., 1997)
- ♦ 15% of the CH_4 produced at the landfill is flared
- ♦ 64% of the CH_4 produced due to the decomposition of biosolids is released to the atmosphere

The gases generated during the decomposition of biosolids at the landfill result in a total carbon debit of approximately 3.37 Mt CO_2 per dt of biosolids.

If the CH_4 generated at the landfill were harvested for energy use, however, landfilling could create carbon credits for King County. Following the same set of assumptions described above, each dt of biosolids landfilled would generate carbon credits equal to approximately 3.85 Mt of CO_2 (0.73 Mt of CO_2 that would otherwise be flared plus 3.12 Mt of CO_2 that would otherwise be released to the atmosphere).

Land Application The nutrient content of biosolids makes it possible to use biosolids in lieu of commercial fertilizers. In the Northwest, commercial fertilizer use is typical in agriculture and is also fairly common in forestry. The use of biosolids instead of commercial fertilizers offsets the high energy requirements (and fossil fuel consumption) associated with N and phosphate fertilizer production. According to the University of Washington analysis, producing the chemical equivalent of one unit of N requires 1.4 units of C and one unit of P requires three units of C. The energy savings resulting from substituting commercial fertilizer with King County biosolids (excluding transportation of the biosolids) translate to a carbon credit of approximately 0.22 Mt of CO_2 per dt of land applied biosolids. This estimate was calculated based on the following assumptions:

- ♦ The average N in King County biosolids is between 5.9% and 7.2%
- ♦ Of the N content in the biosolids, approximately 82.5% is available as organic N, approximately 25% of which is available for plant uptake after land application
- ♦ Average N application rate for most agronomic crops is approximately 0.07 Mt per acre
- ♦ Application of biosolids to meet the N needs of the crop would also meet the P needs of the crop
- ♦ The N requirement for forestry is equal to that for agronomic crops

Sources of Carbon Credits As shown in Table 5-6, landfilling with energy recovery (as compared to land application or landfilling without energy recovery) may be the end use that enables King County to accrue the most C credits per dt of biosolids. Biosolids, however, have additional value that is lost when biosolids are landfilled. Many municipalities, including King County, have established management programs that strive towards putting biosolids to beneficial use. Table 5-7, which is presented from a "beneficial use only" perspective, summarizes the components of a biosolids management program that could be potential sources of carbon credits. It provides a range of potential C credits that King County could earn (either by offsetting GHG emissions or sequestering carbon) per dt of biosolids put to beneficial use. These components (digester gas recovery, biosolids land application, biofuel production, no-till land management, and composting) are described in further detail below.

Table 5-7. Potential Sources of C Credits for King County's Biosolids from a "Beneficial Use Only" Management Perspective.[a]

Biosolids Management Component	Potential range of C Credits per dt of Biosolids (Mt of CO_2)	Notes, Assumptions, and Conclusions
Digester gas recovery (hydrogen source for fuel cell)	2-3	*Note:* A methane collection system is used in combination with King County's anaerobic digester. The methane provides hydrogen for a fuel cell that supplies a portion of the power used to operate the treatment plant. **Conclusion: GHG emissions are reduced by approximately 1,830 Mt CO_2 per year.**
Biosolids land application (avoided commercial fertilizer needs and associated energy use)	< 0.5	*Note:* Average N content of King County biosolids is between 5.9% and 7.2%, 82.5% of which is available as organic N, and 25% of the organic portion is available for plant uptake. **Conclusion: C credits for land application of King County biosolids could be 0.16 Mt C.**
Biofuel production (avoided diesel use)	1+2	*Assumption: 21.6 lbs of CO_2 are released per gallon of diesel fuel consumed.* **Conclusion: The net C credit for growing canola for biodiesel would be 2.2 Mt CO_2 per acre.**
No-till management practices (additional soil C reserves)	0-1	*Assumptions: 1) higher C accumulations result from application to forest and range lands (as compared to agricultural lands); 2) applications to dry land wheat with conventional tillage will result in reduced to no C accumulations; and 3) under no-till management, soil C increases at a rate of 0.025% per year when biosolids are applied at a rate of 5 dt per acre.* **Conclusion: Annual application of biosolids (at a rate of 5 dt per acre) under no-till management practices could increase soil C reserves by approximately 0.4 Mt per acre.**
Composting (additional soil C reserves)	< 0.5	*Note:* 20% of the initial organic matter in biosolids remains after composting. *Assumption: C in the compost will not be mineralized over time.* **Conclusion: For each dt of biosolids that is composted, King County could accrue a C credit of 0.22 Mt CO_2.**

[a]Brown and Leonard, 2004b.

Digester Gas Recovery In combination with an anaerobic digester, King County installed a CH_4 collection system. The CH_4 gas provides a hydrogen source for a 1 MW fuel cell that supplies a portion of the power to run the treatment plant. Using the fuel cell (instead of energy produced from burning fossil fuels) offsets GHG emissions. An estimate of the annual reduction in emissions resulting from use of the fuel cell is approximately 1,830 Mt of CO_2. That equates to C credits of roughly 0.07 Mt CO_2 per dt of biosolids produced by King County.

Biosolids Land Application As discussed in detail in a previous section (*Land Application*), land application of biosolids offsets King County's demand for commercial fertilizers and the energy intensive processes required to produce commercial fertilizers. The potential carbon credit for land application is approximately 0.22 Mt of CO_2 per dt of biosolids.

Biofuel Production Biofuels are fuels, such as ethanol and biodiesel, made directly from plant materials (e.g., corn, switchgrass, canola, soy beans) (U.S. DOE, 2006). Biofuels, unlike fossil fuels, are a renewable fuel source. Biodiesel, when used in its pure form (B100) reduces CO_2 emissions by over 75% as compared to petroleum diesel. King County's biosolids King County's biosolids are used to fertilize canola, which is then processed to extract oil for biodiesel production. The biosolids program is piloting the use of a biodiesel blend as fuel for their long-haul fleet. Assuming that petroleum diesel results in emissions of 21.6 lbs of CO_2 per gallon, growing canola would result in a net C credit of 2.2 Mt CO_2 per acre.

No-Till Land Management Soils contain organic carbon and provide a large potential sink for carbon. Urbanization, conventional agricultural practices, and other changes in land use, however, can cause the organic carbon in soils to mineralize, which leads to the release of CO_2 to the atmosphere. Increased cultivation of agricultural soils has been found to result in a decrease in the organic carbon content of the soils (Robinson et al., 1996; as cited in Brown and Leonard, 2004b). Biosolids use as a fertilizer or soil amendment, coupled with no-till land management, could increase soil carbon reserves. In another relevant 10-year study also conducted by Brown and Leonard (2004b), plots were treated with either biosolids (9 dt per year) or commercial fertilizer (360 lbs of N per year) and compared to control plots (not treated). All plots were maintained in continuous fescue with a no-till management practice. The results of the study showed that the soil C in the biosolids amended plots increased by 0.5% over the fertilizer treated plots. Applying these findings to King County's biosolids program suggests that annual application of biosolids at a rate of 5 dt per acre could result in C credits of approximately 0.4 Mt of CO_2 per acre.

Composting Composting stabilizes the organic matter in biosolids. Assuming that the carbon in the compost will not be mineralized over time (i.e., will not form CO_2 that is released to the atmosphere), carbon credits could be earned for sequestering carbon (similar to the C credits that could accrue for soil C accumulation). King County composts biosolids using static piles, so the energy costs for composting are low. Most of the compost is used locally so transportation is assumed to be negligible. The biosolids are roughly 50% organic material and the overall volume of biosolids is reduced to 40% as a result of composting, so only 20% of the original organic matter present in the biosolids remains after composting. The C credit for each dt of King County biosolids that is composted is approximately 0.22 Mt of CO_2.

5.3 Illustration 3: Innovative Process Development and Energy Recovery in Columbus, GA

5.3.1 Introduction and Overview

Columbus Water Works (CWW) is a municipally owned water and wastewater utility serving 186,000 people in Columbus, Georgia, which treats an average of 42 million gallons of wastewater per day. CWW has helped develop a new biosolids treatment process to further reduce pathogens (PFRP) that they are currently implementing at pilot scale at the South Columbus Water Resource Facility (SCWRF). This new process, the Columbus Biosolids Flow-Through Thermophilic Treatment ($CBFT^3$), will involve retrofitting and adapting their existing mesophilic anaerobic digestion systems (which produce Class B product biosolids) to thermophilic anaerobic digestion systems (which produce Class A biosolids) and recovering energy and heat to be used as a recycled power source. The key points of this process are that 1) it can be retrofitted to existing treatment systems (thus making it cost-effective); and 2) energy can be recovered to power the process.

The pilot study is part of an effort to obtain approval of the $CBFT^3$ process as a PFRP from the Pathogen Equivalent Committee (PEC) of the U.S. EPA. CWW has partnered with a private engineering firm and WERF to conduct the research necessary for approval. CWW has turned the patent over to WERF, so that once approval is granted, the process will be available to replicate at wastewater facilities nationwide.

This case study examines the benefits and the costs of implementing this new technology. Benefits include increased pathogen reductions (Class B to Class A), energy and heat recovery benefits that include the avoided costs of purchasing energy and lowered emissions, and the cost-effective nature of retrofitting current mesophilic treatment facilities.

5.3.2 Current Biosolids Management Practices

SCWRF generates approximately 6,000 dt of biosolids per year (CWW, 2006a). Biosolids are treated using a mesophilic anaerobic digestion treatment process to produce Class B biosolids. Fifty percent of these biosolids are land applied at two sites owned by CWW:

- ♦ The Land Reclamation site consists of 268 acres and has been utilized by CWW since 1981
- ♦ The Oxbow Meadows site consists of 296 acres and has been utilized by CWW since 1996

Both sites are used to grow brown top millet and winter wheat. In 2005, the yields were 15,000 bales at the Land Reclamation site and 20,000 bales at the Oxbow Meadows site. The remaining 50% of biosolid production is dewatered and hauled for off-site disposal at one or more land application sites.

Along with its regular biosolids production, CWW is currently doing a demonstration project of the $CBFT^3$ process. This is discussed in detail in Sections 5.3.3 and 5.3.4.

5.3.3 Issues Shaping the Future for the Agency's Biosolids Program

CWW has found it increasingly more difficult to obtain permits for land application of its Class B biosolids product and has consequently been motivated to switch to Class A biosolids production. The following issues motivated CWW to switch from Class B to Class A biosolids production:

- More flexible permitting requirements
- Less exposure to public opposition
- Increased marketability of their biosolids product

Under Georgia law, Class B biosolids must not only meet the federally mandated Part 503 Biosolids Regulations, they must also meet the Georgia Water Quality Control Act water quality standards. These state standards are more stringent than the Part 503 Biosolids Regulations and application requires a public notice and a public hearing. This has led to difficulty in obtaining a permit for additional land application sites. In 2000, CWW applied for 3,500 additional acres to apply Class B product, but was met with enough opposition to motivate CWW to back off to avoid negative publicity. Land application of Class A biosolids, however, does not require a state permit, making it much easier to administer. Class A biosolids can also be marketed and sold to private farmers (Cliff Arnett, CWW, personal communication, August 2006).

5.3.4 Biosolids Management Options under Development for the Future

As far back as 2001, CWW had begun exploring all available options that would produce Class A biosolids. Working with a consultant, CWW chose to implement a plan to produce Class A biosolids with a new approach to produce a new PFRP, which became the CBFT^3 process. This process can be retrofitted to existing mesophilic treatment facilities, thus offering a viable, cost effective, alternative to older, existing processes which were not conducive to retrofitting existing treatment facilities.

CWW is currently in the process of retrofitting its mesophilic anaerobic digesters with thermophilic digesters through a pilot project for the CBFT^3 process. The full-scale system will be operated under a prescribed testing protocol in order to demonstrate Site-Specific Equivalency as a PFRP (Shaw et al., 2006). The pilot program will be operational in the summer of 2008.

5.3.5 Define Suitable Baseline

Absent the CBFT^3 retrofit, it is assumed that CWW would continue producing Class B biosolids using mesophilic anaerobic digestion and land applying on their two sites. As previously discussed, CWW uses digester gas to fuel boilers that heat the mesophilic digesters. Approximately 50% of this gas is recovered and the other 50% is lost to the atmosphere.

5.3.6 Identify and Assess Key Benefits and Key Costs and Risks

Because the two aspects of CWW's program [increased pathogen standards (Class B to Class A) and energy recovery] have separate costs and benefits, they will be evaluated separately in this analysis.

5.3.6.1 Increased Pathogen Standards (Class B to Class A) Benefits

The benefit of increasing pathogen standards from Class B to Class A are summarized in Table 5-8.

Table 5-8. Summary of Benefits of Retrofitting Treatment Plant to Produce Class A Biosolids.

Benefit Category	Assessment Level	Beneficiaries
Increased pathogen standards (Class B to Class A)		
Reduced regulatory requirements	Qualitative	Agency
Improve public image	Qualitative	Agency/local
Increased marketability	Qualitative	Agency
Cost-effectiveness of retrofit capabilities	Qualitative	Agency

Improved Public Image Class A biosolids are often viewed by the general public as being safer than Class B. As a result, application of Class A biosolids is less likely to cause major public outcry, opposition by public officials, local or regional restrictions, or potential bans.

Increased Marketability With no restrictions on use, Class A products provide both the utility and end-user with a broader range of beneficial reuse options. In addition to increasing the flexibility of land use, production of Class A biosolids makes it possible to expand land application programs to include additional markets such as sod and turf farms, forestry, and biomass production. This allows for the possibility of selling Class A product for additional revenue, although the market for biosolids products is not especially strong in the Columbus area.

Cost-Effectiveness of Retrofit CWW consultants compared CBFT^3 to three existing technologies: heat drying, time and temperature batch, and Class A alkaline stabilization. They tentatively estimate that CBFT^3 could save between \$12 million and \$18 million for a 200-million gallon per day (MGD) plant, between \$3 million and \$4 million for a 40 MGD plant, and between \$0.4 million and \$2.9 million for a 5 MGD plant, assuming a 20-year lifespan (Cliff Arnett, CWW, personal communication, August 2006). Table 5-9 summarizes the costs of the various options CWW considered.

Table 5-9. Present Value Comparison of CBFT^3 to Existing Technologies by Plant Capacity.

	Total Present Value		
Technology	5 MGD Capacity	40 MGD Capacity	200 MGD Capacity
Heat drying	$6,100,000	$22,100,000	$99,000,000
Time and temperature batch	$3,600,000	$19,900,000	$93,000,000
Class-A alkaline stabilization	$4,900,000	$21,200,000	$97,400,000
CBFT^3	$3,200,000	$17,300,000	$80,800,000
Cost savings range	$0.4 million to $2.9 million	$2.6 million to $4.8 million	$12.2 million to $18.2 million

Source: Cliff Arnett, CWW, personal communication, August 2006.

5.3.6.2 Increased Pathogen Standards (Class B to Class A) Financial Costs

Financial Costs of Retrofit While CWW's costs were partially funded as a pilot project, this analysis will focus on the true costs of retrofitting a mesophilic anaerobic digestion treatment facility to a thermophilic facility. The PV costs (assuming a 20-year life-time) of the CBFT^3 plug flow reactors are summarized in Table 5-10.

Table 5-10. Present Value of Costs of Retrofitting Treatment Plant to Produce Class A Biosolids.

Description	Estimated Construction Cost	Annual O&M cost	20-Year Present Value of Operational Costs	Total Present Value
CBFT[3] plug flow reactor	$3,443,100	$1,234,200	$16,149,903	$19,593,003

Source: Cliff Arnett, CWW, personal communication, August 2006.

Risks While CWW is diversifying its product markets and its options for land application by switching to Class A production, it is limiting its disposal strategy to only land application. While there are few regulatory constraints for land application of Class A biosolids in the Columbus area, they are vulnerable to future changes in regulatory policy. There are examples of county-wide bans of biosolids of Class A and B biosolids (see case study on Orange County).

Although federal regulations (the Part 503 rule) set standards for pathogen reduction, chemical limits, and management practices, biosolids are nonetheless a product of household, commercial, and industrial wastewaters, which contain contaminants. These contaminants include pathogens (e.g., viruses and bacteria), pharmaceuticals, and metals. Applying biosolids to agricultural lands may pose perceived or real risks to human health. Since Class A biosolids require 100% pathogen reduction, risk of pathogen transmission is mitigated through the switch to Class A product. However, transmission of pharmaceuticals and metals remains a risk.

The odors associated with biosolids can be a nuisance to neighbors, particularly during the unloading and application process. Odors may prompt complaints from affected parties, motivated by the unpleasant smell itself and also by a mental association of the odor with a perceived health risk. Odors and associated concerns can cause considerable distress to those affected, even leading to political pressure and bans or limits on the utility's ability to apply biosolids at the sites.

The benefits and costs of increasing the pathogen standards are summarized in Table 5-11.

Table 5-11. Benefit-Cost Comparison of Pathogen Standards.

	Present Value
Quantifiable costs	
Capital costs of retrofit	$3,443,100
Operating and maintenance costs	$16,149,903
Total monetized costs	$19,593,003
Monetized net benefits (monetized benefits minus costs)[a]	**($19,593,003)**
Benefits or costs requiring qualitative assessment[b]	
Reduced regulatory requirements of biosolids disposal (Class A versus Class B)	++
Improved public image	+
Increased marketability of biosolids product (Class A versus Class B)	+

[a]There are no benefits monetized in this portion of the illustration.
[b](+) indicates positive benefits anticipated but not monetizable with readily available data; and (-) indicates costs anticipated, but not monetizable with readily available data.

5.3.6.3 Energy Recovery Benefits

Energy Savings/Reduced Costs CWW currently purchases 8.7 million kWh of power and 55,000 British thermal units (BTUs) of heat from its local energy supplier at rates of $.053/kWh and $8.00/million BTU (MMBTU),[8] respectively. As part of the retrofit, CWW plans to use a new engine design, Advanced Reciprocating Engine System (ARES), to efficiently recover energy from the biosolids treatment process. The ARES engine component of CWW's retrofit will allow them to recover power and heat to be self-supportive. This section estimates the benefits and costs of the energy recovery process using templates that are available in Appendix C: Energy Recovery.

Tables 5-12 and 5-13 are examples of templates in Appendix C: Energy Recovery. The templates are provided to guide utility managers through a BCA of energy recovery options. Table 5-12 illustrates the template used to identify the inputs used for quantifying and monetizing the benefits. Table 5-13 illustrates the template used to summarize the monetized benefits and costs.

Table 5-12. Inputs for Quantified and Monetized Benefits and Costs.

Base Year	**2008**
Life-cycle for "general" benefits and costs (years)	**20**
Discount rate	**5%**
Benefit/cost category	**User inputs**
General energy recovery benefits	*Note: it is critical that input units correspond to units specified in column B in spreadsheet
Avoided cost of purchasing power from an outside provider	
Baseline power use (kWh, annually)	8,673,130
Cost of baseline power use ($/kWh)	$0.053
Avoided cost of purchasing heat from an outside provider	
Baseline heat use (MMBTU, annually)	55,188
Cost of baseline heat use ($/MMBTU)	$8.00
Lowered air pollutant emissions (GHG, SO_2, NO_x)	*1 ton = 2,205 lbs*
Baseline emissions of air pollutants (tons)	
CO_2	6,696
SO_2	39
NO_x	14
"Value" of emissions reductions ($/ton)	
CO_2	$10.00
SO_2	$565.00
NO_x	$850.00
General energy recovery costs	
Costs—total capital and O&M	
Capital costs	$2,690,000
Annual O&M costs	$247,289

8. This is an estimate. The national average price for a MMBTU of natural gas in $9.98 commercial, $7.31 industrial (EIA, 2006a).

Table 5-13. Present Value Costs and Benefits of Energy Recovery Project.

	Dollar Amount
Cost components	
Costs—total capital and O&M	$5,925,856
Total monetized costs	$5,925,856
Benefit components	
Avoided cost of purchasing power from an outside provider	$6,015,007
Avoided cost of purchasing heat from an outside provider	$5,777,222
Lowered air pollutant emissions (GHG, SO_2, NO_x)	$1,320,243
Total monetized benefits	$13,112,471
Benefits/costs requiring qualitative assessment[a]	
Increased reliability of power supply	+
Monetized net benefits (monetized benefits minus costs)	**$7,186,616**

[a]+ indicates positive benefits anticipated, but not monetizable with readily available data, and - indicates costs anticipated but not monetizable with readily available data.

Increased Reliability Recovering energy as a primary or backup option ensures WWTPs continued operations in the event of a utility failure or power shortage. Because WWTPs provide critical infrastructure for maintaining public health and the environment, they must operate under any conditions. The use of recovered energy as a prime power source or as backup can provide critical off-grid reliability to enable WWTPs to continue operations in the event of a utility failure (U.S. EPA, 2007).

5.3.7 Distributional Issues: Identification of Key Beneficiaries and Cost-Bearers

Beneficiaries of increased pathogen standards include the agency and the end-users of the products. These benefits are realized through additional application sites and increased marketability. Recipients of energy recovery benefits are the agency (through energy savings and associated reduced costs and increased reliability of energy) and the global community (through lowered green house gas emissions). The agency will also benefit through the cost-effectiveness of the retrofit process.

Key risks of continued land application will be realized by the agency (through lack of diversified disposal options) and through neighbors of the land application sites. The risks realized by neighbors, however, are lower than baseline risks.

Effected parties and the level of the impact are summarized in Table 5-14.

5.3.8 Public Outreach and Communication Issues

CWW has an Emergency Preparedness and Response Plan as part of an EMS that includes responses to public complaints of public nuisance (e.g., odor complaints, fly complaints, spills) (CWW, 2006b).

Further initiatives embedded in the CWW strategic plan provide an environment for real-time feedback for any customer related contacts due to either complaints or positive feedback. This information, as well as a monthly customer survey by an independent consultant, form the basis for a Customer Satisfaction Index which is used to guide company policy in all areas of business activity, including the biosolids area.

Table 5-14. Affected Parties and Their Level of Impact.

Affected Party	Benefit/ Cost Category	Level of Impact[a]	Description
Agency/utility	Increased pathogen standard	++	Reduces regulatory constraints, improves public image, and increased the marketability of biosolids products
	Energy recovery	++	Significant cost savings through avoided costs of energy (power and heat) purchase
	Cost effectiveness of process	++	Retrofit capabilities of CBFT[3] process allow for cost-effective upgrade
	Lack of diversified disposal options	-	Leaves agency vulnerable to changes in regulatory policies
Neighbors	Land application	-	Odors associated with biosolids; greatest nuisance during application (or short-term storage on fields), potential nuisance during transportation
			Traffic associated with biosolids transportation can impact negatively affect neighbors
Local community	Energy recovery	++	Lowered emissions of GHGs
Global community	Energy recovery	++	Lowered emissions of GHGs

[a]Direction and magnitude of impact:

++ = Very positive impact
- = Slightly negative impact
+ = Slightly positive impact
-- = Very negative impact.

5.3.9 Comparing Benefits to Costs; Summary of Findings

The main benefits of retrofitting a treatment facility with the CBFT[3] process is the ability to switch from Class B biosolids production to Class A without the high capital costs of building a new treatment facility. The capital cost of including the ARES engine in the retrofit project has a payback of only 6.5 years, allowing the utility to make a profit (as seen through avoided energy costs) for the remainder of the engine life (~ 20 years). Nonfinancial benefits of the retrofit include increased sustainability of the CWW biosolids program (through diversification of product markets and increased land for disposal), decreased energy use and associated lowered emissions, and improved public image. Costs and risks of the retrofit process include upfront capital costs of the retrofit (while this did not apply to CWW due to partial grant funding, it will apply to other utilities) and the lack of diversification of disposal method (e.g., land application only). Monetized net present value benefits of CWW's upgrade to CBFT[3] system are over $7 million.

5.4 Illustration 4: Multi-Objective Evaluation of Process Changes at Reedy Creek Improvement District

5.4.1 Introduction and Overview

Reedy Creek Improvement District (RCID) provides municipal services for the Walt Disney World Resort and its affiliates, in Orlando, Florida. A full suite of 10 utility systems is provided to its customers, including wastewater treatment, effluent reuse and biosolids treatment, and utilization. The service area is about 25,000 acres and the estimated population of the area ranges between 150,000 and 200,000. Current flows to the WWTP are between 11 and 12 MGD. All effluent is reused.

Current biosolids generation averages about 12 dt per day (55-60 wet tons). Biosolids from the facility (consisting of primary sludge and thickened waste activated sludge) are dewatered to 20% or higher cake solids via belt filter presses and composted in an aerated static pile (ASP) mode. The static pile facility, which is situated about 1,500 feet from the WWTP, is roofed and partially enclosed. The final compost product is used internally by the RCID.

This case study serves to illustrate:

- The process of conducting a multi-objective evaluation of alternatives to a current biosolids management practice (the multi-objective evaluation approach may be viewed as a variant of BCA, wherein the various attributes or objectives of an option are subjectively scored and weighted by the evaluators)
- The benefits of composting (as well as some of the difficulties associated with this widely utilized biosolids beneficial use practice)
- How utilizing a new technology can increase the flexibility of RCID's biosolids management program by producing a product suitable for composting or biofuel

5.4.2 Current Biosolids Management Practices

5.4.2.1 Biosolids Production

The RCID has been using composting as a treatment process for biosolids since 1988; prior to that time, biosolids were aerobically digested and land applied. To ensure a biosolids treatment process was available at all times, the District constructed an "outdoor" ASP composting system. This compost process requires a bulking agent or amendment to ensure proper aeration during treatment; RCID utilizes a mixture of wood chips, ground landscaping debris, and recycled wood chips (oversize wood chips screened from the final compost product) for this purpose. A portion of the chips are purchased and the balance generated from grinding wood waste from construction and demolition projects. During the composing process, the compost piles are covered with finished compost for odor control.

5.4.2.2 Biosolids End Use and Characteristics

Three to four thousand tons of finished compost products are generated annually. The end product meets Class A-A requirements as defined by the State of Florida, meaning that the material has achieved the most stringent pathogen destruction criteria and has heavy metal levels below the most stringent limits. As a consequence, the material is suitable for distribution without restriction. Nitrogen, phosphorous, and potassium values of the finished compost are typically 3-3-0.5, but can be variable. The end compost product is stockpiled and then used in "backstage" areas (areas where there is little chance for the product to come in contact with the general public), particularly as topsoil for major construction projects.

5.4.3 Issues Shaping the Future for the Agency's Biosolids Program

Throughout the 1980s and most of the 1990s, the RCID wastewater treatment facility and the adjacent static pile composting facility were fairly remote and had few neighbors. Consequently, dust and odors were not a concern. But in the late 1990s the surrounding area began to develop and each year brought more neighbors. In late 2005, a major arterial roadway (Western Way) opened 100 yards from the static pile composting facility. An issue of concern for RCID is that the normal dust and odor from the ASP composting facility will have an adverse impact on guests and other travelers along the road.

In response, RCID took on a number of measures for better odor and dust control. The first of these were operational—inventory of stored compost product was reduced to a minimum, which meant giving away the final product rather than stockpiling and selling it during peak demand periods. Operating hours were altered and certain activities were scheduled to correspond with prevailing wind patterns. A portion of the static pile facility was enclosed to better control odors and a misting system was installed for fugitive dust control and to mask some of the odors. These measures have proved mildly effective, but there is still potential that RCID will have to abandon the current ASP composting process, relocate it, or seek an alternative technology altogether.

5.4.4 Biosolids Management Options under Consideration for the Future

In anticipation of a potential closure of the ASP composting facility, the RCID staff has undertaken an evaluation of some of the more conventional and proven biosolids treatment processes available. Having initially considered about half a dozen options, the three alternatives that RCID chose to examine in depth are listed below.

5.4.4.1 Potential Alternatives

1. Thermal dryers

   There are two types of thermal drying: direct and indirect. Direct thermal dryers heat air or gas that comes in direct contact with wet solids, raising these gases to evaporation temperature; indirect dryers are very similar but the wet solids are heated via a metal surface. Both types of thermal drying reduce the volume and mass of solids by evaporating their water content. The high temperatures help produce products that meet Class A and EQ biosolids standards but also make this technology relatively energy intensive (i.e., it typically requires an external fuel source such as natural gas or oil).

   RCID evaluated dryers from both Komline and Andritz. In RCID's evaluation of alternatives, natural gas costs were assumed to be $7/MMBTUs.

2. In-vessel composting with biological drying (the Wright Environmental System)

   In-vessel composting produces a similar end-product to ASP composting but occurs within an enclosed vessel. Process air can be contained and treated (typically using a biofilter), which can reduce odors (EPA 832-F-00-061; U.S. EPA, 2000b).

   Three of the most common methods of composting biosolids are windrow, aerated static pile, and in-vessel (U.S. EPA, 2002b). All three methods involve the same basic principal: mixing dewatered solids with a bulking agent (e.g., wood chips, saw dust) to promote the decomposition of organic material under controlled aerobic conditions. Aerobic conditions are maintained by supplying oxygen to the mixture, either through pipes or by physically turning and mixing the material in the piles.

   Unlike the other two methods in which the composting material is generally outdoors in either piles or rows, in-vessel composting occurs within a completely enclosed container (e.g., a silo, tunnel, or other vessel). This method is also more mechanized than the others. Table 5-15 summarizes the potential benefits and disadvantages of employing in-vessel technology rather than other types of composting.

Table 5-15. In-Vessel Composting: Benefits and Disadvantages.

Benefits	Disadvantages
Process air can be captured and treated, thus reducing odors	Requires relatively high capital investment
Generates relatively little dust outside of the facility	Highly dependent on mechanical equipment
Requires less land area	Higher energy requirements than windrow
Weather effects are negligible	
Not labor intensive	
Requires less bulking material	

Instead of using a conventional thermal dryer for dewatering, the specific technology that RCID evaluated (the Wright System) utilizes the exothermic heat (7,450 BTUs per pound of dry organic matter)[9] generated during the aerobic decomposition process. The hot process air that would normally be exhausted through the biofilter is recovered and used to reduce the volume and mass of the solids by evaporating their water content. By utilizing recovered heat, the system is a low energy consumer. The two possible end-products are 1) conventional compost and 2) biofuel.

3. Landfill disposal

Under this option, RCID would dispose of the biosolids at the Okechobee landfill, which is roughly 100 miles from the processing facility. Total disposal costs were assumed to be roughly $40 per wet ton; transportation costs were assumed to be approximately $10 per wet ton and the tipping fee $30 per wet ton. Assuming daily biosolids production of 100 wet tons, the annual cost of disposal to Okeechobee would be nearly $1.5 million.[10]

5.4.4.2 Multi-Objective Evaluation Process

The RCID's evaluation involved identifying the pluses and minuses of each of the potential processes. While cost is a significant factor, the RCID recognized that it is not necessarily the overriding issue. Risks associated with control, amendment availability, end product markets, and utilization are just some of the issues that need to be carefully weighed in the decision-making.

In total, the RCID selected 11 issues to consider: capital costs, operating costs, environmental impacts, odors, public perception, product use, existing facility use, operational issues, level of control, ability to accommodate side-streams, and regulatory requirements. RCID incorporated these issues into the multi-objective assessment of the various alternatives to the ASP composting process currently in use.

Some issues (such as cost) were more important than others (such as whether or not a particular alternative would require new permits). To account for this, each issue was weighted according to its overall significance [a weight factor of 5 represented the most important issue(s) and a weight factor of 1 represented the least significant issue(s)].

9. This is specific to the Wright Biodryer™ (General Bioenergy, 2005).

10. Calculation: 100 wet tons/day H $40/wet ton H 365 days = $1.5 million/year.

The RCID then used a ranking system to compare all three alternatives (and the current ASP composting process) against each other. For a given issue (e.g., costs) the RCID determined whether each alternative possessed highly desirable characteristics (e.g., no capital investment required) or highly undesirable characteristics (e.g., high capital investment required). Highly desirable characteristics received a rank of 5 and highly undesirable characteristics received a rank of 1.

Table 5-16 provides an overview of the multi-objective evaluation process applied by RCID. Multiplying the weighting factor by the rank yields a single "score" per issue for each of the alternatives. For example, "capital costs" has a weight factor of 5; the current operation received a ranking of "3" (cautionary characteristic), yielding a total score of 15 for this particular issue. Summing these total scores (11 in all) for each alternative resulted in a single score for each alternative. Since important issues were weighted more heavily than less important issues and desirable characteristics were ranked higher than undesirable characteristics, the higher the final score, the more desirable a particular option. The alternative composting system (the Wright In-Vessel System) received the highest final score (112) whereas disposal to the landfill at Lake Okeechobee received the lowest score (89).

5.4.4.3 "Best" Alternative: In-Vessel Composting System

The results of the RCID's multi-objective, weighted evaluation of the various alternatives suggest that they should pursue the alternative composting option (in-vessel composting). As a biosolids management option, in-vessel composting will require a high initial capital investment, but will provide a relatively flexible disposal program because it can produce either conventional compost (roughly 60% solids) or a material that is 90+% solids that can be used as a biofuel. The conventional compost will likely be used internally (as it is currently) or could be distributed to the public, and the biofuel will be given to a local waste-to-energy facility.

5.4.4.4 Biosolids Management

Currently, the cost of the ASP composting process to RCID is roughly $26.00 per wet ton of biosolids. The cost per wet ton will increase due to the costs associated with the grit removal system and additional wood chips. The capital investment for the grit removal system would be approximately $2.2 million[11] and costs for wood chips are expected to increase by $20,000 to $25,000 per year.

Roughly the same volume and tonnage of end product will be produced. The compost will continue to be used internally for various construction projects. If the RCID ends up with excess product, it may be sold as a topical fertilizer (to users in the citrus industry) at roughly $11 per ton or simply given away in order to avoid large stockpiles and minimize odors.

5.4.5 Identify and Assess Key Benefits

Adopting an in-vessel composting system for biosolids management, as an alternative to the ASP composting facility currently in use, will provide the RCID with a more flexible biosolids management program while reducing nuisances such as dust and odor. These, and other associated benefits are summarized in Table 5-17.

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11. Implementation of the grit removal system began in 2006 (before a final decision was made about whether or not to invest in a new composting system), therefore, this is not considered a possible avoided cost if RCID moves forward with the Wright in-vessel composting system.

Table 5-16. Multi-Objective Evaluation of RCID's Biosolids Options.

Issue/Option	Weight Factor	Continue Current Operation	Rank	Mult[a]	Landfill at Lake Okeechobee	Rank	Mult	Wright In-Vessel System	Rank	Mult
Capital costs	**5**	Depends on odor, dust, and visual controls (could be high if enclose and treat air)	**3**	**15**	No capital investment required	**5**	**25**	High capital investment	**1**	**5**
Operating costs	**4**	Low operating cost Highest labor requirement	4 3 **3.5**	**14**	High operating cost Somewhat fuel cost dependent	1 2 **1.5**	**6**	Modest operating cost (low labor and energy)	**4**	**16**
Environ-mental impacts	**2**	Low environmental impact other than odors (considered as *green* technology)	**4**	**8**	Potential high impact (leachate and odors) at Okeechobee Landfill (not directly our issue)	**2**	**4**	Low environmental impact (waste-to-energy/green technology)	**5**	**10**
Odors	**5**	Control of odors is a major challenge Elimination of primary sludge will help	2 3 **2.5**	**13**	Odors in transit may be an issue Elimination of primary sludge will help	2 3 **2.5**	**13**	Odors should be controllable End product needs immediate use	4 3 **3.5**	**18**
Public perception	**4**	Neighbors will continue with complaints/guest complaints are likely/employee complaints will likely continue	**1**	**4**	Landfilling of biosolids opposed by many groups including SFWMD and LOER (image of Disney landfilling biosolids undesirable)	**1**	**4**	Little to no public opposition at RCID WM may have some via emissions at Wheelabrator facility	4 3 **3.5**	**14**
Product use	**3**	Internal use and/or sale to others Future land application bans are a concern	4 3 **3.5**	**11**	None (waste will be entombed, no reuse/recycling)	**3**	**9**	Can make compost or biofuel; volume maybe 75-100 tons/day (no curing facility is envisioned)	**4**	**12**
Existing facility uses	**2**	Existing facility will remain operational Has both good and bad characteristics	4 3 **3.5**	**7**	Will need to find alternative use for ASP facility	**3**	**6**	Will need to find alternative use for ASP facility	**3**	**6**

Table 5-16. Multi-Objective Evaluation of RCID's Biosolids Options (cont.).

	Weight Factor	Continue Current Operation	Rank	Mult[a]	Landfill at Lake Okeechobee	Rank	Mult	Wright In-Vessel System	Rank	Mult
Operational issues	**3**	Odor control difficult/impossible	1		Odors from over the road transit	2		Amendment availability and cost	2	
		Amendment availability and cost	2		Growing opposition to landfill disposal of biosolids	3		Product market guarantee?	1	
		Future bans/restrictions on product use likely	3		Future bans/restrictions highly likely	2		Operate or not?	3	
			2	**6**		**2.33**	**7**		**2**	**6**
Control	**2**	RCID retains complete control of operation	4		Puts RCID at some risk, due to third party	3		If RCID owns, should not be an issue	4	
		External marketing remains uncontrollable	2		Statewide events may also influence	3		But reliability of end market of concern	3	
			3	**6**		**3**	**6**		**3.5**	**7**
Sidestreams	**3**	Currently accommodates all sidestreams except excess FW	4		Some sidestreams will have to go to the landfills since there are no other suitable options (Bay Lake may take some) (disposal costs for these sidestreams could exceed $200,000 annually)	**2**	**6**	Should be able to accommodate all sidestreams, including excess FW, manure from AK/Ft Wilderness and the suitable wood waste FW compost could go to same end market	**5**	**15**
		Will require finding a means to address greasy sidestream treatment of food waste leachate.	3							
			3.5	**11**						
Regulatory issues	**1**	No permits if do nothing	5		No permits required	5		Will require FDEP permit for WWTP major modification and ERP for stormwater (WM have air emission issues at Wheelabrator)	**3**	**3**
		May need minor modification if enclose or add odor control facilities	3		FDEP will be unhappy with this choice	3				
					Agencies are opposed to landfilling of biosolids	2				
			4	**4**		**3.33**	**3.3**			
Sum of rankings times multiplier				**98**			**88.8**			**112**
	Rank			**2nd**			**3rd**			**1st**

[a]Multiplier = weight times ranking.

Rank: 1 = highly undesirable characteristic; 2 = undesirable characteristic; 3 = cautionary characteristic; 4 = desirable characteristic; 5 = highly desirable characteristic.

FW = food waste; WM = waste management; ASP = aerated static pile compost facility; LOER = Lake Okeechobee Estuary Recovery; FDEP = Florida Department of Environmental Protection; ERP = environmental resource permitting.

Table 5-17. Benefits Analysis Overview.

Type of Benefit	Assessment Level	Measure of Benefit	Beneficiary
Increased flexibility of biosolids management	Qualitative	++[a]	Agency
In-vessel composting benefits			
Lower labor requirements	Monetized	$81,000[b]/year	Agency
Smaller land requirement	Qualitative	+	Agency
Reduced nuisances (odors and dust)	Qualitative	++	General public
Avoided side-stream disposal costs[c]	Monetized	$219,000/year	Agency
Energy benefit			
Biofuel production (heating value)	Qualitative	+	Agency

[a]Qualitative indicator of magnitude of effect on net benefits: + = Likely to increase net benefits relative to quantified estimates; ++ = Likely to increase net benefits significantly.
[b]Measured in 2005 USD.
[c]This is specific to the RCID case study. The Wright system is designed to be able to accommodate additional side-streams (e.g., food waste) and RCID is responsible for all of Disney's utility services, which includes disposal of food waste, manure, and wood waste.

5.4.5.1 Increased Flexibility of Biosolids Management

By using in-vessel composting with biological drying, RCID will produce a biofuel material (90+% solids), conventional compost, or both. If there is an increase in demand for biofuel or if RCID is expecting to take on a large internal construction project, they will have the flexibility to increase their biofuel or conventional compost production accordingly. The biosolids management program will be more resilient to external market changes or annual fluctuations in internal needs for compost products. With more than one biosolids end-product option available to RCID at all times, the agency will be able to ensure continuous product distribution (i.e., RCID is unlikely to run into a situation where it cannot dispose of its biosolids as planned).

5.4.5.2 In-Vessel Composting Benefits

In-vessel composting, as an alternative to RCID's current ASP composting process,[12] creates benefits for the agency, which include lower labor requirements and smaller land requirements, and benefits for the public, such as reduced nuisances. The specific technology that RCID is considering adopting allows RCID to eliminate some disposal costs that were incurred when the ASP facility was used for composting. These benefits are discussed in further detail below.

Lower Labor Requirements In general, in-vessel composting requires less manpower for operation than ASP composing. RCID expects to need only four full-time employees to run the in-vessel system, as compared to five to run the ASP composting facility, thereby reducing annual labor costs by $81,000.

12. There are additional advantages to in-vessel composting in comparison with other composting methods that are not applicable to this case study; see Section 5.4.4.1 for a more general discussion of in-vessel composting.

Smaller Land Requirement In-vessel composting facilities require much less space than typical ASP facilities. Whereas RCID's ASP composting site occupies about 17.5 acres, the area needed for operation of an in-vessel system ranges from less than 100 square feet up to approximately 3 acres (i.e., in-vessel composting requires roughly 15% of the land area needed for ASP composting). Within RCID most of the developable land is slated for higher purpose use than biosolids treatment.

As urbanization brings more people closer to areas that were at one point considered rural, and as land availability decreases while land prices increase, other agencies may run into the same problem as RCID: there is not enough land available in a remote, suitable, non-impact area to accommodate other composting processes The compact nature of in-vessel technology makes it a feasible biosolids disposal option when space is limited (even in suburban and urban settings).

Reduced Nuisances (Odors and Dust) The primary driver for RCID to consider adopting a new biosolids management program was the nuisance created by odors and dust, which affected travelers on the new road alongside the ASP composting facility. The welfare of travelers on this road is particularly important to RCID because they include: Disney guests, Disney employees, and neighbors. By shutting down the old facility, impacts due to dust and odors are completely eliminated.

Relocating the ASP facility to a new site could have temporarily eliminated this burden, but there is inevitably dust and odor associated with this type of composting, so the RCID would potentially run into the same problem again in the future as development in the region (which is also inevitable) continues. By adopting in-vessel technology for composting, the RCID will reduce both dust and odors because:

- In-vessel composting is enclosed (essentially eliminating the potential for the release of dust within the vicinity of the facility)
- Process air is usually collected and treated (by passing through a biofilter), thus reducing process odors such as volatile organic compounds and ammonia (General Bioenergy, 2005)

Avoided Side-Stream Disposal Costs The specific technology that RCID is considering adopting (the Wright system) can, in addition to biosolids, accommodate side-streams, including food waste, manure, and wood wastes. Since the RCID is responsible for all utility systems within the Disney service area, the agency is responsible for disposal of such materials and the associated costs. The ASP composting facility cannot handle the same volume of side-streams as the new system. The RCID estimates that composting at the current ASP facility necessitates the disposal of approximately 15 tons per day of side-stream wastes at the landfill at a cost of $40 per ton.[13] Enabling the RCID to dispose of these side-streams internally, rather than at the landfill, the new system creates an annual cost savings for the agency of $219,000.[14]

5.4.5.3 Energy Benefits

Biofuel Production (Heating Value) Using the in-vessel composting and biological drying system, RCID has the potential to dry the biosolids material to 90+% solids (as compared to 21%

13. The $40 per ton cost includes both tipping fees ($30/ton) and transportation costs ($10/ton).

14. Calculation: 365 days H 15 tons/day H $40/ton = $219,000.

solids for the current system), making the end product attractive for use as a biofuel. This material has an estimated heating value, measured in BTUs, equivalent to medium grade coal, or roughly 7,000 to 8,000 BTUs per pound of dry biosolids material. Assuming the new in-vessel system produces approximately 40 dt of material per day (and runs 365 days per year), the potential annual heating value of the biofuel is roughly 204,400 MMBTUs.

A local waste-to-energy facility (Wheelabrator-Ridge Waste-to-Energy), located about 20 miles from RCID, is interested in burning this fuel. The facility currently burns wood waste, tires and biogas from a nearby landfill. Biofuel, like these other waste products, is a renewable energy source and using it for energy production offsets the need to burn fossil fuels (such as coal and oil). As of late 2006, a dollar-value for the biofuel had not been determined by either RCID or the waste-to-energy facility.

5.4.6 Identify and Assess Key Costs and Risks

Shifting from the current ASP composting process to the Wright in-vessel system will require a relatively high initial capital investment on behalf of the RCID. The initial capital cost of the new system is expected to be roughly $16 million. Table 5-18 summarizes the expected annual costs associated with the new system. Although annual electricity and O&M costs are estimated to be $67,000 and $422,000, respectively, the increase in these expenses over current costs (i.e., those associated with the current ASP composting system) are only $5,000 per year (for electricity) and $81,000 per year (for O&M). Once the new composting system is in place, the cost of biosolids processing (on a per wet ton basis) is expected to double.[15] All additional costs will be borne by RCID. An overview of project costs is provided in Table 5-18.

Table 5-18. Estimated Project Costs for Implementation of In-Vessel Composting System.[a]

	Annual Cost[b] (in 2005)		
	New, In-Vessel System	Current ASP System	Expected Increase from ASP to In-Vessel
Initial capital cost (Wright in-vessel system)	$1,264,000	-	$1,264,000
O&M	$422,000	$341,000	$81,000
Electricity ($0.03 per kWh)	$67,000	$62,000	$5,000
Labor	$323,000	$404,000	($81,000)

[a]Modified from Table 2B of McKim (2001).
[b]Present value calculated using a 5% discount rate over a 20-year time horizon.

5.4.7 Distributional Issues: Identification of Key Beneficiaries and Cost-Bearers

The impetus for making changes to RCID's current biosolids management program was the construction of the new road and the potential adverse affect that odors and dust could have on travelers. The primary beneficiary of any biosolids process alternative being considered for RCID, therefore, is the public—both the out-of-town visitors as well as the resident population

15. Assuming biosolids production of 60 wet tons per day, these costs are roughly $47/wet ton with the current ASP process and would be roughly $95/wet ton with the new system. If biosolids production increases to 107 wet tons/day (as assumed in the calculations in Table 2B of McKim, 2001), the costs of the current ASP system are roughly $26/wet ton and would increase to $53/wet ton.

that relies on the tourism-based local economy. The key benefit is the reduction (or elimination) of nuisances, specifically odors and dust.

The RCID will bear the cost of any new capital investment and/or operating costs associated with a new biosolids program.

5.4.8 Public Outreach and Communication Issues

Little or no public opposition is expected because the new system will eliminate the odor and dust issues associated with the current ASP composting facility.

5.4.9 Comparing Benefits to Costs; Summary of Findings

The multi-objective analysis that RCID conducted indicated that the best alternative to their current biosolids management program (ASP composting) would be in-vessel composting. The specific technology best suited for RCID's purposes is the Wright in-vessel system, which enables the agency to also dispose of food and other wastes on site (rather paying to have them hauled off-site for disposal). A summary of the benefits and costs of this project are presented in Table 5-19.

Table 5-19. Benefit-Cost Comparison.

	Monetized (Per Year)	Total Present Value[a] (2005, USD)
Monetized costs		
Capital costs[b]		$15,238,095
Increased O&M and electricity requirements		$1,125,338
Total costs		$16,886,845
Monetized benefits		
Lower labor costs	$81,000/yr	$1,059,911
Avoided side-stream disposal costs	$219,000/yr	$2,865,568
Avoided amendment purchases	$20,000/yr	$261,706
Total monetized benefits		$4,187,185
Total monetized net benefits (NPV)		($12,699,660)
Qualitative benefits and costs	**Qualitative indicator[c]**	
Qualitative costs and risks	*None identified*	
Qualitative benefits		
Increased flexibility of biosolids management	++	
Smaller land requirement	+	
Reduced nuisances (odors and dust)	++	
Biofuel production (heating value)	+	

[a]Evaluated using a 5% discount rate, over a 20-year time horizon.
[b]Assuming new system is implemented in 2006.
[c]Qualitative indicator of magnitude of effect on net benefits:
+ = Likely to increase net benefits relative to quantified estimates.
++ = Likely to increase net benefits significantly.

Implementing the Wright in-vessel composting system would essentially eliminate RCID's current odor and dust concerns, which were the primary drivers for the agency to consider changing its biosolids management program. Although the initial capital investment is much greater than the monetizeable benefits (the NPV of benefits is approximately -$12 million), the immediate, qualitative benefit of reduced odors and dust is critically important to the functioning of RCID's biosolids program. The additional qualitative benefits of increased program flexibility and the creation of a renewable energy source may reduce (or even prevent) future program roadblocks (such as the current odor issue).

5.5 Illustration 5: Energy Recovery at the Denver Metro Wastewater Reclamation District

5.5.1 Introduction and Overview

The Metro Wastewater Reclamation District (Metro) is a regional government entity, formed under Colorado law in 1961, to provide wastewater transmission and treatment services to member municipalities and special connectors in the Denver metropolitan area. Metro provides services for 58 local governments (1.5 million people) in a 380-square mile service area that includes Denver, Arvada, Aurora, Lakewood, Thornton, and Westminster.

The focus of this case is on the energy recovery aspects of Metro's current biosolids management plan. A full case study on Metro's program is included as Appendix L.

Metro treats 130 MGD of wastewater using anaerobic digestion. The treatment process produces water, Class B biosolids, and methane gas. Metro recovers and recycles the produced digester gas using cogeneration. The recovered digester gas is used as a fuel for four large engines that drive electrical generators, producing both power and heat. Per day, Metro recovers over 3 million cubic feet of digester gas, producing an average of 4 MW of electricity and providing process heating for the 12 digesters, building heat for a portion of Metro's facilities, and biosolids preheating before dewatering. The electricity from cogeneration accounts for approximately 40% of the facilities' energy needs.

The district originally sold the electricity to the local power plant and then purchased the full power to operate the plant from the utility. In 1999, Metro began directly consuming all of the power that it produced, and purchasing supplemental electricity from the electrical utility. In 1999, Metro also entered into an Energy Services agreement with a private company to provide new generating equipment and to operate and maintain the cogeneration facility. As part of the agreement, two gas fired turbine generators were installed to replace the aging internal combustion engine generators. The turbines are largely operated remotely by the private company, Trigen, who then sells the energy back to Metro at a discounted price. The 2005 price was $0.041 per kWh (Steve Rogowski, Metro Wastewater Reclamation District, personal communication, October 2006).

5.5.2 Define Suitable Baseline

In order to evaluate the benefits and costs of Metro's current energy recovery program, the researchers assumed baseline to be the absence of energy recovery and that Metro would purchase both power and heat from an outside provider at market rates.

5.5.3 Identify and Assess Key Benefits

Energy Savings/Reduced Costs Metro currently purchases 29.6 million kWh of power from Trigen at a discounted cost of $0.0413 per kWh and recovers 149,000 MMBTUs of heat each year (Steve Rogowski, Metro Wastewater Reclamation District, personal communication, October 2006). The estimated cost to Metro to purchase that power and heat from an outside provider is $0.0554 per kWh[16] and $8.00 per MMBTU,[17] respectively.

Table 5-20 is an example of a template in Appendix C: Energy Recovery. This template is one of several templates provided to guide utility managers through a BCA of energy recovery options. Table 5-20 specifically illustrates the template used to identify the inputs used for quantifying and monetizing benefits.

Table 5-20. Inputs Used for Quantifying and Monetizing Benefits.

Base Year	**2006**
Life-cycle for "general" benefits/costs (years)	**20**
Discount rate	**5%**
Benefit/cost category	**User inputs**
General energy recovery benefits	*Note: it is critical that input units correspond to units specified in column B in spreadsheet
Avoided cost of purchasing power from an outside provider	
Baseline power use (kWh, annually)	29,583,220
Cost of baseline power use ($/kWh)	$0.014
Avoided cost of purchasing heat from an outside provider	
Baseline heat use (MMBTU, annually)	149,000
Cost of baseline heat use ($/MMBTU)	$8.00
Lowered air pollutant emissions (GHG, SO_2, NO_x)	*1 ton = 2,205 lbs*
Baseline emissions of air pollutants (tons)	
CO_2	27,388
SO_2	48
NO_x	46
"Value" of emissions reductions ($/ton)	
CO_2	$10.00
SO_2	$565.00
NO_x	$850.00

16. This is the average price of electricity to industrial customers in the State of Colorado, reported by the Energy Information Administration (EIA).

