SOCIO-ECONOMIC ANALYSIS OF PROPOSED UPDATED CRITERIA CANADA-WIDE STANDARD FOR PETROLEUM HYDROCARBONS IN SOIL

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EXECUTIVE SUMMARY

The Canada-wide Standard (CWS) for Petroleum Hydrocarbons (PHC) in Soil was developed in 2000 by the Canadian Council of Ministers of the Environment (CCME) and was endorsed by the provincial and territorial environment ministers (with the exception of Quebec) in May 2001. Development of the original PHC CWS included a commitment to undertake a five-year review with the aim of updating the standard to reflect new scientific, technical and economic information. The review commenced in the fall of 2005 and culminated in the recommendation in late 2006 of a revised standard containing updated numerical criteria. The revised standard is expected to be finalized in 2007.

A socio-economic analysis has been completed in order to evaluate and compare the costs and benefits of implementing the current (2000) and proposed updated (2007) PHC CWS. Costs of remediation have been estimated by determining the remediation requirements for a number of scenarios, representing a range of PHC contaminated sites, under the 2000 and proposed 2007 standard. Using data from actual sites, provided by industry, remediation requirements and costs have been determined regionally for each scenario, and aggregated across the various industry sectors and on a national basis, in order to determine the total cost to remediate presently existing PHC contaminated sites to the 2000 and 2007 standards. The overall remediation costs have been compared to remediation industry data to determine the capacity of the industry to perform the work, and the likely timeline over which the work can be completed. The benefits of remediation, not only to the remediation industry, but also to operators, land owners, municipalities and the public, have also been considered, primarily in a qualitative manner.

In summary, the results of the socio-economic analysis indicate that the effects of the proposed 2007 revisions to the PHC CWS on overall remediation costs for PHC contaminated sites across Canada are relatively small. Total undiscounted remediation costs for all industries, in constant 2006 dollars, are projected to increase from $40.1 billion to $40.6 billion, an increase of approximately 1.4%. Costs for the remediation of upstream sites comprise approximately 82% of the total, and are projected to increase slightly (1.0%). Remediation costs for downstream sites and other (government, commercial and residential) sites represent 6% and 12% of the total costs, respectively; the respective increases in these costs are forecast to be 2.6% and 3.1%.

The very small increase in costs for upstream sites is attributed to the proposed increase in the F3 criteria and decrease in the F2 criteria for a number of the soil type, land and water use combinations. This results in a shift of governing fraction from F3 to F2. For downstream sites, the slightly greater increase in costs is due in part to the decrease in F2 criteria as well as a decrease in the F1 values for certain scenarios.

The estimated magnitude of remediation work associated with PHC contaminated sites is projected to exceed the current annual capacity of the remediation industry by more than 57 times. If reasonable growth in the sector is considered, the estimated time to complete remediation of all existing sites is approximately 30 years on a national basis. However, the largest PHC contaminated site liabilities are in the provinces with large upstream oil and gas industries; those provinces also have relatively small remediation industries in comparison with estimated remediation requirements, which may necessitate geographic redistribution of resources in order to meet demand.

Aside from the direct benefits to the remediation industry flowing from the expenditure of remediation costs, the primary tangible or monetizable benefits are the elimination or reduction of operators' balance sheet liabilities associated with contaminated sites and the increase in land values and/or revenues from productive land. The difference in market value between a contaminated site and the same site in an unimpacted or remediated condition is generally considered to be equal to the cost of remediation; the increase in land value in most cases is equal to the cost of remediation. In most cases, therefore, there is no net monetizable benefit to the economy as a whole associated with the remediation of a contaminated site, although the benefit may be transferred between stakeholders. Exceptions to the above apply in situations where the remediation cost exceeds the market value of the property, or in situations where remediation results in an added increase in land value due to the ability to redevelop the land for a more intensive and/or profitable purpose (e.g. low density commercial to high-rise residential).

Due to the neutrality of costs and benefits in most situations, and the difficulty in assessing the exceptions on a generic basis, the net benefits associated with increased land values have been discussed qualitatively herein but have not been quantified. Other societal benefits include improvements in health and environmental quality, increased enjoyment of the land, elimination or reduction of blight and reduction in contingent liabilities related to the potential for adverse impact. These are generally not considered to be monetizable benefits.

The estimation of overall remediation costs is subject to a number of uncertainties arising from variability in conditions and remediation requirements between sites and across regions, as well variability in remediation unit costs. Those factors contributing significantly to the variability in overall cost include remediation unit costs, particularly for upstream sites, and the estimated soil remediation volumes associated with different scenarios. The variability of some of these factors has been characterized herein on the basis of actual data and used in a probabilistic analysis of total costs. This has permitted the generation of a probability distribution of total projected remediation costs. The median cost on a national basis is \$37.8 billion, and upper and lower deciles (90^{th} and 10^{th} percentiles) are \$134.1 billion and \$14.3 billion respectively

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1.0 INTRODUCTION

1.1 Background

The Canada-wide Standard (CWS) for Petroleum Hydrocarbons (PHC) in Soil was developed in 2000 by the Canadian Council of Ministers of the Environment and was endorsed by the provincial and territorial environment ministers (with the exception of Quebec) in May 2001 (CCME, 2001). The PHC CWS is a risk-based remediation standard that identifies acceptable PHC concentrations in soil for the protection of human and ecological receptors under various land and water uses. In addition to the protection of human health and the environment, the standard is also based on policy and socio-economic considerations.

Development of the original PHC CWS included a commitment to undertake a five-year review with the aim of updating the standard to reflect new scientific, technical and economic information. The review commenced in the fall of 2005 and was undertaken by the Soil Quality Guidelines Task Group, with the support of three multi-stakeholder Advisory Subgroups and culminated in the recommendation in late 2006 of a revised standard containing updated numerical criteria (CCME, 2007). The revised standard is expected to be finalized in 2007, and is referred to hereafter as the 2007 standard.

The original PHC CWS was supported by a socio-economic analysis to estimate the costs and benefits of applying the standard to PHC contaminated sites in Canada (Komex, 2000). The purpose of the present study is to assess the costs and benefits associated with the proposed revised standard, and the effects of the proposed changes from 2000 to 2007.

1.2 Objectives and Scope of Work

The objective of the study is to evaluate and compare the costs and benefits of implementing the current (2000) and proposed updated (2007) PHC CWS. Costs of remediation are estimated by determining the remediation requirements for a number of scenarios, representing a range of PHC contaminated sites, under the 2000 and proposed 2007 standard. Using data from actual sites, provided by industry, remediation requirements and costs are determined regionally for each scenario, and aggregated across the various industry sectors and on a national basis, in order to determine the total cost to remediate presently existing PHC contaminated sites to the 2000 and 2007 standard. The overall remediation costs are compared to remediation industry data to determine the capacity of the industry to perform the work. Projected timelines for completion of remediation are assessed. The benefits of remediation, not only to the remediation industry, but also to operators, land owners, municipalities and the public, are also considered, primarily in a qualitative manner. Conclusions are presented with respect to the overall socio-economic impacts of the proposed changes to the standard.

1.3 Summary of Proposed Changes to PHC CWS

Changes have been proposed to a number of pathway-specific numerical criteria for various PHC fractions as recommended by the advisory subgroups and the SQGTG. Changes are based primarily on modified modelling procedures, revised assumptions and new scientific information on the physical, chemical and toxicological behavior of the fractions. However, some additional criteria have been developed based on policy and management considerations.

The proposed 2007 numerical values are presented in Tables 1.1 and 1.2 for coarse grained and fine grained surface soils, respectively. The existing 2000 numerical values are also presented in the tables for comparison.

1.4 Significance of Proposed Changes to PHC CWS

A number of the criteria (as proposed) have decreased, others have remained the same, and a smaller number of values have increased. The effect of a proposed change in the numerical criterion for a specific fraction on remediation requirements for a given site is not always readily apparent or unique, since it will depend on the governing PHC fraction(s) for each facility, soil type and land and water uses.

One of the main components of the present study is to identify the overall effect of changes in the numerical values on soil remediation volumes for different facility types under various land and water use and soil type scenarios. Selection of the scenarios is described in Section 3.0. The significance of changes in the numerical values depends not only on the governing PHC fraction(s), but also on the applicable pathways (based on land and water use) and on the magnitude of the numerical changes. Given the inherent uncertainty and/or potential error in determining PHC concentrations and the extent of PHC contamination in excess of a particular guideline value, it is considered for the purposes of this study that changes of less than 20% in a guideline value are essentially insignificant. Changes of between 20% and 200% are considered of low to moderate significance and changes of greater than 200% are considered highly significant.

Table 1.3 presents a comparison of the governing criteria for PHC fractions F1 through F4, between 2000 and 2007 (proposed) for various combinations of land and water use. Changes of low to moderate and high significance are highlighted, as are significant increases in numerical values. The table facilitates identification of the likely significance of criteria changes under different scenarios. A similar exercise was performed to compare subsoil criteria; this table is not presented herein.

A number of observations can be made from the comparisons in Table 1.3. In fine grained soils, the presence of an aquatic life exposure pathway has no effect on the applicable criteria. The drinking water pathway is significant with respect to remediation requirements under the 2000 standard and less significant under the proposed 2007 values. On the other hand, for coarse grained soils, the aquatic life pathway is more important than the drinking water pathway, except in the case of residential or agricultural land use where vapour inhalation is the governing exposure pathway. Changes between 2000 and 2007 differ in magnitude (i.e. significance) for different PHC fractions. The governing fractions will depend in part on the hydrocarbon mixtures present, which is largely a function of facility type.

2.0 OVERVIEW OF METHODOLOGY FOR SOCIO-ECONOMIC ANALYSIS

2.1 General

The objective of the socio-economic analysis (SEA) is to determine the costs and, to the extent possible, the benefits of implementing the proposed 2007 revisions to the standard, in comparison with the costs and benefits associated with the 2000 standard. The analysis involves five main components:

- Determination of the estimated remediation costs associated with meeting the 2000 standard and proposed 2007 revisions for different facility types in different settings
- Aggregation of remediation costs across industry sectors and on a regional and national basis
- Projections of timing of remediation, based on capacity of the remediation industry and other constraints, and assessment of discounted costs and residual liabilities
- Discussion and, where possible, quantification of benefits of achieving the 2000 and proposed 2007 standards
- Analysis of the effect of the proposed revisions on costs and benefits, including the effects of changes in individual PHC fraction criteria and the sensitivity of the analysis to uncertainties.

The overall approach to each of these components is summarized below and is described in detail in subsequent sections of the report.

2.2 Determination of Estimated Remediation Costs by Facility Type and Setting

The estimation of remediation costs serves as the basis for all subsequent aspects of the analysis. The process involved the collection of industry data on volumes of soil, at actual sites or facilities, that would require remediation to meet the 2000 and 2007 numerical criteria. Industry data were compiled for a number of scenarios, comprising different combinations of facility type, land and water use, and soil type, each of which would generally lead to the selection of different governing criteria. Scenarios were selected to ensure representation of the conditions most likely to be encountered in different industries and regions. Additional scenarios were identified in order to assess the sensitivity to the exclusion of a particular pathway or modification of a pathway criterion. Not all possible combinations of facility type, land and water use and soil type were designated for industry data collection; some scenarios were equivalent or similar to one another in terms of governing numerical criteria, and data sets for these could be generated by extrapolation. A review of typical unit costs for soil remediation was undertaken and applied to the soil volumes determined from the data capture process.

2.3 Aggregation of Remediation Costs by Industry Sector, Regionally and Nationally

The frequency or incidence of different site settings (land use, water use and soil type) was estimated by region for each facility type using geographic and/or demographic data and other available information. In this way, a weighted average cost for remediation of each facility type was determined that could be aggregated across each industry sector by region and nationally. The objective of this was to obtain an estimate of the overall magnitude of remediation costs associated with the 2000 and 2007 standards, as well as the cost implications of the proposed changes. A spreadsheet model, referred to as the "basic remediation cost model" was developed for this purpose and is described further in Section 4.0.

2.4 Cost-Time Analysis

The outcome of the basic remediation cost model is an undiscounted cost applicable to immediate remediation. In reality, remediation will occur over a number of years, due both to constraints in the capacity of the remediation industry and to phasing of remediation by owners and operators based on operational and business considerations. Taking these considerations into account, the annual remediation volume by industry sector has been projected and a discounted present value of overall remediation costs as well as residual liability (unremediated sites remaining after a period of time) is estimated.

2.5 Discussion and Quantification of Benefits

The benefits associated with remediation of sites in different regions and site settings are discussed. Benefits are discussed qualitatively for the most part although, where possible, certain monetizable benefits have been quantified. Monetizable benefits in the context of this SEA include increased land values or revenues from return to productive land use, revenues to the remediation sector and reduction in liabilities to industry for unremediated land. However, many categories of benefits are less amenable to quantification (such as reductions in human health risk and environmental impairment or blight). Benefits are discussed in the context of both the 2000 and proposed 2007 standards.

2.6 Analysis and Evaluation of Results

The results from the basic remediation cost model, coupled with the cost-time analysis and discussion of benefits, have been analyzed with the aim of assessing the overall effect of the proposed changes in the standard. Specific issues addressed include the increase or decrease in cost, to various industry sectors and regions, of changes in the numerical criteria, the influence of changes in the individual fraction criteria on remediation requirements, and the effects of uncertainties in the data collection, assumptions and modelling.

3.0 IDENTIFICATION OF SCENARIOS AND INDUSTRY DATA CAPTURE PROCESS

3.1 General

The scenarios used to represent the facilities and settings most likely to be encountered in the various industry sectors and regions were initially identified by a project steering group comprising SQGTG, representatives of the Canadian Association of Petroleum Producers (CAPP) and the Canadian Petroleum Products Institute (CPPI), in consultation with the authors of the present study. Facility types were selected to ensure a distinction between operations where different hydrocarbon mixtures would be produced or handled (e.g. crude oil vs. refined motor fuels). The scenarios were categorized as "dominant" and "minor". Dominant scenarios were those considered likely to be representative of a majority of sites, i.e. wellsites and service stations, and encompassing the major portion of total remediation costs. Sufficient combinations of site conditions and settings were identified to minimize the amount of extrapolation required between scenarios and hence avoid the compounding of uncertainties as a result of the large number of sites. Due to the smaller number of sites and/or lower estimated soil remediation volumes associated with minor scenarios (e.g. residential heating oil tanks), the uncertainties introduced by extrapolating between scenarios are likely to be less significant; therefore fewer minor scenarios were required and fewer industry data sets were requested for each scenario. The procedures for defining the scenarios, collecting the industry data, and extrapolating between scenarios are described in the following sections.

3.2 Dominant Scenarios

Each dominant scenario was defined in terms of a primary identifier (A, B, C or D) representing a facility type, soil texture and typical or default land use, and a secondary identifier based on groundwater use and potential modifications to other exposure pathways. Both fine and coarse grained soil textures were considered for both types of facility (wellsites and service stations). A single land use setting, based on the most probable land use, was applied in each case. For instance, agricultural land use was applied to wellsites based on their predominantly rural settings, whereas commercial land use was selected for services stations to reflect urban settings. However, sufficient contrasting scenarios were felt to have been defined to permit other combinations of factors to be assessed. Groundwater uses include combinations of drinking water and aquatic life. Modifications to other exposure pathways were intended to address unique situations or potential jurisdictional modifications to criteria. These include: exclusion of the indoor vapour inhalation pathway; inclusion of ecological soil contact below a depth of 3 m (representing a full depth as opposed to stratified remediation scenario); and an increased ecological soil contact value between depths of 1.5 m and 3 m (representing a variation on stratified remediation). The primary and secondary identifiers for the dominant scenarios, as adopted and defined by the project steering group, are defined in Table 3.1.

A complete set of combinations of primary and secondary modifiers would yield 28 scenarios. In order to minimize the level of effort and reduce duplication in collecting industry data pertaining to contaminated soil volumes, a number of scenarios were excluded from the data capture process where they were considered identical or similar to other scenarios or where soil volumes could be estimated by extrapolation. The 2000 and proposed 2007 numerical criteria were considered in selecting scenarios for exclusion, along with the significance of the proposed changes from 2000 to 2007 as discussed in Section 1.4. A total of 15 cases were retained for data capture. These are defined in Table 3.2. Table 3.3 summarizes those cases that were excluded, and provides a brief rationale for their exclusion. Further details on the extrapolation of data between scenarios are provided in a subsequent section.

3.3 Minor Scenarios

Similar to the dominant scenarios, the minor scenarios were also defined in terms of a primary identifier and secondary identifier. Primary identifiers (E through J) again considered facility types (satellite/battery, bulk plant, residential heating oil tank), along with soil texture (both fine and coarse for each facility type) and most probable land use. Groundwater uses included all combinations of drinking water and aquatic life, although no other exposure pathway modifications were considered in the minor scenarios. Given the fact that the overall remediation costs for sites encompassed by the minor scenarios are expected to be less sensitive to uncertainties or extrapolation, as noted above, the 24 possible combinations of primary and secondary identifiers were reduced to 7 scenarios for data capture purposes. Table 3.4 lists the minor scenarios that were used for data capture, and Table 3.5 summarizes those cases that were excluded, with supporting rationale.

3.4 Other Scenarios

Additional scenarios were defined for four additional facility types: refineries, gas plants, government facilities and commercial tank sites. However, these were not used in the data capture process given their more limited occurrence and the fact that any industry data that could be compiled for such facilities would likely be statistically less representative than for the other facility types. Estimates of soil remediation volumes for these facilities were done strictly by extrapolation. Table 3.1 lists these additional scenarios.

3.5 Compilation of Estimated Soil Remediation Volumes for Major and Minor Scenarios

Estimated soil remediation volumes for major and minor scenarios were compiled based on actual site data collected from industry. The industry data capture process was conducted in consultation with CAPP and CPPI. Participating member companies were asked to estimate soil volumes exceeding the 2000 and proposed 2007 numerical standards for actual sites representative of the major and minor scenarios identified above. Specifically, the following basic information was requested for each site:

- Estimated soil volume exceeding 2000 numerical standards for each PHC fraction (F1 through F4) as well as a generic benzene criterion
- Estimated soil volume exceeding 2000 standards for any PHC fraction
- Estimated soil volume exceeding 2000 criteria for any PHC fraction or benzene
- Estimated soil volume exceeding 2007 numerical standards for each PHC fraction (F1 through F4) as well as a generic benzene criterion
- Estimated soil volume exceeding 2007 standards for any PHC fraction
- Estimated soil volume exceeding 2007 criteria for any PHC fraction or benzene

The benzene criterion was introduced in order to identify cases in which benzene dominates the requirement for remediation, whereby proposed changes in the values for individual PHC fractions may not influence soil remediation volumes. A standardized generic benzene guideline was adopted for each scenario, although it is recognized that actual benzene guidelines vary by province. The values were based on the CCME guideline values for benzene, with modifications to reflect jurisdictional decisions (e.g. target cancer risk level) to the greatest extent possible, while remaining broadly applicable. The criteria used to estimate soil remediation volumes are presented in Tables 3.2 and 3.4 for the dominant and minor scenarios, respectively.

The objective was to compile a total of approximately 20 data sets for each of the dominant scenarios and 5 data sets for each of the minor scenarios. The participating companies were advised that it was not necessary for each scenario be represented by a unique site. Data for a given site, representing a particular facility type and soil texture (e.g. a service station underlain by fine grained soils – major identifier “C”), could be used to estimate soil remediation volumes for all scenarios having the same major identifier (i.e. C1 through C7), since the process simply involved comparing the site data with different combinations of soil criteria.

The actual numbers of data sets submitted by industry varied from the original target; the numbers of data sets received for each scenario are summarized in Tables 3.6 and 3.7. The actual data received are tabulated by scenario, without reference to source, in Appendix A.

It is noted that, although the above process yields contaminated soil volumes associated with the 2000 and 2007 criteria for each fraction (as well as the generic benzene value), these soil volumes are likely to overlap in practice, and the overall remediation requirements for a given site is dictated by the volume of soil exceeding any one or more of the fractions or benzene rather than the sum of the individual fraction-specific volumes. For the purposes of the initial estimation of remediation costs (discussed in the following section), only these total volumes for 2000 and 2007 were carried forward into the analysis. Subsequent analysis of the effect of individual fraction criteria was also performed, however, and is discussed in Section 7.3. A summary of the soil remediation volumes exceeding the criteria for any PHC fraction or benzene is presented, for each scenario used in the data capture process, in Tables 3.6 and 3.7, for the 2000 and 2007 criteria respectively.

4.0 ESTIMATION OF REMEDIATION COSTS

4.1 General

A spreadsheet model, the “basic remediation cost model” was developed to extend the total soil remediation volumes obtained from the industry data capture process to estimated remediation costs by scenario and, ultimately, facility type by industry sector and on a regional and nationally aggregated basis. The structure of the basic remediation cost model is illustrated schematically in Figure 4.1. The following sections describe the major components in the estimation of remediation costs.

Note that all costs are expressed in 2006 dollars. They therefore represent the costs at the same point in time of meeting the 2000 and proposed 2007 standards, not the costs of remediation in each of the respective years.

4.2 Regional Distributions of Site Settings and Land/Water Use Scenarios

Each scenario defined previously, and for which soil remediation volumes were estimated, represents a unique combination of facility type, land use, water use and soil texture. In order to obtain representative remediation costs for a particular facility type within a region, on either an average or aggregate basis, the incidence or frequency of occurrence of each scenario must be determined. For instance, of all the wellsites in a given province, *a*% may be represented by scenario A1, *b*% by scenario A2 and so on. The frequency of occurrence of the scenarios is a function of a number of geographic and demographic factors. A complete characterization of these fractions is beyond the scope of the present project. Instead, a number of assumptions have been made on the basis of professional judgement, anecdotal information and readily available demographic information (e.g. census data) in order to estimate these frequencies of occurrence. The general logic of the estimation process is described briefly below. The basis for the assumptions is described in Section B1, Appendix B.

Assumptions were made as to the distribution of each facility type amongst three different site settings (urban, rural and remote) within each province or territory. For each province or territory, the distribution of expected groundwater use (potable groundwater use vs. no potable groundwater use; surface water sustaining aquatic life vs. no surface water) was estimated for each of the three settings. By combining these distributions, the four combinations of water use could be apportioned amongst each facility type. The estimated percentages of sites underlain by fine textured versus coarse textured soils were also estimated by facility type and region. Combining the latter percentages with the various combinations of water uses enabled the complete distribution of facility type by scenario to be determined for each province or territory. Given the subjective nature of this process, a sensitivity analysis was conducted to assess the influence of the key assumptions on the overall results of the basic remediation cost model.

The final scenario distributions by facility type and region are summarized in Table 4.1. The values given are percentages for each soil texture and water use combination; the percentages for a given facility type sum to 100%.

4.3 Extrapolation of Soil Volumes to Other Scenarios

As discussed previously, scenarios for which soil remediation volumes could be estimated by extrapolation from other scenarios were excluded from the industry data capture process. The extrapolation of data was, in most cases, based on the identification of a scenario with conditions leading to identical or similar remediation requirements. In a few cases, such as where data were collected for a fine textured soil but the corresponding coarse textured scenario was excluded, the extrapolation was based on coarse/fine soil volume ratios for other relevant facilities. Soil volumes for the “other” scenarios, described previously in Section 3.4, were estimated on the basis of data for different facility types within the same industry sector (i.e. upstream or downstream) under corresponding land and water use conditions. These data were adjusted using ratios of typical volumes for similar pairs of facility types reported by Komex (2000) in the earlier socio-economic analysis.

Table 4.2 lists the scenarios excluded from the data capture process, together with the basis for extrapolating the soil remediation volume data to those scenarios. Soil remediation volumes estimated on this basis were then input to the basic remediation cost model along with the actual industry data described in Section 3.5.

4.4 Remediation Unit Costs

Typical unit costs for soil remediation have been estimated on the basis of information obtained from a number of sources. Remediation costs vary by region, and are also a function of the proposed remediation method. Although a broad range of remediation methods are applicable to PHC contaminated sites in both the upstream and downstream sectors, it is felt that the overall costs of remediation can be characterized by considering the methods most commonly applied to the main categories of sites. Remediation methods and the basis for the unit cost information are discussed briefly in the following paragraphs. Note that long term risk management, while appropriate in some situations, is not considered herein as a primary method of achieving the prescribed remediation criteria.

Upstream sites

Soil remediation at upstream sites is typically conducted using excavation and either ex situ treatment (land treatment or landfarming) or disposal (landfilling). The choice of method and resulting costs depend on a number of factors including nature of the contamination, availability of a suitable area for land treatment, and hauling distance to an appropriate landfill. In some cases, other methods such as in situ remediation or monitored natural attenuation may be used, particularly for groundwater. However, since the primary focus of the present study is the cost to achieve the applicable numerical standard in soil, the costs are based on the above ex situ methods. In general, soils affected by the lighter PHC fractions (F1 and F2) or BTEX are more amenable to remediation by land treatment which, if feasible, is typically more economical. However, when significant concentrations of the heavier fractions (F3 and F4) are present, the concentrations often cannot be reduced sufficiently by treatment, and disposal is required. In many cases a combination of treatment and disposal is used. In a few cases, specialized methods such as thermal desorption may be used; however, the costs associated with such methods are not considered likely to influence average industry costs significantly, and these methods are not addressed further herein.

A review of remediation costs compiled as part of a confidential industry data set of abandonment and reclamation costs provided by CAPP (CAPP, 2007a) revealed that overall unit costs were reflective of a combination of land treatment and disposal, which is also supported by professional judgement and experience. Although the above-referenced data set provides some limited information on variation in cost with region and location (i.e. haul distance), there did not appear to be a reliable correlation between remediation cost and remoteness of site. Therefore, for the purpose of the present analysis, an overall unit cost was considered appropriate for remediaton of upstream sites. The review suggested that remediation costs tend to be lognormally distributed, with a median unit cost of $\$122.1/m^3$; other statistical parameters are summarized in Table 4.3. The value selected for use in this study was the mean unit cost for the aggregate volume of soil reported as remediated in the data set ($\$90.9/m^3$), rather than the mean of the individual site-specific unit costs. The latter is considered to be biased upwards by a significant number of small-volume remediation projects. Unit costs are assumed to include assessment costs.

