Appendix A:

Illustrative Cost-Benefit Analysis of Pipeline Mapping

Appendix A: Cost-Benefit Analysis of Pipeline Mapping
Executive Summary

To illustrate, test, and refine the OPS cost-benefit framework, the Joint OPS/Stakeholder Workgroup conducted a cost-benefit analysis of a recent OPS alternative. Because extensive cost data are available that describe a voluntary pipeline mapping program, the Workgroup chose to analyze this alternative. In addition, the Workgroup considered a hypothetical mapping mandate as an alternative to the voluntary approach. The objective of this case study is to set the framework into action and to thereby identify common challenges inherent to assessing OPS alternatives. Because the scope of this case study analysis is thus limited, benefits were assessed qualitatively but were not quantified. With "lessons learned" from the case study in hand, OPS may identify some standard approaches for improving the quality and effectiveness of future OPS analyses.

Analytical Results

Step 1: Identifying the Target Problem

The target problem addressed by the voluntary pipeline mapping alternative is as follows: Congress, in the 1992 Pipeline Safety Act, requested that OPS create a system of accurate, standardized, and widely accessible pipeline mapping data that "...enhance the pipeline communication system and improve decisionmaking about the national pipeline system."[1] The Workgroup assumes that Congressional intent is to reduce environmental and/or safety risks to the pipeline system by improving this data. Under this directive, OPS formed the Mapping Quality Action Team (MQAT) to develop various regulatory and non-regulatory alternatives that address the target problem. The Workgroup evaluated each alternative's uniqueness, reasonableness, and feasibility of implementation, and decided to include the following alternatives in the analysis: (1) the voluntary pipeline mapping program being developed by OPS, and (2) a hypothetical mapping mandate requiring pipeline operators to submit more extensive data.

Steps 2 and 3: Identifying Available Alternatives and Performing a Screen of Alternatives

Step 4: Defining the Baseline(s)

The Workgroup determined that economic and regulatory conditions in the baseline may affect the incremental impacts of pipeline mapping somewhat, but changes in relevant mapping technologies, although uncertain, are likely to be the most influential component of the baseline. The Workgroup assume that by 2015, fifty to seventy percent of total pipeline mileage will be mapped digitally in the baseline case, depending on the ability of operators to make investments in mapping software and data conversion.

Step 5: Defining the Scope and Parameters of the Analysis

The majority of government and industry costs of the pipeline mapping will be realized from 1995 to 2015. The timing of benefits is likely to extend to and possibly even beyond 2015. However, because benefits beyond 2015 are highly uncertain, the time period included in this analysis is 1995 to 2015.

Costs of Pipeline Mapping

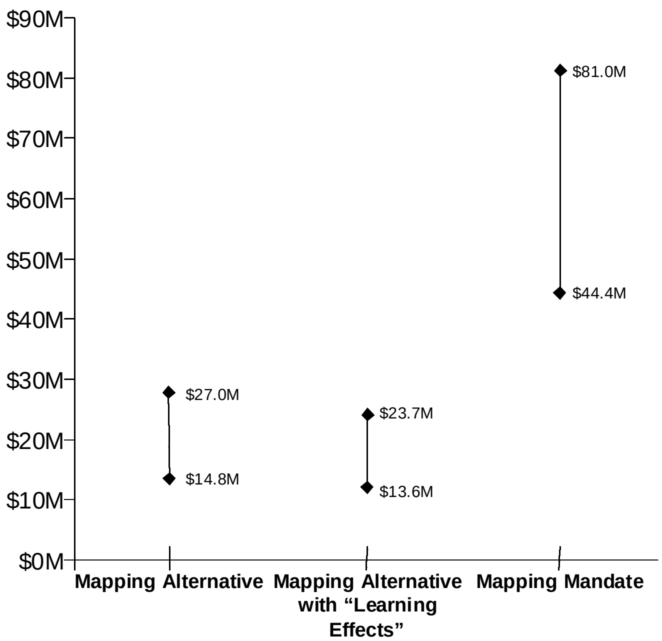
Step 6: Defining and Analyzing Costs

Categories of direct costs addressed in the assessment include capital and operation and maintenance costs incurred by private firms, OPS, and government agencies. Significant indirect costs, such as consumer surplus losses caused by price changes, are unlikely to result from pipeline mapping activities. As shown in Exhibit A-1, based on analysis of operator responses to an OPS mapping cost survey and OPS estimates of government costs, the present value of total costs of the mapping alternative is estimated to range from $14.8 million to $27.0 million (1995 dollars). This range is derived by conducting sensitivity analysis on low and high values provided for discount rates and industry mapping costs.

[1] *Pipeline Safety Act of 1992*. P.L. 102-508, 1992.

If modifications to the mapping data standards and "learning" effects reduce industry costs by twenty percent, the present value of total costs would then range from $13.6 million to $23.7 million (1995 dollars). Industry and OPS estimate that costs to map additional data points required by a mapping mandate would be at least three times those of the mapping alternative, or $44.4 million to $81.0 million (1995 dollars). This range is derived by conducting sensitivity analysis on low and high values provided for discount rates and industry mapping costs.

Exhibit A-1
Summary of Mapping Costs (millions of dollars)



Benefits of Pipeline Mapping

While there is a great deal of uncertainty in forecasting how mapping data will be used in decisionmaking, the following benefits may be created by improvements to pipeline mapping data: improved emergency response data, improved infrastructure planning, improved government oversight, improved emergency response, improved risk assessment, improved performance by one-call systems, improved business operations, and enhanced public confidence. The two major categories of mapping benefits, direct and indirect, are described below:

- Direct benefits will be realized in the categories of emergency response planning and infrastructure planning, government oversight capabilities, and improved response to public inquiries. These benefits are certain to be positive. Because they depend upon the extent that mapping data are used to reduce risks, however, their magnitude is uncertain.

Step 6: Defining and Analyzing Benefits

- Indirect benefits are contingent upon the occurrence of a variety of events, such as the extent and nature of improvements to mapping data. Indirect benefits could include improvements to the following activities: emergency response activities, one-call system activities, and pipeline business operations. Further research would be required to ascertain whether and how much mapping data could be used to improve these activities.

Because of the resources required and challenges inherent to quantifying both direct and indirect benefits, we address these potential benefits qualitatively in this analysis.

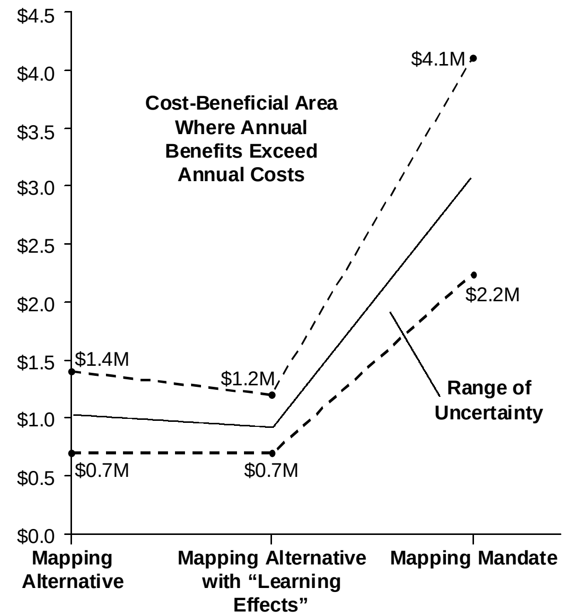
Summary of Costs and Benefits

Step 7: Comparing Costs and Benefits

As described above, the benefits of pipeline mapping are both highly uncertain and assessed only in qualitative terms, so at first glance, the results may not seem to provide OPS with a definitive sense of whether mapping alternatives (i.e., an alternative or mandate) meet a strict cost-benefit test. Although this assessment quantifies only costs, it still provides OPS and industry valuable information describing the potential magnitude of the difference between costs and benefits. As shown in Exhibit A-2, if OPS makes a conservative assumption that the upper-end of the cost ranges associated with each mapping alternative represents a lower bound for the minimum benefits needed to make the mapping program cost-beneficial, then the present value of total benefits would need to equal, at minimum, from $1.2 million to $4.1 million per year (depending on the chosen alternative) for each of the twenty years of this analysis. The shaded area shows the range of uncertainty around this result. Using the low-end of the cost ranges associated with the various alternatives, the cost-beneficial area extends from $0.7 million per year to $2.2 million per year. Given a less conservative range of discount rates (i.e., higher), the differential between benefits and costs of the mapping program is smaller.

Although benefits are not quantified, OPS can use this approach to describe the relationship between costs and benefits, expressed in annual present value cash flows, to get a sense of the mix of benefits and costs that would be required to satisfy a cost-beneficial criteria. As an example, given DOT's value-of-statistical-life of $2.7 million, the low end of the annual cost range ($07 million to $1.2 million) in this example would be met with approximately one statistical life saved per year.

Exhibit A-2
Cost-Benefit Summary of Pipeline Mapping Alternatives
(millions of dollars per year, in present value)



Key Uncertainties

The following are uncertainties that characterize the quantitative assessment of mapping costs:

Step 8: Interpreting Cost-Benefit Results

- The sample of operators and pipeline mileage used to survey mapping costs is small and probably does not reflect the full range of the actual variability in costs to be incurred by operators nationally. We do not, however, have enough information to discern whether estimation errors result from use of this small sample.

- Additionally, the cost survey may not represent key segments of operators who may be affected by the mapping alternative (i.e., operators who may incur high costs when converting from paper to digital systems). This source of uncertainty probably results in an underestimation of total costs.

- Finally, this analysis assumes all costs are linear (i.e., the same cost per mile is applied to all of an operator's mileage). Some operators have noted that, when mapping out their entire system, they may experience some cost non-linearities (e.g., economies or diseconomies of scale). It is unclear whether this will have a positive or negative influence on total costs.

Below we describe uncertainties associated with the qualitative estimate of mapping benefits:

- Benefits are uncertain because it is unclear whether mapping data will be significantly improved, and whether users of mapping data (e.g., pipeline operators, one-call agencies, and public agencies) will improve decisionmaking by using these data.

- Additional uncertainty arises because it is unclear to what extent improved decisionmaking would in turn reduce the various components of pipeline risk. These components include: risks inherent due to the physical properties of pipelines; risks associated with physical environments surrounding pipelines; and risks associated with the effectiveness of pipeline management. Some categories of benefits will be realized only if mapping data are used to effectively mitigate some or all of these risk components.

"Lessons Learned"

The following "lessons learned" reflect observations made about possible implications of the application of the OPS cost-benefit framework to this case study for conducting OPS analyses in the future:

Step 8: Using and Interpreting Cost-Benefit Results

- **Use of survey data:** Cost results from this analysis indicate that it may be worthwhile for OPS to conduct additional research to explore the nature of variability across various segments of the national pipeline system, including key differences among operator groups. This research may provide OPS with data that can be used to refine future cost estimates.
- **Quantitative assessment of OPS alternatives:** Developing quantitative assessments of future OPS alternatives such as pipeline mapping, many of which will use a risk-based approach to managing pipeline safety, may be challenging and very resource-intensive. Such assessments will require sophisticated probabilistic modeling (e.g., failure analysis, risk engineering).
- **Value of collaborative approach:** The process of conducting this cost-benefit analysis of the mapping alternative clearly demonstrates the value of collaborative stakeholder teamwork, particularly during the steps of defining target problems, identifying alternative alternatives to address problems, and contributing to cost-benefit analysis of alternatives. Numerous insights about the value of stakeholder teamwork can be found in two reports produced by the mapping teams.[2]
- **Value of key process steps:** Throughout this case study, the Workgroup identified the first process step of *defining the target problem* as particularly important, since the rest of the analysis stems directly from this step and from the subsequent step of identifying alternatives chosen to address the target problem.

[2] The first Joint Government/Industry Pipeline Mapping Quality Action Team (MQAT I) convened to define the mapping problem in detail and to identify mapping alternatives. The second Joint Government/Industry Mapping Quality Action Team (MQAT II) developed the data standards for paper and electronic pipeline mapping submissions, among other tasks.

Appendix A:
Cost-Benefit Analysis of Pipeline Mapping

Background

The goal of this Appendix is to illustrate the process of conducting a cost-benefit analysis of a proposed OPS alternative. Each of the major elements of this process are described in detail in Section V of this report. To illuminate key elements of the process, we assess an existing OPS alternative for which data are readily available, and an alternative to the alternative. Specifically, we consider the voluntary pipeline mapping alternative presently being developed by OPS, and a pipeline mapping mandate representing an alternative to that alternative. The objective of this case study is to identify common challenges and potential difficulties inherent in conducting cost-benefit analysis of OPS alternatives. In doing so, our intent is to improve future OPS analyses, rather than to provide a full quantitative assessment of the costs and benefits of the pipeline mapping program.

The remainder of this Appendix is divided into sections that parallel the cost-benefit process steps presented in Section V of this report. The first part of the Appendix describes the results of our efforts to identify the target problem, identify alternatives, scope the analysis, and to establish a baseline scenario. The final half of the Appendix describes the costs and benefits of the mapping alternative, and compares the results of these assessments. In the final section, we discuss the value of the process of conducting this type of assessment.

The Pipeline Mapping Alternative

The end-product of the pipeline mapping alternative will be the National Pipeline Mapping System. OPS' Internet site (http://ops.dot.gov) describes the features of this system:

"The system, when complete, will show the location and selected attributes of the major natural gas and hazardous liquid pipelines and liquefied natural gas facilities operating in the U.S. OPS will add additional data layers into the system, including layers on population, unusually sensitive areas, natural disaster probability and high consequence areas, hydrography, and transportation networks. OPS will use the system to depict pipelines in relation to the public and the environment, and to work with other government agencies and industry during an incident.

Operator participation is voluntary. This voluntary participation hopes to encourage industry to upgrade the quality of pipeline data in a manner that is consistent with other business needs."

The Target Problem

In 1995, representatives from OPS, other federal and state agencies, and the pipeline and mapping industries formed an action team to respond to the requirements of the 1992 Pipeline Safety Act. While the Act did not explicitly state the target problem addressed by the mapping requirement, the Workgroup assumes that Congressional intent was to reduce safety and/or environmental risks to pipelines by improving data that describe the national pipeline system. The Act called on OPS to adopt rules requiring pipeline operators to identify facilities located in unusually sensitive environments and high-density population areas, to maintain maps and records detailing that information, and to provide those maps and records to federal and state officials upon request. The action team, known as the Mapping Quality Action Team (MQAT), developed an approach to creating a reasonably accurate mapping system for thousands of miles of natural gas and hazardous liquid transmission pipelines in the U.S. that could also be shared with other federal and state agencies, industry, and the public.