17. This is an estimate. From the EIA, the national average price for a MMBTU of natural gas is $9.98 per MMBTU for commercial customers and $7.31 per MMBTU for industrial customers.

5.5.4 Identify and Assess Key Costs and Risks

The capital investment for the power generating turbines, day-to-day operations, and electricity is $1.2 million. The total present value of the energy recovery costs[18] is $14,771,948 (Steve Rogowski, Metro Wastewater Reclamation District, personal communication, October 2006). These costs are summarized in Table 5-21.

Table 5-21. Cost Analysis Overview (2005, USD).

	Present Value	Cost Bearer
Energy recovery costs		
Quantifiable costs		
Operating and maintenance of energy recovery	$14,771,948	Agency
Costs requiring qualitative assessment[a]		
Air emissions from on-site generation	-	Agency
Total monetized energy recovery costs	*$14,771,948*	

[a](-) indicates positive cost anticipated but not monetizable with readily available data.

5.5.5 Comparing Benefits to Costs; Summary of Findings

Net monetized benefits of Metro's energy recovery process are $7.6 million. The benefits and costs of the energy recovery process are summarized in Table 5-22.

Table 5-22. Costs and Benefits of Energy Recovery Project.

	Dollar Amount
Cost components	
Costs—Total capital and O&M	$14,771,948
Total monetized costs	$14,771,948
Benefit components	
Avoided cost of purchasing power from an outside provider	$5,041,070
Avoided cost of purchasing heat from an outside provider	$13,270,464
Lowered air pollutant emissions (GHG, SO_2, NO_x)	$4,110,218
Total monetized benefits	$22,421,752
Benefits/costs requiring qualitative assessment[a]	
Increased reliability of power supply	+
Air emissions from on-site generation (with energy recovery system)	-
Monetized net benefits (monetized benefits minus costs)	**$7,649,804**

[a]+ indicates positive benefits anticipated, but not monetizable with readily available data, and - indicates costs anticipated but not monetizable with readily available data.

18. Costs do not include the basic infrastructure Trigen purchased prior to the contract (the building, the electrical transmission gear, the water lines, the connection to the digestion complex, etc.) This cost, however, may be incorporated in the cost per kWh of electricity Trigen charges.

5.6 Illustration 6: Expanding Biosolids Land Application to Reclaimed Mine Sites at the Western Lake Superior Sanitary District

5.6.1 Introduction and Overview

WLSSD is the wastewater and solid waste authority for the Duluth, Minnesota, region and owns and operates the regional WWTP, which is designed to treat an average of 43 million gallons of wastewater per day. All wastewater treatment agencies, including the WLSSD, have to manage biosolids (either through disposal or beneficial use), although the exact management program a particular agency adopts can be tailored to that agency's specific situation (its size, its financial resources, its geographical location, etc.). As an agency's budget, a community's perception of biosolids, and a region's market for biosolids change over time, a biosolids management program may need to adapt to those changes in order to be sustainable. This case study serves to highlight some of the WLSSD's management considerations and address the benefits, risks, and costs associated with them. In particular, the following sections address the possibility of the WLSSD increasing land application at reclaimed mine sites (which will reduce the amount of biosolids land applied to agricultural sites).

WLSSD's evaluation of alternative biosolids management options has not been limited to just increasing the number of mine sites in their land application program. The agency has also considered increasing pathogen reduction during biosolids processing (to create a Class A product rather than Class B) and has conducted a study to evaluate new markets for their biosolids (e.g., forestry, sod farms, and biomass production). These alternatives are discussed in the full version of this case study, included as Appendix M of this report.

5.6.2 Current Biosolids Management Practices

Biosolids Production Currently, WLSSD produces Class B biosolids. In 2005, WLSSD biosolids production was 8,570 dt (34,400 wet tons); that volume is expected to increase by nearly 10% (to 9,375 dt) by 2011 (CH2M Hill, 2006).

Biosolids Recycling One hundred percent of the biosolids produced by WLSSD are beneficially used through a year-round land application program. The majority (85%) are spread on local agricultural lands (roughly 1,800 acres annually) that are used to produce feed crops for livestock. The remainder are used for mine land reclamation (approximately 300 acres/year) to help re-vegetate the otherwise virtually sterile land (WLSSD, 2004). The average size of a given land application site is 20 acres and the average round-trip haul distance from WLSSD is 40 miles (WLSSD, 2006a).

By 2010, WLSSD will target 500 acres of mine land reclamation each year, an increase of 67% (Kathy Hamel, Professional Engineer, Operations Supervisor, WLSSD, personal communication, August 2006).

Biosolids Storage There are times throughout the year when land application is not possible (e.g., when the soil is too soft to accommodate the application equipment due to snowmelt in the spring). During these periods the biosolids must be stored. The WLSSD has approximately 19 days of biosolids cake storage capacity at the WWTP and another 41 days of storage capacity (for current production rates) at an enclosed off site facility in Carlton County (CH2M Hill, 2006).

Biosolids Characteristics WLSSD's anaerobically digested biosolids comprise about 25% solids. Odors from the cake product are considered to be moderate and are suitable for agricultural application (CH2M Hill, 2006). The biosolids cake contains approximately 20 to 25 lbs of N per dt and provides about 29 lbs of plant available nitrogen (PAN) per dt when surface applied and 37 lbs of PAN when incorporated (MDNR, 2004).

5.6.3 Issues Shaping the Future for the Agency's Biosolids Program

Since 2004, the WLSSD has been working towards the development of a Master Plan to provide for the sustainable management of biosolids in the region for the next 20 years. The WLSSD has defined a sustainable program as one that:

> "incorporates products and practices that ensure the safety of human health and the environment; encompasses diversity in products, markets and practices to ensure continuous product distribution; provides high-quality biosolids products that enhance the resources on which they are used and are desired by end-users; is adaptable to changes in technology and in markets; fosters good relationships with stakeholders, end-users, and the public; considers local economic benefits; and integrates with existing waste processing technology" (WLSSD, 2006a).

Some key issues related to biosolids management that the WLSSD is considering include costs, public acceptance, and market diversity.

Costs Rising fuel costs continue to add to the costs associated with all land application programs, but are of particular concern with regard to mine land reclamation projects. as these sites tend to be located further from the WWTP than many of the agricultural land application sites. As a result, hauling distance is a key determinant in the feasibility of land application projects.

Public Acceptance Public concern has resulted in local ordinances banning or restricting land application of biosolids. This is an issue for utilities such as WLSSD because the result is a reduction in the amount of available sites for agricultural land application. Bans have been enacted in 11 different townships in Carlton, Pine, and St. Louis counties. Around half of the bans were already in place when WLSSD began its land application program in the 1990s. Of the more recent bans, the most noteworthy is the Automba Township. Until the use of biosolids was banned there in 2003, the township comprised 12% of the approved land base for biosolids (Kathy Hamel, Professional Engineer, Operations Supervisor, WLSSD, personal communication, August 2006). This portion of biosolids is now land applied elsewhere in the region.

Other towns have not banned biosolids but have instead implemented various restrictions on land application. A few examples of the specific requirements include: same day incorporation of biosolids (no overnight storage), fees paid to the town by the land-owners using the biosolids, and signed agreements by farmers indemnifying the township from any future issues that could arise as a result of the biosolids land application (CH2M Hill, 2006). Currently, the bans within WLSSD's service area are not specific to Class A or Class B biosolids.

Market Diversity In 2005, the WLSSD identified the following improvement goal: "develop enough diversity in biosolids products, markets, and practices to ensure continuous product distribution." For WLSSD this means continuing to utilize existing agriculture and mine land markets and expanding into one or more new market(s). Potential new markets for WLSSD are discussed in further detail in Appendix M.

5.6.4 Biosolids Management Options under Consideration for the Future

With the long-term goal of establishing a sustainable biosolids program, the WLSSD has identified the need for management practices that ensure continuous product distribution (i.e., the agency does not want to run into a situation where it cannot put its biosolids to use as "planned" and is forced to find new storage or disposal options). To achieve this, the WLSSD is considering altering current land application practices. By 2010 the agency will shift towards decreasing the amount of biosolids applied to agricultural lands in favor of increasing the amount used for reclamation of disturbed lands (in most cases taconite tailings at mining sites).

Although the exact size of the mine land reclamation program will vary slightly each year, for the purpose of this case study the researchers assumed that biosolids will be land applied to an additional 200 acres of reclaimed mine lands each year beginning in 2010 (this equates to a total of 500 acres per year).

5.6.5 Define Suitable Baseline

Without adequate funding for capital investments (e.g., new biosolids processing equipment), the WLSSD will have to continue with the current digestion and treatment processes—treating biosolids to Class B pathogen reduction levels. The WLSSD will maintain a biosolids management program that depends exclusively on land application. Approximately 85% of the biosolids will be applied to agricultural lands and the remaining 15% will be distributed to reclaimed mine sites. Reclaimed mine sites in the region that do not receive biosolids will have to purchase commercial fertilizers and soil enhancement products. If fuel costs continue to rise, WLSSD can expect to incur higher biosolids management costs. If additional towns implement bans or restrictions on biosolids storage and/or land application, WLSSD will need to expand their land application services to sites outside of the current 20 mile radius (40 miles round-trip).

5.6.6 Identify and Assess Key Benefits

Land application is a widely practiced biosolids end-use option. Biosolids are most commonly land applied to agricultural sites or reclaimed mine sites. The need for and benefits associated with mine site reclamation are discussed below (and in further detail in Appendix B). Although not addressed in this section, an assessment of the benefits of agricultural land application is included in Appendix A.

By 2010, the WLSSD plans to increase the amount of biosolids applied to reclaimed mine sites, and in turn, decrease the amount applied to agricultural lands. Erosion and acid mine drainage are common problems at abandoned mine areas. Minnesota reclamation laws require mining companies to stabilize tailings, waste rock, and surface overburden stockpiles with vegetation. Mined soils tend to be infertile and have poor water holding capacity—properties not favorable for plant growth. Typical remediation techniques include adding soil amendments such as lime and chemical fertilizer before planting grass, legume, or trees. These practices often fail, primarily because of the poor physical, chemical and/or biological properties of the disturbed lands. According the Minnesota Department of Natural Resources, "of all the organic amendments tested over the years (including municipal solid waste, yard waste and paper mill waste), biosolids seem to be the most practical and economical way to increase fertility on reclamation sites" (MDNR, 2004).

Recycling biosolids through land application at reclaimed mine sites rather than at agricultural sites creates benefits realized by the WLSSD, mine site managers and landowners, and the local community. The benefits, which are summarized in Table 5-23, include avoided commercial fertilizer costs, established vegetation, improved reliability of biosolids end use, greater land application rates, reduced demand for synthetic fertilizers, soil and water quality benefits, and carbon sequestration benefits.

Table 5-23. Benefits Summary (Increased Acreage of WLSSD's Mine Land Reclamation Program).

Type of Benefit	Assessment Level	Beneficiaries
Avoided commercial fertilizer costs	Monetized	Mining company
Vegetation establishment benefits	Qualitative	Mining company
Improved reliability of biosolids end use	Qualitative	Agency
Greater land application rates	Quantified	Agency
Reduced demand for synthetic fertilizers	Qualitative	Local, regional
Soil and water quality benefits	Qualitative	Local
Carbon sequestration benefits	Qualitative	Global

Avoided Commercial Fertilizer Costs Traditional remediation techniques for reclaiming mine sites include stockpiling and reusing topsoil (which is often infertile), then applying lime and commercial fertilizers to initiate vegetative growth. In Minnesota, the standard mine land reclamation practice employed by taconite mining companies for tailings revegetation is to incorporate diammonium phosphate fertilizer (DAP) at a rate of 550 lbs per acre (0.275 tons/acre). The average price of DAP fertilizer is $303 per ton (USDA,[19] 2006). Applied at a rate of 0.275 tons per acre, the cost to reclamation site managers for DAP fertilizer is approximately $83 per acre. Depending on the prevailing soil and climatic conditions at the site, fertilizer application may be required one-time or for several years until a vegetative cover has been established.

The WLSSD delivers and incorporates biosolids free of charge, which offsets the costs of commercial fertilizers typically incurred by reclamation site managers (approximately $83 per acre per application). Mine site managers could realize a cost savings benefit of over $1,600 on a 20-acre site requiring one-time application and $8,300 for a 20-acre site, requiring nutrient application for 5 growing seasons.

In this case study it is assumed that the expansion of the mine land reclamation component of WLSSD's biosolids management program involves increasing mine site application by 200 acres (for a total of 500 acres per year, rather than 300 acres per year) beginning in 2010. This equates to annual cost savings in avoided commercial fertilizer costs (in excess of avoided commercial fertilizer costs associated with the current application to 300 acres of reclaimed mine lands per year) of approximately $16,600.[20] The present value of this benefit over 20 years is nearly $142,000.

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19. According to the U.S. Department of Agriculture (USDA), fertilizer prices vary between approximately $215 and $416 per ton; the prices of seven additional types of fertilizer are listed in Appendix B.

20. Avoided fertilizer cost = $83/acre: $83/acre H 200 acres/year = $16,600/year.

Vegetation Establishment Benefits Successful establishment of permanent vegetation provides benefits to the mining company by reducing the amount of time and money spent on administering and managing sites after mining operations cease.

The State of Minnesota requires that mining companies initiate the establishment of vegetation during the first planting period following completion of mining. The area must be 90% covered with vegetation within three years of closure. Standard mine land reclamation (SMR) practices generally involve adding seed, fertilizer (e.g., diammonium phosphate fertilizer), and mulch to the disturbed soils. While results will vary from one site to the next depending on initial site conditions and the characteristics of the biosolids, numerous studies have shown biosolids applications to be more successful than commercial fertilizer in establishing vegetation on reclamation sites.

Studies conducted at taconite tailings basins in Minnesota indicate that percent vegetative cover and biomass generally increase as the rate of biosolids application increases. One year after site closure and biosolids application, the percent of vegetative cover was approximately 65% where 3.1 dt per acre were applied and 85% where 12.4 dt per acre were applied (as compared to 25% where SMR practices had been employed). After four years, over 30% more vegetative cover was established where biosolids had been applied than where SMR practices were used (MDNR, 2004). At a study site in British Columbia, average total biomass was approximately 3 times higher where biosolids had been applied than where chemical fertilizers had been used (Duynstee, 2002).

Depending on the type of mining conducted at the reclaimed site (e.g., strip mining for coal, taconite mining), rapidly establishing a vegetative cover may provide additional benefits to the mining company. These are described in further detail in Appendix B.

Improved Reliability of Biosolids End Use Land application of biosolids at reclaimed mine sites is not subject to as many restrictions as application at agricultural sites. Application at agricultural sites is limited by: nitrogen needs of the crops, cropping rotation cycles and harvesting schedules, and weather constraints (e.g., wet field conditions during spring snow-melt prohibits vehicle access). Increasing the acreage of the mine land reclamation program (and reducing the acreage of the agricultural land application program) will provide the WLSSD with a more reliable, less restrictive, year-round biosolids management option. This will reduce the amount of time the WLSSD spends coordinating with end-users and will reduce the risk of running out of storage space during winter months.

Greater Land Application Rates Use of biosolids for restoration purposes (generally a one-time application) may be exempt from additional regulations that apply to agricultural application. Biosolids application rates at reclamation sites are often higher than the agronomic rate (which limits the amount of biosolids that may be applied to agricultural soils). According to the U.S. EPA, a relatively large amount of biosolids must be applied to disturbed lands to provide sufficient organic matter and nutrients for effective establishment of vegetation (U.S. EPA, 1995). Successful application rates ranging from 3 to 400 dt per acre have been reported, but the typical rate is approximately 50 dt per acre (U.S. EPA, 1995; Toffey et al., 1999; Brown and Henry, 2001). Biosolids application rates on agricultural lands are lower, ranging from 1 to 30 dt per acre (U.S. EPA, 1995).

WLSSD applies roughly 8.5 dt per acre to reclaimed mine sites to establish the initial vegetation on the tailings basin. To meet the reclamation cover requirements, an additional 4.3 dt per acre is applied at year 3 or 4 into the reclamation process. Once reclaimed, biosolids are not needed to sustain the vegetative cover. Reclamation rate for biosolids in Minnesota was established and approved by the Minnesota Department of Natural Resources. WLSSD generally applies biosolids to agricultural soils at rates of 100 lbs of nitrogen per acre per year (roughly 4.3 dt per acre per year).

The average WLSSD land application site is 20 acres. Applying biosolids at a rate of 8.5 dt per acre, the WLSSD is able to put 170 dt of biosolids to beneficial use at a single average-sized reclamation site (as compared to 86 dt at an average-sized agricultural site). Using biosolids at reclaimed mine lands allows the WLSSD to land apply roughly two times more biosolids per acre than would be permitted at most agricultural sites.

In this case study it is assumed that the expansion of the mine land reclamation component of WLSSD's biosolids management program will increase annual mine site application by 200 acres (or a total of 500 acres per year) beginning in 2010. This equates to the potential for an increase in total volume of land applied biosolids of approximately 840 dt per year[21] for as many years as the WLSSD is able to secure 500 acres of reclamation land for application.

As local regulations or public perception issues arise in the future (e.g., due to concerns related to odors or pollutant levels), an agency's number of eligible/permitted acres for land application may decrease. By enabling the WLSSD to put more biosolids to beneficial use per acre, increasing mine land reclamation (and decreasing agricultural land application) will reduce the risk of encountering a "disposal crisis."

Reduced Demand for Synthetic Fertilizers The nutrient and organic matter content of biosolids enables mining companies to utilize biosolids at reclamation sites in lieu of synthetic fertilizers. By reducing demand for (and use of) chemical fertilizers, mine land application of biosolids indirectly reduces demands on chemical feedstocks, as well as the adverse impacts associated with synthetic chemical production, storage, and transport.

Soil and Water Quality Benefits Land application of biosolids at reclaimed mine sites reduces erosion potential, both through improved soil quality and increased vegetative cover. Following biosolids application, the soil is better aerated, allowing water to infiltrate the soil rather than eroding off the soil surface. The nutrient content in biosolids enhances plant growth and the organic matter content in biosolids increases cation exchange capacity (which improves the soil's ability to retain nutrients). These features help facilitate more rapid re-vegetation at reclamation sites, which reduces the potential for windblown dust and erosion (and the subsequent sediment loading to nearby water bodies).

Acid mine drainage (i.e., drainage of water that has a particularly low pH as a result of contact with mine spoils), is a serious problem at many mine sites throughout North America, including several in Minnesota. Although no comprehensive study has been conducted, monitoring data collected in Pennsylvania suggest that acid mine drainage is significantly reduced at sites where biosolids have been applied (Toffey, 2003).

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21. Increased mine site application: 8.5 dt/acre H 200 acres/year = 1,700 dt/year. Decrease in agricultural application: 4.3 dt/acre H 200 acres/year = 860 dt/year. Difference: 1,700 – 860 = 840 dt/year (this is roughly 90% of the projected total biosolids production for the year 2010).

Carbon Sequestration Benefits Reclaimed mine sites offer a potential carbon sink that may help mitigate a portion of GHG emissions. Carbon sequestration refers to the uptake and storage of carbon. Carbon may be sequestered in above- or below-ground biomass (e.g., trees, grasses, or other vegetation) as well as in the soils. Sequestration rates vary depending on the geographic location of the site as well as the end use for the land (e.g., pasture, forest, or cropland) (Sperow, 2006). According to the Intergovernmental Panel on Climate Change (IPCC, 1998), soil accumulation of carbon on reclaimed mine sites ranges from 0.04 to 2.8 metric tons of carbon per acre per year; whereas for cropland soils, that range is from 0.12 to 0.45 tons of C per acre (IPCC, 1998). Additional estimates of soil accumulation of carbon based on land use type are presented in Appendix B.

In this case study it is assumed that the expansion of the mine land reclamation component of WLSSD's biosolids management program will increase annual mine site application by 200 acres (or a total of 500 acres per year) beginning in 2010. This could potentially lead to a decrease in soil carbon accumulation of as much as 82 tons of C per acre per year or an increase in soil accumulation of as much as carbon of 536 tons of C per acre per year. Due to the uncertainty associated with determining the amount of carbon sequestered per acre of land, these values are presented simply to provide an illustration of the potential for mitigating GHG emissions through the application of biosolids at mine sites.

5.6.7 Identify and Assess Key Costs and Risks

5.6.7.1 Increased Haul Distance to Land Application Sites

Expanding the mine land reclamation component of WLSSD's biosolids management program will likely necessitate the delivery of biosolids to sites outside of the WLSSD's current 20-mile delivery radius. New equipment (a new trailer and a new semi-tractor) will be needed and operating costs will increase (predominantly due to the additional fuel and labor requirements). Table 5-24 summarizes the expected incremental costs due to an increase in haul distance from the current average of 40 miles round-trip to either 60 miles round-trip or 80 miles round-trip. The WLSSD expects to incur these increases in costs if there is an increase in haul distance for land application of biosolids, irrespective of the type of biosolids produced (i.e., Class B or Class A). However, it is worth noting, that production of a Class A product (instead of Class B) does have the potential to reduce the likelihood that the WLSSD will have to seek out land application sites located at greater distances (i.e., 60 and 80 miles round-trip) from the treatment facility.

Table 5-24. Costs Associated with Increasing Distance to Land Application Sites (Compared to Average Haul Distance, in 2005, of 40 Miles Round-Trip).

	Total Present Value[a] (2005, USD)	
	Increase to 60 Miles Round-Trip	**Increase to 80 Miles Round-Trip**
Capital investments	$205,593	$420,112
Total O&M	$2,461,312	$3,271,234
Total	**$2,666,905**	**$3,691,345**

[a]Assumes a 5% discount rate, over the course of 20 years (from 2006 to 2024).

5.6.7.2 Increased Fertilizer Costs

Local farmers that had previously received biosolids from the WLSSD may need to purchase commercial fertilizers if the WLSSD reduces the acreage of the agricultural land application program. Most agricultural producers in the Duluth region use urea as a commercial fertilizer source. The cost of urea has been estimated to be $400/ton for a 45% nitrogen product; ($0.44/lb of N). Assuming an application rate of 100 lbs maximum allowable nitrogen application (MANA) per acre per year, the agricultural end-users pay $44/acre for urea (CH2M Hill, 2006).

The number of acres comprising the agricultural land application component of the WLSSD's biosolids management program varies by year, but is roughly 1,800 acres. Although the total amount of biosolids produced by WLSSD is expected to increase each year (most likely by approximately 10% by 2010), the total amount of biosolids applied at agricultural sites is expected to decrease by 41%[22] by 2010 (due to the expansion of the mine site reclamation program). As a conservative estimate, it is assumed that the number of agricultural acres receiving biosolids will be reduced by 630 acres (approximately 35%) by 2010. In 2010, the cost to farmers having purchase urea (instead of using free biosolids) is expected to be roughly $27,700. Assuming the amount of agricultural land requiring urea as a nutrient source is 630 acres each year between 2010 and 2024 and that the price of urea remains at $44 per acre, the present value of urea purchases by farmers that no longer receive biosolids is expected to total nearly $237,000.[23]

5.6.7.3 Potential Risks

There are inevitably going to be potential risks associated with the production, transport, and/or biosolid end use. None of the future changes that WLSSD is considering for their biosolids management program (production of a Class A product instead of Class B, diversifying end-use markets, and/or altering their land application program to include more mine land reclamation) are likely to introduce any new risks. While several risks posed by the WLSSD's current biosolids management practices may still exist despite these changes, one of the reasons the WLSSD is working to create a more sustainable program is to mitigate some of these risks.

Increasing Land Application at Reclaimed Mine Sites Issues related to land application of biosolids (both at agricultural sites and reclamation sites) include potential bans or limits on application and/or transportation of biosolids (this may apply to either Class B or Class A biosolids), nuisances to the public (odors and traffic), and environmental and human health risks associated with possible contaminants and metals in biosolids.

Although federal regulations (the Part 503 rule) set standards for pathogen reduction, chemical limits, and management practices, biosolids are nonetheless a product of household, commercial and industrial wastewaters, which contain contaminants. These contaminants include pathogens (e.g., viruses and bacteria), pharmaceuticals, and metals. Applying biosolids to mine lands or agricultural lands may pose risks (perceived or real) to human health. Since Class A biosolids require 100% pathogen reduction, risk of pathogen transmission is reduced through the switch to production of a Class A product. Potential transmission of pharmaceuticals and metals

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22. In 2005, 85% of all biosolids produced were land applied to agricultural sites, but in 2010 only 50% of all biosolids will go to agricultural sites (i.e., a 41% decrease).

23. The present value of total cost in 2005$ (through 2024), assuming a 5% discount rate.

may remain a risk (although whether these risks are real or perceived is still debated by researchers and scientists).

The odors associated with biosolids can be a nuisance to neighbors, particularly during the unloading and application process. These odors may prompt complaints from affected parties, motivated by the unpleasant smell itself and/or by a perceived (and perhaps real) mental association of the odors with the potential to pose a health risk. Odors and associated concerns can impose considerable loss of welfare on the impacted individuals. Odors can create political pressure that may ultimately preclude or limit the utility's ability to continue to apply biosolids at the sites (e.g., by leading to bans on some land application options and/or sites).

Risks and concerns associated with land application in general, and land application at mine sites in particular, are discussed in further detail in Appendix B.

5.6.8 Distributional Issues: Identification of Key Beneficiaries and Cost-Bearers

The WLSSD's biosolids management program does not affect only the agency, but could lead to benefits accrued by mine site managers and costs incurred by local farmers. The biosolids management program could create both benefits for and risks to neighbors, the environment, and society as a whole. Table 5-25 summarizes the parties potentially affected by a decrease in agricultural land application of biosolids in favor of an increase in mine site reclamation.

Table 5-25. Affected Parties.

Affected Party	Benefits	Risks/Concerns	Costs
WLSSD	Improved reliability of biosolids end use Greater land application rates		Possible increased labor and fuel requirements (related to transport to application sites)
Mine site managers/ land owners	Avoided commercial fertilizer costs Vegetation establishment benefits		
Neighbors		Odors Traffic	
Local farmers			Increased costs for urea fertilizer (for biosolids application to agricultural lands is reduced)
Environment and society as a whole	Reduced demand for synthetic fertilizers Soil and water quality benefits Carbon sequestration benefits	Potential public health and environmental risks (real and/or perceived), associated with metals and other pollutants in the soil or nearby waters.	

5.6.9 Public Outreach and Communication

Part of the WLSSD's efforts to improve the biosolids management program involves working with individuals and organizations outside of the District. These efforts include public outreach programs, collaborative research with universities, and partnerships with new end-users.

- **Public outreach:** WLSSD staff attend and present biosolids information at county and township meetings; produce brochures, semi-annual newsletters, and factsheets (all of which are available through their Website); and conduct tours of the treatment plant and hold field days at local farms.

- **Collaboration with universities:** WLSSD is working with Bucknell University to measure and control odors. The WLSSD is also working with researchers at the University of Minnesota to determine mineralization rates of nitrogen and phosphorous in WLSSD's biosolids.
- **Partnerships with new end-users:** As part of their efforts to increase market diversity, the WLSSD has been developing relationships with local sod farmers, companies throughout the United States that would be willing to purchase biomass, and members of the local forestry industry.

5.6.10 Comparing Benefits to Costs

The benefits that could accrue if the WLSSD increases the amount of biosolids land applied at reclaimed mine sites (and decreases land application at agricultural sites) include: avoided commercial fertilizer costs, greater land application rates, improved vegetation establishment, improved biosolids end-use reliability, reduced demand for synthetic fertilizers, soil and water quality benefits, and increased carbon sequestration. Local farmers that once relied on biosolids for nutrients may incur costs associated with purchasing urea when biosolids are no longer available to them. A relatively large increase in annual operations and maintenance costs are expected if the haul distances to land application sites increases, which is likely since many of the reclamation sites are further than the currently utilized agricultural sites. Although it was not possible to monetize the benefits of greater land application rates or improved reliability of biosolids end use, these benefits would improve the sustainability of WLSSD's biosolids program by helping the agency ensure continuous product distribution.

A summary of the benefits and costs/risks of the expansion of the mine site reclamation program is included in Table 5-26.

Table 5-26. Benefit-Cost Comparison (Increased Land Application at Reclaimed Mine Sites).

	Quantified	Total Present Value[a] (2005, USD)
Quantifiable costs and risks		
Increased haul distance to land application sites (from 40-miles to 80-miles, round-trip)		$3,564,711
Urea fertilizer costs (due to the reduction in biosolids available to farmers)		$236,711
Total cost		*$3,801,422*
Quantifiable benefits		
Avoided commercial fertilizer costs		$141,745
Greater land application rates	*840 dt/acre/year*	
Total monetized benefits		*$141,745*
Total monetized net benefits		($3,659,669)
Qualitative benefits	**Qualitative indicator[b]**	
Vegetation establishment benefits	++	
Improved reliability of biosolids end use	++	
Reduced demand for synthetic fertilizers	+	
Soil and water quality benefits	+	
Carbon sequestration benefits	+	

[a] Evaluated using a 5% discount rate, over a 20 year time horizon.
[b]Magnitude of effect on net benefits.
+ = Likely to increase net benefits relative to quantified estimates.
++ = Likely to increase net benefits significantly.

While the current landscape for biosolids management appears to be continually evolving and future opportunities, regulations, and roadblocks are uncertain, the fact that biosolids will continue to be used is certain. Although there are costs associated with the alternatives to WLSSD's current biosolids management program (specifically a transition to increased land application at mine sites), this case study has illustrated the fact that there is also a range of potential benefits, some of which are expected to enhance the stability of WLSSD's biosolids program.

5.7 Illustration 7: Energy Recovery at Orange County Sanitation District

5.7.1 Introduction and Overview

The OCSD provides wastewater treatment to 2.5 million residents in Orange County, California. They operate two facilities that treat an average of 240 million gallons of wastewater and produce 650 tons of biosolids each day using anaerobic digestion (CH2M Hill, 2003). The biosolids are beneficially used primarily as a fertilizer and soil amendment on farms in California and Arizona.

In recent years, regulatory issues, land application ordinances and bans, and public perception challenges have prompted OCSD to re-evaluate its management program and assess alternative production, beneficial use, and disposal options. This case study serves to highlight the benefits of conducting and implementing a long-range management plan (LRMP), and evaluate the benefits and costs of the associated outcomes. The following sections address:

- OCSD's motivation for changing its biosolids management program
- The evaluation of the program's long term viability and the associated need for failsafe beneficial use options
- The use of the TBL approach to assessing biosolids management options by evaluating options economically, environmentally, and socially
- The costs and benefits (financial, social, and environmental) of OCSD's selected biosolids management plan

5.7.2 Current Biosolids Management Practices

Currently, OCSD uses mesophilic anaerobic digestion to produce 650 tons of Class B biosolids per day. Seventy percent of OCSD's biosolids are further treated at off-site locations to become Class A biosolids products. The District currently has four contracts for biosolids hauling and beneficial use (OCSD, 2006c). Figure 5-2 displays the percent of biosolids being distributed to each end-use location.

5.7.3 Issues Shaping the Future for the Agency's Biosolids Program

Several counties throughout California and Arizona have developed, or are in the process of developing, ordinances that severely restrict or ban the land application of Class B biosolids (CH2M Hill, 2003). As pointed out in OCSD's LRMP, it is clear that future requirements for managing biosolids will be more restrictive and OCSD will have to switch to more costly alternatives as current options are eliminated. The LRMP estimated that 3-5 years after that 2003 study, land application options may not be available. Kern County recently banned Class A biosolids application at the time of this report were being sued by the City of Los Angeles, the OCSD, and other stakeholders. The ban has been enjoined pending the outcome of the trial.

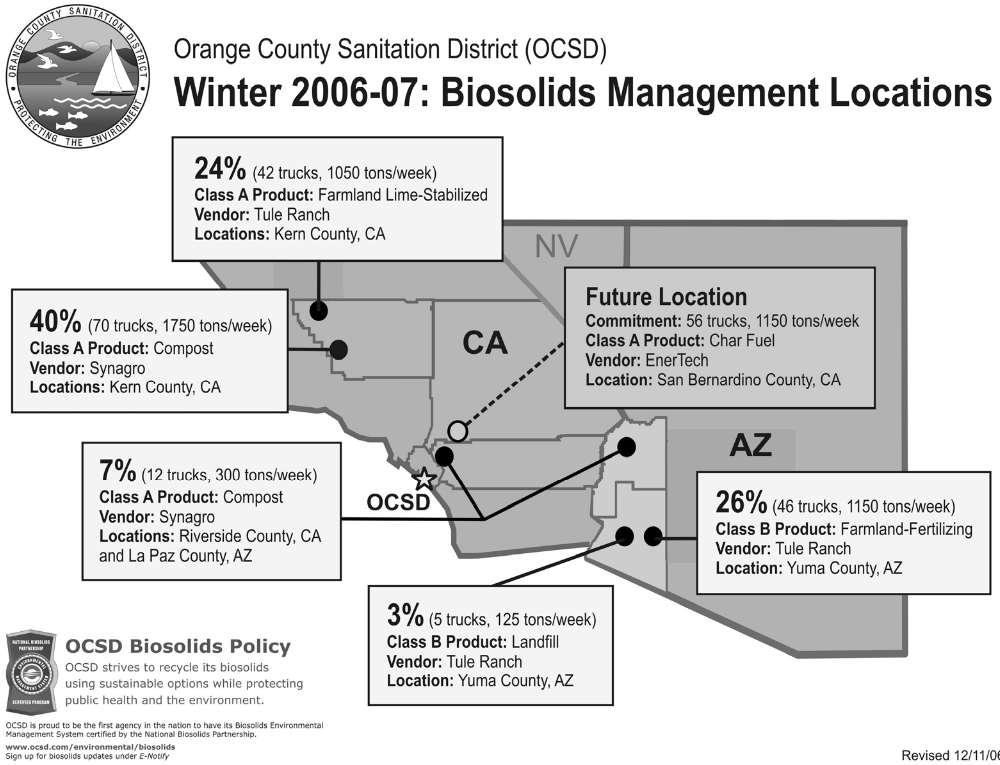

Figure 5-2. Biosolids Distribution Locations for OCSD.

Reprinted with permission from the Orange County Sanitation District (OCSD, 2006b).

Along with the loss of beneficial use options, OCSD expects the production of biosolids to increase by about 35% over the next 30 years (CH2M Hill, 2003). The implementation of new alternative treatment facilities could take up to 8 years. In order to avoid problems during this time gap, OCSD has developed a Biosolids Management Program Implementation Plan that recommends contracting to a merchant facility to “phase the gap between the phase-out of existing reuse contracts and the startup of future District-owned facilities.”

5.7.4 Biosolids Management Options under Development for the Future

The LRMP is based on a business model approach to evaluate biosolids management options by identifying viable biosolids markets and the technologies that can economically manufacture biosolids-based products for those markets.

The guidelines of the OCSD LRMP are:

- Maximize the reliability of the long-term biosolids management program
- Improve public perception and confidence
- Maximize the value of the work completed to date
- Realize innovative, cost effective, and environmentally sound ideas (CH2M Hill, 2003)

As mentioned in the previous section, OCSD identified the opportunity of contracting with a merchant facility to provide a short-term alternative treatment and biosolids use option. OCSD (with the help of its Citizens' Advisory Group) evaluated a number of proposals before selecting a contract with an energy company called EnerTech (www.enertech.com). EnerTech will receive 225 tons of biosolids per day and convert them into a certified "green" fuel (E-fuel) using a patented process called "SlurryCarb."

The fuel produced by the SlurryCarb process has the heating equivalent of a low-grade coal. EnerTech has contracted with a local cement factory to sell them the fuel as a power source and use the ash as an additive in their cement mixture, thus resulting in zero waste (Kearney, 2006).

The contract commits OCSD to pay a set price for the company's services and provide them with a set amount of biosolids daily (OCSD, 2006a). These biosolids will continue being treated at the two OCSD treatment facilities using anaerobic digestion, then shipped to EnerTech's facility. Hence, the program change will only affect biosolid end uses, not treatment.

Beginning in late 2008, OCSD will provide 200 tons per day of their biosolids (about 30% of total production) to EnerTech. Another 250 tons (about 40%) will continue to go to Synagro's South Kern Composting facility. To address the remaining biosolids—250 tons currently, and approximately 375 tons in the future—OCSD will put out a request for proposals for yet another biosolids management alternative (Deirdre Bingman, OCSD, personal communication, November 2006). For simplicity of this analysis, it is assumed that one-half of the current biosolids production is land applied and the remainder is sent to EnerTech.

5.7.5 Define Suitable Baseline

Due to the changes in land application regulations, OCSD will most likely have to adopt an alternative biosolids use strategy. For simplicity of this analysis, however, it is assumed baseline to be continued land application as distributed in Figure 5-2.

5.7.6 Identify and Assess Key Benefits

The benefits of conducting and implementing a long-range management plan and the decisions and changes associated with such a plan are summarized in Table 5-27 and discussed in the text below.

Table 5-27. Benefits Summary.

Benefit Category	Assessment Level	Beneficiaries
Sustainability benefits		
Diversification of biosolids management options	Qualitative	Agency
Social benefits		
Improved public perception	Qualitative	Agency/local
Permanent recycling of biosolids	Qualitative	Agency
Environmental benefits		
Lowered air pollutant emissions (GHG, SO_2, NO_x)	Monetized	Agency/global
Production of a certified renewable fuel	Qualitative	Fuel purchaser

5.7.6.1 Sustainability

Diversification of Biosolids Management Options By adding additional product markets to its beneficial use options, OCSD is protecting itself from the effects of weakening markets and failed contracts, thus ensuring continuous beneficial use. This is also the first "energy" contract which helps OCSD move away from the agriculturally based markets in hopes that energy is a more publicly acceptable use for biosolids. Using a merchant facility allows for timely and stable biosolids beneficial use. The use of a marketing contract ensures a failsafe biosolids management option for the life of the contract. The use of a local company also stimulates the local economy.

Use of TBL Decision-Making

Introduction to the TBL Using the TBL approach, OCSD was able to evaluate the environmental and social effects, in addition to the financial effects, of several potential biosolids management scenarios. While the financial bottom line often reveals whether or not certain management options are feasible from a cash flow or cost management perspective, public utilities may have more than just the financial bottom line to consider. For many agencies, promoting environmental stewardship and looking out for the health, safety, and general well-being of the community they serve are also important components of a management program. Measuring the social and environmental effects of a program is not typically as straightforward as determining the financial impact. The TBL approach enables an agency to address all three of these elements (financial, social and environmental) in a systematic way. Among utilities in North America, the TBL is still an emerging concept, though it appears to be gaining momentum quickly (currently, the TBL is applied more routinely in Australia and New Zealand). While there is not yet a well-defined set of rules for how to incorporate the TBL into an agency's decision-making-process, basing biosolids management planning on the TBL can provide a useful way of evaluating alternative options.

OCSD Approach to the TBL OCSD evaluated the financial bottom line using a cost evaluation model. Financially, the contract with EnerTech was the most expensive option. The lack of up-front capital costs and public-private venture that allows "design-build" contracts, however, allowed OCSD to transition into a new biosolids management option in a timely manner.

A second bottom line, to reflect "social" impacts, was evaluated. This evaluation illuminated the social benefits that are realized through avoided public concerns associated with land application and improved public perception.

The odors and flies associated with land applying biosolids can be a nuisance to neighbors, particularly during the unloading and application process. These may prompt complaints from affected parties, motivated by the unpleasant smell itself and/or by a mental association of the odors with the perceived potential to pose a health risk. Odors and associated concerns can impose considerable loss of welfare on the impacted individuals. They also can create political pressure that may ultimately preclude or limit the agency's ability to continue to apply biosolids at the sites (e.g., by leading to bans on some land application options). Since biosolids are being delivered directly to EnerTech and handled indoors, these odor-related concerns are dissolved.

By diversifying their beneficial use options, OCSD has limited its needs to land apply biosolids. Since there were considerable public concerns over this matter in Southern California, limited need for this management option may improve public acceptance of OCSD's beneficial use of biosolids. Since EnerTech's proposal was selected in part by the Citizen's Advisory Board, OCSD's risk of public opposition is reduced. The process used to convert biosolids to fuel destroys all pathogens, thus eliminating the public health concern. The use of biosolids as a renewable energy source has positive public perception, and eliminates the "exposure" of the land in the agricultural cycle. The fuel being produced by EnerTech is certified by the California Energy Commission as a renewable fuel and marketed as an "E-fuel."

A third, environmental bottom line was evaluated to reflect resource consumption and the overall "environmental burden" of OCSD's biosolids management options.

OCSD's partnership with EnerTech provides lowered air pollutant emissions [GHG, sulfur dioxide (SO_2), NO_x], and generates a certified renewable fuel. The process of drying the sludge using SlurryCarb is reported to require 65% of the amount of energy to treat biosolids using anaerobic digestion. By offsetting the demand for electricity and thus decreasing electricity production, emissions of air pollutants (GHGs, SO_2, and NO_x) are lowered. Assuming OCSD currently uses around 30 million MW of electricity per year,[24] if they provide half of their biosolids to EnerTech, the estimated annual reductions in emissions of CO_2, SO_2, and NO_x are 4.6 million, 5,600, and 3,200 tons, respectively. By applying estimated values of $10 per ton CO_2, $826 per ton SO_2, and $850 per ton NO_x, and taking the present value for 20 years, the estimated monetized benefit of emissions reduction is $312,187.[25]

There are substantial benefits associated with the conversion of biosolids to fuel. These include:

- Provides permanent recycling of biosolids
- Produces a high BTU content fuel
- Produces a fuel that has a low carbon dioxide production compared to fossil fuels
- Creates existence of options for ash removal and beneficial use (e.g., use in cement) (Kearney, 2006)

Figure 5-3 provides a visual representation of the transition from a purely financial management strategy to one that includes the social and environmental impacts of biosolids reuse. The dot labeled "1" reflects the option that maximizes the financial aspect of biosolids management (i.e., results in the lowest financial cost to OCSD). The dot labeled "2" reflects the energy recovery option. Notice that dot "2" is larger than dot "1" to reflect the magnitude of the benefits associated with this option. Even though the energy recovery option has a higher financial cost than other alternatives, it provides greater social and environmental benefits.

5.7.7 Identify and Assess Key Costs and Risks

At $347 per dt, EnerTech's proposal offered the most expensive (financially) beneficial use alternative under contract. This will pose a burden to OCSD, as it is considerably more expensive than land application. The current, baseline average cost for biosolids beneficial use (anaerobic treatment and land application) is $163 per ton (Kearney, 2006). The present value[26] of the increase in costs is $785,000.

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24. Amount of energy used by Denver Metro Wastewater, a similar size utility.

25. See Appendix C, Energy Recovery, for more information on the basis for estimating emissions reductions benefits. A 5% discount rate was used for this estimate.

26. Present value over 20 years using a 5% discount rate.

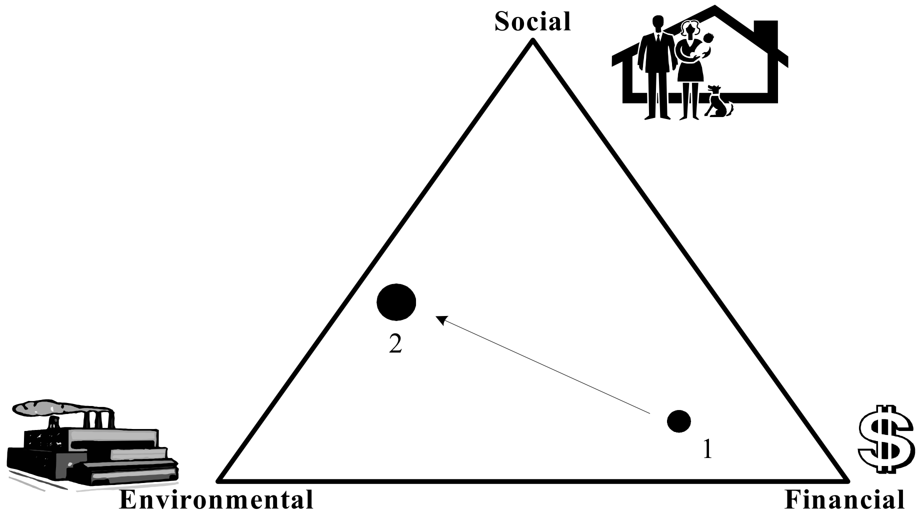


Figure 5-3. TBL Depiction of Moving from Land Application (Option 1) to Energy Recovery (Option 2). Note that the Size of Dot Indicates Relative Net Total Benefits Anticipated from an Option.

While diversification of products and markets will mitigate the risks associated with market failures and vulnerability to regulatory changes due to the expected increase in the biosolids quantities, the risk is not completely eliminated.

5.7.8 Distributional Issues: Identification of Key Beneficiaries and Cost-Bearers

Key benefits of OCSD's biosolids management option are realized socially and environmentally by the local community and communities near land application sites, as well as globally through decreased emissions. Costs of the more expensive process will be realized by the agency. Table 5-28 summarizes the distribution of these benefits and costs.

Table 5-28. Distribution of Benefits and Costs for Energy Recovery at OCSD.

Affected Party	Level of Impact	Benefit/Cost Category
Agency	++	Diversification of biosolids management options
	--	High cost per ton
	+	Permanent recycling of biosolids
	+	Mitigated public concerns associated with land application/ Improved public perception
Fuel purchaser	+	Production of a certified renewable fuel
Environment and society as a whole	+	Reduced land application
	+	Renewable energy source
	+	Lowered air pollutant emissions (GHG, SO_2, NO_x)

5.7.9 Comparing Benefits to Costs; Summary of Findings

Although the option to team up with EnerTech for energy production was the most expensive option considered, OCSD determined that it was the best option to meet their TBL approach to biosolids management. The costs and benefits of OCSD's plan to contract one half of their biosolids to EnerTech are summarized in Table 5-29.

Table 5-29. Benefit-Cost Comparison.

	Present Value	Beneficiary
Energy recovery component		
Quantifiable costs		
Additional cost of EnerTech contract	$784,629	Agency
Total monetized energy recovery Costs	*$784,629*	
Quantifiable benefits		
Lowered air pollutant emissions (GHG, SO_2, NO_x)	$312,187	Agency/ community/global
Total monetized energy recovery benefits	*$312,187*	
Monetized net energy recovery benefits (monetized benefits minus costs)	($472,442)	
Benefits or costs requiring qualitative assessment[a]		
Improved public perception	+	Agency/global
Sustainable biosolids program	++	Agency and community
Production of a certified renewable fuel	+	Fuel purchaser

[a](+) indicates positive benefits anticipated but not monetizable with readily available data; and (-) indicates a cost anticipated but not monetizable with readily available data.

5.8 Conclusions from Case Illustrations

The series of case illustrations provided in this chapter help reveal how benefits and costs of a broad (but not exhaustive) range of biosolids management programs may arise and be portrayed. The information provided in these illustrations has in many instances been simplified or assumed, in order to facilitate the discussion and provide a basis for demonstrating a concept. The specific dollar values should not necessarily be construed as robust, case-specific estimates. Rather, the case studies are used here to provide insight on where and how beneficial use benefits and costs can be estimated, and also to reveal some common challenges and potential pitfalls for which analysts need to be alert. (More expansive versions of the case studies for two of the utilities illustrated above are provided in Appendices L and M.) A challenge common to all utilities highlighted in this chapter (and likely common to all biosolids managers) is to find a way to ensure a sustainable biosolids management program in the face of ongoing and anticipated hurdles, such as growing populations, restrictions on land application, treatment costs, energy demands, and complaints about odors. The combination of challenges and opportunities for benefits will vary amongst utilities. As a result, there is no single "best" approach to attaining a sustainable biosolids program. For some utilities it may require adopting a new treatment technology, for others it may require diversifying their end-use options. Table 5-30 summarizes the key elements of the seven biosolids management programs described in this chapter and, much like Table 5-1, provides a primarily qualitative overview of each case illustration. By highlighting the size, key issues, and key program elements specific to each utility discussed in this chapter, Table 5-30 serves as a quick reference for the reader to compare his or her utility's situation with those presented in the case illustrations.

Throughout the chapter, the researchers provided estimates of values associated with beneficial use of biosolids. Indeed, for many utilities there will be instances in which it is possible to develop useful empirical estimates of beneficial values. However, at the same time, caveats (such as simplifications) should be clearly understood and well documented, and sensitivity analyses need to be used to reveal the impact of key assumptions and uncertainties. Further, it always is important to identify and qualitatively describe important benefits (and costs), regardless of whether they are amenable to quantification and monetization.

Table 5-30. Summary of Issues Evaluated in Case Study Illustrations.

	WWTP Capacity (MGD)	Key Issues	Key Elements of Biosolids Management Program Evaluated in Case Illustrations							
			Energy Recovery	Switch from Class B to Class A	Land Application	Landfill	Compost	Evaluation of New Markets	New Technology	"New" Program Evaluation Approach
Reedy Creek Improvement District, FL	12	Odors				x	x			x (multi-objective evaluation)
Columbus Water Works, GA	42	Difficulty obtaining permits; public opposition	x	x					x (CBFT3)	
Western Lake Superior Sanitation District, Duluth, MN	43	Increasing fuel costs, public perception, market diversity		x	x			x		
Metro Wastewater Reclamation District, Denver, CO	130	Increasing fuel costs and urban development	x		x			x		
King County, WA	200	Identification of carbon sources/sinks within biosolids program	x		x	x	x			x (carbon accounting)
Orange County Sanitation District, CA	240	Restrictions on land application of Class B and Class A biosolids			x			x	x (conversion of biosolids to fuel)	x (TBL)
Greater Vancouver Regional District, BC	300+	Anticipated increase in volume of biosolids; limited land application sites			x	x				x (TBL)

CHAPTER 6.0

CONCLUSIONS AND AGENDA FOR FUTURE RESEARCH

Wastewater agencies, regulatory bodies, the research community, and other entities have identified and implemented a suite of practices, processes, and regulations that enable the safe and prudent management of biosolids. There are also numerous existing and emerging options that enable biosolids to be used as a valuable resource (e.g., for energy recovery) rather than as a waste product. Still, there are numerous significant challenges faced by wastewater agencies and other interested parties as they consider how to best manage biosolids.

BCA and related economics-based decision support tools—if conducted with a suitably broad "social" perspective and based on a transparent application of appropriate methods and data—offer a well-established framework for addressing these challenges. Accordingly, the researchers' approach in this report is to provide wastewater agencies with a practical way to better recognize and account for the impacts of the biosolids management options they are considering, regardless of who realizes the benefits, or who bears the costs and risks.

Conducting these BCAs and/or related Business Case Evaluation analyses typically is a complex, highly location-specific, and technically specialized endeavor. In some cases, utilities may need specialized technical expertise to assist in the framing, implementation, and presentation of these analyses. In these instances, this report can be used to help utilities be better-informed managers, reviewers, and users of the analyses that are developed on their behalf.

There are many critical gaps in the base of knowledge as related to understanding the benefits, costs, and risks of alternative biosolids management options. The science has progressed considerably over the past decade, but many critical knowledge gaps remain. Below is a limited agenda for future research that is designed to help address some of these gaps and help utilities (and society as a whole) better understand the relative merits and concerns of various biosolids alternatives.

6.1 Odors—How Much Odor Reduction is Enough, and What Is It Worth?

There has been considerable engineering and scientific advancement on odor-related issues, based on WERF-sponsored and other research. This has indicated that there are no physiological health-related risks associated with odors per se. However, there remains a real mental association between odors and health risk for the people who are impacted. And, beyond the potential association with health concerns, biosolids-related odors are unpleasant. People in proximity to biosolids operations simply do not want to suffer the negative aesthetic impacts of odorous biosolids processes and products.

Past and on-going research also has helped identify the odor-associated chemicals (total volatile organic sulfur compounds), and increased the understanding of where they arise in the process (often cake-related). This has enabled a growing understanding of what modifications to processes (e.g., shearing) and practices (e.g., chemical additions) may help reduce the formation and release of the odorous compounds.