Downstream sites

Remediation at downstream sites (which include government and commercial facilities as well as residential heating oil tanks) is also commonly conducted by excavation and disposal or ex situ treatment. Ex situ treatment may be less common in urban areas due to the availability of space. However, it can often be accomplished in a shorter period of time at downstream sites due to the prevalence of lighter PHC fractions (F1 and F2) and the availability of treatment methods such as mechanical aeration. In situ methods are also commonly used at downstream sites. Methods include soil vapour extraction, enhanced bioremediation, chemical oxidation and monitored natural attenuation. These methods are particularly suited to situations with access problems, e.g. where contaminant plumes extend beneath buildings and roadways, or at operating sites where excavation is not considered practical or desirable and longer term methods are more consistent with eventual closure plans. Experience has shown that, given the time required for achieving remediation using longer term methods, the unit costs for such methods may be similar to, or greater than, the costs of ex situ methods. The costs for excavation and landfill disposal are considered to provide a reasonably representative estimate of typical costs in the downstream sector of the industry.

An objective, defensible source of remediation cost information for downstream sites was not identified in the public domain. Previous studies of remediation costs have been conducted by CPPI (CPPI, 1993 – cited in Komex, 2000; OAEI, 1998) but unit cost data are relatively limited as costs are expressed as total per site costs. Unit cost information for more recent remediation projects is available in our project files and those of a number of CPPI member companies contacted during the present study. However, this information cannot be cited for confidentiality reasons. Selected remediation contractors and landfills were contacted on a regional basis in an attempt to compile typical unit cost data, but the information was not found to be meaningful in the absence of specific projects for which contractor quotes could be provided. A more structured approach to obtaining contractor cost data was beyond the scope of the present study.

Based on the lack of definitive unit cost information, typical costs for use in this study were established on the basis of judgement and experience, anecdotal information provided by industry operators on a non-attributable basis, and rough cost data inferred from the previous CPPI studies and updated to reflect 2006 costs. The result was a typical range of unit costs for different regions, the regional variations being based on the anecdotal information obtained from companies operating in different regions of the country. Table 4.3 provides a summary of the unit costs for remediation of downstream sites as used in this study.

4.5 Estimated Remediation Costs by Scenario

As noted previously only the costs of meeting overall remediation requirements for a site were considered in the basic remediation cost model. The typical remediation cost for a given scenario was determined based on applying a representative unit remediation cost to a representative total soil volume obtained either directly from the data capture process or by extrapolation from a scenario considered in that process.

The representative soil volume was considered to be the mean of the soil volume data set (see Tables 3.6 and 3.7). The representative unit cost was taken as the mean or modal (most probable) values, for upstream and downstream sites respectively (see Table 4.3). Since unit remediation costs for downstream facilities were developed for different regions, estimated total remediation costs for downstream facilities were also calculated and presented on a regional basis. The above statistics were considered representative of soil volumes and costs for the purposes of a deterministic estimate of typical costs. However, it is noted that soil volumes tended to be approximately lognormally distributed. Representative distributions of both volume and cost were used in a subsequent probabilistic analysis (Section 7.4.2).

4.6 Regional Remediation Costs by Facility Type

The remediation cost of a given facility type in a particular province or territory is determined by obtaining a weighted average of the estimated regional remediation costs for each scenario that corresponds to that facility type, in accordance with the relative occurrence of each scenario in the province or territory. Note that only the first four scenarios under each facility type and soil texture (i.e. the four combinations of aquatic life and drinking water use; minor identifiers 1 through 4) are considered, since the remaining scenarios are special cases of pathway modification. Thus the remediation cost for a given facility type represents the blended cost of remediating such facilities in the various land and water use settings and soil types that would be expected within the specific province or territory.

4.7 Normalization of Soil Remediation Volumes

To this point, the regional facility remediation costs are based on the soil remediation volumes determined for the different scenarios through the industry data capture process. A "reality check" of the soil volumes discussed and presented in Section 3.5, based on experience and professional judgement with respect to the remediation of various facility types, suggests that the data capture process may have resulted in an unintentional bias towards larger volumes. This bias is believed to arise from the fact that individual sites selected by CAPP or CPPI member companies for data capture are generally those that are well-characterized, i.e. those for which the available site data support the determination of soil volumes corresponding to the various PHC fraction criteria, consistent with the intent of the project steering group. It is reasoned that many of these sites may have been well-characterized because they are large or "problem" sites. The potential for over-estimation of soil volumes and, hence, costs was recognized by the project steering group at the outset, but is not considered to be material from the standpoint of analyzing the effect of changes in individual fraction criteria between 2000 and 2007, and other related aspects of the analysis. However, in the estimation of overall industry costs on a regional and national basis, it is considered appropriate to "normalize" the soil volumes to more representative levels to avoid overstating total remediation costs.

Therefore, an adjustment factor is applied to the overall remediation cost for each facility type. The basis for determination of a suitable adjustment factor is discussed in Section B2, Appendix

B. Adjustment factors are applied uniformly across all regions. The final average remediation cost by facility type for each province or territory, after normalization of soil remediation volumes, is summarized in Tables 4.4 and 4.5 for the 2000 and 2007 criteria, respectively.

4.8 Aggregation of Remediation Costs by Facility Type and Industry

Remediation costs for each facility type are aggregated across each province or territory, and nationally, in accordance with the numbers of facilities reportedly existing within each province or territory. Table 4.6 presents a summary of the number of facilities by province and territory, compiled from various public domain sources. The basis for these numbers is discussed in Section B3, Appendix B. One additional factor is included at this stage. The average remediation cost per facility presumes that the facility is impacted and requires remediation (as was the case for all sites used in the data capture process). In reality, a certain proportion of all the sites in each category would be expected to meet the standards and therefore not require remediation. The estimated percentages of sites of each type expected to require remediation, referred to as probability of impact, are also presented in Table 4.6. These percentages were based on those presented in the previous SEA (Komex, 2000) adjusted as appropriate based on professional judgement and experience. The probability of impact for wellsites was established with input from CAPP.

The overall costs by facility, and province or territory, together with provincial/territorial and national totals for all facilities and national totals for each facility, are presented in Tables 4.7 and 4.8 for the 2000 and 2007 criteria respectively.

On a national basis, the total remediation cost for all facilities is estimated to be approximately $40.1 billion based on the 2000 standard, and $40.6 billion based on the proposed 2007 revisions to the standard. On an industry basis, the total national cost of remediation of upstream facilities is $33.1 billion and $33.4 billion based on the 2000 and 2007 criteria respectively. The total national cost for downstream facilities (excluding government, commercial and residential sites) is $2.4 billion under both the 2000 and 2007 criteria (with a very slight increase). For government, commercial and residential sites the cost is $4.6 billion and $4.8 billion for 2000 and 2007, respectively.

5.0 COST-TIME ANALYSIS

5.1 General

The remediation costs obtained from the basic remediation cost model represent an estimate of the undiscounted total cost (in constant 2006 dollars) of remediation of all PHC impacted sites, if all remediation were to take place instantaneously. In reality remediation will likely be phased in over time, the main reasons being constraints in the annual capacity of the remediation industry, deferral of complete remediation of operating facilities until site reconstruction or end-of-life abandonment, and business considerations such as corporate spending priorities. As a result of these factors, the present value cost of remediation, or total remediation liability, will vary from the undiscounted total predicted above.

Factors influencing the present value include timing and interest rate effects (i.e. time value of money) and potential escalation in remediation costs. Escalation in remediation costs may be due to inflationary increases in cost as well as changes related to technological factors (e.g. the availability of new technologies), market factors (e.g. scarcity of equipment and human resources or declining landfill space) and regulatory requirements. For the purpose of the present study, it is assumed that technological and market factors remain constant and that regulatory requirements will not change. Any estimate of changes in the latter factors would be subject to considerable uncertainty and are considered to be beyond the scope of the present study.

Inflationary increases are accounted for by considering all future remediation costs to be in constant (2006) dollars, and applying a discount rate for present value calculations that does not consider inflation, i.e. a "real" interest rate or internal rate of return. This analysis is presented and discussed for the proposed 2007 standard only. The analysis was conducted for the 2000 case as well; however, given the relatively small differences in total remediation costs, the conclusions are similar in both cases.

5.2 Remediation Industry Capacity and Projections

The environmental industry in Canada, as measured by the total revenues from sales of environmental goods and services, has increased from $14,360 million in 2000 to $15,778 million in 2002 and to $18,453 million in 2004, an average annual growth rate of 6.5%. (Statistics Canada, 2000, 2002, 2004, 2007a). Waste management and remediation services (NAICS 562) is a major component of the environmental industry and was $3,020 million in 2000 , $3,742 million in 2002 and $4,212 million in 2004 (Statistics Canada 2000, 2002, 2004, 2007a). Remediation services (NAICS 562910) is a subset of waste management and remediation services and Statistics Canada does not present separate revenues for this sector (NAICS 562910). However, based on its raw data, remediation services (NAICS 562910) totalled $525.8 million in 2004 (Gudz, pers. comm.). The remediation industry includes not only remediation services (NAICS 562910), but also a portion of environmental consulting services (NAICS 541620). Environmental consulting services totaled $645.3 million in 2002 (the first year the data were tabulated separately) and $806.4 million in 2004 (Statistics Canada, 2007a).

The remediation industry is further divided between the petroleum sector and all other sectors. For the purposes of this study the petroleum sector is considered to represent all producers, distributors and end users of petroleum hydrocarbons and thus encompasses all PHC contaminated sites. The allocation of resources within the remediation industry between PHC contaminated sites and other types of contaminated sites is not expected to be fixed, but is likely to vary according to demand. In estimating the capacity of the remediation industry to undertake the PHC remediation projected in this study, an assumed distribution of resources between the two categories of contaminated sites has been assumed, even though the theoretical maximum capacity may be the revenue presently derived from all contaminated sites, depending on the demand at any point in time in other sectors.

An estimate of the annual capacity of the remediation industry, to undertake remediation of PHC contaminated sites, is presented by region for the year 2006 in Table 5.1. The annual capacity for 2006 is estimated at $702.1 million. This estimate is based on the Statistics Canada data summarized above, projected to the year 2006. A number of assumptions have been made in inferring the capacity of the remediation industry from this information. Key assumptions are discussed below.

- Revenues for remediation services are included in the broader category of "waste management and remediation services" (NAICS 562) which accounts for roughly 23% of total revenue for environmental goods and services. Remediation services (NAICS 562910) accounts for approximately 12% to 15% of the "waste management and remediation services" group. It has been assumed that the remediation industry consists of remediation services (NAICS 562910) as well as 50% of "environmental consulting services" (NAICS 541620).

- The average growth rate by geographic region between 2000 and 2004 of revenues from environmental goods and services was also considered applicable to revenues related to remediation services (Statistics Canada, 2002, 2004, 2007a). However it is believed that the geographic distribution of revenues is not a limiting factor with respect to capacity due to mobility and the fact that many environmental consultants and contractors operate in more than a single region.

- Growth rates were observed to differ between the relevant categories of environmental services. For instance, remediation services, for which only two data points were available, appeared to decline between 2002 and 2004. It is assumed that this decline may reflect other factors that may drive the particular activity rather than a decline in capacity. Therefore, the 2000 to 2004 growth rate of 6.5% for the environmental industry as a whole was applied to the remediation sector in order to project the data to 2006 and beyond.

- It is assumed that a nominal two-thirds of the capacity of the remediation industry is available for the remediation of PHC contaminated sites. Any exports of services by the remediation industry to other countries are considered to be part of the one-third of the capacity not available to the domestic PHC contaminated sites market.

- For the purpose of projecting the growth in the capacity of the remediation industry beyond 2006, the average growth in revenues for the environmental industry as a whole, for the period 2000 to 2004, has been adjusted to a "real growth" rate by excluding the inflationary component. This is consistent with the use of constant 2006 dollars for remediation costs. The average growth in revenues between 2000 and 2004 was 6.5%. The average annual inflation rate (consumer price index) over the same period was 2.3% (Statistics Canada, 2007b). Therefore the real growth rate in the remediation sector was taken as 4.2%.

The influence of industry capacity and projected growth on the timing of the remediation of PHC contaminated sites is discussed further in Section 5.4.

5.3 Other Considerations Influencing Timing of Remediation

Although all PHC impacted sites where PHC concentrations exceed the applicable standard are assumed to require remediation, it does not necessarily follow that remediation of all sites would occur immediately or within any particular time frame. A number of factors, beside the annual capacity of the remediation industry, may influence the timing of remediation. Unless immediate remediation is required to address a situation where there are significant environmental or human health risks, or where there is a potential for offsite impacts, owners and operators of operating facilities would typically be anticipated to defer remediation until site closure or redevelopment. For an upstream facility this would occur at the time of end-of-life decommissioning; for a downstream site it may either occur at the time of decommissioning or in conjunction with upgrading of underground tanks. It is estimated that the average production life of an oil or gas well is in the range of 15 to 20 years, although a number of wellsites may be active for more than double this period. Wells often remain suspended for a period of time prior to abandonment, and many abandoned wells do not undergo immediate remediation and reclamation. The length of time between upgrades at typical downstream sites is also anticipated to be between 15 and 20 years, although the overall life of such a facility may be much greater.

Other factors may affect the timing of remediation, including practical, technological, business and regulatory considerations. Closed facilities often remain idle and unremediated for many years, particularly where there is limited opportunity for sale or redevelopment of the property, and where contamination is not expected to give rise to adverse offsite effects. These sites may be gradually dealt with by operating companies that have strategies to systematically reduce corporate environmental liabilities. The use of long term remediation techniques, risk management and reliance on natural attenuation processes may also affect the timing of remediation at sites which are either in operation or are abandoned but remain under the care and control of the operator. Other business or economic factors, such as the portion of an oil and gas company's revenue being re-invested or otherwise available for operations, may also influence when such activities are undertaken in the absence of regulatory pressures or requirements.

A detailed evaluation of all the factors that may dictate the timing of PHC remediation is beyond the scope of the present study. However, for illustrative purposes, in the context of this study, it is assumed that remediation of most PHC contaminated sites or facilities would occur at the end of a 20-year life; therefore, an average of approximately 5% of all PHC contaminated sites would require remediation in any given year, subject to the capacity of the remediation industry. Note that this is a simplification; in fact it is expected that a larger proportion of sites would be ready for remediation in the short term, due to a relatively large number of sites that are already idle or suspended, but unremediated. Also Included in this category would be sites at which remediation/reclamation has commenced but is not complete. For example, in 2004 an estimated 35,000 wellsites in Alberta had been abandoned but had not received reclamation certificates (Alberta Environment, 2005). The number of sites receiving reclamation certificates in 2006 kept pace with the number of wells abandoned during the year (CAPP, 2007b), suggesting that this latter figure would remain approximately constant.

5.4 Projected Remediation Activity with Time

Table 5.1 compares the estimated annual capacity of the remediation industry with the total projected remediation costs related to the proposed 2007 PHC standard. Although both sets of data are broken down into regions in the table, the following discussion primarily addresses the national totals, since it is assumed that mobility and geographic redeployment could occur to a certain extent in response to regional variations in demand.

Based on a total (national aggregate) remediation cost of $40,633 million and a national projected annual capacity of industry to remediate PHC contaminated sites of $702.1 million, the estimated time to complete remediation would be 57.9 years (Table 5.1). The time to undertake complete remediation ranges from a low of 7.6 years in Ontario to a high of 525 years in Saskatchewan, where the estimated remediation cost far outweighs the available industry capacity. Periods significantly longer than the national value are anticipated in both Saskatchewan and Alberta, due to the large number of upstream oil and gas facilities in those provinces.

As noted above, the real growth in the remediation industry is presently estimated to be 4.2%. If future growth occurs at the same rate, the estimated time to complete remediation of all PHC contaminated sites, on a nationally aggregated basis, would be 30.0 years. On a regional basis, this ranges from 6.8 years in Ontario to 76.3 years in Saskatchewan (Table 5.1).

With no growth in the remediation industry, the rate of remediation on a national basis would be approximately one-third of the estimated closure rate of PHC sites, resulting in a build-up of sites awaiting remediation. With a projected annual growth in capacity of 4.2%, the rate of remediation nationally would still be lower than the average rate at which sites would become due for remediation. The balance between supply and demand varies between regions, and would likely trigger some re-distribution of resources.

5.5 Estimated Present Value Remediation Costs and Unremediated Liabilities

Assuming that the timing of remediation is governed only by the capacity of the remediation industry, and allowing for 4.2% real annual growth in that sector, the net present value of the total, nationally aggregated, remediation cost is estimated to be $23,733 million based on a discount rate of 5%[1]. The breakdown by region is presented in Table 5.1.

There are obviously considerable uncertainties in projecting remediation requirements and activity 20 years or more into the future. The timeframe over which remediation would be undertaken, the rate at which sites would be closed or abandoned, the capacity of the industry, growth rate and future regulatory requirements are all subject to uncertainty. As a result, the length of time required to achieve complete remediation of all PHC contaminated sites, particularly in those regions where the projected volume or cost of remediation far outweighs the

[1] The net present value of a future cost is the "discounted" amount that, if invested today, would grow to equal the future cost based on a prescribed rate of return (referred to as the discount rate).

capacity of the local remediation industry, may not be a meaningful or useful result from the present analysis. Since shorter term projections are likely to be more reliable, the analysis focuses on the remediation that can be accomplished in a 5 to 10 year period, and estimates of the residual liabilities after 5 and 10 years are provided.

5 years

Based on the capacity of the industry and the above real growth projection, it is estimated that the total (national aggregate) undiscounted value of PHC remediation work that can be undertaken in 5 years is $3,818 million (Table 5.1). The present value of this work would be $3,592 million. At the end of a 5 year period, the present value of the remaining remediation costs (of unremediated sites), assuming no increase in the number of sites, would be $20,141 million. This may be considered as the residual liability, after 5 years, associated with existing PHC contaminated sites under presently projected remediation requirements.

10 years

Similarly, it is estimated that the total undiscounted value of PHC remediation work that can be undertaken in 10 years is $8,508 million (Table 5.2). The present value of this work would be $7,324 million. At the end of a 10 year period, the present value of the remaining remediation costs (of unremediated sites), assuming no increase in the number of sites, would be $16,409 million. This may be considered as the residual liability, after 10 years, associated with existing PHC contaminated sites under presently projected remediation requirements.

5.6 Discussion

The estimated growth rate of the environmental industry and the timeline for remediation may differ from those forecast in this report for a number of reasons. These include uncertainties in the Canadian environment in the areas of government environmental priorities, the availability of environmental practitioners for the remediation industry, the priorities and finances of the oil and gas industry, and the rising costs of remediation.

Given the current social and political environment in Canada, there could be a shift in government priorities and resources away from the remediation of PHC contaminated sites to other environmental priorities such as the reduction of greenhouse gas emissions in the environment. As a result, subsidized funding programs that exist in some jurisdictions, or other government-funded remediation activities (e.g. for government sites) could be reduced or not renewed. Private companies and the remediation industry itself are highly dependent on funding from federal, provincial and municipal sources to make the remediation of many sites economically feasible (Quality Engineering Solutions, 2005).

Seventy percent of the employees in the remediation industry are reported to be highly skilled and are trained in the fields of engineering, hydrology, and pure sciences (Quality Engineering Solutions, 2005). There is a shortage of trained environmental practitioners in Canada, at all levels including senior and intermediate professionals and field technicians (The Delphi Group, 2006). Students interested in science and technology are also choosing other industry sectors to work in, such as the oil and gas sector or the computer technology sector (The Delphi Group, 2006). With a current shortage of practitioners in the remediation industry and limited graduates entering the field, it will be a challenge for the industry to increase its capacity continuously over the next 10 years.

The priorities of the oil and gas industry in terms of the allocation of its environmental budgets may change in response to new federal and/or provincial regulations related to greenhouse gas emissions in the extraction processes of oil from conventional oil and gas sites and oil sands sites. In addition, the effect on industry profits of a reduction in the price of oil, or a reinvestment of profits in other forms of exploration and production could lead to less funds being available for remediation of PHC contaminated sites.

Finally, costs of remediating PHC sites could escalate over time, due both to a shortage of environmental practitioners as well as declining landfill capacities and greater costs of transporting contaminated soils longer distances to disposal or treatment locations.

6.0 BENEFIT ANALYSIS

6.1 General

Due to the similarity of projected overall remediation requirements and hence costs between implementation of the 2000 standard and the proposed 2007 values (presented in Section 4 and discussed further in Section 7), the differences in benefits arising from remediation are, for the most part, anticipated to be relatively minor. Therefore, the analysis of benefits presented in the following sections does not attempt to discuss incremental benefits, or otherwise, associated with a change from the 2000 to the proposed 2007 values. Instead, general benefits associated with remediation of PHC contaminated sites to levels consistent with current and proposed standards are discussed and, where possible, quantified. The potential impact of any significant differences between the 2000 and 2007 values, such as a shift in remediation requirements between industry sectors or regions, is addressed in the discussion.

The benefits discussed herein are limited to those that can be monetized. Benefits that are less amenable to quantification, such as reduction in human health risk, environmental impairment and blight, and reductions in contingent liabilities for damages to third parties, are discussed qualitatively in the overall context of PHC contaminated site remediation, but are not addressed in detail. The following sections consider the monetizable benefits such as increased land values associated with site remediation and the return of land to productive use, benefits arising from revenues to the remediation industry, and reductions in liabilities for future remediation.

Some monetizable benefits are directly realizable in the form of increased value or revenue. Other benefits arise from reductions in costs or liabilities. In some cases the benefits are the inverse of corresponding costs. For example, the realization of value by remediating a site is equivalent to the elimination of the opportunity cost of not remediating the site. The way in which such a cost or benefit is categorized can depend on the party to which the benefit accrues (e.g. the operator, landowner, purchaser, the public, etc.). It is important to categorize equivalent or offsetting costs and benefits appropriately and ensure that they are not double-counted.

The monetizable benefits associated with remediation of a contaminated site include the following:

- Increased land value
- Increased revenue from crop production
- Elimination of lease costs paid to land owner
- Elimination of liability associated with an unremediated site
- Revenues to the remediation industry

6.2 Land Value and/or Revenue Benefits from Productive Land Use

6.2.1 General Considerations

Land value is affected by the presence of contamination. Excluding from consideration factors not related to contamination, land that is not contaminated may be considered to exhibit "full" market value, based on its suitability for use, development and/or productivity consistent with other similar properties with a similar land use designation. Anything that limits the land's use or productivity will have a negative effect on value. Direct effects on value associated with contamination may be due, for example, to a reduction in crop yield of agricultural land, or the inability to use or develop a piece of commercial land for a desired purpose. Since, in most cases, a site can be brought to a condition whereby it can realize its full use or productivity for a cost equal to the cost of remediation, the reduction in value of the land while contaminated is generally accepted as being equal to the cost of remediation. For the purposes of this discussion, a site that has been remediated to accepted generic human health and environmental risk-based standards is assumed to be equivalent in value to a site that has never been contaminated. A number of other related factors may influence value, such as desirability, blight, property value trends and development potential. However, these are market factors, some of which (e.g. desirability) are based on a purchaser's willingness to pay, and as such are more difficult to quantify.

As long as the reduction in value of a property is equal to the cost of remediation, then the monetizable benefit realized from the expenditure on remediation is equal to the amount spent. In the simplest of situations, therefore, the costs and benefits are equal and there is no net increase in monetizable value to the economy as a whole. (Note that there may be an increase in non-monetizable, or societal value). However, even where there is no overall increase in economic value, costs and benefits may be redistributed between sections of the economy or between stakeholders in a contaminated site.

The potential increase in value will not always be equal to the cost of remediation. For example, if the remediation of a site would permit its redevelopment for an alternative land use with higher revenue potential, the increase in value may exceed the cost of remediation. Conversely for some sites with limited market potential, the cost of remediation may exceed the expected value of the land when remediated. In the following discussions, market values of unimpacted or remediated land are assumed to be constant in 2006 dollars; in other words appreciation or depreciation of land values with time is not considered herein for discussion purposes.

Each of the foregoing considerations may apply differently in different land use situations. The following sections discuss the value, revenue considerations and related costs and benefits for selected site remediation and closure scenarios in different land use settings. The following discussions pertain primarily to sites or facilities that have ceased operations.

6.2.2 Upstream Oil and Gas Facilities on Agricultural Land

Situation

In a typical situation involving a wellsite on private agricultural land, the operator leases the land from the landowner (farmer) for a cost that is intended, at least in part, to compensate the owner for loss of use of the potentially productive land. The operator continues to lease the land after abandonment until such time as the land is reclaimed and/or remediated and is certified by the appropriate government agency, at which time the land is returned to the owner.

Costs and benefits to the operator

Prior to remediation, the operator makes an annual lease payment, and carries a balance sheet liability related to the cost of remediating and/or reclaiming the land. In addition, there is a contingent liability associated with the presence of contamination and the potential for adverse human or environmental impact. The presence of contamination may also necessitate ongoing monitoring or risk management measures, the cost of which would be incurred by the operator. Meanwhile the operator has the use of the remediation funds for other activities.

The remediation cost is borne by the operator. Upon completion of remediation, the balance sheet liability for clean-up costs is eliminated; the contingent liability would be reduced to a level related to potential undiscovered contamination and would remain for a period of time dictated by statutory requirements. Following remediation and reclamation, there would be no further lease costs or ongoing costs related to monitoring or maintenance. The monetizable benefits to the operator, therefore, would be a reduction in liability (directly offsetting the remediation cost) and an elimination of ongoing lease and operating costs.

Costs and benefits to the landowner

Prior to remediation, the landowner receives lease payments in compensation for access and loss of productivity. The reduction in land value and productivity is offset by the lease revenue; assuming that lease payments are reasonably appropriate, the pre-remediation monetizable costs and benefits to the landowner would be essentially zero.

Following remediation, the land is returned to productive use, resulting in the potential for agricultural revenue. However, this is offset by a loss of lease revenue. Unless there is an increase in land value beyond that related to productivity (for example due to a perceived benefit related to the termination of oil and gas operations) or other gain due to the removal of potential constraints to full agricultural operation, remediation would essentially be neutral to the land owner in terms of monetizable costs and benefits.

Costs and benefits to society and the economy

Although the land allocated for oil and gas operations in agricultural areas represents a relatively small proportion of total agricultural land, the return of oil and gas sites to grazing or crop production results in a gradual increase in the total land available for agriculture. An increase in a region's food production would generally be viewed as positive by society and so this, combined with the reduction or elimination of the numbers of contaminated sites, would be considered a societal benefit, although the benefit is not readily quantifiable. The SEA performed for the original 2000 PHC standard examined benefits from increased agricultural production and reported them as very small (Komex, 2000).

While the land generates revenue to the land owner and hence to the regional economy, both before and after remediation, the return of the land to agriculture represents a shift in the source of that revenue from the oil industry to the agricultural products market.

Finally, the costs of remediation and reclamation, borne by the operator, result in revenues to the remediation and reclamation industry. In some cases, particularly with respect to reclamation, this may result in direct benefits to the local economy or the land owner. Benefits to the remediation industry are discussed in a subsequent section.