After evaluating the shortcomings of existing systems and various pipeline mapping alternatives, MQAT decided on a voluntary approach under which pipeline operators, OPS, and state agencies would cooperatively provide standardized pipeline locational data. The goal of this voluntary approach is summarized by the joint OPS/Stakeholder Workgroup on cost-benefit analysis (the Workgroup) as follows:

> *The mapping requirement requires pipeline operators to locate their pipelines in the U.S. to enhance the pipeline communication system and to improve decisionmaking about the national pipeline system.*[3]

[3] Based on discussions of the Joint OPS/Stakeholder Workgroup, conducted at the Gas Research Institute; Washington, DC; March 31, 1998.

The target problem assumed above exists because there is no single pipeline data source that provides information which: (1) accurately describes the location of all major pipelines in the U.S.; (2) is referenced in a standard way; and (3) is widely accessible and available to the public. Results of surveys done by MQAT show that neither the pipeline industry, OPS, the mapping industry nor government agencies possess a complete set of standardized and comprehensive maps for the entire U.S. pipeline infrastructure. As a result, entities that use pipeline location information in their decisionmaking, including pipeline operators, government agencies, 'one-call' systems, and the public, may lack complete information on which to base decisions that could mitigate safety and / or environmental pipeline risks. The needs of these user groups vary greatly. For example, the pipeline industry uses pipeline maps to meet business and operating needs while government uses pipeline maps for planning, regulatory oversight, and assessment. Each user group, however, makes decisions that rely upon the accuracy, accessibility, and overall quality of locational data. The lack of a national mapping system has impacts on each of these user groups that could be mitigated by creating such a system.

Alternative Approaches to Pipeline Mapping

Before deciding on the voluntary mapping alternative and the accompanying standards, the MQAT evaluated many other alternatives. As described in Section V, an important step in the cost-benefit process is the identification and condition of alternatives that have distinct costs and / or benefits. MQAT screened out alternatives that lacked political, economic, or technical feasibility, or that were clearly not cost-beneficial.[4] Exhibit A-3 describes each proposed alternative for creating a national pipeline mapping system.

Exhibit A-3
Pipeline Mapping Alternatives

Alternative 1:	OPS issues guidance to operators.
Alternative 2:	OPS issues regulation requiring operator compliance.
Alternative 3:	OPS anticipates that the marketplace develops mapping products and systems.
Alternative 4:	OPS forms partnership with industry to address issues through: (i) trade association standards or guidance, or (ii) a voluntary initiative.
Alternative 5:	OPS anticipates states will develop their own systems.
Alternative 6:	OPS anticipates that the U.S. Geological Survey will address the target problem via quad sheet updates and digital line graphs (DLGs).
Alternative 7:	OPS forms long-term project to develop national mapping system by updating information as it becomes available via current regulatory requirements outside of OPS (e.g., FERC or state requirements).
Alternative 8:	OPS anticipates that various one-call systems address the problem by enhancing their databases.
Alternative 9:	OPS anticipates that other federal agencies develop and provide mapping information (e.g., Department of Energy).

We determined that this case study should clearly consider the alternative that OPS and industry are currently pursuing — the voluntary pipeline mapping alternative (Alternative 4(ii)). After reviewing each of the other alternatives, we determined that some of these alternatives are not particularly distinct from the mapping alternative in terms of their requirements, and are thus unlikely to generate benefits and costs that are distinct from Alternative 4(ii). These alternatives are described in more detail below:

- **Alternative 7:** Participants in the Workgroup felt that this alternative, forming a long-term project with OPS to develop the national mapping system as more information becomes available, would actually be a component of the long-term strategy for the voluntary alternative.

- **Alternative 4(i):** MQAT and the Workgroup determined that these alternatives are not substantively different from the requirements of the voluntary pipeline mapping alternative.

Other alternatives on the list were likely to be addressed by characterizing the baseline scenario, i.e., the conditions and requirements of these alternatives would take place in the

[4] While it may seem inappropriate to make a judgment as to the net costs of any alternative at such an early phase of the assessment, in many cases price analyses and other information will allow for such determinations. These are sometimes referred to more formally as *preliminary assessments*.

absence of either a regulation or a voluntary alternative focused on improving pipeline location information. These include Alternatives 3, 5, 6, 8, and 9. Thus, in our base case, we assume that state agencies, USGS, other federal agencies, and one-call systems are all currently pursuing some mapping activities that include pipelines and would continue to do so in the future.

In addition, it is not likely that OPS would pursue and implement some of the listed alternatives. For example, under Alternative 1, OPS would issue guidance to operators to encourage voluntary submission of pipeline mapping information. Because voluntary guidance typically results in a lower rate of participation than under the type of program under development in Alternative 4(ii), it is unlikely that OPS would implement this alternative.

Prior to selection of the voluntary alternative, Alternative 2 (OPS issues a regulation requiring operator compliance) was considered a feasible alternative due to the Congressional mandate in the Pipeline Safety Act of 1992. A stringent mandate that requires pipeline operators to provide other data about their systems in addition to locational data would definitely result in different benefits and costs than a voluntary alternative. The mapping mandate we envisioned for this case study would require operators to provide data describing pipeline location (as required by the alternative), as well as data describing pipeline age, pipeline material, diameter of pipeline, and valve location, for all operators' transmission and larger distribution pipelines.

At the outset of the analysis of this case study, MQAT had already devoted much effort into developing and screening various alternatives. This may not be the case for other OPS alternatives, so the step of identifying and screening alternatives may require more development and resources for future analyses. In general, however, the cooperative assessment of these alternatives performed by both MQAT and the Workgroup developing this report in the pipeline mapping case is representative of how OPS will likely conduct this process step in the future.

The Mapping Baseline

The goal of a cost-benefit analysis is to estimate and compare the incremental costs and benefits of an alternative. To do this, we first must define the baseline scenario, or "the world without the pipeline mapping alternative (or pipeline mapping mandate)." Because the incremental impacts of these actions are measured relative to conditions that would exist in the baseline, it is important to develop an understanding of these baseline conditions.

Describing the baseline case for the pipeline mapping alternative is relatively complex. This baseline includes the actions of a very diverse affected community (natural gas and liquid operators, one-call systems, state agencies, other federal agencies, and other business entities) as well as economic, regulatory, and technological conditions that are likely to change in the absence of either the pipeline mapping alternative or a pipeline mapping mandate.

The Workgroup addressed each of these elements of the baseline case. The group determined that economic and regulatory conditions in the baseline may influence mapping costs and benefits somewhat, but changes in relevant technologies, although highly uncertain, are likely to be the most influential component of the baseline. These factors and conclusions are described in more detail below:

Key Baseline Assumptions

Economic Conditions

- Both the natural gas and liquid pipeline industries face economic constraints in the near-term that may limit their ability to make mapping investments in the baseline.

Regulatory Conditions

- Federal regulations are not expected to have a significant influence on the cost or benefits of the alternative or mandate. Pipeline operators are currently required to maintain maps and records of their pipeline system under 49 CFR 195.404
- State requirements in a few key states may affect the mapping baseline for existing pipelines. In addition, any costs or benefits associated with mapping of new natural gas pipelines should not be assigned to the alternative or mandate.

Technological Conditions

- Fifteen percent of mapping data was in digital form at the time the alternative took effect.
- Expected baseline rates of technological change (i.e., digital mapping):
  Baseline A: by 2015, 50 percent of mileage in digital form.
  Baseline B: by 2015, 70 percent of mileage in digital form.

Time Period

- 1995 to 2015

Economic conditions: As discussed in Section V, baseline economic conditions in the pipeline industry and in the economy at-large will determine product demand, industry and firm incomes, profitability, and industry access to capital markets. Each of these factors in turn will influence the resources and capital available to individual pipeline operators or segments of the pipeline industry to make investments in mapping projects, such as new hardware or GPS technologies, that would reduce the incremental effects attributable to the mapping alternative. To illustrate, some pipeline operators or industry segments facing low growth and high costs with limited ability to pass these costs through to consumers would probably initiate few or no new pipeline mapping activities in the baseline case (i.e., a static or flat baseline). If this is the case, most or all of the benefits and costs of pipeline mapping would be incremental and thus attributable to the alternative.

Recent economic trends in the liquids pipeline industry include declining oil prices and falling incomes and profits. These trends have in turn resulted in pressure on costs. Due in part to heightened cost-consciousness, growth by liquids industry firms in the last few years has primarily been achieved through consolidation rather than through expansion. In addition, new investments in the liquids industry have tended to focus on immediate business needs.

In the natural gas pipeline industry, economic conditions have changed dramatically due to recent deregulation of the industry.[5] A key result of deregulation has been the "unbundling" of prices for natural gas transport, product, and storage, each of which is now determined in independent markets. In addition, pass-throughs of price changes to consumers are not regulated by FERC as stringently as in the past. Recent economic trends in the natural gas industry include rising demand and prices for natural gas. Subsequently, natural gas transmission companies now have greater incentives to expand their infrastructure. As a result, natural gas operators have used consolidation even more aggressively than liquids operators as a means to expand operations and capacity. Because rapid expansion has required significant capital investments by many operators, the natural gas industry is currently experiencing somewhat limited access to capital, particularly for investments in projects not critical to primary business operations.

Forecasting whether economic trends will be rising or falling over time is subject to a high degree of uncertainty, particularly in these energy-related industries, which are highly dependent upon macroeconomic conditions. Thus, it is difficult to determine to what extent pipeline operators would have engaged in mapping activities in the baseline. Due to price and cost pressures on the liquids side, and limited capital access on the natural gas side, it is fairly certain that economic conditions in the near-term future will constrain operators' ability to undertake major new incremental mapping activities, such as converting to electronic mapping systems, in the absence of the voluntary alternative or a mandate. For this case study, because of the difficulty of forecasting economic conditions and the fact that technological conditions are a more significant factor in the baseline, we did not conduct an in-depth treatment of these factors. However, we feel the baseline assumptions reflected in Exhibit A-4 reflect experts' forecasts of near-term economic conditions in the pipeline industry.

[5] FERC is the regulatory body responsible for implementing deregulation of the natural gas industry. By 1993, FERC had completed the most substantive of these deregulatory changes.

Regulatory conditions: Any federal or state regulations that would require pipeline mapping data similar to the data required by the mapping alternative could effectively reduce the incremental costs and benefits attributable to the mapping alternative and mandate. For example, if a few state pipeline agencies unilaterally developed regulations requiring operators to submit pipeline location data to an accuracy of 100 feet of pipeline centerline, the incremental costs and benefits in those states could not be assigned to the OPS alternative. Currently, under 49 CFR 195.404, pipeline operators are required to maintain maps and records of their pipeline system. Other federal agencies are unlikely to require all operators to submit pipeline mapping data before OPS, even though they may use this type of data once it is developed.[6] However, some states are developing requirements for pipeline maps or location data. Thus, to the extent that these requirements would have resulted in the creation of new mapping data in the absence of OPS' voluntary alternative, the costs and benefits attributable to the alternative would be reduced commensurately. We feel the two baseline scenarios presented here, shown in Exhibit A-4, account for the rising dynamics in the regulatory conditions.

The base case that applies to new pipelines is different than that for existing pipelines because of regulatory requirements for these pipelines. FERC currently requires that new natural gas pipelines be mapped, and most natural gas operators do map new pipelines when they are installed. In addition, some states require that new liquid pipeline "right-of-ways" be mapped. Because of these requirements, therefore, any costs or benefits associated with mapping new natural gas and liquid pipelines should not be assigned to the alternative or mandate.

Technological conditions: Technological conditions may be the most uncertain component of the base case. Similar to trends for other software, prices for mapping applications have fallen dramatically over time and will probably continue to do so. Computer hardware has also become more efficient as processing times fall. Additionally, the cost of global positioning system (GPS) hardware for survey work has fallen. Overall, the expected rate of technological change is highly volatile because relevant mapping technologies are evolving very rapidly, especially for GIS-based software.

To determine the influence of technology on the baseline for this case study, it is critical to establish the rate at which electronic mapping technologies would be adopted by pipeline operators in the absence of the pipeline alternative. This is because a rising rate of adoption will decrease the magnitude of costs and benefits that can be attributed to the alternative. Exhibit A-4 displays the impacts of a "rising technological baseline," as well as our assumptions about the rate of technological change in the baseline. Because results are so sensitive to the technological baseline, we assume two different rates of technological change.

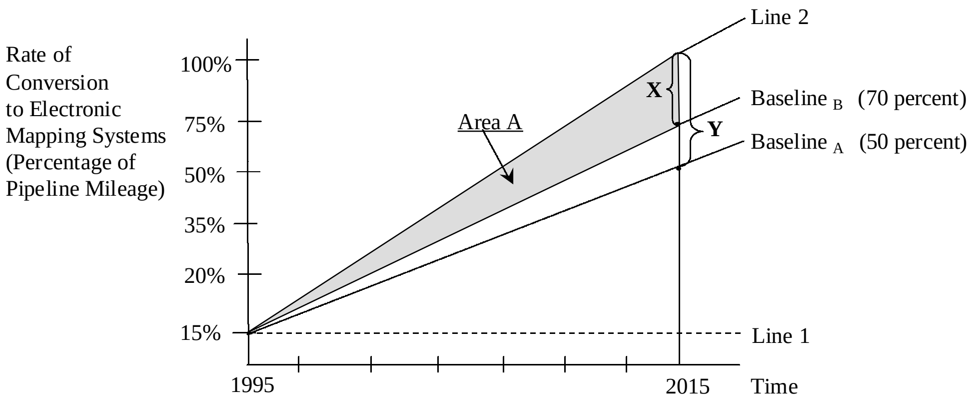
Currently, acquiring mapping software and conducting data conversion are still significant investments for operators. The majority of pipeline operators are not likely to purchase and use mapping software until they feel it adds significant value to their business operations relative to other investments, or unless the price of the technology and data conversion fall dramatically. In Exhibit A-4, *Line 1* shows our assumption, based on Workgroup input, that fifteen percent of pipeline data mileage was in digital form at the time the alternative took effect.[7] *Baseline A* represents a conservative assumption that an additional thirty-five percent of pipeline mileage will be converted to digital systems by

[6] For example, the U.S. Fish and Wildlife Service may use digitized pipeline data in conjunction with computerized National Wetlands Inventory digital maps to determine the proximity of pipelines to critical wetlands.