Ultimately, however, the key questions become "what will it cost to reduce odors?" and "is it worth the expense?" As the odor-controlling biosolids strategies appear to be quite expensive, it becomes increasingly important to gain a better understanding of "how much odor control is needed to get the job done?" Additional research is needed to understand at what level odorous releases become less apparent and/or offensive. Some target levels of odors is needed so that processes and practices can be examined in the context of reaching these targets. More information on the value of odor reduction or odor elimination to those people affected is also needed. This will provide the wastewater sector with a better gauge of whether the expense of odor control is justified, or how much money impacted parties might be suitably compensated for enduring odors.

6.2 Sustainability of Biosolids Programs—How Much Is Diversification Worth as a Risk Management Strategy?

As some traditional biosolids management options are becoming more constrained for many utilities, these agencies are facing heightening risks that at some future time they will have only extremely high cost biosolids options available to them. For example, the loss of land application or disposal sites in reasonable proximity may require very long-haul shipments, with associated high costs. Or, the supply-side flooding of local Class A product market may mean there is no demand for the biosolids products produced.

Future research would be valuable on how much risk may be faced by some agencies if they do not invest near-term in developing a diversified portfolio of biosolids management options. Since "biosolids happen" on an on-going basis, utilities always need to have some viable methods to store and disperse their product. If some storage and dispersement approaches are eliminated (e.g., via a land application ban or the loss of a product market), then what risks will agencies face, and what will be the cost of being caught unprepared? This line of research would help determine whether the expenses many utilities are incurring are justified when they explore or implement diverse and often very costly biosolids management options. Research exploring the real benefits of continuous diversification (or, the cost of being nondiversified) would be very useful to many utilities.

6.3 Energy-Related Values for Biosolids—What Are the Full Lifecycle Benefits and Costs?

The researchers' case study illustrations revealed that there appear to be considerable net internal and external benefits from energy recovery and other energy-related investments and practices by biosolids management agencies. Continued empirical research in this area will help better identify and estimate the full social value of a range of energy-enhancing options for utilities. This in turn will help agencies make more benefit-cost justified investments in energy-related practices and processes.

6.4 Climate Change Impacts—How Can Biosolids Management Reduce the Carbon Footprint of Wastewater Utilities, and Is It Worth the Investment?

There is increasing interest in how wastewater utilities may contribute to GHG emissions and associated climate change impacts. The researchers' guidance and case studies reveal some of the ways that biosolids management practices can alter the net carbon account for utilities. Future research that includes expanded tool development and case study applications will help utilities better understand how they can reduce their carbon debits and enhance their carbon credits. This research could be aimed at helping utilities 1) audit their own current practices, 2) better understand what options they have to improve their carbon footprint, and 3) evaluate whether and why investment in the carbon account-enhancing alternatives may be warranted on a social benefit-cost basis.

6.5 Community Values for Beneficial Use—What Is the Willingness to Pay of Community Households for Having a Biosolids Program that Embraces the Recycling Ethic?

There appears to be a strong social ethic in North America for recycling many materials, reflecting a sentiment in favor of environmental protection and promoting the sustainable use of natural resources. Many utilities consider beneficial use options for their biosolids as being consistent with their community's preferences and value system; that the added expense of some options is warranted because the community values recycling natural resources. However, there is no real empirical assessment that articulates community preferences and values. Future research that takes a rigorous empirical assessment of the public's preferences, attitudes, and values (or rankings) in this realm would be very informative and useful for the biosolids management community. This research would need to apply best practices in survey design and implementation, including focus groups and pretesting to develop reliable stated preference survey instruments.

APPENDIX A

AGRICULTURAL LAND APPLICATION

A.1 Introduction

Land application of biosolids is a long-standing and widely used practice, and has been the subject of considerable scientific investigation and review. As a result, land application using best practices and in accordance with federal and state regulations is widely viewed as a beneficial use of biosolids that poses minimal and acceptable risk. Nonetheless, there remain several open scientific questions and uncertainties that lead some individuals and organizations to remain highly concerned about some risks that may be associated with land application. Hence, land application remains a controversial issue in biosolids management.

In this project in general, and this appendix in specific, the researchers attempt to offer an open and objective summary of the benefits, costs, and potential risks associated with land application. Their aim is to provide information in a balanced manner, and to indicate to readers what the issues are, what the science suggests, and where they can obtain additional information. The researchers do not seek to resolve the remaining conflicts, nor do they endorse one set of views over the others. They simply try to state the issues, present the data, and point readers to additional resources.

Finally, one of the researchers' core goals is to apply a constructive *comparative* context that reflects the fact that "biosolids happen," i.e., biosolids will exist and they need to be managed in some fashion. Thus, land applications—and its associated benefits, costs, and risks (real, potential, or perceived)—need to be viewed in comparison to alternative biosolids management options. The overall intent of the benefit-cost framework developed in this report is to facilitate such comparative analyses.

A.2 Overview of Agricultural Land Application

According to the U.S. EPA, land application accounts for 68% of beneficial use of biosolids (U.S. EPA, 1999). Applying biosolids to land recycles nutrients, minerals, and organic matter back to the soil while reducing the amount of wastes that may otherwise be incinerated or sent to landfills.

Agricultural land application of biosolids involves spreading or spraying biosolids on the soil surface or incorporating (tilling) the biosolids into the soil. The organic matter in the biosolids helps to improve soil tilth, root penetration, moisture retention, and the soil's ability to retain and provide nutrients (Evanylo, 1999), which can improve crop production. Agricultural land application is, in many cases, the most cost-effective biosolids recycling option for the municipal wastewater agency (Toffey, 2002) and provides farmers with a low- or no-cost alternative to conventional fertilizers and soil amendments. Both Class A and Class B biosolids can be applied to agricultural lands, but there are crop type, harvesting, grazing, and public access restrictions associated with Class B.

Two of the most common applications of biosolids are to agricultural lands and reclaimed mine sites. This appendix focuses on the benefits and risks associated with land application at agricultural sites. Mine site reclamation is evaluated in greater detail in Appendix B.

A.3 Affected Parties

Treating wastewater inevitably leads to the production of biosolids, which leaves wastewater treatment agencies with the responsibility of biosolids management. The management option employed will not only affect the agency directly, but also has the potential to create benefits for and impose risks upon biosolids end-users, local residents, the environment, and society as a whole.

Agricultural land application can be a cost-effective component of an agency's biosolids management program, although agencies face the risk that future changes to local regulations could limit (or eliminate) this beneficial use option. The agency may incur costs associated with each component of agricultural land application, including securing agricultural lands on which to apply biosolids (access to private farm lands, however, is free in many cases, although the agency typically absorbs the cost of land application), transporting biosolids, and application. Farmers, who often receive biosolids at no-cost, realize benefits of land application through cost-effective fertilization and the associated benefits of improved soil quality and crop productivity. The delivery and application of biosolids to agricultural lands may cause nuisances to neighbors and create risks (real, potential, or perceived) to public health and the environment. Biosolids as an alternative to chemical fertilizers, however, may potentially lead to environmental benefits, such as improved water quality.

Table A-1 summarizes the various parties affected by agricultural land application of biosolids.

Table A-1. Affected Parties.

Affected Party	Benefits	Risks (real and/or perceived)	Costs
Agency/utility	Potential costs savings (compared to other biosolids management alternatives)	Potential limits (or bans) on application	Transportation costs
Farmers (and other end-users)	Avoided fertilizer costs Improved soil quality Improved crop yield	Reduced livestock fertility Copper deficiency Phytotoxicity	
Neighbors		Potential or perceived health impacts	Odors Traffic
Environment and society as a whole	Potential water quality benefits (due to reduced erosion) Reduced dependence on chemical fertilizers	Water quality risks (due to increased nutrient concentrations in soils) Contamination risks (pathogens, pharmaceuticals, metals, and other chemicals) Potential general public health risks	

A.4 Benefits

A.4.1 Benefits to the Agency

Agricultural land application is generally an easy and straightforward method of putting biosolids to beneficial use. Local regulations permitting, either Class A or Class B biosolids can be applied to agricultural sites, enabling wastewater treatment agencies to be able to continue with biosolids application on agricultural lands without making changes to the treatment process already in use at their facility. As an alternative to other biosolids management options that may require larger capital investments, greater hauling distances, disposal fees (such as tipping fees at landfills), the purchase of amendments (such as sand for soil enhancement products), or expensive marketing efforts, agricultural land application offers potential cost-savings to wastewater treatment agencies.

A.4.2 Benefits to Farmers

Biosolids, which contain nutrients necessary for crop growth, can be applied to agricultural lands as an alternative to commercial fertilizers. Because they are approximately 50% organic matter, biosolids also have soil conditioning properties that distinguish them from most commercial fertilizers. Wastewater treatment agencies often obtain the relevant permits, deliver, apply, and incorporate biosolids at no charge to the end-user, thus creating significant cost saving opportunities for farmers.

The magnitude of the benefits realized by farmers will vary depending on the type of biosolids, the application method, the existing soil conditions, the crops being grown, and the alternative fertilizer and tillage practices that would have been employed without biosolids. Despite such variations, the range of savings and crop improvements reported by studies undertaken across the country illustrate that biosolids may provide substantial benefits to farmers. These benefits are described in further detail in the following sections.

A.4.3 Avoided Costs

Overall Cost Savings Economic benefits realized by farmers utilizing biosolids in place of commercial fertilizers as high as $100-150 per acre have been reported by utilities and other proponents of biosolids beneficial use, although the details of how these benefits were calculated are unavailable. The most common range of total savings to farmers utilizing biosolids in place of commercial fertilizers found in the literature is between $25 and $75 per acre. Table A-2 summarizes several studies contributing to this estimate. For a farmer with a 20-acre field, land application of biosolids as an alternative to commercial fertilizers could provide cost savings between $500 and $1,500, per application (generally, one time a year, but may vary depending on specific farming practices and soil needs).

Several factors influence avoided cost estimates, including 1) the specific type of commercial fertilizer that would have been used if biosolids were not land applied, 2) the value of the specific macro-nutrient provided by biosolids, and 3) services provided by the utility delivering the biosolids.

Table A-2. Overall Cost Savings to Agricultural End-Users Receiving Biosolids as an Alternative to Commercial Fertilizer.

Location	Crop(s)	Savings ($/Acre)	Citation	Summary of Study
Bennett, Colorado	Winter wheat	$18	Ippolito et al., 2000	Results from an 18-year project in the region around Englewood, CO, show that biosolids use is an effective alternative to commercial nitrogen fertilizer (urea).
Virginia	Pastures	$25-50	Faulkner, 2001	Results from case studies in the Coastal Plains and Piedmont regions of Virginia.
Denver, Colorado	Winter wheat	$30-60	Donna Hull, Metro Wastewater Reclamation District, personal communication, October 2006	General savings reported by Metro using the Class B product produced by the agency.
King County, Washington	Agronomic crops	$50	Sally Brown, Research Associate Professor, University of Washington, personal communication, September 2006	Savings on irrigated land $75-100/acre, savings on dry land $25/acre.
Virginia	Corn, small grains, and soybeans	$50-70	Faulkner, 2001	Results from case studies in New Kent, Louisa, and Hanover counties. Savings estimates based on $0.23/lb for N, $0.30/lb for P, and $0.14/lb for potassium.

Cost Savings According to Avoided Commercial Fertilizer Purchases Agricultural land application of biosolids reduces (and may eliminate) the need for commercial fertilizers. Table A-3 presents the average prices (2005 USD) per ton (or, per 2,000 lbs) of eight commercial fertilizers. Utilizing biosolids may create a costs savings benefit to farmers equal to the avoided cost of commercial fertilizer.

Table A-3. Overall Cost Savings (Per Ton of Commercial Fertilizer Offset by Biosolids Use) to Agricultural Users.

Type of Commercial Fertilizer	Anhydrous Ammonia	Nitrogen Solutions (30%)	Urea (45% N)	Ammonium Nitrate	Sulfate of Ammonium	Super-Phosphate 44-46% Phosphate	Diammonium Phosphate (18-46-0)	Potassium Chloride (60% P)
Cost savings[a] ($/ton)	$416	$215	$332	$292	$244	$299	$303	$245

[a]Average prices of selected fertilizers in 2005.
Source: USDA, 2006.

Cost Savings According to Nutrient Provided Like commercial fertilizers, biosolids provide nutrients necessary for crop production and growth, such as nitrogen (N), phosphorous, (P) and potassium (K). Biosolids are usually applied at rates specific to the N needs of the crop, known as the agronomic N rate. Specific nutrient requirements will be different for different crops (corn, for example, has a high N requirement, whereas soybeans do not). Depending on the biosolids treatment process, each type of biosolids will have different total N, P, and K. Studies conducted in Virginia (Faulkner, 2001) and Colorado (Ippolito et al., 2000) estimated the cost savings to the farmer according to the specific nutrient provided by biosolids. On average, the N content of biosolids provided a cost savings to farmers of approximately $25 per acre and the P and K content provided a costs savings of $10 per acre and $6 per acre, respectively. Table A-4 summarizes the range of cost savings presented by these studies.

Table A-4. Cost Savings[a] to Agricultural End-Users According to Nutrient Provided by Biosolids.

Nutrient	Average Value ($/Acre)	Low Value ($/Acre)	High Value ($/Acre)	Number of Sites Studied
N	$24.59	$18.00	$44.00	5
P	$10.70	$9.00	$12.60	3
K	$6.45	$2.55	$12.60	3

[a]These estimates were based on $0.23/lb for N, $0.30/lb for P, and $0.14/lb for K.
Source: Faulkner, 2001.

Cost Savings for Services Provided by Utility Typically, the farmer or commercial fertilizer provider must apply commercial fertilizers and till the fields. Utilities will generally deliver, apply, and incorporate biosolids free of charge, which saves the farmer time and/or money. Fields that have slightly acidic soils may require supplemental lime application; biosolids that have been lime stabilized may eliminate this requirement, creating additional cost savings to the farmer. A study conducted in Virginia (Faulkner, 2001) estimated the cost savings to agricultural end-users associated with services provided by the utility free of charge. These are summarized in Table A-5.

Table A-5. Cost Savings to Farmers Resulting from "No-Cost" Biosolids[a] Application and Incorporation.

Fertilizer Application (Savings/Acre)	Lime Application (Savings/Acre)	Additional Savings Related to Biosolids Incorporation (Savings/Acre)
$4.50-5.50	$50.53	$13.50

[a]Fertilizer contains N, P, K; New Kent County, Virginia.
Source: Faulkner, 2001.

A.4.4 Soil and Crop Improvements (Increased Yield, Protein, and Nutrient Content)

Applying biosolids to agricultural lands can improve soil quality and enhance crop growth. Due to the high organic matter content of biosolids, agricultural land application can:

- Reduce erosion potential
- Facilitate tillage and seedling emergence (by reducing bulk density)
- Mitigate the effects of dry periods during critical growth stages (by increasing the water holding capacity of the soil)
- Improve the soil's ability to retain nutrients (by increasing soil cation exchange capacity) (Moss et al., 2002)

In addition, the organic forms of N and P present in biosolids are released slowly, which allows crops to absorb these nutrients throughout the growing season. Biosolids also contain essential trace elements such as calcium, copper, iron, magnesium, manganese, sulfur, and zinc which can improve deficiencies in the soil (Brown and Henry, 2001).

These improvements to the overall quality and productivity of the soil lead to quantifiable benefits realized by farmers. Crop yields on land amended with biosolids can be as great or greater than land fertilized with commercial fertilizers (Evanylo, 1999). Biosolids application can also increase both grain protein and nutrient content. Studies conducted in Colorado, Utah, and British Columbia measured these improvements. The observed/measured effect of biosolids application on crop yield, grain protein content and nutrient content are summarized in Tables A-6, A-7, and A-8.

Table A-6. Biosolids Land Application: Effect on Crop Yields.

Crop	Increase in Yield (Applying Biosolids)	Increase in Yield (Applying Commercial Fertilizer)	Study (Citation)	Study Description
Dryland winter wheat	15%	NA	CSU[a]	Results from at 18-year project in the region around Englewood, CO, show that biosolids use is an effective alternative to commercial N fertilizer
Alfalfa-oat nurse crop	35%	42%	Utah State[b]	Biosolids application versus inorganic fertilizer (as compared to an untreated control plot)
Grass hay	30%	115%	Utah State[b]	Biosolids application to grass hay resulted in yield that was intermediate between nitrogen fertilizer applied at 150 lb N/acre and an untreated control plot

[a]City of Englewood, 2006.
[b]USU Extension, 2006.

Table A-7. Biosolids Land Application: Effect on Grain Protein Content.

Crop	Increase in Protein, Biosolids	Increase in Protein, Commercial Fertilizer	Study (Citation)	Study Description
Dryland winter wheat	15%	NA	CSU[a]	Results from at 18-year project in the region around Englewood, CO, show that biosolids use is an effective alternative to commercial N fertilizer
Grass hay	23%	14%	Utah State[b]	Biosolids application (versus nitrogen fertilizer applied at 150 lb N/acre) to grass hay as compared to an untreated control plot

[a]City of Englewood, 2006.
[b]USU Extension, 2006.

Table A-8. Increased Mineral Content of Crops Grown with Biosolids.

	(% Increase above Amount Found on Untreated Control Plots)									
	Ca	P	K	Zn	Cu	S	Fe	Mg	Mn	Study
Grasses	100	0	47	72	32	100	29	0	136	GVRD[a]
Legumes	-14	0	19	21	4	200	20	0	37	GVRD[a]
Grass hay	20	38	10	62	106	9	163	10	11	Utah State[b]

[a]Braman, 1997.
[b]USU Extension, 2006.

A.4.5 Environmental Benefits

Reduced Demand for Synthetic Fertilizers The nutrient and organic matter content of biosolids enables farmers to apply biosolids to their fields in lieu of synthetic fertilizers and chemical pesticides. By reducing demand for (and use of) chemical fertilizers, agricultural land application of biosolids indirectly reduces demands on chemical feedstocks as well as the adverse impacts associated with agricultural chemical production, storage, and transport.

Potential Water Quality Benefits Nonpoint source pollution to surface- and groundwaters is sometimes attributed to agricultural practices (e.g., use of livestock manures, commercial fertilizers, agricultural chemicals). Application of additional nutrients to agricultural lands coupled with steep slopes and wet weather can result in runoff containing concentrations of nutrients that could negatively impact nearby waters. As an alternative to other nutrient sources, some research indicates that biosolids may not have as large of a negative impact on water quality. The organic forms of N and P present in biosolids are not as soluble as those in chemical fertilizers and are less likely to leach into groundwater or runoff into surface waters (U.S. EPA, 2000c). In a study assessing P availability, as defined by water extractable phosphorus (WEP), Brandt et al. (2001) found that the WEP in biosolids (3%) was substantially lower than that found in dairy manure (48%) or triplesuperphosphate fertilizer (85%). On a study farm in Virginia, lower or similar transport rates for total suspended solids, N and P can occur from applications of biosolids compared to commercial fertilizer (Evanylo and Ross, 1997). Furthermore, the regulations for biosolids (Part 503 rule) are designed to limit potential movement of excess nutrients to water, whereas such rules do not apply to commercial fertilizers or manures.

Applying biosolids to agricultural lands rather than commercial fertilizers may reduce the risk of nutrient loadings (particularly N and P) to local streams and lakes, thus reducing the risk of eutrophication. Any potential environmental benefit of biosolids use as an alternative to other fertilizers is, of course, dependent on the composition of the biosolids, the location and conditions of the application site, the application rate, and general farming practices employed by the agency and the farmer.

A.5 Risks, Concerns, and Costs

Risks to Human Health Applying biosolids to agricultural lands may pose risks (perceived or real) to human health. Federal regulations (the Part 503 rule) set standards for pathogen reduction, chemical limits on eight specific elements (though hundreds of compounds may be present in sludge), and management practices. Biosolids are nonetheless a product of household, commercial and industrial wastewaters, which contain contaminants. These contaminants include pathogens (e.g., viruses and bacteria), pharmaceuticals, organic chemicals, and metals. The potential risks and concerns associated with these contaminants are addressed in Appendix E.

Limits, Restrictions, and Potential Bans on Application Agricultural land application does not ensure the long-term viability of an agency's biosolids management program. There are several factors beyond the control of the agency that could limit, restrict, interrupt, or even prevent an agency from employing agricultural land application as part of a biosolids management program. These include:

- **A Potential Increase in Population:** Biosolids application rates on agricultural lands are limited by the agronomic needs of the crop. If the population in a municipality increases, then the volume of biosolids produced will increase. Since regulations restrict the rate at which biosolids can be applied to agricultural lands according to crop needs, the agency will have to secure additional acreage to maintain a land application program.

- **Management Decisions by Farmers:** Farmers and other end-users generally do not have a long-term contract with the wastewater agency and can "cancel" their receipt of biosolids at any time, which is essentially the same as eliminating a portion of the agency's land application program.
- **Harvesting Schedules and Inclement Weather:** Agricultural land application requires the agency to plan transportation and application at times that are compatible with planting and harvesting schedules. Particularly wet weather may make some farm roads inaccessible or some fields too soft to accommodate the application equipment. There may also be restrictions or physical limitations on winter application in some regions, particularly after the ground has frozen. Agricultural demand for biosolids may fluctuate throughout the year.
- **Public Perception:** Regardless of whether public opposition to agricultural land application stems from the odors associated with biosolids, the risks (both real and perceived) that biosolids may pose to human and environmental health, or any other negative perception of the disposal method, public outcries against land application can lead to opposition by public officials and/or changes to local and regional restrictions. Ultimately, these issues may lead to significant limitations or bans on agricultural land application. In several communities throughout the country, such as Kern County, California, bans on land application of Class B biosolids are already in place.

Odors and Traffic The odors associated with biosolids can be a nuisance to neighbors, particularly during the unloading and application process. These may prompt complaints from affected parties, motivated by the unpleasant smell itself and/or by a perceived (and perhaps real) mental association of the odors with the potential to pose health risk. Odors and associated concerns can impose considerable loss of welfare on the impacted individuals. Odors can create political pressure that may ultimately preclude or limit the utility's ability to continue to apply biosolids at the sites (e.g., by leading to bans on some land application options and/or sites, as mentioned in the previous section).

The agency and farmer can work together to try to reduce the nuisance caused by biosolids odor by 1) selecting the appropriate biosolids stabilization process (products of aerobic digestion, heat treatment, and composting tend to result in the least objectionable odors); 2) avoiding overnight (or longer) storage at the application site; 3) incorporating (tilling) the biosolids into the fields, rather than simply surface applying the biosolids; 4) factoring in weather conditions when applying biosolids (e.g., spreading in the morning when air is warming and rising may help dilute the odor); 5) timing applications to minimize public exposure (e.g., avoid applications on weekends when neighbors are more likely to be outside recreating); and 6) if necessary, postponing or canceling land application at sites when the odors are deemed too offensive (the biosolids programs in both Denver and Washington, D.C., for example, send a staff member to sites to determine if odors are "unacceptable).

A similar nuisance and possible public safety risk stems from the added truck traffic along routes used to transport biosolids from utilities to land application sites. Accessing these sites often requires travel along dirt roads; deliveries during dry weather conditions may create dust and noise disturbances. Because biosolids are inevitably going to exist and be moved from utilities to some other location (regardless of what disposal or beneficial use option is adopted), the issue for any given utility is how the congestion, noise, and risk associated with biosolids transport may differ from one option to another. For example, the key question may be whether trucking to a landfill for disposal and/or energy recovery, as compared to trucking to a land application site, will likely add to the net traffic congestion and road risk (or might it reduce such costs and risks)?

Nutrient Loading and Water Quality Concerns Although the organic forms of N and P present in biosolids are not as soluble as those in chemical fertilizers, as mentioned in Section A.4.4, Environmental Benefits, of this appendix, as with any fertilizer, the potential for excess N or P to affect surface or groundwater quality is still a negative environmental concern with land application of biosolids. When excess nutrients are present in soil (which can result from the application biosolids, manure, or chemical fertilizers) erosion, extreme rainfall events causing surface runoff, or longer-term groundwater flows can lead to nonpoint source pollution of nearby surface waters. Nutrient loading to water bodies (eutrophication) can lead to low oxygen levels that negatively affect aquatic life. Sites where biosolids are stockpiled prior to application pose a greater risk of pollution than those where biosolids are applied immediately upon delivery.

The regulations on land application (e.g., for Class B, steep slopes must be avoided and applications are prohibited within a certain distance of a water body) are designed to minimize these negative environmental impacts. When the regulations are followed, the risks associated with land applying biosolids (as compared to commercial fertilizers and manures) are relatively small (Chaney et al., 1996; Faulkner, 2001; U.S. EPA, 2003). As previously mentioned, the impact of land applied biosolids on nearby waters inevitably depends on the composition of the biosolids, the location and conditions of the application site, the application rate, and general farming practices employed by the agency and the farmer.

Costs Wastewater agencies typically are responsible for delivering biosolids to agricultural land application sites, so hauling distances can have a sizeable impact on the costs incurred by the agency. Although some agencies may only need to drive 40 or 50 miles round-trip to reach agricultural sites, others (such as King County, Washington) may have to deliver to sites over 200 miles away, and still others may have to send their biosolids to end-users over a thousand miles away (as is the case for agencies in Boston and New York). The volume of biosolids produced (which will depend on the volume of effluent as well as the type of biosolids treatment employed) will affect the number truckloads an agency must send out to land application sites. Clearly, transportation costs incurred by the agency will be directly correlated with the volume of biosolids the agency produces. Agricultural land application, like any other biosolids end use that requires transport (including land filling, mine land reclamation, and even some composting programs) is subject to increasing fuel costs and potential volatility in the fuel market.

APPENDIX B

LAND APPLICATION AT RECLAMATION SITES

B.1 Introduction

Land application of biosolids is a long-standing and widely used practice, and has been the subject of considerable scientific investigation and review. As a result, land application using best practices and in accordance with federal and state regulations is widely viewed as a beneficial use of biosolids that poses minimal and acceptable risk. Nonetheless, there remain several open scientific questions and uncertainties that lead some individuals and organizations to remain highly concerned about some risks that may be associated with land application. Hence, land application remains a controversial issue in biosolids management.

In this project in general, and this appendix in specific, the researchers attempt to offer a open and objective summary of the benefits, costs, and potential risks associated with land application. Their aim is to provide information in a balanced manner, and to indicate to readers what the issues are, what the science suggests, and where they can obtain additional information. The researchers do not seek to resolve the remaining conflicts, nor do they endorse one set of views over the others. They simply try to state the issues, present the data, and point readers to additional resources.

Finally, a core goal is to apply a constructive *comparative* context that reflects the fact that “biosolids happen”—i.e., biosolids will exist and they need to be managed in some fashion. Thus, land application—and its associated benefits, costs and risks (real, potential, or perceived)—needs to be viewed in comparison to alternative biosolids management options. The overall intent of the benefit-cost framework developed in this report is to facilitate such comparative analyses.

Overview of Land Application According to the U.S. EPA, land application accounts for 68% of beneficial use of biosolids (U.S. EPA, 1999). Land application involves spreading or spraying biosolids on the soil surface (e.g., pastures, rangeland, or reclaimed mine lands) or incorporating (tilling) the biosolids into the soil for producing row crops and other vegetation. Applying biosolids to land recycles nutrients, minerals and organic matter back to the soil while reducing the amount of wastes that may otherwise be incinerated or sent to landfills. The organic matter in the biosolids helps to improve soil tilth, root penetration, moisture retention, and the soil’s ability to retain and provide nutrients (Evanylo, 1999). As a result, land application of biosolids can benefit vegetation or re-vegetation efforts, landscaping practices, turf growth, forest establishment, crop production, and other efforts.

Two of the most common applications of biosolids are to agricultural lands and reclaimed mine sites. This appendix focuses on benefits and risks associated with mine site reclamation using biosolids. Land application at agricultural sites is discussed in greater detail in Appendix A.

Overview of Reclaimed Mine Lands The term “reclaimed mine lands” refers to the sites of active or former mining operations. The surface mining of coal, iron ore and other minerals, the accumulation of waste rock and mine spoils from underground mines, and the generation of piles of mill tailings, are just a few of the mining-related activities that have created over 3.7 million acres of disturbed land in the United States (U.S. EPA, 1995).

By removing topsoil, nutrients, and vegetation, mining activities drastically affect the physical, biological and chemical properties of the land. Without remediation, disturbed lands generally are not able to support permanent vegetation. This is a result of several conditions common to reclaimed mine sites, including:

- Lack of nutrients
- Poor water-holding capacity
- Acidic or alkaline tailings and soils
- Presence of contaminants
- Low amounts of organic matter and soil microbes
- Steep slopes subject to erosion

Depending on the type of mining activity and the location and age of the mine site, restoration may be required by state or federal regulations or simply encouraged (e.g., as a Best Management Practice). In the case of surface mining, for example, federal regulations require mining companies to 1) return the land to roughly its original contour, 2) reestablish vegetation, and 3) create a site capable of supporting the pre-mining land use (The Surface Mining Control and Reclamation Act of 1977, 2006).

Conventional reclamation techniques include 1) grading the surface of the site to slopes that minimize erosion, and 2) adding topsoil, lime, and/or commercial fertilizers to facilitate revegetation. These methods are not always effective in reestablishing permanent vegetation or a productive land use.

Overview of Biosolids Application on Reclaimed Mine Lands Biosolids have been used at mine sites to establish sustainable vegetation, as evidenced by successful demonstrations projects in at least 20 states (U.S. EPA, 1995) and in British Columbia (Duynstee, 2002). Although the conditions of the disturbed lands at reclamation sites can vary regionally and according to the type of mining activity, and the properties of the biosolids vary depending on the treatment process, the general benefits of biosolids use at reclamation sites seem to be widely accepted (Sopper, 1993; U.S. EPA, 1995; Toffey et al., 1999; Brown and Henry, 2001; Jenness, 2001; Duynstee, 2002; MDNR, 2004).

According to the Minnesota Department of Natural Resources, “of all the organic amendments tested over the years (including municipal solid waste, yard waste and paper mill waste), biosolids seem to be the most practical and economical way to increase fertility on reclamation sites” (MDNR, 2004). In addition to the macronutrients that chemical fertilizers supply (e.g., N and P), biosolids contain various micronutrients as well as organic matter. The organic matter in the biosolids helps to remedy some of the conditions listed above that make the soils at mine sites unfavorable to plant growth. In particular, organic matter 1) increases water holding capacity, 2) increases and buffers soil pH, 3) enhances the development of microbial communities, and 4) improves soil stability.

B.1.1 Affected Parties

All end-use options affect the agency responsible for processing and managing biosolids. Mine site reclamation can be a cost effective component of an agency's biosolids management program, although agencies face the risk that future changes to local regulations could limit (or eliminate) this beneficial use option. Mine site managers realize benefits of biosolids application through cost-effective fertilization and the associated benefits of improved soil quality and vegetative growth. The delivery and application of biosolids to mine sites may create nuisances to neighbors and risks (either real or perceived) to the environment and society as a whole. As an alternative to chemical fertilizers, however, biosolids in many cases have demonstrated greater efficacy for restoration and may have additional environmental benefits, such as improved water quality. Increased carbon sequestration as a result of successful revegetation at mine sites may help mitigate a portion of greenhouse gas emissions (Sperow, 2006).

Table B-1 summarizes the various parties affected by mine site application of biosolids (including the level and type of impact this disposal method has on each party). The benefits and risks listed in Table B-1 are discussed in further detail in subsequent sections of this appendix.

Table B-1. Affected Parties.

Affected Party	Benefits	Risks	Costs
Agency	Potential costs savings (compared to other biosolids management alternatives) Higher application rates (compared to agricultural land application)	Potential limits (or bans) on land application (probably a greater risk with Class B biosolids)	Transportation costs
Mine site managers (and other end-users)	Avoided commercial fertilizer and soil amendment costs Improved soil quality and vegetative establishment Increased likelihood of release of liability under the Surface Mining Control and Reclamation Act		
Neighbors		Odors Traffic	
Environment and society as a whole	Water quality benefits (due to reduced erosion and reduced acid mine drainage) Reduced demand for chemical fertilizers	Water quality risks (due to increased nutrient concentrations in soils) Contamination risks (pathogens, pharmaceuticals, metals, and other chemicals)	

B.1.2 Benefits

B.1.2.1 Benefits to the Agency

While the extent to which biosolids can be used for mine reclamation is subject to conditions specific to each agency, including 1) the agency's geographic location and proximity to reclamation sites, and 2) the type of biosolids produced and the nutrient deficiencies at the mine site, it is, nonetheless, a viable management option. Agencies generally find that application at mine sites is a relatively cost-effective and straightforward method of putting biosolids to beneficial use. As mine sites generally require high loading rates of amendments (either biosolids or another nutrient source), a single mine site can provide an opportunity for the agency to apply a large quantity of biosolids.

Cost-Effective and Straightforward Management Option As an alternative to other biosolids management options that may require larger capital investments, disposal fees (such as tipping fees at landfills), the purchase of amendments (such as sand for soil enhancement products), research and development, or marketing efforts, mine land reclamation offers potential time- and cost-savings benefits to wastewater treatment agencies. Local regulations permitting, either Class A or Class B biosolids can be applied to mine sites. Wastewater treatment agencies should be able to continue with (or initiate) biosolids application at mine sites without making changes to the treatment process already in use at their facility. Furthermore, since the processing, delivery and application can all be handled by the agency, the agency is able to retain control of the biosolids throughout each step of this management scheme.

Increased Reliability

- **Mine reclamation as an alternative to agricultural land application.**

Land application of biosolids for restoration purposes is generally a one-time application and is usually exempt from regulations that apply to agricultural application. Biosolids application rates at reclamation sites are often higher than the agronomic rate (which limits the amount of biosolids that may be applied to agricultural soils). Successful application rates ranging from 3 to 400 dry tons per acre have been reported, but the typical reclamation application rate is approximately 50 dry tons of per acre per year (U.S. EPA, 1995). Biosolids application rates on agricultural lands are lower, ranging from 1 to 10 dry tons per acre per year (U.S. EPA, 1995; Ippolito et al., 2000; Faulkner, 2001). The typical agricultural application rate is 5 dry tons per acre per year. Applying biosolids to reclaimed mine lands allows the agency to utilize approximately five times more biosolids per acre than would be permitted at most agricultural sites.

Land application for restoration purposes (as compared to agricultural purposes) may be less likely to be limited by factors beyond an agency’s control, such as harvesting schedules and weather conditions (wet field conditions during spring snowmelt, for example, could prohibit vehicle access to application sites).

As local regulations or public perception issues arise in the future (due to concerns related to odors or pollutant levels), an agency’s number of eligible/permitted acres for land application may decrease. By enabling the agency to dispose of more biosolids per acre, mine land reclamation (as compared to agricultural land application) could reduce the risk of encountering a “disposal crisis.” In addition, since it is unlikely that a suburban community will develop next to a mine site (whereas suburban development near farmed lands is possible), public acceptance of land application is less likely to be an issue at mine sites

- **Mine reclamation as an alternative to landfilling.**

Land application is a biosolids management option that may reduce (or eliminate) the amount of biosolids going to landfills. Since there is only a finite amount of space available at landfills, land application of biosolids contributes to extending the useful life of the local landfill. In effect, this leaves more room for MSW, which is a benefit to the municipality (or whichever party is responsible for MSW disposal).

B.1.2.2 Benefits to Mine Site Managers (and Other End-Users)

Avoided Commercial Fertilizer Costs Traditional remediation techniques for reclamation sites include stockpiling and reusing topsoil (which is often infertile), then applying lime and commercial fertilizers to initiate vegetative growth. The type and amount of commercial fertilizer used for reclamation varies depending on conditions specific to the site, including: pre-mining characteristics of the soil, type of mining, post-mining soil conditions, and proposed end use for the land. Total commercial fertilizer costs for reclaiming a mine site also vary depending on type of fertilizer used, size of the site, and the number of applications (e.g., one-time application or application twice a year for five years). This appendix presents a range of likely commercial fertilizer costs for reclamation using the range of recommended fertilizer application rates and a range of typical fertilizer prices.

Average commercial fertilizer prices in the United States in 2005 ranged from \$215 to \$416 per ton (USDA, 2006); Table B-2 provides the average cost of 8 specific types of fertilizer. When soil conditions at mine sites are unknown, the typical "rule-of-thumb" recommended fertilizer application rates published in the literature range from 0.15 tons/acre (State of Colorado, 2002) to 0.275 tons/acre (MDNR, 2004). Drawing upon these values, an approximate range of fertilizer costs to mine site managers is between \$32/acre and \$114/acre.

Table B-2. Overall Cost Savings (Per Ton of Commercial Fertilizer Offset by Biosolids Use) to Mine Site Managers (or Other End-Users).

Type of Commercial Fertilizer	Anhydrous Ammonia	Nitrogen Solutions (30%)	Urea (45% N)	Ammonium Nitrate	Sulfate of Ammonium	Super-Phosphate 44-46% Phosphate	Diammonium Phosphate (18-46-0)	Potassium Chloride (60% P)
Cost savings[a] (\$/ton)	\$416	\$215	\$332	\$292	\$244	\$299	\$303	\$245

[a]Average prices of selected fertilizers in 2005.
Source: USDA, 2006.

In certain regions, there may be a standard mine land reclamation practice, in which case determining a rough estimate of the cost of fertilizer for reclamation in that region will be relatively straightforward. In Minnesota, for example, standard mine land reclamation practice for revegetation at taconite (iron ore) tailings is to apply diammonium phosphate fertilizer (DAP) at a rate of 550 lbs per acre (0.275 tons/acre) (MDNR, 2004). The average price of DAP fertilizer is \$303 per ton (USDA, 2006). Applied at a rate of 0.275 tons per acre, the cost to reclamation site managers of DAP fertilizer is approximately \$83 per acre.

Wastewater treatment agencies will typically deliver, apply and incorporate the biosolids free of charge. Depending on the prevailing soil and climatic conditions at the site, fertilizer application may be required one-time or for several years until a vegetative cover has been established. The resulting benefit to the mining company is avoided commercial fertilizer costs ranging from \$32 to \$114 per acre per application. A summary of cost savings benefits is provided in Table B-2.

Vegetation Establishment Benefits Mining companies are responsible for reestablishing a vegetative cover at mine sites. The Surface Mining Control and Reclamation Act of 1977 requires mine lands to be restored to a condition capable of supporting the pre-mining land use. State regulations vary, but in many cases states have specific requirements for vegetation; in

Minnesota, for example, within three years of closure 90% of the disturbed land must be covered with vegetation.

While results will vary from one site to the next depending on initial site conditions, mining activities, and the characteristics of the biosolids, numerous studies have shown biosolids applications to be more successful than commercial fertilizer in establishing vegetation on reclamation sites (U.S. EPA, 1995; Duynstee, 2002; Toffey, 2003; MDNR, 2004; Brown et al., 2005). Examples of successful vegetation establishment with biosolids include cases in Minnesota, Pennsylvania, and British Columbia.

- **Minnesota:** Studies conducted at taconite tailings basins in Minnesota indicate that percent vegetative cover and biomass generally increase as the rate of biosolids application increases. One year after site closure and biosolids application, the percent of vegetative cover was approximately 65% where 3.1 dry tons of biosolids per acre were applied and 85% where 12.4 dry tons per acre were applied (as compared to a vegetative cover of approximately 25% where standard practices had been employed). After four years, over 30% more vegetative cover was established where biosolids had been applied than where standard practices were used (MDNR, 2004).
- **Pennsylvania:** During the past 25 years, over 4,000 acres of mined land in Pennsylvania have been reclaimed using one million tons of municipal biosolids (Toffey, 2003). All sites that have been restored with biosolids in the state have established a 70% vegetative cover after five years, whereas few sites using conventional techniques have been able to do so (Toffey, 2003).
- **British Columbia:** At a copper tailings site in British Columbia, average total biomass was approximately three times higher where biosolids had been land applied than where chemical fertilizers had been used (Duynstee, 2002).

Rapid, successful establishment of permanent vegetation provides benefits to the mining company by reducing the amount of time and money spent on administering and managing sites after mining operations cease. In some cases, such as coal mining, this provides an additional monetary benefit. Federal law requires coal mining companies to post bond; the release of bond monies is contingent on meeting specific reclamation standards. The final 15% of the bond is only released if the site exhibits 70% vegetative cover after five years (this is referred to as the stage 3 requirement).

Improved re-vegetation has additional benefits to society, including less wind- and water-based erosion, increased carbon sequestration, and enhanced habitat restoration. These benefits are addressed in subsequent sections of this appendix.

B.1.2.3 Environmental Benefits

Reduced Demand for Synthetic Fertilizers The organic matter and nutrient content of biosolids enables mining companies to utilize biosolids at reclamation sites in lieu of synthetic fertilizers. By reducing demand for (and use of) chemical fertilizers, land application of biosolids indirectly reduces demands on chemical feedstocks as well as the adverse impacts associated with synthetic chemical production, storage, and transport.

Soil and Water Quality Benefits Land application of biosolids at reclaimed mine sties reduces erosion potential, both through improved soil quality and increased vegetative cover. Following biosolids application, the soil is better aerated allowing water to infiltrate the soil rather than eroding off the soil surface. The nutrient content in biosolids enhances plant growth and the organic matter content in biosolids increases cation exchange capacity (which improves the soil's ability to retain nutrients). These features help facilitate more rapid re-vegetation at reclamation sites, which reduces the potential for windblown dust and erosion (and the subsequent sediment loading to nearby water bodies).

Acid mine drainage (drainage of water that has a particularly low pH as a result of contact with mine spoils), is a serious problem at many abandoned mine sites throughout North America. Although no comprehensive study has been conducted, monitoring data collected in Pennsylvania suggests that acid mine drainage is significantly reduced at sites where biosolids have been applied (Toffey, 2003). Lime stabilized biosolids may offer the added benefit of simultaneously providing lime organic material that can help stabilize the pH and improve the stability of the soil to prevent water runoff (Hunley, 2002).

The addition of nutrients to soils (through the application of fertilizers and/or soil amendments) improves vegetative growth, but also increases the potential for those nutrients to reach the groundwater or nearby surface waters. As an alternative to other nutrient sources, some research indicates that biosolids may not have as large of a negative impact on water quality. The organic forms of nutrients, such as N present in biosolids are not as soluble as those in chemical fertilizers and are therefore less likely to leach into groundwater or runoff into surface waters (U.S. EPA, 2000b). In a study assessing phosphorous availability, as defined by WEP, Brandt et al. (2001) found that the WEP in biosolids (3%) was substantially lower than that found in dairy manure (48%) or triplesuperphosphate fertilizer (85%). Using biosolids at reclamation sites rather than commercial fertilizers may reduce the risk of nutrient loadings (particularly N and P) to local streams and lakes, thus reducing the risk of eutrophication.

The potential for nutrients (particularly N) to be present in ground water and surface waters in concentrations above drinking water standards (as a result of high application rates) should not be ignored; these risks are addressed in a subsequent section of this appendix.

Wildlife Habitat Benefits Utilizing biosolids to restore a vegetative cover at reclaimed mine sites may have the added benefit of enhancing wildlife habitat. Several biosolids programs throughout the United States have experienced increases in wildlife on and around land application sites. A study conducted in Leadville, Colorado, concluded that a tailings site initially incapable of supporting an earthworm population (an important component of many self-sustaining ecosystems), was able to support such a population after the soil was amended with biosolids (Brown et al., 2005). In Everett, Washington, for example, biosolids were used to restore a wetland habitat; the biosolids helped to stabilize the slopes and provide the nutrients required by the native wetland species (NBMA, 2004). In Pennsylvania, numerous mine sites that were at one time barren are now home to grasshopper, mice and vole, turkey, and deer populations (Toffey, 2003).

Quantification of Carbon Sequestration Reclaimed mine sites offer a potential carbon sink that may help mitigate a portion of GHG emissions. Carbon sequestration refers to the uptake and storage of carbon. Carbon may be sequestered in above- or belowground biomass (e.g., trees, grasses, or other vegetation) as well as in soils. Sequestration rates vary depending on the geographic location of the site as well as the end use for the land (e.g., pasture, forest, or cropland) (Sperow, 2006). Sperow (2006) reviewed over 10 studies on carbon sequestration rates on reclaimed mine lands in the United States. Table B-3, which presents the average, minimum,

Table B-3. Carbon Storage by Land Use.

Land Use (*C Sink Component*)	C Sequestered (Tons/Acre/Year)		
	Average	Minimum	Maximum
Forest *(total)*	1.04	0.24	1.66
Forest *(biomass)*	0.76	0.24	1.34
Forest *(litter)*	0.11	-0.08	0.36
Forest *(soil)*	0.26	-0.08	0.73
Pasture *(soil)*	0.57	0.38	0.77
Cropland *(soil)*	0.38	0.10	0.81

and maximum values of C storage according to the end use for the land and the component of the land where the carbon is accumulating (e.g., soil, biomass or litter), summarizes Sperow's findings.

According to the IPCC (1998), soil accumulation of carbon on reclaimed mine sites in particular, ranges from 0.04 to 2.8 Mt of carbon per acre per year; and the most like rate is 0.1 ton/acre/yr (IPCC, 1998). Although the volume of carbon sequestered depends on the location of the site and the post-reclamation land-use, forests appear to present the greatest carbon sink potential.

There is not yet a "rule of thumb" for estimating the exact amount of CO_2 offset per acre of mine lands reclaimed using biosolids (due to the numerous variables affecting this estimate, such as geographic location and end use of the land). To put carbon sequestration in perspective, however, the researchers considered the amount of reclaimed land that must be converted to forests to offset the CO_2 emissions from a medium sized coal-fired power plant. Assuming roughly 1 metric ton of carbon is sequestered per acre of forestland per year (from Table B-3) and utilizing estimates by the National Energy Technology Laboratory,[1] approximately 660,000 acres of disturbed land would need to be converted to forest. The development of these estimates did not consider the use of high carbon residuals, which could actually lead to greater carbon sequestration rates (Sally Brown, Research Associate Professor, University of Washington, personal communication, January 2007). While it may not be realistic for a single agency to try to apply biosolids to over half a million acres of disturbed lands, partnering with a power plant may create a potential benefit for both agencies. For example, it is expensive to capture the last 5-10% of carbon dioxide emissions from a fossil fuel conversion plant, due to the law of diminishing returns. A cost-effective approach for zero emissions might be to capture 90% of emissions and offset the remaining 10% with forest land (NETL, 2006).

B.1.2.4 Monetization (Valuation) of Carbon Sequestration

There are several carbon trading exchanges from which a monetary value for CO_2 emissions can be derived. The two most well-known exchanges are the European Union Trading Scheme and the Chicago Climate Exchange. The values from these exchanges range from $1.50

1. NETL (2006) estimates that "about 220,000 acres would be required to offset emissions from a average size power plant. This assumes an average coal power plant from the existing fleet and a forest uptake rate of 3 tons of carbon per acre per year."

to \$18 per ton of CO_2. For simplicity, the researchers combine these and assume approximately \$10/ton. Further discussion of carbon valuation is provided in Appendices C and D.

A biosolids management program that includes land application at reclaimed mine sites may contribute to offsetting GHG emissions, a benefit realized globally.

B.1.2.5 Risks, Concerns, and Costs

Risks to Human Health Land application of biosolids may pose risks (perceived or real) to human health. Although federal regulations (the Part 503 rule) set standards for pathogen reduction, chemical limits on eight specific elements (though hundreds of compounds may be present in sludge), and management practices, biosolids are nonetheless a product of household, commercial and industrial wastewaters, which contain contaminants. These contaminants include pathogens (e.g., viruses and bacteria), pharmaceuticals, organic chemicals and metals. The potential risks and concerns associated with these contaminants are addressed in Appendix E.

Limits, Restrictions, and Potential Bans on Application Mine land application does not ensure the long-term viability of an agency's biosolids management program. There are a couple of factors beyond the control of the agency that could limit, restrict, interrupt or even prevent an agency from employing mine land application as a biosolids management option. These include:

- **Management Decisions by Mining Companies:** Mining companies and other end-users generally do not have a contract with the wastewater agency and can "cancel" their receipt of biosolids at any time, which is essentially the same as eliminating a portion of the agency's land application program.
- **Public Perception:** Regardless of whether public opposition to land application stems from the odors associated with biosolids, the risks (both real and perceived) that biosolids pose to human and environmental health, or any other negative perception of the management option, public outcries against land application can lead to opposition by public officials and/or changes to local and regional restrictions. Ultimately, these issues may lead to significant limitations or bans on land application. In several communities throughout the country, such as Kern County, California, bans on land application of Class B biosolids are already in place.

Odors and Traffic The odors associated with biosolids can be a nuisance to neighbors, particularly during the unloading and application process. These may prompt complaints from affected parties, motivated by the unpleasant smell itself and/or by a perceived (and perhaps real) mental association of the odors with the potential to pose health risks. Odors and associated concerns can impose considerable loss of welfare on the impacted individuals. Odors can create political pressure that may ultimately preclude or limit the utility's ability to continue to apply biosolids at the sites (e.g., by leading to bans on some land application options and/or sites, as mentioned in the previous section).

The agency and mine site manager can work together to try to reduce the nuisance caused by biosolids odor by 1) selecting the appropriate biosolids stabilization process (products of aerobic digestion, heat treatment, and composting tend to result in the least objectionable odors); 2) avoiding overnight (or longer) storage at the application site; and 3) factoring in weather conditions when applying biosolids (e.g., spreading in the morning when air is warming and rising may help dilute the odor).

A similar nuisance and possible public safety risk stems from the added truck traffic along routes used to transport biosolids from utilities to land application sites. Accessing these sites often requires travel along dirt roads and deliveries during dry weather conditions may create dust and noise disturbances. Because biosolids are inevitably going to exist and be moved from utilities to some other location (regardless of what disposal or beneficial use option is adopted), the issue for any given utility is how the congestion, noise, and risk associated with biosolids transport may differ from one option to another. For example, the key question may be whether trucking to a landfill for disposal and/or energy recovery, as compared to trucking to a land application site, will likely add to the net traffic congestion and road risk (or might it reduce such costs and risks)?

Nutrient Loading and Water Quality Concerns Although the organic forms of N and P present in biosolids are not as soluble as those in chemical fertilizers, as mentioned in the "Environmental Benefits" section of this Appendix, the potential for excess N or P to affect surface or groundwater quality is still an environmental concern related to land application of biosolids. When excess nutrients are present in soils (which can result from the application biosolids, manure or chemical fertilizers), erosion, extreme rainfall events causing surface runoff, or longer-term groundwater flows can lead to nonpoint source pollution of nearby surface waters. Nutrient loading to water bodies (eutrophication) can lead to low oxygen levels that negatively affect aquatic life.

Since biosolids are often applied at reclamation sites at relatively high rates (as much as 10 times the agronomic rate) to provide the necessary organic matter to the disturbed soils, excess concentrations of N and P are usually present, too. Studies conducted at or near reclamation sites in Pennsylvania, Virginia, and the Pacific Northwest where biosolids have been applied found elevated levels of nitrogen in the groundwater (Brown, 2006c). In some cases the concentrations were above the drinking water standards, but generally remained above regulatory limits for a limited amount of time (typically during the winter of the first year following application) (Brown, 2006c). Some studies suggest that one way to mitigate the risk of nitrogen leaching to groundwater is to add a high carbon material to the biosolids product during land application (Brown, 2006c).

The CFR Part 503 regulations on land application of biosolids were established based on the belief that the short term potential increase in groundwater nitrate levels over a limited area would not pose a serious threat to groundwater quality (U.S. EPA, 1995). The magnitude of the impact of land applied biosolids on nearby waters will depend on the composition of the biosolids and the application rate, as well as the location and conditions of the reclamation site.

Costs Wastewater agencies typically are responsible for delivering biosolids to reclaimed mine land sites, so hauling distances can have a sizeable impact on the costs incurred by the agency. The volume of biosolids produced (which will depend on the volume of effluent as well as the type of biosolids treatment employed) will affect the number truck-loads an agency must send out to land application sites. Clearly, transportation costs incurred by the agency will be directly correlated with the volume of biosolids the agency produces. Mine land reclamation, like any other biosolids end use that requires transport (including land filling, agricultural land application, and even some composting programs) is subject to increasing fuel costs and potential volatility in the fuel market.

APPENDIX C

ENERGY RECOVERY

C.1 Introduction

When wastewater is treated, energy is lost in the form of heat, waste gases, and gas pressure changes. Since the drying of biosolids requires relatively high temperatures, a substantial amount of energy can be lost. There are several industrial processes that can recover this emitted energy and use it productively for on-site use. This energy can be used to displace part or all of the energy input needs for operation of the facility. The energy recovery process also produces excess heat that can be used to treat biosolids. The combined recovery of power and heat decreases the demand for traditional energy and heat sources from outside suppliers, thus reducing overall emissions of greenhouse gases and other air pollutants, and increasing the reliability (and lowering the cost) of the power and heat source.