6.2.3 Service Station or Bulk Plant in Rural Area or Small Community

Situation

Due to increased centralization of fuel distribution operations and consolidation or relocation of retail facilities, a number of service stations and bulk plants in rural areas, along highways and in small communities have ceased operations over the years. While growing communities, highway and commercial redevelopment and other development trends may create demand for land in some areas, it is common for such properties to revert to a low intensity commercial use (e.g. auto service, convenience store, restaurant or other form of business) or to become idle. Designated land use is typically commercial but, in some cases, may be agricultural or may allow residential use.

Such properties are commonly operator-owned, although they may occasionally be leased. Owners range from major oil companies to small independent owner-operators. Land values are often low and relatively static, and with limited opportunity for sale or redevelopment, there may not be major financial incentives to undertake full remediation. In some cases remediation costs may exceed the value of the property in an unimpacted or remediated condition. Situations exist in which the ownership of such properties has reverted to the municipality for non-payment of taxes.

Costs and benefits to the owner or operator

Prior to remediation of an idle property in a setting such as that described above, the owner or operator would be responsible for paying municipal taxes, maintaining the property (e.g. controlling weeds), monitoring or managing existing contamination and meeting other carrying costs of the property. Taxes would likely be low if there were no economic or business activity on the land. The owner would carry a balance-sheet liability equal to the cost of remediating the site as well as potential contingent liabilities related to the potential for adverse human or environmental impacts. Should there be a potential for offsite impact, immediate remediation, source removal and/or active risk management may be required. Prior to remediation the owner has the use of the remediation funds for other activities; conversely, however, the capital tied up in the property results in an opportunity cost if the site is not put to productive use. In some cases, depending on local needs and opportunities, the operator may be able to derive some modest revenue from the site by leasing it for temporary, low sensitivity use such as storage or parking. Until the site is remediated, the operator faces a potential intangible cost in terms of tarnished image or reputation associated with a perceived lack of action.

In situations such as described above, it is not uncommon for the cost of remediation to exceed the potential market value of the property. If this is the case, and in the absence of any regulatory or other obligation to address the contamination, there may not be any incentive for an operator to undertake remediation, other than the elimination of the liabilities and ongoing monitoring and maintenance costs and taxes. If the remediated value of the site is equal to or exceeds the cost of remediation, then, aside from the savings in ongoing costs and liabilities, the monetizable costs and benefits of remediation would essentially be neutral for the operator.

An alternative strategy for an operator responsible for an idle site, under a scenario where there is no significant incentive for complete and immediate remediation, would be partial remediation (e.g. source removal) in combination with the implementation of a long term remediation and risk management program. A low intensity but potentially beneficial use, such as a park, may be an option provided human health risks (including safety risks) were appropriately managed. This would provide positive benefit to the community, nearby property owners and society in general (see below), but would not significantly affect the balance of costs and benefits to the operator, other than the opportunity to take advantage of long term remediation technology and the potential generation of community goodwill.

Costs and benefits to adjacent property owners and/or the municipality

The tangible costs to the municipality associated with an idle contaminated site would primarily be limited to the loss of tax revenue that would be realized were the site in productive use. Other, less readily monetized, costs would include additional foregone taxes and other potential broader economic losses due to the inability to attract investment and/or redevelopment of other land in the vicinity of the site. Similar economic costs would be felt by adjacent land owners, whose land values may be directly or indirectly affected by the presence of the idle property.

Depending on the financial stability of the operator, the municipality may face the potential risk of assuming ownership of the site through default on taxes. Whether this represents a potential liability or benefit would depend on the cost of remediation vis-à-vis the value of the property.

Upon remediation, benefits may accrue to the adjacent properties and the municipality in terms of the potential for increased economic activity and improved property values. Modest, though less tangible, benefits may also arise from the implementation of long term remediation or risk management, as noted above.

Costs and benefits to society and the economy

The societal costs of an idle contaminated site in a rural area or small community are more likely to be aesthetic (visual blight, loss of enjoyment of land etc.) than economic, although these may be partially offset if the operator were to take some measures to allow a low intensity use of the site such as a park in conjunction with risk management. There would, however, be potential economic benefits if the site were remediated to a condition where sale or redevelopment could take place, provided that economic conditions allowed such benefits to be realized.

The costs of remediation, borne by the operator, result in revenues to the remediation and reclamation industry and, in some cases, may result in direct benefits to the local economy. Benefits to the remediation industry are discussed in a subsequent section.

6.2.4 Service Station in Urban Area

Situation

Although service stations often have long operating lives, during which remediation of PHC contamination may be required, the facilities themselves are typically subject to periodic upgrading which provides opportunities for remediation other than in conjunction with closure. Although remediation of an operating site has a number of benefits in terms of regulatory compliance and reduction of liability, the following discussion is limited to sites undergoing closure, in which the costs and benefits may extend beyond the operator. Due to land values and development demands in many urban areas of Canada, service station sites undergoing closure and decommissioning in urban areas are considered less likely to remain idle than similar properties in rural areas. Typical urban service station sites may be located in residential, commercial or industrial areas. Depending on economic conditions, municipal zoning and development trends, a former service station site may be put to any of a number of potential uses including, but not limited to:

- Continued use for similar or related commercial purposes (e.g. auto maintenance)
- Commercial retail or professional use (e.g. strip mall, restaurant, office centre)
- Lower sensitivity commercial use (e.g. parking or storage)
- Mixed commercial and/or residential (e.g. retail with residential above)
- Single-family or multi-family residential use

Some of the above options involve more sensitive land use and would require not only remediation to an appropriate level but also potential upgrading of land use designation or zoning (e.g. commercial to residential). Other options, including similar or lower sensitivity usage, may permit either a risk management approach and/or deferral of remediation. The site may be sold for redevelopment, retained or leased, again depending on economic factors. Under favourable economic conditions, there is often a potential for increasing the market value or revenue potential of a remediated site by redeveloping the site to an upgraded land use. Sale or redevelopment for similar use would be expected at least to maintain the value of a property. In addition to economic factors and market potential, the cost of remediation and liability considerations would also likely influence an operator's decision with respect to remediation and disposition of the property.

Costs and benefits to the owner or operator

Prior to remediation of a PHC contaminated service station site that is no longer in operation, the costs incurred by the responsible party (referred to in this section as the operator) would include financial carrying costs, business taxes, site operating and management costs (e.g. maintenance and security) and the costs of monitoring and managing subsurface contamination. For an operating site a number of these costs are offset by revenues, but if the site is idle they represent net costs to the operator. In addition, the operator assumes the balance sheet liability associated with the requirement for eventual remediation, as well as contingent liabilities for potential adverse impacts. Due to the proximity of offsite human receptors in urban areas, the potential for adverse impact to human health is potentially greater than it would be in a rural area. Based on the visibility of an urban site, the operator may also experience a negative impact on image or reputation as a result of a perceived lack of action.

The benefits to the operator of remediating such a site depends on the options for disposition and redevelopment. While any remediation would likely reduce the liabilities associated with the contamination, only full remediation to generic or other unconditional objectives would enable the operator to realize the full value of the site. Under risk management and ongoing low sensitivity usage, the benefits may include modest revenue. Under full remediation, the site in most cases could be sold or leased at market value. As with a rural site, it is possible that the remediation cost may exceed the value of the site, particularly if there is extensive offsite contamination, but generally it is assumed that the cost of remediation would be directly offset by an increase in the value of the site. Aside from the reduction or elimination of liabilities and management and maintenance costs, therefore, the costs and benefits of remediation are neutral to the operator.

Where there is a significant demand for land and a potential to redevelop to an increased level or intensity of land use, as noted above, remediation of a site may result in an increase in market value, beyond that of an equivalent commercial property. In this case, there could be considered to be a net benefit to the operator from the expenditure of remediation costs.

Costs and benefits to adjacent property owners and/or the municipality

While idle, an urban contaminated site would incur a cost to the municipality in terms of foregone or reduced tax revenues. Depending on the cost of remediation relative to the value of the property, there may also be a liability related to the potential for assuming ownership of the site through default on taxes and/or insolvency of the operator. The presence of an idle site may also negatively influence surrounding property values and may result in a loss or reduction in economic benefits due to an inability to redevelop the area to its full potential.

Upon redevelopment of a site, the above costs would be offset by the corresponding benefits, in other words increased tax revenues, increased adjacent property values and any added overall economic benefits associated with potential improvement or revitalization of the surrounding area. The potential for any net benefit would depend on the ability of the area to realize a higher level or standard of development, which would depend on existing land uses and development trends.

Intangible benefits of remediation to an adjacent property owner may include the alleviation of concerns or fears associated with the potential for adverse impacts associated with the presence of contamination. This is likely to arise to a greater extent in a residential area than in a commercial or industrial area.

Costs and benefits to society and the economy

Similar to rural settings, the societal costs of an idle contaminated site in an urban area are likely to be based on aesthetic considerations (visual blight, loss of enjoyment of land etc.). These issues would probably be of greater public concern in residential areas than in commercial or industrial areas. In all cases, there is likely to be a perceived societal benefit if the sites are returned to a productive land use consistent with the surrounding area. In many areas, partial or temporary redevelopment for a lower intensity usage, such as a park, would also provide some degree of perceived benefit to society.

The costs of remediation, borne by the operator, result in revenues to the remediation and reclamation industry and, in some cases, may result in direct benefits to the local economy. Benefits to the remediation industry are discussed in a subsequent section.

6.2.5 Summary

In summary, increased land values and/or revenues arising from remediation of a contaminated site typically represent a direct offset to the costs of remediation, and in most cases there is no net monetizable benefit associated with remediation. The main exceptions to this would be situations where the cost of remediation exceeds the value of the remediated land or site, in which case the benefit would be less than the cost of remediation, and in the case where remediation would permit redevelopment of the site to a higher standard or intensity of use (subject to other economic conditions). In the latter case there would a positive incremental benefit. Although this may be tangible and therefore theoretically monetizable, it is a benefit that would be difficult to estimate in practice due to the considerable variability of local economic conditions across the country.

6.3 Benefits to Remediation Industry

The majority of the cost of remediation of a PHC contaminated site may be translated into revenue to the remediation industry. Remediation costs typically include the costs of site assessment (including drilling and laboratory analysis), contractor costs such as soil excavation and hauling, purchase and installation of remedial equipment (where applicable), soil treatment costs and/or landfill tipping fees. With some exceptions, most of these goods and services are provided by firms or individuals working specifically in the remediation industry. Exceptions include: certain categories of landfill disposal, where landfills are operated by municipalities or local waste management authorities and are not dedicated to contaminated soils; soil treatment sites (e.g. landfarms) that are privately operated by the oil companies themselves; construction or excavation equipment that may be used for remediation but is not generally considered part of the remediation industry. Although some of the remediation costs may flow to companies outside the remediation sector, these expenditures would still be used to purchase goods and services related to remediation. They are therefore included herein in the benefits to the remediation industry.

Section 5 compared the estimated overall volume of PHC remediation work associated with existing sites and facilities with the annual capacity of the industry to undertake the work. Based on the capacity of the industry, the volume of remediation work, aggregated nationally, would sustain the industry for over 18 years, allowing for growth in the industry. On a regional basis, even in those regions where capacity is highest in relation to the estimated remediation costs (i.e. British Columbia and Ontario), the amount of remediation work would sustain the industry (with growth) for more than 5 years. As noted previously, mobility would likely even out the regional differences between supply and demand to some extent.

Total employment in the environment industry in Canada was 159,720 in 2002, the last year for which Statistics Canada collected such employment data (Statistics Canada, 2002). Based on the estimated real growth rate of 4.2% (see Section 5.2), the total employment in the industry in 2006 is estimated to be 188,291. Employment in the waste management and remediation services sector (NAICS 562) was 23,757 in 2002. The number of employees in remediation services alone (NAICS 562910) in 2002 is estimated to be 3,682, based on the ratio of revenues between these groups. Employees in environmental consulting in 2002 totalled 8,062 (Statistics Canada, 2002).

Using the same basis as used to estimate total revenues in the remediation industry (Section 5.2) the number of employees engaged in the remediation of contaminated sites is assumed to be the total of those working in the remediation services sector plus 50% of those in the environmental consulting sector. Of these, two thirds are assumed to be available to the petroleum sector. Therefore, the total number of employees involved in the remediation of PHC contaminated sites in 2002 is estimated to be 5,142. Applying a real growth rate of 4.2%, the projected employment in this sector in 2006 is 6,062.

The estimated annual revenues related to remediation of PHC contaminated sites (i.e. the industry capacity) is $702 million. Given the undiscounted total estimated remediation costs of all PHC contaminated sites of $40,633 million, it is estimated that, on a national basis, PHC remediation will sustain approximately 350,800 person-years of employment in this sector. Table 6.1 indicates the breakdown of projected employment by region, based on the regional distribution of remediation costs.

6.4 Reduction in Liabilities for Future Remediation

As noted previously, liabilities associated with a contaminated site include the cost of future remediation and contingent liabilities related to the potential for an adverse impact to a third party. The reduction or elimination of these liabilities as a result of remediation can be considered a benefit of remediation. This benefit in the first instance accrues to the operator, since it enables the liability to be removed from the balance sheet. However, it can also be considered a benefit to the public, since the liability for an unremediated contaminated site may be involuntarily assumed by the public (or the government) in the event of insolvency of the operator.

Contingent liabilities related to potential adverse impact are not readily quantifiable and are not discussed further herein. Liabilities related to future remediation can be assumed to be equal to the undiscounted estimated cost of remediation. A number of factors may affect the future cost of remediation, including an escalation in remediation costs in real terms, changes in regulatory requirements, or the availability of a more economical or cost effective remediation technology. These factors cannot be directly quantified and incorporated into the liability estimate; however the elimination of the uncertainty associated with these factors may also be considered a benefit of remediation.

The total monetizable benefit related to the reduction in liability is concluded to be equal to the total remediation cost for existing PHC contaminated sites, as estimated in Section 4.8. This liability is reduced as sites are remediated, as illustrated by the residual liability for unremediated sites after 5 and 10 years, discussed in Section 5.5.

7.0 ANALYSIS AND DISCUSSION

7.1 Comparison of 2000 and 2007 Remediation Costs

National aggregate costs

On a national basis, the total remediation cost for all facilities is estimated to be approximately $40.1 billion based on the 2000 standard, and $40.6 billion based on the proposed 2007 revisions to the standard. This represents an increase of approximately 1.4% in total estimated costs as a result of the proposed revisions to the standard.

Costs by industry sector and facility type

The remediation costs associated with upstream facilities are approximately $33.1 billion and $33.4 billion, based on the original and proposed revised standard respectively, with an increase of 1.0%. Costs related to the remediation of downstream facilities (excluding government, commercial and residential sites) are approximately $2.38 billion based on the 2000 standard and $2.45 billion based on the proposed 2007 revisions, an increase of 2.6%. Costs for government, commercial and residential sites are $4.62 billion and $4.76 billion for 2000 and 2007 respectively, an increase of 3.1%. The costs by industry sector and region for 2000 and 2007, as well as the percentage change between the two standards, are summarized in Table 7.1.

Under the proposed 2007 standard, the remediation costs associated with upstream facilities and downstream facilities (excluding government, commercial and residential sites) represent 82.3% and 6.0%, respectively, of total estimated remediation costs.

The average per-site remediation cost associated with wellsites and gas plants decreased by approximately 2.5% from 2000 to 2007; the average remediation costs for batteries/satellites and compressor stations were estimated to increase by roughly 4.4%. In the downstream sector, all facility types were projected to exhibit an increase in remediation cost, ranging from 1.9% for commercial UST sites to 5.9% for residential heating oil tanks. Note that the estimated change for residential heating oil tanks is based on very limited data.

The variation in cost differences between the 2000 and 2007 standards for different facility types can be attributed in part to the different hydrocarbon mixtures anticipated at different facilities and the changes in criteria for the PHC fractions (see section 7.2 below). However, the change in estimated remediation costs for a given facility also depends on the relative proportions of different soil types, land uses and water uses associated with the facility type, since these factors also affect the governing criteria for each PHC fraction.

Due to the relatively small estimated remediation cost differences between the 2000 and 2007 standards, no further analysis has been conducted of the breakdown of costs between different types and sizes of operating companies within a given industry sector. While the aggregate costs are distributed between all operators, the trends between the two sets of standards are expected to be similar for a given facility type, regardless of operator size and type.

Costs by region

On a regional basis, the overall estimated increase in remediation costs between the implementation of the 2000 standard and the proposed 2007 revisions was greatest in Quebec (4.0%) and lowest in Prince Edward Island (a very small decrease). The increases in Alberta and Saskatchewan were lower than the overall national increase, due primarily to the large numbers of upstream oil and gas facilities in those provinces, relative to other provinces. The small decrease in PEI, in spite of the absence of an upstream industry, is attributed to a higher proportion of scenarios in which the governing criteria increase, due to the groundwater pathways being applicable in more situations than in other regions.

With respect to the regional distribution of overall costs, 55% and 24% of the costs are forecast to be incurred in Alberta and Saskatchewan, respectively (see Table 4.8), due to the large numbers of upstream facilities. Ontario, Quebec and the Atlantic region account for 6%, 5% and 4% of the total national costs, respectively.

Summary

In all, the projected differences in remediation costs due to the proposed 2007 revisions to the standard are relatively small, and are likely within the margin of error of the data collection, modelling and analysis (see above and Section 7.4 below). While it is apparent that the downstream industry and government, commercial and residential sectors are affected to a greater degree than the upstream industry, no clear or significant trends can be identified between provinces and regions (other than those noted above with respect to geographic distribution of overall remediation costs).

7.2 Effects of PHC Fraction Criteria on Soil Volumes

Based on the soil volumes determined from the industry data capture process, a number of observations can be made with respect to changes in soil volumes between the 2000 standard and the proposed 2007 revised standard, and their relationship to the individual fraction criteria. These are discussed briefly in the following paragraphs, with respect to the general scenarios encompassed by the data capture.

Upstream, fine-grained sites

Soil volumes exceeding one or more PHC fraction increase from 2000 to 2007 in approximately 33% of cases, and decrease in 15% of cases (the remainder being unchanged). There is a shift from F3 to F2 as the governing fraction, although benzene was found to govern in approximately 41% of cases. Given the effect of benzene, the volumes actually requiring remediation (i.e. exceeding PHC and/or benzene) increase in 19% of cases and decrease in 15% of cases. The overall average volume change is a decrease of approximately 5%. The average decrease in volume is more pronounced at sites where the drinking water pathway is not applicable.

Upstream, coarse-grained sites

Soil volumes exceeding one or more PHC fraction decrease from 2000 to 2007 in 4% of the cases and are unchanged in the remainder. Most sites are governed by more than one fraction, but there is a slight shift from F3 to F2. The overall average soil volume decreases by approximately 1%.

Downstream, fine-grained sites

Soil volumes exceeding one or more PHC fraction increase from 2000 to 2007 in approximately 46% of the cases, predominantly those with no drinking water use, and are unchanged in the remainder. These latter sites are dominated by F1. The volumes exceeding the PHC and/or benzene criteria increase in 43% of the cases. The average soil volume increase is in the order of 15%, and is dominated by sites at which the drinking water pathway is not applicable.

Downstream, coarse-grained sites

Soil volumes exceeding one or more PHC fraction increase from 2000 to 2007 in 14% of the cases and decrease in 34% of the cases. The volumes exceeding the PHC and/or benzene criteria increase in 10% of the cases and decrease in 34% of the cases. Overall average soil volumes decrease by approximately 3%.

It is pointed out that the percentages by which the average soil volume changes do not directly correspond to changes in remediation costs discussed in the foregoing sections, since the latter are adjusted by an occurrence probability for each facility type (see Section 4).

7.3 Effect of Modified Pathway-Specific Criteria on Soil Volumes

7.3.1 Application of Ecological Soil Contact Criteria at Depth

Two situations were evaluated involving modification of the criteria for ecological soil contact. The first involved application of the ecological soil contact criteria below a depth of 3 m. The proposed standards, and those of a number of jurisdictions, do not require consideration of the ecological soil contact pathway below 3 m. This situation was only examined for service stations (Scenarios C5 and D5). The second involved the application of modified criteria between depths of 1.5 m and 3 m. The criteria were modified (increased) by a factor of 2. This situation was only examined for wellsites (Scenarios A6 and B6).

Application of ecological soil contact criteria below 3 m

For fine grained soils, the application of ecological soil contact criteria below 3 m increased the soil volumes exceeding one or more PHC fraction (based on 2007 criteria) from the basic scenario (i.e. no ecological soil contact below 3 m) in 38% of the cases. The volumes exceeding any PHC fraction or benzene increased in only 8% of the cases. The average volume exceeding any PHC fraction increased from the basic scenario by approximately 18%, but the increase in average volume exceeding any PHC fraction or benzene was negligible.

For coarse grained soils, when applying ecological soil contact criteria below 3 m, the soil volumes exceeding one or more PHC fraction (2007) were observed to increase in 54% of the cases, and the volumes exceeding any PHC fraction or benzene increased in 36% of the cases. The average volume exceeding any PHC fraction, and any PHC fraction or benzene, increased by approximately 8% and 6% respectively.

Modification of ecological soil contact criteria between 1.5 m and 3 m

For fine grained soils, doubling the ecological soil contact criteria between 1.5 m and 3 m, the soil volumes exceeding one or more PHC fraction (2007) decreased from the basic scenario in 25% of the cases, and the volumes exceeding any PHC fraction or benzene decreased in 17% of the cases. The average volume exceeding any PHC fraction decreased by approximately 15%, and the average volume exceeding any PHC fraction or benzene decreased by 8%.

For coarse grained soils, when doubling the ecological soil contact criteria between 1.5 m and 3 m, the average soil volumes exceeding any PHC fraction, as well as any PHC fraction or benzene, decreased by approximately 11%. The decrease in average volumes exceeding any PHC fraction, as well as any PHC fraction or benzene, was approximately 2%.

7.3.2 Exclusion of Vapour Inhalation Pathway

Exclusion of the vapour inhalation pathway, based on an assumed vapour monitoring and/or risk management program, or on the absence of a pathway (e.g. agricultural land without a residence), was evaluated only for coarse grained soils in both upstream and downstream settings (Scenarios B7 and D7)

For wellsites, the soil volume exceeding any PHC fraction, as well as any PHC fraction or benzene, decreased in approximately 44% of cases. The average volume decreased by approximately 32%. For service station sites, exclusion of the vapour inhalation pathway would not affect the F1 criterion, but would significantly affect the benzene criterion. Volumes exceeding any PHC fraction decreased in 45% of cases, with an average volume decrease of 13%. However, with benzene no longer driving in most cases, volumes exceeding any PHC fraction or benzene decreased in 82% of the cases, with an average volume decrease of 36%.

7.4 Uncertainty and Sensitivity Analysis

7.4.1 Areas of Uncertainty

The estimation of remediation soil volumes and costs, their extrapolation to the full range of facility types, settings and physical conditions, and the subsequent aggregation of costs by industry, region and on a national basis, involves a large array of input data and assumptions. These data and assumptions are subject to varying degrees of uncertainty. Key areas in which uncertainty may exist, and their expected influence on the results of the analysis, are summarized below.

Numbers of facilities

The numbers of each type of facility by region are based on the most current readily available data. Data on upstream facilities, service stations and government tank sites are considered to be reasonably complete and reliable for most regions, with the possible exception of the territories where it is anticipated that the numbers of most types of facilities are likely to be underestimated. Data for commercial and residential sites are based primarily on information presented in the 2000 SEA (Komex, 2000), which in turn was based on a combination of industry statistics, government registries and company files, and only limited updating has been possible in this study. Uncertainties in these data would directly and proportionately affect total aggregated remediation costs and, to a lesser extent, distributions of costs between regions and industry sectors. The facility types that are subject to greatest uncertainty in numbers account for approximately 12% of the total costs, so the effect of uncertainty in these numbers would be relatively minor, and would only affect total costs and not the assessment of the impact of the proposed revisions to the standard.

Regional distribution of site settings and land/water use scenarios

The regional distribution of site settings and land/water use scenarios is based largely on professional judgement, anecdotal information and assumptions with respect to frequency of occurrence of certain conditions such as urban and rural settings, soil types, potable groundwater use and presence of aquatic life. The approach and assumptions are described in Section 4.2 and in Section B1, Appendix B. The frequency of occurrence of each combination of conditions, for each facility type, is used to extrapolate impacted soil volumes from the data capture process across industry sectors and regions.

The relative frequencies of occurrence of the various scenarios are the product of a number of assumptions, all of which are subject to some uncertainty. For example, the number of fine grained service station sites at which the protection of drinking water and aquatic life pathways apply is a function of the distribution of service stations between urban and rural settings, the estimated percentages of urban and rural sites having potable groundwater use and aquatic life receptors, and the estimated occurrence of sites with fine grained soils. In order to estimate the degree to which these assumptions may affect the overall results of the analysis, a discrete sensitivity analysis was performed, whereby the values for key assumptions were varied discretely between likely upper and lower bounds, with other parameters held constant to determine the variation in the result. The sensitivity analysis was performed on the aggregate remediation cost for all facilities, for both Alberta and Ontario. These provinces were selected based on the weighting of costs towards upstream and downstream facilities, respectively.

For both Alberta and Ontario, the largest influence was noted when increasing the number of sites with drinking water use. In Alberta, increasing the proportion of coarse grained versus fine grained sites between the extremes (i.e. 100% coarse or 100% fine) did not change aggregate costs from the base case by more than about 5%. The largest influence of any single assumption was noted for the percentage of sites with drinking water use, which increased costs by up to 12% in the extreme case where all sites were considered to have drinking water use. The extreme combination of drinking water and aquatic life at all sites increased overall costs by approximately 16%. Differences in cost between the 2000 and 2007 standard did not depart from the base case by more than approximately 3% of total costs, for most parameter variations other than those considered extreme (e.g. drinking water and aquatic life at all sites, or 100% coarse and 100% fine soils). Similar trends were noted for Ontario; the variations in total costs associated with 100% coarse grained or 100% fine grained sites, or 100% drinking water use and/or aquatic life were greater than for Alberta. However, the influence on cost differences between 2000 and 2007 was lower in most cases (less than 2% of total costs for variations other than those considered extreme as indicated above).

Although the results of the remediation cost model are sensitive to uncertainties in the above assumptions, given the influence of uncertainty and variability in other parameters (particularly those discussed below), the above assumptions are not considered sufficiently influential to warrant significant additional refinement.