[7] Results of surveys by two industry associations indicate that approximately 15 percent of pipeline mileage surveyed had been either converted to or gathered in digital form by 1996. ("Strategies for Creating a National Pipeline Mapping System," prepared by OPS, American Petroleum Institute, American Gas Association, and the Interstate Natural Gas Association of America, 1996; p. 2-1).

2015 operators and one-call systems in the absence of the alternative, for a total of fifty percent. This is a more probable base case if operators are constrained from making investments in new projects. *Baseline B* represents a more aggressive assumption that an additional fifty-five percent of pipeline mileage will be converted to electronic systems, for a total of seventy percent in 2015. This is a more probable base case if operators find value from using digitized mapping data in other applications, or find ways to convert data more economically.

Exhibit A-4
Technological Baseline: Pipeline Mapping



If *Line 2* is the rate of conversion under the mapping alternative, which shows that 100 percent of pipeline miles will be mapped electronically by 2015, then *Area A* represents the difference between conditions in Baseline B and those expected under the alternative. Obviously, the higher the rate of digital conversion in the baseline, the less the impact of the mapping alternative. Our alternative assumptions regarding the rates of baseline change are used in this case study to create lower- and upper-bound estimates of the costs of the mapping alternative and the mandate, and to thereby reflect uncertainty in future economic, regulatory, and technological conditions.

Scope and Parameters of the Analysis

As described in Section V, an important step in cost-benefit analysis is to outline and consider some of the fundamental factors that define the analysis. For this case study of the mapping alternative and a mapping mandate, for example, the goal was to illustrate key elements of this scoping process rather than to complete a quantitative estimate of net benefits, so we designed the analysis *a priori* to take advantage of existing data that describe the costs of the mapping alternative.

Two of the key parameters that can be used to limit the scope of an analysis are the time period of the analysis and the categories of costs and benefits considered. In the section below, we describe the period of time assessed in the pipeline mapping case study, as well as the categories of benefits and costs deemed most significant during our consultations with OPS, industry, and others involved with pipeline operation and risk management.

Time Period

Operators' participation in activities associated with the mapping alternative began in 1995, during which MQAT developed the mapping strategies, including the strategy that OPS has elected to implement. According to OPS and industry representatives involved in establishing the voluntary alternative, the majority of costs will be realized within 20 years of this starting date, or by 2015. Specifically, the majority of industry costs associated with short-term mapping activities will be incurred from 1997 to 2001, while longer-term costs associated with updating and maintaining mapping data are likely to extend to 2015. The majority of government costs incurred by OPS and states will be completed by 2010. The timing of benefits will depend on the actual dates at which operators begin participating in the alternative, but will likely extend to and possibly even beyond 2015. However, because benefits beyond 2015 are highly uncertain, the time period we include in this analysis is 1995 to 2015.

Categories of Benefits and Costs

After soliciting input from OPS and industry, we composed a preliminary list of benefit and cost categories potentially attributable to the mapping alternatives. While we considered whether other costs and benefits would be likely to result from these alternatives, we focused most of our analysis on these primary categories. These are discussed below.

Costs

The Workgroup estimated that individual natural gas transmission and liquid pipeline operators, OPS, and state agencies will each incur direct costs that include capital costs (e.g., purchasing GPS systems) and costs associated with short-term and long-term mapping activities such as data conversion, data maintenance, and data updates. It is unlikely that mapping requirements will create indirect costs, such as price changes. We describe both capital costs and operations and maintenance costs below in greater detail.

Benefits

According to the MQAT report, the categories of benefits that may result from pipeline mapping will stem from improved decisionmaking by the users of pipeline mapping data, including operators, OPS, state agencies, one-call systems, and the public. While there is a great deal of uncertainty in forecasting how mapping data will be used in decisionmaking, the Workgroup finds that improved decisionmaking may result in creating some or all of the following categories of benefits:

- Improved Emergency Response Planning
- Improved Municipal Planning and development
- Improved Government Planning and Oversight
- Enhanced Public Confidence
- Improved Emergency Response
- Improved Risk Assessment and Environmental Management
- Improved One-Call Performance
- Improved Business Operations

In the next section, we discuss the results of the detailed analysis of the costs of mapping. The section that follows thereafter provides more discussion of each of these benefit categories, as well the results of our qualitative benefits assessment.

Costs of the Pipeline Mapping Alternative

As described in Section V of the report, the objective of cost analysis is to estimate the costs incurred by industry, government entities, and public entities in meeting the requirements of an OPS alternative or risk management program. Such an analysis should reflect only those incremental costs incurred by these groups as a result of participating in the alternative (i.e., an analysis should not include costs that they would have incurred in the baseline case).

We conducted a detailed analysis of the costs of the voluntary mapping alternative and the hypothetical mapping mandate. The primary sources of data and information used to develop these estimates were as follows: (1) a pilot test of both natural gas and liquid pipeline operators administered by MQAT;[8] (2) OPS' estimates of federal and state costs; and (3) other estimates provided by operators and mapping software industry representatives.[9] Based on input from these respondents, the two primary groups of costs resulting from the mapping alternative and the mapping mandate are *industry costs* and *costs to government*.

Key Assumptions: Industry Costs

Timing of Costs
Seventy percent of total costs are incurred from 1997 to 2001.
Thirty percent of total costs will be incurred from 2002 to 2015.
Costs will be incurred evenly within these periods.

Affected Pipeline Mileage
Total: 448,000 miles;
Natural Gas: 292,000 miles;
Liquid: 156,000 miles.

Weighted Average Cost Per Mile
Natural Gas:
Paper: \$37 to \$205 per mile;
Electronic: \$27 to \$58 per mile.
Liquid:
Paper: \$25 to \$37 per mile;
Electronic: \$20 to \$27 per mile.
(See "Key Cost Uncertainties" for more information on these cost ranges.)

Range of Discount Rates
Seven percent is estimated to be the closest approximation of the current cost of capital in the pipeline industry; ten percent is used as a value to conduct sensitivity analysis.

Industry Costs

Natural gas and liquid pipeline operators will incur various direct costs in the course of participating in the mapping alternative, including:

- **Capital Costs:** In some cases, operators will purchase computer hardware and software, equipment such as workstations, plotters, digitizers, printers, Global Positioning System (GPS) units, and GIS-related applications.

- **Operation and Maintenance Costs:** Pipeline operators will spend time and effort surveying, collecting, verifying, maintaining, and updating pipeline locational data and related metadata (i.e., data that describe attributes of the mapping data). In addition, they will incur costs for other non-capital purchases such as USGS Quad sheets, other base maps, other supplies (e.g., diskettes, CD-ROMs), and consulting services.

MQAT conducted two pilot tests of the mapping standards to evaluate operators' opinions about the mapping standards, the level of effort required to develop the data, and opinions about the quality of the data being provided. These pilots also requested that some operators, on a voluntary basis, submit mapping data that meet the standards developed by MQAT for a limited section of their pipeline

[8] Extensive survey data describing industry costs were readily available for this case study as a result of MQAT's efforts. For future analyses, it may be necessary to design and administer cost surveys, an engineering cost model, or another approach to collecting cost data.

[9] *National Pipeline Mapping System Survey*, prepared by MQAT, 1997.

system, and to provide an estimate of the costs associated with this effort. In the pilots, MQAT distinguished between liquid and natural gas operators and between operators submitting paper mapping data and electronic mapping data.

We used cost figures from the pilot results to develop an aggregate estimate of the national cost to industry of participating in the mapping alternative. This aggregate estimate is the product of the total affected pipeline mileage and an estimate of the average cost per mile of mapping for the following distinct operator groups: (1) natural gas operators currently mapping in paper; (2) natural gas operators currently mapping electronically; (3) liquid operators currently mapping in paper; and (4) liquid operators currently mapping electronically.

Based on discussions with OPS and industry representatives, approximately 70 percent of the costs of the mapping alternative will be incurred by each of these operator groups by 2001. There may be differences among individual operators in the timing of costs incurred, but on average, most costs will be incurred by this time, while the remaining 30 percent will be incurred from 2002 to 2015 to perform data maintenance. We also assume that these costs will be incurred in amounts that are relatively evenly disbursed over these time periods (e.g., $10,000 each year for ten years).

Affected Mileage

Over 447,000 miles of the U.S. national pipeline system will be mapped to meet standards developed by the alternative. Natural gas transmission lines account for approximately 292,000 miles of this total, and liquid pipelines account for approximately 156,000 miles.[10] At present, the costs of mapping software and data conversion are significant investments for some operators. However, in spite of the expense, many of the natural gas operators responding to the MQAT pilot have begun to map digitally. We assume that this group is reasonably representative of the industry at-large, and that under the alternative, the natural gas industry will map between 90 and 100 percent of total natural gas pipeline mileage digitally, or between 262,800 miles and 292,000 miles by 2015.

Results from the pilot, as well as input from liquid pipeline industry representatives, indicate that a somewhat higher percentage of liquid pipeline operators will submit paper maps for the majority of their pipeline systems to meet the alternative's standards. Again, we assume that respondents to the pilot form a fairly representative group, and we conduct sensitivity analysis on the percentage represented. Hence, we assume that the liquid industry will submit between 85 and 100 percent of mileage mapped in a digitized format by 2015, or between 132,600 and 156,000 miles.

Average Cost per Mile

Operators provided data in response to MQAT pilot that reflected the costs they incurred per mile for mapping a sample of their pipeline system to meet either paper or electronic standards set by the alternative. These operators generally included the costs of assembling existing data, verifying data, preparing metadata that describe the attributes of mapping data, and delivering data to a repository. While most operators participating in the pilot considered the costs of mapping only a small percentage of their entire system, we assume that these samples reflect pipeline sections that are reasonably representative of their entire system in terms of the relative difficulty or ease of mapping.

[10] Based on OPS's 1997 calculation of user fees for pipeline facilities, the exact mileage for natural gas transmission pipelines is 291,765 miles; the mileage for liquid pipelines is 155,558 miles. ("Pipeline Safety User Fees," U.S. DOT, *Federal Register 64042*, December 3, 1997).

To develop an average cost per mile for the distinct groups of operators mentioned above, we averaged the costs for each operator group, and then weighted these averages by the percentage of total pipeline mileage mapped by each operator group, as compared to the total mileage mapped in the pilot. Based on submissions from natural gas operators, the weighted average cost for paper submissions ranges from $37 to $205 per mile, and the weighted average cost for electronic submissions ranges from $27 to $58 per mile. Based on submissions by liquid operators, the weighted average cost for paper submissions ranges from $25 to $37 per mile, and the weighted average cost for electronic submissions ranges from $20 to $27 per mile.[11]

Note that the high-end of the range for the weighted average cost per mile for paper submissions from natural gas operators differs by up to an order of magnitude from the high-end of the ranges for other submissions (i.e., $205 per mile versus between $20 and $58 per mile). This value is derived from only one data point in the survey, a natural gas respondent describing their paper submissions. This case raises an illustrative point about data quality. Because this value is so much higher than other estimates submitted by natural gas operators, the Workgroup discussed eliminating this data point as an "outlier." As a general rule, however, analysts should dismiss "outlier" data such as this only if additional research proves them to be invalid. In this case, we did not conduct additional inquiries to determine whether this data submission is biased or erroneous. Thus, we did not have a specific reason to eliminate it from the range of estimates.

Total Industry Costs

Using the above figures for pipeline mileage and the calculated ranges of weighted average costs per mile, we determine a range of total present value costs to industry given discount rates of seven percent and ten percent. As shown in Exhibit A-5, the present value of total costs for industry participation in the mapping alternative ranges from $6.0 million to $13.9 million assuming a ten percent discount rate, and from $7.0 million to $16.3 million assuming a seven percent discount rate.[12,13] The low-end and high-end of these ranges are based on low-end and high-end estimates of weighted average costs per mile, and low-end and high-end assumptions about the percentage of mileage that will be mapped digitally, respectively.

Since the first MQAT standards were published and pilot-tested, OPS has modified and revised the standards (e.g., clarifying some standards, increasing the data elements to be submitted, reducing metadata requirements) in response to input from operators and government agencies. The Workgroup estimates that these changes to the standards, in conjunction with expected "learning" effects, could reduce total industry costs by an additional twenty percent. Learning effects are productivity gains that may occur as operators gain experience with the standards. Exhibit A-5 illustrates that if this is the case, the present value of the total costs to industry would then range from $4.8 million to $11.1 million

[11] The endpoints of these ranges for average cost per mile are based on: 1) actual cost data provided by operators for the pipeline segments they mapped in the survey sample (i.e., actual cost of mapping survey sample divided by number of miles in the survey sample); and 2) estimates of the average cost per mile for mapping their entire pipeline system. Respondents for whom these two figures differed significantly may be expecting to experience nonlinearities in costs of mapping their entire pipeline system. We discuss cost non-linearities later in this document, under "Key Cost Uncertainties."

[12] As discussed in Section V of the report, discounting is a procedure which allows comparison of cash or economic resources that occur in different time periods. Throughout this case study analysis, we assume discount rates of three to seven percent for costs incurred by government, and seven to ten percent for industry costs. Based on Workgroup input, a range of seven to ten percent closely approximates the opportunity cost of capital to the pipeline industry.

[13] Note that we are not endorsing these discount rates or any particular range of discount rates as a standard for use in OPS or other regulatory cost-benefit analyses. The general rule is that an analysis should always make explicit the choice of discount rate, or range of discount rates used, and the reasoning behind the choice.

assuming a ten percent discount rate, and from $5.6 million to $13.0 million assuming a seven percent discount rate.

Exhibit A-5
Industry Costs of Mapping Alternative: 1995 - 2010
(in millions of 1995 dollars)

	Undiscounted Costs	Discounted Costs	
NATURAL GAS PIPELINE OPERATORS:		**Seven Percent**	**Ten Percent**
Low-end	$7.9	$5.0	$4.3
High-end	$21.2	$13.5	$11.5
LIQUID PIPELINE OPERATORS:			
Low-end	$3.1	$2.0	$1.7
High-end	$4.4	$2.8	$2.4

TOTAL DISCOUNTED COSTS:		
All Operators	**Seven Percent**	**Ten Percent**
Low-end	$7.0	$6.0
High-end	$16.3	$13.9
TOTAL DISCOUNTED COSTS:		
All Operators, with "Learning" Effects	**Seven Percent**	**Ten Percent**
Low-end	$5.6	$4.8
High-end	$13.0	$11.1

Note: Seven percent is estimated to be the closest approximation of the current cost of capital in the pipeline industry. Ten percent is used for sensitivity analysis.
Low-end and high-ends of totals are based on: (1) low-end and high-end of average cost per mile mapped, and (2) low-end and high-end assumptions about percentage of mileage mapped digitally.
Sources: *National Pipeline Mapping System Survey*, 1997; and IEc analysis.