There are several industrial processes that recover and recycle energy. These include anaerobic digestion, thermal oxidation, thermal drying, and biogasification.

Anaerobic digestion uses the process of bioenergy conversion to change volatile solids into biogas. Biogas is used to either produce hot water or steam in boilers, or to produce both electricity and heat in combined heat and power (CHP) systems. Recovered heat is usually adequate to meet the plant's space heating requirements and the heating requirements of the anaerobic digester process. Systems can generate enough electricity to provide as much as 60% of the plant's average electricity needs (Water Environment Federation, 1999).

Thermal oxidation turns biosolids into an energy source, producing carbon dioxide, water, and the inert material called ash. Thermal oxidation is generally carried out in one of two types of reactors, fluidized bed or multiple hearth. Although multiple-hearth reactors are more prevalent, virtually every new thermal oxidation facility built in the past 15 years has used a fluidized-bed unit. Fluidized-bed reactors can be highly energy-efficient and can become autogenous, or self-sustaining without auxiliary fuel, when the combustion air is preheated to high temperatures (1,000 to 1,200°F). These entirely self-fueling reactors actually recover more energy—in the form of heated air, gas, steam, water, or oil, any of which can be converted to electricity—than they use. Fluidized-bed reactors' rapid combustion gives them generous processing capacity. And, properly outfitted, they comply with all recent stringent emissions regulations (Water Environment Federation, 1999).

Thermal drying reduces the volume and mass of solids by evaporating their water content. High temperatures can also help meet U.S. EPA requirements for Class A and EQ biosolids. There are two general categories of thermal dryers: direct and indirect. Direct thermal dryers heat air or gas, which then comes into direct contact with wet solids and heats them to evaporation temperature. The dried material is separated from the warm exhaust gas, screened, and either recycled back to the dryer as seed material for the drying process or stored in silos. Exhaust gas is either cooled and recycled or treated and released into the atmosphere. Indirect thermal dryers use steam, hot water, or hot oil to heat a metal surface over which the solids are passed. The solids, which never directly contact the steam, water or oil, are heated to evaporation temperature by conduction. Exhaust is sent to a condenser, and exhaust and odors are either combusted in the furnace that produces the steam, hot water, or hot oil, or may be passed through another process for subsequent treatment (Water Environment Federation, 1999).

Biogasification uses heat and a chemical reaction to convert larger-molecule nonfossil biomaterials such as municipal solids into smaller molecule combustible gas products. A wide range of devices can then be used to convert biogas to energy, including gas turbines, reciprocating engines, and hydrogen-powered fuel cells, and recent innovations have helped to lower capital costs and increase efficiency. One such advancement uses hydrogen from the biogasification process to produce electrical current (Water Environment Federation, 1999).

C.2 Overview

The costs and benefits of energy recovery vary across process and plant size. This appendix provides a guide to assessing these costs and benefits by providing spreadsheet templates that calculate and summarize monetized and qualified costs and benefits while allowing for specific inputs to account for this variation. This appendix also provides partially filled-in versions along with guidance on how to estimate values for several key variables.

C.3 The Steps

Figure C-1 provides a visual road map to users as they examine the accompanying template and spreadsheet tool material.

The following templates are intended to help guide users and provide a systematic way to monetize the benefits and costs of the energy recovery process and organize and present the information. The accompanying spreadsheet contains worksheets (referred to here as templates) that assist in the steps labeled 1-7.

The processes of defining and recording baseline information and defining the type of energy recovery process that will be evaluated do not have templates. These typically will entail considering what the future will look like in terms of purchasing energy (in the form of both power and heat) from typical providers, along with the associated costs and emissions. A detailed discussion of estimating current power and heat quantities, prices, and emissions is provided below and will be used in Step 3 for monetizing benefits. The process of defining the type of energy recovery process being evaluated includes information on the type of process (e.g., anaerobic digestion, CHP), the size and costs associated with the process, other entities associated with the project, key project dates, and key project stakeholders.

Steps 1 and 2 on the worksheet labeled “Identification.Ben&Cost” are part of a screening analysis for identification of project benefits and costs. The “Benefits & Costs Screening” button will open a user input form. For each benefit or cost, the user is asked to determine if the item can be monetized or should instead be given a qualitative assessment.

Figure C-2 illustrates the blank user input form for Steps 1 and 2 (Benefit & Cost Screening).

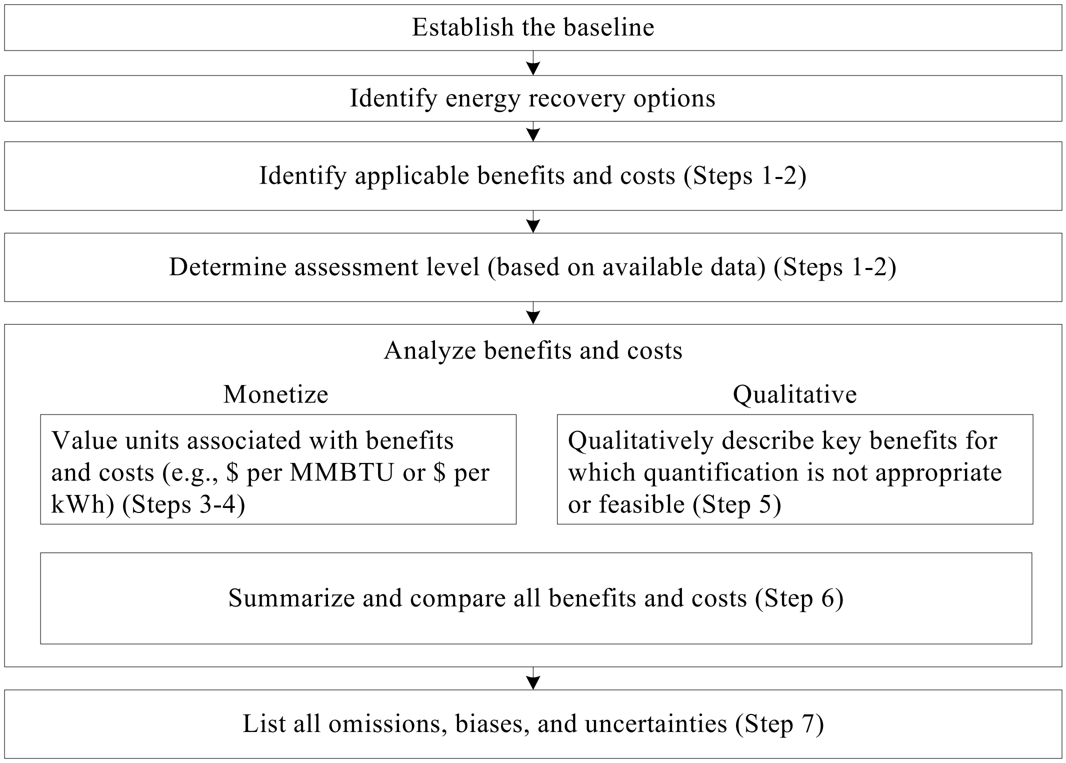


Figure C-1. Steps in the Energy Recovery Benefit-Cost Framework.

Since all energy recovery projects off-set power and heat purchases from an outside provider, the template is set up to walk the user through the monetization process of these benefits (however, if for some reason the user does not want to monetize these benefits, they may select to qualify these benefits or ignore them entirely). Similarly, as power and heat purchases decrease, emissions of air pollutants from traditionally generated energy also decrease. These are also listed as benefits that can be monetized (but the user can opt not to monetize these).

The increased reliability of energy supply is also listed as a benefit as it, too, is applicable to all energy recovery processes.

Two blank spaces are provided for both Step 1 and Step 2 to allow users to include additional, user-specified benefits and costs. These may be monetized or evaluated qualitatively if data are not available.

Steps 3 and 4 provide templates to monetize the benefits (Step 3) and costs (Step 4) identified in Steps 1 and 2. For each benefit or cost category identified for quantitative assessment in the Step 1, the tool will set up a section for valuation. A separate worksheet will calculate the present value. The user can enter the quantity associated with that benefit (e.g., kWh) and the range of $/unit values associated with that item. Users can also enter a discount rate, base year (year in which the project is expected to begin), and expected life-time of the energy recovery project. These inputs will be used to calculate the present value of each benefit and cost over time. Please note that the present value calculations are programmed on worksheets “PV_benefits” and “PV_costs.” These are locked worksheets that cannot be viewed by the user.

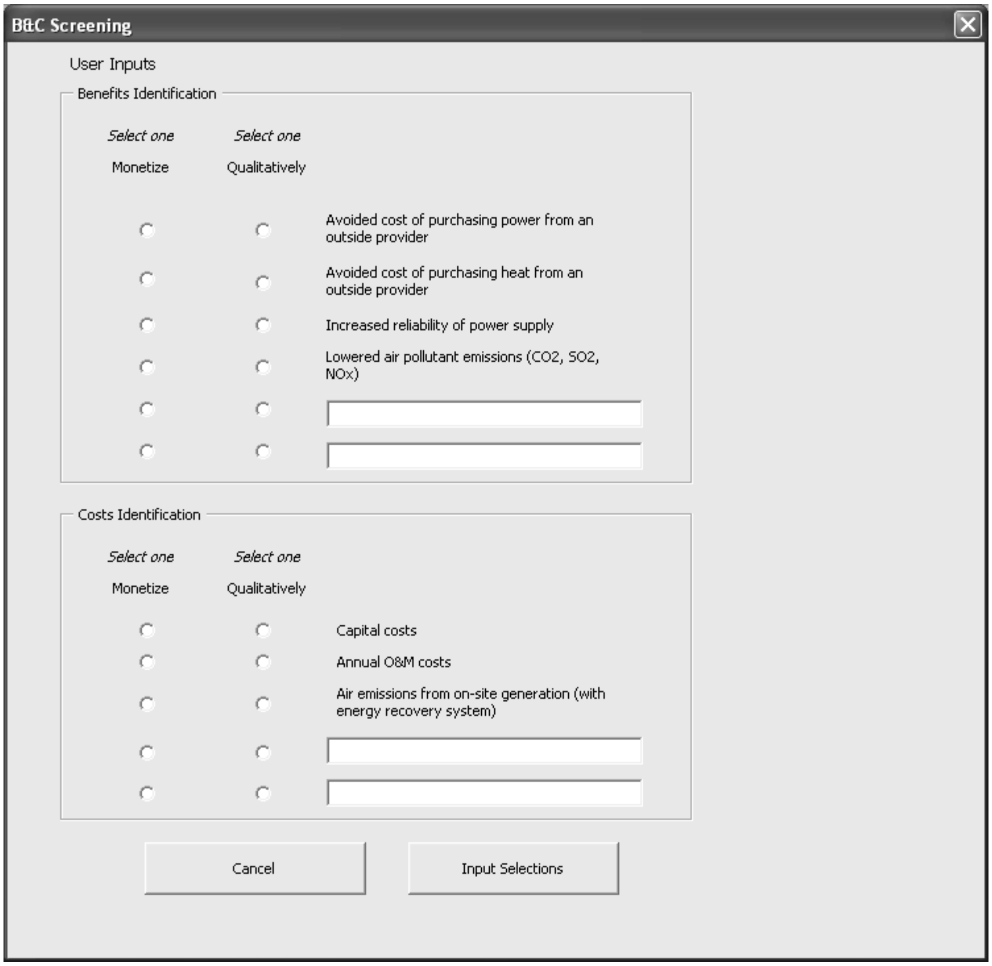


Figure C-2. User Input Form for Identifying Benefits and Costs, Steps 1 and 2.

Figures C-3 and C-4 provide examples of the templates for Steps 3 and 4. These examples contain the default benefits only, as the spreadsheet is programmed to set up the valuation tool for only those benefits identified in Steps 1 and 2. The following section provides instructions on estimating baseline power and heat prices and baseline emissions. If site-specific data are available, that should be used in place of the estimates. Users will need their energy use in kWh/year in order to quantify the benefits.

Cost of baseline power use ($/kWh): This is the price that the agency is currently paying for electricity. Utility managers should have access to this information, but if necessary, generic estimates from the EIA can be used. Users can access the average price of electricity to industrial customers in their state from the EIA, available at: http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html (EIA, 2006a).

Step 3: Monetized analysis of benefits

What discount rate should be used for this analysis?
What is the expected life-cycle of the process?
What is the base year of the project?

Benefit/Cost Category				
	Baseline power (kWh/year) *	Cost of baseline power ($/kWh) =	Avoided cost ($/year)	Present value
Avoided cost of purchasing power from an outside provider			0	**0**
	Baseline heat (MMBTU/year) *	Cost of baseline heat ($/MMBTU) =	Avoided cost ($/year)	Present value
Avoided cost of purchasing heat from an outside provider			0	**0**
	Baseline emissions of air pollutants (tons)	"Value" of emissions reductions ($/ton)	Lowered emissions benefit ($/year)	Present value
Lowered air pollutant emissions (CO_2, SO_2, NO_x)				**0**
CO_2			0	0
SO_2			0	0
NO_X			0	0
	Quantity of benefit (specify unit) *(if avoided cost benefit, use baseline use)*	Per unit value of benefit (specify $/unit) *(if avoided cost benefit, use baseline use)*	Annual value ($/year)	Present value
			0	**0**
			0	**0**

Estimate baseline power cost

Estimate baseline heat cost

Estimate emissions

Return to Overview-Inputs

Go to Step 4 ==>

Figure C-3. Quantitative Analysis of Benefits, Step 3.

Step 4: Quantitative analysis of costs

What discount rate should be used for this analysis?
What is the expected life-cycle of the process?
What is the base year of the project?

Cost Category	*Cost Payment: enter capital or annual cost* Capital cost	Annual O&M cost		Present Value
Capital costs				0
Annual O&M costs				0

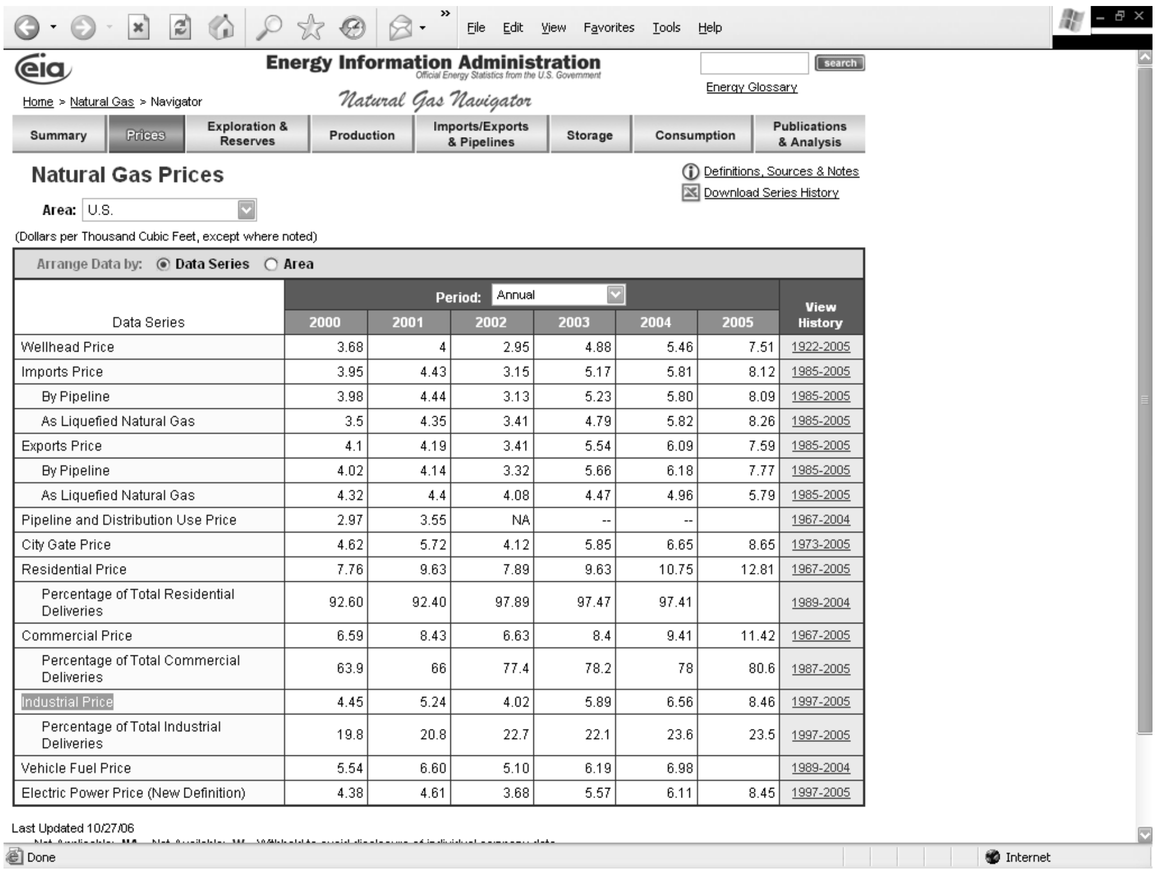
	Emissions of air pollutants (tons)	'Value' of emissions ($/ton)	Cost of emissions from on site generation ($/year)	Present value
Air emissions from on-site generation (with energy recovery system)				0
CO2			0	0
SO2			0	0
NOX			0	0

Return to Overview-Inputs

Go to Step 5 ==>

Figure C-4. Quantitative Analysis of Benefits, Step 4.

Cost of baseline heat use ($/MMBTU): The EIA also provides average retail price of natural gas to industrial users, available at: http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_a.htm (EIA, 2006b) (see Figure C-5). Users can select a state in the “Area” drop down menu. The units for this source are dollars per thousand cubic foot. Since heat is usually measured in MMBTU, the conversion factor is 1 MMBTU = 1,000 cubic feet.



Data Series	2000	2001	2002	2003	2004	2005	View History
Wellhead Price	3.68	4	2.95	4.88	5.46	7.51	1922-2005
Imports Price	3.95	4.43	3.15	5.17	5.81	8.12	1985-2005
By Pipeline	3.98	4.44	3.13	5.23	5.80	8.09	1985-2005
As Liquefied Natural Gas	3.5	4.35	3.41	4.79	5.82	8.26	1985-2005
Exports Price	4.1	4.19	3.41	5.54	6.09	7.59	1985-2005
By Pipeline	4.02	4.14	3.32	5.66	6.18	7.77	1985-2005
As Liquefied Natural Gas	4.32	4.4	4.08	4.47	4.96	5.79	1985-2005
Pipeline and Distribution Use Price	2.97	3.55	NA	--	--		1967-2004
City Gate Price	4.62	5.72	4.12	5.85	6.65	8.65	1973-2005
Residential Price	7.76	9.63	7.89	9.63	10.75	12.81	1967-2005
Percentage of Total Residential Deliveries	92.60	92.40	97.89	97.47	97.41		1989-2004
Commercial Price	6.59	8.43	6.63	8.4	9.41	11.42	1967-2005
Percentage of Total Commercial Deliveries	63.9	66	77.4	78.2	78	80.6	1987-2005
Industrial Price	4.45	5.24	4.02	5.89	6.56	8.46	1997-2005
Percentage of Total Industrial Deliveries	19.8	20.8	22.7	22.1	23.6	23.5	1997-2005
Vehicle Fuel Price	5.54	6.60	5.10	6.19	6.98		1989-2004
Electric Power Price (New Definition)	4.38	4.61	3.68	5.57	6.11	8.45	1997-2005

Figure C-5. Natural Gas Price Navigator from the EIA.

Emissions of air pollutants (quantity and “value”): Emission reductions are quantified by multiplying the amount of electricity offset by energy recovery by the emissions per kWh of traditionally generated electricity. The U.S. EPA’s Clean Energy program provides a free tool to estimate emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrous oxides (NO_x) per kWh of power used. Biosolids facilities can use this tool to estimate the emissions reduction for recovering energy by entering the amount of power they would otherwise purchase from the regional supplier. This tool is available online at: http://www.epa.gov/cleanrgy/powerprofiler.htm (U.S. EPA, 2006b).

There are several carbon trading exchanges from which a monetary value for CO_2 emissions can be derived. The two most well-known exchanges are the European Union Emissions Trading Scheme and the Chicago Climate Exchange. The values from these exchanges range from $1.50 to $18 per ton of CO_2. For simplicity, the researchers combine these and assume approximately $10/ton.

The U.S. EPA's Acid Rain Program allots SO_2 allowances that can be traded among polluters. The market price of these allowances is used as an indicator of the value of SO_2 emissions. Evolution Markets (2006b) provides a summary page of the prices, available at: http://www.evomarkets.com/emissions/index.php?xp1 = SO2.

While not regulated at the federal level, the U.S. EPA also has a NO_x emission allowance program that is regulated at the state level by participating states. While less applicable in nonparticipant states, this nonetheless offers a value of NO_x emissions. Evolution Markets (2006b) also provides a summary page of these tradable prices, available at: http://www.evomarkets.com/emissions/index.php?xp1 = sipnox.

Step 5 lists the qualitative benefits and costs identified in Steps 1 and 2. The user can then rate the likely impact on net benefits (the monetized benefits minus the monetized costs for the project) using a qualitative ranking system. Explanation of the values can be recorded to the right of the ratings. Figure C-6 provides an example of the template for Step 5.

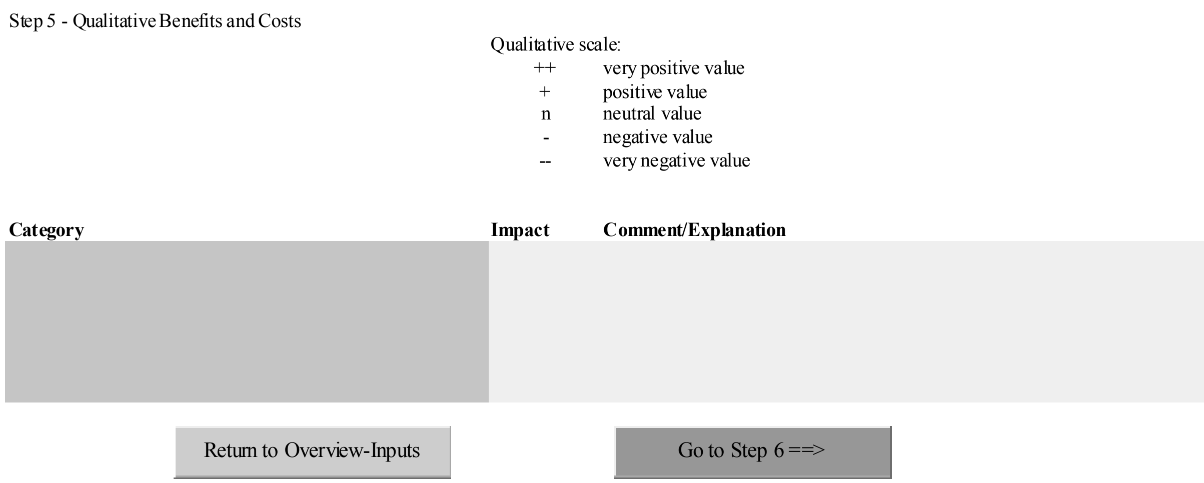


Figure C-6. Qualitative Analysis of Benefits and Costs, Step 5.

Increased reliability of power supply: Because WWTPs provide critical infrastructure for maintaining public health and the environment, they must operate under any conditions. The use of recovered energy as a prime power source or as backup can provide critical off-grid reliability to enable WWTPs to continue operations in the event of a power shortage (http://www.epa.gov/CHP/project_resources/wastewater.htm; U.S. EPA, 2007).

Air emissions from on-site generation (with energy recovery system): Emissions from the proposed energy recovery system should be quantified where possible, however, in most cases, it is difficult to quantify emissions prior to system installation. If quantification is not possible, users must qualitatively acknowledge that energy recovery systems do not eliminate emissions, but rather reduce them by replacing the use of higher emitting energy resources.

Step 6 involves summarizing and comparing all benefits and costs. The template labeled "summary" provides a table that updates automatically to include the benefits and costs calculated in Steps 3 and 4. Figure C-7 displays the summary template.

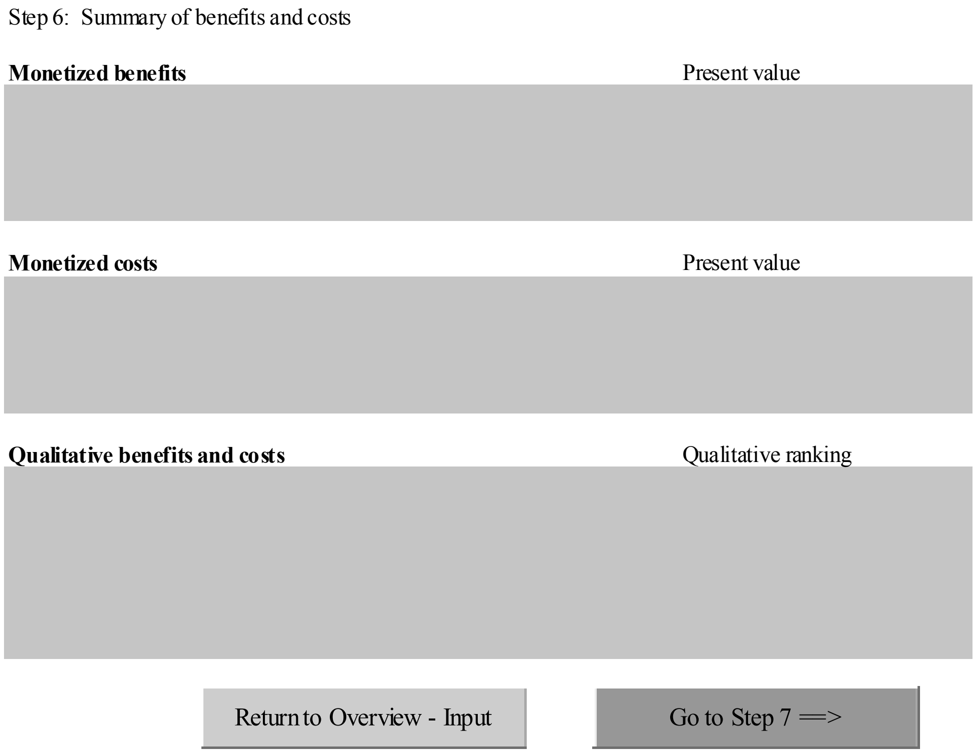


Figure C-7. Summary of Benefits and Costs, Step 6.

Step 7 is a listing of omissions, biases, and uncertainties associated with all values in the analysis—both quantitative and qualitative. Here, "omissions" refer to possibly important benefits or costs that could not be explicitly included in the analysis. "Biases" refer to quantified outcomes that the user knows are likely to be skewed to be lower bound or upper bound (rather than "most likely") estimates, as may occur due to data limitations or other unavoidable reasons (note that the term "bias" here does *not* imply any intentional intrusion of opinion over fact, and instead refers to empirical outcomes arising from data limitations). "Uncertainties" reflect results that quite possibly are inaccurate, but for which it is not clear whether they may be too low or too high. The template contains two benefits that are likely to increase net benefits relative to quantified estimates. The calculations for the avoided cost of purchasing power and heat from an outside source assume a constant energy price for the life of the process, yet they are likely to increase with time. Figure C-8 is the omissions, biases, and uncertainties table.

Step 7: Omissions, biases, and uncertainties and their effect on the project

Benefit or cost category	Likely impact on net benefits*	Comment

*Direction and magnitude of effect on net benefits:
+ = Likely to increase net benefits relative to quantified estimates.
++ = Likely to increase net benefits significantly.
- = Likely to decrease benefits.
-- = Likely to decrease net benefits significantly.
U = Uncertain, could be + or -.

Return to Overview - Input

Return to Summary

Figure C-8. Step 7 Template.

APPENDIX D

CARBON ACCOUNTING AND CLIMATE CHANGE

D.1 Introduction and Overview

Several biosolids management options have the potential to create opportunities for slowing the rate of global climate change. Some of these opportunities are more straightforward than others, and in most cases, the magnitude and range of "climate change benefits" are situation-specific. The purpose of this appendix is to provide some basic background information on the role that biosolids play in the global effort to mitigate climate change. This report provides a quick primer on the important elements of any discussion on climate change (e.g., the definition of global warming, a description of key GHGs), but the focus of this appendix is on how certain biosolids management alternatives may create opportunities for C sequestration and the potential benefits that could accrue both for the agency and society as a whole.

Drawing upon recent studies and reviews of existing carbon markets, the researchers provide information on how to potentially quantify and monetize the benefits of carbon sequestration. Not all carbon sequestration activities can be monetized, so this report includes some basic illustrations of carbon emissions, offsets, and sequestration to put the quantified values in perspective. The appendix also touches on some of the factors, such as land-use, that may affect the rate of carbon sequestration, as well as some of the limitations of sequestration.

As climate change is still a highly debated topic, with new information, theories, and research emerging on what seems to be a nearly day-to-day basis, this appendix is not meant to be an exhaustive discussion on the relationship between biosolids and the global carbon cycle. Instead, this appendix should provide biosolids program managers with enough information to be able to determine how potential carbon management (e.g., sequestration) benefits might fit in with their agency's program. For those readers interested in pursuing this area further, the researchers have included a list of additional resources at the end of the appendix.

D.2 Carbon, Greenhouse Gases and Climate Change: A Primer

CO_2, N_2O, and CH_4 are the three GHGs of primary concern with regard to biosolids management. They are naturally occurring but have anthropogenic sources as well. GHGs absorb infrared radiation in the atmosphere and trap heat near the Earth's surface. This "insulating" effect is known as the greenhouse effect (Pew Center on Global Climate Change, 2006). If concentrations of GHGs in the atmosphere rise, the result could be an increase in average temperatures at the Earth's surface (i.e., global warming) (Pew Center on Global Climate Change, 2006).

In terms of heat absorption, not all GHGs are created equal. Methane, for example, is estimated to have 23 times the warming effect of CO_2 (IPCC, 2001). The concept of global warming potential (GWP) was developed to make possible an "apples-to-apples" comparison of the warming effects of various GHGs over time. The IPCC defines GWP as a measure of a particular GHG's relative contribution of radiative forcing (i.e., its warming effect). The warming effect of CO_2 is assigned a value of 1, and the warming effects of other gases are reported relative to CO_2 (e.g., CH_4 has a warming effect 23 times greater than CO_2). The atmospheric life of these gases affects the magnitude of their warming effects and is factored in to the GWP. While the GWP of methane, for example, is reported to be 23 times that of CO_2, that only holds true over a 100-year time horizon. Over 500 years, the GWP of methane is only 7 times that of CO_2 (IPCC, 2001). Emissions of GHGs are often reported in terms of their carbon dioxide equivalents (CO_2e), which is essentially the same as the GWP (i.e., the GWP of CH_4 is 23 and the CO_2e of one metric ton of CH_4 is 23 metric tons of CO_2). Table D-1 presents a basic summary of these three GHGs, including their GWP over various time horizons.

Table D-1. "Important" Greenhouse Gases (With Respect to Biosolids Management).[a]

	Atmospheric Lifetime (Years)	GWP[c] (Over Three Time Horizons)			Anthropogenic Sources
		20 Years	100 Years	500 Years	
CO_2	Variable[b]	1	1	1	Fossil-fuel combustion Land-use (e.g., agricultural practices, deforestation) Cement production
CH_4	12	62	23	7	Fossil fuels Rice paddies Landfills Livestock
N_2O	114	275	296	156	Fertilizer Industrial processes Combustion

[a]Adapted from Table 1, The Main Greenhouse Gases; Pew Center on Global Climate Change, 2007.
[b]No single lifetime for CO_2 can be defined because of the different rates of uptake by different sink processes.
[c]Source: Table 6.7, Direct Global Warming Potentials (mass basis) relative to carbon dioxide, IPCC, 2001.

Sources of GHG emissions include fossil fuel combustion, deforestation, and methane releases from landfills. Although there are numerous ways to reduce these emissions, eliminating GHG emissions altogether is not feasible. Carbon sequestration, however, may be one way to potentially slow, or mitigate, the rate of global warming. Carbon sequestration is the process through which CO_2 is removed from the atmosphere. Terrestrial sequestration (the type of carbon sequestration most relevant to biosolids management), refers to the uptake and storage of carbon by trees, crops, and other vegetation. The carbon may be stored in above ground biomass (e.g., leaves and branches), below ground biomass (e.g., roots), or soils.

D.3 Putting CO_2 Emissions and Sequestration in Perspective: How Much is One Metric Ton of CO_2?

The amount of carbon sequestered is often reported in metric tons of CO_2, just as GHG emissions are often reported in metric tons of CO_2 (or CO_2e). But just how much is one metric ton of CO_2? A typical passenger car in the United States that is driven approximately 12,000 miles per year, emits roughly 4-5 metric tons of CO_2 annually (U.S. EPA, 2000d; TerraPass, 2007). Average annual GHG emissions resulting from heating, air conditioning, lighting, and appliance use for a typical single-family home in the United States are roughly 11.5 metric tons of CO_2 (RMI, 1999). According to the U.S. EPA, one million metric tons of CO_2e is roughly equal to the annual GHG emissions of an average U.S. power plant (U.S. EPA, 2006d).

A more detailed discussion of sequestration rates is included in a subsequent section of this appendix, but the following two examples provide a general idea of the amount of carbon that could be sequestered by different land types. One acre of pine forest in the southeastern United States can sequester approximately one metric ton of carbon per year (Birdsey, 1996), whereas one acre of agricultural land has the potential to sequester between 0.1 and 0.3 metric tons as a result of a change in cropping practices, (e.g., from conventional to conservation tillage) (Lal et al., 1999).

D.4 The Role of Biosolids in Carbon Sequestration and GHG Emissions Reduction

There are several general land use and management practices that provide opportunities for carbon sequestration, including: forestry, agriculture, biomass production, and reclamation of disturbed lands. Examples of these practices and their impacts on carbon storage and/or GHG emissions are listed in Table D-2. The primary biosolids management practice that can be employed in conjunction with several of these more general land uses is land application. When used as an alternative to synthetic fertilizers on agricultural lands or in forests, or as an amendment to improve degraded soils, land applied biosolids may contribute to an offset of carbon emissions or an increase in carbon sequestration.

Table D-2. Land Use and Management Practices that Sequester Carbon and/or Reduce GHG Emissions.[a]

Land Use/Management Practice	Examples	Effect
Forestry		
Reforestation	Restoring trees on severely burned lands that will demonstrably not regenerate without intervention	Increases carbon storage in above- and below-ground biomass, as well as soils
Afforestation	Conversion of marginal cropland to trees	Increases carbon storage in above- and below-ground biomass, as well as soils
Agriculture		
Yield promoting practices	Growing winter crops or eliminating fallow	Increases carbon storage in biomass and soils
Conservation tillage	No-till, ridge-till, or mulch till	Increases carbon storage in soils
Alternative fertilizer use	Replacing synthetic fertilizers with biosolids	Offsets GHG emissions from energy-intensive production of synthetic fertilizers
Biomass production	Crops and trees grown specifically for use in energy production	Offsets GHG emissions from burning fossil fuels for energy
Reclamation of disturbed lands	Recreating soils or reestablishing permanent vegetation on sites of former coal mines	Increases carbon storage in soils and biomass

[a]Table adapted from the U.S. EPA Website's tables: "Agricultural Practices that Sequester Carbon and/or Reduce Emissions of Other Greenhouse Gases" and "Forestry Practices that Sequester or Preserve Carbon" (U.S. EPA, 2006a).

Agricultural Lands Biosolids are typically applied to agricultural sites at a rate that meets the nitrogen needs of the crop. In a study conducted in King County, Washington, the carbon emissions offset resulting from the use of biosolids rather than commercial fertilizers was estimated to be 1.5 metric tons of CO_2 per hectare of agricultural land treated with biosolids (Brown and Leonard, 2004a). That estimate did not include the carbon emissions associated with the transport or application of biosolids, however, and as a result, the actual carbon offset is likely to be substantially lower (Brown, 2006b). In terms of carbon sequestration, the two primary means of increasing carbon storage on agricultural lands are to increase yields (e.g., by growing winter crops) and by promoting conservation tillage practices. While land application of biosolids in and of itself may not increase carbon storage, the use of biosolids in conjunction with one of these agriculture management strategies could indeed lead to increased carbon sequestration.

Forest Sites Biosolids can be land applied for their value as a fertilizer at commercial forest sites, as well. Clearly, increased tree growth would lead to increased carbon sequestration. Different forest management strategies can also contribute to increasing the amount of carbon sequestered, such as selling timber for structural use rather than paper. Quantified estimates of the increase in carbon sequestration as a result of biosolids application are included in a subsequent section of this appendix.

Reclaimed Mine Sites Another possible way to sequester carbon is by using biosolids (which contain nutrients and organic matter) as a soil amendment to re-establish soils and vegetation at reclaimed mine sites. Sequestration rates vary depending on the geographic location of the site as well as the end use for the land (e.g., pasture, forest, or cropland) (Sperow, 2006). Potential sequestration rates are included in a subsequent section of this appendix.

Since much of the carbon storage potential at agricultural sites is a result of farming practices, at this time, land application at reclaimed mine sites appears to be the biosolids management practice that provides the greatest opportunity for increasing carbon sequestration.

D.5 Carbon Sequestration Quantified

Estimating carbon sequestration for various types of vegetation or land use is a new and developing technique. There is not yet a “rule of thumb” for estimating the exact amount of CO_2 sequestered per acre of land. Geographic location, the type of vegetation being developed, and the land management practices employed will affect the amount of carbon that can be sequestered (Sperow, 2006; U.S. EPA 2006a). Attributing a specific amount of carbon stored, either in biomass or in the soils, as a result of the land application of biosolids still requires assumptions and estimations, and will vary from site to site. This appendix is not meant to serve as a tool for users to calculate the exact amount of carbon that could be sequestered as a result of a particular biosolids management strategy, but rather to illustrate to biosolids program managers that numerous opportunities to increase carbon sequestration as a result of land application do exist, and that there seems to be an increasing trend to try to quantify carbon sequestration.

Several studies have been conducted (or are ongoing) to estimate carbon sequestration rates. The researchers have summarized a few of those studies, specifically, one study that focused on carbon sequestration in reclaimed mine sties, one study that focused on accruing carbon credits as a result of biosolids application at forest sites, and one ongoing study that focuses on carbon storage in soils at reclaimed mine sites where biosolids are applied. Table D-3 lists the titles of these studies and where (if possible) the studies can be accessed.

Carbon Sequestration Potential in Reclaimed Mine Sites in Seven East-Central States Sequestration rates vary depending on the geographic location of the site as well as the end use for the land (e.g., pasture, forest, or cropland) (Sperow, 2006). After reviewing over 10 studies on carbon sequestration rates on reclaimed mine lands in the United States, Sperow (2006) reported the carbon sequestration rates in cropland, forest, and soils, forest litter layer and aboveground biomass as estimated for a seven state region (Indiana, Kentucky, Maryland, Michigan, Ohio, Pennsylvania, and West Virginia).

Table D-3. Studies Providing Estimates of Potential C Sequestration Rates and/or C Credits.

Title	Author/Contact	Key Information Presented	Where to Find the Study
Carbon sequestration potential in reclaimed mine sites in seven East-Central states	Mark Sperow, Division of Water Resource Management, West Virginia University	Provides carbon sequestration rates on reclaimed mine lands in: IN, KY, MD, MI, OH, PA, and WV, as reported by 11 different studies	Sperow, 2006
Potential carbon credits for biosolids used as fertilizer commercial forestry	Sally Brown, Research Associate Professor, University of Washington	Provides estimates of potential carbon credits for various biosolids application regimes at a Douglas fir plantation in King County, Washington	Sally Brown, slb@u.washington.edu
Carbon sequestration in reclaimed mine soils of Ohio	Sean Plasynski, Sequestration Technology Manager, National Energy Technology Laboratory (NETL) and John Litynski, Project Manager (NETL)	Proposed research to assess the effect of biosolids application rate and carbon and nitrogen content of biosolids on the soil carbon sequestration potential of reclaimed mined soils	NETL and U.S. DOE, 2006

Table D-4, which presents the range of values of C sequestration rates according to the end use for the land and the component of the land where the carbon is accumulating (e.g., soil, biomass or litter), summarizes Sperow's findings. In some cases, carbon sequestration at reclaimed mine sites is negative, which suggests that more carbon is released than is stored during the restoration process. In general, though, it appears that in all states, forest biomass has the greatest potential for carbon storage, and pasture soils have the potential for nearly 1 metric ton of storage per hectare[1] in all states. Although this study did not specifically address the role of biosolids, land application of biosolids at mine sites is a common biosolids management strategy. Additional information about biosolids application at mine sites is available in Appendix B of this document.

Table D-4. Range of Annual Carbon Sequestration Rates per Hectare by Carbon Sink Component for Different Post-Reclamation Land Uses.

Land Use (*C Sink Component*)	Indiana	Kentucky	Maryland	Michigan	Ohio	Pennsylvania	West Virginia
	Metric Tons of C per Hectare per Year						
Forest total	1.2-3.5	0.6-3.5	1.4-4.1	1.2-4.1	1.2-3.6	1.4-4.0	1.4-4.1
Forest biomass	0.8-2.6	0.6-2.9	0.9-2.9	0.8-2.1	0.8-2.8	0.9-2.5	0.9-3.3
Forest litter	0.13-0.3	0.12-0.2	0.1-0.6	0.3-0.9	-0.04 to 0.3	-0.2 to 0.7	0.13-0.6
Forest soil	0.02-1.8	-0.2 to 1.8	0.1-1.8	0.1-1.8	0.1-1.8	-0.2 to 1.8	-0.1 to 1.8
Pasture soil	0.96-1.9	0.95-1.9	0.95-1.9	1.0-1.9	0.96-1.9	0.97-1.9	0.96-1.9
Cropland soil	0.25-2.0	0.25-2.0	0.25-2.0	0.25-2.0	0.25-2.0	0.25-2.0	0.25-2.0

Adapted from Table 2, Sperow, 2006.

1. Note that Sperow's findings are reported on a per hectare basis, rather than per acre. One hectare is equal to 2.47 acres. One metric ton of C sequestered per hectare is roughly equal to 0.4 metric tons of C sequestered per acre.

Potential Carbon Credits for Biosolids Used as Fertilizers in Commercial Forestry In a study by Sally Brown (Research Associate Professor, University of Washington), CO_2 credits per acre of land at a Douglas fir plantation where biosolids were used as fertilizer were estimated. King County, Washington's biosolids management has, historically, included application as a fertilizer for commercial Douglas fir plantations. Typical application involves an initial application when the trees are four years old, additional applications every four years until the trees are between 10-15 years old, and additional applications when the trees are roughly 30 years old. Biosolids application rates are established with the goal of minimizing the potential for detectable nitrogen movement to ground or surface water. Prior research indicates an absence of adverse environmental effects as a result of biosolids application and additional work has been done to estimate the growth response of trees to biosolids (Brown, 2006b). This particular study reported potential carbon credits associated with biosolids application rather than sequestration rates because CO_2 and CO_2e emissions (during application and transportation) were considered in addition to the amount of carbon sequestered in harvestable biomass. The study indicated that CO_2 credits increased by between 9 and 97% as a result of biosolids use, depending on the biosolids application rate and the type of forest site class,[2] (site class is an index of the rate of tree height growth, with lower values indicating faster growing trees). Brown's findings are detailed in Table D-5.

Table D-5. Potential Carbon Credits at a Douglas Fir Plantation Where Biosolids Are Used as Fertilizer.

Forest Site Class	Biosolids Application Rate (Tons of Biosolids per Acre Applied Four Times per Year)	CO_2 Credit without Biosolids	CO_2 Credit with Biosolids	Percent Increase in CO_2 Credits
V	7.5	66.1	108.2	62%
V	15	66.1	131.8	97%
IV	7.5	99.2	126.4	27%
IV	15	99.2	183.4	83%
III	7.5	112.4	162.0	43%
III	15	112.4	184.7	63%
II	7.5	158.7	173.8	9%
II	15	158.7	203.2	27%

Carbon Sequestration in Reclaimed Mine Soils of Ohio This ongoing study sponsored by the NETL and in partnership with Ohio State University was designed to assess the soil organic carbon sequestration potential of reclaimed mine soils. The study involves data gathering and the testing of several hypotheses, including:

- That the rate of carbon sequestration in soils increases linearly with the rate of biosolids application and is proportional to the amount and rate of release of mineralizable nitrogen
- That the rate of aggregation depends upon the mineralizable carbon and nitrogen in biosolids

2. Site classes evaluated in Brown's study were obtained from the University of Washington Stand Management Cooperative.

D.6 Possible Monetization of Sequestered Carbon (and Carbon Offsets)

The Kyoto Protocol, an international agreement designed to address global warming (which became legally binding in 2005), sets binding targets for developed countries to reduce GHG emissions on average 5.2% below 1990 levels. All but three of the world's developed countries (Australia, Morocco, and the United States), and nearly all developing countries have approved the Protocol. Under the Kyoto Protocol there are two mechanisms under which emissions can be reduced: Clean Development Mechanism (developed countries can ear credits for projects established in developing countries) and Joint Implementation projects (which are implemented between developed countries). The European Union (EU) Emissions Trading Scheme (ETS) was developed to help EU members achieve their emissions reductions goals under Kyoto. In 2005, the market value of one ton of CO_2 ranged from over \$10 per ton to approximately \$18 per ton.

The United States did not ratify the Kyoto Treaty and there are no mandatory GHG reduction programs in place in the Unites States. There are several voluntary emission reduction programs (including the Regional Greenhouse Gas Initiative) and one operational carbon trading scheme, the Chicago Climate Exchange (CCX) in the United States. The market value of one ton of CO_2 on the CCX has ranged from around \$1.50 per ton to over \$4.00 per ton. These exchange prices probably understate the full monetary value of reducing carbon emissions, because the trading market is very limited to date. Table D-6 provides a summary of both Kyoto and non-Kyoto carbon markets around the world.

Since there is no single monetary value for carbon, for simplicity's sake the researchers have combined the values from these various markets and assume \$10 per ton of CO_2 is a representative value. For biosolids program managers it may be worthwhile to consider how biosolids management strategies that include land application might count as carbon offset projects. Carbon sequestration could potentially provide revenue to biosolids projects, roughly on the order of \$10 per ton of CO_2 sequestered or offset. In addition to possible carbon offset credits, CO_2 sequestered (or emissions reduced) may have a higher value in terms of damages avoided from global climate impacts. A review of the empirical research by Tol (2005) finds that the mean estimate of the marginal damages caused by carbon dioxide emissions is on the order of nearly \$100 per ton of carbon, which translates to about \$25 to \$30 per ton of CO_2 emissions.[3]

D.7 Limitations

There are a few limitations associated with carbon sequestration that must be noted. While carbon sequestration may help mitigate the problems associated with GHG emissions, terrestrial carbon sequestration is not limitless. Carbon storage soils and vegetation eventually reaches a saturation point. This occurs when, for example, trees reach maturity, or when carbon storage in soils reaches original levels before losses (due to tillage or other disturbances) occurred (U.S. EPA, 2006a). Two issues that may be of particular concern to biosolids program managers include: there are costs associated with measuring carbon storage (Brown, 2006b) and alterations to biosolids programs for the purpose of increasing carbon sequestration may require increased transportation distances, and subsequently increase the net lifecycle amount of GHGs emitted by the agency (Brown, 2006b).

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3. 1 g C = 0.083 mole CO_2 = 3.664 g CO_2, thus \$1/tC = \$0.27/tCO_2.

Table D-6. Summary of Carbon Markets (as of January 2007).

Current Markets	Brief Description	Representative Trading Prices for CO_2 Equivalents (2005 USD per Metric Ton of CO_2)	Year of Trade(s)
Kyoto Protocol: Clean Development Mechanism (CDM) and Joint Implementation (JI)	Became legally binding for participating countries (all developed countries except the United States, Australia, and Monaco) in February 2005. Countries can reach their emission reduction targets by actually reducing emissions within their country, implementing emission reducing projects in other countries, or via trading.	$3.10-6.70[a]	2004
EU ETS	Became effective January 2005. Established a mandatory carbon dioxide cap and trade system. Participants unable to reduce their emissions can either buy allowances on the open market or are financially penalized. In two months in 2005 over 14 million tons of CO_2 were traded.	$12.35-18.05[b]	2005
Non-Kyoto			
Oregon CO_2 standard	Established in 1997. Requires new power plants in Oregon to reduce emissions or finance carbon offset projects. A voluntary market also exits (for companies to: demonstrate social responsibility, improve carbon trading knowledge, etc). As of early 2005, offset projects funded by this scheme were expected offset a total of 1.6 million metric tons of CO_2 equivalent.	$2.50[c]	2005
CCX	Voluntary cap and trade system with 24 members. Members can meet reduction targets via internal reductions, purchasing allowances from other members or purchasing credits from carbon offset projects (e.g., carbon sequestration in soils).	$3.80[d]	2007
Regional Greenhouse Gas Initiative (RGGI)	Proposed in 2003, this is a cap and trade program for CO_2 emissions of power plants in the Northeast and Mid-Atlantic regions of the United States will go into effect in 2009. The program established targets to limit emissions to 110 million metric tons between 2009 and 2015. The program includes offset opportunities for programs such as methane capture and afforestation.	NA	NA[e]
New South Wales Greenhouse Gas Abatement Scheme	Initiated in 2003 and is legally binding through 2012. All electricity retailers in New South Wales must reduce GHG emissions. The goal is to lower GHG emissions by 5% by 2007 and maintain the reduced level until at least 2012.	$8.15- 11.40	2004

[a]As reported by Katoomba Group (2006c).
[b]As reported by Katoomba Group (2006d), and assuming 1 British pound (2005) = approximately $1.9 (2005 USD).
[c]Estimated assuming $4 million in projects that offset 1.6 million metric tons of CO_2 (source: Katoomba Group, 2006a, 2006b).
[d]As reported on the CCX Website (CCX, 2006).
[e]This program does not go into effect until 2009; no trading yet to date.

D.8 Where to Find More Information

- **General**

  Intergovernmental Panel on Climate Change Third Assessment Report
  http://www.grida.no/climate/ipcc_tar/index.htm

  National Energy Technology Laboratory (NETL): Carbon Sequestration Frequently Asked Questions http://www.netl.doe.gov/technologies/carbon_seq/faqs.html

  U.S. EPA Website: Carbon Sequestration Homepage
  http://www.epa.gov/sequestration/index.html

  New Zealand's Ministry of Agriculture and Forestry

- **Glossaries**

  Pew Center on Global Climate Change, Glossary: http://www.pewclimate.org/global-warming-basics/full_glossary/

  U.S. EPA, Glossary of Climate Change Terms:
  http://www.epa.gov/climatechange/glossary.html#G

- **"Tools"** There are several organizations active in establishing and/or assessing carbon sequestration projects as GHG offsets. These include:

  American Electric Power

  California Climate Action Registry

  EcoSecurities

  Edison Electric Institute

  Chicago Climate Exchange

  The Climate Trust

  National Carbon Offset Coalition

  The Nature Conservancy

  Pacific Forest Trust

  Trexler and Associates, Inc.

  World Bank Prototype Carbon Fund

  (This list of organizations was generated by the U.S. EPA.)

APPENDIX E

POTENTIAL RISKS TO HUMAN HEALTH FROM LAND APPLICATION

As noted in prior appendices, land application of biosolids is a long-standing and widely used practice, and has been the subject of considerable scientific investigation and review. As a result, land application using best practices and in accordance with federal and state regulations is widely viewed as a beneficial use of biosolids that poses minimal and generally acceptable risk. Nonetheless, there remain several open scientific questions and uncertainties that lead some individuals and organizations to remain highly concerned about some risks that may be associated with land application. Anecdotal reports and scientific inquiries indicate that exposure to biosolids may be associated with adverse health impacts, ranging from mild irritations to chronic health problems (e.g., Harrison and Oakes, 2002). Hence, the potential for health risks from land application remains a controversial issue in biosolids management.

In this appendix, the researchers attempt to offer an open and objective overview of the potential health risks associated with land application. Their aim is to provide information in a balanced manner, and to indicate to readers what the issues are, what the science suggests, and where they can obtain additional information. They do not seek to resolve the remaining conflicts, nor do they endorse one set of views over the others. They simply try to state the issues, present the data, and point readers to additional resources.