Unit remediation costs

The selection of unit remediation costs for use in the basic remediation cost model was described in Section 4.4. These costs are subject to considerable variability due to factors such as remediation method selected, geographic location, hauling distances and tipping fees (for landfill disposal), degree of contamination and time to achieve remediation objectives (for soil treatment and other longer term approaches) and other considerations. The estimated overall costs of remediation to achieve the 2000 and 2007 standards are directly proportional to the unit remediation cost; a large variation in unit cost therefore has a significant effect on the overall costs.

As described in Section 4.4, unit remediation costs for upstream sites were obtained in part from confidential industry data provided by CAPP (CAPP, 2007a). Costs were observed to range from less than $50/m^3 to more than $300/m^3. Costs for the remediation of downstream sites, based on anecdotal information and project experience, were in the range of approximately $90/m^3 to $240/m^3. In order to account for the effect of these large potential variations, a probabilistic analysis of overall remediation costs was conducted using probability distributions for unit remediation costs and other influential parameters. The probabilistic analysis is described in Section 7.4.2, below.

Probability of impact

Probability of impact refers to the proportion of sites of a particular type that are expected to be impacted and hence would require remediation. In the absence of reliable statistics on the proportion of impacted sites, this parameter was assumed for the purposes of this study, based on project experience, professional judgement and anecdotal information. Although they are related, the influence of this assumption is potentially more significant than inaccuracies in the data for total numbers of sites or facilities (discussed above).

It is known that almost all underground storage tank sites have historically experienced spills or leaks at some point. Therefore, an assumption that all downstream sites are impacted to a greater or lesser degree is considered reasonable. However, a significant proportion of upstream facilities are known to require little remediation or in some cases only surface reclamation, although the precise percentages are not known with certainty. Given the large number of upstream facilities, the probability of impact for wellsites and batteries is influential on total costs, and so this parameter was assigned a probability distribution, based on industry input, in the probabilistic analysis described in Section 7.4.2.

Impacted soil volume

The soil volume requiring remediation for a typical site, obtained from the industry data capture process, is obviously one of the key variables in the estimation of overall remediation costs. As illustrated by the data collected (Section 3.0 and Appendix A), this parameter is subject to considerable variability between sites with varying degrees of contamination, as well as uncertainty in the actual estimation of impacted soil volume at a given site.

For most scenarios (with the notable exception of residential heating oil tank sites), sufficient data were collected to assess the potential variability in soil volume statistically and to assign a probability distribution to this parameter. To assess the influence of variability in soil volume on overall remediation costs, contaminated soil volumes were specified as probability distributions in the probabilistic analysis described in the following section.

The changes in soil volumes requiring remediation based on the 2000 and proposed 2007 standard are also subject to some uncertainty. Given the relatively small magnitude of the changes in most cases, these changes have the potential to be masked by inter-site variability and uncertainties in the estimation of volumes. The statistical significance of the changes was assessed by performing 2-tailed t-tests on paired 2000 and 2007 soil volumes for each of the data capture scenarios. For approximately 50 percent of the data capture scenarios, the results of the tests did not provide strong evidence that the changes were statistically significant. In general the level of significance was found to be higher for the downstream scenarios (scenarios C and D); the reason for this is not readily apparent. Further non-statistical evaluation of the changes, however, revealed trends that were directionally consistent with expectations and could be explained by consideration of changes in individual fraction criteria and the nature of the contaminants and other pathway-related factors associated with the respective scenarios. The results, therefore, are concluded to be generally valid even though there is likely to be uncertainty in the magnitudes of the differences in soil volumes.

7.4.2 Probabilistic Cost Analysis

In order to assess the effect of variability in the key parameters and assumptions discussed above on overall remediation costs, a probabilistic analysis was conducted of the cost of remediation to meet the proposed 2007 standard. In a probabilistic analysis, sometimes referred to as a Monte Carlo simulation, key input parameters are specified as probability distributions instead of single "point estimate" values. In each iteration of the analysis, the model uses input parameters randomly sampled from the specified distributions to calculate a result, in this case remediation cost. The results from a large number of iterations are combined to generate a probability distribution representing the predicted variability in the result. The probabilistic analysis in this study was conducted using the spreadsheet-based remediation cost model in conjunction with Crystal Ball™, Version 7.2 (Decisioneering, 2006).

Probability distributions were assigned to the soil remediation volumes, unit remediation costs and the probabilities of impact (for wellsites and batteries only). Soil remediation volumes for different scenarios obtained from the industry data capture process were observed to be approximately lognormally distributed.

The specified distributions are presented in Table 7.2. Predicted probability distributions were generated for total (nationally aggregated) remediation costs for upstream sites, downstream sites and other (government, commercial and residential) sites, and also total costs for all categories of facilities combined. In addition, the average cost per facility for each facility type was determined probabilistically.

The probability distribution of estimated total remediation costs is presented in Figure 7.2. The total cost is approximately lognormally distributed with a mean of $66.9 billion, a median of $37.8 billion, and 10th and 90th percentile values of $14.3 billion and $134.1 billion respectively. The statistics for the distributions of total costs by industry sector and average costs by facility type are summarized in Tables 7.3 and 7.4 respectively. A report of the probabilistic analysis, generated by Crystal Ball™, is included in Appendix C. The results indicate the range and distribution of potential aggregate costs, based on uncertainty and variability in the assumptions. The potential range and distribution provide a context for the interpretation of, and reliance on, the deterministic estimates of remediation cost presented previously.

Based on a sensitivity analysis produced by the model in conjunction with the probabilistic analysis, the most influential parameters affecting upstream remediation costs is the unit remediation cost (73% contribution to the variance of the result). For downstream sites, the most influential parameter is the soil volume for service stations in fine grained soils with no groundwater use (41% contribution to variance). For other sites, the same parameter represents 32% of the contribution to variance, since it is used as the basis for extrapolation of soil volumes from service stations to other facilities. The unit remediation cost for upstream sites also represents 72% of the contribution to variance in the total national remediation cost for all industries.

8.0 SUMMARY AND CONCLUSIONS

In summary, the results of the socio-economic analysis indicate that the effects of the proposed 2007 revisions to the PHC CWS on overall remediation costs for PHC contaminated sites across Canada are relatively small. Total undiscounted remediation costs for all industries, in constant 2006 dollars, are projected to increase from $40.1 billion to $40.6 billion, an increase of approximately 1.4%. Costs for the remediation of upstream sites comprise approximately 82% of the total, and are projected to increase slightly (1.0%). Remediation costs for downstream sites and other (government, commercial and residential) sites represent 6% and 12% of the total costs, respectively; the respective increases in these costs are forecast to be 2.6% and 3.1%.

The very small increase in costs for upstream sites is attributed to the proposed increase in the F3 criteria and decrease in the F2 criteria for a number of the soil type, land and water use combinations. This results in a shift of governing fraction from F3 to F2. For downstream sites, the slightly greater increase in costs is due in part to the decrease in F2 criteria as well as a decrease in the F1 values for certain scenarios.

The estimated magnitude of remediation work associated with PHC contaminated sites is projected to exceed the current annual capacity of the remediation industry by more than 57 times. If reasonable growth in the sector is considered, the estimated time to complete remediation of all existing sites is approximately 30 years on a national basis. However, the largest PHC contaminated site liabilities are in the provinces with large upstream oil and gas industries; those provinces also have relatively small remediation industries in comparison with estimated remediation requirements, which may necessitate geographic redistribution of resources in order to meet demand.

Aside from the direct benefits to the remediation industry flowing from the expenditure of remediation costs, the primary tangible or monetizable benefits are the elimination or reduction of operators' balance sheet liabilities associated with contaminated sites and the increase in land values and/or revenues from productive land. The difference in market value between a contaminated site and the same site in an unimpacted or remediated condition is generally considered to be equal to the cost of remediation; the increase in land value in most cases is equal to the cost of remediation. In most cases, therefore, there is no net monetizable benefit to the economy as a whole associated with the remediation of a contaminated site, although the benefit may be transferred between stakeholders. Exceptions to the above apply in situations where the remediation cost exceeds the market value of the property, or in situations where remediation results in an added increase in land value due to the ability to redevelop the land for a more intensive and/or profitable purpose (e.g. low density commercial to high-rise residential).

Due to the neutrality of costs and benefits in most situations, and the difficulty in assessing the exceptions on a generic basis, the net benefits associated with increased land values have been discussed qualitatively herein but have not been quantified.

Other societal benefits include improvements in health and environmental quality, increased enjoyment of the land, elimination or reduction of blight and reduction in contingent liabilities related to the potential for adverse impact. These in general are not considered to be monetizable benefits.

The estimation of overall remediation costs is subject to a number of uncertainties arising from variability in conditions and remediation requirements between sites and across regions, as well variability in remediation unit costs. Those factors contributing significantly to the variability in overall cost include remediation unit costs, particularly for upstream sites, and the estimated soil remediation volumes associated with different scenarios. The variability of some of these factors has been characterized herein on the basis of actual data and used in a probabilistic analysis of total costs. This has permitted the generation of a probability distribution of total projected remediation costs. The median cost on a national basis is $37.8 billion, and upper and lower deciles (90^{th} and 10^{th} percentiles) are $134.1 billion and $14.3 billion respectively.

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TABLES

Table 1.1: Proposed (2007) and Existing (2000) Numerical Criteria - Coarse Grained Soils

Values in mg/kg (2000 values in italics)

Land Use	Exposure Pathways	F1 (C6-C10)		F2 (>C10-C16)		F3 (>C16-C34)		F4 (>C34)	
Agricultural	Direct Contact (Ingestion + Dermal Contact)	12 000	*15000*	6800	*8000*	15 000	*18000*	21 000	*25000*
	Vapour Inhalation (indoor, basement)	40	*NC*[4]	190	*NC*[4]	NA	*NA*	NA	*NA*
	Vapour Inhalation (indoor, slab-on-grade)	30	*NC*[4]	150	*NC*[4]	NA	*NA*	NA	*NA*
	Protection of Potable GW	240	*860*	320	*1200*	NA	*NA*	NA	*NA*
	Protection of GW for Aquatic Life[1]	970	*230*	380	*150*	NA	*NA*	NA	*NA*
	Protection of GW for Livestock Watering[2]	5300	*9000*	14 000	*4000*	NA	*NA*	NA	*NA*
	Nutrient Cycling	NC	*TBD*	NC	*TBD*	NC	*TBD*	NC	*TBD*
	Eco Soil Contact	210	*130*	150	*450*	300	*400*	2800	*2800*
	Eco Soil Ingestion	NC	*TBD*	NC	*TBD*	NC	*TBD*	NC	*TBD*
	Produce, Meat and Milk	NC	*NC*	NC	*NC*	NC	*NC*	NC	*NC*
	Management Limit[3]	700	*NC*	1000	*NC*	2500	*NC*	10 000	*NC*
Residential	Direct Contact (Ingestion + Dermal Contact)	12 000	*15000*	6800	*8000*	15 000	*18000*	21 000	*25000*
	Vapour Inhalation (indoor, basement)	40	*50*	190	*240*	NA	*NA*	NA	*NA*
	Vapour Inhalation (indoor, slab-on-grade)	30	*30*	150	*150*	NA	*NA*	NA	*NA*
	Protection of Potable GW	240	*860*	320	*1200*	NA	*NA*	NA	*NA*
	Protection of GW for Aquatic Life[1]	970	*230*	380	*150*	NA	*NA*	NA	*NA*
	Nutrient Cycling	NC	*TBD*	NC	*TBD*	NC	*TBD*	NC	*TBD*
	Eco Soil Contact	210	*130*	150	*450*	300	*400*	2800	*2800*
	Produce	NC	*NC*	NC	*NC*	NC	*NC*	NC	*NC*
	Management Limit[3]	700	*NC*	1000	*NC*	2500	*NC*	10 000	*NC*
Commercial	Direct Contact (Ingestion + Dermal Contact)	19 000	*RES*	10 000	*29000*	23 000	*RES*	RES	*RES*
	Vapour Inhalation (indoor)	320	*310*	1700	*1700*	NA	*NA*	NA	*NA*
	Protection of Potable GW	240	*860*	320	*1200*	NA	*NA*	NA	*NA*
	Protection of GW for Aquatic Life[1]	970	*230*	380	*150*	NA	*NC*	NA	*NC*
	Nutrient Cycling	NC	*TBD*	NC	*TBD*	NC	*TBD*	NC	*TBD*
	Eco Soil Contact	320	*330*	260	*760*	1700	*1700*	3300	*3300*
	Offsite Migration	NA	*NC*	NA	*NC*	4300	*NC*	RES	*NC*
	Management Limit[3]	700	*NC*	1000	*NC*	3500	*NC*	10 000	*NC*
Industrial	Direct Contact (Ingestion + Dermal Contact)	RES	*RES*	RES	*RES*	RES	*NA*	RES	*NA*
	Vapour Inhalation (indoor)	320	*310*	1700	*1700*	NA	*NA*	NA	*NA*
	Protection of Potable GW	240	*860*	320	*1200*	NA	*NA*	NA	*NA*
	Protection of GW for Aquatic Life[1]	970	*230*	380	*150*	NA	*NC*	NA	*NC*
	Nutrient Cycling	NC	*TBD*	NC	*TBD*	NC	*TBD*	NC	*TBD*
	Eco Soil Contact	320	*330*	260	*760*	1700	*1700*	3300	*3300*
	Offsite Migration	NA	*NA*	NA	*NA*	4,300	*RES*	RES	*RES*
	Management Limit[3]	700	*NC*	1000	*NC*	3500	*NC*	10 000	*NC*

NA = Not applicable

RES = Residual PHC formation. Calculated value exceeds 30,000 mg/kg and solubility limit for PHC fraction.

NC = Not calculated. Insufficient data to allow derivation.

1 = Assumes surface water body at 10 m from site.

2 = Includes use of dugouts and wells for supply of livestock water.

3 = Includes additional considerations such as free phase formation, explosive hazards and buried infrastructure effects

4 = 2000 values were based on 30 m horizontal offset

Table 1.2: Proposed (2007) and Existing (2000) Numerical Criteria - Fine Grained Soils

Values in mg/kg (2000 values in italics)

Land Use	Exposure Pathways	F1 (C6-C10)		F2 (>C10-C16)		F3 (>C16-C34)		F4 (>C34)	
Agricultural	Direct Contact (Ingestion + Dermal Contact)	12 000	*15000*	6800	*8000*	15 000	*18000*	21 000	*25000*
	Vapour Inhalation (indoor, basement)	710	*NC*[5]	3600	*NC*[5]	NA	*NA*	NA	*NA*
	Vapour Inhalation (indoor, slab-on-grade)	610	*NC*[5]	3100	*NC*[5]	NA	*NA*	NA	*NA*
	Protection of Potable GW[1]	170	*180*	230	*250*	NA	*NA*	NA	*NA*
	Protection of GW for Aquatic Life[2]	RES	*TBD*	RES	*TBD*	NA	*NA*	NA	*NA*
	Protection of GW for Livestock Watering[3]	4200	*TBD*	10 000	*TBD*	NA	*NA*	NA	*NA*
	Nutrient Cycling	NC	*TBD*	NC	*TBD*	NC	*TBD*	NC	*TBD*
	Eco Soil Contact	210	*260*	150	*900*	1300	*800*	5600	*5600*
	Eco Soil Ingestion	NC	*TBD*	NC	*TBD*	NC	*TBD*	NC	*TBD*
	Produce, Meat and Milk	NC	*NC*	NC	*NC*	NC	*NC*	NC	*NC*
	Management Limit[4]	800	*NC*	1000	*NC*	3500	*NC*	10 000	*NC*
Residential	Direct Contact (Ingestion + Dermal Contact)	12 000	*15000*	6800	*8000*	15 000	*18000*	21 000	*25000*
	Vapour Inhalation (indoor, basement)	710	*940*	3600	*5200*	NA	*NA*	NA	*NA*
	Vapour Inhalation (indoor, slab-on-grade)	610	*940*	3100	*5200*	NA	*NA*	NA	*NA*
	Protection of Potable GW[1]	170	*180*	230	*250*	NA	*NA*	NA	*NA*
	Protection of GW for Aquatic Life[2]	RES	*TBD*	RES	*TBD*	NA	*NA*	NA	*NA*
	Nutrient Cycling	NC	*TBD*	NC	*TBD*	NC	*TBD*	NC	*TBD*
	Eco Soil Contact	210	*260*	150	*900*	1300	*800*	5600	*5600*
	Produce	NC	*NC*	NC	*NC*	NC	*NC*	NC	*NC*
	Management Limit[4]	800	*NC*	1000	*NC*	3500	*NC*	10 000	*NC*
Commercial	Direct Contact (Ingestion + Dermal Contact)	19 000	*RES*	10 000	*29000*	23 000	*RES*	RES	*RES*
	Vapour Inhalation (indoor)	4600	*4600*	23 000	*25000*	NA	*NA*	NA	*NA*
	Protection of Potable GW[1]	170	*180*	230	*250*	NA	*NA*	NA	*NA*
	Protection of GW for Aquatic Life[2]	RES	*TBD*	RES	*TBD*	NA	*NA*	NA	*NA*
	Nutrient Cycling	NC	*TBD*	NC	*TBD*	NC	*TBD*	NC	*TBD*
	Eco Soil Contact	320	*660*	260	*1500*	2500	*2500*	6600	*6600*
	Offsite Migration	NA	*NC*	NA	*NC*	19 000	*NC*	RES	*NC*
	Management Limit[4]	800	*NC*	1000	*NC*	5000	*NC*	10 000	*NC*
Industrial	Direct Contact (Ingestion + Dermal Contact)	RES	*RES*	RES	*RES*	RES	*NA*	RES	*NA*
	Vapour Inhalation (indoor)	4600	*4600*	23 000	*25000*	NA	*NA*	NA	*NA*
	Protection of Potable GW[1]	170	*180*	230	*250*	NA	*NA*	NA	*NA*
	Protection of GW for Aquatic Life[2]	RES	*TBD*	RES	*TBD*	NA	*NA*	NA	*NA*
	Nutrient Cycling	NC	*TBD*	NC	*TBD*	NC	*TBD*	NC	*TBD*
	Eco Soil Contact	320	*660*	260	*1500*	2500	*2500*	6600	*6600*
	Offsite Migration	NA	*NA*	NA	*NA*	19,000	*12000*	RES	*RES*
	Management Limit[4]	800	*NC*	1000	*NC*	5000	*NC*	10 000	*NC*

NA = Not applicable. Calculated value exceeds 1,000,000 mg/kg or pathway excluded.

RES = Residual PHC formation. Calculated value exceeds 30,000 mg/kg and solubility limit for PHC fraction.

NC = Not calculated. Insufficient data to allow derivation.

1 = Assumes site is underlain by groundwater of potable quality in sufficient yield (K of 10^{-4} cm/sec or greater).

2 = Assumes surface water body at 10 m from site.

3 = Generally applicable for this land use as related to use of dugouts and wells for supply of livestock water.

4 = Includes additional considerations such as free phase formation, explosive hazards and buried infrastructure effects

5 = 2000 values were based on 30 m horizontal offset

Table 1.3: Summary of 2000 and Proposed 2007 PHC CWS Criteria

Land Use	Soil Type	Drinking Water	Aquatic Life	Proposed 2007 Values (mg/kg) F1	F2	F3	F4	2000 Values (mg/kg) F1	F2	F3	F4
Agricultural	Fine	Y	Y	170	150	1300	5600	180	250	800	5600
		Y	N	170	150	1300	5600	180	250	800	5600
		N	Y	210	150	1300	5600	260	900	800	5600
		N	N	210	150	1300	5600	260	900	800	5600
	Coarse	Y	Y	30	150	300	2800	130	150	400	2800
		Y	N	30	150	300	2800	130	450	400	2800
		N	Y	30	150	300	2800	130	150	400	2800
		N	N	30	150	300	2800	130	450	400	2800
Residential	Fine	Y	Y	170	150	1300	5600	180	250	800	5600
		Y	N	170	150	1300	5600	180	250	800	5600
		N	Y	210	150	1300	5600	260	900	800	5600
		N	N	210	150	1300	5600	260	900	800	5600
	Coarse	Y	Y	30	150	300	2800	30	150	400	2800
		Y	N	30	150	300	2800	30	150	400	2800
		N	Y	30	150	300	2800	30	150	400	2800
		N	N	30	150	300	2800	30	150	400	2800
Commercial	Fine	Y	Y	170	230	2500	6600	180	250	2500	6600
		Y	N	170	230	2500	6600	180	250	2500	6600
		N	Y	320	260	2500	6600	660	1500	2500	6600
		N	N	320	260	2500	6600	660	1500	2500	6600
	Coarse	Y	Y	240	260	1700	3300	230	150	1700	3300
		Y	N	240	260	1700	3300	310	760	1700	3300
		N	Y	320	260	1700	3300	230	150	1700	3300
		N	N	320	260	1700	3300	310	760	1700	3300
Industrial	Fine	Y	Y	170	230	2500	6600	180	250	2500	6600
		Y	N	170	230	2500	6600	180	250	2500	6600
		N	Y	320	260	2500	6600	660	1500	2500	6600
		N	N	320	260	2500	6600	660	1500	2500	6600
	Coarse	Y	Y	240	260	1700	3300	230	150	1700	3300
		Y	N	240	260	1700	3300	310	760	1700	3300
		N	Y	320	260	1700	3300	230	150	1700	3300
		N	N	320	260	1700	3300	310	760	1700	3300

Critical pathway: (text colour)
- Vapour inhalation
- Drinking water
- Aquatic life
- Eco soil contact
- Management limit

Significance of change:

Minimal	<20%
Low - Moderate	20 - 200%
High	>200%
Signif. Increase	>20%

Table 3.1: Facility, Soil Type, Land and Water Use Categories

Primary Identifiers - Facility, Soil Type and Land Use

Identifier	Scenario Type	Industry Sector	Soil Texture	Default Land Use
A	Major	Oil Well	Fine Grained	Agriculture
B	Major	Oil Well	Coarse Grained	Agriculture
C	Major	Service Station	Fine Grained	Commercial
D	Major	Service Station	Coarse Grained	Commercial
E	Minor	Satellite/Battery	Fine Grained	Agriculture
F	Minor	Satellite/Battery	Coarse Grained	Agriculture
G	Minor	Bulk Plant	Fine Grained	Commercial
H	Minor	Bulk Plant	Coarse Grained	Commercial
I	Minor	Home Heating Oil	Fine Grained	Residential
J	Minor	Home Heating Oil	Coarse Grained	Residential
K	Other	Refinery	Fine Grained	Industrial
L	Other	Refinery	Coarse Grained	Industrial
M	Other	Gas Plant	Fine Grained	Agriculture
N	Other	Gas Plant	Coarse Grained	Agriculture
O	Other	Government	Fine Grained	Commercial
P	Other	Government	Coarse Grained	Commercial
Q	Other	Commercial	Fine Grained	Commercial
R	Other	Commercial	Coarse Grained	Commercial

Secondary Identifiers - Pathways Considered

Identifier	Pathways Considered			
	Eco applies >3m (2006 only)	Aquatic Life	Drinking Water	Vapour Intrusion
1	no	yes	yes	yes
2	no	yes	no	yes
3	no	no	no	yes
4	no	no	yes	yes
5	yes*	yes	no	yes
6	no and include a 2x factor for 1.5 to 3 m **	no	no	yes
7	no	no	no	no***

Notes:

* - determine effect of criterion applying below 3 m

** - determine effect of modified criterion between 1.5 m and 3 m

*** - determine effect of excluding vapour pathway (based on monitoring)

Table 3.2: Major Scenarios Retained for Data Capture

SCENARIO NO.	INDUSTRY SECTOR	SCENARIO	DEFAULT LAND USE	TEXTURE	FINAL SITE CONDITION Pathways and Receptor Considerations - POST REMEDIATION				2000 CWS SEED VALUES (mg/kg)					ANTICIPATED 2007 SEED VALUES (mg/kg)				
					Eco Contact Applies at > 3 m	Aquatic Life Applies	Drinking Water Applies	Vapour Intrusion Applies	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene
A1	Upstream	Oil/Gas Wellsite	Agricultural*	Fine Grained	no	yes	yes	yes	180	250	800	5,600	0.010	170	150 (>3 m, 230)	1,300 (>3 m, 3500)	5,600 (>3 m, 10,000)	0.010
A3	Upstream	Oil/Gas Wellsite	Agricultural*	Fine Grained	no	no	no	yes	260	900	800	5,600	2.100	210 (>3 m, 610)	150 (>3 m, 1,000)	1,300 (>3 m, 3500)	5,600 (>3 m, 10,000)	2.100
A6	Upstream	Oil/Gas Wellsite	Agricultural*	Fine Grained	no AND include a 2x factor from 1.5 to 3 m depth	no	no	yes	260	900	800	5,600	2.100	210 (>1.5 m, 420) (>3 m, 610)	150 (>1.5 m, 300) (>3 m, 1,000)	1,300 (1.5-3 m, 2,600) (>3 m, 3500)	5,600 (1.5-3 m, 10,000) (>3 m, 10,000)	2.100
B1	Upstream	Oil/Gas Wellsite	Agricultural*	Coarse Grained	no	yes	yes	yes	30	150	400	2,800	0.030	30	150	300 (>3 m, 2500)	2800 (>3 m, 10,000)	0.030
B6	Upstream	Oil/Gas Wellsite	Agricultural*	Coarse Grained	no AND include a 2x factor from 1.5 to 3 m depth	no	no	yes	30	150	400	2,800	0.030	30	150	300 (1.5-3 m, 600) (>3 m, 2500)	2800 (1.5-3 m, 5600) (>3 m, 10,000)	0.030
B7	Upstream	Oil/Gas Wellsite	Agricultural*	Coarse Grained	no	no	no	no	130	450	400	2,800	25.000	210 (>3 m, 700)	150 (>3 m, 1,000)	300 (>3 m, 2500)	2800 (>3 m 10,000)	25.000
C1	Downstream	Service Station	Commercial	Fine Grained	no	yes	yes	yes	180	250	2,500	6,600	0.030	170	230	2500 (5000 below 3 m)	6600 (10,000 below 3 m)	0.030
C3	Downstream	Service Station	Commercial	Fine Grained	no	no	no	yes	660	1,500	2,500	6,600	2.100	320 (800 below 3 m)	260 (1000 below 3 m)	2500 (5000 below 3 m)	6600 (10,000 below 3 m)	2.100
C5	Downstream	Service Station	Commercial	Fine Grained	yes	yes	no	yes	660	1500	2,500	6,600	2.100	320	260	2,500	6,600	2.100
D1	Downstream	Service Station	Commercial	Coarse Grained	no	yes	yes	yes	230	150	1,700	3,300	0.030	240	260 (320 below 3 m)	1700 (3500 below 3 m)	3300 (10,000 below 3 m)	0.030
D2	Downstream	Service Station	Commercial	Coarse Grained	no	yes	no	yes	230	150	1,700	3,300	0.100	320	260 (380 below 3 m)	1700 (3,500 below 3 m)	3300 (10,000 below 3 m)	0.100
D3	Downstream	Service Station	Commercial	Coarse Grained	no	no	no	yes	310	760	1700	3,300	0.100	320	260 (1000 below 3 m)	1700 (3,500 below 3 m)	3300 (10,000 below 3 m)	0.100
D4	Downstream	Service Station	Commercial	Coarse Grained	no	no	yes	yes	310	760	1700	3,300	0.030	240	260 (320 below 3 m)	1700 (3,500 below 3 m)	3300 (10,000 below 3 m)	0.030
D5	Downstream	Service Station	Commercial	Coarse Grained	yes	yes	no	yes	230	150	1,700	3,300	0.100	320	260	1,700	3,300	0.100
D7	Downstream	Service Station	Commercial	Coarse Grained	no	no	no	no	330	760	1,700	3,300	25.000	320 (700 below 3 m)	260 (1000 below 3 m)	1700 (3,500 below 3 m)	3300 (10,000 below 3 m)	25.000

Table 3.3: Major Scenarios Excluded from Data Capture

Identifier	Scenario that This is Similar To	Comments
A2	Captured in A3	Where aquatic life does not govern, results will be similar for removal of drinking water or both drinking water and aquatic life. Fine grained criteria is not affected by removal of Aquatic Life Pathway.
A4	Captured in A1	Fine grained sites will not be governed by PHC aquatic life criteria. Therefore this scenario is the same as for A1.
A5	N/A	The importance of the 3 m cutoff is only assessed for downstream facilities to reduce workload implications. This is less of a jurisdictional issue than for urban settings.
A7	Captured in A3	The only thing that changes significantly with removal of the vapour pathway from fine grained soil is the criteria for benzene. Therefore, this scenario can be assumed to be similar to A3 for everything else
B2	Captured in B3	Where aquatic life does not govern, results will be similar for removal of drinking water or both drinking water and aquatic life. Fine grained criteria is not affected by removal of Aquatic Life Pathway.
B3	Captured in B1	Elimination of Groundwater Pathways From Coarse Grained Residential/Agricultural does not change criteria as it is still driven by the Vapour inhalation (F1, F2) or ecological (F3) criteria.
B4	Captured in B1	TheAquatic Life Pathway does not govern on the residential or agricultural pathway for F1 or F2. Therefore this scenario ends up being the same as 1, with inclusion of Aquatic Life and Drinking Water.
B5	N/A	The importance of the 3 m cutoff is only assessed for downstream facilities to reduce workload implications. This is less of a jurisdictional issue than for urban settings.
C2	Captured in C3	Where aquatic life does not govern, results will be similar for removal of drinking water or both drinking water and aquatic life. Fine grained criteria is not affected by removal of Aquatic Life Pathway.
C4	Captured in C1	Aquatic Life values do not affect the criteria for fine soils. Therefore, this scenario ends up being similar to C1.
C6	N/A	Use of the factor of 2 at 1.5 m will only be considered for well site data to reduce workload implications.
C7	Captured in C3	Only benzene changes significantly with removal of vapour inhalation for fine soil. Therefore, this is captured in C3.
D6	N/A	Use of the factor of 2 at 1.5 m will only be considered for well site data to reduce workload implications.