Costs to Government

The total costs to government of the mapping alternative are the sum of costs incurred by OPS and by states.[14] It is unlikely that local governments will incur any costs as a result of the alternative.

OPS Costs

Over the time period 1995 to 2001, OPS will have incurred approximately 50 percent of the total costs of developing the national pipeline mapping system. These costs include capital and non-capital costs similar to those incurred by industry (e.g., hardware, software, data collection, data verification and maintenance, and supplies). In addition, OPS incurs costs for pilot projects such as the operator mapping survey, the costs of developing national and state repositories for mapping data, and the costs of staff participation in mapping development activities, including MQAT. OPS also expects to incur, and has requested from Congress, additional funding of $0.8 million for each year from 2000 through 2002 to finalize the mapping system, and $0.6 million annually from 2003 to 2010 for ongoing data maintenance, data updates, and administration. At this time, OPS does not expect to incur any costs for mapping from 2010 to 2015.

Key Assumptions: Government Costs

Timing of OPS Costs
Fifty percent of total costs will be incurred from 1995 to 2001.
Fifty percent of total costs will be incurred from 2002 to 2010.
Costs are generally incurred in the year received, except for 1995 and 1996 funding, and funding set aside for repositories.

Timing of State Costs
75 percent of total costs are incurred from 1996 to 1998.

Number of Participating Repositories
Ten states will develop mapping repositories.

Range of Discount Rates
Three to seven percent.

Based on data from OPS' annual budgets from 1995 to 1999 and projections of costs from 2000 to 2010, we estimate that the present value of the total cost to OPS for the mapping alternative ranges from $7.4 million to $9.3 million (in 1995 dollars), as shown in Exhibit A-6. This estimate assumes that funds received in 1995 were used to support mapping activities in 1995, 1996, 1997, and 1998. These activities include the costs of administering MQAT, purchasing hardware and software, and creating mapping standards. Funds received in 1996 were spent in 1998 on the national repository, additional MQAT meetings and pilot testing, computer hardware and software, and technical support. Funds received in 1997, 1998, and 1999 will be spent in 1999 on the state repositories and the national repository. Finally, we assume that funds received from 2002 to 2010 will be expended in the year that they are received.

[14] As discussed in Section V of the report, OPS is funded by user fees paid by natural gas and liquid pipeline operators of transmission lines of a certain size that are regulated by OPS. These user fees are based on both regulated mileage and the quantity of product transmitted through an operator's system each year. Thus, all or most of OPS' costs are ultimately borne by pipeline operators in the form of annual user fees.

State Costs

The primary cost to states of the mapping alternative will be the cost of establishing state repositories for pipeline location information. Of the total funding for OPS described above, OPS has designated $1.5 million toward funding states' efforts to establish state mapping repositories. OPS estimates that these funds will cover 50 percent of the states' needs. We assume that 10 states will participate in the alternative by developing repositories. These states will contribute the other 50 percent of funding at an additional cost of $1.5 million. We assume that the majority of this $1.5 million (75 percent) is spent in the first three years of the alternative beginning in 1998. As shown in Exhibit A-6, the present value of these additional state costs is $1.4 million (in 1995 dollars).

Total Government Costs

Exhibit A-6 displays the present value of the total OPS and state costs for the mapping alternative. These costs range from $8.8 million to $10.7 million (in 1995 dollars), using a seven percent and three percent discount rate, respectively.

Other Costs

The public availability of higher quality integrated pipeline location information may increase the probability that terrorists and saboteurs are able to identify and locate critical infrastructures more accurately. This increased availability may result in increased security costs for the industry and government.

Total Costs

As shown in Exhibit A-7, the total present value cost of the mapping alternative, which includes the costs of industry and government participation, ranges from $14.8 million to $22.7 million (in 1995 dollars) using high-end discount rates and from $17.7 million to $27.0 million (in 1995 dollars) using low-end discount rates.[15]

Because we lack data that describe the costs operators will incur to map the 50 to 70 percent of total pipeline miles that we assume they would map in the base case, we must make the very conservative assumption that these costs equal zero. Thus, this total cost estimate is likely to overstate the true costs of the alternative by an amount equal to the present value of costs that operators incur to conduct mapping activities in the baseline, i.e., in the absence of the alternative. Referring to Exhibit A-4 again, if Line 2 represents the costs under the mapping alternative, and Baseline_A and Baseline_B represent costs incurred for mapping 50 to 70 percent of mileage in the base case respectively, then the costs of the alternative are overstated by the amounts represented by "Y" and "X", respectively.

In the discussion of industry costs, we noted that recent changes to the mapping standards, in addition to operators experiencing "learning" with respect to conducting mapping activities, may reduce industry costs by as much as twenty percent. Exhibit A-7 shows that this would reduce the total costs of the alternative by an additional eight to twelve percent over the costs of alternative if no learning takes place.

Costs of a Pipeline Mapping Mandate

The OPS pilot used to develop the above cost estimates for the voluntary pipeline alternative did not query operators about the costs of participating in a hypothetical mapping mandate. The Workgroup developed an assumption that a hypothetical mandate would

[15] The high-end of the range of discount rates is ten percent for industry costs and seven percent for costs to government. Low-end discount rates are seven percent for industry costs and three percent for costs to government.

Exhibit A-6
Government Costs of Mapping
(in millions of 1995 dollars)

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
OPS Costs, Undiscounted	$1.2	$1.2	$0.4	$0.4	$0.8	$0.8	$0.8	$0.8	$0.6	$0.6	$0.6	$0.6	$0.6	$0.6	$0.6
Discounted OPS Costs, Seven Percent	$1.2	$1.1	$0.3	$0.3	$0.6	$0.6	$0.5	$0.5	$0.3	$0.3	$0.3	$0.3	$0.3	$0.2	$0.2
Discounted OPS Costs, Three Percent	$1.2	$1.2	$0.4	$0.4	$0.7	$0.7	$0.7	$0.7	$0.5	$0.5	$0.4	$0.4	$0.4	$0.4	$0.4
State Costs, Undiscounted	--	$0.4	$0.4	$0.4	$0.15	$0.15	--	--	--	--	--	--	--	--	--
Discounted State Costs, Seven Percent	--	$0.4	$0.4	$0.4	$0.1	$0.1	--	--	--	--	--	--	--	--	--
Discounted State Costs, Three Percent	--	$0.4	$0.4	$0.4	$0.1	$0.1	--	--	--	--	--	--	--	--	--
Total Government Costs:															
Seven Percent	$8.8														
Three Percent	$10.7														

Notes: We assume that states begin mapping activities in 1996, and that they will incur about 75 percent of costs in the first three years. '--' denotes zero cos

Sources: Annual mapping budgets, Office of Pipeline Safety, 1998; and IEc analysis, 1998.

Exhibit A-7
Total Costs of Mapping
(in millions of 1995 dollars)

		Discount Rate	
		High-end	**Low-end**
Cost of Pipeline Mapping Initiative:			
	Low-end	$14.8	$17.7
	High-end	$22.7	$27.0
Cost of Pipeline Mapping Initiative, with "Learning" Effects:			
	Low-end	$13.6	$16.3
	High-end	$19.9	$23.7
Cost of Pipeline Mapping Mandate:			
	Low-end	$44.4	$53.1
	High-end	$68.1	$81.0

Notes: Low-ends and high-ends of the range of costs are based on low-end and high-ends of ranges of weighted average industry costs per mile mapped, and percentages of pipeline mileage mapped digitally. Low-end of the range of discount rates is seven and three percent for industry and government costs, respectively. High-end of the range is ten and seven percent for industry and government, respectively. We assume the costs of the mandate are three times the cost of a voluntary initiative.
Source: IEc analysis, 1998.

require operators to submit four other data points in addition to pipeline location data. These four data points include: pipeline age, pipeline material, diameter of pipeline, and valve location. We assume that a mapping mandate would require these data for all pipelines affected by the voluntary alternative (i.e., over 447,000 miles). While pipeline location data can be gathered by surveying a pipeline at three or four points per mile and then "connecting the dots," many of the additional data elements required by the hypothetical mandate vary significantly over a given pipeline section. This implies that acquiring these data would require much greater effort than developing pipeline location data, and thus would be much more costly on a per mile basis. For example, the age of pipe can vary along individual sections of pipeline, so developing data on pipeline age would require data on each individual segment of pipeline.

While we do not have detailed estimates of the costs of acquiring data to meet the requirements of this hypothetical mandate, industry and OPS estimate that the incremental cost of acquiring, maintaining, and updating the extensive additional data would be at least three times the costs of the mapping alternative. Hence, we estimate that a reasonable lower bound of the cost of a mapping mandate is from $44.4 million to $68.1 million (in 1995 dollars) assuming the high-end discount range, or from $53.1 million to $81.0 million (in 1995 dollars) assuming the low-end discount range.[16]

Key Cost Uncertainties

There are a number of uncertainties associated with the cost estimates presented above. Below we describe each of these uncertainties and the probable direction of their influence on the total estimate.

Small Sample Size: These estimates are based on cost data submitted by 19 pipeline operators that mapped approximately 620 of their miles for inclusion in the survey, or less than one percent of the total mileage in the national pipeline system. Because we extrapo-

[16] In general, the width of these ranges are driven by high average dollar per mile costs for natural gas operators who currently use paper maps. It is important to note that we had data for only one natural gas operator who submitted paper maps; thus, this one observation has significant influence on the reported range of expected costs.

late the cost per mile estimates provided by respondents to develop costs for the remainder of the national pipeline system, results are particularly sensitive if there are any errors or biases in these estimates. For example, the high cost incurred by the one natural gas respondent who submitted paper mapping data ($205 per mile) has a significant influence on the high-end estimate of the total national cost for industry. The fact that the sample of operators and pipeline mileage used is small and probably does not reflect the full range of actual variability in costs to be incurred by operators nationally is likely to result in some estimation error, but we do not have enough information to discern if this error has an upward or downward influence on the total cost estimate.

Representativeness of Survey Population: In addition, the operators responding to the survey may not be representative of key segments of operators that will be affected by the mapping alternative. One major group not explicitly represented in the survey are operators who will convert from paper mapping systems to electronic systems as a result of the alternative. These operators, for example, may incur additional costs in acquiring software and training their staff to use it. This uncertainty probably results in an underestimation of total costs.

Potential Non-linearities in Costs: In this analysis, we assume that costs are linear, i.e., the same cost per mile is applied to all mileage represented by a given operator group. This does not account for potential non-linearities in cost that operators may experience when mapping their entire systems. For example, operators may find ways to gather digital data by "GPSing" pipelines while performing maintenance or replacing sections of older pipeline, thereby lowering average cost per mile. Alternatively, operators may experience much higher costs for mapping pipeline in urban areas, which would increase average cost per mile. It is unclear whether these possible non-linearities will have a positive or negative influence on the total cost estimate.

Benefits of Pipeline Mapping

The goal of this benefits assessment is to identify probable benefit categories and potential challenges in analyzing a typical OPS alternative, rather than to perform a comprehensive quantitative analysis of benefits. Below we discuss, in qualitative terms, the two primary groups of benefits from pipeline mapping. These groups are *direct* and *indirect* benefits.

Direct Benefits

Direct benefits are benefits that clearly result from the output of the mapping alternative – pipeline location data that are more widely accessible, standardized, and in some cases, more accurate. According to the industry and government experts who provided information about likely benefits, there is little uncertainty that these benefits will occur. There is, however, uncertainty over the relative magnitude of these benefits. In addition, there may be additional costs that must be incurred in order to realize certain benefits.

Direct benefits from the mapping alternative may result from improved emergency response planning, improved OPS and state oversight capabilities, and improved efficiency when responding to public inquiries. We describe each of these categories of potential benefits below.

Key Benefits Assumptions

- Benefits of pipeline mapping are either direct or indirect. Direct benefits will result from the alternative. Indirect benefits may or may not, depending on how mapping data are used in decisionmaking.
- The relative magnitude of benefits of both direct and indirect benefits is uncertain.
- Additional costs may be incurred in order to realize certain categories of benefits.
- Quantitative assessment of mapping benefits would require extensive probabilistic modeling. In this analysis, we provide only qualitative assessments.

Improved Emergency Response Planning

The mapping alternative may result in improved emergency response planning by pipeline operators and natural resource managers.

Pipeline Operators

Emergency response plans of pipeline operators usually consist of multi-step, multi-scenario action plans. Operators may benefit economically by formulating response plans more quickly and thoroughly for each step of an emergency response plan.[17] Economic benefits may also arise from reduced effort in compiling pipeline location data. Depending on the information made available by the mapping alternative, response plans could include enhanced information regarding pipeline location, accessibility, and allowing plans to target sensitive areas. Managers may also be able to set up more realistic "what if" scenarios. In such scenarios, OPS would be able to depict the area around a pipeline failure and quickly communicate the potential consequences during long duration events to appropriate non-local officials and to the public.[18] Pipeline operators that use GIS or other electronic mapping systems could benefit from combining pipeline maps with other data layers for applications.[19]

Natural Resource Managers

Natural resource managers also depend on information describing pipeline locations for emergency response planning. Depending on the type of information provided by operators, these managers could more efficiently locate pipelines that run near sensitive natural resources and could formulate more specific response plans. For example, plans could include standardized references of pipeline locations (i.e., latitude/longitude coordinates) for identifying the source of release, specific actions to minimize damages, approximate travel time of released product, nearest access routes, necessary response equipment, and post-accident monitoring and remediation steps.[20]

Improved Municipal Planning and Development

City planners and contractors will benefit if the mapping alternative results in faster and easier identification of areas where development projects may conflict with pipelines.[21] Reduced time and effort in planning could result from standardized and more accessible maps. Improved infrastructure planning, may, in turn, reduce the number of potential hits, increase worker safety, and minimize damages from accidental pipeline ruptures.

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[17] Based on phone conversations with Ann Walker, President, Environmental Associates; and Harry Norris, emergency response planner, Department of Environmental Protection, Florida Marine Research Institute; August 1998.

[18] "Strategies for Creating a National Pipeline Mapping System," prepared by the Joint Government/Industry Pipeline Mapping Quality Action Team, July 26, 1996.