E.1 The Debate over "Real" versus "Perceived" Risk, and "Known" versus "Uncertain" Risk

There is debate among the scientific community as to whether or not land application of biosolids creates scientifically based risks to public health (or greater than de minimus risks), or whether the concerns and complaints aired by some parties reflect only perceived (or potential) risks. Whether or not the risks are only "perceived" (and, by implication, not deemed by some as "real"), the fact that there is public concern means that the health risk issue is one that biosolids management agencies must take into account. Public opposition, regardless of the strength of the scientific underpinnings, will threaten the sustainability of a biosolids program.

Further, there is another important dimension to the debate—between what the research community thinks it knows from the existing scientific inquiries, and what remains unknown and uncertain scientifically. For example, with improved analytic methods, trace organics (e.g., EDCs) have been detected in very low levels in wastewater effluent and biosolids. At this time, it appears that the resulting human exposures through biosolids-related pathways would be extremely small (especially compared to doses many people are exposed to routinely in their foods and medical choices). Nonetheless, it remains a matter of scientific uncertainty as to whether there are any risks associated with any potential low level of exposure through biosolids. Some researchers have expressed that there is no real scientific debate on human health risks from trace organics in biosolids that are land applied (i.e., some members of the research community believe such risks would be de minimus), and that ecologic risk is the big driver in the scientific community. When the debate over possible health risks is driven by this uncertainty (i.e., a lack of scientific evidence one way or the other), then it becomes one of suitable burden of proof for biosolids applications. Does land application of biosolids need to prove it is innocent and safe before land application is deemed acceptable? Or, does society presume biosolids are innocent (exposing humans to de minimus and acceptable risks) based on what science has already demonstrated, and only change the verdict to guilty if future scientific evidence provides compelling evidence of likely harm? Since this is a philosophical debate, there will be some people who presume innocence, and other who presume guilt. Ultimately, wastewater agencies will need to accommodate all perspectives if their biosolids programs are to remain viable in terms of public acceptance and support.

Thus, regardless of where one stands in the "real versus perceived risk" debate, or the "known versus uncertain" state of the science, the health risk issue will be one to which utilities need to be sensitive and responsive.

E.2 The NRC View of the State of the Science

An NRC committee evaluated the relevant existing studies and found only one study pertaining specifically to populations near agricultural application sites. The findings indicate that no significant differences in respiratory illness, gastrointestinal illness or general symptoms were found between residents at the land application sites and individuals at control sites (NRC, 2002).

In response to what appears to be a lack of sufficient epidemiological studies to address the public's concerns about potential adverse health effects of biosolids land application, the committee recommended that new studies (both short-term investigations of unusual reports of disease and exposure to biosolids as well as preplanned, large-scale studies of biosolids exposure and the potential link to health problems) be conducted.

E.3 Contaminants of Concern

The concern about possible human health risks is founded on the fact that there are several classes of contaminants found in biosolids that might—at sufficiently high doses and levels of exposure—pose risks to human health. This section describes each class of contaminants.

E.3.1 Pathogens

One concern when land-applying biosolids is preventing the transmission of pathogens (disease causing microorganisms, such as *Salmonella*). Federal regulations (the Part 503 rule) establish two levels of pathogen reduction. Class A standards require indicator pathogen reduction to below detectable levels. Class B standards require that pathogens are reduced to levels that are unlikely to cause a threat to public health and the environment (about 99% of the bacteria, 90% of the viruses, and a lower percentage of the more resistant parasites are killed). The site restrictions for land application of Class B biosolids are meant to provide the same level of protection as Class A treatment.

The degree to which pathogens in biosolids applied to land pose a human health risk (real or perceived) is currently unclear. Studies conducted by researchers at the University of Arizona suggest that the risks of infection from pathogens in land applied biosolids are on the order of magnitude of 10^{-5} for residents 100 ft downwind of application sites, and between 10^{-7} and 10^{-10}

for residents 300 ft downwind of application sites (Brooks et al., 2005a). These studies have not allayed all the concerns of all stakeholders and some researchers, who have raised questions about methods issues with the Brooks et al. studies. Thus, potential risks associated with pathogens remain to some an important unresolved matter.

In their 2002 report, the NRC called for more research on land application of biosolids, "to reduce persistent uncertainty about the potential for adverse human health effects from exposure to biosolids" (NRC, 2002). With respect to pathogens in particular, the report recommended that the U.S. EPA conduct a national survey of pathogen occurrence in biosolids and that quantitative microbial risk assessment methods should be used to establish regulations for pathogen concentrations in biosolids.

One way to likely reduce the potential risks and concerns of pathogen exposure resulting from biosolids land application is for the wastewater treatment plant to increase pathogen reduction at the biosolids treatment facility and produce a Class A product rather than a Class B product.

E.3.2 Pharmaceuticals and Other Trace Organics

In a recent study conducted at Eastern Washington University, researchers found dozens of medicinal, industrial and household compounds in biosolids products from seven states. Regardless of the wastewater treatment method used, the nine different biosolids products examined all contained at least 30 different compounds. The researchers tested the samples for 87 different compounds (Gordon, 2006). In addition, a survey of data regarding organic chemicals in sludges found that 516 organic chemicals have been reported (Harrison et al., 2006).

The presence of low levels of various chemical compounds that humans develop and use widely (including pharmaceuticals and personal care products) will inevitably find their way into wastewater and biosolids. The key scientific question is whether the specific chemicals found are at concentrations that may pose unreasonable risks to human health and the environment. Some researchers suggest that the risks are unlikely to be significant, when accounting for the initial low concentrations of these chemicals in biosolids, and given the potential biosolids-related exposure pathways (i.e., the chemicals' fate and uptake or transport) from a given land use application of the biosolids. However, other researchers and stakeholders remain concerned that reintroducing these compounds into the environment through land application may indeed pose nontrivial risks.

There are also concerns about the presence of dioxin, antibiotic residues, and personal care products (these compounds may act as endocrine disruptors) in biosolids. These may have negative impacts in aquatic systems or on human health (although exposure to people is much greater and more direct in the household setting and/or when these products are being used/consumed). The concentrations of these compounds reaching soils (and, perhaps, eventually groundwater or surface water) are likely to vary depending on the local population (i.e., the types of products and medicines they use) and may fluctuate or change over time (particularly as new personal care, household cleaning, and medicinal products are introduced to the market). A study conducted by the Association of Metropolitan Sewerage Agencies found biosolids dioxin concentrations to be less than 1/6th of the limit proposed for the revised Part 503 rule (Moss et al., 2002).

The scientific question that remains is whether there is any unacceptable health risk associated with the land application of biosolids with such very low levels of antibiotics and other chemicals. Many scientists currently believe there is no notable health or environmental risk posed by chemicals at the concentrations believed to exist in biosolids that are land applied. However, the science cannot preclude the possibility of risk, and many individuals may be very concerned about such uncertain and potential risks.

E.3.3 Metals

There is concern among some scientists (and parts of the general public) about the cumulative effects of metals (e.g., Zn, Pb, Cd, Cu, Mn, Mo, Ni) in soils amended with biosolids. Some metals present in biosolids are necessary micronutrients that improve vegetative growth, but in high concentrations they may be harmful to plants, animals and humans.

The fate and transport of biosolids-applied metals and the effects on human health and the environment, however, are unclear. According to WERF, the results of several studies indicate that metals from biosolids accumulate in surface soils and do not migrate to groundwater. Accumulated metals in the soil may not be available for uptake by plants because the stability of biosolids retards the release of bound metals (Switzenbaum et al., 1997). Additional studies show that metals in biosolids are less available than metals added to soils as salts, in fertilizers or in manures (Brown et al., 1998, 2003, 2004c). Biosolids with a high iron content have been shown to reduce lead availability through in vivo and in vitro studies when applied to lead contaminated soils (Brown et al., 2003).

Several studies on the fate and transport of metals in biosolids have been conducted at reclaimed mine sites in Pennsylvania. In some cases, metal concentrations near biosolids amended sites were similar to the concentrations at control sites, in other cases metal concentrations increased (particularly when the water pH was low). Overall, the results from these studies generally indicate that the potential for metal leaching to groundwater from biosolids amended soils is low and can be controlled by proper management of soil pH (Brown, 2006c). Still, there also is research that suggests that metals can and sometimes do accumulate and leach from land-applied soils in some settings (McBride, 1995, 2003; McBride et al., 1997).

E.3.4 Bioaerosols

Depending on the type of biosolids product and the method of land application, windblown fine particles (bioaerosols) may be a cause for concern (particularly with respect to possible respiratory impacts) when biosolids are land applied at agricultural sites. The degree to which bioaerosols pose a human health risk is currently unclear. In response to both local and national concern about bioaerosols from biosolids, Denver Metro, for example, is participating in ongoing research to study the potential risks. Research conducted at the University of Arizona (in which researchers collected air samples from land application sites at several states across the United States), indicates that bioaerosols may not pose a major health risk to either the people applying the biosolids or those that live near application sites (where "near" was conservatively defined as 100 feet downwind of an application site) (Brooks et al., 2005b; Brown, 2006a). As with all potential risks, even perceived risks need to be considered by the agency, as perceived risks may influence public acceptance of (or opposition to) land application.

APPENDIX F

CONSIDERATION OF ODORS IN THE BIOSOLIDS MANAGEMENT PLANNING PROCESS

Odor problems have caused many facilities and land application programs to be discontinued. Therefore, it is important to evaluate the potential odors caused by all management alternatives under consideration. The benefits of odor control may be that they enable a biosolids program to continue; odor control may be a critical element of ensuring the sustainability of a biosolids program.

F.1 Odor Issues Past and Present

***In the past*,** aerobic or anaerobic digestion was considered to be adequate treatment and processing to reduce odors to acceptable levels. However, neighbors living near WWTPs and land application sites have complained and worked diligently to eliminate what they feel is an unacceptable compromise to their quality of life. WWTPs have a responsibility to manage odors at the wastewater treatment plant and at the site of end use or disposal. WERF-sponsored research conducted by Ned Beecher found that public perception of biosolids management practices are largely influenced by odors (Beecher, 2003).

Present situation. The trends in dewatering technologies have steered toward high speed centrifuges which result in a dewatered product that generates significantly greater odors. As a result, long standing and successful biosolids land application programs have been discontinued at many locations throughout the country. In addition, many states require that wastewater residuals be stabilized, to Class B levels or undergo a process to reduce vector attraction reduction and significantly reduce pathogens prior to disposal in a landfill. Increasingly, MSW landfills are making the decision not to accept biosolids in an effort to control odors.

F.2 Research Findings

In 2003-2004, the Mid-Atlantic Biosolids Association and WERF sponsored research into the question of "What causes biosolids odors and what can we do about it?" At a NJWEA Conference in May 2004, Prof. Matt Higgins of Bucknell University discussed the mechanism by which odors are created. Proteins especially are subject to breakdown into odorous volatile organic sulfur compounds (VOSCs). For example, methiomine is converted to methyl mercaptan, cystine is converted to hydrogen sulfide, the protein tryptophene is converted to indole and skatole and tyrosene is converted to p-creosol. The next phase of research is focusing on use of an enzyme or additive that would block the reaction that results in formation of these odor causing compounds.

According to that research, factors that effect odors include:

- Digestion—solids retention time and process type
- Dewatering method—high sheer forces in high speed centrifuges result in more odors, (1,000 times more VOSCs than belt press)

- Cake handling and storage practices, shear forces such as pumping and screw conveyors create more available protein in the biosolids and increase the potential for odor generation
- Higher polymer dose—increasing polymer dose from 24-32 lbs per ton solids can double or triple the VOSC concentrations
- Mannich polymers used during dewatering can sequester proteins in the biosolids cake
- Polymer injection location has an impact on polymer dose and therefore odors
- pH—low dose lime to adjust pH to 8-9 pH resulted in greater odors
- Long term storage of cake can change the odor causing compounds (VOSCs) to volatile aromatics such as cresol, toluene, styrene, indole, and skatole
- Addition of Gilberton coal ash after dewatering, reduced odors during land application by 80%
- Addition of iron after dewatering actually increased odors (more testing needed)
- Addition of alum after dewatering somewhat reduced odors (more testing needed)

A paper titled "Impact of Lime Dosage Rates and Lime Incorporation Levels on Biosolids Odor Production" (Murthy et al., 2003c) reported on research sponsored by the District of Columbia Water and Sewer Authority. Some of the important findings were that lime should be dosed at 20% or greater on a dry weight basis and thorough blending of lime and biosolids is important to minimize odors. This dosage should be increased to 30% if the biosolids will be stored for more than a week before land application. A clever approach was developed to determine if lime was well mixed—the approach is to take very small samples (~1 gram) of the lime stabilized biosolids and analyze for Calcium (Ca) concentration. Taking 8 or more samples and observing the variation in Ca is a good indicator of the efficacy of mixing and the potential for pH to drop and ultimately, the potential to create odors. The study also found that lime characteristics were very important in process optimization. Lime purity, dosage rate, and most importantly, particle size were found to impact biosolids stability and odor causing potential.

F.3 Applying the Research

Although the research is not yet complete, the information can be used to mitigate odors by employing the following practices:

- Avoid septic conditions in the WWTP
- Optimize digestion or lime stabilization and polymer dose
- Go beyond compliance to ensure vector attraction reduction and stabilization is achieved
- Use an EMS to address critical control points in the process
- Covered field storage will prevent rain water from entering the biosolids and will avoid odor problems when land applied
- Measure changes in odors over time and provide covered storage for several days until odors are reduced before trucking the biosolids to an end use or disposal site

Ongoing research at WERF will continue to look for practical ways to reduce odors in biosolids.

F.4 Significance When Comparing Options

Considering how unmitigated odors have been a fatal flaw in many biosolids management programs it is important to utilize all the information available when evaluating alternatives.

Biosolids odors vary at each wastewater treatment plant. Even if two plants utilize the same treatment processes odors can vary significantly. Whenever possible, perform pilot testing to determine odor potential. This testing should characterize the odors and measure changes over time. For example, Philadelphia's biosolids increased in odors for one week after dewatering. With this knowledge they can build in practices and capacity to avoid land applying the biosolids during that time frame.

Alternatives should be evaluated for the following scenarios:

- How severe is the odor potential at the processing facility?
- How severe is the odor potential at the end use and disposal facility?
- How well can the odors be controlled at both the WWTP and the end use or disposal site?

All feasible biosolids management alternatives must control odors. When comparing alternatives each should be developed to the level of detail that clearly define odor causing potential and capital and operating needs to mitigate odors to an acceptable level. Some of the measures that can be taken to control odors include:

- Enclosures with foul air treatment
- Selection of processing equipment that does not increase odors
- Processing to minimize odors in biosolids
- Best management practices in storage and land application
- Biofilters
- Activated sludge basins
- Wet scrubbers
- Regenerative thermal oxidizers
- Counteractant or neutralizing agents
- Addition of oxidizing agents to biosolids before or after digestion/dewatering

Challenges when comparing odor causing potential of various alternatives include:

- Biosolids odor intensity varies from plant to plant
- Multiple end-use sites make evaluating odor problems complex
- May not be able to evaluate odor potential until entire plant is up and operating
- How much odor receptors will tolerate varies

F.5 Role in Building Public Support

Once wastewater treatment plants were located on the outskirts of towns in a relatively low population density. As towns and cities have grown, homes and businesses are often located very close to the WWTPs. Similarly, agricultural use was practiced on farms surrounded only by other farms. Now suburban sprawl has introduced residences on every corner of the farming community. Despite Right to Farm Laws that protect farmers from nuisance ordinances, odors from biosolids have sparked and fueled public opposition to biosolids recycling.

An increase in the use of PFRP have produced biosolids products that may be used with less restrictions and reporting requirements. However, if these products are bringing bad odors into highly populated areas, the results can be a derailment of the beneficial use program.

By producing biosolids products with the least odor causing potential, utilities mitigate odors both at the processing facility and the end use or disposal site. The costs of odor control fall into both the direct and external categories.

F.6 Effective Responses to Odor Complaints

In addition to capital equipment and operating procedures to control odors, it is important to be able to communicate a commitment to odor control. Increased public concerns, whether they are scientifically justified or not, must be addressed. The following are some ways to effectively communicate your solutions for odor reduction:

- Explain steps that are taken to mitigate odors
- Implement an EMS to assure consistent and adequate treatment
- Explain that there is ongoing research into what cause odors and how utilities can control odors
- Keep a written log of all odor complaints

F.7 Additional Resources on Odor Issues

There are several papers and other resources available to readers that address odor-related issues for biosolids. Several useful resources include:

Bowker, R.P.G. Activated sludge diffusion; clearing the air on an overlooked odor control technique. *Water Environ. Technol.* WEF February 1999.

Chen, Y., M.J. Higgins, N.A. Maas, S.N. Murthy, and W.E. Toffey. Roles of Methanogens on Volatile Organic Sulfur Compound Production in Anaerobically Digested Wastewater Biosolids. *International Water Association the 10th Congress on Anaerobic Digestion*, Montreal, Canada, 2004a.

Chen, Y.C., M.J. Higgins, S.N. Murthy, N. Maas, K. Covert, J. Weaver, W. Toffey, M. Rupke, and D. Ross. Mechanisms for the production of odorous volatile aromatic compounds in wastewater biosolids. *Proceedings Water Env. Federation Annual Biosolids and Residuals Conference,* Salt Lake City, UT, 2004b.

Hentz, L.H. and W.E. Toffey. Biosolids Air Emissions are Good Indicators of Process Conditions. 10th Annual Residuals & Biosolids Management Conference: 10 Years of Progress and a Look Toward the Future Proceedings. Denver, CO: Rocky Mountain Water Environment Association, 1996.

Higgins, M.J., Y. Chen, N.A. Maas, S.N. Murthy, and C. Peot. State of knowledge: Odors in anaerobically digested biosolids. In Workshop C: Understanding and Managing Odors from Biosolids. *Proceedings of WEF/WEAU Residuals and Biosolids Management Conference,* Salt Lake City, UT, 2004.

Higgins, M.J., D.P. Yarosz, Y.C. Chen, S.N. Murthy, N. Maas, J. Cooney, and D. Glindemann. Mechanisms of volatile sulfur production in digested biosolids. *Proceedings of Water Env. Federation and AWWA Annual Biosolids and Residuals Conference,* Baltimore, MD, 2003.

Higgins, M.J., K. Hamel, Y.C. Chen, S.N. Murthy, E.J. Barben, A. Livadaros, M. Travis, and N.A. Maas. Part II of field research: Impact of centrifuge torque and polymer dose on odor production from anaerobically digested biosolids. *Proceedings of WEF/AWWA Joint Residuals and Biosolids Management Conference,* Nashville, TN, 2005.

Higgins, M.J., D.P. Yarosz, Y.C. Chen, S.N. Murthy, N. Maas, J. Cooney, D. Glindemann, and J.T. Novak. Cycling of volatile organic sulfur compounds in anaerobically digested biosolids and its implications for odors. *Water Env. Res.* 2006, 78(3):243–252.

Murthy, S.N., M.J. Higgins, and Y.C. Chen. The effect of dewatering equipment on VSC and odor production from digested biosolids. *Proceedings of Water Env. Fed. 76th Annual Conf.*, Los Angeles, CA, 2003a.

Murthy, S., M. Higgins, Y.C. Chen, C. Poet, and W. Toffey. High solids centrifuge is a boon and a curse for managing anaerobically digested biosolids. *Water Sci. Technol.* 2006, 53:245–253.

Murthy, S.N., M.J. Higgins, Y.C. Chen, W. Toffey, and J. Golembeski. Influence of solids characteristics and dewatering process on VSC production from anaerobically digested biosolids. *Proceedings of Water Env. Federation and AWWA Annual Biosolids and Residuals Conference,* Baltimore, MD, 2003b.

Murthy, S.N., C. Peot, W. Bailey, J.T. Novak, M.J. Higgins, Y.C. Chen, T. Sadick, and P. Schaefer. Effect of digestion practice on production of odorants from anaerobically digested biosolids. Accepted for publication in *Water Env. Federation and AWWA Odors and Air Emissions Conference,* Bellevue, WA, Forthcoming.

Murthy, S.N., B. Forbes, P. Burrowes, T. Esqueda, D. Glindemann, J. Novak, M.J. Higgins, T. Mendenhall, W. Toffey, and C. Peot. Impact of high shear solids processing on odor production from anaerobically digested biosolids. *Proceedings of Water Env. Fed. 75th Annual Conf.*, Chicago, IL, 2002.

Rosenfeld, P. Characterization, Quantification, and Control of Odor Emissions from Biosolids Application to Forest Soil. PhD Dissertation. Seattle, WA: University of Washington, 1999.

Toffey, W. and M. Higgins. Reports of Trials of Chemicals, Enzymes, and Biological Agents in Reducing Odor Intensity of Biosolids. NJWEA Annual Conference, May 2006.

USDA, U.S. EPA, and WEF. *Guide to Field Storage of Biosolids*. EPA/832-B-00-007. U.S. Environmental Protection Agency, Office of Wastewater Management, Washington, D.C.; U.S. Department of Agriculture, Agriculture Research Service, Beltsville, MD, 2000.

U.S. EPA. *Biosolids and Residuals Management Fact Sheet—Odor Control in Biosolids Management*. EPA-832-F-00-067. Washington, D.C.: U.S. Environmental Protection Agency, September 2000a.

U.S. EPA. *Biosolids Technology Fact Sheet: Use of Composting for Biosolids Management*. EPA 832-F-02-024. Washington, D.C.: U.S. Environmental Protection Agency, September 2002a.

Wu, N. Using Odor Modeling to Evaluate Odor Control and Improve Public Acceptance. 14th Annual Residuals and Biosolids Management Conference. Boston, MA: WEF, 2000.

APPENDIX G

EVALUATION OF INNOVATIVE ALTERNATIVES

In an effort to achieve continuing improvement or to improve efficiency, cost effectiveness and safety, many wastewater treatment plants look to innovative alternatives. In a recent publication by the U.S. EPA titled Emerging Technologies for Biosolids Management (U.S. EPA, 2006c), emerging technologies are broken into two categories:

Embryonic: Technologies in the development stage and/or tested at laboratory or bench scale. New technologies that have reached the demonstration stage overseas, but cannot yet be considered to be established there, are also considered to be embryonic with respect to North American applications.

Innovative: Technologies meeting one of the following qualifications: 1) have been tested at a full-scale demonstration site in this country; 2) have been available and implemented in the United States for less than five years; 3) have some degree of initial use (i.e., implemented in less than 25 utilities in the United States; and 4) are established technologies overseas with some degree of initial use in the United States.

It is difficult to evaluate emerging or innovative technology because there is not a lot of information on design standards or operating experience. Furthermore, the level of effort required to obtain regulatory compliance is impossible to predict. An illustration at the end of this appendix, based on experience at CWW, provides an example of this challenge.

G.0 Potential Benefits

The advantages of an innovative technology should be evaluated in terms of cost savings and benefits to society as a whole and the environment. Some advantages may include:

Volume and weight reduction: This could save costs of processing steps such as digestion, dewatering, conveyors, trucking, storage, end use, or disposal. It could reduce capital costs of equipment, buildings, heating, ventilating, and air conditioning (HVAC), land, storage facilities, etc. Volume and weight reduction could benefit society as a whole and the environment by using less fuel for processing and transportation, reduced truck traffic, using less landfill space or impacting fewer neighbors at land application sites.

Improved pathogen reduction: This could save costs such as avoided cost of landfill disposal, reduced trucking to closer land application sites, or if the product is sold or given away, avoided costs of land application. If the end product meets EQ standards, the amount of effort needed to build public support could be reduced. Improved pathogen reduction could benefit society as a whole and the environment by further reducing the risk of spreading disease, increasing the likelihood that the biosolids could be recycled rather than disposed, conserve landfill space, and reduce trucking.

Creating an added value product: Technologies that produce a product that can be sold as a source of fuel, fertilizer, or soil conditioner could present an opportunity to generate revenues in addition to saving the cost of landfill disposal, land application or incineration. If utilities create an added value product this could benefit society as a whole and the environment. For example, if the energy used to make the product is less than the energy needed to manufacture fertilizer or fuel, this could reduce dependence on fossil fuel. Alternatively, a product that conserves natural resources such as phosphorous and other plant nutrients or prevents further removal of virgin topsoil provides benefits to society as a whole.

Reduced foul air requiring treatment: Air pollution control and odor control equipment can account for 30-50% of capital and operating costs at biosolids processing facilities such as incinerators, dryers, composting, and alkaline stabilization facilities. In addition, even after treatment, air emissions may be contributing unregulated pollutants such as GHGs or ozone precursors.

External benefits of pursuing innovative alternatives may also include:

- ♦ Supporting public and private research organizations. Often local universities or WERF are hired to evaluate or optimize new technologies.
- ♦ Advancing the state of the art technologies. This will benefit other WWTPs and the communities they serve.
- ♦ Reducing adverse impacts to the community surrounding the end use or disposal activities.

Recovery of resources: When an innovative alternative has the potential to recover resources, then the quantity and value of those resources should be evaluated.

- ♦ *Heating value:* Will the process utilize the BTU value of the biosolids? If so, what is the net value of the heat, steam, or electricity (considering efficiencies)? Will the process create a product that has heating value such as methane gas or charcoal? If so, what is the net gain in energy after considering the energy used to create the product? How much fossil fuel usage will be avoided once this process is operating (gallons of oil or tons of coal)? Is the energy produced from the process considered "Alternative" energy and will power utilities or industries pay a premium to utilize this source of energy?
- ♦ *Nutrient content:* What is the nutrient content (nitrogen, phosphorous and potassium) of the end product in lbs/dry ton? What portion of the nutrients are plant available? What is the current cost of fertilizer in your area? Will use of this product conserve natural resources such as fossil fuel used to make fertilizer or finite sources of minerals such as phosphorous, copper, boron, zinc?
- ♦ *Organic matter or soil conditioning characteristics:* What is the concentration of organic matter? How will this benefit soils, crops, water quality? What is the cost of other sources of organic matter in your area, i.e., compost, peat moss, manure, other residuals? If alkaline material is added, what is the effective neutralizing value of the final product? What is the cost of other sources of lime in your area? Will use of this product conserve natural resources such as peat moss or minerals such as lime and magnesium?

Market demand: If an innovative process includes the marketing of a product such as compost, fertilizer, or fuel, it is important to understand the specifics of that market in your area.

- ♦ *Seasonal fluctuations:* Products used in agriculture or horticulture experience seasonal demand. Will you build or procure storage facilities? Will the price fluctuate during the year? Will you dispose of the product during certain seasons?

- *Distance to customers:* Transportation costs can be a serious disincentive for potential users of your product. Is there a demand for the product in your area? For example, will an alkaline stabilized product be marketable in an area with high pH soils? Will fuel products be marketable in a coal mining region? Any product will have a higher value if it can be marketed locally.
- *Competition:* What products will your product be competing with? Are other wastewater treatment plants in the area marketing similar products? Have they saturated the local market or is it all spoken for before it is produced? Do they have to transport the product long distances? Will you be required to out-compete a widely recognized and well respected manufacturer such as Scott's fertilizer?
- *Market development and sales effort:* Will the product compete directly with other commercially available products? Will you have to educate the consumer on how to use the material, and on the benefits and needs for the material? Are you likely to have many small quantity users or a few large users? How much time will your staff dedicate to marketing and distribution?
- *Value of product:* If the product is replacing a commercially available material, what do customers pay? For example, one innovative process produced material that could be used as road aggregate that would be used to fill potholes. The community thought it was wonderful that because they could make their own road aggregate, they could reduce the number of potholes. However, the cost of the road aggregate itself was minimal. The expense of repairing potholes was primarily the cost of trucking the aggregate and other materials and the labor to do the repairs.

  If the product is sold for its heating value it may not be valued at its BTU value alone. Considerations include additional permitting, processing, or storage needed at the combustion site. A higher value may be assigned if it qualifies as an alternative fuel and enables the power utility or industry to meet its goal for Renewable Energy Portfolio standards.
- *Diversity of end uses and customer base:* Market demand will be more robust and sustainable if the product can be used by a variety of businesses. For example, year round demand for heat dried pellets can be developed by marketing to sod growers, fertilizer manufacturers, as well as top soil blenders and potting soil blenders. In addition, if one type of customer leaves the area or finds an alternative product, there are several other customers who will fill in the demand.
- *Quality control requirements:* Quality and consistency are necessary for successful marketing. Will the proposed process produce a consistent product? Are your sewer use controls stringent enough to protect biosolids quality?

G.0 Potential Costs

Evaluating the costs or disadvantages of innovative technologies can be even more challenging than evaluation of the benefits. Innovative technologies may have a limited operating history in this country or no full scale operating history at all. If there is an operating facility, it is important to gather all the information possible from the facility, including a site inspection. This information can be used to verify the vendor's or manufacturer's claims. Even before packing for the field trip, there should be significant perceived advantages over other feasible alternatives. The following is a checklist of factors to consider when comparing to a baseline alternative.

Reliability: How much down time do other facilities experience? Does it employ high speed, high temperature equipment that is more likely to break down?

Long-term viability and sustainability: Are there pending regulatory changes that could impact the feasibility? Will neighbors and host communities be offended by operating conditions? Does it rely on natural resources that could be in short supply (e.g., fossil fuels, wood products, farm land, alkaline materials)?

Self sufficiency: Will the utility have to rely on outside parties to operate or maintain the facility? To manage the end product? To dispose of byproducts?

Public support: Will the facility produce nuisance conditions? Will the end use or disposal sites experience odors? Do the benefits outweigh the perceived risks?

It also is critical to understand and assess how well the process will operate in a utility's specific operating environment and field conditions, including the range of considerations described below.

Tolerance to changes in residuals characteristics:

- *Metals concentration:* Volume reduction and thermal processes tend to concentrate the heavy metals. Will the quality be adequate for end use or disposal?
- *Volatile solids:* If the process relies on a consistent supply of fuel, will daily or seasonal changes in the volatile solids content complicate operations?
- *Total solids:* If the process relies on a consistent amount of moisture, will daily or seasonal changes in the solid content complicate operations?

Health and safety:

- *Employees and contractors:* During processing, are pathogens, volatile organics, or dust present in the working environment?
- *Contiguous community:* Are there any gaseous or liquid byproducts that could reach the neighbors? What are the chances of explosions or fires?
- *End-user or disposal community*: Is there a possibility that groundwater/drinking water will be adversely impacted? Is the end product infectious, caustic, dusty, or flammable?

Space requirements:

- *On-site foot print:* What size will the buildings be? Will you need space for storage of feed stuffs or end products? What are the reasonable buffer zones from contiguous land owners (present and future)?
- *Off-site acreage required for beneficial use:* What is the anticipated nutrient value or lime equivalent of the end product? Determine how many acres of farmland will be needed and triple it to account for changing land uses, and changes in farming practices and fields that for logistical reasons cannot be fertilized before planting.

Raw materials required:

- *Energy:* How much natural gas or electricity is required and does the local provider have the capability of meeting your needs? What is the projected energy availability and costs over the life of the equipment?
- *Bulking agents:* Are wood products required? If so, how much and how many vendors can supply that quantity?
- *Chemicals:* Are additional chemicals required? What has their cost been historically? How much is available locally?
- *Lime:* What quality and quantity of lime or alkaline materials are needed? What is the cost delivered? Is it consistently available in the quantities and quality needed?
- *Other materials:* If other waste products are being considered for blending, what are the regulatory requirements for storage, blending, and end use or disposal? Will the materials be continuously available? How likely is it that the wastes will change in characteristics? Who will monitor quality?

By-products and their need for treatment, use, or disposal:

- *Gaseous emissions*: What is the air quality status in the location where the facility will be located? Is it a non-attainment area for any pollutants that have the potential to exit the stack? How much foul air must be treated and what pollutants must be removed? If, in the future, GHGs are treated as pollutants, how will it affect the feasibility? What is the carbon footprint of the processing and end-use alternative?
- *Liquid waste streams:* What is the quality and quantity of liquid wastes produced? Can they be treated at the wastewater treatment plant (i.e., capacity studies)? Is the liquid waste a potential source of odors? Is the liquid waste stream a co-product or can it be used in industry?
- *Solids, residuals:* Are there any solids or residual by-products, i.e., fly ash, baghouse dust, screenings from the sludge before treatment? If so, how will these be further processed or disposed? Can they be used as a substitute for a commercially available product?

Operational complexity: Many utilities avoid complex processes because it is too great an expense to hire the staff with the skills to operate and maintain. The complexity of an innovative process can be judged by considering the following factors:

- High speed, pressure, temperature equipment requires more maintenance
- Multiple processing steps, conveyance mechanisms
- Sensitivity to changes in feed characteristics
- Operator skill level and training requirements

Water quality impacts: The objective of creating biosolids is to produce clean water. The process itself or the end product should not threaten water quality.

- *Liquid waste streams* requiring treatment at the wastewater treatment plant should be evaluated for treatability, and the plant capacity must be adequate to handle the additional loading.

- *Potential for pollution at end use or disposal sites* should be considered. When biosolids are used in agriculture in accordance with regulations and best management practices, water quality is protected. If the end product is sold or given away, instructions should be provided to the user to ensure that water quality is protected during storage or utilization.

Air quality impacts: Local emissions standards at the processing facility should be evaluated. Is it a non-attainment area for any pollutants that have the potential to exit the stack? How much foul air must be treated and what pollutants must be removed? If, in the future, GHGs are treated as pollutants, how will it affect the feasibility? What is the carbon footprint of the processing and end-use alternative?

Odor potential: The residuals processing facility has a responsibility to control odors at the processing site and to produce a product with as little odor as possible.

- *On-site:* Does the processing generate odors, dust, or fumes? Can these be contained, collected, and treated?
- *Off-site:* Does the end product have an objectionable odor? Will the odor characteristics change during storage or blending with other products? Are certain handling practices required to avoid odor generation?

Nuisance factors such as noise, traffic, and dust:

- *Noise:* Trucks, fans, regenerative thermal oxidizers, high speed equipment, and pumps all create noise that may be offensive to neighbors and employees.
- *Truck traffic:* Will truck traffic be increased or decreased? Are additives needed hat must be trucked in? Is the overall weight and volume increased or decreased during processing?
- *Dust:* Both on-site and off-site dust can be difficult to mitigate if the product is dusty. At the processing site, fugitive emissions can result in air quality violations and create an unpleasant working environment.

Permitting effort required: Operating data are usually required for a processing, use, or disposal permit. This can be difficult with an innovative process.

- *Regulatory feasibility:* Determine exactly which method and type of monitoring will be used to demonstrate pathogen reduction and vector attraction reduction. Meet with state and federal regulators and obtain their input. What would be their concerns? What would they recommend in terms of monitoring requirements?
- *Level of research and development needed for approval:* If a demonstration project is planned, what are the objectives? How do you define success or failure? What is the timeline?
- *Unknown obstacles:* An innovative process can experience obstacles that are unforeseen in the planning stages. Have a backup plan to handle the residuals on a temporary or permanent basis.

Time line: Develop an implementation schedule. Be aware that innovative processes will take longer to implement than conventional methods. Major milestones should include (at a minimum):

- Research and development
- Bench testing/pilot projects/full scale demo
- Public outreach
- Market research
- Design
- Permitting
- Construction
- Start up
- Performance testing

G.0 Conclusions

Embarking on an innovative technology should be done one step at a time. Gather additional information through research and development and re-evaluate the benefits compared to the baseline.

Yet, utilities have a responsibility for continuous improvement and for identifying the best combination of processing and utilization or disposal. Innovative technologies can potentially achieve this goal and broaden utilities' range of alternatives.

G.0 An Illustration of Issues in Implementing an Innovative Process

CWW, along with a private consultancy, have developed a new PFRP and, thereby, generate Class A biosolids. They currently are implementing this process at their SCWRF plant as a pilot study. This innovative approach, which has been named the Columbus Biosolids Flow-Through Thermophilic Treatment ($CBFT^3$) process, allows utilities to retrofit and adapt their existing mesophilic anaerobic digestion systems (that produce Class B product) to produce Class A product. The process also includes using the produced digester gas for the generation of CHP (or cogeneration) to help run the process (Willis et al., 2006).

CWW is currently retrofitting their mesophilic anaerobic digesters with thermophilic digesters, as a pilot project for the $CBFT^3$ process. The pilot study is part of an effort to obtain approval of the $CBFT^3$ process as a PFRP, from the U.S. EPA PEC. The full-scale system will be operated under a prescribed testing protocol to demonstrate Site-Specific Equivalency as a PFRP (Shaw et al., 2006). The pilot program will be up and running in the summer of 2008. Motivation for adopting the new process, an overview of the process, and innovation-related issues the utility has faced along the way, are discussed below.

G.1.1 Motivation for Change: Why $CBFT^3$?

CWW's motivation to switch from Class B to Class A biosolids was to achieve greater flexibility in distributing biosolids for land application. There are a number of currently available processes to further reduce pathogens, and operational options, for achieving Class A biosolids quality as specified in the 40 CFR, Part 503 regulations. However, CWW identified the $CBFT^3$ process to be very cost-effective for retrofit to an existing treatment plant with existing anaerobic digesters (Shaw et al., 2006). CWW has received a patent for this process and has donated the patent to WERF for the benefit of wastewater utilities nationwide. CWW expects to provide adequate pathogen sampling and analysis at full scale to convince the U.S. EPA PEC to designate PFRP equivalency to the process.

G.0.0 Process Overview

The CBFT[3] process allows utilities to convert their anaerobic digestion operations from mesophilic temperatures (which produce Class B product) to temperatures in the thermophilic range (which produce Class A product), while saving valuable construction space and considerable construction time and money. The introduction of one or more plug flow reactors at the end of the thermophilic digestion process enables the production of Class A product in a much shorter holding time than previously thought possible.

The CBFT[3] process enables 100% recovery and recycling of the produced digester gas. Additionally, CWW plans to use a new engine design (called ARES) in the first application of this more efficient technology at a wastewater treatment plant. The ARES design can produce over 20% more power than current lean-burn engines for the same supplied fuel. As a final new element, one of the two proposed ARES engines would be equipped with a catalytic converter that will further reduce the produced air pollution to levels approaching the cleanest technologies available today at a fraction of the cost for other technologies (Cliff Arnett, CWW, personal communication, September 2006).

G.0.0 Issues faced in Applying an Innovative Process

PEC Approval from the U.S. EPA In order for CBFT[3] to be considered a PFRP, approval from the PEC of the U.S. EPA is needed. Part of the requirements for approval is to show site-specific equivalency.

The PEC is comprised of a number of U.S. EPA experts on biosolids production. In order to achieve national equivalency for a new process, the applying agency must provide detailed scientific data and performance criteria to enable the PEC to arrive at a final decision. This process is extremely time consuming because of time constraints on the PEC and the amount of time to adequately gather the appropriate information about the process. The CBFT[3] process began in 2002 and was granted site-specific equivalency by the PEC in 2005. Much more detailed evaluation at a full scale will be necessary in order to achieve national equivalency. CWW expects to begin this process in the summer of 2008, and that it will take as much as one year to achieve the final approvals (Cliff Arnett, CWW, personal communication, September 2006). Thus, there may well be a seven-year lag between the time the process was first operationalized and tested on a pilot scale (2002), and final full-scale approval (2009).

Funding Testing an innovative process for PEC approval is typically an expensive undertaking. Fortunately for CWW, the majority of the pilot study implementation was grant funded. CWW received four funding allocations from two agencies. The first two allocations were received from Congress through the U.S. EPA's Environment Programs and Management (EPM) account. Their third and forth allocations were received from Congress through the State and Tribal Grant (STAG) program. The application processes for these two agencies were considerably different and led to an increased administrative burden for CWW staff.

G.0.0 Conclusions

Innovative processes have the potential to deliver both higher quality product (e.g., Class A versus Class B) and considerable cost savings (e.g., facilitating continued and more proximate land application, and increased energy recovery and energy efficiency). They also can be pragmatic in terms of on-site feasibility (e.g., enable easy retrofit with existing configurations and equipment). However, even when an innovative approach shows considerable promise in delivering these benefits, it may take considerable time and money to get the necessary regulatory approvals to operate at full scale.

APPENDIX H

RECREATION[1]

Introduction

Biosolids projects may contribute to recreational values in a number of ways. Biosolids used in land reclamation may reduce runoff from disturbed lands, thereby enhancing the instream water flows and/or improve instream quality (by reducing sediment and other pollutant loadings). Likewise, the use of biosolids in agricultural land applications in lieu of animal manures and/or chemical fertilizers may also result in enhanced surface water conditions. A change in either quantity or quality of water could lead to changes in recreational benefits. For increases in environmental quality, the resource may draw more recreational users, and recreationists might increase their value of the activity, increase frequency of the activity, or both. Conversely, a decrease in value or use of resource might occur with a decrease in water quantity or quality.

For example, swimmers may experience benefits from improved water quality, and fishers, wildlife viewers, and hunters may experience benefits from improved habitat. A significant portion of recreational spending is tied to fish and wildlife, both of which require suitable quantities and quality of water and the habitats they support, such as wetlands, for survival (wildlife to a much lesser extent than fish).

Affected Parties

Many recreational beneficiaries may reside in areas outside of the agency's service district. Of course, utility customers may also directly benefit, such as when recreational opportunities are created or enhanced in or near the utility's service area. Individuals using wetlands or surface waters that are enhanced by biosolids management activities derive recreational use benefits for the days of outdoor activities that they get to experience (and/or the quality of their experience is improved, and thus each user day becomes more highly valued). Likewise, in downstream locations, swimmers may experience benefits from improved water quality, and fishers, wildlife viewers, and hunters may experience benefits from improved habitat. In addition, recreation-related businesses may experience an increase in revenues.

Qualitative Assessment

It may not be possible or desirable to quantify impacts for a particular category. In those cases, it may be appropriate to qualitatively assess impacts.

If benefits were to be qualitatively assessed, a scaling approach may be used to illustrate general magnitudes of benefits. If a "-2 to +2" scale were applied, with a "-2" equal to "Large costs" and a "+2" equal to "Large benefits," the following definitions may be used (see Table H-1):

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1. A similar version of this appendix was originally prepared for and appears in the WateReuse Foundation report 03-006-02, *An Economic Framework for Evaluating the Benefits and Costs of Water Reuse* (Raucher et al., 2006).

Table H-1. Scaling of Recreational Benefits.

Large Costs	Small Costs	No Impact	Small Benefits	Large Benefits
-2	-1	0	+1	+2

- -2 = Large costs: Change in water quality or quantity will entail large negative impacts on recreation. Costs of change far outweigh benefits (if any exist). This may arise where wastewater discharges are reduced in streams that are critically reliant on the return flows to support recreational uses.
- -1 = Small costs: Change in water quality or quantity will cause minor negative impacts on recreation. Costs of change are slightly greater than benefits (if any exist).
- 0 = No impact: Change in water quality or quantity will not affect water-related recreational activities in any way, or will have benefits commensurate with the costs.
- +1 = Small benefits: Change in water quality or quantity will have a small positive impact on at least one or more water-related recreational activities. Benefits will slightly outweigh the costs.
- +2 = Large benefits: Change in water quality or quantity will have a large positive impact on at least one or more water-related recreational activities. Benefits will significantly outweigh the costs.

Quantifying the Outcomes (Identifying Units of Measurement)

Values for recreation activities such as swimming or fishing are most frequently cited in dollars per user activity day. An activity day is the typical amount of time pursuing an activity within a 24-hour period. Other units of measurement for water-related recreational activities include per season and per year. For fishing, units of measurement also may include values per fish caught and per fish kept.

These values per specified unit of measurement are then applied to the appropriate quantity. If values are cited in dollars per user activity day, then one needs to apply this value to the geographically appropriate total number of user days.

Monetizing the Outcomes

The total value of recreational activities is often divided into two components: 1) what people actually pay in out-of-pocket expenses to participate in a given sport (e.g., equipment and travel expenditures); and 2) what they would be willing to pay over and above what they currently pay. The first component of value can be represented simply by the expenditures incurred. However, cost is typically an underestimate of value, and thus there is the second component of value. Recreational site visits cost money and time, and recreationists would not undertake visits unless the visits yielded net benefits, known as *consumer surplus*. Thus, even though there are often not direct markets to “purchase” recreational activities, there are prices, both money and time, that individuals pay to participate in recreational activities. Those prices can be used to estimate an individual’s willingness to pay, and thus demand, for water-related activities.

Once a value (or range of values) per user day has been identified, it needs to be applied to the appropriate number of user days. For example, in 2001, residents of the State of California fished 27,878 days (USFWS and U.S. Census Bureau, 2003). If a water quality or quantity change had a positive impact such that user days would increase by 5% (or 1,394 days), then the impact could entail a benefit to the recreational fishing sector of approximately $46,000 (assuming a value of $32.83 per fishing day). Additional benefits may be experienced if fishers increase the value of their fishing day or if existing fishers opt to fish more.

Resources (Where to Look up Further Information)

See subcategories in the sections below:

- H.1 In-Water Recreation
- H.2 Near-Water Recreation

Also, the end of this appendix provides a resource guide to several useful recreation valuation databases.

H.1 Recreation: In-Water Recreation

H.1.1 Introduction

In-water recreational activities for rivers primarily consist of swimming, float boating (e.g., canoeing, river rafting), motor boating, and fishing. In-water recreational activities for lakes and reservoirs can include these activities plus jet skiing, water skiing, house boating, and sailing. For increases in environmental quality, the resource may draw more in-water recreation and existing recreationists might increase their value of the activity. Conversely, a decrease in use or value of a resource for in-water recreation might occur with a decrease in water quantity or quality.

H.1.2 Affected Parties

Recreation will generally affect the societal impact category. In particular, swimmers, boaters, and skiers may experience benefits from improved water quantity or quality, and fishers may experience benefits from improved habitat. Recreation-related businesses may experience impacts as well. Beneficiaries will often include many individuals who reside beyond the service area boundaries of the utility.

H.1.3 Qualitative Assessment

It may not be possible or desirable to quantify impacts for a particular category. In those cases, it may be appropriate to qualitatively assess impacts.

If benefits were to be qualitatively assessed, a scaling approach may be used to illustrate general magnitudes of benefits. If a “-2 to +2” scale were applied, with a “-2” equal to “Large costs” and a “+2” equal to “Large benefits,” the following definitions may be used (see Table H-2):

Table H-2. Scaling of In-Water Recreational Benefits.

Large Costs	Small Costs	No Impact	Small Benefits	Large Benefits
-2	-1	0	+1	+2

- -2 = Large costs: Change in water quality or quantity will entail large negative impacts on in-water recreation. Costs of change far outweigh benefits (if any exist).
- -1 = Small costs: Change in water quality or quantity will cause minor negative impacts on in-water recreation. Costs of change are slightly greater than benefits (if any exist).
- 0 = No impact: Change in water quality or quantity will not affect in-water recreational activities in any way, or will have benefits commensurate with the costs.

- +1 = Small benefits: Change in water quality or quantity will have a small positive impact on at least one or more in-water recreational activities. Benefits will slightly outweigh the costs.
- +2 = Large benefits: Change in water quality or quantity will have a large positive impact on at least one or more in-water recreational activities. Benefits will significantly outweigh the costs.

H.1.4 Quantifying the Outcomes (Identifying Units of Measurement)

Values for recreation activities such as swimming or fishing are most frequently cited in dollars per user activity day. An activity day is the typical amount of time pursuing an activity within a 24-hour period. Other units of measurement for water-related recreational activities include per season and per year. For fishing, units of measurement also may include per fish caught and per fish kept.

H.1.5 Monetizing the Outcomes

The total value of recreational activities is often divided into two components: 1) what people actually pay to participate in a given sport (e.g., equipment expenditures); and 2) what they would be willing to pay over and above what they currently pay. The first component of value can be represented simply by the expenditures incurred. However, cost is typically an underestimate of value, and thus there is the second component of value. Recreational site visits cost money and time, and recreationists would not undertake visits unless the visits yielded net benefits, known as *consumer surplus*. Thus, even though there are often not direct markets to "purchase" recreational activities, there are prices, both money and time, that individuals pay to participate in recreational activities. Those prices can be used to estimate an individual's willingness to pay, and thus demand, for water-related activities.

A meta-analysis of studies estimating recreational benefits (Rosenberger and Loomis, 2001) provided the following values, which are stated per person per day of activity (all values stated in June 2004 USD):

- Swimming (13 studies): average $27.09 (low: $2.18; high: $135.73)
- Float boating (river rafting; 15 studies): $37.27 (low: $17.93; high: $314.37)
- Motor boating (15 studies): $38.13 (low: $5.26; high: $202.30)

One study estimated the following recreational benefits for water skiing and canoeing/kayaking in the United States (Bergstrom and Cordell, 1991; all values stated in June 2004 USD):

- Water skiing: $40.96
- Canoeing/kayaking: $19.28
- Rowing/other boating: $41.67

The individual values for activities within these categories vary due to a number of factors including geographic location and site quality (e.g., ease of access, quality of experience).

There is a large body of literature supporting values for fishing. Fishing values may vary significantly, depending on aspects of the experience such as species, bodies of water (which may be specified as type of waterbody such as stream or lake, or by type of water such as warm water or cold water), and angling techniques. The database created in Rosenberger and Loomis (2001) reports an average value of $39.14 per fishing day per user, obtained from 118 different studies. Values ranged from $2.06 to $251.49. The lower estimate is for trout and salmon fishing in Wisconsin on Lake Michigan (Samples and Bishop, 1985) and the higher for sportfishing in Maine (Boyle et al., 1990).

Identifying more accurate values for specific species of fish in a given location may be accomplished by using some of the fishing-specific databases (Boyle, 1997; Industrial Economics, 2004). These databases may contain many of the same studies in the Rosenberger and Loomis (2001) database, but present study results by more specific attributes such as species, water body type, and location. However, values presented in many databases are not consistent across all studies included in the analysis, so precise conversions will need to be conducted to compare or combine values. Results may be presented in dollar values which vary by units of time (e.g., hour, day, trip, season, year); measures of consumer surplus (e.g., marginal or total); and other measures such as per fish caught or per fish kept.

Table H-3 summarizes some of the available monetary values for in-water recreational activities.

Table H-3. Summary of Economic Values (Willingness to Pay) of In-Water Recreational Activities (per User Day; June 2004 USD).

Activity	Average Value	Low Value	High Value	Number of Sources
Swimming	$27.09[a]	$2.18	$135.73	13
Float boating	$37.27[a]	$17.93	$314.37	14
Motor boating	$38.13[a]	$5.26	$202.30	15
Fishing	$39.14[a]	$2.06	$251.49	118
Water skiing	$40.96[b]	na	na	1
Canoeing/ kayaking	$19.28[b]	na	na	1
Row boating/ other boating	$41.67[b]	na	na	1

[a]Average values were obtained from the average values reported in 1996 USD in the meta-analysis conducted by Rosenberger and Loomis (2001), and updated to June 2004 USD, using the appropriate Consumer Price Index (CPI) of 0.1923.
[b]Values were reported in the Bergstrom and Cordell (1991) in 1987 USD and updated to June 2004 USD, using the appropriate CPI of 0.5214.

H.1.6 Resources (Where to Look up Further Information)

Recreation values (e.g., values for swimming, fishing, float boating, motor boating):

- Environment Canada. 2004. Environmental Valuation Resource Inventory (EVRI). http://www.evri.ca.
- Rosenberger, R. and J. Loomis. 2001. Benefit Transfer of Outdoor Recreation Use Values. Gen. Tech. Rep. RMRS-GTR-72. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO. http://www.fs.fed.us/rm/pubs/rmrs_gtr72.html.

- Lew, D.K., D.M. Larson, H. Suenaga, and R. DeSousa. 2001. The Beneficial Use Values Database. Department of Agricultural and Resource Economics, April. http://buvd.ucdavis.edu.
- U.S. EPA. 2004. Environmental Economic Reports Inventory (EERI). http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/EnvironmentalEconomicsReports.html.

Additional fishing values:

- Industrial Economics. 2004. Sportfishing Values Database. Prepared for the U.S. Fish and Wildlife Service. http://www.indecon.com/fish/default.asp.
- Boyle, K. 1997. Meta-Analysis of Sport Fishing Values. U.S. Fish and Wildlife Service.

H.1.7 Crosswalk to Other Categories

Additional benefits may be experienced by other sectors (discussed in other sections). Some local and regional recreation-related businesses may experience a change in revenues which will have local/regional economic impacts.