Table 3.4: Minor Scenarios Retained for Data Capture

SCENARIO NO.	INDUSTRY SECTOR	SCENARIO	DEFAULT LAND USE	TEXTURE	FINAL SITE CONDITION Pathways and Receptor Considerations - POST REMEDIATION				2000 CWS SEED VALUES (mg/kg)					ANTICIPATED 2007 SEED VALUES (mg/kg)				
					Eco Contact Applies at > 3 m	Aquatic Life Applies	Drinking Water Applies	Vapour Intrusion Applies	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene
E1	Upstream	Sattelite/Battery	Agricultural*	Fine Grained	no	yes	yes	yes	180	250	800	5,600	0.010	170	150 (>3 m, 230)	1,300 (>3 m, 3500)	5,600 (>3 m, 10,000)	0.010
E3	Upstream	Sattelite/Battery	Agricultural*	Fine Grained	no	no	no	yes	260	900	800	5,600	2.100	210 (>3 m, 610)	150 (>3 m, 1,000)	1,300 (>3 m, 3500)	5,600 (>3 m, 10,000)	2.100
G1	Downstream	Bulk Plant	Commercial	Fine Grained	no	yes	yes	yes	180	250	2,500	6,600	0.030	170	230	2500 (5000 below 3 m)	6600 (10,000 below 3 m)	0.030
G3	Downstream	Bulk Plant	Commercial	Fine Grained	no	no	no	yes	660	1,500	2,500	6,600	2.100	320 (800 below 3 m)	260 (1000 below 3 m)	2500 (5000 below 3 m)	6600 (10,000 below 3 m)	2.100
I1	Downstream	Residential Heating Oil	Residential	Fine Grained	no	yes	yes	yes	180	250	800	5,600	0.010	170	150 (>3 m, 230)	1,300 (>3 m, 3500)	5,600 (>3 m, 10,000)	0.010
I3	Downstream	Residential Heating Oil	Residential	Fine Grained	no	no	no	yes	260	900	800	5,600	2.100	210 (>3 m, 610)	150 (>3 m, 1,000)	1,300 (>3 m, 3500)	5,600 (>3 m, 10,000)	2.100
J1	Downstream	Residential Heating Oil	Residential	Coarse Grained	no	yes	yes	yes	30	150	400	2,800	0.030	30	150	300 (>3 m, 2500)	2800 (>3 m, 10,000)	0.030

Table 3.5: Minor Scenarios Excluded from Data Capture

Identifier	Scenario that This is Similar To	Comments
E2, E4,E5, E6, E7	Captured in E1, E3; pathway modifiers based on A	E1and E3 encompass the primary variables. All other possibilities are dealt with semi-qualitiatively based on operation size and comparison with appropriate scenario in A.
All F	Based on corresponding E scenarios and comparison of A and B	Data are limited so study will concentrate on fine grained sites. The scenario is similar to the coarse grained well site and this can be used to give a qualitative estimate of what will occur for these sites.
G2, G4,G5, G6, G7	Captured in G1, G3; pathway modifiers based on C	G1 and G3 encompass the primary variables. All other possibilities are dealt with qualitiatively based on operation size and comparison with appropriate scenario in C.
All H	Based on corresponding G scenarios and comparison of C and D	Data are limited so study will concentrate on fine grained sites. The scenario is similar to the coarse grained well site and this can be used to give a qualitative estimate of what will occur for these sites.
I2, I4, I5, I6, I7	N/A	Data are limited so these will not be included in the analysis.
J2, J4, J5, J6, J7	N/A	Data are limited so these will not be included in the analysis.
J3	Captured in J1	For coarse grained soil, does not change criteria since it is driven dominantly by vapour in lower (F1 and F2) and ecological in higher (F3) fraction weights
All K,L,M,N	N/A	Not enough data to include. Intended that these scenarios should be extrapolated from other representative scenarios and adjusted or calibrated to empirical overall costs or liability estimates

Table 3.6: Summary of Soil Remediation Volumes - 2000

Scenario	Volume Based on 2000 Criteria (m^3)					
	No. Data Sets	Minimum	Maximum	Median	Mean	Std. Dev
A1	14	611	23000	1510	4690	6774
A3	12	10	7000	618	1146	1887
A6	12	611	23000	1625	5059	7034
B1	23	380	16253	1738	3487	3853
B6	9	500	10100	1492	3166	3508
B7	9	500	7300	1492	2785	2766
C1	17	447	17825	1643	3313	4326
C3	18	0	8586	1330	2038	2276
C5	16	60	3800	740	1083	1105
D1	16	264	17825	1500	4043	5356
D2	13	264	9934	2539	3310	2809
D3	12	201	8877	1775	2768	2639
D4	11	201	14643	2298	3657	4228
D5	11	264	15794	2298	3883	4544
D7	11	201	6865	1350	2092	2057
E1	13	525	40000	3500	10666	13017
E3	13	100	26300	3000	5089	6979
G1	4	300	11579	3427	4683	4915
G3	3	60	720	699	493	375
I1	0					
I3	1			171	171	
J1	1			9	9	

Table 3.7: Summary of Soil Remediation Volumes - 2007

Scenario	Volume Based on 2007 Criteria (m^3)					
	No. Data Sets	Minimum	Maximum	Median	Mean	Std. Dev
A1	14	445	23000	1560	4627	6813
A3	12	0	4000	625	901	1059
A6	12	650	23000	1625	5049	7041
B1	23	380	16253	1738	3460	3826
B6	9	500	10100	1492	3096	3418
B7	9	100	4940	1492	2066	1780
C1	17	447	17825	1643	3334	4333
C3	18	275	8586	1711	2310	2217
C5	16	60	3800	1129	1332	1135
D1	16	264	17825	1500	3959	5217
D2	13	201	8877	2539	3100	2539
D3	12	201	8877	1775	2719	2553
D4	11	264	14837	2298	3767	4286
D5	11	201	14837	2298	3739	4301
D7	11	0	6357	1126	1733	1932
E1	13	525	40000	5000	10897	12877
E3	13	100	26300	3250	6064	7854
G1	4	300	11579	3427	4683	4915
G3	3	60	1669	1300	1010	843
I1	0					
I3	1			230	230	
J1	1			9	9	

Table 4.1: Scenario Distributions by Facility Type and Region (Page 1 of 2)

Scenario	Facility Type	Soil Texture	Aquatic Life	Drinking Water	BC	AB	SK	MN	ON	QC	NB	NS	PE	NL	YK	NT	NU
A 1	Wellsite	Fine	Y	Y	51.0	41.9	47.6	43.1	30.0	41.6	39.9	31.2	45.0	24.2	22.7	15.3	6.1
A 2	Wellsite	Fine	Y	N	9.0	18.1	12.4	16.9	0.0	3.5	5.1	13.8	0.0	20.8	11.0	22.2	31.4
A 3	Wellsite	Fine	N	N	3.0	6.0	4.1	5.6	0.0	1.2	1.7	4.6	0.0	6.9	3.7	7.4	10.5
A 4	Wellsite	Fine	N	Y	17.0	14.0	15.9	14.4	10.0	13.9	13.3	10.4	15.0	8.1	7.6	5.1	2.0
B 1	Wellsite	Coarse	Y	Y	12.8	10.5	11.9	10.8	45.0	27.7	26.6	20.8	30.0	16.1	27.8	15.3	6.1
B 2	Wellsite	Coarse	Y	N	2.3	4.5	3.1	4.2	0.0	2.3	3.4	9.2	0.0	13.9	13.5	22.2	31.4
B 3	Wellsite	Coarse	N	N	0.8	1.5	1.0	1.4	0.0	0.8	1.1	3.1	0.0	4.6	4.5	7.4	10.5
B 4	Wellsite	Coarse	N	Y	4.3	3.5	4.0	3.6	15.0	9.2	8.9	6.9	10.0	5.4	9.3	5.1	2.0
C 1	Service station	Fine	Y	Y	10.0	8.9	17.7	12.0	6.1	9.1	24.9	16.8	38.3	12.3	13.0	8.5	4.7
C 2	Service station	Fine	Y	N	25.4	29.5	21.9	26.8	15.7	23.8	11.0	17.8	0.0	21.7	12.8	19.7	23.5
C 3	Service station	Fine	N	N	21.5	24.4	16.4	21.0	13.2	19.5	7.5	12.7	0.0	15.7	9.3	14.2	14.3
C 4	Service station	Fine	N	Y	8.6	7.3	12.3	9.1	5.3	7.5	15.0	10.7	21.8	8.0	8.6	5.5	2.3
D 1	Service station	Coarse	Y	Y	5.4	3.8	7.6	5.2	9.2	6.1	16.6	11.2	25.5	8.2	15.9	8.5	4.7
D 2	Service station	Coarse	Y	N	13.7	12.6	9.4	11.5	23.5	15.8	7.3	11.9	0.0	14.5	15.7	19.7	23.5
D 3	Service station	Coarse	N	N	11.6	10.4	7.0	9.0	19.8	13.0	5.0	8.5	0.0	10.4	11.4	14.2	14.3
D 4	Service station	Coarse	N	Y	4.6	3.1	5.3	3.9	7.9	5.0	10.0	7.1	14.5	5.4	10.5	5.5	2.3
E 1	Satellite/battery	Fine	Y	Y	51.0	41.9	47.6	43.1	30.0	41.6	39.9	31.2	45.0	24.2	22.7	15.3	6.1
E 2	Satellite/battery	Fine	Y	N	9.0	18.1	12.4	16.9	0.0	3.5	5.1	13.8	0.0	20.8	11.0	22.2	31.4
E 3	Satellite/battery	Fine	N	N	3.0	6.0	4.1	5.6	0.0	1.2	1.7	4.6	0.0	6.9	3.7	7.4	10.5
E 4	Satellite/battery	Fine	N	Y	17.0	14.0	15.9	14.4	10.0	13.9	13.3	10.4	15.0	8.1	7.6	5.1	2.0
F 1	Satellite/battery	Coarse	Y	Y	12.8	10.5	11.9	10.8	45.0	27.7	26.6	20.8	30.0	16.1	27.8	15.3	6.1
F 2	Satellite/battery	Coarse	Y	N	2.3	4.5	3.1	4.2	0.0	2.3	3.4	9.2	0.0	13.9	13.5	22.2	31.4
F 3	Satellite/battery	Coarse	N	N	0.8	1.5	1.0	1.4	0.0	0.8	1.1	3.1	0.0	4.6	4.5	7.4	10.5
F 4	Satellite/battery	Coarse	N	Y	4.3	3.5	4.0	3.6	15.0	9.2	8.9	6.9	10.0	5.4	9.3	5.1	2.0
G 1	Bulk plant	Fine	Y	Y	10.0	8.9	17.7	12.0	6.1	9.1	24.9	16.8	38.3	12.3	13.0	8.5	4.7
G 2	Bulk plant	Fine	Y	N	25.0	29.5	23.6	27.9	15.4	23.9	12.6	19.8	0.0	24.0	14.1	21.7	28.7
G 3	Bulk plant	Fine	N	N	21.5	24.4	16.4	21.0	13.2	19.5	7.5	12.7	0.0	15.7	9.3	14.2	14.3
G 4	Bulk plant	Fine	N	Y	8.6	7.3	12.3	9.1	5.3	7.5	15.0	10.7	21.8	8.0	8.6	5.5	2.3
H 1	Bulk plant	Coarse	Y	Y	5.4	3.8	7.6	5.2	9.2	6.1	16.6	11.2	25.5	8.2	15.9	8.5	4.7
H 2	Bulk plant	Coarse	Y	N	13.5	12.6	10.1	11.9	23.1	15.9	8.4	13.2	0.0	16.0	17.3	21.7	28.7
H 3	Bulk plant	Coarse	N	N	11.6	10.4	7.0	9.0	19.8	13.0	5.0	8.5	0.0	10.4	11.4	14.2	14.3
H 4	Bulk plant	Coarse	N	Y	4.6	3.1	5.3	3.9	7.9	5.0	10.0	7.1	14.5	5.4	10.5	5.5	2.3
I 1	Home heating	Fine	Y	Y	13.9	13.1	23.2	16.8	8.6	13.5	29.6	20.8	40.6	15.5	16.4	10.7	4.9
I 2	Home heating	Fine	Y	N	22.8	27.5	21.0	25.9	14.1	21.5	10.4	18.4	0.0	23.4	12.6	21.7	30.1
I 3	Home heating	Fine	N	N	17.6	19.9	12.2	16.6	10.8	15.4	5.2	9.8	0.0	12.7	6.9	11.8	12.9
I 4	Home heating	Fine	N	Y	10.7	9.5	13.5	10.8	6.6	9.6	14.8	11.0	19.4	8.4	9.0	5.8	2.1
J 1	Home heating	Coarse	Y	Y	7.5	5.6	10.0	7.2	12.8	9.0	19.7	13.8	27.1	10.3	20.1	10.7	4.9
J 2	Home heating	Coarse	Y	N	12.3	11.8	9.0	11.1	21.1	14.4	7.0	12.3	0.0	15.6	15.4	21.7	30.1
J 3	Home heating	Coarse	N	N	9.5	8.5	5.2	7.1	16.2	10.3	3.5	6.5	0.0	8.5	8.5	11.8	12.9
J 4	Home heating	Coarse	N	Y	5.8	4.1	5.8	4.6	9.9	6.4	9.9	7.4	12.9	5.6	11.0	5.8	2.1

Table 4.1: Scenario Distributions by Facility Type and Region (Page 2 of 2)

Scenario	Facility Type	Soil Texture	Aquatic Life	Drinking Water	BC	AB	SK	MN	ON	QC	NB	NS	PE	NL	YK	NT	NU
M 1	Gas plant	Fine	Y	Y	51.0	41.9	47.6	43.1	30.0	41.6	39.9	31.2	45.0	24.2	22.7	15.3	6.1
M 2	Gas plant	Fine	Y	N	9.0	18.1	12.4	16.9	0.0	3.5	5.1	13.8	0.0	20.8	11.0	22.2	31.4
M 3	Gas plant	Fine	N	N	3.0	6.0	4.1	5.6	0.0	1.2	1.7	4.6	0.0	6.9	3.7	7.4	10.5
M 4	Gas plant	Fine	N	Y	17.0	14.0	15.9	14.4	10.0	13.9	13.3	10.4	15.0	8.1	7.6	5.1	2.0
N 1	Gas plant	Coarse	Y	Y	12.8	10.5	11.9	10.8	45.0	27.7	26.6	20.8	30.0	16.1	27.8	15.3	6.1
N 2	Gas plant	Coarse	Y	N	2.3	4.5	3.1	4.2	0.0	2.3	3.4	9.2	0.0	13.9	13.5	22.2	31.4
N 3	Gas plant	Coarse	N	N	0.8	1.5	1.0	1.4	0.0	0.8	1.1	3.1	0.0	4.6	4.5	7.4	10.5
N 4	Gas plant	Coarse	N	Y	4.3	3.5	4.0	3.6	15.0	9.2	8.9	6.9	10.0	5.4	9.3	5.1	2.0
O 1	Government	Fine	Y	Y	10.1	9.1	17.5	12.1	6.2	9.3	24.4	16.6	37.1	12.3	12.8	8.6	4.9
O 2	Government	Fine	Y	N	25.5	30.0	24.3	28.4	15.7	24.3	13.5	20.4	1.4	24.4	14.6	22.1	28.7
O 3	Government	Fine	N	N	21.1	23.8	16.3	20.6	13.0	19.1	7.9	12.7	0.8	15.5	9.3	14.0	14.0
O 4	Government	Fine	N	Y	8.3	7.2	11.8	8.8	5.1	7.3	14.3	10.3	20.6	7.8	8.2	5.4	2.4
P 1	Government	Coarse	Y	Y	5.4	3.9	7.5	5.2	9.3	6.2	16.3	11.0	24.8	8.2	15.7	8.6	4.9
P 2	Government	Coarse	Y	N	13.8	12.8	10.4	12.2	23.6	16.2	9.0	13.6	1.0	16.3	17.9	22.1	28.7
P 3	Government	Coarse	N	N	11.3	10.2	7.0	8.8	19.4	12.7	5.2	8.5	0.5	10.3	11.4	14.0	14.0
P 4	Government	Coarse	N	Y	4.5	3.1	5.1	3.8	7.7	4.9	9.5	6.9	13.7	5.2	10.0	5.4	2.4
Q 1	Commercial	Fine	Y	Y	10.0	8.9	17.7	12.0	6.1	9.1	24.9	16.8	38.3	12.3	13.0	8.5	4.7
Q 2	Commercial	Fine	Y	N	25.0	29.5	23.6	27.9	15.4	23.9	12.6	19.8	0.0	24.0	14.1	21.7	28.7
Q 3	Commercial	Fine	N	N	21.5	24.4	16.4	21.0	13.2	19.5	7.5	12.7	0.0	15.7	9.3	14.2	14.3
Q 4	Commercial	Fine	N	Y	8.6	7.3	12.3	9.1	5.3	7.5	15.0	10.7	21.8	8.0	8.6	5.5	2.3
R 1	Commercial	Coarse	Y	Y	5.4	3.8	7.6	5.2	9.2	6.1	16.6	11.2	25.5	8.2	15.9	8.5	4.7
R 2	Commercial	Coarse	Y	N	13.5	12.6	10.1	11.9	23.1	15.9	8.4	13.2	0.0	16.0	17.3	21.7	28.7
R 3	Commercial	Coarse	N	N	11.6	10.4	7.0	9.0	19.8	13.0	5.0	8.5	0.0	10.4	11.4	14.2	14.3
R 4	Commercial	Coarse	N	Y	4.6	3.1	5.3	3.9	7.9	5.0	10.0	7.1	14.5	5.4	10.5	5.5	2.3

Note: Values given are percentages of each facility per combination of soil type, land and water use and sum to 100% for each facility

Table 4.2: Method of Extrapolation of Soil Volumes from Data Capture to Excluded Scenarios (Page 1 of 2)

Scenario	Facility Type	Soil Texture	Aquatic Life	Drinking Water	Extrapolation Method
A 1	Wellsite	F	Y	Y	*Included in data capture*
A 2	Wellsite	F	Y	N	Similar to A3
A 3	Wellsite	F	N	N	*Included in data capture*
A 4	Wellsite	F	N	Y	Similar to A1
B 1	Wellsite	C	Y	Y	*Included in data capture*
B 2	Wellsite	C	Y	N	Similar to B1
B 3	Wellsite	C	N	N	Similar to B1
B 4	Wellsite	C	N	Y	Similar to B1
C 1	Service station	F	Y	Y	*Included in data capture*
C 2	Service station	F	Y	N	Similar to C3
C 3	Service station	F	N	N	*Included in data capture*
C 4	Service station	F	N	Y	Similar to C1
D 1	Service station	C	Y	Y	*Included in data capture*
D 2	Service station	C	Y	N	*Included in data capture*
D 3	Service station	C	N	N	*Included in data capture*
D 4	Service station	C	N	Y	*Included in data capture*
E 1	Satellite/battery	F	Y	Y	*Included in data capture*
E 2	Satellite/battery	F	Y	N	Similar to E3
E 3	Satellite/battery	F	N	N	*Included in data capture*
E 4	Satellite/battery	F	N	Y	Similar to E1
F 1	Satellite/battery	C	Y	Y	Extrapolate from E1 based on ratio B1/A1
F 2	Satellite/battery	C	Y	N	Similar to F1
F 3	Satellite/battery	C	N	N	Similar to F1
F 4	Satellite/battery	C	N	Y	Similar to F1
G 1	Bulk plant	F	Y	Y	*Included in data capture*
G 2	Bulk plant	F	Y	N	Similar to G3
G 3	Bulk plant	F	N	N	*Included in data capture*
G 4	Bulk plant	F	N	Y	Similar to G1
H 1	Bulk plant	C	Y	Y	Extrapolate from G1 based on ratio D1/C1
H 2	Bulk plant	C	Y	N	Extrapolate from H1 based on ratio D2/D1
H 3	Bulk plant	C	N	N	Extrapolate from H1 based on ratio D3/D1
H 4	Bulk plant	C	N	Y	Extrapolate from H1 based on ratio D4/D1
I 1	Home heating	F	Y	Y	*Included in data capture*
I 2	Home heating	F	Y	N	Similar to I3
I 3	Home heating	F	N	N	*Included in data capture*
I 4	Home heating	F	N	Y	Similar to I1
J 1	Home heating	C	Y	Y	*Included in data capture*
J 2	Home heating	C	Y	N	Similar to J1
J 3	Home heating	C	N	N	Similar to J1
J 4	Home heating	C	N	Y	Similar to J1

Table 4.2: Method of Extrapolation of Soil Volumes from Data Capture to Excluded Scenarios (Page 2 of 2)

Scenario	Facility Type	Soil Texture	Aquatic Life	Drinking Water	Extrapolation Method
M 1	Gas plant	F	Y	Y	Multiply corresponding wellsite scenario volume by 8.1 *
M 2	Gas plant	F	Y	N	Multiply corresponding wellsite scenario volume by 8.1 *
M 3	Gas plant	F	N	N	Multiply corresponding wellsite scenario volume by 8.1 *
M 4	Gas plant	F	N	Y	Multiply corresponding wellsite scenario volume by 8.1 *
N 1	Gas plant	C	Y	Y	Multiply corresponding wellsite scenario volume by 8.1 *
N 2	Gas plant	C	Y	N	Multiply corresponding wellsite scenario volume by 8.1 *
N 3	Gas plant	C	N	N	Multiply corresponding wellsite scenario volume by 8.1 *
N 4	Gas plant	C	N	Y	Multiply corresponding wellsite scenario volume by 8.1 *
O 1	Government	F	Y	Y	Multiply corresponding service station scenario volume by 0.34 *
O 2	Government	F	Y	N	Multiply corresponding service station scenario volume by 0.34 *
O 3	Government	F	N	N	Multiply corresponding service station scenario volume by 0.34 *
O 4	Government	F	N	Y	Multiply corresponding service station scenario volume by 0.34 *
P 1	Government	C	Y	Y	Multiply corresponding service station scenario volume by 0.34 *
P 2	Government	C	Y	N	Multiply corresponding service station scenario volume by 0.34 *
P 3	Government	C	N	N	Multiply corresponding service station scenario volume by 0.34 *
P 4	Government	C	N	Y	Multiply corresponding service station scenario volume by 0.34 *
Q 1	Commercial	F	Y	Y	Multiply corresponding service station scenario volume by 0.29 *
Q 2	Commercial	F	Y	N	Multiply corresponding service station scenario volume by 0.29 *
Q 3	Commercial	F	N	N	Multiply corresponding service station scenario volume by 0.29 *
Q 4	Commercial	F	N	Y	Multiply corresponding service station scenario volume by 0.29 *
R 1	Commercial	C	Y	Y	Multiply corresponding service station scenario volume by 0.29 *
R 2	Commercial	C	Y	N	Multiply corresponding service station scenario volume by 0.29 *
R 3	Commercial	C	N	N	Multiply corresponding service station scenario volume by 0.29 *
R 4	Commercial	C	N	Y	Multiply corresponding service station scenario volume by 0.29 *

Note: * - empirical factor based on ratios of soil volumes between facility types, obtained from Komex (2000)

Table 4.3: Unit Soil Remediation Costs

Upstream Remediation Unit Costs

	Costs ($/m3)						
	Minimum	Maximum	Median	Mean	P10	P90	Std. Dev
BC	3.0	2242.1	122.1	164.3	53.1	288.1	192.7
Prairies	3.0	2242.1	122.1	164.3	53.1	288.1	192.7
Central	3.0	2242.1	122.1	164.3	53.1	288.1	192.7
Atlantic	3.0	2242.1	122.1	164.3	53.1	288.1	192.7
North	3.0	2242.1	122.1	164.3	53.1	288.1	192.7

Notes:
Upstream costs are based on combination of land treatment and landfilling (based on confidential data provided by CAPP(2007)
Data provided by CAPP (2007) were aggregated for BC and Prairies. Same unit costs were assumed to apply to all regions
Statistics presented represent the distributions across actual remediation projects of various sizes. For the purpose of aggregating costs, a more appropriate mean is the total remediation cost (all projects) divided by the aggregate soil volume. This value was $90.90/m3 for the data provided by CAPP (2007).