[19] Based on phone conversation with Don Smith, U.S. EPA, On-Scene Coordinator, emergency spill response planning, August 1998.

[20] Based on phone conversations with Jacqui Michel, RPI; Don Smith, Harry Norris, and Kim McCleneghan, Department of Fish and Game, State of California, Office of Spill Prevention and Response, July 1998.

[21] Based on phone conversations with Jacqui Michel, Harry Norris, and Kim McCleneghan, August 1998.

Improved Government Oversight Capabilities

OPS and state agencies that regulate and audit pipelines may accrue economic benefits from improved management and storage of pipeline location data and maps; they may also realize efficiency improvements when monitoring pipelines.[22]

- **Improved Maintenance and Storage of Maps:** OPS and state agencies that regulate pipeline activity may more effectively maintain, update, and store maps if the mapping alternative provides required information in a more accessible and more efficiently packaged format.

- **Improved Auditing of Pipelines:** Less time may be spent auditing pipelines because of standardized and more accessible maps. Depending on the information provided by the alternative, economic, social, and environmental benefits may arise from improved ability to identify areas needing enhanced auditing because of risk factors such as proximity to dense populations.[23] Economic benefits could also arise by avoiding unnecessary monitoring in low-risk areas.

Improved Response to Public Inquiries

OPS and state pipeline agencies receive numerous inquiries from the public regarding the location of pipelines. Responses require significant effort on the part of government agencies, and operator personnel to locate relevant maps. Economic benefits, therefore, may arise from improved effectiveness and effort in responding to inquiries if maps are more standardized and accessible.

Enhanced Public Confidence

More standardized and accessible mapping information provides other potential benefits to the general public. Benefits from improved information are dependent upon whether and how the information is used to make decisions. Most notably, a component of the value of improved information is the positive benefit associated with enhanced public confidence. The mapping alternative may provide the public with an enhanced sense of safety. From 1994 to 1996, the number of telephone inquiries from the public to OPS for information regarding pipelines and pipeline safety increased by 200 percent.[24] With more standardized and accessible information about pipeline locations, the public may have more confidence that external risks to pipelines due to uncertainty about location will be managed more effectively.

Guidance on Quantifying and Monetizing Benefits

Example Benefit Categories: Improved Pipeline Oversight and Response to Public Inquiries

Analytical Approach

To quantify these benefit categories, an analyst could develop a quantitative estimate of efficiencies realized by OPS and state agencies from using improved mapping data. Efficiencies may take the form of reduced time and labor conducting pipeline oversight activities and responding to public inquiries concerning pipelines. Because time and labor are market-based goods, these benefits, when qualified, can be easily monetized as the product of time or effort saved times an average labor rate for OPS and state employees that typically handle public inquiries.*

Key Questions

- Will mapping data provided by the alternative create net efficiencies to pipeline agencies?
- If so, how much time savings will there be for public employees performing oversight and public response tasks as a result of mapping information gained from the alternative?
- What agency contacts can provide estimates or actual measures of differences in time spent?

Data Needs

- Total hours spent by OPS and state employees performing oversight responsibilities and responding to public inquiries regarding pipeline location in the baseline (i.e., before mapping alternative).
- Expected reduction in number of hours needed to perform oversight responsibilities and to respond to public inquiries using enhanced information from the mapping alternative.
- Average fully loaded labor rate for OPS and state employees.

Example Calculation of Benefit Value

Assume that OPS and state employees spent an average of 50,000 hours annually performing oversight activities and responding to public inquiries before a PL mapping alternative is in place (i.e., the base case). As a result of information provided by the PL mapping alternative, time spent by government employees on oversight decreases by 25 percent, or 12,500 hours per year.

If the average labor rate for OPS and state employees responsible for oversight is $50 per hour, then the cost savings (i.e., the benefit) associated with this category equals $0.6 million annually.

* In the practice of conducting cost analyses, analysts typically use fully loaded labor rates, i.e., rates that reflect both labor costs as well as the overhead costs associated with each unit of labor.

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22 Based on phone conversation with Ann Walker, August 1998.

23 Based on phone conversation with Jacqui Michel, Don Smith, Harry Norris, Gary Zimmerman, and Kim McCleneghan.

24 "Strategies for Creating A National Pipeline Mapping System," prepared by the Joint Industry-OPS Pipeline Mapping Quality Action Team, July 26, 1996.

Guidance on Quantifying and Monetizing Benefits

Example 2: Improved Emergency Response

Analytical Approach

Quantifying and monetizing benefits resulting from improved emergency response requires a two-step approach. First, an analyst must determine whether mapping information improves the quality and effectiveness of emergency response activities. This assessment would most likely be based upon expert opinion. For example, using mapping data, experts could assess efficiency increases when locating a release source and determining the type of product transported. The second step is to determine how improved response results in quantifiable benefits, such as reductions in product losses, natural resource impacts, and property damages. Depending on the nature of the benefit, an analyst could then monetize these benefits using market-based values or non-market based approaches described in Exhibit 6-5 of the report. Decreased natural resource damages, for example, could be valued using benefits transfer or a contingent valuation study eliciting respondents' willingness to pay for the natural resource attribute of interest. Due to the resource-intensiveness of contingent valuation, however, benefits transfer is more likely to be used.

Key Questions

- Will the data provided by the mapping alternative improve emergency response activities? If so, how and to what extent? How can these improvements be measured tangibly?
- Will improved emergency response activities result in quantifiable benefit metrics, such as decreased product losses and decreased natural resource damages? If so, what type of modeling and risk assessment (e.g., failure analysis, ecological risk assessment) is required to generate valid measures of benefits metrics?
- What is the appropriate unit value of the characteristic of interest (e.g., units of drinking water)?

Data Needs

Quantification

- Improvements in emergency response activities due to information provided by mapping alternative.
- Expected incremental decrease in annual impacts in each benefit category because of improved response, based on risk assessment or other modeling.

Monetization

- Unit value of benefit measure of interest (e.g., unit cost of drinking water treatment).

Example Calculation of Benefit Value

Assume that expert opinion determines information provided by the mapping alternative will improve emergency response activities, which will in turn mitigate impacts of pipeline incidents by 10 to 15 percent annually. Assume also that probabilistic modeling has determined the primary impact of incidents to be recreational fishing losses equaling 200,000 angler days per year.

Reducing these losses by 10 to 15 percent (20,000 to 30,000 angler days per year) and transferring a value of $40 per angler day from the available economics literature on recreational fishing results in an emergency response benefit of $0.8 million to $1.2 million per year.

Even though the probability of a pipeline release is low, there may be a positive value to the public's knowledge or perception that these risks are being managed more effectively using an improved information base.

Indirect Benefits

Other potential benefits of pipeline mapping are more secondary or *indirect* than those described above. These benefits will only be realized under certain circumstances, i.e., they are highly contingent upon the occurrence of a series of other events or decisions. In this case, other data fields will need to be added to the locational database for many of these indirect benefits to occur. As a result, whether these benefits will occur at all is highly uncertain, but we provide discussion of these categories as described by individuals contacted during this assessment.

Indirect benefits will depend on the quality, availability, and accessibility of data provided by the mapping alternative. They will also depend on the extent to which data are utilized and applied by pipeline operators, natural resource managers, and one-call systems. In addition, it may be necessary to incur additional costs to realize some of these benefits. Assuming various parties make use of these data, indirect benefits may include improved emergency response, improved one-call system performance, increased public confidence, and improved pipeline business operations.

Improved Emergency Response

Improved emergency response enhances the effectiveness of response activities. Indirect benefits from improved emergency response may arise from reductions in product losses, remediation costs and property damages, losses to commercial fisheries, losses in recreational fishing and tourism, avoided supply shocks, reductions in aesthetic losses, reductions in environmental damages, decreased effort identifying pipelines, and other factors. These are discussed further below.

- **Decreased Product Loss:** Pipeline operators experience economic impacts from product losses. Better emergency response may result in more timely identification of the source of product releases, allowing response personnel to more quickly shut valves or repair ruptures to minimize product loss.[25]

[25] Based on phone conversation with Norman Mead, NOAA Damage Assessment Center, and Ann Walker, July 1998.

- **Decreased Site Remediation Costs:** Remediation expenses are a substantial component of the total cost of pipeline releases. Expenses arise from the actual costs of cleaning up an area as well as from natural resource restoration, pipeline repair, and post-spill monitoring for potential impacts on human health and the environment.[26] The mapping alternative could reduce remediation costs by allowing more efficient initial response actions.

- **Decreased Property Damages:** Better emergency response may minimize property damages from accidents. Property damage results in economic losses borne by both injured parties as well as responsible parties. Responsible parties may be required to compensate injured parties, and also can incur various damage-assessment and legal costs. Therefore, mitigation of property damages will lead to cost savings and economic benefits for all affected parties.[27]

- **Decreased Losses to Commercial Activities:** Releases to surface water bodies may result in real economic losses to commercial activities. For example, economic losses could result from diversion of commercial fishing or shipping activities or water intakes. Economic losses are not only incurred by owners of commercial operations, but by consumers who potentially face reduced supply and higher prices.

- **Decreased Losses to Recreational Activities and Tourism:** Recreational activities associated with waterways and other areas near pipelines are components of the economy and human welfare. Releases from pipelines may result in economic and social losses to recreationalists engaging in activities such as fishing, swimming, boating, water sports, bird watching, nature appreciation, and relaxation. Economic losses in such instances are also incurred by nearby towns that depend on tourism as a source of income.[28]

- **Avoided Supply Shocks:** Pipeline releases result in product losses and, in some cases, pipeline shutdown, reducing or even temporarily halting supply to consumers. Such supply problems can impose costs on product users as well as pipeline operators.

- **Avoided Damages to Aesthetic Appearance:** Aesthetics are an important component of the overall value of a natural setting to human beings. Damages from pipeline releases may reduce the aesthetic qualities of an area.

- **Decreased Natural Resource Impacts**: Pipeline releases may harm the natural resources in an affected area. Depending on the magnitude and location of releases, damages could include wildlife injuries and fatalities, and degradation of pristine areas such as marshes, wetlands, deserts, and coastal zones.

Guidance on Quantifying and Monetizing Benefits

Example Benefit Category 3: Improved Public Confidence

Analytical Approach

To quantify this benefit category, OPS would assess the increase in the public's confidence based on the public's knowledge or perception that mapping data are being used by operators, one-call systems, and public agencies to improve pipeline safety. OPS would then need to determine the number of public users of pipeline information and measure the extent to which enhanced and more readily available mapping information provides them an improved sense of safety or well-being. Because improved public confidence is a non-market good, contingent valuation would be one method to quantify and monetize this benefit.

Key questions

- Is the public concerned with pipeline safety?
- Is improved confidence in the pipeline system measurable?
- Are quantifiable metrics available that illustrate the public's concerns (e.g., number of inquiries to public officials or pipeline agencies)? If so, what are they?
- Will public confidence increase due to information gained from the mapping alternative?

Data Needs

- Expected incremental increase in public confidence due to information provided by the mapping alternative.
- Number of public users of pipeline location data.
- Public's willingness to pay for enhanced confidence in the safety of the pipeline system.

Example Calculation of Benefit Value

For purposes of illustration, assume that the economics literature provides empirical evidence that public users of pipeline information systems are willing to pay from $30 to $50 per person annually for the incremental increase in confidence in the pipeline system due to the mapping alternative. Assume also that the number of public users of pipeline information is 50,000 persons annually. The value of the benefit provided by improved public confidence therefore ranges from $1.5 million to $2.5 million annually.

[26] Based on phone conversation with Norman Mead, July 1998.

[27] Ibid.

[28] Based on phone conversation with Kim McCleneghan, July 1998.

Improved Risk Assessment and Environmental Management

Natural resource managers depend on standard and accessible pipeline location information for conducting risk assessments and managing environmental resources. Specifically, in performing risk assessments, natural resource managers identify potential future problems associated with nearby pipelines. For example, managers can identify potable water sources near pipelines and the communities that rely on these sources. With such information, these managers could better monitor for emergencies in these areas, yielding social and environmental benefits.[29]

Improved One-Call Performance

A one-call system is a state-wide or regional communication system that is established by underground facilities owners.[30] One-call systems provide one telephone number for people to call to notify of their intent to dig. These systems may benefit from improvements to the quality and accessibility of maps describing pipeline location. Specifically, benefits may arise from reduced calls to utility operators, reduced number of field trips to verify excavation locations, and more accurate determinations of whether pipelines conflict with development plans. One-call systems using GIS or other electronic mapping systems may experience additional benefits. Benefits to one-call systems are contingent upon such system operators adopting geographically referenced requirements for location information from facility operators, one-call system operators, and one-call system users (e.g., excavators).

- **Reduced Calls:** In some cases, one-call systems may mistakenly contact pipeline operators, despite the fact that the operator has no pipelines in the area of interest. According to a representative of a liquids pipeline company, only a small percentage of the notifications received each year are relevant, yet all require the dispatching of a field worker to investigate the situation. Notifications to operators that do not have pipelines in the area of interest are often due to the one-call systems' lack of standardized pipeline maps. Therefore, the mapping alternative may help one-call systems reduce the number of referrals to pipeline owners.[31] Potential economic benefits that arise from reduced numbers of phone calls include reduced effort and number of response personnel.

- **Reduced Trips into the Field:** A reduced number of notifications from one-call systems to operators may lead to a reduced number of trips into the field.[32] Pipeline operators would benefit economically from dispatching fewer field workers through reduced expenses, effort, and number of necessary response personnel. Reduced expenses may be especially significant in remote areas such as parts of Alaska where labor and travel expenses associated with trips to the field can be significant.[33]

- **Improved Decision Making:** Improvements to pipeline maps may allow one-call operators to make better decisions when identifying pipelines that may

[29] Based on phone conversation with Jacqui Michel, Gary Zimmerman, Harry Norris, and Don Walker, as well as correspondence with Angus Wood, ESRI, August 1998.

[30] Based on conversation with Larry Shamp, Equilon Pipeline Company, July 1998; and "One-Call System Mapping," prepared by Larry Shamp, Shell Oil Products Company, 1998.

[31] Based on phone conversation with Larry Shamp as well as correspondence with Angus Wood and Ed Sweet, Vice-President of Oil and Gas Industry Solutions, Intergraph Corporation, August 1998.

[32] Based on phone conversation with Larry Shamp, July 1998.