H.2 Recreation: Near-Water Recreation

H.2.1 Introduction

Near-stream recreational activities may include hiking, picnicking, camping, waterfowl hunting, wildlife viewing, and sightseeing. For increases in environmental quality, the resource may draw more near-water recreation and existing recreationists might increase their value of the activity. Conversely, a decrease in use or value of a resource for near-water recreation might occur with a decrease in water quantity or quality.

H.2.2 Affected Parties

Near-water recreation will generally affect the societal impact category. In particular, hikers, picnickers, campers, hunters, wildlife viewers, and sightseers may experience benefits from improved water quantity or quality, and associated habitat. Recreation-related businesses may experience impacts as well. Beneficiaries are likely to include many people who reside outside of the utility service area.

H.2.3 Qualitative Assessment

It may not be possible or desirable to quantify impacts for a particular category. In those cases, it may be appropriate to qualitatively assess impacts.

If benefits were to be qualitatively assessed, a scaling approach may be used to illustrate general magnitudes of benefits. If a “-2 to +2” scale were applied, with a “-2” equal to “Large costs” and a “+2” equal to “Large benefits,” the following definitions may be used (see Table H-4):

Table H-4. Scaling of Near-Water Recreational Benefits.

Large Costs	Small Costs	No Impact	Small Benefits	Large Benefits
-2	-1	0	+1	+2

- -2 = Large costs: Change in water quality or quantity will entail large negative impacts on near-water recreation. Costs of change far outweigh benefits (if any exist).
- -1 = Small costs: Change in water quality or quantity will cause minor negative impacts on near-water recreation. Costs of change are slightly greater than benefits (if any exist).

- 0 = No impact: Change in water quality or quantity will not affect near-water recreational activities in any way, or will have benefits commensurate with the costs.
- +1 = Small benefits: Change in water quality or quantity will have a small positive impact on at least one or more near-water recreational activities. Benefits will slightly outweigh the costs.
- +2 = Large benefits: Change in water quality or quantity will have a large positive impact on at least one or more near-water recreational activities. Benefits will significantly outweigh the costs.

H.2.4 Quantifying the Outcomes (Identifying Units of Measurement)

Values for recreation activities such as swimming or fishing are most frequently cited in dollars per user activity day. An activity day is the typical amount of time pursuing an activity within a 24-hour period. Other units of measurement for water-related recreational activities include per season and per year. For fishing, units of measurement also may include per fish caught and per fish kept.

H.2.5 Monetizing the Outcomes

The total value of recreational activities is often divided into 2 components: 1) what people actually pay to participate in a given sport (e.g., equipment expenditures); and 2) what they would be willing to pay over and above what they currently pay. The first component of value can be represented simply by the expenditures incurred. However, cost is typically an underestimate of value, and thus there is the second component of value. Recreational site visits cost money and time, and recreationists would not undertake visits unless the visits yielded net benefits, known as *consumer surplus*. Thus, even though there are often not direct markets to "purchase" recreational activities, there are prices, both money and time, that individuals pay to participate in recreational activities. Those prices can be used to estimate an individual's willingness to pay, and thus demand, for water related activities.

Table H-5 summarizes some of the values for near-water recreational activities. These values were obtained from a meta-analysis of studies estimating recreational benefits and all values are stated per person per day of activity. Values for these activities vary due to a number of factors including geographic location and site quality (e.g., ease of access, quality of experience).

Table H-5. Summary of Economic Values (Willingness to Pay) of Near-Water Recreational Activities (per User Day; June 2004 USD).

Activity	Average Value[a]	Low Value	High Value	Number of Sources
Hiking	$32.00	$1.86	$260.35	27
Picnicking	$44.02	$13.52	$141.82	10
Camping	$42.10	$2.01	$223.08	40
Waterfowl hunting	$36.20	$2.59	$170.28	58
Wildlife viewing	$37.13	$2.81	$160.82	116

[a]Average values were obtained from the average values reported in 1996 USD in the meta-analysis conducted by Rosenberger and Loomis (2001), and updated to June 2004 USD, using the appropriate CPI of 0.1923.

H.2.6 Resources (Where to Look up Further Information)

Recreation values:

- Environment Canada. 2004. Environmental Valuation Resource Inventory (EVRI). http://www.evri.ca.
- Rosenberger, R. and J. Loomis. 2001. Benefit Transfer of Outdoor Recreation Use Values. Gen. Tech. Rep. RMRS-GTR-72. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO. http://www.fs.fed.us/rm/pubs/rmrs_gtr72.html.
- Lew, D.K., D.M. Larson, H. Suenaga, and R. DeSousa. 2001. The Beneficial Use Values Database. Department of Agricultural and Resource Economics. April. http://buvd.ucdavis.edu.
- U.S. EPA. 2004. Environmental Economic Reports Inventory (EERI). http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/EnvironmentalEconomicsReports.html.

H.2.7 Crosswalk to Other Categories

Additional benefits may be experienced by other sectors (discussed in other sections). Some local and regional recreation-related businesses may experience a change in revenues which will have local/regional economic impacts.

H.3 A Sourcebook on Recreational Values for Water Resources

This document briefly summarizes and identifies the location of a number of sources where values of water resources may be obtained. Several databases are summarized that contain primarily nonmarket, but some market, values in meta-analysis format which can be used for benefits transfer in a wide variety of applications.

H.3.1 Environmental Valuation Resource Inventory Database

The Environmental Valuation Resource Inventory (EVRI) database is an Environment Canada database located on the Web. It includes nonmarket (e.g., contingent valuation) and market (e.g., commercial fishing) values alike for a wide range of resource categories, including air, land, water, and artificial structures. Studies included in the database were conducted from 1960 to the present, but focus on the late 1980s and early 1990s.

At present, entries in the EVRI are concentrated in the area of water valuation studies. This is a consequence of initial focus on water valuation in the Americas during the testing phases of the development of the infobase. The scope of the EVRI is being broadened to include valuation studies for many types of natural capital from all parts of the world. The EVRI is intended primarily as a tool to assist policy analysts using the benefits transfer approach in estimating economic values for changes in environmental goods and services or human health. For the benefits transfer approach, the results of the previous studies held within the EVRI can be used (transferred) to estimate the economic value of changes stemming from current programs or policies.

The main challenge faced in conducting an economic valuation with a benefits transfer approach is in finding the most appropriate studies to use in the transfer exercise. Choosing an appropriate set of studies involves matching the context of the previous economic study(ies), termed study sites, with the context of the current program or policy, termed the policy site. The

EVRI has been designed specifically to help analysts evaluate the quality of the information about the study site(s) and to match the studies with current policy sites. The EVRI's Searching Module helps the user define the good or service to be valued and identifies studies with potential for transfer. The Screening Module helps the user assess the suitability of the studies identified in the search according to criteria outlined in the benefits transfer literature.

Using the EVRI and the benefits transfer approach appropriately will yield significant time and cost savings as compared to the time and resource intensive process of designing, testing, and implementing a new valuation study. Beyond its role in facilitating defensible benefits transfers, the EVRI can assist in the design of new valuation studies since it contains concise, detailed, and easily accessed information about the methods and approaches taken in existing valuation studies. In the long run, the EVRI will illustrate the gaps in the body of valuation research with respect to environmental goods and services and different parts of the world.

The EVRI's abstracts of valuation studies outline the pertinent valuation issues and results necessary for a researcher to identify the best candidate studies for a potential benefits transfer. There are six main categories of information, contained in more than 30 fields:

- Study reference—basic bibliographic information
- Study area and population characteristics—information about the location of the study along with population and site data
- Environmental focus of the study—fields that describe the environmental asset being valued, the stressors on the environment, and the specific purpose of the study
- Study methods—technical information on the actual study, along with the specific techniques that were used to arrive at the results
- Estimated values—the monetary values that are presented in the study as well as the specific units of measure
- Alternative language summary—an abstract of the study available in English, French, and Spanish

The EVRI database and its searching modules are located at the following Website: http://www.evri.ca (Environment Canada, 2004). This is a subscription (i.e., fee-based) database (see fee rates in Canadian dollars below).

- C$900 per 12-month subscription or per 100 log-ons to the EVRI site, whichever comes first
- C$600 per 6-month subscription or per 50 log-ons to the EVRI site, whichever comes first
- C$200 per 1-month subscription or per 20 log-ons to the EVRI site, whichever comes first

H.3.2 John Loomis Recreation Meta-Analysis Database

John Loomis is a nonmarket valuation economics professor at Colorado State University. The Loomis Recreation Meta-Analysis database is a comprehensive collection of 701 recreational nonmarket valuation studies from 1970 through 1998, but focuses on the late 1980s and 1990s. The file is in Excel format. Individual study values are reported, and a useful summary sheet reporting national averages and the means over five regions is included (values reported in 1996 USD). The categories likely to be most useful to water resources include fishing, swimming, float-boating, motor-boating, picnicking, waterfowl hunting, and camping.

Results from the database are presented in a report entitled "Benefit Transfer of Outdoor Recreation Use Values" (Rosenberger and Loomis, 2001), located on the Internet at http://www.fs.fed.us/rm/pubs/rmrs_gtr72.html.

H.3.3 Sportfishing Values Database by IEC

Prepared by Industrial Economics, Incorporated (IEC) under contract to the U.S. Fish and Wildlife Service (USFWS), the Sportfishing Values database provides a detailed account of the contents of numerous recent nonmarket valuation studies. Included in the database is information from over 100 travel cost and contingent valuation studies of sportfishing activity. To the extent possible, the database describes the resource and the change that provide the basis for the reported value, including species and resource quality characteristics. In addition, the database describes the associated study characteristics (including respondent sample information), the valuation methodology, and other study-specific conditions.

The database is located at the following Website: www.indecon.com/fish/default.asp (Industrial Economics, 2004).

H.3.4 Beneficial Use Values Database

The purpose of the Beneficial Use Values database (BUVD) is to provide an educational and informational tool to the general public and interested specialists, documenting the economic values for beneficial uses of water identified by the California State Water Resources Control Board (SWRCB). It is envisioned that the BUVD be a companion to the Water Quality Standards Inventory Database (WQSID), which currently provides information to the public on water quality standards for, and beneficial uses of, water bodies throughout California, but no information on the value of those beneficial uses.

In preparing this alpha version of the database, the literature on economic values of water was consulted widely but not exhaustively, so in its current form the BUVD should be considered as:

- A representation of many, though not necessarily all, economic values for beneficial uses of water available in the current literature.
- A template which can be added to as more studies are identified as suitable for inclusion in the database over time.
- The current version has a basic front-end search engine that simplifies the use of the database for persons less familiar with Microsoft Access, relational databases, and query building. It is expected that the Web-based version of the database to be implemented later will have a more powerful search engine that will allow users to do more complicated data searches.

H.3.4.1 Basic Structure and Contents of the Beneficial Use Values Database

The BUVD is a Microsoft Access relational database with nine underlying tables. These tables contain the beneficial use values that will appear in the Web-based version and the documents in which they were reported. The nine tables are linked. Currently, there are over

2,000 values for a diverse set of amenities, including values for water for recreation, habitat, municipal, and industrial uses.

The database design centers on the Documents table, which contains reference information (pubyear, title, and refinfo), a field describing the type of publication (pubtype), and general information specific to each document (amenity, sitedesc, and comments). Documents were classified as one of the following publication types:

- Journal article
- Book/book chapter
- Report
- Unpublished/working paper
- Other

Of the 131 studies included in the edited database, there were eight books or book chapters, 101 journal articles, 17 reports, and five working or unpublished papers. Because six of the book chapters were separate chapters in three books, there are actually 128 distinctly different studies reported on in the database. The vast majority of the studies were conducted in the last 25 years, which reflects the relative paucity of studies valuing water and its uses in the literature before the 1970s.

H.3.4.2 Valuation Methods Used in Reported Studies

Market Valuation Methods When market data are available, market price and quantity information can be used to estimate demand, supply, or production relationships. These relationships provide a means for directly measuring economic value.

Contingent Valuation Methods Use survey questions to obtain direct estimates of willingness to pay. These methods are frequently used to value goods for which there is little or no behavioral (market) data. These are also the only methods that can obtain estimates of nonuse values.

Conjoint Analysis Methods A survey-based approach in which people are asked to rate or rank several different scenarios, each with different levels of attributes taken from a common set. Statistical methods are then used to estimate the willingness to pay of individual attributes.

Damage Function Approach Methods These methods seek to determine a “dose-response” relationship between an environmental quality change and some physical effect, and then use market values for the estimated marginal effect to determine a monetary value for the overall effect.

Hedonic Methods Hedonic methods assume that the price of a good is a function of its attributes. Thus, the price of a good is regressed on its characteristics to find the marginal value of the characteristics.

Averting Behavior Approaches Averting behavior approaches infer the value people place on an amenity by what they spend to prevent its removal or degradation.

Optimization Models Optimization models are mathematical representations of an economic problem and include mathematical programming, calculus of variations, and optimal control models.

Opportunity Cost Methods This approach views the opportunity cost associated with using an amenity for one use as the value of the amenity used in its next best alternative use.

Simulation Models Simulation models used in valuation of beneficial uses are typically used to determine the biological or physical response to economic stimuli.

Travel Cost Methods (TCM) Although there are many variants of this approach, all TCM studies use expenditure and trip visitation data for visitors to a natural resource to extrapolate the associated value of a resource.

Replacement Cost Methods The replacement cost methods use the monetary cost of replacing or restoring an amenity as a measure of the value of the amenity.

Other Methods Valuation methods falling into this category represent a variety of approaches to valuing beneficial uses that include three cost-based valuation techniques, an energy analysis approach, and an agricultural yield comparison approach.

The Website is located with the University of California, Davis at: http://buvd.ucdavis.edu (Lew et al., 2001).

H.3.5 U.S. EPA's Environmental Economic Reports Inventory

At the U.S. EPA Environmental Economic Report Inventory (EERI) Website, over 200 downloadable reports are available, although the site contains no fields or spreadsheets to summarize values or other study information. The search capabilities are advanced: you can search for reports under author, title, subject, or geography, among others. This inventory also contains downloadable working papers and some U.S. EPA datasets.

The Website is located at: http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/EnvironmentalEconomicsReports.html (U.S. EPA, 2004).

H.3.6 Wetlands and Economics: An Annotated Review of the Literature

This bibliography provides a comprehensive review of recent wetland valuation studies. The main portion consists of an annotated bibliography of published and unpublished literature. The annotations focus on those studies of particular relevance for the Great Lakes basin, and in particular on the monetized aspects of the studies. In total, 277 papers are included in the bibliography.

On a geographical basis, over half of the studies are of U.S. wetlands (representing 22 states). Thirty papers provide insight into the economics of Canadian wetlands—from six provinces. Relatively few (11) studies address the value of wetlands in the Great Lakes basin specifically. In addition, case studies from 24 other countries are included—the largest number European.

The greatest number of studies refer to freshwater marshes, although a significant number of studies are of coastal (saltwater) marshes, especially in the eastern United States. Also notable are the 18 papers on mangroves. Recreation represents the focus of the largest number of studies in the bibliography (including those papers specifically valuing the use of wetlands for hunting and fishing). Of those papers assessing the value of the production or support of commercial products by wetlands, those dealing with commercial fisheries are most numerous. In addition, 19 papers deal with the values of wetlands for water control/supply and 29 are on their values for enhancing water quality. The large number of studies on existence/option/bequest values corresponds to the interest in contingent valuation studies, especially in the United States where recent legal developments have placed an increased interest on this methodology. While legal issues most likely contribute to the number of papers on property appraisals of wetlands as property, the interest in rehabilitation and construction of wetlands also contribute to the number of papers on project financial accounting.

Although case studies predominate numerically in the references, the significant number of papers on methodological issues points to the continuing debate over and development of methods appropriate for the determination of wetland values.

A draft of the document can be accessed at: http://www.gruponahise.com/eaere2003/POSTERS/BRANDER.doc (Brander et al., 2006).

H.3.7 Meta-Analysis of Sport Fishing Values

This database contains sport fishing studies only. It was compiled by Kevin Boyle at the University of Maine and others to provide the USFWS a means to systematically explore variation in sport fishing value estimates across studies. A total of 161 studies are reviewed in detail, producing 3,104 valuation estimates. The file is in Excel format and can be perused by any of a large number of study variables, including location.

An accompanying report entitled "Meta Analysis of Sport Fishing Values" (Boyle, 1997) is available that subjects the data to statistical analysis. A subset of 1,002 value estimates from 70 studies are used to conduct meta analyses and regressions to verify hypothesized determinants of value, such as water type, methodology, and species. The Excel file can be used without the report, although the report provides some insight and aid in using the data in the spreadsheet.

APPENDIX I

ENVIRONMENTAL VALUES[1]

Introduction

Biosolids management, as noted in the previous appendix, can alter the quality and/or quantity of water in rivers and streams, be used to restore vegetation on disturbed lands, and also can enhance aquifers. Improved flows and quality in turn can enhance ecosystems by providing better habitat conditions for aquatic, riparian, or terrestrial species. These ecosystem service improvements can generate benefits that include recreational activities and other benefits associated with resource use. These may also include public health values, for example, where improved resource quality is believed by some users to provide them reduced risk of adverse health effects.

Ecosystem services also generate what is referred to in economics as passive use or nonuse values, which reflect the value individuals place on preserving or enhancing environmental conditions regardless of whether they use them. These are often described as bequest and stewardship values, to reflect human motives to pass a healthy environment to the next generation, and to preserve the environment in general. For the purposes of this economic framework, the researchers refer to these ecosystem-services related nonuse values and "environmental" values, since this is a more transparent term to communicate with lay persons.

An important caveat is that for some of the subcategories provided below, the monetary values provided for some resources, based on the literature review, may contain several categories or types of benefits. That is, these values may in some cases be "total values" that embody the combined benefits that people associate with the resource (e.g., total values reflect both use and nonuse values combined, such as the sum of recreation values plus bequest values). Readers are therefore cautioned about how they interpret and use these values, so that they avoid potential double-counting of benefits.

Affected Parties

Environmental impacts will generally affect utility customers and, in many cases, the broader population (e.g., where improved stream conditions may help preserve an endangered species). In particular, environmental changes may impact all individuals state-wide, and society-wide, who value protecting the environment. Thus, stakeholders may include various local and national environmental groups, property owners whose property values might be impacted with changes in local environmental quality, and recreationists such as wildlife viewers and hunters whose activities are impacted with changes in environmental quality. Thus, not only will water agencies and their customers be affected, but individuals and municipal users downstream also are likely to be beneficially affected.

1. This appendix was originally prepared for and appears in the WateReuse Foundation report 03-006-02, *An Economic Framework for Evaluating the Benefits and Costs of Water Reuse* (Raucher et al., 2006).

Qualitative Assessment

It may not be possible or desirable to quantify impacts for a particular category. In these cases, it may be appropriate to qualitatively assess impacts. If benefits were to be qualitatively assessed, a scaling approach may be used to illustrate general magnitudes of benefits. If a "-2 to +2" scale were applied, with a "-2" equal to "Large costs" and a "+2" equal to "Large benefits," the following definitions may be used (see Table I-1):

Table I-1. Scaling of Environmental Qualitative Assessment.

Large Costs	Small Costs	No Impact	Small Benefits	Large Benefits
-2	-1	0	+1	+2

- -2 = Large costs: Environmental change will cause large negative impacts on environmental quality that entail costs which are much greater than benefits (if any exist).
- -1 = Small costs: Environmental change will cause minor negative impacts on environmental quality that entail costs which are slightly greater than benefits (if any exist).
- 0 = No impact: Environmental change will not affect environmental quality in any way, or will have benefits commensurate with the costs.
- +1 = Small benefits: Environmental change will have a small impact on environmental quality, which will induce benefits that are slightly greater than the costs.
- +2 = Large benefits: Environmental change will have a large impact on environmental quality, which will induce benefits that are significantly greater than the costs.

Quantifying the Outcomes (Identifying Units of Measurement)

See subcategories in Sections I.1 through I.6, below, which address the following environmental resources and impacts:

- Water Quality (I.1)
- Groundwater (I.2)
- Habitat for T&E Species (I.3)
- Habitat (non-T&E species) (I.4)
- Coastal Ecosystems (I.5)
- Wetlands (I.6)

Monetizing the Outcomes

See subcategories, in Sections I.1 through I.6, below.

Resources (Where to Look up Further Information)

See subcategories.

I.1 Water Quality

I.1.1 Introduction

Water quantity impacts water quality. Increased quantity of water may help protect water quality by diluting wastewater and through natural water purification (while the reverse holds true for decreased quantities of water). Reduced groundwater extraction can avoid pumping groundwater from lower depths, which hold waters of lower quality.

Adequate quantities of water are essential for diluting fertilizers and pesticides that run-off from farm fields, and wastewater discharges from treatment plants and pollutants in urban stormwater. This dilution ensures that waterbodies are not too toxic to fish and are safe for water-based recreation such as boating.

The Clean Water Act requires point sources of pollutants to obtain a National Pollutant Discharge Elimination System (NPDES) permit before pollutants are discharged into U.S. waters. In part, the requirements of individual NPDES permits are based on streamflow. Therefore, treatment costs could be impacted to adjust to the changes in streamflows.

Natural water purification is provided by streamside vegetation and wetlands. Run-off from city streets and agricultural fields contain various pollutants such as oil, pesticides, and fertilizer as well as excess soil. These pollutants are absorbed by plants and broken down by plants and bacteria to less harmful substances. Pollutants attached to suspended soil particles are filtered out by grasses and other plants and deposited in floodplains. This process helps improve water quality. The vegetation and wetlands providing this service all require certain levels of water quantity and quality.

Water quality may also be affected by changes in treatment plant discharges. Reduced treatment plant discharges may positively affect water quality.

I.1.2 Affected Parties

Water quality will generally affect the societal and customer impact categories [see Section 3.19, Distributional Perspectives (Equity Concerns)—Who Benefits? Who Pays?]. In particular, impacts to water quality may include individuals that value the environment, various local and national environmental groups, property owners whose property values might be impacted with changes in water quality, and recreationists such as swimmers, boaters, wildlife viewers, and hunters whose activities are enhanced with improved water quality. Also, water customers may be affected (including industrial and agricultural). Downstream water users also may be affected.

I.1.3 Qualitative Assessment

It may not be possible or desirable to quantify impacts for a particular category. In these cases, it may be appropriate to qualitatively assess impacts. If benefits were to be qualitatively assessed, a scaling approach may be used to illustrate general magnitudes of benefits. If a "-2 to +2" scale were applied, with a "-2" equal to "Large costs" and a "+2" equal to "Large benefits," the following definitions may be used (see Table I-2):

Table I-2. Scaling of Water Quality Qualitative Assessment.

Large Costs	Small Costs	No Impact	Small Benefits	Large Benefits
-2	-1	0	+1	+2

- -2 = Large costs: Environmental change will cause large negative impacts on water quality that entail costs which are much greater than benefits (if any exist).
- -1 = Small costs: Environmental change will cause minor negative impacts on water quality that entail costs which are slightly greater than benefits (if any exist).
- 0 = No impact: Environmental change will not affect water quality in any way, or will have benefits commensurate with the costs.
- +1 = Small benefits: Environmental change will have a small impact on water quality, which will induce benefits that are slightly greater than the costs.
- +2 = Large benefits: Environmental change will have a large impact on water quality, which will induce benefits that are significantly greater than the costs.

I.1.4 Quantifying the Outcomes (Identifying Units of Measurement)

Values for changes in water quality are typically expressed in willingness to pay—what households are willing to pay for the change in water quality. These values may be expressed in dollars per person or per household, and may be given as a one time payment or as a monthly or yearly payment, or even per unit of change (such as a unit change in trophic level or some other index of environmental condition).

These values per specified unit of measurement are then applied to the appropriate geographic scope and time dimension. For example, if a value is cited in dollars per household per year, then one needs to apply the value to the geographically appropriate total number of years that the change will have impacts (e.g., $10 per household per year for the State of California for 10 years). The geographic scope may be as small as a community project affecting only the surrounding community, or a project impacting several counties, or even a larger area such as a state or group of states. The time dimension may range from a short-term project (one or several months) to several years. Some impacts may be perpetual, with unending economic impacts.

I.1.5 Monetizing the Outcomes

Several studies have conducted surveys asking households what they would be willing to pay to protect water resources. A common method is to use a hypothetical referendum, where households are asked if they would vote in favor of a particular resource protection action, if it cost their household $X. The amount of $X varies across households, so that a demand curve can be traced. From this demand curve, willingness to pay is calculated. Willingness-to-pay values are commonly reported in dollars per year (or per month or other specified period of time) per household. Some willingness-to-pay values are stated as a one time payment.

Several studies have examined values for changes in water quality and are summarized in Table I-3. The studies reveal people's total values for water quality through their associated values for recreation, protection of human health (through drinking water), and protection of ecological services.

Table I-3. Examples of Values for Water Quality.

Value (June 2004 USD)	Description	Source
$97.98 per household, per year	This is the amount Ohio residents were willing to pay for increased protection of surface water. This value includes residents' value for improved water quality both for improved ecological services and for protection of drinking water.	De Zoysa (1995)
$4.64-9.58 per household, per month	This is the amount Ontario residents were willing to pay for improved water quality in the Grand River watershed both for improved ecological services and for protection of drinking water.	Brox et al. (2003)
$15.22-105.29 one time payment	Residents of the Pennsylvania portion of the Monongahela River basin revealed the following range in values: 1) $29 to $57.40 for a decline in quality from boatable to unsuitable for any activity; 2) $15.90 to $36.90 for an improvement in quality from boatable to fishable; 3) $8.70 to $18.80 for an improvement in quality from fishable to swimmable; and 4) $25.10 to $60.20 for an improvement from boatable to swimmable.[a]	Desvousges et al. (1987)
$60-81 per household, per year	The study estimated the annual willingness to pay for 5 years to improve stream B, Loyalhanna Creek, from current severely polluted status to moderately polluted status.[b]	Farber and Griner (2000)
$231-238 one time payment	The study estimated what North Carolina residents were willing to pay for an improvement in water quality from the 1995 (current) degraded level back to the 1981 level.	Huang et al. (1997)
$2,564 per unit of trophic state index	The study finds that each unit increase in the trophic state index (with 0 meaning very good and 100 meaning bad) results in a decrease in the parcel selling price.	Feather (1992)

[a]A "water quality ladder" is a water quality rating scale that is commonly used in the economic literature. It reflects the ability of a body of water to support a particular designated use (based on its water quality). In this study, using a water quality ladder, respondents were asked to value three scenarios with changes in water quality: 1) a decline in water quality from a level where it is suitable for boating (but not for swimming) to a level that is unsuitable for any water-based activities (including boating), 2) improving water quality from boatable to a level where gamefish would survive, 3) improving water quality from fishable to swimmable, and 4) improving water quality from boatable to swimmable.

[b]Severely polluted streams are incapable of supporting fish and other organisms, and fishing would be poor to nonexistent; moderately polluted streams support some fish but reproductive conditions for fish are poor while unpolluted streams are streams where fish and organisms can thrive.

I.1.6 Resources (Where to Look up Further Information)

Values for environmental services (e.g., water quality):

- Environment Canada. 2004. Environmental Valuation Resource Inventory (EVRI). http://www.evri.ca.
- Lew, D.K., D.M. Larson, H. Suenaga, and R. DeSousa. 2001. The Beneficial Use Values Database. Department of Agricultural and Resource Economics. April. http://buvd.ucdavis.edu.
- U.S. EPA. 2004. Environmental Economic Reports Inventory (EERI). http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/EnvironmentalEconomicsReports.html.

I.2 Groundwater

I.2.1 Introduction

Groundwater systems provide services that may include, but are not necessarily limited to 1) providing safe drinking water to a community; 2) supporting aquatic ecosystems through hydrologic interactions with surface waters such as riparian corridors or wetlands; 3) enabling development of overlying land resources for residential, commercial, or other uses; and 4) generating existence, option, and bequest values as a resource left in its "natural" state, and conserved for potential future use by present or future generations.

Changes to instream flows and/or levels of groundwater extraction affect recharge of groundwater which may impact potential for future extraction, water quality, and salt water intrusion into fresh water aquifers. A reuse-generated increase in stream flows or groundwater recharge may positively affect these aspects while a decrease may have a negative impact. For example, an increase in groundwater levels may increase future extraction capabilities, improve water quality, and reduce salt water intrusion.

I.2.2 Affected Parties

Groundwater will generally affect the societal and customer impact categories. In particular, beneficiaries of increased groundwater recharge may include water districts or industries who have their needs supplied from groundwater, individuals that value an improved environment, various local and national environmental groups, property owners whose property values might increase with improved environmental quality, and recreationists such as wildlife viewers and hunters whose activities are enhanced with improved water quality.

I.2.3 Qualitative Assessment

It may not be possible or desirable to quantify impacts for a particular category. In these cases, it may be appropriate to qualitatively assess impacts. If benefits were to be qualitatively assessed, a scaling approach may be used to illustrate general magnitudes of benefits. If a "-2 to +2" scale were applied, with a "-2" equal to "Large costs" and a "+2" equal to "Large benefits," the following definitions may be used (see Table I-4):

Table I-4. Scaling of Groundwater Recharge Qualitative Assessment.

Large Costs	Small Costs	No Impact	Small Benefits	Large Benefits
-2	-1	0	+1	+2

- -2 = Large costs: Environmental change will cause large negative impacts on groundwater that entail costs which are much greater than benefits (if any exist).
- -1 = Small costs: Environmental change will cause minor negative impacts on groundwater that entail costs which are slightly greater than benefits (if any exist).
- 0 = No impact: Environmental change will not affect groundwater in any way, or will have benefits commensurate with the costs.
- +1 = Small benefits: Environmental change will have a small impact on groundwater, which will induce benefits that are slightly greater than the costs.
- +2 = Large benefits: Environmental change will have a large impact on groundwater, which will induce benefits that are significantly greater than the costs.

I.2.4 Quantifying the Outcomes (Identifying Units of Measurement)

Values for changes to groundwater are typically expressed in willingness to pay—what households are willing to pay for the change in groundwater. These values may be expressed in dollars per person or per household, and may be given as a one time payment or per month or year, or even per unit of change (such as unit change in trophic level or some other index of environmental condition).

Values for changes to groundwater may also be given in a certain dollar amount per volume of water such as per acre-feet or per gallon (or some number of gallons such as 1,000 gallons).

Table I-5 summarizes key studies and their findings. These values per specified unit of measurement are then applied to the appropriate quantity. For example, if values are cited in dollars per household per year, then one needs to apply the value(s) to the geographically appropriate total number of years (e.g., $10 per household per year for the State of California for 10 years).

Table I-5. Examples of Values for Groundwater.

Value (June 2004 USD)	Description	Source
$0.88-2.72 per 1,000 gallons	Scarcity present values of groundwater in Hawaii, which may reflect values of recharging groundwater sources.[a]	Moncur and Pollock, 1988
$46-917 per household, per year	Values for ensuring uncontaminated groundwater supplies for the future.	Low: Powell et al., 1994 High: Henglen et al., 1992
$73-1,507 annually per household	This meta-analysis (of eight studies) examined household willingness to pay for restoration of contaminated groundwater.	Boyle et al., 1994
$2.70-3.45 annually per household	Passive use values for restoration of contaminated groundwater in Montana (adjusted from total use values of $3.67-6.10).	Schulze et al., 1993
$66 annually per household	Value reflecting what Ohio residents were willing to pay for increased protection of groundwater.	De Zoysa, 1995

[a]For most natural resources, the existence of scarcity and the extent of the scarcity rent can be determined. That portion of the resource price in excess of extraction costs signals scarcity and defines the value of the resource in situ (Moncur and Pollock, 1988).

I.2.5 Monetizing the Outcomes

Several studies have conducted surveys asking households what they would be willing to pay to protect water resources. A common method is to use a hypothetical referendum, where households are asked if they would vote in favor of a particular resource protection action, if it cost their household $X. The amount of $X varies across households, so that a demand curve can be traced. From this demand curve, willingness to pay is calculated; this is the contingent valuation method. Willingness-to-pay values are commonly reported in dollars per year (or per month or other specified period of time) per household. Some willingness-to-pay values are stated as a one time payment.

I.2.6 Resources (Where to Look up Further Information)

Values for environmental services:

- Environment Canada. 2004. Environmental Valuation Resource Inventory (EVRI). http://www.evri.ca.
- Lew, D.K., D.M. Larson, H. Suenaga, and R. DeSousa. 2001. The Beneficial Use Values Database. Department of Agricultural and Resource Economics. April. http://buvd.ucdavis.edu.
- U.S. EPA. 2004. Environmental Economic Reports Inventory (EERI). http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/EnvironmentalEconomicsReports.html.

I.3 Habitat for T&E Species

I.3.1 Introduction

Changes in water quantity (both surface and ground) may impact habitat for T&E species.

I.3.2 Affected Parties

Protection of T&E species will generally affect the societal impact category. In particular, beneficiaries of improved habitat for T&E species may include individuals that value biological diversity, and various local and national environmental groups.

I.3.3 Qualitative Assessment

It may not be possible or desirable to quantify impacts for a particular category. In these cases, it may be appropriate to qualitatively assess impacts. If benefits were to be qualitatively assessed, a scaling approach may be used to illustrate general magnitudes of benefits. If a "-2 to +2" scale were applied, with a "-2" equal to "Large costs" and a "+2" equal to "Large benefits," the following definitions may be used (see Table I-6):

Table I-6. Scaling of Habitat for T&E Species Qualitative Assessment.

Large Costs	Small Costs	No Impact	Small Benefits	Large Benefits
-2	-1	0	+1	+2

- -2 = Large costs: Environmental change will cause large negative impacts on T&E species that entail costs which are much greater than benefits (if any exist).
- -1 = Small costs: Environmental change will cause minor negative impacts on T&E species that entail costs which are slightly greater than benefits (if any exist).
- 0 = No impact: Environmental change will not affect T&E species in any way, or will have benefits commensurate with the costs.
- +1 = Small benefits: Environmental change will have a small impact on T&E species, which will induce benefits that are slightly greater than the costs.
- +2 = Large benefits: Environmental change will have a large impact on T&E species, which will induce benefits that are significantly greater than the costs.

I.3.4 Quantifying the Outcomes (Identifying Units of Measurement)

All of the values listed in this section for changes to T&E species are expressed in willingness to pay—what households are willing to pay for the change in circumstances affecting

T&E species. These values may be expressed in dollars per person or per household, and may be given as a one time payment or per month or year, or even per unit of change in an indicator (e.g., some index of condition of habitat and population).

Some values may also exist for protection of habitat per area of habitat such as per acre, but are not presented here.

These values per specified unit of measurement are then applied to the appropriate quantity. For example, if values are cited in dollars per household per year, then one needs to apply the value(s) to the geographically appropriate total number of years (e.g., $10 per household per year for the State of California for 10 years).

I.3.5 Monetizing the Outcomes

Several studies have conducted surveys asking households what they would be willing to pay to protect water resources. A common method is to use a hypothetical referendum, where households are asked if they would vote in favor of a particular resource protection action, if it cost their household $X. The amount of $X varies across households, so that a demand curve can be traced. From this demand curve, willingness to pay is calculated; this is the contingent valuation method. Willingness-to-pay values are commonly reported in dollars per year (or per month or other specified period of time) per household. Some willingness-to-pay values are slated as a one time payment.

Table I-7 presents examples of values for some aquatic T&E species. These values are for certain species in specified locations, and using these values for direct transfer for use in BT is discouraged against, but do reflect the range of values obtained in the literature. Refer to the guidance document on use of BT for further information on the process of applying these values to other species and other locations.

Table I-7. Examples of Values for Aquatic T&E Species.

Value (June 2004 USD)	Description	Source
$7.25 per household per year	This study found an average state-wide bid of $6.88 (2002 USD) per household to preserve the striped shiner, a state-listed endangered minnow with no direct use value in Wisconsin (the striped shiner is state listed as an endangered species, but not listed federally).	Boyle and Bishop (1987)
$10.79 annually per taxpayer[a]	This study found that taxpayers would be willing to pay an average of $10.24 (2002 USD) annually to preserve the federally listed endangered Colorado squawfish in New Mexico.	Cummings et al. (1994)
$40-112 (average of $80) annually per household	This meta-analysis examined willingness-to-pay values for the protection of Pacific salmon/steelhead.	Loomis and White (1996)
$9-10 (average of $10) annually per household	This meta-analysis examined willingness-to-pay values for protection of Atlantic salmon.	Loomis and White (1996)
$9.77 annually per household	This study estimated willingness to pay for protecting instream flows specifically for the silvery minnow on the middle Rio Grande and to protect minimum instream flows on all major New Mexico rivers to protect 11 total listed fish species.	Berrens et al. (1996)

[a]More than one taxpayer may reside per household.

I.3.6 Resources (where to look up further information)

Values for environmental services:

- Environment Canada. 2004. Environmental Valuation Resource Inventory (EVRI). http://www.evri.ca.
- Lew, D.K., D.M. Larson, H. Suenaga, and R. DeSousa. 2001. The Beneficial Use Values Database. Department of Agricultural and Resource Economics. April. http://buvd.ucdavis.edu.
- U.S. EPA. 2004. Environmental Economic Reports Inventory (EERI). http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/EnvironmentalEconomicsReports.html.

I.4 Habitat (Non-T&E Species)

I.4.1 Introduction

Changes in water quantity (both surface and ground) may impact habitat for numerous aquatic and riparian species (not necessarily T&E species).

I.4.2 Affected Parties

Beneficiaries of protected or improved habitats may include individuals that value a protected or improved environment, various local and national environmental groups, and recreationists such as wildlife viewers and hunters whose activities are enhanced with improved water quality. Many beneficiaries (perhaps a large majority) may reside outside of the water agency's service area.

I.4.3 Qualitative Assessment

It may not be possible or desirable to quantify impacts for a particular category. In these cases, it may be appropriate to qualitatively assess impacts. If benefits were to be qualitatively assessed, a scaling approach may be used to illustrate general magnitudes of benefits. If a "-2 to +2" scale were applied, with a "-2" equal to "Large costs" and a "+2" equal to "Large benefits," the following definitions may be used (see Table I-8):

Table I-8. Scaling of Habitat Qualitative Assessment.

Large Costs	Small Costs	No Impact	Small Benefits	Large Benefits
-2	-1	0	+1	+2

- -2 = Large costs: Environmental change will cause large negative impacts on habitat that entail costs which are much greater than benefits (if any exist).
- -1 = Small costs: Environmental change will cause minor negative impacts on habitat that entail costs which are slightly greater than benefits (if any exist).
- 0 = No impact: Environmental change will not affect habitat in any way, or will have benefits commensurate with the costs.
- +1 = Small benefits: Environmental change will have a small impact on habitat, which will induce benefits that are slightly greater than the costs.
- +2 = Large benefits: Environmental change will have a large impact on habitat, which will induce benefits that are significantly greater than the costs.

I.4.4 Quantifying the Outcomes (Identifying Units of Measurement)

Values for changes to habitat are typically expressed in willingness to pay—what households are willing to pay for the change in habitat. These values may be expressed in dollars per person or per household, and may be given as a one time payment or per month or year, or even per unit of change (such as unit change in trophic level or some other index of environmental condition).

Values for changes to habitat may also be given in a certain dollar amount per area of habitat such as per acre, or per volume of water needed to support habitat such as per acre-feet or per gallon (or some number of gallons such as 1,000 gallons).

These values per specified unit of measurement are then applied to the appropriate quantity. For example, if values are cited in dollars per household per year, then one needs to apply the value(s) to the geographically appropriate total number of years (e.g., $10 per household per year for the State of California for 10 years).

I.4.5 Monetizing the Outcomes

Several studies have conducted surveys asking households what they would be willing to pay to protect water resources. A common method is to use a hypothetical referendum, where households are asked if they would vote in favor of a particular resource protection action, if it cost their household $X. The amount of $X varies across households, so that a demand curve can be traced. From this demand curve, willingness to pay is calculated; this is the contingent valuation method. Willingness-to-pay values are commonly reported in dollars per year (or per month or other specified period of time) per household. Some willingness-to-pay values are stated as a one time payment.

Table I-9 presents a few values observed in the literature for impacts to habitat from changes in water quality or quantity.

Table I-9. Examples of Values of Water for Habitat.

Value (June 2004 USD)	Description	Source
$29-120 per person annually	Value is marginal willingness to pay for improved water quality to protect the estuarine habitat of the Albemarle-Pamlico Estuarine System of North Carolina.	Whitehead et al. (1995)
$158-386 per household annually	Value is what California households would be willing to pay to protect Mono Lake water supply in California by providing water for fish, birds, and other parts of the Mono Lake ecosystem.	Loomis (1987)
$85-620 per acre-foot (AF) (average of $221/AF)	This is the average price of a water right purchased for instream uses in the Pacific Northwest to protect habitat and other ecological services.[a]	Low: Rigby (1997) Average: Landry (1998) High: OWT (1998)

[a]This value is an average sales price, and does not reflect the value of the numerous ecological services provided by instream flows; it is believed to be an underestimate of true value.

I.4.6 Resources (Where to Look up Further Information)

Values for environmental services:

- Environment Canada. 2004. Environmental Valuation Resource Inventory (EVRI). http://www.evri.ca.
- Lew, D.K., D.M. Larson, H. Suenaga, and R. DeSousa. 2001. The Beneficial Use Values Database. Department of Agricultural and Resource Economics. April. http://buvd.ucdavis.edu.
- U.S. EPA. 2004. Environmental Economic Reports Inventory (EERI). http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/EnvironmentalEconomicsReports.html.

I.5 Coastal Ecosystems

I.5.1 Introduction

Adequate flows of fresh water are critical to coastal and estuarine resources as well as all of the economic activities associated with these resources. At some point in its lifecycle, approximately 95% of marine life "depends on the wide range of salinities and abundant food and shelter provided by bays and estuaries. [T]he health of our bays and marine life in our oceans is intrinsically linked to adequate freshwater flowing from our rivers to the bays" (TCPS, 2002).

I.5.2 Affected Parties

Beneficiaries of protected or improved coastal ecosystems may include individuals that value a protected or improved environment, various local and national environmental groups, and recreationists such as wildlife viewers and hunters whose activities are enhanced with improved coastal ecosystems. Many beneficiaries (perhaps most) will reside outside of the water agency's service area.

I.5.3 Qualitative Assessment

It may not be possible or desirable to quantify impacts for a particular category. In these cases, it may be appropriate to qualitatively assess impacts. If benefits were to be qualitatively assessed, a scaling approach may be used to illustrate general magnitudes of benefits. If a "-2 to +2" scale were applied, with a "-2" equal to "Large costs" and a "+2" equal to "Large benefits," the following definitions may be used (see Table I-10):

Table I-10. Scaling of Coastal Ecosystems Qualitative Assessment.

Large Costs	Small Costs	No Impact	Small Benefits	Large Benefits
-2	-1	0	+1	+2

- -2 = Large costs: Environmental change will cause large negative impacts on coastal ecosystems that entail costs which are much greater than benefits (if any exist).
- -1 = Small costs: Environmental change will cause minor negative impacts on coastal ecosystems that entail costs which are slightly greater than benefits (if any exist).
- 0 = No impact: Environmental change will not affect coastal ecosystems in any way, or will have benefits commensurate with the costs.

- +1 = Small benefits: Environmental change will have a small impact on coastal ecosystems, which will induce benefits that are slightly greater than the costs.
- +2 = Large benefits: Environmental change will have a large impact on coastal ecosystems, which will induce benefits that are significantly greater than the costs.

I.5.4 Quantifying the Outcomes (Identifying Units of Measurement)

Values for changes to coastal ecosystems are typically expressed in willingness to pay—what households are willing to pay for the change in coastal ecosystems. These values may be expressed in dollars per person or per household, and may be given as a one time payment or per month or year, or even per unit of change (such as unit change in trophic level or some other index of environmental condition).

Values for changes to coastal ecosystems may also be given in a certain dollar amount per acre, or per volume of water needed to support coastal ecosystems services such as per acre-feet or per gallon (or some number of gallons such as 1,000 gallons).

These values per specified unit of measurement are then applied to the appropriate quantity. For example, if values are cited in dollars per household per year, then one needs to apply the value(s) to the geographically appropriate total number of years (e.g., $10 per household per year for the State of California for 10 years).

I.5.5 Monetizing the Outcomes

Several studies have conducted surveys asking households what they would be willing to pay to protect water resources. Several studies are summarized in Table I-11. A common method is to use a hypothetical referendum, where households are asked if they would vote in favor of a particular resource protection action, if it cost their household $X. The amount of $X varies across households, so that a demand curve can be traced. From this demand curve, willingness to pay is calculated; this is the contingent valuation method. Willingness-to-pay values are commonly reported in dollars per year (or per month or other specified period of time) per household. Some willingness-to-pay values are stated as a one time payment.

Table I-11. Examples of Values of Coastal Ecosystems.

Value (June 2004 USD)	Description	Source
$29-120 per person per year	Value is marginal willingness to pay for improved water quality to protect the estuarine system of the Albemarle-Pamlico Estuarine System of North Carolina.	Whitehead et al. (1995)
$17 per household (one time payment)	Existence (intrinsic) value component of mean household willingness to pay ($33.35) for beach maintenance along the north shore of metropolitan Chicago.	Croke et al. (1987)
$111 per household per year	The existence value component of mean household annual willingness to pay to raise the water quality of the coastal ponds in Martha's Vineyard, Massachusetts, so that shellfishing could be done year round.	Kaoru (1993)

Disrupting freshwater flows into bays and estuaries could have tremendous impacts on the coastal economy, directly affecting commercial and recreational fisheries and other nature-based tourism activities. In Georgia, the Center for a Sustainable Coast has argued that reduced streamflows into coastal and estuarine areas could have significant adverse impacts on "fisheries and nature-based tourism activities, worth at least $1 billion annually, and supporting some 40,000 jobs" (Kyler, 2001). Similar adverse impacts, particularly on the production of oysters, could occur in Apalachicola Bay, Florida, if freshwater inflows are reduced (Christensen et al., 1998).

I.5.6 Resources (Where to Look up Further Information)

Values for environmental services:

- Environment Canada. 2004. Environmental Valuation Resource Inventory (EVRI). http://www.evri.ca/.
- Lew, D.K., D.M. Larson, H. Suenaga, and R. DeSousa. 2001. The Beneficial Use Values Database. Department of Agricultural and Resource Economics. April. http://buvd.ucdavis.edu.
- U.S. EPA. 2004. Environmental Economic Reports Inventory (EERI). http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/EnvironmentalEconomicsReports.html.

I.6 Wetlands

I.6.1 Introduction

Changes to instream flows or groundwater levels may affect hydrologically connected wetlands. Changes in wastewater discharges may affect wetlands that are dependent on those discharges, and changes in salt water discharges may affect salt marsh wetlands. In addition, reuse water may be used to create or restore wetlands.

I.6.2 Affected Parties

Impacts to wetlands will generally affect the societal impact category. In particular, beneficiaries of protected or improved wetlands may include individuals that value a protected or improved environment, various local and national environmental groups, and recreationists such as wildlife viewers and hunters whose activities are enhanced with improved wetlands. Many beneficiaries will probably reside outside of the utility's service area.

I.6.3 Qualitative Assessment

It may not be possible or desirable to quantify impacts for a particular category. In these cases, it may be appropriate to qualitatively assess impacts. If benefits were to be qualitatively assessed, a scaling approach may be used to illustrate general magnitudes of benefits. If a "-2 to +2" scale were applied, with a "-2" equal to "Large costs" and a "+2" equal to "Large benefits," the following definitions may be used (see Table I-12):

- -2 = Large costs: Environmental change will cause large negative impacts on wetlands that entail costs which are much greater than benefits (if any exist).
- -1 = Small costs: Environmental change will cause minor negative impacts on wetlands that entail costs which are slightly greater than benefits (if any exist).

Table I-12. Scaling of Wetlands Assessment.

Large Costs	Small Costs	No Impact	Small Benefits	Large Benefits
-2	-1	0	+1	+2

- 0 = No impact: Environmental change will not affect wetlands in any way, or will have benefits commensurate with the costs.
- +1 = Small benefits: Environmental change will have a small impact on wetlands, which will induce benefits that are slightly greater than the costs.
- +2 = Large benefits: Environmental change will have a large impact on wetlands, which will induce benefits that are significantly greater than the costs.

I.6.4 Quantifying the Outcomes (Identifying Units of Measurement)

Values for changes to wetlands are typically expressed in willingness to pay—what households are willing to pay for the change occurring to wetlands. These values may be expressed in dollars per person or per household, and may be given as a one time payment or per month or year, or even per unit of change (such as a change in some index of wetland condition).

Values for changes to wetlands may also be given in a certain dollar amount per area of wetlands such as per acre, or per volume of water needed to support wetlands such as per acre-feet or per gallon (or some number of gallons such as 1,000 gallons).

These values per specified unit of measurement are then applied to the appropriate quantity. For example, if values are cited in dollars per household per year, then one needs to apply the value(s) to the geographically appropriate total number of years (e.g., $10 per household per year for the State of California for 10 years).

I.6.5 Monetizing the Outcomes

Several studies have conducted surveys asking households what they would be willing to pay for protection of water resources. A common method is to use a hypothetical referendum, where households are asked if they would vote in favor of a particular resource protection action, if it cost their household $X. The amount of $X varies across households, so that a demand curve can be traced. From this demand curve, willingness to pay is calculated; this is the contingent valuation method. Willingness-to-pay values are commonly reported in dollars per year (or per month or other specified period of time) per household. Some willingness-to-pay values are stated as a one time payment. Tables I-13 and I-14 present some values observed in the literature for impacts to wetlands from changes in water quality or quantity.

I.6.6 Resources (Where to Look up Further Information)

Values for wetlands:

- Bardecki, M.J. 1998. Wetlands and Economics: An Annotated Review of the Literature, 1988-1998. Environment Canada, Ontario.
- Environment Canada. 2004. Environmental Valuation Resource Inventory (EVRI). http://www.evri.ca.
- Lew, D.K., D.M. Larson, H. Suenaga, and R. DeSousa. 2001. The Beneficial Use Values Database. Department of Agricultural and Resource Economics. April. http://buvd.ucdavis.edu.
- U.S. EPA. 2004. Environmental Economic Reports Inventory (EERI). http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/EnvironmentalEconomicsReports.html.

Table I-13. Examples of Values of Wetlands.

Value (June 2004 USD)	Description	Source
$12,496 per wetland acre	Using a discount rate of 3%, this study estimated that present values per wetland acre are: commercial fishery = $846; trapping = $401; recreation = $181; storm protection = $7,549; total of these values = $8,977/acre (1983 USD).	Costanza et al., 1989
$66 annually per household	This study examined what Ohio residents were willing to pay for increased protection of wetlands of the Maumee River and Western Lake Erie basins in Ohio.	De Zoysa, 1995
$9-34 per household per year	This study estimated willingness to pay for wetland preservation benefits in western Kentucky.	Dalecki et al., 1993
$1,238 per acre per year for 30 years ($339,298 per acre over 15 years)	This study estimated economic benefits of wetlands for wastewater treatment use, in terms of savings over conventional wastewater treatment methods.	Breaux et al., 1995
$7 and $24 annually per household	This study estimated willingness to pay for preserving the Clear Creek wetland in western Kentucky.	Whitehead and Bloomquist, 1991
$150-2,391 per acre lump sum	Values reflect the range of restoring wetlands from croplands, by estimating easement costs, restoration costs, and the present discounted value of perpetual crop production.	Heimlich, 1994
$94-146 annually per respondent	Values reflect what respondents are willing to pay for protection of wetlands in New England.	Stevens et al., 1995
$50 annually per household	This study is a meta-analysis of 30 studies. The largest mean willingness to pay by wetland function was in terms of flood control ($75), with the smallest for water generation ($18).	Brouwer et al., 1997
$585-10,524 per acre for residents of the drainage basin, and from $8,418 to $71,507 across residents of the State of Michigan.	The study estimated wetland benefits for Saginaw Bay, Michigan.	Cangelosi et al., 2001
$4-1,670 per acre annually	The predicted values per acre of single-service wetlands range from $4 for presence of amenities to $1,670 for presence of birdwatching opportunities, with most services having predicted values in the $275-550 range (see Table I-14 for breakdown of all values).	Woodward and Wui, 2001

Table I-14. Per Acre Annual Values of Wetland Services.