Downstream Remediation Unit Costs

	Costs ($/m3)						
	Minimum	Maximum	Mode	Mean	P10	P90	Std. Dev
BC	90.0	150.0	120.0	120.0	-	-	-
Prairies	90.0	150.0	120.0	120.0	-	-	-
Central	100.0	180.0	140.0	140.0	-	-	-
Atlantic	120.0	200.0	160.0	160.0	-	-	-
North	160.0	240.0	200.0	200.0	-	-	-

Note:
Downstream costs are based primarily on landfilling (based on data presented by OAEI (1998) and confidential industry data)

Table 4.4: Average Remediation Cost by Facility Type - 2000 Criteria

Facility Type	2000 Average Remediation Cost ($)												
	BC	AB	SK	MN	ON	QC	NB	NS	PE	NL	YK	NT	NU
Wellsite, oil	271,911	242,868	260,912	246,820	268,137	273,377	268,108	240,413	284,394	218,019	236,969	205,233	175,944
Wellsite, gas	65,867	58,831	63,202	59,789	64,952	66,222	64,945	58,237	68,890	52,812	57,402	49,715	42,620
Battery/satellite, oil	345,707	320,967	336,338	324,334	330,156	340,788	336,300	312,707	350,173	293,630	305,147	279,655	254,704
Battery/satellite, gas	628,116	583,166	611,092	589,283	599,861	619,178	611,023	568,159	636,230	533,497	554,422	508,105	462,772
Compressor station	628,116	583,166	611,092	589,283	599,861	619,178	611,023	568,159	636,230	533,497	554,422	508,105	462,772
Gas plant	1,367,998	1,221,885	1,312,661	1,241,768	1,349,012	1,375,374	1,348,865	1,209,532	1,430,800	1,096,864	1,192,203	1,032,540	885,186
Service station	110,999	106,046	112,977	107,908	140,133	130,250	169,076	155,697	192,403	148,091	205,001	186,183	166,280
Bulk plant	99,646	87,837	111,745	96,514	147,864	121,713	196,182	166,084	244,709	148,819	233,350	193,970	172,694
Government site	37,493	36,092	39,102	37,192	47,345	44,368	58,312	54,344	64,686	52,073	71,285	65,854	63,041
Commercial site	31,980	30,753	33,457	31,741	40,363	37,836	50,072	46,509	55,797	44,469	60,992	56,166	53,639
Home heating oil site	772	748	748	748	1,044	930	1,062	1,062	1,062	1,062	1,451	1,410	1,410

Table 4.5: Average Remediation Cost by Facility Type - 2007 Criteria

Facility Type	2007 Average Remediation Cost ($)												
	BC	AB	SK	MN	ON	QC	NB	NS	PE	NL	YK	NT	NU
Wellsite, oil	266,691	236,158	255,128	240,313	265,361	269,551	264,012	234,896	281,134	211,352	232,263	198,569	167,777
Wellsite, gas	64,602	57,206	61,801	58,212	64,280	65,295	63,953	56,900	68,101	51,197	56,263	48,101	40,642
Battery/satellite, oil	357,321	335,881	349,201	338,798	338,320	350,295	346,406	325,960	358,429	309,428	317,337	295,936	274,313
Battery/satellite, gas	649,216	610,262	634,463	615,563	614,693	636,452	629,385	592,238	651,229	562,200	576,570	537,686	498,400
Compressor station	649,216	610,262	634,463	615,563	614,693	636,452	629,385	592,238	651,229	562,200	576,570	537,686	498,400
Gas plant	1,341,739	1,188,125	1,283,561	1,209,029	1,335,048	1,356,128	1,328,259	1,181,773	1,414,400	1,063,321	1,168,530	999,013	844,095
Service station	114,958	110,847	116,496	112,197	141,201	134,120	171,122	158,832	192,783	151,838	206,637	189,262	169,410
Bulk plant	106,336	96,079	117,672	103,903	149,973	128,406	199,018	171,372	243,629	155,496	235,930	199,777	179,453
Government site	38,823	37,715	40,352	38,676	47,693	45,677	59,073	55,468	64,873	53,401	71,839	66,918	64,163
Commercial site	33,120	32,146	34,514	33,009	40,674	38,960	50,697	47,460	55,907	45,602	61,470	57,084	54,608
Home heating oil site	841	829	804	820	1,088	1,002	1,094	1,124	1,056	1,143	1,499	1,501	1,529

Table 4.6: Inventory of Facilities by Province and Territory

Facility Type	Number of Facilities													Totals	Probability of Impact
	BC	AB	SK	MN	ON	QC	NB	NS	PE	NL	YK	NT	NU		
Wellsite, oil	2,694	85,865	47,390	3,337	581	-	6	-	-	-	-	224	-	140,097	0.35
Wellsite, gas	8,364	131,085	19,857	5	2,046	5	5	5	5	5	-	139	-	161,521	0.25
Battery/satellite, oil	773	24,642	13,600	958	167	-	2	-	-	-	-	64	-	40,206	0.90
Battery/satellite, gas	514	8,060	1,221	-	126	-	-	-	-	-	-	9	-	9,930	0.50
Compressor station	278	4,372	661	-	68	-	-	-	-	-	-	5	-	5,384	0.75
Gas plant	54	853	129	-	13	-	-	-	-	-	-	1	-	1,050	1.00
Service station	1,836	1,896	900	736	4,577	4,975	564	569	130	581	66	36	24	16,889	1.00
Bulk plant	198	401	280	131	221	83	22	28	11	40	24	70	70	1,576	1.00
Government site	865	904	595	455	3,232	2,800	1,460	1,435	301	1,589	2	11	7	13,656	1.00
Commercial site	2,294	2,506	688	526	22,623	19,600	4,167	4,095	858	4,534	361	965	626	63,843	1.00
Home heating oil site	75,115	40,072	13,158	14,751	318,263	417,728	70,966	266,901	50,829	74,798	9,850	12,177	8,489	1,373,097	1.00

Note: Refer to Appendix B for sources of above information

Table 4.7: Overall Remediation Costs by Facility Type and Province/Territory - 2000 Criteria

Facility Type	2000 Total Remediation Costs (x $1000)													Totals
	BC	AB	SK	MN	ON	QC	NB	NS	PE	NL	YK	NT	NU	
Wellsite, oil	256,385	7,298,865	4,327,610	288,274	54,526	-	563	-	-	-	-	16,090	-	12,242,312
Wellsite, gas	137,727	1,927,981	313,751	75	33,223	83	81	73	86	66	-	1,728	-	2,414,874
Battery/satellite, oil	240,509	7,118,347	4,116,772	279,641	49,622	-	605	-	-	-	-	16,108	-	11,821,604
Battery/satellite, gas	161,426	2,350,158	373,072	-	37,791	-	-	-	-	-	-	2,286	-	2,924,734
Compressor station	130,962	1,912,201	302,949	-	30,593	-	-	-	-	-	-	1,905	-	2,378,610
Gas plant	73,872	1,042,268	169,333	-	17,537	-	-	-	-	-	-	1,033	-	1,304,043
Service station	203,795	201,063	101,679	79,377	641,359	648,018	95,359	88,560	24,935	86,011	13,530	6,703	3,991	2,194,380
Bulk plant	19,730	35,205	31,244	12,624	32,648	10,078	4,238	4,584	2,643	5,893	5,600	13,500	12,019	190,007
Government site	32,431	32,627	23,266	16,922	153,020	124,229	85,135	77,984	19,471	82,744	143	724	441	649,137
Commercial site	73,363	77,068	23,018	16,696	913,130	741,580	208,649	190,453	47,874	201,620	22,018	54,200	33,578	2,603,247
Home heating oil site	58,004	29,958	9,837	11,028	332,394	388,320	75,394	283,556	54,001	79,465	14,292	17,170	11,969	1,365,388
Totals	1,388,204	22,025,740	9,792,531	704,636	2,295,844	1,912,308	470,025	645,209	149,009	455,800	55,584	131,447	61,999	40,088,336

Table 4.8: Overall Remediation Costs by Facility Type and Province/Territory - 2007 Criteria

Facility Type	2007 Total Remediation Costs (x $1000)													Totals
	BC	AB	SK	MN	ON	QC	NB	NS	PE	NL	YK	NT	NU	
Wellsite, oil	251,463	7,097,204	4,231,673	280,674	53,961	-	554	-	-	-	-	15,568	-	11,931,097
Wellsite, gas	135,083	1,874,713	306,796	73	32,879	82	80	71	85	64	-	1,671	-	2,351,598
Battery/satellite, oil	248,588	7,449,093	4,274,217	292,112	50,849	-	624	-	-	-	-	17,046	-	12,332,528
Battery/satellite, gas	166,849	2,459,356	387,340	-	38,726	-	-	-	-	-	-	2,420	-	3,054,689
Compressor station	135,362	2,001,049	314,535	-	31,349	-	-	-	-	-	-	2,016	-	2,484,311
Gas plant	72,454	1,013,471	165,579	-	17,356	-	-	-	-	-	-	999	-	1,269,859
Service station	211,063	210,166	104,847	82,532	646,249	667,272	96,513	90,343	24,985	88,188	13,638	6,813	4,066	2,246,675
Bulk plant	21,055	38,508	32,901	13,590	33,114	10,632	4,299	4,730	2,631	6,158	5,662	13,904	12,490	199,675
Government site	33,582	34,095	24,009	17,598	154,145	127,895	86,246	79,597	19,527	84,854	144	736	449	662,877
Commercial site	75,977	80,557	23,746	17,363	920,179	763,616	211,256	194,347	47,968	206,761	22,191	55,086	34,185	2,653,230
Home heating oil site	63,152	33,229	10,578	12,103	346,342	418,365	77,608	299,908	53,675	85,472	14,761	18,272	12,979	1,446,444
Totals	1,414,627	22,291,441	9,876,220	716,044	2,325,150	1,987,862	477,180	668,996	148,872	471,496	56,396	134,532	64,169	40,632,983

Table 5.1: Influence of Remediation Industry Capacity on Completion of Remediation and Residual Liabilities

Remediation Industry Revenues by Province/Territory (Projected 2006)

	Revenues (x $1 million) unless stated								
	BC	AB	SK	MN	ON	QC	Atlantic	North	Total
Total environmental goods and services	2,674.9	3,446.2	563.5	479.5	9,141.5	3,646.7	1,025.6	60.6	21,038.4
% of total revenues 2006	12.7%	16.4%	2.7%	2.3%	43.5%	17.3%	4.9%	0.3%	100.0%
Total remediation industry[a]	133.9	172.5	28.2	24.0	457.6	182.5	51.3	3.0	1,053.1
PHC remediation industry[b]	89.3	115.0	18.8	16.0	305.1	121.7	34.2	2.0	702.1

a - Based on assumption of remediation services (562910) and 50% of environmental consulting (541620).
b - Based on 2/3 times estimated remediation industry

Comparison of Industry Capacity with Remediation Costs

	Costs (x $1 million) unless stated								
	BC	AB	SK	MN	ON	QC	Atlantic	North	Overall
Total remediation costs	1,414.6	22,291.4	9,876.2	716.0	2,325.1	1,987.9	1,766.5	255.1	40,633.0
% total cost by region	3.5%	54.9%	24.3%	1.8%	5.7%	4.9%	4.3%	0.6%	100.0%
Number of years to complete PHC remediation (constant industry size)	15.8	193.8	525.2	44.7	7.6	16.3	51.6	126.2	57.9
Number of years to complete PHC remediation (4.2% industry growth rate)	12.4	53.8	76.3	25.7	6.8	12.7	28.0	44.7	30.0
Present value of total remediation cost[c,d]	1,165.6	7,680.8	1,954.8	456.3	2,121.5	1,628.9	1,073.9	108.2	23,733.5

c - Assuming 4.2% industry growth rate
d - Using discount rate of 5%

Projection of Remediation Timing and Residual Liabilites

	Costs (x $1million)								
	BC	AB	SK	MN	ON	QC	Atlantic	North	Overall
10 year analysis									
Amount of work that can be completed in 10 years (with industry growth)[e]	1,081.7	1,393.7	227.9	193.9	3,696.8	1,474.7	414.8	24.5	8,507.9
Present value of the above[f]	931.2	1,199.8	196.2	166.9	3,182.5	1,269.5	357.1	21.1	7,324.3
Present value of residual liability after 10 years[f]	234.3	6,481.1	1,758.6	289.4	-	359.4	716.8	87.1	16,409.3
5 year analysis									
Amount of work that can be completed in 5 years (with industry growth)[e]	485.4	625.4	102.3	87.0	1,658.9	661.8	186.1	11.0	3,818.0
Present value of the above[f]	456.7	588.4	96.2	81.9	1,560.8	622.6	175.1	10.3	3,592.1
Present value of residual liability after 5 years[f]	708.9	7,092.4	1,858.6	374.4	560.6	1,006.3	898.8	97.9	20,141.4

e - Assuming 4.2% industry growth rate
f - Using discount rate of 5%

Table 6.1: Employment in Remediation Industry and Projected Employment Arising From PHC Site Remediation

	BC	AB	SK	MN	ON	QC	Atlantic	North	Totals
2006 PHC Remediation Industry Size (x $1 million)	89.3	115.0	18.8	16.0	305.1	121.7	34.2	2.0	702.1
2006 Estimated Employment in PHC Remediation Industry (persons)	771	993	162	138	2,634	1,051	296	17	6,062
Estimated Total Employment for Remediation of PHC Sites (person-years)	12,214	192,470	85,274	6,183	20,076	17,164	15,253	2,203	350,836

Table 7.1: Summary of Remediation Costs by Industry Sector

2000 PHC Standard

Industry Sector	2000 Total Remediation Costs (x $1000)								Totals
	BC	AB	SK	MN	ON	QC	Atlantic	North	
Upstream	1,000,880	21,649,820	9,603,487	567,989	223,293	83	1,474	39,150	33,086,177
Downstream	223,525	236,268	132,923	92,001	674,007	658,096	312,224	55,344	2,384,387
Other	163,798	139,652	56,121	44,646	1,398,544	1,254,130	1,406,345	154,536	4,617,772
Totals	1,388,204	22,025,740	9,792,531	704,636	2,295,844	1,912,308	1,720,043	249,030	40,088,336

Proposed 2007 PHC Standard

Industry Sector	2007 Total Remediation Costs (x $1000)								Totals
	BC	AB	SK	MN	ON	QC	Atlantic	North	
Upstream	1,009,799	21,894,886	9,680,140	572,858	225,121	82	1,478	39,720	33,424,083
Downstream	232,117	248,675	137,748	96,123	679,363	677,904	317,846	56,574	2,446,350
Other	172,711	147,881	58,333	47,063	1,420,666	1,309,876	1,447,219	158,802	4,762,551
Totals	1,414,627	22,291,441	9,876,220	716,044	2,325,150	1,987,862	1,766,544	255,096	40,632,983

Effect of Proposed Revisions on Costs

Industry Sector	Percentage Change								Overall
	BC	AB	SK	MN	ON	QC	Atlantic	North	
Upstream	0.9%	1.1%	0.8%	0.9%	0.8%	-1.4%	0.2%	1.5%	1.0%
Downstream	3.8%	5.3%	3.6%	4.5%	0.8%	3.0%	1.8%	2.2%	2.6%
Other	5.4%	5.9%	3.9%	5.4%	1.6%	4.4%	2.9%	2.8%	3.1%
Overall	1.9%	1.2%	0.9%	1.6%	1.3%	4.0%	2.7%	2.4%	1.4%

Table 7.2: Input Probability Distributions for Probabilistic Analysis

Assumption	Unit	Distribution Type	Distribution Parameters					
			Minimum	Maximum	Mode	Mean	Std. Dev	P90
Probability of impact - oil well	-	Uniform	0.1	0.6	-	-	-	-
Probability of impact - gas well	-	Uniform	0.2	0.3	-	-	-	-
Probability of impact - oil battery	-	Uniform	0.8	1	-	-	-	-
Remediation unit cost (downstream) - BC	$\$/m^3$	Triangular	90	150	120	-	-	-
Remediation unit cost (downstream) - Prairies	$\$/m^3$	Triangular	90	150	120	-	-	-
Remediation unit cost (downstream) - Central	$\$/m^3$	Triangular	100	180	140	-	-	-
Remediation unit cost (downstream) - Atlantic	$\$/m^3$	Triangular	120	200	160	-	-	-
Remediation unit cost (downstream) - North	$\$/m^3$	Triangular	160	240	200	-	-	-
Remediation unit cost (upstream)	$\$/m^3$	Lognormal	-	-	-	91	-	288
Scenario A1 volume	m^3	Lognormal	-	-	-	4627	6813	-
Scenario A3 volume	m^3	Lognormal	-	-	-	901	1059	-
Scenario B1 volume	m^3	Lognormal	-	-	-	3460	3826	-
Scenario C1 volume	m^3	Lognormal	-	-	-	3334	4333	-
Scenario C3 volume	m^3	Lognormal	-	-	-	2310	2217	-
Scenario D1 volume	m^3	Lognormal	-	-	-	3959	5217	-
Scenario D2 volume	m^3	Lognormal	-	-	-	3100	2539	-
Scenario D3 volume	m^3	Lognormal	-	-	-	2719	2553	-
Scenario D4 volume	m^3	Lognormal	-	-	-	3767	4286	-
Scenario E1 volume	m^3	Lognormal	-	-	-	10897	12877	-
Scenario E3 volume	m^3	Lognormal	-	-	-	6064	7854	-

Table 7.3: Summary of Results of Probabilistic Analysis - Total Remediation Costs (2007)

	Total Industry Sector Costs (x $1 million)			
	Upstream	Downstream	Other	Combined
Median	30,390	2,389	4,424	37,776
Mean	59,528	2,646	4,762	66,936
Std. Dev	112,953	1,164	1,560	112,941
P10	7,318	1,515	3,220	14,380
P90	126,309	4,064	6,663	134,123

Table 7.4: Summary of Results of Probabilistic Analysis - Average Remediation Costs by Facility (2007)

	Average Remediation Cost per Facility (x $1000)										
	Oil Well	Gas Well	Oil Battery/ Satellite	Gas Battery/ Satellite	Compressor Station	Gas Plant	Service Station	Bulk Plant	Government Site	Commercial Site	Home Heating
Median	171.5	41.2	288.7	523.6	523.6	855.8	118.9	160.5	43.5	37.4	1.1
Mean	367.7	88.0	680.8	1,236.1	1,236.1	1,827.3	133.0	253.7	48.5	41.6	1.1
Std. Dev	794.9	188.8	1,670.6	3,047.2	3,047.2	3,921.2	62.3	313.1	23.2	19.2	NA
P10	39.2	9.4	60.1	109.3	109.3	195.3	71.9	80.4	25.9	22.6	NA
P90	829.4	197.9	1,427.3	2,590.3	2,590.3	4,109.2	208.7	501.2	76.2	65.1	NA

FIGURES

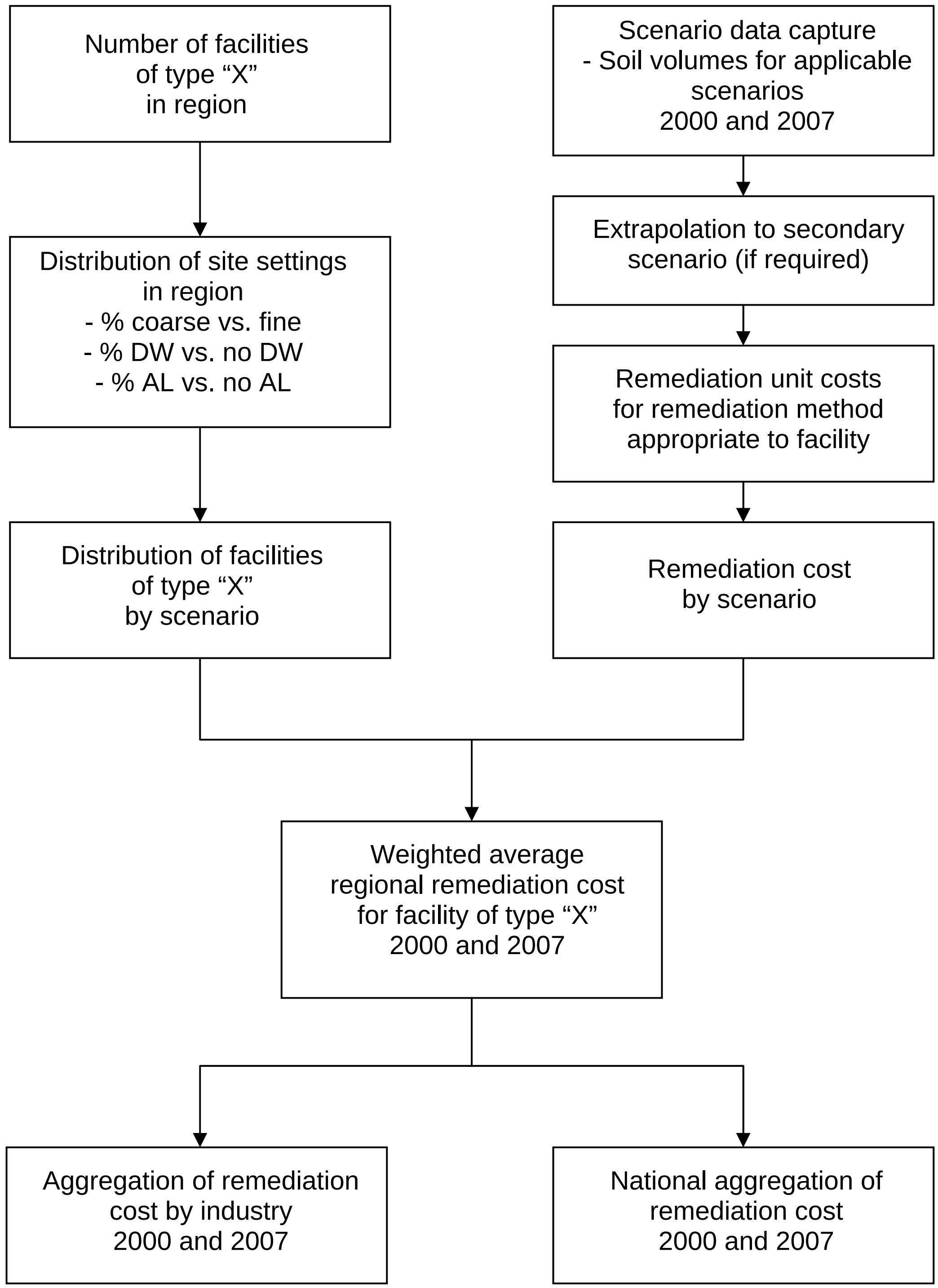

Figure 4.1: Schematic of Basic Remediation Cost Model

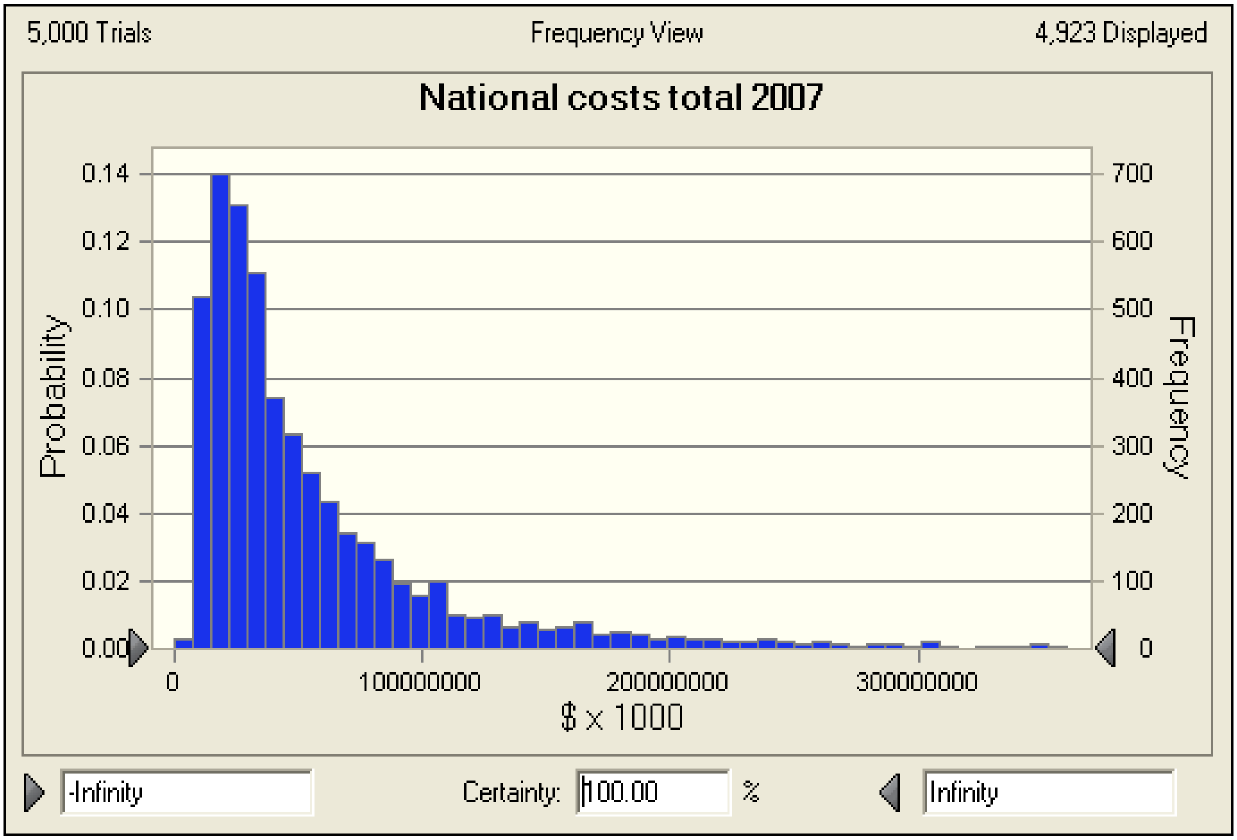

Figure 7.1: Probability Distribution of Projected Total Remediation Costs (2007)