[33] Based on phone conversation with state one-call system representative in Alaska, August 1998.

interfere with excavation plans. Moreover, reductions in the number of notifications to utility companies may free up inspectors and support staff to concentrate on inquiries that truly require a site visit. For example, many hits have occurred when a one-call system was notified but a utility worker or assigned contractor did not successfully identify the location of their pipeline.[34] Better site assessments may reduce the number of accidental hits, improve the safety of utility workers, excavators, and the public, reduce environmental damages, and minimize product loss.[35]

- **Improvements with GIS:** While one-call systems have been slow to adopt electronic mapping systems, more systems are likely to convert as the various system subscribers realize the benefits of converting.[36,37] Benefits to one-call systems from the information provided by the alternative, therefore, should increase substantially over time. One-call systems that use GIS may benefit economically from standardized and more accessible pipeline mapping data by more efficiently identifying the location of pipelines and using the information in conjunction with a variety of other layers of data.[38] For example, a one-call operator can use GIS to pinpoint an area of concern and fax or e-mail a map of the area to relevant parties.[39] This may cut response time from several hours to several minutes.

Improved Pipeline Business Operations

Pipeline operators may benefit from improved pipeline management and facilities planning, market and asset analysis, and pipeline maintenance.

- **Improved Pipeline Management and Facilities Planning:** Access to enhanced maps may benefit pipeline operators by improving their ability to manage pipelines.[40] For example, less time and effort may be required when making management and planning decisions.[41] Mapped pipeline networks coupled with quick data access may lead to economic benefits from enhanced route optimization, pipeline management, and facilities planning.

- **Improved Pipeline Maintenance:** Pipeline operators may benefit if they are able to locate pipelines more efficiently for field personnel conducting pipeline maintenance. The extent of these economic, social, and environmental benefits are contingent upon the type of information made available.

[34] Based on phone conversation with Larry Shamp; and, "The 'One Call' Centers: Survey Results, Analysis, and Recommendations," report prepared by the Hartford Steam Boiler Inspection and Insurance Company for the Gas Research Institute, December 1997.

[35] Based on phone conversation with state one-call representative in Colorado, August 1998.

[36] Based on phone conversation with Larry Shamp, July 1998.

[37] Many one-calls are non-profit organizations that are funded by user fees paid by member utilities. Under this funding approach, these organizations can find it difficult to recover the costs of investments in such capital improvements to their systems, such as mapping software and pipeline data conversions. This constraint is a major barrier inhibiting one-calls' ability to adopt new technologies.

[38] Based on correspondence with Angus Wood, and Ed Sweet, August 1998.

[39] Ibid.

[40] Ibid.

[41] Ibid.

The benefits discussed qualitatively above could only be quantified through extensive research and risk analysis. However, several conclusions can be drawn from this qualitative assessment.

- Direct economic, social, and environmental benefits from the mapping alternative are likely to be positive, but their magnitude is uncertain. Direct benefits will be realized in the categories of emergency response planning, infrastructure planning, OPS and state pipeline oversight capabilities, and improved response to public inquiries. The magnitude is dependent upon the extent that benefits allow for a reduction in risks inherent to these activities.

- Indirect benefits are dependent upon the occurrence of a variety of events such as improvements to the quality of information provided. Further research is needed to define indirect benefits with more certainty. Various economics, social, and environmental benefits could result from improved emergency response, risk assessments and environmental management, one-call performance, pipeline business operation, and public communication. The magnitude of benefits is dependent upon how risks inherent to the pipeline system, physical environment, and pipeline management are reduced. There may be additional incremental costs incurred when realizing many of the benefits. These costs will depend, in part, on how mapping information is employed by the various users of the data.

- Many of these benefits are likely to be realized later in time as operators provide more comprehensive information, adopt electronic systems, and find new applications of the information.

Key Benefits Uncertainties

There are a number of uncertainties associated with the benefits of the pipeline mapping alternative. First, uncertainty arises because many benefits are dependent upon whether mapping data are used to improve decisionmaking. For example, users of mapping data, such as operators, one-call systems, and public agencies, may not use these mapping data to enhance management of pipelines or other resources located nearby (e.g., sensitive natural resources). Second, it is unclear to what extent improved decisionmaking made possible by mapping data will in turn reduce risks associated with pipelines. Pipeline risk may be grouped by the following categories: risk inherent to pipelines, risk associated with potentially affected environments, and risk due to pipeline operation and management. Below we describe each of these categories of benefits uncertainties associated with a reduction of risks inherent to each of these three groups.

Risks Inherent to Pipelines: Risks associated with the pipeline systems include: third party damages, natural disasters, corrosion, and fatigue, all of which may result in accidental leakage or releases. Uncertainty results because it is unclear the extent to which mapping data would be used to improve pipeline functions and thereby result in a reduction of these risks. For example, benefits may be realized with greater certainty if mapping data is used to identify sections in need of repair or replacement.

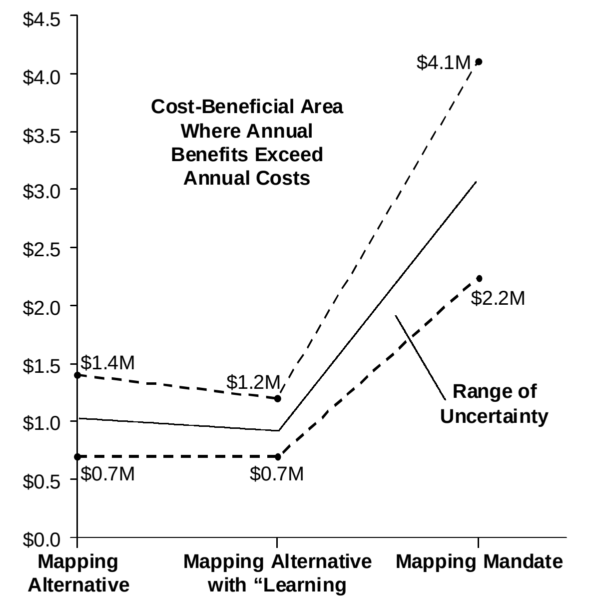
Risks to Potentially Affected Environments: Pipeline systems pose risks to the quality of the environment and human health because of the potential for leaks, releases, or explosions. Risks associated with pipeline incidents are in part defined by the characteristics of ecosystems and human populations that could potentially be affected by these events. Benefits that arise from avoiding or mitigating the effects of pipeline incidents are thus linked to the physical attributes of locations, such as property attributes or characteristics of fisheries and recreational areas, where releases would be avoided. For example, different benefits would arise from a release avoided near a popular fishing site than a release avoided near a site not used for any recreational activities. Because predicting the location of incidents avoided or mitigated due to the use of mapping data is highly uncertain, benefits related to the features of these locations are highly uncertain.

Risk Associated with Pipeline Operation and Management: Another significant component of pipeline risk is the degree of effectiveness of pipeline management. Uncertainty arises when determining if the information provided by the mapping alternative would enable operators, one-call systems, and public agencies to make better management decisions. Benefits to pipeline operators depend upon whether enhanced mapping data would allow them to avoid supply shocks, improve pipeline monitoring and inspection, avoid human or mechanical error, or avoid pipeline incidents, such as leaks, releases, or explosions. Benefits to natural resource managers will depend on the extent to which mapping data helps improve risk assessments, emergency response planning, emergency response activities, and other actions to reduce damages from pipeline releases. Benefits to one-call systems depend upon the type of mapping system already employed, and one-calls' ability to use mapping data for improving decisionmaking and responses to public inquiries.

Summary of Costs and Benefits

As stated above, this analysis addresses the benefits of pipeline mapping only in qualitative terms. As a result, the results may not seem to provide OPS with a definitive sense of whether mapping alternatives (i.e., an alternative or mandate) may meet a strict cost-benefit test. Despite the fact that this assessment quantifies only costs, however, the cost data alone still provide OPS with useful information describing the magnitude of benefits that would be required to make the mapping program cost-beneficial. Exhibit A-8 shows how the range of cost estimates can be used to determine the lower and upper boundaries of the range of benefits that would outweigh costs. For example, if OPS implements the mapping alternative, which costs from $0.7M to $1.4M per year, then the present value of total benefits would need to equal $0.7M per year, at *minimum*, for the alternative to generate positive net benefits. If the net present value of benefits ranges between $0.7M and $1.4M, the alternative is in the range of uncertainty surrounding the cost estimates, but it is probably close to being cost-beneficial (i.e., a cost-benefit ratio greater than 1). Finally, Exhibit A-8 shows that when the alternative generates net benefits greater than $1.4M, the alternative is definitely cost-beneficial.

Exhibit A-8
Cost-Benefit Summary of Pipeline Mapping Alternatives
(millions of dollars per year, in present value)



This interpretation of the mapping alternative cost estimate is subject to some uncertainty because of the base case, i.e., the fact that many operators will map pipelines even without the mapping alternative. Because we lack data that describe the costs operators will incur to map the 50 to 70 percent of total pipeline miles that we assume they are likely to map in the base case, we must make the very conservative assumption that these costs equal zero. Thus, this total cost estimate is likely to overstate the true costs of the alternative by an amount equal to the present value of costs that operators incur to conduct mapping activities in the baseline, i.e., in the absence of the alternative. Referring back to Exhibit A-4 again, if Line 2 represents the costs under the mapping alternative, and Baseline_A and Baseline_B represent costs incurred for mapping 50 to 70 percent of mileage in the base case respectively, then the costs of the alternative are overstated by the amounts represented by "Y" and "X", respectively. Hence, net benefits required for the alternative to be cost-beneficial are also overstated by a (more or less) commensurate amount.

For the purpose of illustrating the entire analytical process (i.e., determining and interpreting quantified costs *and* benefits), we also provide examples of monetized benefits for certain mapping benefit categories (*see the section entitled:* <u>Example Calculation of Benefit Category</u> *in the text boxes on pages A-21, A-22, and A-23*). Note that these are hypothetical, simplified examples for the purpose of comparing these values to the quantified estimate of mapping costs; actual benefit calculations for these types of benefits would be more involved and characterized by significant uncertainty.

In these hypothetical examples, mapping benefits associated with improved pipeline oversight, improved emergency response, and improved public confidence are quantified and monetized using the methods described. Assume that benefits of improved pipeline oversight are estimated at $0.6 million annually; benefits of improved emergency response are estimated to range from $0.8 million to $1.2 million, and benefits of improved public confidence are estimated to range from $1.5 million to $2.5 million (all expressed in undiscounted 1995 dollars). Appendix C-5 illustrates how annual net benefits of the pipeline mapping alternative are calculated. Using these hypothetical values for benefits, Appendix C-5 determines the difference between the present value of total benefits and total costs on an annual basis. Using the low-end of the benefit estimates described above, and the assumptions and cost estimates described in this analysis (and in the *Data Summary*), the net present value of benefits of the pipeline mapping alternative are estimated to be $19.4 million per year. Similar calculations using the other ends of the ranges for benefits and costs would then yield an estimate that indicates the full range of certainty describing the net benefits of this alternative. Arriving at such a quantified net benefit estimate is obviously of value, but OPS should be mindful of the caveats associated with using one net benefit figure (or a range of figures) for decisionmaking.

Effectiveness of the Analysis/"Lessons Learned"

Performing an analysis of the mapping alternative and a hypothetical mandate provides insights on the workings of the process and how resources are deployed during a typical cost-benefit analysis. Below we describe a few of our observations regarding the process conducted for this analysis that may have implications for how OPS conducts future analyses.

- **Use of survey data:** Cost results from this analysis indicate that it may be worthwhile for OPS to conduct additional research to explore the nature of variability across various segments of the national pipeline system, including key differences among operator groups. This research may provide OPS with data that can be used to refine future cost estimates.

- **Quantitative assessment of OPS alternatives:** Developing quantitative assessments of future OPS alternatives such as pipeline mapping, many of which will use a risk-based approach to managing pipeline safety, may be challenging and very resource-intensive. Such assessments will require sophisticated probabilistic modeling (e.g., failure analysis, risk engineering).

- **Value of collaborative approach:** The process of conducting this cost-benefit analysis of the mapping alternative clearly demonstrates the value of collaborative stakeholder teamwork, particularly during the steps of defining target problems, identifying alternative alternatives to address problems, and contributing to cost-benefit analysis of alternatives. Numerous insights about the value of stakeholder teamwork can be found in two reports produced by the mapping teams.

- **Value of key process steps:** Throughout this case study, the Workgroup identified the first process step of *defining the target problem* as particularly important, since the rest of the analysis stems directly from this step and from the subsequent step of identifying alternatives chosen to address the target problem.

Appendix B:

Data Summary of the Mapping Cost-Benefit Analysis

Data Summary: Mapping Cost-Benefit Analysis

Statement of the Target Problem

In the 1992 Pipeline Safety Act, Congress called on OPS to adopt rules requiring pipeline operators to map pipeline facilities and to make maps and records publicly available. While the Act did not explicitly state the target problem addressed by the pipeline mapping requirement, the Workgroup assumes that Congressional intent was to reduce environmental and/or safety risks to pipelines by improving data that describe the national pipeline system.

Alternatives Assessed in the Analysis

In response to the requirements of the Pipeline Safety Act, the Mapping Quality Action Teams considered many alternatives. This analysis addresses the following alternatives:

- OPS forms a partnership with industry to address pipeline mapping data needs through a *voluntary initiative.*
- As an alternative to an initiative, OPS could issue a *mandate* requiring pipeline operators to submit extensive data describing their pipeline systems (e.g., valve location) in addition to locational data.

Definition of Baseline

Economic Conditions

- Both the natural gas and liquid pipeline industries face economic constraints in the near-term that may limit their ability to make mapping investments in the baseline.

Regulatory Conditions

- Federal regulations are not expected to have a significant influence on the costs or benefits of this specific mapping alternative or mandate.
- State requirements in a few key states may affect the mapping baseline for existing pipelines. In addition, any costs or benefits associated with mapping of new natural gas pipelines should not be assigned to the initiative or mandate.

Technological Conditions

- Fifteen percent of mapping data was in digital form at the time the initiative took effect.
- Expected baseline rates of technological change (i.e., digital mapping):

  Baseline A: by 2015, 50 percent of mileage in digital form.

  Baseline B: by 2015, 70 percent of mileage in digital form.