Service	Mean Value Per Acre[a] (June 2004 USD)
Flood	$542
Quality	$575
Quantity	$175
Recreational fishing	$492
Commercial fishing	$1,072
Bird hunting	$96
Bird watching	$1,670
Amenity	$4
Habitat	$422
Storm	$327

[a]The predicted values are obtained at the means of year and acre variables. It must be emphasized that the values do not represent marginal values and cannot be summed to obtain the value of multiple function wetlands.
Source: Woodward and Wui, 2001.

APPENDIX J

SPREADSHEET VERSION OF BIOSOLIDS ECONOMIC EVALUATION FRAMEWORK

The software tool for the economic framework is designed as a series of steps to lead users through the process of identifying and documenting the full range of benefits and costs associated with a biosolids management project.

The user should follow the worksheets in order from Step 1 to Step 8 in the process. As the user proceeds through the steps, the tool will set up information for later steps based on information entered by the user. Green cells on each worksheet page are places for the user to enter information. Yellow cells on each worksheet represents spaces where the tool is expected to fill in information based on user input from previous steps.[1]

Note that the "steps" in the electronic spreadsheet version do not always correspond directly with the framework steps (e.g., Figure 4-1) in order to take advantage of the spreadsheet capabilities.

Step 1 is a place to record information regarding the water reuse project to be evaluated. This includes information on the type of project (e.g., indirect nonpotable, indirect potable), the type and number of customers associated with a project, other entities associated with the project, key project dates, and key project stakeholders.

Step 2 is a worksheet for defining and recording baseline information. This is primarily cost information for the case without the project—which is the avoided costs with the project.

Steps 3 and 4 (B and C) helps users with the identification of benefits and costs (Step 3), and also initiates the screening analysis (Step 4) for project benefits (B) and costs (C), respectively. In each step, for each benefit or cost, the user is asked to determine if the item can be quantified in dollar terms, should instead be given a qualitative assessment, or is so small that it can be eliminated from further consideration in the analysis. Also, for each benefit or cost category, the user can identify key customers or stakeholders associated with that benefit or cost category. If multiple customers or stakeholders are affected, then multiple entities can be identified in columns to the right.

Steps 5 and 6 (B and C) provide space to quantify dollar benefits or costs identified in Steps 3 and 4. For each benefit or cost category identified for quantitative assessment in the screening steps, the tool will set up a section for valuation of that item over time. The user can enter the quantity associated with that benefit (e.g., acres of cropland) and the range of $/unit values associated with that item. Projection of the units and $/unit values over time can be used to calculate total benefit or cost over time. Once the total has been calculated, a net present value is given according to the discount rate specified by the user.

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1. In this black and white paper version, the spreadsheets depicted shows these colored cells as gray (darker gray reflects the green cells for user inputs, and the light gray reflects yellow cells).

Step 7 lists the qualitative benefits and costs identified in Steps 3 and 4. The user can then rate the likely impact on net benefits (the monetized benefits minus the monetized costs for the project) using a five-point scale, with +2 showing a very positive impact on net benefits, -2 showing a very negative impact on net benefits, and 0 showing a neutral impact on net benefits. Users can also insert a +1 (or -1) for modest positive (or negative) impacts on net benefits, respectively. Explanation of the values can be recorded to the right of the ratings.

Step 8 is a summary of all the benefit and cost findings, including both quantified and qualitative information on all the benefits and costs of significance associated with the project. This page shows a summary of net benefits for the project along with the qualitative assessments developed in previous steps.

Step 9 is a listing of omissions, biases, and uncertainties associated with all values in the analysis—both quantitative and qualitative.

Step 10 in the spreadsheet tool provides text with guidance for conducting and reporting the results of sensitivity analyses. The text is not repeated here, but the tracking and reporting of sensitivity analyses can be done using the off-line paper template provided.

Step 11 provides an opportunity to seek stakeholder input throughout the project identification and identification process. At the end of the process, the results from the quantitative and qualitative analyses should be compared with stakeholder expectation of values.

Step 1—Biosolids project information and agency information

Name of Agency	
Name of person conducting analysis	
Phone number	
E-mail:	
Biosolids project information	
Project name	
Project location	
Type of biosolids project	
Project operational date	
Does the project operate year-round or seasonally	
Annual volume of wastewater treated	
Annual amount of biosolids produced	

Other non-regulatory entities involved in biosolids project	Entity type	Role

Key project dates (existing or planned)	
Beginning of planning	
Beginning of permitting	
Funding application	
Beginning of construction	
Beginning of operation	
How many years operation should be included in the analysis period?	

Listing of key stakeholders

Step 2—Baseline (without project) information

Is this a regional project or "go it alone?"	
In the absence of this project, would an alternative biosolids management project be developed?	
If, YES:	
Will this project lead to avoided capital and/or O&M costs of biosolids treatment (associated with the alternative project)?	
Will this project lead to avoided capital and/or O&M costs of biosolids disposal (associated with the alternative project)?	
If, NO:	
Will this project lead to avoided future O&M costs of current biosolids treatment practices?	
Will this project lead to avoided future O&M costs of current biosolids disposal practices?	

Steps 3 and 4B—Biosolids project benefit identification

Benefits				
Check one	*Check one*	*Check one*	*(Mark with an "x" in the appropriate cell)* *(Categories not checked assumed to be not applicable)*	
Monetized	**Qualitative**	**Very small or mitigated—no analysis**	**Direct benefits (agency or customer)**	**Entity accruing benefit**
			Avoided capital costs of biosolids treatment	Choose One
			Avoided O&M costs of biosolids treatment	Choose One
			Avoided penalties from baseline biosolids management practices	Choose One
			Avoided storage costs	Choose One
			Avoided land purchase costs	Choose One
			Avoided transportation costs	Choose One
			Avoided labor costs associated with product management	Choose One
			Avoided administrative fees (landfill fees, permitting costs)	Choose One
			Avoided fuel costs (electricity, natural gas, diesel)	Choose One
			Avoided heating costs due to heat recovery	Choose One
			Avoided energy costs (energy recovery)	Choose One
			Program sustainability and reliability (qualitative benefit only)	Choose One
			Other (specify):	Choose One
			Other (specify):	Choose One
			Other (specify):	Choose One
			Indirect benefits (societal)	
			Environment	
			Improved groundwater quality	Choose One
			Revegetation	Choose One
			Improved wildlife habitat	Choose One
			Carbon sequestration/carbon offsets	Choose One
			Reduced air pollution emissions	Choose One
			Avoided external costs from fertilizer production and use	Choose One
			Other (specify):	Choose One
			Beneficial use applications	
			Value of fertilizer use offset by use of biosolids	Choose One
			Value of soil amendment offset by use of biosolids	Choose One
			Value of fuel use offset by use of biosolid end product	Choose One
			Other (specify):	Choose One
			Human health	
			Change in real risk of illness (morbidity)	Choose One
			Change in perceived risk of illness (morbidity)	Choose One
			Change in risk of premature fatality (mortality)	Choose One
			Other (specify):	Choose One
			Economic, social, and equity	
			Increased economic development	Choose One
			Synergies with other utilities	Choose One
			Reduced odors	Choose One
			Improved visibility/aesthetics/dust	Choose One
			Reduced noise	Choose One
			Reduced traffic	Choose One
			Positive distributional effects (social justice)	Choose One
			Public support	Choose One
			Other (specify):	Choose One

Steps 3 and 4C—Biosolids project cost identification

Costs				
Check one	*Check one*	*Check one*	*(Mark with an "x" in the appropriate cell)* *(Categories not checked assumed to be not applicable)*	
Monetized	**Qualitative**	**Very small or mitigated—no analysis**	**Direct costs (agency or customer)**	**Entity incurring cost**
			Capital costs for biosolids treatment	Choose One
			O&M costs for biosolids treatment	Choose One
			Land costs (for facilities or disposal)	Choose One
			Transportation costs	Choose One
			Capital costs for storage	Choose One
			O&M costs for storage	Choose One
			Additional capital costs for biosolids management	Choose One
			Additional O&M costs for biosolids management	Choose One
			Administrative costs (landfill fees or permitting costs)	Choose One
			Other (specify):	Choose One
			Indirect costs (societal)	
			Environment	
			Increased air pollution emissions	Choose One
			Degraded groundwater quality	Choose One
			Vegetation impacts	Choose One
			Wildlife habitat impacts	Choose One
			Other (specify):	Choose One
			Human health	
			Change in real risk of illness (morbidity)	Choose One
			Change in perceived risk of illness (morbidity)	Choose One
			Change in risk of premature fatality (mortality)	Choose One
			Other (specify):	Choose One
			Economic and social	
			Increased economic development (congestion, other negative impacts)	Choose One
			Increased odors	Choose One
			Air pollution increases	Choose One
			Reduced visibility/aesthetics, increased dust	Choose One
			Increased noise	Choose One
			Increased traffic	Choose One
			Negative distributional effects (social justice)	Choose One
			Public opposition	Choose One
			Other (specify):	Choose One

Steps 5 and 6B—Benefits calculation

What discount rate should be used for this analysis?

Avoided capital costs of wastewater treatment

			Years	0	1	2	3	4	5
	Amount		Low						
	Unit		Med						
			High						
	$/unit values		Low						
			Med						
			High						
	Total value		Low						
	(unit * $/unit)		Med						
			High						
	Net present value								
Low		$0	Low	$0	$0	$0	$0	$0	$0
Med		$0	Med	$0	$0	$0	$0	$0	$0
High		$0	High	$0	$0	$0	$0	$0	$0
	Comment:								

Avoided O&M costs of wastewater treatment

			Years	0	1	2	3	4	5
	Amount		Low						
	Unit		Med						
			High						
	$/unit values		Low						
			Med						
			High						
	Total value		Low						
	(unit * $/unit)		Med						
			High						
	Net present value								
Low		$0	Low	$0	$0	$0	$0	$0	$0
Med		$0	Med	$0	$0	$0	$0	$0	$0
High		$0	High	$0	$0	$0	$0	$0	$0
	Comment:								

Steps 5 and 6C—Costs calculation

Capital costs for biosolids treatment										
			Years	0	1	2	3	4	5
	Amount		Low						
	Unit		Med						
			High						
	$/unit values		Low						
			Med						
			High						
	Total value		Low						
	(unit * $/unit)		Med						
			High						
	Net present value								
Low		$0	Low	$0	$0	$0	$0	$0	$0
Med		$0	Med	$0	$0	$0	$0	$0	$0
High		$0	High	$0	$0	$0	$0	$0	$0
	Comment:								

O&M costs for biosolids treatment									
			Years	0	1	2	3	4	5
	Amount		Low						
	Unit		Med						
			High						
	$/unit values		Low						
			Med						
			High						
	Total value		Low						
	(unit * $/unit)		Med						
			High						
	Net present value								
Low		$0	Low	$0	$0	$0	$0	$0	$0
Med		$0	Med	$0	$0	$0	$0	$0	$0
High		$0	High	$0	$0	$0	$0	$0	$0
	Comment:								

Step 7—Qualitative benefits and costs

Five point scale:

2	very positive value
1	positive value
0	neutral value
-1	negative value
-2	very negative value

Category	Impact (-2 to 2)	Comment/explanation

Step 8—Summary of Benefits and Costs

Benefits	Dollar amount: Low	Medium	High	Stakeholder accruing cost or benefit
Total	$0	$0	$0	
Costs	Low	Medium	High	
Total	$0	$0	$0	

Qualitative costs and benefits	Qualitative rating	Stakeholder accruing cost or benefit

	Low	Medium	High
Net benefits	$0	$0	$0

WERF

Step 9—Omissions, biases, and uncertainties

Benefit or cost category	Likely impact on net benefits	Comment

Step 10—Sensitivity analysis for key variables

Variable 1—Enter variable name

Values	Total monetized benefit	Total cost	Total monetized net benefit

Variable 2—Enter variable name

Values	Total monetized benefit	Total cost	Total monetized net benefit

Variable 3—Enter variable name

Values	Total monetized benefit	Total cost	Total monetized net benefit

Variable 4—Enter variable name

Values	Total monetized benefit	Total cost	Total monetized net benefit

Step 11—Compare analysis results to stakeholder perception of value

Stakeholder input should be sought throughout the project identification and identification process. At the end of the process, the results from the quantitative and qualitative analyses should be compared with stakeholder expectation of values. This comparison of expected values to the values derived in the analysis can be informative both as a check on the reasonableness of the analysis results and as a process of working with stakeholders to realize (or at least better articulate) the values that the reuse project provides to stakeholders. This understanding of values may become the basis for cost-sharing agreements with stakeholders to share costs for a project according to the relative shares of benefits derived from the project.

Summary of screening analysis (Steps 3 and 4)

Benefits and costs for quantitative assessment

Benefits and costs requiring qualitative assessment

( )
( )
( )
( )
( )
( )
( )
( )
( )
( )
( )
( )

Impacts that exist, but are deleted from further analysis

-
-
-
-
-
-
-
-
-
-

APPENDIX K

USING MONTE CARLO SIMULATIONS TO EVALUATE NET BENEFITS UNDER UNCERTAINTY

Managers often need to make large-scale capital spending decisions when there is considerable uncertainty about the possible payoff or cost of their utility's potential investment. In such cases, relying solely on "most likely" or "expected" estimates of the present value of net benefits (i.e., the NPV) of the project can lead to results that do not necessarily reflect important risks that the utility may face. In such cases, Monte Carlo simulations can be a useful tool to help guide decision-making under uncertainty. This is illustrated in the example developed below.

K.1 Introduction

Analysts can sometimes address key uncertainties by conducting simple sensitivity analyses showing the estimated NPV under a range of plausible scenarios. However, where uncertainty and variability exist simultaneously for more than one key parameter, the analysis can become very complicated. Often, the scenarios approach can generate widely divergent NPV results, with some providing outcomes with NPV significantly less than zero, and other plausible scenarios yielding NPVs that are well above zero. Such divergent results may not help the decision-maker resolve his or her uncertainty about the merits of proceeding with the project.

Monte Carlo analysis is a useful tool that can be very helpful in such cases. Monte Carlo analyses can assess multiple probability-based scenarios simultaneously, thereby providing planners with a more complete sense of how likely (or unlikely) it is that the pending investment will yield a positive NPV.

K.2 An Example Scenario

As an example, consider evaluating the benefits of implementing an energy recovery system at a utility. Table K-1 summarizes the basic information describing the anticipated details of the energy recovery system.

Table K-1. Energy Recovery System—General Description.

Capital costs (equipment and permits)	$10 million (split over 2 years)
O&M expenses	$0.5 million per year
Project lifetime	20 years
Real rate of discount	3%
Expected real price (value) of electricity	$0.07 per kWh
Expected electricity yield	20 million kWh per year

A benefit-cost comparison of this potential capital improvement project is provided in Table K-2. The PV of avoided energy purchasing costs are greater than the PV of the total project cost, and as a result the NPV of monetized net benefits is over $2 million.

Table K-2. Costs and Benefits of Energy Recovery Project ($0.07/kWh).

	Present Value
Costs—Total capital and O&M	$16,680,000
Quantifiable benefits	
Avoided energy purchasing costs	$18,690,000
Monetized net benefits (monetized benefits minus costs)	**$2,010,000**

K.2.1 Uncertain Outcomes

What if an agency has considerable uncertainty about the true level of costs and benefits that will be realized? In this example, there may be important underlying uncertainties associated with the cost and timing in which the project can be completed and made operable—such as may arise with construction and permitting delays that would escalate costs and postpone the generation of power benefits. There is also uncertainty about the value of the electricity generated (cost per kWh), and in the volume of energy produced during the project's life.

It is not unusual to conduct a sensitivity analysis as part of a benefit-cost analysis in order to identify which costs and/or benefits have the biggest impact on the overall NPV of a project. The NPV of monetized benefits of an energy recovery system could be negative if, for example, capital costs are higher than the initial estimate, or if the electricity yield of the system is less than expected. Table K-3 illustrates that the NPV of monetized benefits could drop to $-4.3 million if the future real price of electricity is 2 cents per kilowatt-hour less than forecast, and when the total project costs increases by $1 million.

Table K-3. Costs and Benefits of Energy Recovery System (Escalated Cost, and $0.05/kWh).

	Present Value
Costs—Total capital and O&M	$17,680,000
Avoided energy purchasing costs	$13,380,000
Monetized net benefits (monetized benefits minus costs)	**($4,300,000)**

Another sensitivity analysis might, on the other hand, reveal that an increase in the real price of electricity would increase the benefits significantly, offsetting the possible escalation in the project cost. Table K-4 illustrates that the NPV under this scenario would be $4 million, if the price of electricity is $0.09/kWh, even with an escalated project cost.

Table K-4. Costs and Benefits of Energy Recovery System (Escalated Costs, and $0.09/kWh).

	Present Value
Costs—Total capital and O&M	$17,680,000
Avoided energy purchasing costs	$21,680,000
Monetized net benefits (monetized benefits minus costs)	**$4,000,000**

Even more subtle changes to expected values may have a notable impact on the NPV of a project. In this example, if there is no change in the total capital costs but the expected real price of electricity drops from $0.07/kWh to $0.0625/kWh, then the NPV of the energy recovery system would be roughly $0.

These examples reveal that a sensitivity analysis may indicate that a capital improvement project could possibly lead to net savings of several million dollars *or* result in a net loss of several million dollars, depending on one or more factors outside of the decision-maker's control (such as the price of electricity, and the cost of completing and permitting a facility). For the individual(s) that must ultimately decide whether a capital improvement project, such as the implementation of an energy recovery system, is a "go" or "no go," the uncertainty makes a tough decision even tougher.

K.3 Monte Carlo Assessment of Compounded Uncertainties

Rather than trying to make sense of several possible independent outcomes for the energy recovery facility, an estimate of the likelihood of a particular outcome (e.g., whether the NPV of an energy recovery system will be greater than zero) could be extremely useful to a decision-maker dealing with these various sources and levels of uncertainty. The Monte Carlo method enables us to include the range of possible values associated with each variable in the estimate of the NPV of the energy recovery system (e.g., electricity price and electricity yield) in a single analysis.

The Monte Carlo method involves conducting a large number (e.g., several thousand) probability-based simulations of the problem of calculating the NPV of the project given the simultaneous uncertainties. For each simulation, a value for each uncertain variable is randomly generated based on probabilities within the expected range of possible values for that variable. The simulations will provide a range of possible outcomes (i.e., a range of possible NPVs of the energy recovery system). The outcomes that are more likely will be simulated more frequently than the outcomes that are less likely. Collectively, the simulated estimates of the NPV of the energy recovery system create a probability distribution. As a result, the Monte Carlo method can be used to determine the probability of a particular outcome (e.g., that the NPV of an energy recovery system will be greater than zero).

The following sections describe the components of the Monte Carlo simulation used to estimate the probability that the NPV of the example energy recovery system will be greater than zero.

K.3.1 Components of a Monte Carlo Simulation

K.3.1.1 Avoided Energy Purchasing Costs

The PV of the benefit of avoided energy purchases is the product of total electricity yield (kilowatt-hours) and the PV of a single kWh of electricity ($/kWh).

Electricity Yield. Although the expected electricity yield of the energy recovery system (over the 20-year lifetime of the system) is 20 million kWh, it is known that the actual electricity yield may vary. For this illustration, assume that total electricity yield may range from between 18 million kWh and 22 million kWh, and follows a uniform distribution, as illustrated in Figure K-1.

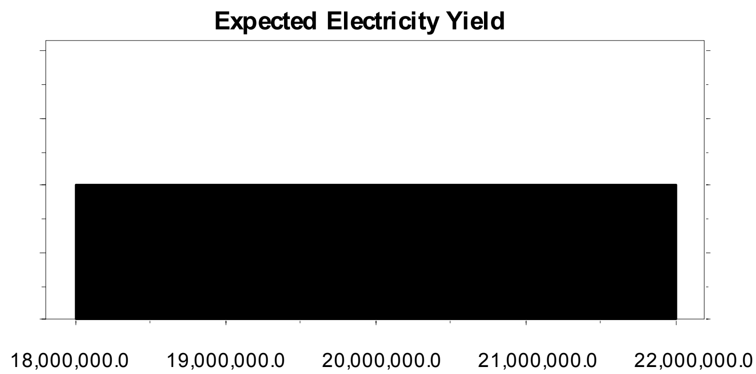

Figure K-1. Probability Distribution of Electricity Yield (in Total kWh) over the 20-Year Lifetime of the System.

Electricity Prices Although the real price of electricity is projected to be \$0.07/kWh during the plant lifetime, it is known that this price may vary. Assume that the price of electricity may range from between \$0.06/kWh and \$0.09/kWh, and that the PV of electricity price follows a distribution similar to that depicted in Figure K-2.

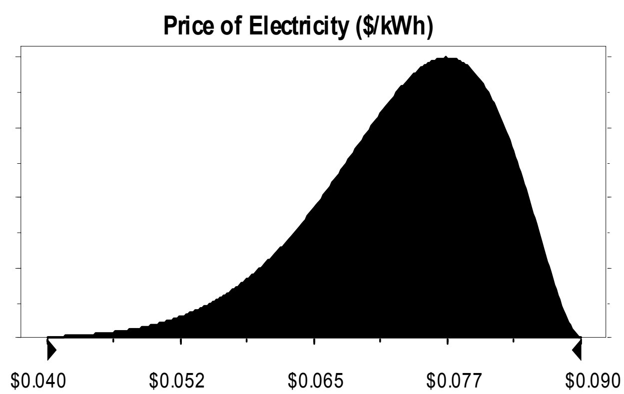

Figure K-2. Probability Distribution of NPV of the Price of Electricity (\$/kWh).

Since the PV of avoided energy purchases is the product of two uncertain variables, the value of this benefit is also uncertain. Figure K-3 illustrates the probability distribution associated with the total PV of energy purchases over the 20-year lifetime of the energy recovery system.

K.3.1.2 Project Costs

Although the expected PV of the project cost is \$16.7 million, analysts know that the true cost may vary from this estimate. Assume that the PV of the total project cost may range from between \$15 million and \$20 million, and follows a triangular distribution (as illustrated in Figure K-4).

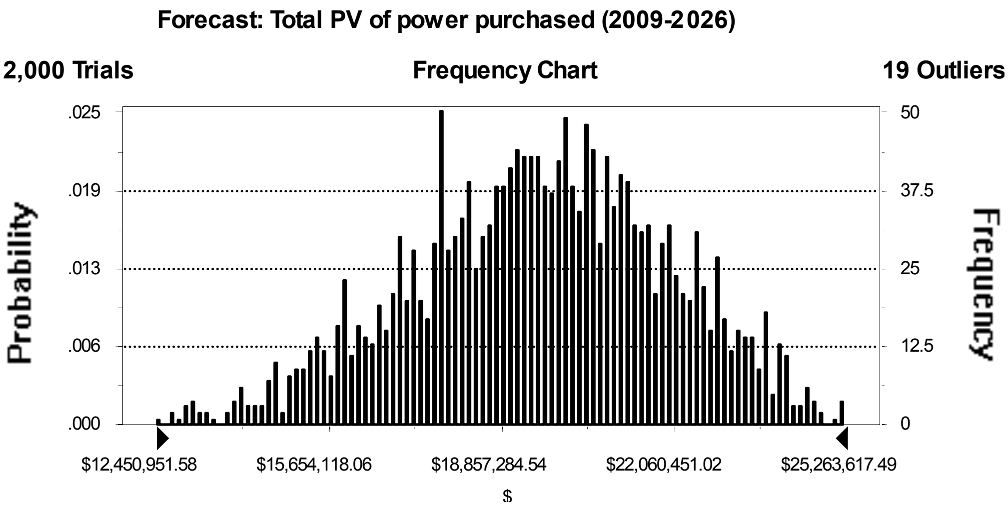

Figure K-3. Probability Distribution of NPV of the Price Electricity Purchased ($/kWh) over 20 Years.

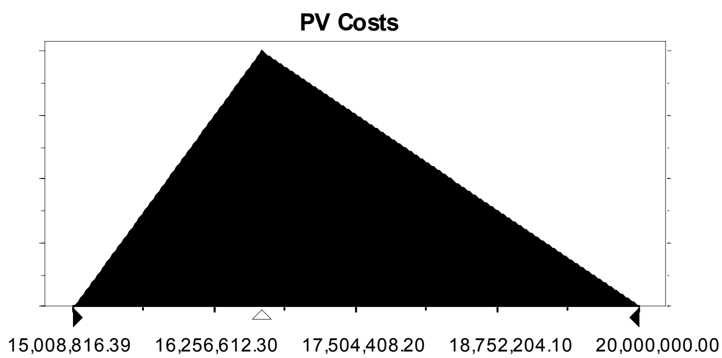

Figure K-4. Probability Distribution of the PV of Total Project Costs ($) over 20 Years.

K.3.1.3 Results: Monetized Net Benefits

Drawing upon the assumptions listed above for each of the uncertain variables that affect the NPV of benefits of an energy recovery project, a Monte Carlo simulation can be run to determine the probability that the NPV of benefits will be greater than zero. For this example, 2,000 simulations were used (calculating NPV of benefits), from which a probability distribution for NPV was derived, as shown in Figure K-5. This distribution shows that while there is a chance that the NPV of benefits will be less than zero, the probability that the NPV of benefits will be greater than zero is approximately 80%. In other words, the NPV calculated in approximately 1,600 of the 2,000 simulations was above $0.00 [this is represented in Figure K-5 by the area under the curve defined by the solid line (to the right of the vertical line)].

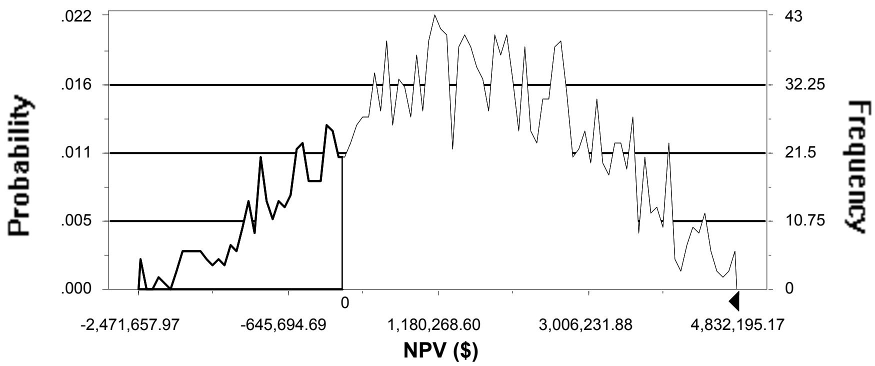

Figure K-5. Probability Distribution of NPV of Monetized Net Benefits over 20 Year Lifetime of Project.

K.3.2 Using the Results of a Monte Carlo Simulation

As the example provided in this appendix illustrates, running a Monte Carlo simulation can help the analyst identify whether the uncertainty associated with a particular component (or set of components) of a project (e.g., a biosolids management option) has a significant effect on the outcome of that project (e.g., the NPV of monetized benefits). An analyst can use the results of the Monte Carlo simulation to inform decision-makers and stakeholder about the likelihood of a particular scenario (e.g., managing a biosolids program that will result in positive NPV of benefits). Monte Carlo simulation provides the analyst with flexibility to look at new scenarios if/when new information becomes available or to make the analysis more robust (e.g., decrease the lower bound of future electricity prices to reflect a more conservative estimate of potential avoided electricity costs).

K.4 Conclusions

Uncertainty in underlying variables can, in some cases, have a measurable impact on the ultimate outcome of an analysis. In the case of a biosolids management option there may be uncertainty underlying key variables (e.g., future fuel costs or electricity prices) that could ultimately prevent a particular option from being pursued. The Monte Carlo approach to scenario analysis is useful to help inform an analyst about the impact of uncertainty. The quantitative results of a Monte Carlo simulation may be instructive to the analyst, decision-makers, and other stakeholders. The results may help focus future research efforts or guide dialogue between stakeholders and decision-makers. Such dialogue may even lead to better-informed estimates of the values associated with certain benefits or costs. Overall, the Monte Carlo approach to a scenario or sensitivity analysis enables managers to assess multiple uncertainties associated with a particular management option (or set of options) with an informed estimate of how likely (or unlikely) various outcomes may be.

APPENDIX L

METRO WASTEWATER RECLAMATION DISTRICT, DENVER, CO

L.1 Introduction and Overview

Metro is a regional government entity, formed under Colorado law in 1961, to provide wastewater transmission and treatment services to member municipalities and special connectors in the Denver metropolitan area. Metro provides services for 58 local governments (1.5 million people) in a 380-square mile service area that includes Denver, Arvada, Aurora, Lakewood, Thornton, and Westminster.

The focus of this case is on the key aspects of Metro's current biosolids management plan and the agency's ongoing commitment to adapt to changing circumstances. Key elements of this case study include:

- Class B land application and associated core issues:
  - Land purchase for the application site (including the ability to monitor the effects of biosolid application)
  - The value added to agricultural production
  - Addressing public opposition to land application
  - Methane recovery for energy generation
- Metro's ongoing commitment to program sustainability in the ever-changing landscape of biosolids management

Recent challenges in national trends of biosolids management and increasing development along the Front Range have prompted Metro to team up with a private consultancy and conduct a Biosolids Management/Facility Plan to re-evaluate their management plan. However, this case study will focus on the benefits and costs of Metro's current management of biosolids and the District's examination of a more diversified portfolio of biosolids management options.

L.2 Current Biosolids Management Practices

Metro currently treats an average of about 140 MGD of wastewater and processes the primary and secondary sludges that are generated using anaerobic digestion. The treated water is discharged into the South Platt River where it makes up nearly 90% of the river's instream flow for nine months of the year. The digestion treatment process produces Class B biosolids and methane gas. The biosolids are land applied as agricultural fertilizer to both land owned by the district and to private farms. The methane gas is recovered and used to generate electrical power, meeting approximately 40% of the treatment plant electrical needs.

L.2.1 Biosolids Production

Metro currently produces approximately 30,000 dt of anaerobically digested Class B biosolids annually [82 dry tons per day (dtpd)]. About 90% of the biosolids are land applied as a Class B product under the Trade Name METROGRO® Cake. The remaining 10% are mixed with woodfiber or yardwaste and further treated to become Class A product that is sold under the trade name METROGRO® Compost.

Energy Recovery As part of the biosolids production process, Metro recovers and recycles the produced digester gas using cogeneration. Per day, Metro recovers over 3 million cubic feet of digester gas, producing an average of 4 MW of electricity and providing 1) process heating for the 12 digesters, 2) building heat for a portion of the District facilities, and 3) biosolids preheating prior to dewatering. The electricity from cogeneration accounts for approximately 40% of the facility's energy needs.

The District initiated cogeneration in the 1980s and originally sold the electricity generated to the local utility and then purchased back the full power to operate the wastewater treatment plant. In 1999, due primarily to changes in electrical regulation, Metro began directly consuming all of the power that it produced in cogeneration and purchasing supplemental electricity from the electrical utility. In 1999, the District also entered into an Energy Services Agreement with a private company to provide new generating equipment and to operate and maintain the cogeneration facility. As part of the agreement, two gas fired turbine generators were installed to replace the aging internal combustion engine generators. The turbines are largely operated remotely by the private company, Trigen, who charges the District a monthly fixed fee and a variable fee based on the actual level of electrical production. The 2005 net cost to the District for cogenerated electrical power was $0.041 per kWh.

L.2.2 Biosolids End Use

Land Application Approximately 90% of the annual biosolids production is transported and land applied to farmland in eastern Colorado. Farmland utilized for biosolids application consists of Metro District owned farmland as well as privately owned lands.

In 1993 and 1995, Metro purchased 52,000 acres of farm land near Deer Trail, Colorado. This site is referred to as the METROGRO® Farm. While the total area of METROGRO® Farm is 52,000 acres, only half is accessible crop land. Of the accessible cropland, only 12,000 to 13,000 acres are available annually due to dryland wheat growing cycles (Donna Hull, Metro, personal communication, September 12, 2006).

Including the METROGRO® Farm, the District has over 300 approved application sites in five counties. The District aims at 50/50 distribution between applying at the METROGRO® Farm and private farmland.

On average, the round-trip to distribute the METROGRO® Cake from the Central Treatment Plant to the application sites is 86 miles. The biosolids are surface applied at agronomic rates based on 1) soil nutrient levels, 2) intended crop to be produced, and 3) crop yield goals.

The remaining 10% of the District's biosolids production is composted during inclement weather when access to agricultural property is prohibited. The method of composting is an aerated static pile process, which produces a Class A product marketed under the name

METROGRO® Compost, which can be used for gardens, nurseries, golf courses, and reclamation projects (Donna Hull, Metro, personal communication, October 4, 2006).

On rare occasions during inclement weather when the District's short-term storage facilities are at capacity, the biosolids are either diverted to a private company that produces Class A compost to market under their own label, or are landfilled. Since the amount of biosolids falling into these categories is insignificant and inconsistent, these two methods are not considered in the following sections.

L.3 Issues Shaping the Future for the Agency's Biosolids Program

Current plans for the biosolids program are to continue land applying Class B biosolids.[1] The District has identified several issues that have already emerged or may arise in the future:

Drought Drought conditions in Colorado have historically caused minimal nutrient uptake, and consequently lowered crop yield. Drought conditions in the early 2000s resulted in a decision to substantially reduce the biosolids applied to the METROGRO® Farm in 2005. This required staff to aggressively pursue more private sites in 2005 to land apply biosolids while only applying a small percentage to the METROGRO® Farm. Drought conditions have also impacted private farmers with dryland for the same reasons as the METROGRO® Farm.

Land Application Rates The Water Quality Control Division of the Colorado Department of Public Health and Environment is proposing a change in their Biosolids Regulations to include a standard method for calculating land application rates for all Colorado biosolids applicators. If this method is approved, it will require staff to reduce the amount of biosolids currently being applied under the current calculation method by 30%. This will create a need for additional land application sites to handle the daily Central Treatment Plant biosolids production.

While no other regulation changes are anticipated, other biosolids agencies have faced huge roadblocks resulting from regulation change (see case study on Orange County).

Urban Development Continuous and extensive growth and urbanization along the front range of Colorado will decrease the availability of private land for land application. This means that Metro will be forced to drive greater distances to find suitable land for biosolids application, thereby increasing costs, reducing reliability, as well as creating more potential for vehicle accidents. Urbanization brings people in closer contact with the Metro District's land application program, increasing the possibility of citizen complaints to local regulatory officials. Such complaints could trigger more restrictions on beneficial practices at the local level and make land application of Class B biosolids more difficult. The continued growth and urbanization will also increase the application load as more waste will be treated to produce more solids. The current production of 82 dtpd is expected to increase to more than 90 dtpd by 2025.

Fuel Costs Rising fuel costs continue to impact transportation costs as well as many other functions related to transportation such as manufacturing and delivery of vehicle parts. Metro staff continue to evaluate ways to reduce fuel consumption, such as reducing idling time on vehicles and field equipment during the day-to-day operation. The Metro District is currently testing and evaluating the use of biodiesel in two of its biosolids transportation trucks as an alternate fuel source.

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1. Although Metro currently conducted a Biosolids Management Program/Facility Plan to re-evaluate their options, no plans for change have been made.

L.4 Biosolids Management Strategy

The recent Biosolids Management Program/Facility Study provides a comprehensive evaluation of the Metro District's biosolids management program and facilities. The biosolids management recommendations from the Study are:

- Continue with land application of Class B biosolids as the primary practice.
- Continue with composting, only it will be reduced from 10 dtpd to 1-2 dtpd due to the loss of a portion of the compost facility.
- Construct a third cake tower for on-site storage.
- Use an outside compost contractor when necessary.
- Develop a permitted, long-term off-site storage facility (not as critical as on-site).
- Add thermal drying (either direct or indirect), brought on-line in two phases. This would eliminate the need for composting.

This case study focuses on energy recovery during treatment and land application during disposal as the biosolids management options to be considered.

L.5 Define Suitable Baseline

In order to evaluate the benefits of energy recovery process and diversified land application program, this case study will assume a retrospective baseline that entails purchasing energy directly from an outside energy provider and landfilling Class B biosolids.

L.6 Identify and Assess Key Benefits

Because the two aspects of Metro's program (energy recovery during treatment and diversified land application during disposal) have separate costs and benefits, they will be evaluated separately in this analysis. The benefits of Metro's biosolids program are summarized in Table L-1. The magnitude of benefits, monetized where possible, is reported in Table L-2.

Table L-1. Benefits Summary.

Benefit Category	Assessment Level	Beneficiaries
Energy recovery benefits		
Avoided cost of purchasing power from an outside provider	Monetized	Agency/global
Avoided cost of purchasing heat from an outside provider	Monetized	Agency/global
Lowered air pollutant emissions (GHG, SO_2, NO_x)	Monetized	Agency/global
Increased reliability of energy supply	Qualitative	Agency
Land application benefits		
Revenue from product sales	Monetized	Agency
Avoided cost of purchasing fertilizer	Qualitative	Local: farmers using METROGRO®
Carbon sequestration	Qualitative	Agency
Diversification of disposal markets	Qualitative	Agency

Table L-2. Benefit Analysis Overview (2005, USD).

		Beneficiary
Energy recovery benefits		
Quantifiable benefits		
Avoided cost of purchasing power from an outside provider	$19,806,758	Agency
Avoided cost of purchasing heat from an outside provider	$13,270,464	Agency
Lowered air pollutant emissions (GHG, SO_2, NO_x)	$4,110,218	Agency/global
Benefits requiring qualitative assessment[a]		
Increased reliability of energy supply	+	Agency
Total monetized energy recovery benefits	*$37,187,440*	
Land application benefits		
Quantifiable benefits		
Revenue from product sales		Agency
Avoided cost of landfilling biosolids	$2,565,000	Agency
Benefits requiring qualitative assessment[a]		
Carbon sequestration	+	Agency/global
Diversification of disposal markets	+	Agency
Avoided cost of purchasing fertilizer	++	Local: farmers using METROGRO®
Total monetized land application benefits	*$2,565,000.00*	

[a](+) indicates positive benefits anticipated but not monetizable with readily available data.

L.6.1 Energy Recovery Benefits

L.6.1.1 Energy Savings/Reduced Costs

Metro currently purchases 29.6M kWh of power from Trigen at a net cost of $0.0413 per kWh and recovers 149,000 MMBTUs of heat each year (Steve Rogowski, Metro, personal communication, October 17, 2006). The estimated cost to Metro to purchase that power and heat from an outside provider is $0.0554 per kWh[2] and $8.00 per MMBTU,[3] respectively.[4] This section will estimate the benefits and costs of the energy recovery process using templates that are available in Appendix C: Energy Recovery.

The benefits and costs associated with Metro's energy recovery process are identified in Figure L-1, below. The corresponding data inputs are displayed in Figure L-2.

Net monetized benefits of Metro's energy recovery process are $22 million. The benefits and costs of the energy recovery process are summarized in Figure L-3.

2. This is the average price of electricity to industrial customers in the state of Colorado, reported by the EIA.

3. This is an estimate. From EIA, the national average price for a MMBTU of natural gas in $9.98 commercial, $7.31 industrial.

4. This analysis assumes that absent energy recovery, Metro would purchase the power necessary for production from an outside provider. Please note that this assumption is for analysis purposes only.

Template for Steps 3 - 5

Benefit/Cost category	Applicability indicator - check if benefit/cost is applicable	Data needs[a]	Data availability indicator - check if data is available	Assessment level
(Step 3 - blue cells)	(Step 3)	(Step 4)	(Step 5)	(Step 5)
General energy recovery benefits				
Avoided cost of purchasing power from an outside provider	X			Qualify
		Baseline power use (kWh, annually)	X	Quantify
		Cost of baseline power use ($/kWh)	X	Monetize
Avoided cost of purchasing heat from an outside provider	X			Qualify
		Baseline heat use (mmBTU, annually)	X	Quantify
		Cost of baseline heat use ($/mmBTU)	X	Monetize
Lowered air pollutant emissions (GHG, SO2, NOx)	X			Qualify
		Baseline emissions of air pollutants (tons)	X	Quantify
		"Value" of emissions reductions ($/ton)	X	Monetize
Increased reliability of power supply	X		X	Qualify
Process specific benefits				
General energy recovery costs				
Costs – Total capital and O&M	X			Qualify
				Quantify
		Construction and annual O&M costs	X	Monetize
Air emissions from on-site generation (with energy recovery system)	X		X	Qualify
		Emissions of air pollutants (tons)		Quantify
		"Value" of emissions reductions ($/ton)		Monetize

[a] General estimates are available for the cost of power and heat as well as air pollutant emissions, and should be used in the absence of site-specific data (see 'Step 9' in manual).

Figure L-1. Benefit-Cost Identification and Screening for Energy Recovery.

Inputs for quantified and monetized benefits and costs

Base year	**2006**
Life-cycle for 'general' benefits/costs (years)	**20**
Discount rate	**5**

Benefit/cost category	**User Inputs**	
General energy recovery benefits	***Note: it is critical that input units correspond to units specified in **column B**	
Avoided cost of purchasing power from an outside provider		
Baseline power use (kWh, annually)		29,583,220
Cost of baseline power use ($/kWh)	$	0.055
Avoided cost of purchasing heat from an outside provider		
Baseline heat use (mmBTU, annually)		149,000
Cost of baseline heat use ($/mmBTU)	$	8.00
Lowered air pollutant emissions (GHG, SO2, NOx)	*1 ton = 2205 lbs*	
Baseline emissions of air pollutants (tons)		
CO2		27,388
SO2		48
NOx		46
"Value" of emissions reductions ($/ton)		
CO2	$	10.00
SO2	$	565.00
NOx	$	850.00
Process specific benefits		
N/A		
0		
0		
N/A		
General energy recovery costs		
Costs – Total capital and O&M		
Capital costs		
Annual O&M costs	$	1,222,305.00
Air emissions from on-site generation (with energy recovery system)		
Emissions of air pollutants (tons)		
"Value" of emissions reductions ($/ton)		
Process specific costs		
N/A		
N/A		

reflects capital investment in the turbines, day-to-day operating costs, and electrical cost

Figure L-2. Inputs for Quantified and Monetized Benefits and Costs.

Costs and benefits of energy recovery project

		Dollar amount
Cost components		
Costs – Total capital and O&M	$	14,771,948
Total monetized costs	$	14,771,948
Benefit components		
Avoided cost of purchasing power from an outside provider	$	19,806,758
Avoided cost of purchasing heat from an outside provider	$	13,270,464
Lowered air pollutant emissions (GHG, SO2, NOx)	$	4,110,218
Total monetized benefits	$	37,187,439.89
Benefits/costs requiring qualitative assessment[a] (Enter qualitative benefits/costs manually)		
Increased reliability of power supply		+
Air emissions from on-site generation (with energy recovery system)		-
Monetized net benefits (monetized benefits minus costs)	**$**	**22,415,491.78**

[a]+ indicates positive benefits anticipated, but not monetizable with readily available data, and - indicates costs

Figure L-3. Present Value Costs and Benefits of Energy Recovery Project.

L.6.2 Land Application Benefits

L.6.2.1 Revenue from Product Sales

Metro generates revenue from the sale of METROGRO® Cake that is applied to privately owned agricultural farmland and the sale of bulk and bagged METROGRO® Compost. Annual revenue can vary from year to year. The revenue for 2005 was approximately $8,500 for METROGRO® Cake and $83,000 for METROGRO® Compost, totaling $91,500 (Donna Hull, Metro, personal communication, September 19, 2006).

Metro also has a potential for revenue from the crop harvested on the METROGRO® Farm. Under the current Farm and Grazing Lease Agreement (Agreement) with the tenant farmer, the District's share of the niche crops is 25%; the District's share of wheat and barley is determined on a sliding scale which is based on actual average crop yield, ranging from 0% when the yield is below 15 bushels per acre up to 50% when the yield is over 30 bushels per acre. Unfortunately, due to the impact of the drought resulting in poor wheat yields and how the crop share is structured in the Agreement, the Metro District's crop share for the past several years has been minimal (Donna Hull, Metro, personal communication, October 4, 2006).

L.6.2.2 Fertilization Benefits to Farmers

Metro sells its METROGRO® Cake for $4.00 per acre for 75 lbs or less of nitrogen applied per acre and $6.00 per acre for more than 75 lbs of nitrogen applied per acre. This cost to Metro's customers includes obtaining permits and delivering, applying, and incorporating the biosolids at the farm site, thus creating significant cost savings opportunities for the farmers. Metro has roughly estimated value for service provided to their customer farmers as $48.00/acre (Donna Hull, Metro, personal communication, September 19, 2006).

L.6.2.3 Carbon Sequestration

There is potential to increase carbon soil reserves through land application of biosolids. Refer to Appendix D.

L.6.2.4 Diversification of Markets

In order to mitigate issues discussed in Section L.3, Metro has diversified markets and lands to which they sell and apply their solids. This also provides diversity to accommodate various cropping cycles and most inclement weather events. The diversified options for biosolids disposal improves the sustainability of Metro's biosolids program.

L.7 Identify and Assess Key Costs and Risks

The costs of Metro's biosolids program are summarized in Table L-3.

Table L-3. Cost Analysis Overview (2005, USD).

	Present Value	Cost Bearer
Energy recovery costs		
Quantifiable Costs		
Operating and maintenance of energy recovery	$14,771,948	Agency
Costs requiring qualitative assessment[a]		
Air emissions from on-site generation	–	Agency
Total monetized energy recovery costs	*$14,771,948*	
Land application costs		
Quantifiable costs		
Operating and maintenance costs of land applying biosolids	$4,232,597	Agency
Operating and maintenance costs of composting	$674,584	Agency
Total monetized land application costs	*$4,907,181*	Agency

[a](-) indicates positive cost anticipated but not monetizable with readily available data.

L.7.1 Energy Recovery Costs

The annual cost that includes recovery of the capital investment for the power generating turbines, day-to-day operations, and electricity is about $1.2 million. The total present value of the energy recovery costs[5] is $14,771,948.

5. Costs do not include the basic infrastructure Trigen purchased prior to the contract (the building, the electrical transmission gear, the water lines, the connection to the digestion complex, etc.). This cost, however, may be incorporated in the cost per kWh of electricity Trigen charges.

L.7.2 Land Application Costs

The cost in 2005 of land applying biosolids at the METROGRO® Farm and private farm land was $4.9 million. The cost of the baseline option, landfilling, is $8.2 million.[6]

L.7.3 Risks and Concerns

Potential Human Health Risks There are ongoing concerns, both locally and on a national level, about the air quality when particulates are transported by wind from biosolids-applied fields. As part of a 2004 Inter-Governmental Agreement with Elbert and Arapahoe Counties, the Metro District has agreed to add an air quality component during a portion of the next seven year project to determine if air quality (and potential risk to humans inhaling the particles) may be associated with land application—see Section L.1.

Limits, Restrictions, and Potential Bans on Application Agricultural land application does not ensure the long-term viability of an agency's biosolids management program. There are several factors beyond the control of the agency that could limit, restrict, interrupt or even prevent an agency from employing agricultural land application as a biosolids disposal method. These include:

- **A potential increase in population:** Biosolids application rates on agricultural lands are limited by the agronomic needs of the crop. If the population in a municipality increases, then the volume of biosolids produced will increase. Since regulations restrict the rate at which biosolids can be applied to agricultural lands according to crop needs, the agency will have to secure additional acreage to maintain a land application program.
- **Management decisions by farmers:** Farmers and other end-users generally do not have a contract with the wastewater agency and can "cancel" their receipt of biosolids at any time, which is essentially the same as eliminating a portion of the agency's land application program.
- **Harvesting schedules and inclement weather:** Agricultural land application requires the agency to plan transportation and application at times that are compatible with planting and harvesting schedules. Particularly wet weather may make some farm roads inaccessible or some fields too soft to accommodate the application equipment. Agricultural demand for biosolids may fluctuate throughout the year.
- **Public perception:** Regardless of whether public opposition to agricultural land application stems from the odors associated with biosolids, the risks (both real and perceived) that biosolids pose to human and environmental health, or any other negative perception of the disposal method, public outcries against land application can lead to opposition by public officials and/or changes to local and regional restrictions. Ultimately, these issues may lead to significant limitations or bans on agricultural land application. In several communities throughout the country, such as Kern County, CA, bans on land application of Class B biosolids are already in place.
- **Potential changes** to federal regulations (the Part 503 rule).

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6. Cost of landfilling is based on the 2005 cost per dt, $90, applied to all tons produced by Metro.

Odors and Traffic The odors associated with biosolids can be a nuisance to neighbors, particularly during the unloading and application process. These may prompt complaints from affected parties, motivated by the unpleasant smell itself and/or by a perceived (and perhaps real) mental association of the odors with the potential to pose health risk. Odors and associated concerns can impose considerable loss of welfare on the impacted individuals. Odors can create political pressure that may ultimately preclude or limit the utility's ability to continue to apply biosolids at the sites (e.g., by leading to bans on some land application options and/or sites, as mentioned in the previous section). Metro has done substantial work to mitigate the impacts of odors and traffic on the local community. See Appendix A for more detail.

L.8 Distributional Issues: Identification of Key Beneficiaries and Cost-Bearers

Local recipients that benefit from the land application of biosolids include the Denver Metro Wastewater Agency (most economical beneficial biosolids distribution management option) and farmers who receive METROGRO® Cake at reduced cost (compared to using chemical fertilizer). Local recipients of energy recovery benefits include the Metro District (decreased energy costs) and local residents (decreased emissions of air pollutants). The benefits of reduced GHG emissions are also realized at the global level.

Potential bearers of air quality, odor, and traffic issues associated with the land application program include Deer Trail residents, neighbors of private farmers, and residents in close proximity of the Central Treatment Plant. There are a few community members and elected officials (in Deer Trail) near the METROGRO® Farm who are opposed to the application of biosolids. On average, 5-6 complaints a year are filed related to odor generated from the Central Treatment Plant, a transport truck, or near a biosolids application site.

Effected parties and the level of the impact are summarized in Table L-4.

Table L-4. Effected Parties and Their Level of Impact.

Affected Party	Benefit/Cost Category	Level of Impact[a]	Description
Agency	Land application	++	Diversified disposal options decreases risk and vulnerability to whether constraints
		-	Risk of long term viability; leaves agency vulnerable to changes in regulatory policies
	Energy recovery	+	Significant cost savings through avoided costs of energy (power and heat) purchase
Neighbors	Land application	-	Odors associated with biosolids; greatest nuisance during application (or short-term storage on fields), potential nuisance during transportation
			Traffic associated with biosolids transportation can impact negatively affect neighbors
Local community	Energy recovery	++	Lowered emissions of GHGs
Global Community	Energy recovery	++	Lowered emissions of GHGs

[a]Direction and magnitude of impact:
++ = Very positive impact
- = Slightly negative impact
+ = Slightly positive impact
-- = Very negative impact.

L.9 Public Outreach and Communication Issues

In order to address community concerns about the land application of biosolids, the Metro District has implemented various monitoring, conservation, and survey programs including: an up-to-date Website with biosolids information, a 1-800 number for citizen questions/concerns/complaints, an inquiry/complaint database, a Citizen's Advisory Group, etc. (Donna Hull, Metro, personal communication, September 2006). These are explained in more detail in Appendix L.3.

L.10 Comparing Benefits to Costs; Summary of Findings

The benefits of Metro's energy recovery program and diversified land application include avoided costs of energy supply, lowered GHG emissions, a relatively low-cost and easy disposal technique, diversified disposal options, and the availability of less expensive fertilizer to farmers. Costs and risks of the land application program include the lack of diversified treatment techniques, products, and product markets.

While this case study reveals the benefits and costs of diversified land application and biosolids disposal strategies, the issues that Metro is currently facing and expected to face in the future (see Section L.2 above) illustrate the ongoing need of biosolids management strategies to be adaptive to change and diversification. Due to the increasing quantity of biosolids being produced coupled with the decrease in allowable per acre load, Metro will eventually have to implement an alternative technology or become more reliant on private land to maintain its current beneficial use program (Donna Hull, Metro, personal communication, September 19, 2006).

APPENDIX L.1

OUTREACH/COMMUNICATIONS/ MONITORING PROGRAMS

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Independent Monitoring Program An independent monitoring program was developed between the Metro District and the U.S. Geological Survey (USGS) to monitor the effects of land applying biosolids on the Farm. The program was developed to address concerns from the community near the METROGRO® Farm. Constituents of primary concern with the public were arsenic, cadmium, copper, lead, mercury, and molybdenum, nickel, selenium, zinc, plutonium, and gross alpha and beta activity. USGS prepared its findings in a final report titled, *Effects of Surface Application of Biosolids on Soil, Crops, Ground Water, and Streambed Sediment near Deer Trail, Colorado 1999-2003* (Yager et al., 2004), which generally indicates there appears to be no conclusive evidence that the Metro District's land application of biosolids on the METROGRO® Farm is harmful to the soils, crops, groundwater, or surface water on or near the Farm.