APPENDIX A

INDUSTRY DATA CAPTURE TABLES

Table A.1: Summary of Industry Data, Scenario A1

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES								
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene	2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
Wellsite	0	100	100	0	15000	0	100	0	0	15000	100	15000	100	15000
Wellsite with Flare Pit	0	100	900	100	800	0	150	900	100	800	900	900	900	900
Wellsite with Drill Sump	0	10000	7000	0	7000	0	10000	4000	1500	7000	10000	10000	10000	10000
Wellsite	625	0	375	0	5875	625	0	0	0	5875	625	5875	625	5875
Wellsite	375	500	0	0	23000	375	1000	0	0	23000	500	23000	1000	23000
Completed Project: Well centre remediation on lease. No F4 > criteria. Limited PHC assessment data.	642	642	642	0	642	642	642	642	0	642	642	642	642	642
Completed Project: Well centre and sump remediation on lease. F3 primary drivers, assume 35% also exceed, F1, F2 and BTEX criteria, limited PHC assessment data.	445	445	1281	0	445	445	445	0	0	445	1281	1281	445	445
Old historical pipeline spill. Attempted biodegradation effort.	0	795	975	795	0	0	795	795	795	0	975	975	795	795
Old historical pipeline spill. Attempted biodegradation effort.	0	1420	1400	1130	0	0	1520	1400	1130	0	1420	1420	1520	1520
Historic spill over pipeline, not remediated for at least 10 years.	102	550	611	225	0	177	650	420	225	0	611	611	650	650
Vault	250	250	250		1600	250	250	250		1600	250	1600	250	1600
Flare Pit	450	450	20		2000	450	450	20		2000	450	2000	450	2000
Well Centre	150	150	150	50	1650	150	150	75	50	1650	150	1650	150	1650
Well Centre/Separator	10		10		700	10	600	10		700	10	700	600	700

Statistics

Number of data points	14	13	14	11	14	14	14	14	11	14	14	14	14	14
Minimum	0	0	0	0	0	0	0	0	0	0	10	611	100	445
Maximum	642	10000	7000	1130	23000	642	10000	4000	1500	23000	10000	23000	10000	23000
Median	126	450	493	0	1200	164	525	163	50	1200	618	1510	634	1560
Mean	218	1185	980	209	4194	223	1197	608	345	4194	1280	4690	1295	4627
Standard Deviation	244	2675	1796	386	6807	242	2566	1070	539	6807	2545	6774	2532	6813

Table A.2: Summary of Industry Data, Scenario A3

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES					2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene				
Wellsite	0	0	100	0	1000	0	800	0	0	1000	100	1000	800	1000
Wellsite with Flare Pit	0	100	900	100	0	0	150	900	100	0	900	900	900	900
Wellsite with Drill Sump	0	4000	7000	0	0	0	4000	4000	1500	0	7000	7000	4000	4000
Wellsite	625	0	375	0	0	0	0	0	0	0	625	625	0	0
Wellsite	375	0	0	0	225	375	500	0	0	225	375	375	500	500
Old historical pipeline spill. Attempted biodegradation effort.	0	150	975	795	0	0	795	795	795	0	975	975	795	795
Old historical pipeline spill. Attempted biodegradation effort.	0	1330	1400	1130	0	0	1520	1400	1130	0	1400	1400	1520	1520
Historic spill over pipeline, not remediated for at least 10 years.	102	190	611	225	0	102	650	420	225	0	611	611	650	650
Vault	250	250	250		250	250	250	250		250	250	250	250	250
Flare Pit	450	20	20		50	450	450	20		50	450	450	450	450
Well Centre	50	50	150	50	50	50	150	75	50	50	150	150	150	150
Well Centre/Separator			10		10		600	10		10	10	10	600	600

Statistics

Number of data points	11	11	12	9	12	11	12	12	9	12	12	12	12	12
Minimum	0	0	0	0	0	0	0	0	0	0	10	10	0	0
Maximum	625	4000	7000	1130	1000	450	4000	4000	1500	1000	7000	7000	4000	4000
Median	50	100	313	50	5	0	550	163	100	5	531	618	625	625
Mean	168	554	983	256	132	112	822	656	422	132	1071	1146	885	901
Standard Deviation	223	1205	1948	416	287	168	1079	1148	572	287	1911	1887	1058	1059

Table A.3: Summary of Industry Data, Scenario A6

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES								
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene	2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
Wellsite	0	0	100	0	15000	0	100	0	0	15000	100	15000	100	15000
Wellsite with Flare Pit	0	100	900	100	800	0	150	100	100	800	900	900	150	800
Wellsite with Drill Sump	0	4000	7000	0	7000	0	4000	4000	500	7000	7000	7000	4000	7000
Wellsite	625	0	375	0	5875	0	0	0	0	5875	625	5875	0	5875
Wellsite	375	0	0	0	23000	375	500	0	0	23000	375	23000	500	23000
Old historical pipeline spill. Attempted biodegradation effort.	0	150	975	795	0	0	795	795	795	0	975	975	795	795
Old historical pipeline spill. Attempted biodegradation effort.	0	1330	1400	1130	0	0	1520	1400	1130	0	1400	1400	1520	1520
Historic spill over pipeline, not remediated for at least 10 years.	102	190	611	225	0	102	650	420	225	0	611	611	650	650
Vault	250	250	250		1600	250	250	250		1600	250	1600	250	1600
Flare Pit	450	20	20		2000	300	300	10		2000	450	2000	300	2000
Well Centre	50	50	150	50	1650	50	150	75	50	1650	150	1650	150	1650
Well Centre/Separator			10		700		600	10		700	10	700	600	700

Statistics

Number of data points	11	11	12	9	12	11	12	12	9	12	12	12	12	12
Minimum	0	0	0	0	0	0	0	0	0	0	10	611	0	650
Maximum	625	4000	7000	1130	23000	375	4000	4000	1130	23000	7000	23000	4000	23000
Median	50	100	313	50	1625	0	400	88	100	1625	531	1625	400	1625
Mean	168	554	983	256	4802	98	751	588	311	4802	1071	5059	751	5049
Standard Deviation	223	1205	1948	416	7206	142	1104	1156	411	7206	1911	7034	1104	7041

Table A.4: Summary of Industry Data, Scenario B1 (Page 1 of 3)

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES					2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene				
Completed Project: Drilling sump remediation on well lease, F3 PHCs primary driver for cleanup.	190	190	380	0	0	190	190	380	0	0	380	380	380	380
Completed Project: Flare pit remediation off lease, assumes 50% of total volume had F4 > criteria, assumes 25% of volume is F1, F2 plume.	5342	5342	4007	2671	4007	5342	5342	4007	2671	4007	5342	5342	5342	5342
Completed Project: Battery / satellite remediation on lease, assumes 10% of total volume had F4 > criteria; 50% had benzene > criteria and 10% was F1 only plume.	6003	5400	5400	600	3002	6003	5400	5400	600	3002	6003	6003	6003	6003
Completed Project: Remote sump remediation, assumes 15% of total volume > F4 criteria.	16253	16253	16253	3251	16253	16253	16253	16253	3251	16253	16253	16253	16253	16253
Completed Project: Drilling sump (2) and well centre remediation on lease. F3 primary driver, assume 35% also had benzene, F1, F2 and F4 > criteria.	350	350	1008	350	350	350	350	1008	350	350	1008	1008	1008	1008
Completed Project: Drilling sump and well centre (2) remediation on lease. F2 / F3 primary drivers, limited PHC assessment data.	0	1738	1738	0	0	0	1738	1738	0	0	1738	1738	1738	1738
Completed Project: Remote drilling sump remediation off lease. F1, F2 primary drivers, assume 50% exceed benzene and F3, limited PHC assessment data.	4357	4357	2269	0	2269	4357	4357	2279	0	2269	4357	4357	4367	4367

Table A.4: Summary of Industry Data, Scenario B1 (Page 2 of 3)

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2006 SEED VALUES								
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene	2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2006 Volume Exceeding any PHC Fraction (exclude benzene)	2006 Volume Exceeding Any PHC Fraction (include benzene)
Completed Project: Well centre remediation. F2, F3 primary drivers, assume 50% exceed benzene and F1, limited assessment PHC data.	348	698	698	348	0	348	698	698	348	0	698	698	698	698
Completed Project: Well centre remediation on lease. F1, F2, F3 primary drivers, limited PHC assessment data.	993	993	993	0	0	993	993	993	0	0	993	993	993	993
Completed Project: Drilling sump and well centre remediation on lease. Assume 50% exceeds F1 criteria. F2 / F3 primary drivers, limited PHC assessment data.	1087	2174	2174	0	0	1087	2174	2174	0	0	2174	2174	2174	2174
Completed Project: Drilling sump, flare pit, spill area and well centre remediation on lease. F1, F2 / F3 primary drivers; assume 10% from Flare pit also exceeds benzene and F4 criteria, limited PHC assessment data, no volume tracking by source area.	1728	1728	1728	173	173	1728	1728	1728	173	173	1728	1728	1728	1728
Completed Project: Drilling sump and well centre remediation on lease. F2 / F3 primary drivers, assume 10% also exceeds F1 & benzene criteria at well centre, limited PHC assessment data.	450	4545	4545	0	450	450	4545	4555	0	450	4545	4545	4555	4555
Completed Project: Well centre remediation. Limited PHC assessment data.	529	529	529	0	529	529	529	529	0	529	529	529	529	529

Table A.4: Summary of Industry Data, Scenario B1 (Page 3 of 3)

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2006 SEED VALUES								
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene	2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2006 Volume Exceeding any PHC Fraction (exclude benzene)	2006 Volume Exceeding Any PHC Fraction (include benzene)
Completed Project: Drilling sumps (3) and well centre remediation. F2 / F3 primary drivers, assume 10% also exceeds F1 & benzene criteria at well centre, limited PHC assessment data.	600	5955	5955	0	600	600	5955	5955	0	600	5955	5955	5955	5955
Former UST containing condensate	1875	1875	0	0	525	1875	1875	0	0	525	1875	1875	1875	1875
Former UST containing condensate	4880	3690	0	0	4880	4880	3690	0	0	4880	4880	4880	4880	4880
Historical pipeline spill, no apparent remediation.	50.000	580.000	620.000	580.000	0.000	50.000	580.000	620.000	580.000	0.000	620.000	620.000	620.000	620.000
Wellsite	100.000	500.000	350.000	25.000	400.000	100.000	500.000	100.000	0.000	400.000	500.000	500.000	500.000	500.000
Wellsite	450.000	100.000	950.000	100.000	450.000	450.000	100.000	950.000	100.000	450.000	950.000	950.000	950.000	950.000
Spill	650	650	650	650	650	650	650	650	650	650	650	650	650	650
Large pipeline spill near facility	1492.000	1492.000	1492.000	192.000	1492.000	1492.000	1492.000	1467.000	192.000	1492.000	1492.000	1492.000	1492.000	1492.000
Historic buried flare pit on sandy hilltop	6165.000	5535.000	6795.000	1620.000	5625.000	6165.000	5535.000	4275.000	0.000	5625.000	6795.000	7425.000	6165.000	6795.000
Condensate UST release.	10100.000	1685.000	1125.000	0.000	10100.000	10100.000	1685.000	1125.000	0.000	10100.000	10100.000	10100.000	10100.000	10100.000

Statistics

Number of data points	23	23	23	23	23	23	23	23	23	23	23	23	23	23
Minimum	0	100	0	0	0	0	100	0	0	0	380	380	380	380
Maximum	16253	16253	16253	3251	16253	16253	16253	16253	3251	16253	16253	16253	16253	16253
Median	993	1728	1125	25	525	993	1728	1125	0	525	1738	1738	1738	1738
Mean	2782	2885	2594	459	2250	2782	2885	2473	388	2250	3459	3487	3433	3460
Standard Deviation	3967	3516	3574	877	3929	3967	3516	3485	844	3929	3825	3853	3803	3826

Table A.5: Summary of Industry Data, Scenario B6

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES					2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene				
Former UST containing condensate	1875	1875	0	0	525	1875	1875	0	0	525	1875	1875	1875	1875
Former UST containing condensate	4880	3690	0	0	4880	4880	3690	0	0	4880	4880	4880	4880	4880
Historical pipeline spill, no apparent remediation.	50	580	620	580	0	50	580	620	580	0	620	620	620	620
Wellsite	100	500	350	25	400	100	500	100	0	400	500	500	500	500
Wellsite	450	100	950	100	450	450	100	950	100	450	950	950	950	950
Spill	650	650	650	650	650	650	650	650	650	650	650	650	650	650
Large pipeline spill near facility	1492	1492	1492	192	1492	1492	1492	1467	192	1492	1492	1492	1492	1492
Historic buried flare pit on sandy hilltop	6165	5535	6795	1620	5625	6165	5535	4275	0	5625	6795	7425	6165	6795
Condensate UST release.	10100	1685	1125	0	10100	10100	1685	1125	0	10100	10100	10100	10100	10100

Statistics

Number of data points	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Minimum	50	100	0	0	0	50	100	0	0	0	500	500	500	500
Maximum	10100	5535	6795	1620	10100	10100	5535	4275	650	10100	10100	10100	10100	10100
Median	1492	1492	650	100	650	1492	1492	650	0	650	1492	1492	1492	1492
Mean	2862	1790	1331	352	2680	2862	1790	1021	169	2680	3096	3166	3026	3096
Standard Deviation	3473	1769	2108	538	3466	3473	1769	1325	262	3466	3418	3508	3338	3418

Table A.6: Summary of Industry Data, Scenario B7

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES								
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene	2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
Former UST containing condensate	1875	525	0	0	0	525	525	0	0	0	1875	1875	1875	1875
Former UST containing condensate	4880	3690	0	0	0	3690	3690	0	0	0	4880	4880	3690	3690
Historical pipeline spill, no apparent remediation.	0	580	620	580	0	0	580	620	580	0	620	620	620	620
Wellsite	100	500	350	25	0	25	100	100	0	0	500	500	100	100
Wellsite	450	100	950	100	0	100	100	950	100	0	950	950	950	950
Spill	650	650	650	650	100	650	650	650	650	100	650	650	650	650
Large pipeline spill near facility	1492	807	1492	192	0	1322	1492	1467	192	0	1492	1492	1492	1492
Historic buried flare pit on sandy hilltop	4905	4275	6795	1620	0	1620	1620	4275	0	0	6795	6795	4275	4275
Condensate UST release.	7300	0	1125	0	0	4940	1685	1125	0	0	7300	7300	4940	4940

Statistics

Number of data points	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Minimum	0	0	0	0	0	0	100	0	0	0	500	500	100	100
Maximum	7300	4275	6795	1620	100	4940	3690	4275	650	100	7300	7300	4940	4940
Median	1492	580	650	100	0	650	650	650	0	0	1492	1492	1492	1492
Mean	2406	1236	1331	352	11	1430	1160	1021	169	11	2785	2785	2066	2066
Standard Deviation	2633	1584	2108	538	33	1757	1132	1325	262	33	2766	2766	1780	1780

Table A.7: Summary of Industry Data, Scenario C1

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES								
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene	2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
USTs, Pump Islands	492	174	170		1007	492	174	170		1007	492	1007	492	1007
The impacted area was formerly occupied by three USTs and one pump island.		571					571				571	571	571	571
USTs, dispensers and product piping	1400	450	0	0	2300	1400	450	0	0	2300	1400	2350	1400	2350
Pump Islands, Tank Basins and Product Transfer Piping	6250	2208	11		5298	6500	2550	11		5298	6250	6250	6500	6500
USTs	928	489	0	0	1795	927	489	0	0	1795	932	2149	932	2149
USTs	534	341	8	0	1635	544	366	8	0	1635	534	1643	553	1643
Service Station	391	110	0	0	563	391	110	0	0	563	391	563	391	563
Service Station	1350	0	0	0	1350	1350	0	0	0	1350	1350	1350	1350	1350
Service Station	480	320	0	0	100	480	320	0	0	100	480	580	480	580
Service Station	10890	7040	293	0	17825	10890	7040	293	0	17825	13045	17825	13045	17825
Pump Islands & Tank Nest	2120	1300	0	0	2610	2120	1420	0	0	2610	2120	2860	2120	2860
Historical & Former Pump Islands and Tank Nests	2900	1270	40	0	4080	2240	1270	40	0	4080	2240	4490	2240	4490
Assumed impacts beneath the pump islands and tank nest areas. No documented soil impacts were found during the phase II assessment.											447	447	447	447
Impacts beneath the pump islands and tank nest areas.											974	974	1079	1079
Pump Island, UST's, north of Pump Island	1450	350	0	0	8200	1450	350	0	0	8200	1680	8200	1680	8200
Pump Island	1310	375	0	0	1310	1310	375	0	0	1310	1310	1310	1310	1310
Pump Island, UST's	250	150	0	0	3750	300	150	0	0	3750	250	3750	300	3750

Statistics

Number of data points	14	15	14	12	14	14	15	14	12	14	17	17	17	17
Minimum	250	0	0	0	100	300	0	0	0	100	250	447	300	447
Maximum	10890	7040	293	0	17825	10890	7040	293	0	17825	13045	17825	13045	17825
Median	1330	375	0	0	2047	1330	375	0	0	2047	974	1643	1079	1643
Mean	2196	1010	37	0	3702	2171	1042	37	0	3702	2027	3313	2052	3334
Standard Deviation	2941	1768	86	0	4598	2959	1787	86	0	4598	3167	4326	3184	4333

Table A.8: Summary of Industry Data, Scenario C3

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES								
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene	2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
USTs, Pump Islands	54	40	170		55	159	203	170		55	54	109	239	275
USTs, dispensers and product piping	200	15	0	0	350	1400	450	0	0	350	200	400	1400	1400
Pump Islands, Tank Basins and Product Transfer Piping	1048	2	11		567	2211	1835	11		567	1059	1059	2222	2222
USTs	733	85	0	0	332	811	405	0	0	332	733	870	880	948
USTs	307	0	8	0	60	322	336	8	0	60	307	307	336	336
Service Station	110	0	0	0	425	319	110	0	0	425	110	425	319	425
Service Station	0	0	0	0	1350	0	0	0	0	1350	0	1350	0	1350
Service Station	0	0	0	0	0	320	0	0	0	0	0	0	320	320
Pump Islands & Tank Nest	1390	104	0	0	1060	1840	1260	0	0	1060	1390	1740	1840	2090
Historical & Former Pump Islands and Tank Nests	990	50	40	0	480	1900	1270	40	0	480	1030	1270	1940	2180
Petroleum facilities	1000	147	0	0	6486	2356	444	0	0	6486	1000	6486	2356	6726
onsite extending offsite to the southwest.	418	100	0	0	8586	840	960	0	0	8586	418	8586	960	8586
Assumed impacts beneath the pump islands and tank nest areas											1544	1544	1544	1544
Petroleum hydrocarbon impacts were documented beneath the pump islands and tank nest regions.											1877	1877	1877	1877
Assumed impacts beneath the building, pump islands and tank											2158	2158	2789	2789
Pump Island, UST's, north of Pump Island	90	90	0	0	3800	90	90	0	0	3800	90	3800	90	3800
Pump Island	1000	70	0	0	1310	1000	375	0	0	1310	1000	1310	1000	1310
Pump Island, UST's	150	0	0	0	3400	150	150	0	0	3400	150	3400	150	3400

Statistics

Number of data points	15	15	15	13	15	15	15	15	13	15	18	18	18	18
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	275
Maximum	1390	147	170	0	8586	2356	1835	170	0	8586	2158	8586	2789	8586
Median	307	40	0	0	567	811	375	0	0	567	575	1330	980	1711
Mean	499	47	15	0	1884	915	526	15	0	1884	729	2038	1126	2310
Standard Deviation	475	49	44	0	2594	827	550	44	0	2594	686	2276	894	2217

Table A.9: Summary of Industry Data, Scenario C5

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES								
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene	2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
USTs, Pump Islands	54	40	170		55	159	203	170		55	54	109	239	275
Three of the impacted areas were near former UST sites and one location was used as a pump island.	151	65	65		0	216	75	65		0	282	282	357	357
USTs, dispensers and product piping	200	15	0	0	350	1400	450	0	0	350	200	400	1400	1400
Pump Islands, Tank Basins and Product Transfer Piping	1048	2	11		567	2211	1920	11		567	1059	1059	2222	2222
	60	0	0	0	0	60	60	0	0	0	60	60	60	60
				0	0				0	0	609	609	809	809
USTs	733	85	0	0	332	811	405	0	0	332	733	870	880	948
USTs	322	0	8	0	60	371	336	8	0	60	322	322	371	371
Service Station	110	0	0	0	425	425	110	0	0	425	110	425	425	425
Service Station	0	0	0	0	1350	1350	0	0	0	1350	0	1350	1350	1350
Service Station	320	0	0	0	0	320	320	0	0	0	320	320	320	320
Pump Islands & Tank Nest	1390	104	0	0	1060	1710	1260	0	0	1060	1390	1740	1710	2090
Historical & Former Pump Islands and Tank Nests	990	50	40	0	480	1900	1270	40	0	480	1030	1270	1940	2180
Pump Island, UST's, north of Pump Island	90	90	0	0	3800	360	350	0	0	3800	90	3800	610	3800
Pump Island	1000	70	0	0	1310	1000	375	0	0	1310	1000	1310	1000	1310
Pump Island, UST's	150	0	0	0	3400	150	150	0	0	3400	150	3400	150	3400

Statistics

Number of data points	15	15	15	13	16	15	15	15	13	16	16	16	16	16
Minimum	0	0	0	0	0	60	0	0	0	0	0	60	60	60
Maximum	1390	104	170	0	3800	2211	1920	170	0	3800	1390	3800	2222	3800
Median	200	15	0	0	388	425	336	0	0	388	301	740	710	1129
Mean	441	35	20	0	824	830	486	20	0	824	463	1083	865	1332
Standard Deviation	459	39	46	0	1177	717	553	46	0	1177	445	1105	676	1135

Table A.10: Summary of Industry Data, Scenario D1

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES								
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene	2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
USTs, Pump Islands	264	24	0		5	264	24	0		5	264	264	264	264
site	3384	5310	230			3320	4880	60			5658	5658	5406	5406
USTs	6541	7145	604	0	14680	6541	5963	604	0	14680	7923	15794	6865	14837
USTs	1126	1143	0	0	2255	1126	1143	0	0	2255	1126	2298	1126	2298
Service Station	418	115	0	0	590	418	115	0	0	590	418	590	418	590
Service Station	1350	1350	0	0	1350	1350	0	0	0	1350	1350	1350	1350	1350
Service Station	480	480	0	0	100	480	320	0	0	100	480	580	480	580
Service Station	10890	7430	293	0	17825	10890	7040	293	0	17825	13045	17825	13045	17825
Historical & Former Pump Islands and Tank Nests	3170	3220	230	70	6750	3170	1610	70	70	6750	3960	7070	3620	7070
Historical Tank Nests	830	1130	0	0	790	830	1130	0	0	790	1130	1130	1130	1130
Tank Nest	500	0	0	0	1500	500	0	0	0	1500	500	1500	500	1500
Tank Nest	0	0	0	0	1500	0	0	0	0	1500	0	1500	0	1500
Existing tank nest and pump island areas excavated during site upgrades											526	579	526	526
Assumed impacts beneath the pump islands and tank nest areas, and adjacent to tank nest.											1158	1158	1158	1158
Service Station	3400	3400	0	0	3500	3400	1300	0	0	3500	3400	3500	3400	3500
Service Station	3050	3050	0	0	2950	2950	2550	0	0	2950	3050	3900	2950	3810
Statistics														
Number of data points	14	14	14	12	13	14	14	14	12	13	16	16	16	16
Minimum	0	0	0	0	5	0	0	0	0	5	0	264	0	264
Maximum	10890	7430	604	70	17825	10890	7040	604	70	17825	13045	17825	13045	17825
Median	1238	1246	0	0	1500	1238	1136	0	0	1500	1144	1500	1144	1500
Mean	2529	2414	97	6	4138	2517	1863	73	6	4138	2749	4043	2640	3959
Standard Deviation	3022	2613	181	20	5697	3019	2384	172	20	5697	3533	5356	3417	5217

Table A.11: Summary of Industry Data, Scenario D2

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES								
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene	2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
USTs, Pump Islands	264	24	0		5	201	24	0		5	264	264	201	201
site	3384	5310	230			2700	4710	60			5658	5658	5118	5118
USTs	5639	6935	604	0	7688	5639	5754	604	0	7688	7923	9934	6865	8877
USTs	1126	1143	0	0	2156	1077	1084	0	0	2156	1126	2200	1126	2200
Service Station	391	110	0	0	563	391	110	0	0	563	391	563	391	563
Service Station	1350	1350	0	0	1350	1350	0	0	0	1350	1350	1350	1350	1350
Service Station	480	480	0	0	100	320	320	0	0	100	480	580	320	420
Historical & Former Pump Islands and Tank Nests	3170	3220	230	70	5460	1600	1460	70	70	5460	3960	5600	2980	4950
Historical Tank Nests	830	1130	0	0	630	830	1130	0	0	630	1130	1130	1130	1130
majority of central and western portion of the site (between various depths and 6 m below grade), extending off-site.											5447	5447	5447	5447
Majority of central and eastern portion of the site (between various depths and 4.0 m below grade), extending off-site.											2539	2539	2534	2539
Service Station	3400	3400	0	0	3900	2000	1300	0	0	3900	3400	4100	2000	3900
Service Station	2900	2400	0	0	2600	2500	2550	0	0	2600	3165	3670	2550	3610

Statistics

Number of data points	11	11	11	9	10	11	11	11	9	10	13	13	13	13
Minimum	264	24	0	0	5	201	0	0	0	5	264	264	201	201
Maximum	5639	6935	604	70	7688	5639	5754	604	70	7688	7923	9934	6865	8877
Median	1350	1350	0	0	1753	1350	1130	0	0	1753	2539	2539	2000	2539
Mean	2085	2318	97	8	2445	1692	1677	67	8	2445	2833	3310	2463	3100
Standard Deviation	1723	2225	192	23	2545	1562	1930	180	23	2545	2391	2809	2134	2539