  (Source: OPS/Stakeholder Workgroup analysis, 1998)

Key Quantitative Assumptions

- <u>Time period of the analysis:</u> 1995 to 2015 (Source: OPS and Workgroup analysis, 1999).
- <u>Affected Pipeline Mileage:</u> *Total*: 448,000 miles; *Natural Gas*: 292,000 miles; *Liquid*: 156,000 miles. (Source: "Pipeline Safety User Fees," U.S. DOT, *Federal Register* 64042, December 3, 1997).
- <u>Discount rates, industry costs:</u> Seven to ten percent (Source: OPS/Stakeholder Workgroup analysis, 1998).
- <u>Discount rates, costs to government:</u> Three to seven percent (Source: OMB Guidance, 1992).
- <u>Costs to industry:</u> *Natural Gas*: Paper: $37 to $205 per mile; Electronic: $27 to $58 per mile. *Liquid*: Paper: $25 to $37 per mile; Electronic: $20 to $27 per mile. (See "Key Cost Uncertainties" for more information on these cost ranges.) (Source: *National Pipeline Mapping System Survey*, 1997; and IEc analysis, 1998).
- <u>Costs to federal government</u>: Fifty percent of OPS costs to support mapping activities will be incurred from 1995 to 2001; additional costs will be incurred from 2001 to 2010 (*see Exhibit A-6 for a detailed breakout of OPS' costs)* (Source: Annual OPS mapping budgets, 1995-1999; and IEc analysis, 1998).
- <u>Costs to state governments:</u> Ten states will establish mapping repositories, and will incur 50 percent of the costs of these from 1996 to 2000 (OPS will fund the other 50 percent as part of their costs) (*See Exhibit A-6 for a detailed breakout of states' costs)*. (Source: OPS estimates, 1998).

- Depreciation Method / Assumptions: In the analysis of mapping costs, operators noted that the vast majority of mapping costs incurred will be for operational activities (e.g., collecting, verifying, and updating data), rather than capital expenditures (i.e., computer hardware). In addition, cost estimates were provided on the basis of total costs per mile mapped, rather than by capital cost and operating cost designation. Thus, capital costs were not depreciated in this analysis because: 1) no capital costs data were provided, and 2) capital costs comprised a small percentage of total costs of mapping, and therefore, depreciation would have little influence on national results. As a general rule, when capital costs are significant, cost-benefit analyses employ straight-line depreciation methods.

- OPS' Value for Statistical-Life and Injury: $2.7 million per statistical life; value per statistical injury are equal to a fraction of the value per statistical life, ranging from 0.002 (minor injury) to 1.000 (fatal injury), depending on the severity of the injury. (Source: Kaplan, Stephen, and Frank Kruesi, "Update of Value of Life and Injuries for Use in Preparing Economic Evaluations," internal U.S. DOT memorandum, March 14, 1995).

Key Qualitative Assumptions

- Benefits of pipeline mapping are either direct or indirect. *Direct benefits* will result from the alternative. *Indirect benefits* are less certain to result from the alternative, depending on the quality of mapping data and how they are used in decisionmaking.

- The *relative magnitude* of benefits of both direct and indirect benefits is uncertain.

- *Additional costs* may be incurred in order to realize certain categories of benefits.

- *Quantitative assessment of mapping benefits* would require extensive probabilistic modeling. For purposes of this illustrative analysis, we provide only qualitative assessments.

  (Source: OPS / Stakeholder Workgroup and IEc analysis, 1998-1999.)

Summary of Results and Range of Uncertainties

Costs

Estimates of costs to industry are based a range of discount rates (seven percent to ten percent) and ranges of mapping costs provided by operators. OPS' estimates are the basis of the costs to government. Total costs equal costs to industry plus costs to government.

- *Mapping Initiative* — Total costs of a mapping initiative are estimated to range from a present value of $14.8 million to $27.0 million (1995 dollars). (Source: MQAT report, OPS / Stakeholder Workgroup, and IEc analysis, 1998-1999).

- *Mapping Initiative with "Learning Effects"* — OPS has recently modified mapping standards since the initial cost estimate, which may reduce industry's costs by up to 20 percent through "learning effects." Thus, total costs of the mapping initiative may actually be lower than originally estimated, ranging from a present value of $13.6 million to $23.7 million. (Source: OPS estimates and IEc analysis, 1998).

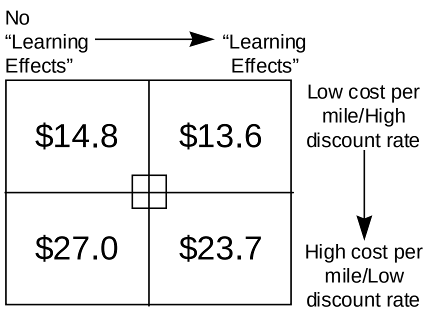
- *Mapping Mandate* — Costs associated with a mapping mandate are estimated to be three times that of the initiative due to more extensive requirements for pipeline data. Thus, they would range from a present value of $44.4 million to $81.0 million. If "learning effects" also reduce industry costs for the mandate by up to 20 percent, then total costs of the mandate could be up to ten percent lower than this range. (Source: OPS estimates and IEc analysis, 1998).

- *Key uncertainties* associated with these cost estimates include: (1) use of a small sample to derive pipeline operator costs, (2) use of a survey population that may be unrepresentative of the pipeline industry at-large, (3) the existence of potential cost non-linearities, and 4) the influence of "learning effects" on industry costs (Please see "*Key Cost Uncertainties*" for more details on these).

- Without further research, it is unclear whether these uncertainties have an upward or downward net influence on the overall cost estimate. However, the illustration below shows sensitivity analysis of total costs of the pipeline industry at-large, i.e., the sensitivity of total mapping costs to changes in the following variables: 1) discount rate and average mapping cost per mile, and 2) the effects of operator "learning."

Illustration of Sensitivity Analysis

Costs of the Pipeline Mapping Initiative
(millions of 1995 dollars)



Benefits

This analysis addresses benefits of pipeline mapping qualitatively by soliciting expert opinion from pipeline and software industry representatives, government pipeline and natural resource agencies, and "one-call" operators.

- *Direct benefits of mapping* will be realized in the categories of emergency response planning, infrastructure planning, OPS and state pipeline oversight capabilities, and improved response to public inquiries. The magnitude of these benefits depends on the extent to which mapping data used for these activities helps to mitigate risks.

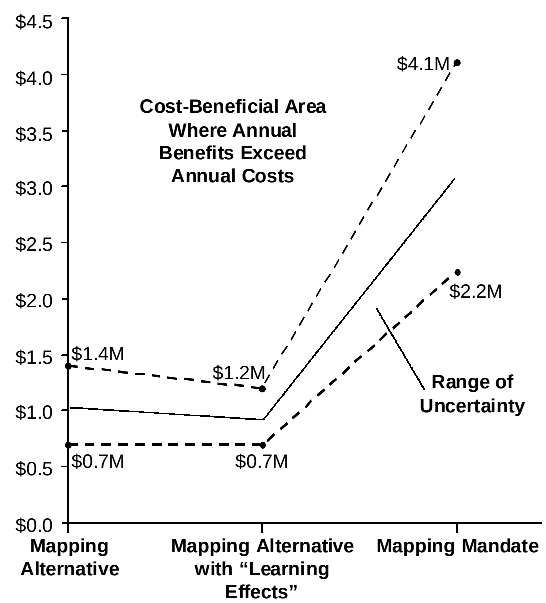
- *Indirect mapping benefits* are contingent upon the occurrence of other events, such as improvements to the quality of pipeline mapping data. Various benefits could indirectly result from improvements to: emergency response activities, risk assessments and environmental management, one-call performance, and pipeline business operations, among others. Further research is required to define the certainty and magnitude of these benefits.

- *Key uncertainties* associated with all mapping benefits include the uncertainties surrounding the quality of the mapping data, how mapping data will be used by different groups, and whether the use of mapping data will mitigate risks to pipeline systems.

Interpretation and Use of Cost-Benefit Results

This analysis provides quantified cost estimates and benefits that are expressed in qualitative terms. To make meaningful comparison between these results, OPS can evaluate likely differences between costs and benefits described above to determine the mix of costs and benefits required to create a program that is cost-beneficial. For example, if OPS makes a conservative assumption that the upper-end of the cost ranges associated with each mapping alternative represents a lower bound for the minimum benefits needed to make the mapping program cost-beneficial, then the present value of total benefits would need to equal, at minimum, from $1.2 million to $4.1 million per year (depending on the alternative chosen) for each of the twenty years of this analysis.

Cost-Benefit Summary of Pipeline Mapping Alternatives
(millions of dollars per year, in present value)



Effectiveness of the Analysis

Applying the OPS cost-benefit framework to this case study provided key "lessons learned" that can be used to improve and inform future analyses. These "lessons" include:

- Use of summary data.
- Value of collaborative approach.
- Quantitative assessment of OPS initiatives.
- Value of key process steps.

Appendix C:

Supporting Schedules

Appendix C-1
Mapping Costs to Industry

This worksheet shows the calculations used to estimate national (undiscounted) industry costs of mapping. These cost estimates were derived by using per mile costs provided by natural gas and liguids operators and extrapolating these estimates to national affected PL mileage. To extrapolate, two different weights were used to model the percentage of PL mileage that would be mapped on paper and electronically.

			Percentage Mapped/ Weight	Weighted Mileage	Weighted Average Cost per PL mile		No. of Operators	Total Undiscounted Costs (1995 dollars)
Natural Gas		Total Miles		**292,000**	Total of 11 operators			
	**	Paper1	0	0	Paper-low	$37	3	$0
		Paper2	0.1	29,200	Paper-high	$205	3	$5,986,000
	**	Electronic1	1	292,000	Electronic-low	$27	8	$7,884,000
		Electronic2	0.9	262,800	Electronic-high	$58	8	$15,242,400
					Weighted Average Cost per PL mile			
Liquid		Total Miles		**156,000**	Total of 12 operators			
	**	Paper1	0	0	Paper-low	$25	7	$0
		Paper2	0.15	23,400	Paper-high	$37	7	$865,800
	**	Electronic1	1	156,000	Electronic-low	$20	5	$3,120,000
		Electronic2	0.85	132,600	Electronic-high	$27	5	$3,580,200
Totals								
Nat gas-low				$7,884,000	Paper-low			$0
Nat gas-high				$21,228,400	Paper-high			$6,851,800
Liquids-low				$3,120,000	Electronic-low			$11,004,000
Liquids-high				$4,446,000	Electronic-high			$18,822,600
Total-low				**$11,004,000**	**Total-low**			**$11,004,000**
Total-high				**$25,674,400**	**Total-high**			**$25,674,400**

NOTES: **We assume two different possiblities, or weights, for the percentage of total PL mileage that will be mapped on paper and electronically (e.g., Paper1, Paper2).
Based on operator responses and other industry input, these percentages (weights) are higher for natural gas than liquid under both scenarios.
These weights are then used to develop the total undiscounted costs, which equal average costs per mile times the weighted pipeline mileage.
Total low-end costs are derived by using the low-end cost per PL mile and the lower assumption for percentage of mileage mapped.
Total high-end costs are derived by using of the high-end cost per PL mile and the higher assumption for percentage of mileage mapped.

Source: OPS pilot test and IEc analysis, 1998.

Appendix C-2
Mapping Costs to Government
(millions of 1995 dollars)

This worksheet shows calculations used to estimate discounted costs to OPS and to state governments.

OPS Costs	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Undiscounted	$1.2	$1.2	$0.4	$0.4	$0.8	$0.8	$0.8	$0.8	$0.6	$0.6	$0.6	$0.6	$0.6	$0.6	$0.6	$0.6	**$11.20**
Present Value, r = 7 percent	$1.2	$1.1	$0.3	$0.3	$0.6	$0.6	$0.5	$0.5	$0.3	$0.3	$0.3	$0.3	$0.3	$0.2	$0.2	$0.2	**$7.44**
Present Value, r = 3 percent	$1.2	$1.2	$0.4	$0.4	$0.7	$0.7	$0.7	$0.7	$0.5	$0.5	$0.4	$0.4	$0.4	$0.4	$0.4	$0.4	**$9.25**
State Costs																	
Undiscounted		$0.40	$0.40	$0.40	$0.15	$0.15											**$1.50**
Present Value, r = 7 percent		$0.4	$0.4	$0.4	$0.1	$0.1											**$1.39**
Present Value, r = 3 percent		$0.4	$0.4	$0.4	$0.1	$0.1											**$1.39**

Total Present Value, Government Costs

	Discount rate	
	7 percent	**3 percent**
OPS	$7.4	$9.3
States	$1.4	$1.4
Range of Total Government Costs	**$8.8**	**$10.7**

Source: OPS estimates and IEc analysis, 1998.

Appendix C-3
Discounted Costs to Industry
(in millions of 1995 dollars)

This worksheet shows the present value calculations used to estimate total *discounted* industry costs by summing totals for natural gas and liquid operators.

Undiscounted Industry Costs (from Appendix C-1)

Total-low	**$11,004,000**
Total-high	**$25,674,400**

Discounted Industry Costs

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Totals: Low-end	
Low Cost Scenario	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$660,240	$660,240	$660,240	$660,240	$660,240	**$11,004,000**	Undiscounted
Present Value, r = 7 percent	$700,255	$654,444	$611,629	$571,616	$534,221	$499,272	$466,609	$436,083	$407,555	$380,892	$355,974	$313,675	$293,154	$273,976	$256,052	$239,301	**$6,994,709**	PV-7 percent
Present Value, r = 10 percent	$700,255	$636,595	$578,723	$526,112	$478,283	$434,803	$395,275	$359,341	$326,674	$296,976	$269,978	$231,410	$210,373	$191,248	$173,862	$158,056	**$5,967,965**	PV-10 percent
																	Totals: High-end	
High Cost Scenario	$1,633,825	$1,633,825	$1,633,825	$1,633,825	$1,633,825	$1,633,825	$1,633,825	$1,633,825	$1,633,825	$1,633,825	$1,633,825	$1,540,464	$1,540,464	$1,540,464	$1,540,464	$1,540,464	**$25,674,400**	Undiscounted
Present Value, r = 7 percent	$1,633,825	$1,526,940	$1,427,046	$1,333,688	$1,246,438	$1,164,895	$1,088,687	$1,017,464	$950,901	$888,693	$830,554	$731,863	$683,984	$639,238	$597,418	$558,335	**$16,319,971**	PV-7 percent
Present Value, r = 10 percent	$1,633,825	$1,485,296	$1,350,269	$1,227,517	$1,115,925	$1,014,477	$922,252	$838,411	$762,192	$692,901	$629,910	$539,923	$490,839	$446,218	$405,652	$368,775	**$13,924,383**	PV-10 percent

NOTES: Under both the low- and high-cost scenarios, we assume 70 percent of industry costs are incurred from 1995 to 2001 and the remaining 30 percent are incurred from 2002 to 2010.
The low-cost scenarios are based on the low-end mapping costs and the low-end assumption about percentage of PL mileage mapped.
Conversely, the high-cost scenarios are based on the high-end mapping costs and the high-end assumption about percentage of PL mileage mapped.
Discount rates of seven and ten percent reflect estimates of the private cost of capital to the pipeline industry.