Under the 2004 Inter-Governmental Agreement with Elbert and Arapahoe Counties, the Metro District voluntarily committed to continue the monitoring program for an additional seven years. In addition, there are ongoing concerns, both locally and on a national level, about the air quality when particulates are transported by wind from biosolids-applied fields. This component will be added to the seven-year program.

Deep Soil Monitoring Program A five-year deep soil-monitoring program is underway at the METROGRO® Farm in conjunction with Colorado State University to determine if biosolids loading rates are causing any accumulation or downward migration of nitrates into the soil.

METROGRO® Farm Management Plan After the Metro District purchased the METROGRO® Farm in 1993 and 1995, concerns were raised by neighbors of the Farm and local conservation districts regarding poor farming techniques that could lead to erosion (water and wind) that would carry biosolids off the Farm property. The METROGRO® Farm Management Plan (Plan) is a collaborative effort between the Metro District and the tenant farmer to coordinate activities and schedule the biosolids land application and farming operations at the Farm. In addition, the Plan provides a means of identifying problem areas and tracking the progress of remedial actions taken. Current information such as capital improvements being made to the property, the ongoing Deep Soil Monitoring Project, and the Independent Monitoring Program conducted by the USGS are included in the Plan. See hard copy of METROGRO® Farm Management Plan June 2006.

Conservation District Projects Cooperative efforts between the Metro District and local conservation district's have led to several erosion control projects being completed on the METROGRO® Farm. Some of these efforts were establishing 50 acres of nonfarmable terraces, planting 933 acres in dry land corn in order to change the rotation and break up larger fields, repairing ten diversion structures, and installing approximately 31,276 linear feet of farmable terraces.

Soil Sampling and Groundwater Soil samples are taken by Resource Recovery and Reuse (RR&R) staff from each site prior to every application of biosolids and tested for nutrients using the latest methods approved by the U.S. EPA and the Colorado Department of Public Health & Environment. Based on the nutrient content of the soil and the crop intended to be grown, a loading rate for biosolids is determined.

District staff also determines the groundwater level at each site prior to the first application of biosolids per the requirements in the "*Colorado State Biosolids Regulations #64*." If groundwater at the proposed application site is determined to be within five feet of the surface, biosolids will not be applied.

Wind Erosion Prediction System The RR&R Department hired a student intern from the Colorado State University in the summer of 2004 and 2005 to begin building the Wind Erosion Prediction System (WEPS) model for the METROGRO® Farm.

Citizen Participation Group The District also has established a formal Citizen Participation Group (CPG). This group includes representatives of environmental groups, civic groups, academics, citizens involved in organics recycling, county biosolids regulators, and ordinary citizens (neighbors to Central Treatment Plant). The group meets at least four times a year with a facilitator to discuss issues and hear from the staff about ongoing operational activities as well as the District's Environmental Management System for Biosolids.

Stakeholder Research Survey The District also conducts a triennial Stakeholder Research Survey. This activity began in 2000 with followup surveys conducted in 2003 and 2006. The survey asks neighbors near the METROGRO® Farm and elected officials serving in the counties where the Farm is located what their concerns are regarding biosolids activities and farm operations. The results of the surveys are used to establish goals, objectives, and action plans for the following years.

Customer Satisfaction Survey Preliminary meetings are now taking place to implement a "Customer Satisfaction Survey" with the private farmers that purchase METROGRO® Cake biosolids that is land applied to their farmland. It is anticipated that this survey will help staff identify areas where improvements can be made in the land application process.

Other Outreach Methods The Metro District has many other methods of outreach to the public such as:

A METROGRO® Farm Newsletter Update that is published twice per year and distributed in a newspaper with approximately 9,000 subscribers.

Contacting neighbors within one mile of a proposed biosolids application site to let them know who and what Metro District is and distributing a packet that includes regulations, business cards, biosolids analyses, and a DVD showing them the Metro District's plant operation and its biosolids land application program; an annual picnic; external Website; various brochures; central Treatment Plant and METROGRO® Farm tours; establishment of a 1-800 number to encourage public feedback; attending the Annual Colorado Farm Show; participating in parades near communities where biosolids is applied.

Denver Metro's EMS Program The Metro District was one of the first 27 "charter" agencies to participate in the National Biosolids Partnership (NBP) EMS for Biosolids demonstration program from its inception in 2000. Beyond providing ways to improve the Metro District's operations while reducing costs, the EMS is a reflection of the District's commitment to producing high quality biosolids products that meet or exceed mandatory regulatory requirements. In addition, the EMS is an excellent tool to address public perception and achieve acceptance of the land application of biosolids.

In December 2002, the Metro District implemented its EMS for Biosolids, and in July 2005 became the eighth agency to receive NBP certification for its EMS for Biosolids Program. NSF International conducted the third-party program verification audit, which is a required component of the program.

In May 2006, the Metro District successfully completed its first third-party interim audit with NSF and maintained its NBP certification.

Costs associated with the EMS for Biosolids Program:

Cost for implementation and maintaining the EMS for Biosolids: Approximately $100,000 to $125,000 per year (includes manpower, materials, and third-party audit fees).

APPENDIX M

WESTERN LAKE SUPERIOR SANITARY DISTRICT, DULUTH, MN

M.1 Introduction and Overview

The WLSSD is responsible for managing the region's WWTP, which is designed to treat an average of 43 million gallons of wastewater per day. The region, which covers an area of roughly 530 square miles, is located in northern Minnesota; the general geography is defined by Lake Superior to the east, inland forests, and open agricultural land. The WLSSD serves approximately 130,000 residents (1990 census figures) of St. Louis and Carlton counties; this includes Duluth and over a dozen surrounding cities and townships (WLSSD, 2004).

All wastewater treatment agencies, including the WLSSD, have to manage (either through disposal or beneficial use) biosolids, although the exact management program a particular agency adopts can be tailored to that agency's specific situation (its size, its financial resources, its geographical location, etc.). As an agency's budget, a community's perception of biosolids, and a region's market for biosolids change over time, a biosolids management program may need to adapt to those changes in order to be sustainable. This case study serves to highlight some of the WLSSD's management considerations and address the benefits, risks, and costs associated with them. In particular, the following sections address the possibility of the WLSSD:

- Transitioning from Class B production to Class A (by increasing pathogen standards)
- Diversifying biosolids beneficial use options to enhance program stability, both by:
  - Evaluating new market opportunities
  - Increasing land application at reclaimed mine sites (while reducing the amount of biosolids land applied to agricultural sites)

These management options are neither mutually exclusive (if the WLSSD produces a Class A product, increased mine site reclamation would still be a beneficial biosolids use option), nor are all of the changes required to improve the long-term sustainability of the agency's program (new market opportunities are available even if the WLSSD continues producing Class B biosolids). In this case study, however, the WLSSD's two key considerations (transitioning from Class B to Class A, and diversifying beneficial use options) are approached as two independent management options. The result is essentially two separate BCAs within the case study.

M.2 Current Biosolids Management Practices

M.2.1 Biosolids Production

Currently, the WLSSD's biosolids are stabilized using an anaerobic temperature-phased digestion process and dewatered in a high-speed centrifuge (WLSSD, 2004). This treatment process meets the U.S. EPA and the Minnesota Pollution Control Agency (MPCA) standards for Class B biosolids. In 2005, WLSSD biosolids production was 8,570 dt (34,400 wet tons); that volume is expected to increase by nearly 10% (to 9,375 dt) by 2011 (CH2M Hill, 2006). The trademark name for the final biosolids product is "Field Green."

M.2.2 Biosolids Recycling

All of the biosolids produced by WLSSD currently are beneficially recycled through a year-round land application program. The majority (85%) are spread on local agricultural lands (approximately 1,800 acres annually) that are used to produce feed crops for livestock. The remainder are used for mine land reclamation (approximately 300 acres/year) to help re-vegetate the otherwise virtually sterile land (WLSSD, 2004). The average size of a given land application site is 20 acres and the average round-trip haul distance from WLSSD is 40 miles (WLSSD, 2004).

M.2.3 Biosolids Storage

There are times throughout the year when land application is not possible (e.g., when the soil is too soft to accommodate the application equipment due to snowmelt in the spring). During these periods the biosolids must be stored. The WLSSD has approximately 19 days of biosolids cake storage capacity at the WWTP and another 41 days of storage capacity (for current production rates) at an enclosed off site facility in Carlton County (CH2M Hill, 2006).

M.2.4 Biosolids Characteristics

WLSSD's anaerobically digested biosolids are about 25% solids. Odors from the cake product are considered to be moderate and acceptable for agricultural application (CH2M Hill, 2006). The biosolids cake contains approximately 20 to 25 lbs nitrogen per dt and provides about 29 lbs of PAN per dt when surface applied and 37 lbs of PAN when incorporated (MDNR, 2004).

M.2.5 Benefits Currently Realized at the Treatment Facility

The WLSSD currently recovers biogas produced during anaerobic digestion of biosolids and uses that energy—the rough equivalent to 250 million BTUs per day—to heat the plant and run the digesters. This energy recovery offsets the agency's need for an outside source of energy, and provides a cost savings of approximately $2,000 per day.

M.3 Issues Shaping the Future for the Agency's Biosolids Program

Since 2004, the WLSSD has been working towards the development of a Master Plan to provide guidance for the sustainable management of biosolids in the region for the next 20 years. The WLSSD has defined a sustainable program as one that:

> "incorporates products and practices that ensure the safety of human health and the environment; encompasses diversity in products, markets and practices to ensure continuous product distribution; provides high-quality biosolids products that enhance the resources on which they are used and are desired by end-users; is adaptable to changes in technology and in markets; fosters good relationships with stakeholders, end-users, and the public; considers local economic benefits; and integrates with existing waste processing technology" (WLSSD, 2006b).

The WLSSD established improvement goals and strategies for the region's current and future biosolids management programs by drawing upon conversations and workshops amongst WLSSD staff, information provided by other municipalities, the results of a Biosolids Market Study, prepared for the WLSSD by CH2M Hill, as well as technical memoranda prepared by the Environmental Financial Group. The strengths, weaknesses and opportunities for change identified by these various parties have helped to shape the plans for WLSSD's biosolids program. Some of the key issues being considered include: costs, public acceptance, and market diversity.

M.3.1 Costs

A major issue for WLSSD is the cost of capital investments that will be necessary during the next 10 years. The District has immediate infrastructure improvement needs at major pump stations and interceptors over the next five years, and the prospect of a significant decrease in wastewater treatment plant loadings creates financial challenges (Kathy Hamel, Professional Engineer, Operations Supervisor, WLSSD, personal communication, September 12, 2006). These budgetary challenges have resulted in the suspension of program investments that are not absolutely necessary.

Although a facility plan to explore and select potential Class A production technologies is being initiated in late 2006, it is possible that the funding necessary for the subsequent research, design, and construction will not be allocated to the biosolids program. The capital cost of a new facility is a key determinant in the feasibility of changing the current biosolids processing program.

In response to higher transportation costs, the WLSSD will also postpone increasing the amount of mine land reclamation that is conducted each year. Initially, WLSSD planned to increase the acreage of the mine land reclamation program by several hundred acres per year beginning in 2006. However, in 2007, the WLSSD will continue with their historical mine land application rates and utilize 300 acres of reclamation mine land per year (Kathy Hamel, Professional Engineer, Operations Supervisor, WLSSD, personal communication, 2006).

Rising fuel costs continue to add to the costs associated with all land application programs, but are of particular concern with regard to mine land reclamation projects as these sites tend to be located further from the WWTP than many of the agricultural land application sites. As a result, hauling distance is a key determinant in the feasibility of land application projects.

M.3.2 Public Acceptance

Public concern has resulted in local ordinances banning or restricting land application of biosolids. This is an issue for utilities such as WLSSD because the result is a reduction in the amount of available sites for agricultural land application. Bans have been enacted in 11 different townships in Carlton, Pine, and St. Louis counties. Around half of the bans were already in place when WLSSD began its land application program in the 1990s. Of the more recent bans, the most noteworthy is the Automba Township. Until the use of biosolids was banned there in 2003, the township comprised 12% of the approved land base for biosolids (Kathy Hamel, Professional Engineer, Operations Supervisor, WLSSD, personal communication, September 2006). This portion of biosolids is now land applied elsewhere in the region. Other towns have not banned biosolids but have instead implemented various restrictions on land application. A few examples of the specific requirements include: same day incorporation of biosolids (no overnight storage), fees paid to the town by the land-owners using the biosolids, and signed agreements by farmers indemnifying the township from any future issues that could arise as a result of the biosolids land application (CH2M Hill, 2006).

At the time of this report, the bans enacted within WLSSD's service area were not specific to Class A or Class B biosolids. Class A biosolids are, however, generally viewed as safer by the general public because of the greater pathogen reduction requirement.

M.3.3 Market Diversity

In 2005, the WLSSD identified the following improvement goal: "develop enough diversity in biosolids products, markets, and practices to ensure continuous product distribution." For WLSSD this means continuing to utilize existing agriculture and mine land markets and expanding into one or more new market(s).

A group of biosolids marketing experts from CH2M Hill conducted a market research study to evaluate new biosolids markets in the region surrounding Duluth. Two key features of the study were:

- **Evaluating the potential market for a Class A soil amendment product.**
  The study identified the most receptive market sectors as: landscapers, turf management, garden centers/resellers and golf courses. As part of the study, potential end-users were surveyed in-person and shown samples of various soil amendment products in order to obtain insight into the development of a new Class A soil amendment. Those surveyed all liked the physical characteristics of Tacoma, Washington's biosolids products (the trademark name for which is TAGRO).
- **Identifying new markets for the existing Class B product (Field Green).**
  Three new markets were considered: sod, forestry, and biomass production (growing and harvesting vegetation for use in energy production).

M.4 Biosolids Management Options under Consideration for Future

M.4.1 Transition from Class B Production to Class A

The WLSSD would like to start processing 100% of its biosolids to Class A. As explained in the WLSSD's 2006 Biosolids Sustainability Master Plan Handbook: "production of Class A biosolids will not only provide for increased market opportunities and flexibility compared to Class B, but will also demonstrate the WLSSD's ongoing commitment to meet the highest standards possible for all its programs. Class A biosolids may have the added benefit of promoting public confidence in the product's safety" (WLSSD, 2006a).

M.4.2 Diversifying Biosolids Beneficial Use Options to Enhance Program Sustainability

With the long-term goal of establishing a sustainable biosolids program, the WLSSD has identified the need for management practices that ensure continuous product distribution (i.e., the agency doesn't want to run into a situation where it cannot put its biosolids to use as "planned" and is forced to find new storage or disposal options). To achieve this, the WLSSD is considering: developing a Class A soil amendment, evaluating new market opportunities for their Class B product (Field Green), and altering current land application practices (decreasing land application at agricultural sites in favor of increasing mine site reclamation).

Developing a Soil Amendment The WLSSD is considering producing a Class A blended biosolids product, such as a potting soil or mulch. The results of the market study indicate that a soil amendment with physical characteristics similar to any of the TAGRO products sold in Tacoma, Washington would be well received in the Duluth region. This program is discussed in further detail in Text Box 1.

Evaluating New Market Opportunities for Field Green Market research, in the form of telephone and in-person surveys, was conducted within the Duluth region's biomass production, forestry, sod industries. The research was also conducted within the local agricultural industry (where biosolids are already being put to beneficial use) for comparison. The findings are summarized in Text Box 2.

Altering Current Land Application Practices While the WLSSD will continue with its land application program, a shift towards decreasing the amount of biosolids applied to agricultural lands in favor of increasing the amount used for reclamation of disturbed lands (in most cases taconite tailings at mining sites) may improve long-term security of the biosolids management program.

Although the exact size of the mine land reclamation program will vary slightly each year, for the purpose of this case study it is assumed that annual land application at reclaimed mine sites will increase by 200 acres beginning in 2010 (this equates to a total of 500 acres per year).

M.5 Define Suitable Baseline

Without adequate funding for capital investments (e.g., new biosolids processing equipment), WLSSD will have to continue with the current digestion and treatment processes (treating biosolids to Class B pathogen reduction levels). If the current "freeze" on new or expanded projects persists, WLSSD will maintain a biosolids management program that depends exclusively land application. Approximately 85% of the biosolids will be applied to agricultural lands and the remaining 15% will be distributed to reclaimed mine sites. Reclaimed mine sites in the region that do not receive biosolids will have to purchase commercial fertilizers and soil enhancement products. If fuel costs continue to rise, WLSSD can expect to incur higher biosolids management costs. If additional towns implement bans or restrictions on biosolids storage and/or land application, WLSSD will need to expand their land application services to sites outside of the current 20-mile radius (40 miles round-trip).

M.6 Identify and Assess Key Benefits

M.6.1 Benefits Resulting from a Transition from Class B Biosolids Production to Class A

The primary distinction between Class A biosolids and Class B biosolids has to do with pathogen reduction. Class A biosolids go through a more stringent pathogen reduction process and as a result contain no detectible levels of pathogens. Motivations for switching from Class B biosolids production to Class A include reduced permitting requirements, reduced likelihood of public opposition, increased marketability, and fewer environmental concerns. These benefits are realized by the agency, the local community, and the end-users. Table M-1 summarizes these benefits.

Text Box 1. TAGRO: Tacoma, Washington's Biosolids Product

Short for "Tacoma Grow," TAGRO is the trademarked name of Tacoma, Washington's suite of lawn and garden products produced from biosolids. By blending biosolids cake with other components such as sand, sawdust and wood chips, Tacoma has created three products that are sold to both commercial landscapers and home gardeners: TAGRO Mulch, TAGRO Potting Soil and TAGRO Mix.

Table 1. TAGRO Products.

	TAGRO Mulch	TAGRO Potting Soil	TAGRO Mix
Popular uses	Outdoor gardening	Flower and vegetable gardens (indoor and outdoor)	Lawn establishment and revitalization
Components			
Biosolids cake content	20%	20%	50%
Additional components	Sawdust	Sawdust, wood chips	Sawdust, sand
Costs			
Cost to produce ($/cubic yard)	$11.88	$12.91	$8.5
Price ($/cubic yard)	$14.00	$30.00	$10.00
Margin ($/cubic yard)	$2.12	$17.09	$1.5

The Biosolids Product: The city's WWTP serves less than 200,000 people and produces approximately 4,000 dt of biosolids annually. Using a two phased digestion system (thermophillic aerobic followed by mesophillic anaerobic), the WWTP produces a Class A biosolids cake that is similar in appearance, odor and moisture content to typical anaerobically stabilized biosolids.

Developing TAGRO: The first efforts to market the dewatered cake were a dismal failure. The cake did not have a user-friendly smell, appearance or texture. As a result, public acceptance and demand for the material were low. The final "formula" for TAGRO Mix took about a year to develop after several iterations and a lot of customer feedback. The potting soil and mulch were developed later in association with Washington State University. The demand for these two products is now higher than for the original soil amendment product, TAGRO Mix.

Marketing TAGRO: Tacoma has been very successful marketing and selling TAGRO products, particularly to the home gardener (the initial target customer for TAGRO). Working within the city's infrastructure has been an integral part of Tacoma's marketing efforts. There is an existing framework through which to reach local residents—utility bills, and Tacoma has taken advantage of this by including informational inserts with the bills. By participating in Home and Garden shows and growing fruits, vegetables and flowers in its demonstration garden, Tacoma in effect advertises its TAGRO products by allowing potential customers to see products grown with TAGRO. This "advertising strategy" has been more successful than more conventional advertising efforts such as radio and print media.

Selling TAGRO: Tacoma charges between $8 and $30 per cubic yard for TAGRO products. Between 2003 and 2005, TAGRO's total revenue increased from $341,154 to $530,000 (net losses during that time, therefore, dropped from $471,910 to $312,537). The total cost for Tacoma to process biosolids decreased by over 30% during that time (from $140/dt in 2003 to $93/dt in 2005). Tacoma expects to turn a profit in a few years.

TAGRO's Awards: Since 1992, fruits, vegetables and flowers that were grown in the TAGRO demonstration garden have won more than 120 ribbons, most of them blue, from the local Western Washington Fair. Tacoma has also been recognized for its excellence in technology and innovation on a national level by such organizations as the National Biosolids Partnership and the Association of Metropolitan Sewerage Agencies and was named the best biosolids program country by the U.S. EPA.

Text Box 2. Additional Market Opportunities for WLSSD Biosolids

The WLSSD had an outside firm (CH2M Hill) conduct a market research study to evaluate new markets for biosolids beneficial use in the Duluth region. The three markets that were explored in depth were: biomass production, forestry, and sod.

- **Biomass:** Biomass production is the practice of growing agricultural, vegetative or woody crops with the purpose of harvesting for use in energy production. Typically, these are fast growing species such as switch grass and hybrid poplars.

  Biosolids application rates for biomass production tend to be significantly greater (sometimes more than 10 times greater) than for application at agricultural sites. According to the market study, utilizing as little as 200 acres, the WLSSD could distribute between 3,800 and 9,800 dt of biosolids per year assuming an annual application rate of between 19 and 49 dt per acre and a 6- to 9-year growing cycle. Even at the most conservative low end application rate (19 dt per acre) and the longest growing cycle (nine years) this represents nearly half the WLSSD annual production on only one-tenth of the acreage currently in the WLSSD agricultural program.

- **Forestry:** Land application of biosolids on forest lands has been practiced on a limited basis for many years throughout North America. Forest land application comprised 20% of King County, Washington's biosolids management program in 2004. Further research may be necessary to illustrate whether or not biosolids application increases production in forests. Application rates for forestry are roughly the same as for agriculture. There is a potential market for biosolids use in forestry in Carlton County (with over 1,000 accessible acres within 25 miles of WLSSD) and by private companies in Minnesota (with over 3,000 accessible acres within 50 miles of WLSSD).

- **Sod:** Sod farmers may use large amounts of commercial fertilizer; the two farmers included in the market study for WLSSD required between 500 and 1,000 lbs of nitrogen (N) per acre per year, or the equivalent of approximately 20 to 40 dt of biosolids per acre per year. A typical agronomic rate is roughly 100 lbs of N per acre per year, or roughly 4.3 dt of biosolids/acre/yr. Both Class B and Class A can be used for sod production since the typical harvest cycle for sod in Minnesota is longer than the restrictions for marketing crops grown with Class B biosolids.

  The two sod farms that were contacted had a combined total of 1,430 acres with 650 in use on an annual basis. If WLSSD could penetrate 50% of that acreage, the biosolids demand would be more than 2,000 dt per year (CH2M Hill, 2006).

WLSSD anticipates utilizing one of these three markets for the beneficial use of 30% of the agency's total biosolids by the year 2010. Table 1 compares the three markets.

Table 1. Comparison of Potential Future Biosolids End-Use Markets (in the Duluth Region).

	Biomass	Forestry	Sod	Agriculture
Biosolids type	Class A or B	Class A or B	Class A preferred	Class A or B
Further research and development needs	Required	Required	Prudent	Not required
Advantages	Sustainable. Potential for significant biosolids outlet on small acreage. Potential for reduced offsite odors.	Vast acreages available near Duluth.	Ready to start.	Program is already well established with sufficient permitted acreage.
Disadvantages	Dependent on commitments from biomass users. Requires demonstration to regulators. Public acceptance issues.	Capital investment (equipment). Requires demonstration to foresters and regulators. Public acceptance issues.	Longer hauling distances. Public acceptance issues.	Public acceptance issues: potential future bans or phosphorous rules.

Table M-1. Benefits Resulting from a Transition from Class B Biosolids Production to Class A.

Type of Benefit	Assessment Level	Beneficiaries
Reduced permitting requirements	Qualitative	Agency
Reduced likelihood of public opposition	Qualitative	Agency/local
Increased marketability	Qualitative	Agency
Improved environmental conditions	Qualitative	Local/regional

Reduced Permitting Requirements The WLSSD is responsible for obtaining permits for land application of biosolids. Class B biosolids must comply with federal restrictions as well as state and local restrictions. In Minnesota, land application is regulated by the Minnesota Pollution Control Agency's sewage sludge management rules. The numerous requirements for Class B land use include:

- Buffer requirements
- Crop type and harvesting limitations
- Grazing restrictions
- Public access restrictions

The waiting periods associated with these limitations are not trivial, ranging from 30 days to over 3 years. Class A biosolids, however, do not require the same level of permitting. In general, permitting will most likely vary by state depending on each state's regulations.

By reducing permitting and regulatory requirements, Class A biosolids production will save the WLSSD time and money. Receipt of Class A biosolids instead of Class B provides greater land use flexibility to farmers and landowners.

Reduced Likelihood of Public Opposition Class A biosolids are often viewed by the general public as being safer than Class B. As a result, major public outcries, opposition by public officials, local and regional restrictions, and bans are less likely to occur when an agency produces a Class A product. In several communities throughout the country, and in towns in the Duluth area, such as Automba, bans on land application of Class B biosolids are already in place. The WLSSD has a policy not to challenge local bans (or restrictions). By producing Class A biosolids, the WLSSD will probably increase the number of potential local land application sites while improving public perception of their product's safety.

Increasing the number of potential local land application sites (or reducing the likelihood that existing available sites may become unavailable due to future bans) has the potential to create cost savings benefits for the WLSSD. Fuel costs are a major component of the cost of the biosolids program; the more sites available implies shorter average hauling distances required for land application, and this will lower the agency's fuel costs.

Increased Marketability With no restrictions on use, Class A products provide both the agency and end-user with a broader range of beneficial use options for biosolids. In addition to increasing the flexibility of land use at sites where biosolids are already applied, production of Class A biosolids makes it possible to expand land application programs to include additional sites not suitable for Class B.

By blending the Class A product with woodchips, sand or other amendments, it is also possible to create soil enhancements, such as mulch or topsoil. Producing soil amendments will generate cost savings benefits for the agency. Even if the WLSSD chooses to continue to make their biosolids product available free of charge, it is expected that customers will pick up the product themselves, thereby reducing transportation costs for the WLSSD. Class A soil amendments could, however, be sold to commercial landscapers and home gardeners, generating revenue for the WLSSD. Several utilities throughout North America currently sell high quality biosolids products, earning revenues between $10 and $30 per cubic yard (CH2M Hill, 2006).

Tacoma, Washington, has a particularly successful program as evidenced by an increase in revenue of 150% between 2003 and 2005 (see Text Box 1).

Improved Environmental Conditions Production of Class A biosolids (instead of Class B) has the potential to create future environmental benefits for the greater Duluth region. Coupled with the likelihood that there will be less public opposition to Class A biosolids, the fact that there are less restrictions on the use of Class A biosolids will most likely provide WLSSD with the flexibility to broaden the biosolids management program to include new sites for agricultural and mine land application as well as alternative distribution options (e.g., sod farms, forestry, and home gardens). This may help prevent a future situation in which large concentrations of Class B biosolids are land applied to a relatively small number of sites year after year, thereby reducing the risk that high concentrations of N, P, metals, or other contaminants will be present in soils at biosolids application sites.

M.6.2 Benefits Resulting from Increased Land Application at Reclaimed Mine Sites (and Reduced Land Application at Agricultural Sites)

Land application is a widely practiced biosolids end-use option. Biosolids are most commonly land applied to agricultural sites or reclaimed mine sites. The need for and benefits associated with mine site reclamation are discussed below (and in further detail in Appendix B). Although not addressed in this section, a complete assessment of the benefits of agricultural land application is included in Appendix A.

Beginning in 2008, the WLSSD plans to increase the amount of biosolids applied to reclaimed mine sites, and in turn, decrease the amount applied to agricultural lands. Erosion and acid mine drainage are common problems at abandoned mine areas. Minnesota reclamation laws require mining companies to stabilize tailings, waste rock and surface overburden stockpiles with vegetation. Mined soils tend to be infertile and have poor water holding capacity—properties not favorable for plant growth. Typical remediation techniques include adding soil amendments such as lime and chemical fertilizer then planting grass, legume or trees. These practices often fail, primarily because of the poor physical, chemical and/or biological properties of the disturbed lands. According to the Minnesota Department of Natural Resources, "of all the organic amendments tested over the years (including municipal solid waste, yard waste and paper mill waste), biosolids seem to be the most practical and economical way to increase fertility on reclamation sites" (MDNR, 2004).

Recycling biosolids through land application at reclaimed mine rather than at agricultural sites creates benefits realized by the WLSSD, mine site managers and landowners, and the local community. The benefits, which are summarized in Table M-2, include: avoided commercial fertilizer costs, vegetation establishment, improved reliability of biosolids end use, greater land application rates, reduced demand for synthetic fertilizers, soil and water quality benefits, and carbon sequestration benefits.

Table M-2. Benefits Resulting from Increased Acreage of the Mine Land Reclamation Program.

Type of Benefit	Assessment Level	Beneficiaries
Avoided commercial fertilizer costs	Monetized	Mining company
Vegetation establishment benefits	Qualitative	Mining company
Improved reliability of biosolids end use	Qualitative	Agency
Greater land application rates	Quantified	Agency
Reduced demand for synthetic fertilizers	Qualitative	Local/regional
Soil and water quality benefits	Qualitative	Local
Carbon sequestration benefits	Qualitative	Global

Avoided Commercial Fertilizer Costs Traditional remediation techniques for reclaiming mine sites include stockpiling and reusing topsoil (which is often infertile), then applying lime and commercial fertilizers to initiate vegetative growth. In Minnesota, standard mine land reclamation practice employed by taconite mining companies for tailings revegetation is to incorporate DAP at a rate of 550 lbs per acre (0.275 tons/acre). The average price of DAP fertilizer is $303 per ton (USDA,[1] 2006). Applied at a rate of 0.275 tons per acre, the cost to reclamation site managers for DAP fertilizer is approximately $83 per acre. Depending on the prevailing soil and climatic conditions at the site, fertilizer application may be required one-time or for several years until a vegetative cover has been established.

The WLSSD delivers and incorporates biosolids free of charge, which offsets the costs of commercial fertilizers typically incurred by reclamation site managers (approximately $83 per acre per application). Mine site managers could realize a cost savings benefit of over $1,600 in savings on a 20-acre site requiring one-time application and $8,300 in savings for a 20-acre site requiring nutrient application for five growing seasons.

This case study assumes that the expansion of the mine land reclamation component of WLSSD's biosolids management program involves increasing mine site application by 200 acres (for a total of 500 acres per year, rather than 300 acres per year) beginning in 2010. This equates to annual cost savings in avoided commercial fertilizer costs (in excess of avoided commercial fertilizer costs associated with the current application to 300 acres of reclaimed mine lands per year) of approximately $16,600.[2] The present value of this benefit, over 20 years, is nearly $142,000.

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1. According to the USDA, fertilizer prices vary between approximately $215 and $416/ton; the prices of 7 additional types of fertilizer are listed in Appendix B.

2. Avoided fertilizer cost = $83/acre: $83/acre H 200 acres/year = $16,600/year.

Vegetation Establishment Benefits Successful establishment of permanent vegetation provides benefits to the mining company by reducing the amount of time and money spent on administering and managing sites after mining operations cease.

The State of Minnesota requires that mining companies initiate the establishment of vegetation during the first planting period following completion of mining. The area must be 90% covered with vegetation within three years of closure. SMR practices generally involve adding seed, fertilizer (e.g., diammonium phosphate fertilizer), and mulch to the disturbed soils. While results will vary from one site to the next depending on initial site conditions and the characteristics of the biosolids, numerous studies have shown biosolids applications to be more successful than commercial fertilizer in establishing vegetation on reclamation sites.

Studies conducted at taconite tailings basins in Minnesota indicate that percent vegetative cover and biomass generally increase as the rate of biosolids application increases. One year after site closure and biosolids application, the percent of vegetative cover was approximately 65% where 3.1 dt per acre were applied and 85% where 12.4 dt per acre were applied (as compared to 25% where SMR practices had been employed). After four years, over 30% more vegetative cover was established where biosolids had been applied than where SMR practices were used (MDNR, 2004). At a study site in British Columbia, average total biomass was approximately 3 times higher where biosolids had been applied than where chemical fertilizers had been used (Duynstee, 2002).

Depending on the type of mining conducted at the reclaimed site (e.g., strip mining for coal, taconite mining), rapidly establishing a vegetative cover may provide additional benefits to the mining company. These are described in further detail in Appendix B.

Improved Reliability of Biosolids End Use Land application of biosolids at reclaimed mine sites is not subject to as many restrictions as application at agricultural sites. Application at agricultural sites is limited by: nitrogen needs of the crops, cropping rotation cycles and harvesting schedules, and weather constraints (e.g., wet field conditions during spring snow-melt prohibits vehicle access). Increasing the acreage of the mine land reclamation program (and reducing the acreage of the agricultural land application program) will provide the WLSSD with a more reliable, less restrictive, year-round biosolids management option. This will reduce the amount of time the WLSSD spends coordinating with end-users and reduces the risk of running out of storage space during winter months.

Greater Land Application Rates Use of biosolids for restoration purposes (generally a one-time application) may be exempt from additional regulations that apply to agricultural application. Biosolids application rates at reclamation sites are often higher than the agronomic rate (which limits the amount of biosolids that may be applied to agricultural soils). According to the U.S. EPA, a relatively large amount of biosolids must be applied to disturbed lands to provide sufficient organic matter and nutrients for effective establishment of vegetation (U.S. EPA, 1995). Successful application rates ranging from 3 to 400 dt per acre have been reported, but the typical rate is approximately 50 dt per acre per year (U.S. EPA, 1995). Biosolids application rates on agricultural lands are lower, ranging from 1 to 30 dt per acre per year (U.S. EPA, 1995).

WLSSD applies roughly 8.5 dt per acre to reclaimed mine sites to establish the initial vegetation on the tailings basin. To meet the reclamation cover requirements, an additional 4.3 dt per acre is applied three or four years into the reclamation process. The reclamation rate for biosolids in Minnesota was established and approved by the Minnesota Department of Natural

Resources. WLSSD generally applies biosolids to agricultural soils at rates of 100 lbs of nitrogen per acre per year (roughly 4.3 dt per acre per year).

The average WLSSD land application site is 20 acres. Applying biosolids at a rate of 8.5 dt per acre, the WLSSD is able to put 170 dt of biosolids to beneficial use at a single average-sized reclamation site (as compared to 86 dt at an average-sized agricultural site). Using biosolids at reclaimed mine lands allows the WLSSD to land apply roughly two times more biosolids per acre than would be permitted at most agricultural sites.

This case study assumes that the expansion of the mine land reclamation component of WLSSD's biosolids management program involves increasing annual mine site application by 200 acres (or a total of 500 acres per year) beginning in 2010. This equates to the potential for an increase in total volume of land applied biosolids of approximately 840 dt per year[3] (this is roughly 90% of the projected total biosolids production for the year 2010).

As local regulations or public perception issues arise in the future (e.g., due to concerns related to odors or pollutant levels), an agency's number of eligible/permitted acres for land application may decrease. By enabling the WLSSD to put more biosolids to beneficial use per acre, increasing mine land reclamation (and decreasing agricultural land application) will reduce the risk of encountering a "disposal crisis."

Reduced Demand for Synthetic Fertilizers The nutrient and organic matter content of biosolids enables mining companies to utilize biosolids at reclamation sites in lieu of synthetic fertilizers. By reducing demand for (and use of) chemical fertilizers, mine land application of biosolids indirectly reduces demands on chemical feedstocks as well as the adverse impacts associated with synthetic chemical production, storage and transport.

Soil and Water Quality Benefits Land application of biosolids at reclaimed mine sties reduces erosion potential, both through improved soil quality and increased vegetative cover. Following biosolids application, the soil is better aerated allowing water to infiltrate the soil rather than eroding off the soil surface. The nutrient content in biosolids enhances plant growth and the organic matter content in biosolids increases cation exchange capacity (which improves the soil's ability to retain nutrients). These features help facilitate more rapid re-vegetation at reclamation sites, which reduces the potential for windblown dust and erosion (and the subsequent sediment loading to nearby waterbodies).

Acid mine drainage (drainage of water that has a particularly low pH as a result of contact with mine spoils), is a serious problem at many mine sites throughout North America, including several in Minnesota. Although no comprehensive study has been conducted, monitoring data collected in Pennsylvania suggests that acid mine drainage is significantly reduced at sites where biosolids have been applied (Toffey, 2003).

Carbon Sequestration Benefits Reclaimed mine sites offer a potential carbon sink that may help mitigate a portion of GHG emissions. Carbon (C) sequestration refers to the uptake and storage of carbon. Carbon may be sequestered in above- or below-ground biomass (e.g., trees, grasses, or other vegetation) as well as in the soils. Sequestration rates vary depending on the geographic location of the site as well as the end use for the land (e.g., pasture, forest, or cropland) (Sperow,

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3. Increased mine site application: 8.5 dt/acre H 200 acres/year = 1,700 dt/year. Decrease in agricultural application: 4.3 dt/acre H 200 acres/year = 860 dt/year. Difference: 1,700 – 860 = 840 dt/year.

2006). According to the IPCC, soil accumulation of carbon on reclaimed mine sites ranges from 0.04 to 2.8 metric tons of carbon per acre per year; whereas for cropland soils, that range is from 0.12 to 0.45 tons of C per acre (IPCC, 1998). Additional estimates of soil accumulation of carbon according to land use type are presented in Appendix B.

In this case study, it is assumed that the expansion of the mine land reclamation component of WLSSD's biosolids management program involves increasing annual mine site application by 200 acres (or a total of 500 acres per year) beginning in 2010. This could potentially lead to a decrease in soil carbon accumulation of as much as 82 tons of C per acre per year or an increase in soil accumulation of as much as carbon of 536 tons of C per acre per year. Due to the uncertainty associated with determining the amount of carbon sequestered per acre of land, these values are presented simply to provide an illustration of the potential for mitigating GHG emissions through the application of biosolids at mine sites.

M.7 Identify and Assess Key Costs and Risks

M.7.1 Costs Associated with a Transition from Class B Biosolids Production to Class A

The WLSSD needs to implement new biosolids treatment technology to begin producing a Class A biosolids product. Numerous technologies are available for treating biosolids to a Class A standard. Although WLSSD has not yet selected the specific technology that they will adopt, the District has estimated both the capital costs and incremental increases to their O&M costs that can be reasonably anticipated as a result of transitioning from Class B production to Class A. These costs, as projected through 2024, are summarized in Table M-3.

Table M-3. Costs Associated with Transitioning from Class B Biosolids Production to Class A.[a]

	Total Present Value[a] (2005$)		
	Class B[b] Treatment	Class A[c] Treatment	Increase in Cost due to Change from Class B to Class A
Capital investments	$782,440	$3,450,566	$2,668,126
Total O&M	$18,922,098	$25,254,889	$6,332,791
Total	**$19,704,538**	**$28,705,455**	**$9,009,917**

[a]Assuming a 5% discount rate, over the course of 20 years (from 2005 to 2024).
[b]Adapted from Table 9, WLSSD Biosolids Master Plan Costs (WLSSD, 2006a).
[c]Adapted from "Biosolids Sustainability Master Plan: Worksheet-10 Year Capital Plan" (WLSSD, 2006a).

M.7.2 Costs Associated with Increased Land Application at Reclaimed Mine Sites (and Reduced Land Application at Agricultural Sites)

M.7.2.1 Increased Haul Distance to Land Application Sites

Expanding the mine land reclamation component of WLSSD's biosolids management program will likely necessitate delivering biosolids to sites outside of the WLSSD's current 20-mile delivery radius. New equipment (a new trailer and a new semi-tractor) will be needed and operating costs will increase (predominantly due to the additional fuel and labor requirements). Table M-4 summarizes the expected incremental costs due to an increase in haul distance from the current average of 40 miles round-trip to either 60 miles round-trip or 80 miles round-trip. The WLSSD expects to incur these increases in costs if there is an increase in haul distance for land application of biosolids, irrespective of the type of biosolids produced

Table M-4. Costs Associated with Increasing Distance to Land Application Sites (Compared to Average Haul Distance, in 2005, of 40 Miles Round-Trip).

	Total Present Value[a] (2005$)	
	Increase to 60 Miles Round-Trip	**Increase to 80 Miles Round-Trip**
Capital investments	$205,593	$420,112
Total O&M	$2,461,312	$3,271,234
Total	**$2,666,905**	**$3,691,345**

[a]Assumes a 5% discount rate, over the course of 20 years (from 2006 to 2024).

(i.e., Class B or Class A). However, it is worth noting, that production of a Class A product (instead of Class B) does have the potential to reduce the likelihood that the WLSSD will have to seek out land application sites located at greater distances (i.e., 60 and 80 miles round-trip) from the treatment facility.

M.7.2.2 Increased Fertilizer Costs

Local farmers that had previously received biosolids from the WLSSD may need to purchase commercial fertilizers if the WLSSD reduces the acreage of the agricultural land application program. Most agricultural producers in the Duluth region use urea as the commercial fertilizer source. The cost of urea is $400/ton for a 45% nitrogen product; $0.44/lb of N. Assuming an application rate of 100 lbs MANA per acre per year the agricultural end-users pay $44/acre for urea (CH2M Hill, 2006).

The number of acres comprising the agricultural land application component of the WLSSD's biosolids management program varies by year, but until the year 2006, ranged from between 1,800 acres and 2,500 acres. Although the total amount of biosolids produced by WLSSD is expected to increase each year (most likely by approximately 10% by 2010), the total amount of biosolids applied at agricultural sites is expected to decrease (due to the expansion of the mine site reclamation program) by 41%[4] by 2010. As a conservative estimate, it is assumed that the number of agricultural acres receiving biosolids is reduced by 630 acres (approximately 35%) in 2010.[5] In 2010, the cost to farmers having to purchase urea (instead of using free biosolids) is expected to be roughly $27,700. Assuming the amount of agricultural land requiring urea as a nutrient source is 630 acres each year between 2010 and 2015 and that the price of urea remains at $44 per acre, the present value of urea purchases by farmers that no longer receive biosolids is expected to total $115,750.[6]

M.7.2.3 Potential Risks

There are inevitably going to be potential risks associated with the production, transport, and/or end use of biosolids. None of the future changes that WLSSD is considering for their biosolids management program (production of a Class A product instead of Class B, diversifying

4. In 2005, 85% of all biosolids produced were land applied to agricultural sites, but in 2010 only 50% of all biosolids will go to agricultural sites (i.e., a 41% decrease).

5. Calculation: using the low end of the range of agricultural land used for land application (1,800 acres), a 35% reduction equates to a reduction of 630 acres (whereas had this been applied to the high end of the range of agricultural land used for land application, the reduction would be 875 acres).

6. The total cost over 6 years (2010-2015), assuming a 5% discount rate.

end-use markets, and/or altering their land application program to include more mine land reclamation) are likely to introduce any new risks. While several of the risks posed by the WLSSD's current biosolids management practices may still exist despite these changes, one of the reasons the WLSSD is working to create a more sustainable program is to mitigate some of these risks.

Transition from Class B Biosolids Production to Class A No risks from producing a Class A biosolids product instead of a Class B product have been identified.

Increasing Land Application at Reclaimed Mine Sites Issues related to land application of biosolids (both at agricultural sites and reclamation sites) include potential bans or limits on application and/or transportation of biosolids (this may apply to either Class B or Class A biosolids), nuisances to the public (odors and traffic), as well as environmental and human health risks associated with possible contaminants and metals in biosolids.

Although federal regulations (the Part 503 rule) set standards for pathogen reduction, chemical limits, and management practices, biosolids are nonetheless a product of household, commercial and industrial wastewaters, which contain contaminants. These contaminants include pathogens (e.g., viruses and bacteria), pharmaceuticals, and metals. Applying biosolids to mine lands or agricultural lands may pose risks (perceived or real) to human health. Since Class A biosolids require 100% pathogen reduction, risk of pathogen transmission is reduced through the switch to production of a Class A product. Transmission of pharmaceuticals and metals may remain a risk (although whether these risks are real or perceived is still debated by researchers and scientists).

The odors associated with biosolids can be a nuisance to neighbors, particularly during the unloading and application process. These may prompt complaints from affected parties, motivated by the unpleasant smell itself and/or by a perceived (and perhaps real) mental association of the odors with the potential to pose health risk. Odors and associated concerns can impose considerable loss of welfare on the impacted individuals. Odors can create political pressure that may ultimately preclude or limit the utility's ability to continue to apply biosolids at the sites (e.g., by leading to bans on some land application options and/or sites).

Risks and concerns associated with land application in general, and land application at mine sites in particular, are discussed in further detail in Appendix B.

M.8 Distributional Issues: Identification of Key Beneficiaries and Cost-Bearers

The WLSSD's biosolids management program not only affects the agency, but could lead to benefits accrued by mine site managers and costs incurred by local farmers. The biosolids management program could create both benefits for and risks to neighbors, the environment, and society as a whole. Table M-5 summarizes the parties potentially affected by 1) the transition from Class B production to Class A, and 2) a decrease in agricultural land application of biosolids in favor of an increase in mine site reclamation.

Table M-5. Affected Parties.

Affected Party	Benefits	Risks/Concerns	Costs
Transition from Class B production to Class A (increase pathogen standards)			
WLSSD	Reduced permitting requirements Reduced likelihood of public opposition Increased marketability		Capital investment requirements Increased O&M costs
Neighbors, environment, and society as a whole	Improved environmental conditions		
Expand mine land reclamation program (decrease land application at agricultural sites)			
WLSSD	Improved reliability of biosolids end use Greater land application rates		Possible increased labor and fuel requirements (related to transport to application sites)
Mine site managers/ land owners	Avoided commercial fertilizer costs Vegetation establishment benefits		
Neighbors		Odors Traffic	
Local farmers			Increased costs for urea fertilizer (for biosolids application to agricultural lands is reduced)
Environment and society as a whole	Reduced demand for synthetic fertilizers Soil and water quality benefits Carbon sequestration benefits	Potential public health and environmental risks (real and/or perceived), associated with metals and other pollutants in the soil or nearby waters.	

M.9 Public Outreach and Communication

Part of the WLSSD's efforts to improve the biosolids management program involves working with individuals and organizations outside of the District. These efforts include: public outreach programs, collaborative research with universities, and partnerships with new end-users.

- **Public outreach:** WLSSD staff attends and presents biosolids information at county and township meetings, they produce brochures, semi-annual newsletters and factsheets (all of which are available through their Website), and they also conduct tours of the treatment plant and hold field days at local farms.
- **Collaboration with universities:** WLSSD is working with Bucknell University on measuring and controlling odors. The WLSSD is also working with researchers at the University of Minnesota to determine mineralization rates of nitrogen and phosphorous in WLSSD's biosolids.
- **Partnerships with new end-users:** As part of their efforts to increase market diversity, the WLSSD has been developing relation ships with local sod farmers, companies throughout the United States that would be willing to purchase biomass, and member of the local forestry industry.

M.10 Comparing Benefits to Costs

M.10.1 Summary of Findings: Transitioning from Class B Biosolids Production to Class A

The benefits that could accrue if the WLSSD increases the pathogen standards at the treatment plant (i.e., produces Class A biosolids instead of Class B) include: reduced permitting requirements, reduced likelihood of public opposition, increased marketability, and improved environmental conditions. A relatively large capital investment would be required for the new treatment technology and annual O&M costs would likely increase. Although it was not possible at this time to monetize the benefits of reduced public opposition and increased marketability, these benefits greatly enhance the WLSSD's ability to ensure continuous product distribution (a key element of a sustainable biosolids management program as defined by the agency). No risks resulting from the transition from Class B to Class A biosolids production have been identified.

A summary of the benefits and costs of this potential change to the WLSSD biosolids management program is included in Table M-6.

Table M-6. Benefit-Cost Comparison (Transition from Class B Production to Class A).

		Total Present Value[a] (2005$)
Quantifiable costs		
Capital investments and increased O&M		$9,009,917
	Qualitative indicator[b]	
Qualitative benefits		
Reduced permitting requirements	+	
Reduced likelihood of public opposition	++	
Increased marketability	++	
Improved environmental conditions	+	

[a]Evaluated using a 5% discount rate, over a 20 year time horizon.
[b]Magnitude of effect on net benefits.
+ = Likely to increase net benefits relative to quantified estimates.
++ = Likely to increase net benefits significantly.

M.10.2 Summary of Findings: Increased Land Application at Reclaimed Mine Sites

The benefits that could accrue if the WLSSD increases the amount of biosolids land applied at reclaimed mine sites (and decreases land application at agricultural sites) include: avoided commercial fertilizer costs, greater land application rates, improved vegetation establishment, improved biosolids end-use reliability, reduced demand for synthetic fertilizers, soil and water quality benefits, and increased carbon sequestration. Local farmers that once relied on biosolids for nutrients may incur costs associated with purchasing urea when biosolids are no longer available to them. A relatively large increase in annual operations and maintenance costs is expected if the haul distances to land application sites increases, which is likely since many of the reclamation sites are further than the currently utilized agricultural sites. Although it was not possible to monetize the benefits of greater land application rates or improved reliability of biosolids end use, these benefits would improve the sustainability of WLSSD's biosolids program by helping the agency ensure continuous product distribution.

A summary of the benefits and costs/risks of the expansion of the mine site reclamation program is included in Table M-7.

Table M-7. Benefit-Cost Comparison (Increased Land Application at Reclaimed Mine Sites).

	Quantified	Total Present Value[a] (2005$)
Quantifiable costs and risks		
Increased haul distance to land application sites (from 40 miles to 80 miles, round-trip)		$3,564,711
Urea fertilizer costs (due to the reduction in biosolids available to farmers)		$236,711
Total cost		*$3,801,422*
Quantifiable benefits		
Avoided commercial fertilizer costs		$141,745
Greater land application rates	840 dt/acre/year	
Total monetized benefits		*$141,745*
Total monetized net benefits		($3,659,669)
Qualitative benefits	**Qualitative indicator[b]**	
Vegetation establishment benefits	++	
Improved reliability of biosolids end use	++	
Reduced demand for synthetic fertilizers	+	
Soil and water quality benefits	+	
Carbon sequestration benefits	+	

[a]Evaluated using a 5% discount rate, over a 20 year time horizon.
[b]Magnitude of effect on net benefits.
+ = Likely to increase net benefits relative to quantified estimates.
++ = Likely to increase net benefits significantly.

While the current landscape for biosolids management appears to be continually evolving and future opportunities, regulations, and roadblocks are uncertain, the fact that biosolids will continue to happen is certain. Although there are costs associated with the alternatives to WLSSD's current biosolids management program (specifically considering a transition to Class A production and/or a transition to more land application at mine sites), this case study has illustrated the fact that there is also a range of potential benefits, some of which are expected to enhance the stability of their biosolids program.

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WASTEWATER UTILITY

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Montgomery Water Works & Sanitary Sewer Board

Alaska
Anchorage Water & Wastewater Utility

Arizona
Glendale, City of, Utilities Department
Mesa, City of
Peoria, City of
Phoenix Water Services Dept.
Pima County Wastewater Management
Safford, City of

Arkansas
Little Rock Wastewater Utility

California
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Corona, City of
Crestline Sanitation District
Delta Diablo Sanitation District
Dublin San Ramon Services District
East Bay Dischargers Authority
East Bay Municipal Utility District
Eastern Municipal Water District
El Dorado Irrigation District
Fairfield-Suisun Sewer District
Fresno Department of Public Utilities
Inland Empire Utilities Agency
Irvine Ranch Water District
Las Virgenes Municipal Water District
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Los Angeles, City of
Los Angeles County, Sanitation Districts of
Napa Sanitation District
Orange County Sanitation District
Palo Alto, City of
Riverside, City of
Sacramento Regional County Sanitation District
San Diego Metropolitan Wastewater Department, City of
San Francisco, City & County of
San Jose, City of
Santa Barbara, City of
Santa Cruz, City of
Santa Rosa, City of
South Bayside System Authority
South Coast Water District
South Orange County Wastewater Authority
Stege Sanitary District
Sunnyvale, City of
Union Sanitary District
West Valley Sanitation District

Colorado
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Boulder, City of
Greeley, City of
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Metro Wastewater Reclamation District, Denver

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Stamford, City of

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District of Columbia Water & Sewer Authority

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Miami-Dade Water & Sewer Authority
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