Source: IEc analysis, 1998.

Appendix C-4
Total Present Value of Mapping Costs
(in millions of 1995 dollars)

This worksheet shows the calculation of national discounted costs of various mapping scenarios, including the mapping initiative, the mapping mandate, and the mapping initiative with "learning" effects, using two discount rates. Total mapping costs equal the total costs to industry plus the total costs to government.

INDUSTRY

Mapping Initiative		Low-end
	7 percent	$7.0
	10 percent	$6.0
		High-end
	7 percent	$16.3
	10 percent	$13.9
Mapping Mandate		
	7 percent	$21.0
	10 percent	$18.0
	7 percent	$49.0
	10 percent	$41.8

GOVERNMENT

Total Percent Value		
of Government Costs	**Discount rate**	
	7 percent	**3 percent**
OPS	$7.4	$9.3
States	$1.4	$1.4
Range of Costs	**$8.8**	**$10.7**

Source: IEc analysis, 1998.

TOTAL: INDUSTRY PLUS GOVERNMENT

Mapping Initiative			**Industry**	**Government**	**Total**
Discount rate		*ind(gov)*	Low-end		
	low-end	7(3) percent	$7.0	$10.7	**$17.7**
	high-end	10(7) percent	$6.0	$8.8	**$14.8**
			High-end		
		ind(gov)			
	low-end	7(3) percent	$16.3	$10.7	**$27.0**
	high-end	10(7) percent	$13.9	$8.8	**$22.7**

Mapping Mandate			**Industry**	**Government**	**Total**
Discount rate		*ind(gov)*	Low-end		
	low-end	7(3) percent	$21.0	$32.1	**$53.1**
	high-end	10(7) percent	$18.0	$26.4	**$44.4**
		ind(gov)			
	low-end	7(3) percent	$48.9	$32.1	**$81.0**
	high-end	10(7) percent	$41.7	$26.4	**$68.1**

Mapping Initiative w/"Learning"			**Industry**	**Government**	**Total**
Discount rate		*ind(gov)*	Low-end		
	low-end	7(3) percent	$5.6	$10.7	**$16.3**
	high-end	10(7) percent	$4.8	$8.8	**$13.6**
		ind(gov)			
	low-end	7(3) percent	$13.0	$10.7	**$23.7**
	high-end	10(7) percent	$11.1	$8.8	**$19.9**

Appendix C-5

Calculation of Net Present Value of Mapping Benefits

COST/BENEFIT ANALYSIS

PROJECT TITLE :	Pipeline Mapping Alternative	02-Sep-99 09:49 AM

SOCIAL ECONOMIC PARAMETERS				
Discount Rate	3.0%			
Income Tax Rate	0%			
Depreciable Investment	0	Excludes Land		
Depreciation Life	3	3, 5, 7, 10, or 15 Years		
Depreciation Method	2	1 =	150%	ACRS
		2 = Straight Line		
INDUSTRY ECONOMIC PARAMETERS				
Discount Rate	7.0%			
Income Tax Rate	28%			
Depreciable Investment	0	Excludes Land		
Depreciation Life	3	3, 5, 7, 10, or 15 Years		
Depreciation Method	2	1 =	150%	ACRS
		2 = Straight Line		
Salvage Value	0	At End of Project Life		

SENSITIVITY VARIABLES	Mult	Base Case	SENSITIVITY
Social Benefit 1: Improved PL Oversight	100%	$600,000	$600,000
Social Benefit 2: Improved Emergency Response	150%	$800,000	$1,200,000
Social Benefit 3: Improved Public Confidence	167%	$1,500,000	$2,500,000
Costs to Government, OPS	100%	$1,200,000	$1,200,000
Costs to Government, States	100%	$400,000	$400,000
Depreciable Industry Capital Investment	100%	0	0
Non Depreciable Industry Capital	100%	0	0
Industry Benefit 1	100%	0	0
Industry Taxable Revenue 1	100%	0	0
Industry Costs: Pipeline Mapping Activities	233%	$700,255	$1,633,824
Industry Expenses 1	100%	0	0

SOCIAL BENEFITS		SENSITIVITY	YR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Social Benefit 1: Improved PL Oversight	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000					$9,600,000
Social Benefit 2: Improved Emergency Response	$800,000	$1,200,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000					$12,800,000
Social Benefit 3: Improved Public Confidence	$1,500,000	$2,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000					$24,000,000
TOTAL BENEFITS RECEIVED ====>	$2,900,000	$4,300,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000					$46,400,000
SOCIAL COSTS		**SENSITIVITY**	**YR 1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
Costs to Government, OPS	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$400,000	$400,000	$800,000	$800,000	$800,000	$800,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000					$11,200,000
Costs to Government, States	$400,000	$400,000	$400,000	$400,000	$400,000	$150,000	$150,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0					$1,500,000
TOTAL COSTS INCURRED ====>	$1,600,000	$1,600,000	$1,600,000	$1,600,002	$800,003	$550,004	$950,005	$800,006	$800,007	$800,008	$600,009	$600,010	$600,011	$600,012	$600,013	$600,014	$600,015	$600,016					$12,700,000
INDUSTRY BENEFITS		**SENSITIVITY**	**YR 1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
Industry Benefit 1	$0	0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0					
TOTAL BENEFITS RECEIVED ====>	$0	$0																					
Industry Taxable Revenue 1	0	0																					
TOTAL TAXABLE REVENUES ====>	0	0																					
INDUSTRY COSTS		**SENSITIVITY**	**YR 1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	
Industry Costs: Pipeline Mapping Activities	$700,255	$1,633,824	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255					$11,204,080
TOTAL INDUSTRY COSTS ====>	$700,255	$1,633,824	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255					$11,204,080
Industry Expenses 1	0	0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0					
TOTAL DEDUCTABLE EXPENSES ====>	0	0																					

Appendix C-5 (continued)

Calculation of Net Present Value of Mapping Benefits

COST/BENEFIT ANALYSIS

SOCIAL BENEFITS	YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Social Benefit 1: Improved PL Oversight			$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000					$9,600,000
Social Benefit 2: Improved Emergency Response			$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000					$12,800,000
Social Benefit 3: Improved Public Confidence			$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000	$1,500,000					$24,000,000
Total Social Benefits:			$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000					$46,400,000
SOCIAL COSTS	**YEAR**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**TOTAL**
Costs to Government, OPS			$1,200,000	$1,200,000	$400,000	$400,000	$800,000	$800,000	$800,000	$800,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000					$11,200,000
Costs to Government, States			$400,000	$400,000	$400,000	$150,000	$150,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0					$1,500,000
Total Social Costs:			$1,600,000	$1,600,000	$800,000	$550,000	$950,000	$800,000	$800,000	$800,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$0	$0	$0	$0	$12,700,000
SOCIAL NET CALCULATION	**YEAR**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**TOTAL**
Total Social Benefits:			$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000					$46,400,000
Total Social Costs::			$1,600,000	$1,600,000	$800,000	$550,000	$950,000	$800,000	$800,000	$800,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000	$600,000					$12,700,000
Undiscounted Net = Benefits - Costs			$1,300,000	$1,300,000	$2,100,000	$2,350,000	$1,950,000	$2,100,000	$2,100,000	$2,100,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000					$33,700,000
Discounted Factor at: 3.0%		1.000	0.971	0.943	0.915	0.888	0.863	0.837	0.813	0.789	0.766	0.744	0.722	0.701	0.681	0.661	0.642	0.623					
Discounted Social Net:			$1,262,136	$1,225,375	$1,921,797	$2,087,945	$1,682,087	$1,758,717	$1,707,492	$1,657,759	$1,762,758	$1,711,416	$1,661,569	$1,613,174	$1,566,188	$1,520,571	$1,476,282	$1,433,284					$26,048,551
INDUSTRY BENEFITS	**YEAR**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**TOTAL**
Industry Benefit 1			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0					$0
Total Industry Benefits:			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0					$0
INDUSTRY COSTS	**YEAR**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**TOTAL**
Industry Costs 1: Mapping Alternative Costs			$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255					$11,204,080
Total Industry Costs:			$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255	$700,255					$11,204,080
Industry Expenses 1			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0						$0
Total Expenses:			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0						$0
INDUSTRY INCOME CALC	**YEAR**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**TOTAL**
Profit Before Tax and Depreciation																							0
Depreciation (Straight Line)																							0
Profit Before Tax			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					0
Federal Income Tax at 28%			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					0
Profit after Tax			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					0
INDUSTRY NET CALCULATION	**YEAR**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**TOTAL**
Industry Benefits			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0					$0
less Industry Costs			-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255					-$11,204,080
less Depreciation and Federal Tax			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0					$0
Undiscounted Net = Benefits - Costs			-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255	-$700,255					-$11,204,080
BENEFIT / COST CALCULATION	**YEAR**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**TOTAL**
Discounted Factor at: 3.0%		1.000	0.971	0.943	0.915	0.888	0.863	0.837	0.813	0.789	0.766	0.744	0.722	0.701	0.681	0.661	0.642	0.623					
Discounted Factor at: 7.0%		1.000	0.935	0.873	0.816	0.763	0.713	0.666	0.623	0.582	0.544	0.508	0.475	0.444	0.415	0.388	0.362	0.339					
Social Benefits discounted at 3.0%			$2,815,534	$2,733,528	$2,653,911	$2,576,612	$2,501,565	$2,428,704	$2,357,965	$2,289,287	$2,222,609	$2,157,872	$2,095,022	$2,034,002	$1,974,759	$1,917,242	$1,861,400	$1,807,184					$36,427,196
Industry Benefits discounted at 7.0%			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
TOTAL BENEFITS:			$2,815,534	$2,733,528	$2,653,911	$2,576,612	$2,501,565	$2,428,704	$2,357,965	$2,289,287	$2,222,609	$2,157,872	$2,095,022	$2,034,002	$1,974,759	$1,917,242	$1,861,400	$1,807,184					$36,427,196
Social Costs discounted at 3.0%			$1,553,398	$1,508,153	$732,113	$488,668	$819,478	$669,987	$650,473	$631,527	$459,850	$446,456	$433,453	$420,828	$408,571	$396,671	$385,117	$373,900					$10,378,645
Industry Costs discounted at 7.0%			$654,444	$611,630	$571,617	$534,221	$499,272	$466,609	$436,084	$407,555	$380,892	$355,974	$332,686	$310,922	$290,581	$271,571	$253,805	$237,201					$6,615,063
Industry Expenses discounted at 7.0%			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0					$0
Depreciation discounted at 7.0%			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0					$0
Federal Income Tax discounted at 7.0%			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0					$0
TOTAL COSTS:			$2,207,842	$2,119,783	$1,303,730	$1,022,889	$1,318,750	$1,136,597	$1,086,557	$1,039,082	$840,742	$802,430	$766,139	$731,750	$699,152	$668,242	$638,922	$611,101					$16,993,708
NET PRESENT VALUE OF BENEFITS===>>>			**$607,692**	**$613,745**	**$1,350,181**	**$1,553,723**	**$1,182,815**	**$1,292,107**	**$1,271,409**	**$1,250,205**	**$1,381,866**	**$1,355,442**	**$1,328,883**	**$1,302,252**	**$1,275,607**	**$1,249,000**	**$1,222,478**	**$1,196,083**					**$19,433,488**

Appendix D:

Discount Factor Table

Appendix D
Discount Factor Table

	Present Value of $1000				Discount factor		
Year	*3 percent*	*7 percent*	*10 percent*	**Year**	*3 percent*	*7 percent*	*10 percent*
0	$1,000	$1,000	$1,000	0	1.000	1.000	1.000
1	$971	$935	$909	1	0.971	0.935	0.909
2	$943	$873	$826	2	0.943	0.873	0.826
3	$915	$816	$751	3	0.915	0.816	0.751
4	$888	$763	$683	4	0.888	0.763	0.683
5	**$863**	**$713**	**$621**	**5**	**0.863**	**0.713**	**0.621**
6	$837	$666	$564	6	0.837	0.666	0.564
7	$813	$623	$513	7	0.813	0.623	0.513
8	$789	$582	$467	8	0.789	0.582	0.467
9	$766	$544	$424	9	0.766	0.544	0.424
10	**$744**	**$508**	**$386**	**10**	**0.744**	**0.508**	**0.386**
11	$722	$475	$350	11	0.722	0.475	0.350
12	$701	$444	$319	12	0.701	0.444	0.319
13	$681	$415	$290	13	0.681	0.415	0.290
14	$661	$388	$263	14	0.661	0.388	0.263
15	**$642**	**$362**	**$239**	**15**	**0.642**	**0.362**	**0.239**
16	$623	$339	$218	16	0.623	0.339	0.218
17	$605	$317	$198	17	0.605	0.317	0.198
18	$587	$296	$180	18	0.587	0.296	0.180
19	$570	$277	$164	19	0.570	0.277	0.164
20	**$554**	**$258**	**$149**	**20**	**0.554**	**0.258**	**0.149**
21	$538	$242	$135	21	0.538	0.242	0.135
22	$522	$226	$123	22	0.522	0.226	0.123
23	$507	$211	$112	23	0.507	0.211	0.112
24	$492	$197	$102	24	0.492	0.197	0.102
25	**$478**	**$184**	**$92**	**25**	**0.478**	**0.184**	**0.092**
26	$464	$172	$84	26	0.464	0.172	0.084
27	$450	$161	$76	27	0.450	0.161	0.076
28	$437	$150	$69	28	0.437	0.150	0.069
29	$424	$141	$63	29	0.424	0.141	0.063
30	**$412**	**$131**	**$57**	**30**	**0.412**	**0.131**	**0.057**

Sources: IEc analysis, 1999.

Notes: To calculate the present value of $1,000 for each of the discount rates shown above, the following formula is used:

$$\textit{Present Value of \$1,000} = \frac{\$1{,}000}{(1+r)^n}$$

where r equals the discount rate (e.g., 3 percent) and n is the time period in which the $1,000 is received (e.g., year 20).