Table A.12: Summary of Industry Data, Scenario D3

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES								
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene	2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
USTs, Pump Islands	201	24	0		5	201	24	0		5	201	201	201	201
site	2764	3782	230			2700	3458	60			4530	4530	4210	4210
USTs	5639	3051	604	0	7688	5639	3171	604	0	7688	6865	8877	6865	8877
USTs	1126	1018	0	0	2156	1077	1084	0	0	2156	1126	2200	1126	2200
Service Station	418	0	0	0	590	418	115	0	0	590	418	590	418	590
Service Station	1350	0	0	0	1350	1350	0	0	0	1350	1350	1350	1350	1350
Service Station	320	0	0	0	100	320	0	0	0	100	320	420	320	420
Historical & Former Pump Islands and Tank Nests	1600	670	230	70	5460	1600	460	70	70	5460	2370	5140	2370	5140
Historical Tank Nests	830	180	0	0	630	830	730	0	0	630	830	830	1130	1130
tank nest area including portions of northwest and southwest walls.	25	864	25	0	600	25	1056	25	0	600	864	864	1056	1056
Service Station	2600	300	0	0	3900	2000	1050	0	0	3900	2600	4550	2000	3900
Service Station	2900	2400	0	0	2600	2500	2000	0	0	2600	3165	3670	2900	3550

Statistics

Number of data points	12	12	12	10	11	12	12	12	10	11	12	12	12	12
Minimum	25	0	0	0	5	25	0	0	0	5	201	201	201	201
Maximum	5639	3782	604	70	7688	5639	3458	604	70	7688	6865	8877	6865	8877
Median	1238	485	0	0	1350	1214	890	0	0	1350	1238	1775	1240	1775
Mean	1648	1024	91	7	2280	1555	1096	63	7	2280	2053	2768	1996	2719
Standard Deviation	1615	1319	184	22	2476	1563	1197	172	22	2476	2007	2639	1928	2553

Table A.13: Summary of Industry Data, Scenario D4

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES								
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene	2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
USTs, Pump Islands	201	24	0		5	264	24	0		5	201	201	264	264
site	2764	3782	230			3320	4880	60			4530	4530	5406	5406
USTs	6478	4844	604	0	14680	6541	5963	604	0	14680	6828	14643	6865	14837
USTs	1073	1018	0	0	2255	1126	1143	0	0	2255	1126	2298	1126	2298
Service Station	418	0	0	0	590	418	115	0	0	590	418	590	418	590
Service Station	1350	0	0	0	1350	1350	0	0	0	1350	1350	1350	1350	1350
Service Station	320	0	0	0	100	480	320	0	0	100	320	420	480	580
Historical & Former Pump Islands and Tank Nests	1600	670	230	70	6750	3170	1610	70	70	6750	2370	7070	3170	7070
Historical Tank Nests	830	180	0	0	790	830	1130	0	0	790	830	1130	1130	1130
Service Station	2600	300	0	0	3500	3400	1300	0	0	3500	2600	4100	3400	4100
Service Station	2900	2400	0	0	2950	2950	2550	0	0	2950	3165	3900	2950	3810

Statistics

Number of data points	11	11	11	9	10	11	11	11	9	10	11	11	11	11
Minimum	201	0	0	0	5	264	0	0	0	5	201	201	264	264
Maximum	6478	4844	604	70	14680	6541	5963	604	70	14680	6828	14643	6865	14837
Median	1350	300	0	0	1803	1350	1143	0	0	1803	1350	2298	1350	2298
Mean	1867	1202	97	8	3297	2168	1730	67	8	3297	2158	3657	2414	3767
Standard Deviation	1816	1710	192	23	4487	1915	1998	180	23	4487	2059	4228	2177	4286

Table A.14: Summary of Industry Data, Scenario D5

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES								
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene	2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
USTs, Pump Islands	264	24	0		5	201	24	0		5	264	264	201	201
site	3384	5310	230			2700	5030	230			5638	5638	5328	5328
USTs	5639	5703	604	0	14680	5639	5703	604	0	14680	7923	15794	6865	14837
USTs	1126	1143	0	0	2255	1077	1143	0	0	2255	1126	2298	1126	2298
Service Station	418	110	0	0	418	418	110	0	0	418	418	590	418	590
Service Station	1350	1350	0	0	1350	1350	0	0	0	1350	1350	1350	1350	1350
Service Station	480	480	0	0	100	320	320	0	0	100	480	580	320	420
Historical & Former Pump Islands and Tank Nests	3170	3220	230	70	6750	1600	1610	230	70	6750	3960	7070	3170	7070
Historical Tank Nests	830	1130	0	0	790	830	1130	0	0	790	1130	1130	1130	1130
Service Station	3400	3400	0	0	3500	2000	1550	0	0	3500	3400	4100	2000	4100
Service Station	3050	3050	0	0	2950	2950	2550	0	0	2950	3050	3900	2950	3810

Statistics

Number of data points	11	11	11	9	10	11	11	11	9	10	11	11	11	11
Minimum	264	24	0	0	5	201	0	0	0	5	264	264	201	201
Maximum	5639	5703	604	70	14680	5639	5703	604	70	14680	7923	15794	6865	14837
Median	1350	1350	0	0	1803	1350	1143	0	0	1803	1350	2298	1350	2298
Mean	2101	2265	97	8	3280	1735	1743	97	8	3280	2613	3883	2260	3739
Standard Deviation	1728	2004	192	23	4499	1588	1965	192	23	4499	2467	4544	2163	4301

Table A.15: Summary of Industry Data, Scenario D7

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES								
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene	2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
USTs, Pump Islands	201	24	0		5	201	24	0		5	201	201	201	201
site	2646	3782	230		8	1136	3458	60		8	4510	4510	3686	3686
USTs	5897	3051	604	0	0	5897	3171	604	0	0	6865	6865	6357	6357
USTs	1126	1018	0	0	496	1077	1084	0	0	496	1126	1126	1126	1126
Service Station	391	0	0	0	47	242	110	0	0	47	391	391	242	242
Service Station	1350	0	0	0	0	0	0	0	0	0	1350	1350	0	0
Service Station	320	0	0	0	0	320	0	0	0	0	320	320	320	320
Historical & Former Pump Islands and Tank Nests	1600	670	230	70	180	670	460	70	70	180	2370	2370	1100	1100
Historical Tank Nests	830	180	0	0	0	830	1130	0	0	0	830	830	1130	1130
Service Station	2000	300	0	0	0	2000	1050	0	0	0	2000	2000	2000	2000
Service Station	2900	2350	0	0	0	2500	2000	0	0	0	3050	3050	2900	2900

Statistics

Number of data points	11	11	11	9	11	11	11	11	9	11	11	11	11	11
Minimum	201	0	0	0	0	0	0	0	0	0	201	201	0	0
Maximum	5897	3782	604	70	496	5897	3458	604	70	496	6865	6865	6357	6357
Median	1350	300	0	0	0	830	1050	0	0	0	1350	1350	1126	1126
Mean	1751	1034	97	8	67	1352	1135	67	8	67	2092	2092	1733	1733
Standard Deviation	1646	1378	192	23	152	1694	1250	180	23	152	2057	2057	1932	1932

Table A.16: Summary of Industry Data, Scenario E1

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES					2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene				
Large Facility and Wellsite	13000	29000	9400	2000	40000	13000	29000	3400	2000	40000	29000	40000	29000	40000
Large Facility with two pits	0	2000	2000	1000	0	2000	5000	1000	1000	0	2000	2000	5000	5000
Facility with AST, UST, and Flare Pit	400	0	0	0	29000	1500	1000	0	0	29000	400	29000	1500	29000
Large Plant/Battery impact from process building	1200	300	0	0	14600	1350	150	0	0	14600	1200	14600	1350	14600
Large Plant/Battery impact from filter storage shack	7900	980	0	0	1000	7900	1080	0	0	1000	7900	1000	7900	1000
Old Battery, sump impact	700	6500	450	0	1050	700	6500	0	0	1050	6500	6500	6500	6500
Production Water Impact	7500	0	0	0	9720	7500	0	0	0	9720	7500	9720	7500	9720
Former Sump		3000	3000				3000	3000			3000	3000	3000	3000
Flare Stack	2250				3500	2250				3500	2250	3500	2250	3500
Flare Stack					525					525	0	525	0	525
Spill (low area)	125	125	125		1000	125	125	125		1000	125	1000	125	1000
Large pipeline spill near facility	782	1252	1227	0	1517	782	1492	1167	0	1517	1252	1517	1492	1517
Former UST containing condensate	26300	14500	0	0	26300	26300	14500	0	0	26300	26300	26300	26300	26300

Statistics

Number of data points	11	11	11	9	12	11	11	11	9	12	13	13	13	13
Minimum	0	0	0	0	0	125	0	0	0	0	0	525	0	525
Maximum	26300	29000	9400	2000	40000	26300	29000	3400	2000	40000	29000	40000	29000	40000
Median	1200	1252	125	0	2509	2000	1492	0	0	2509	2250	3500	3000	5000
Mean	5469	5242	1473	333	10684	5764	5622	790	333	10684	6725	10666	7071	10897
Standard Deviation	8113	8983	2815	707	13779	7925	8855	1268	707	13779	9691	13017	9527	12877

Table A.17: Summary of Industry Data, Scenario E3

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES					2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene				
Large Facility and Wellsite	8500	6000	9400	2000	1000	1000	19000	3400	2000	1000	9400	9400	19000	19000
Large Facility with two pits	0	1000	2000	1000	0	0	5000	1000	1000	0	2000	2000	5000	5000
Facility with AST, UST, and Flare Pit	1500	0	0	0	0	500	1000	0	0	0	1500	1500	1000	1000
Large Plant/Battery impact from process building	975	0	0	0	4000	1200	150	0	0	4000	975	4000	1200	4000
Large Plant/Battery impact from filter storage shack	7900	0	0	0	1500	7900	1080	0	0	1500	7900	1500	7900	1500
Old Battery, sump impact	300	6200	450	0	0	700	6500	0	0	0	6200	6200	6500	6500
Production Water Impact	4300	0	0	0	7560	7500	0	0	0	7560	4300	7560	7500	7560
Former Sump			3000				3000	2000			3000	3000	3000	3000
Flare Stack	2250				3250	1500				3250	2250	3250	1500	3250
Flare Stack					100					100	0	100	0	100
Spill (low area)	125	125	125		125	125	125	125		125	125	125	125	125
Large pipeline spill near facility	782	842	1227	0	744	782	1492	1167	0	744	1227	1227	1492	1492
Former UST containing condensate	26300	14500	0	0	26300	26300	14500	0	0	26300	26300	26300	26300	26300

Statistics

Number of data points	11	10	11	9	12	11	11	11	9	12	13	13	13	13
Minimum	0	0	0	0	0	0	0	0	0	0	0	100	0	100
Maximum	26300	14500	9400	2000	26300	26300	19000	3400	2000	26300	26300	26300	26300	26300
Median	1500	484	125	0	872	1000	1492	0	0	872	2250	3000	3000	3250
Mean	4812	2867	1473	333	3715	4319	4713	699	333	3715	5014	5089	6194	6064
Standard Deviation	7740	4764	2815	707	7469	7818	6384	1121	707	7469	7044	6979	7936	7854

Table A.18: Summary of Industry Data, Scenario G1

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES					2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene				
Tank Farm / ASTs	2259	1701	0	0	3985	2259	1701	0	0	3985	2565	4554	2565	4554
Documented impacts on site in area of former, existing tanks and pump islands, off-site impacts delineated.											11579	11579	11579	11579
Former UST's and Loading Rack	1820	1830	0	0	2300	1820	1830	0	0	2300	2000	2300	2000	2300
Former UST's and Loading Rack	200	0	0	0	300	200	0	0	0	300	200	300	200	300

Statistics

Number of data points	3	3	3	3	3	3	3	3	3	3	4	4	4	4
Minimum	200	0	0	0	300	200	0	0	0	300	200	300	200	300
Maximum	2259	1830	0	0	3985	2259	1830	0	0	3985	11579	11579	11579	11579
Median	1820	1701	0	0	2300	1820	1701	0	0	2300	2283	3427	2283	3427
Mean	1426	1177	0	0	2195	1426	1177	0	0	2195	4086	4683	4086	4683
Standard Deviation	1084	1021	0	0	1845	1084	1021	0	0	1845	5096	4915	5096	4915

Table A.19: Summary of Industry Data, Scenario G3

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES					2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene				
Tank Farm / ASTs	699	0	0	0	678	1156	1425	0	0	678	699	699	1669	1669
Former UST's and Loading Rack	50	130	0	0	720	300	1300	0	0	720	160	720	1300	1300
Former UST's and Loading Rack	0	0	0	0	60	0	0	0	0	60	0	60	0	60

Statistics

Number of data points	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Minimum	0	0	0	0	60	0	0	0	0	60	0	60	0	60
Maximum	699	130	0	0	720	1156	1425	0	0	720	699	720	1669	1669
Median	50	0	0	0	678	300	1300	0	0	678	160	699	1300	1300
Mean	250	43	0	0	486	485	908	0	0	486	286	493	990	1010
Standard Deviation	390	75	0	0	369	600	789	0	0	369	366	375	877	843

Table A.20: Summary of Industry Data, Scenario I3

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES					2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene				
apartment building	66	144	94	0	0	84	205	68	0	0	171	171	230	230

Statistics

Number of data points	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Minimum	66	144	94	0	0	84	205	68	0	0	171	171	230	230
Maximum	66	144	94	0	0	84	205	68	0	0	171	171	230	230
Median	66	144	94	0	0	84	205	68	0	0	171	171	230	230
Mean	66	144	94	0	0	84	205	68	0	0	171	171	230	230
Standard Deviation	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table A.21: Summary of Industry Data, Scenario J1

IMPACTED AREA DESCRIPTION	ESTIMATED IMPACTED SOIL VOLUMES ABOVE SEED VALUES (m^3)										ESTIMATED IMPACTED SOIL VOLUMES AS A WHOLE OF ALL FRACTION CRITERIA (m^3)			
	2000 CWS SEED VALUES					PROPOSED 2007 SEED VALUES					2000 Volume Exceeding any PHC fraction (exclude benzene)	2000 Volume Exceeding any PHC fraction (include benzene)	2007 Volume Exceeding any PHC Fraction (exclude benzene)	2007 Volume Exceeding Any PHC Fraction (include benzene)
	F1	F2	F3	F4	Benzene	F1	F2	F3	F4	Benzene				
private home	7	9	8	0	0	7	9	8	0	0	9	9	9	9

Statistics

Number of data points	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Minimum	7	9	8	0	0	7	9	8	0	0	9	9	9	9
Maximum	7	9	8	0	0	7	9	8	0	0	9	9	9	9
Median	7	9	8	0	0	7	9	8	0	0	9	9	9	9
Mean	7	9	8	0	0	7	9	8	0	0	9	9	9	9
Standard Deviation	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

APPENDIX B

BASIC REMEDIATION COST MODEL – INPUT AND ASSUMPTIONS

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APPENDIX B - DISCUSSION OF ASSUMPTIONS USED IN BASIC REMEDIATION COST MODEL

B1.0 ASSUMPTIONS USED IN ESTIMATE OF SCENARIO DISTRIBUTIONS

B1.1 Fine Grained Versus Coarse Grained Soils

The proportions of sites underlain by fine grained soils versus coarse grained soils were estimated for each province or territory on the basis of professional judgement and experience, a cursory review of available surficial geological maps, and anecdotal information obtained through discussions with representatives of selected provincial environment departments. In most areas of Canada, fine grained soils appear to predominate. For the purposes of this study, proportions are assumed to range from 60/40 (fine/coarse) in Quebec and the Atlantic provinces to 80/20 in the prairies and parts of BC. Urban or settled areas in the western provinces are assumed to have a slightly higher incidence of coarse grained soils; therefore different proportions were assigned to upstream sites and downstream sites in those areas. Exceptions to the predominance of fine grained soils are considered to be Ontario, with an assumed ratio of 40/60 (fine/coarse), the Yukon (45/55) and the Northwest Territories and Nunavut (50/50). The assumptions by province/territory and facility type are presented in Table B.1.

B1.2 Site Setting

The applicability of the drinking water pathway and the aquatic life pathway are considered to some degree to be a function of the site setting, in other words whether a site is located in an urban, rural or remote setting. For example, groundwater ingestion is often excluded in cities and towns with municipal water supply systems, although this is not always the case as protection of any underlying potable aquifer would still normally be required. For the purpose of this study, a remote area is considered an area without permanent human habitation, including uninhabited wild lands or natural areas.

In order to facilitate determination of the applicability of the drinking water and aquatic life pathways, assumptions have been made with respect to the distribution of different facility types between urban, rural and remote settings in each province or territory. All service stations, bulk plants, commercial tank sites and residential heating oil tanks are assumed to be urban or rural settings. The distribution of sites between urban and rural settings for these downstream facilities is assumed to be the same as the proportion of urban versus rural population, obtained from the 2001 census (Statistics Canada 2007c), with the exception of residential heating oil tanks which are assigned a 50% lower frequency in urban areas (except in the territories) due to the availability of other sources of home heating energy (e.g. natural gas, electricity). A similar split between urban and rural is used for government tank sites, except in this case 5% percent are assumed to be in remote settings.

For upstream facilities, all are considered to be located in rural areas, with the exception of BC, Alberta and the territories, in which 20% of upstream facilities are assumed to be located in remote settings. The assumed distribution of facility types by site setting in different provinces and territories, used in this study, is summarized in Table B.2.

B1.3 Drinking Water

Approximately 30% of the population of Canada is dependent on groundwater for potable use, although the percentage varies by province (Environment Canada, 1996). Approximately two thirds of groundwater users live in rural areas. The proportions of sites in urban and rural settings that are subject to the groundwater pathway were assumed to be equal to the percentages of residents of urban and rural areas that are dependent on groundwater. For an urban setting, this was estimated for a given province by dividing one third of the groundwater users by the urban population. A similar approach, using two thirds, was used in rural settings (to a maximum of 100%). For Prince Edward Island, 100 percent of both the urban and rural populations are reported to be dependent on groundwater. In remote areas, 25 percent of sites are assumed to be subject to the drinking water pathway. Note that jurisdictional policy decisions may over-rule these assumptions; however, this has not been considered in the present study. The sensitivity of the results to these assumptions is discussed in Section 7 of the main report.

Based on the above and the distribution of sites by setting, the proportions of different facility types at which drinking water applies are summarized by province or territory in Table B.3.

B1.4 Aquatic Life

Aquatic life is assumed to be applicable at 50% of urban sites and 75% of both rural and remote sites. As with drinking water, jurisdictional policy decisions may over-rule these assumptions; however, this has not been considered in the present study.

Based on the above and the distribution of sites by setting, the proportions of different facility types at which aquatic life applies are summarized by province or territory in Table B.4.

B2.0 ADJUSTMENT FACTORS USED FOR NORMALIZATION OF SOIL VOLUMES

The industry data capture process for the estimation of remediation soil volumes is believed to have resulted in an unintentional bias towards larger volumes. This is attributed to the fact that the sites selected by industry as examples tend to be those for which more data are available, in order to adequately estimate the volumes corresponding to the various PHC fraction criteria. It is reasoned that many of these sites may be well-characterized because they are large or “problem” sites. As a result, the impacted soil volumes may not be representative of typical conditions. While the absolute volumes obtained from the data capture process are not significant in terms of assessing the effect of changes in the PHC standard between 2000 and 2007, the absolute costs are likely to be an overstatement of total remediation costs based on either set of criteria. Therefore, adjustment factors have been used to scale or “normalize” soil volumes from the data capture process to levels considered more representative of typical sites. The following sections describe the methods used to estimate adjustment factors for various facilities.

B2.1 Upstream Sites

In order to estimate the degree by which the data capture process overestimates representative soil volumes for upstream facilities, selected soil volumes obtained from the data capture process are compared with volumes for corresponding scenarios obtained from other sources. Specifically, the median and mean soil volumes determined on the basis of the 2000 PHC standard for wellsites and facilities (satellites/batteries) are compared to volumes presented in the confidential abandonment and reclamation data set provided by CAPP (2007a) and volumes reported by Komex (2000) from an extensive company database of remediation projects. The data capture scenarios used were chosen to correspond with the soil types and groundwater uses reflected in the two comparative data sources. The comparison is presented in Table B.5.

As shown in Table B.5, the mean volumes obtained from the data capture are substantially higher than those from the CAPP data, which in turn are greater than those presented by Komex. Median volumes from the present study also exceed those from CAPP and Komex, although the latter are quite similar and appear to be reasonably representative of volumes that would be expected based on experience. Mean and median volumes in the Komex data are quite similar in magnitude. Based on discussions with CAPP, it was concluded that the confidential data set provided the most representative benchmark of actual volumes, although it was acknowledged that there may still be a degree of upward bias in the volumes.

Given that the mean values from the data capture process have been used in the basic remediation cost model to estimate aggregate remediation costs, it was considered appropriate for the purposes of this study to normalize the volumes obtained from the data capture process by the ratio of the mean volume for a specific facility type to the mean volume for the corresponding category from the CAPP data. The adjustment factors thus determined are summarized in Table B.5. The selection and application of an adjustment factor, and any uncertainties therein, would affect the aggregate remediation costs for both 2000 and 2007, but would not substantially affect any conclusions with respect to the effect of changes in the standard.

B2.2 Downstream Sites

Similarly, in order to estimate the degree by which the data capture process overestimates representative soil volumes for downstream facilities, selected soil volumes obtained from the data capture process are compared with volumes for corresponding scenarios obtained from other sources. In this case, the mean soil volumes determined on the basis of the 2000 PHC standard for service stations and bulk plants are compared to volumes reported by Komex (2000). These are also benchmarked against typical volumes assumed for service stations by OAEI (1998) on behalf of CPPI. The data capture scenarios used were chosen to correspond with the soil types and groundwater uses reflected in the data presented by Komex. The comparison is presented in Table B.6.

As shown in Table B.6, the mean volumes obtained from the data capture are again substantially higher than those presented by Komex. Given that the latter appear to be reasonably representative of volumes that would be expected based on experience, it was considered appropriate for the purposes of this study to normalize the volumes obtained from the data capture process by the ratio of the mean volume for a specific facility type to the mean volume for a corresponding scenario from the Komex data. As noted previously, an inherent assumption is that the remediation requirements to meet the 2000 standard would be the same as those required to meet the "seed values" used in the Komex (2000) report, which is considered reasonable. The adjustment factors thus determined are summarized in Table B.6. Note that adjustment values have also been presented for other types of downstream facilities. These are the same as for services stations (which in the present study are based on extrapolations derived from the Komex data). An adjustment factor is not applied to home heating oil tanks, for which limited actual volume data are available. The selection and application of an adjustment factor, and any uncertainties therein, would affect the aggregate remediation costs for both 2000 and 2007, but would not substantially affect any conclusions with respect to the effect of changes in the standard.

B3.0 NUMBERS OF PETROLEUM FACILITIES

The numbers of facilites of each type, within each province or territory, are used as described in the report to estimate aggregate remediation costs across industry sectors and on a national basis. A summary of the data, with sources and assumptions, is presented in Table B.7. The basis for the determination of numbers of facilities is described briefly in the following sections.

B3.1 Upstream Sites

The numbers of wellsites was obtained from the most current CAPP Statistical Handbook (CAPP, 2006). Data for other facilities, for Alberta only, were found in the Alberta Energy and Utilities Board (EUB) Field Surveillance Summary for 2004 (EUB, 2005). However, these numbers reflect operating facilities; therefore, the greater of the EUB or Komex numbers were used to account for inactive sites. Alberta data were extrapolated to other provinces on the basis of ratios of wellsites to facilities in Alberta. Other assumptions are noted in Table B.7 as appropriate.

B3.2 Downstream Sites

The numbers of service stations by province and territory were obtained from a recent market study (M.J. Ervin & Associates Inc., 2006). Recent data for bulk plants were not found in readily available sources and were taken from Komex (2000), although updating of these numbers was possible to a limited extent based on discussions with various agencies as referenced in Table B.7. All values were increase by a judgement-based factor of 20% to account for inactive sites.

B3.3 Other Sites

Updated data were found for government storage tank sites, although not for commercial facilities (with a few exceptions based on data provided by certain provincial registry programs or anecdotal information provided by provincial or territorial government personnel). Numbers of home heating oil tanks were estimated by combining Canadian Census data with the results of a Statistics Canada survey indicating the percentage of households, by province/territory relying on oil as the primary source of heating fuel (Statistics Canada, 2005; 2007c). Updated numbers of facilities were used where possible, otherwise data presented by Komex were adopted. Sources and assumptions are presented in Table B.7.

B4.0 REFERENCES

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Table B.1: Estimated Distributions of Soil Texture by Facility and Province/Territory
(Values are percentages)

Facility Type	Soil Texture	BC	AB	SK	MN	ON	QC	NB	NS	PE	NL	YK	NT	NU
Wellsite	Coarse	20	20	20	20	60	40	40	40	40	40	55	50	50
	Fine	80	80	80	80	40	60	60	60	60	60	45	50	50
Battery/satellite	Coarse	20	20	20	20	60	40	40	40	40	40	55	50	50
	Fine	80	80	80	80	40	60	60	60	60	60	45	50	50
Compressor plant	Coarse	20	20	20	20	60	40	40	40	40	40	55	50	50
	Fine	80	80	80	80	40	60	60	60	60	60	45	50	50
Gas plant	Coarse	20	20	20	20	60	40	40	40	40	40	55	50	50
	Fine	80	80	80	80	40	60	60	60	60	60	45	50	50
Service station	Coarse	35	30	30	30	60	40	40	40	40	40	55	50	50
	Fine	65	70	70	70	40	60	60	60	60	60	45	50	50
Bulk plant	Coarse	35	30	30	30	60	40	40	40	40	40	55	50	50
	Fine	65	70	70	70	40	60	60	60	60	60	45	50	50
Commercial site	Coarse	35	30	30	30	60	40	40	40	40	40	55	50	50
	Fine	65	70	70	70	40	60	60	60	60	60	45	50	50
Government site	Coarse	35	30	30	30	60	40	40	40	40	40	55	50	50
	Fine	65	70	70	70	40	60	60	60	60	60	45	50	50
Home heating oil site	Coarse	35	30	30	30	60	40	40	40	40	40	55	50	50
	Fine	65	70	70	70	40	60	60	60	60	60	45	50	50

Table B.2: Assumed Site Settings by Facility and Province/Territory
(Values are percentages)

Facility Type	Site Setting	BC	AB	SK	MN	ON	QC	NB	NS	PE	NL	YK	NT	NU
Wellsite	Urban	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rural	80	80	100	100	100	100	100	100	100	100	80	80	80
	Remote	20	20	0	0	0	0	0	0	0	0	20	20	20
Battery/satellite	Urban	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rural	80	80	100	100	100	100	100	100	100	100	80	80	80
	Remote	20	20	0	0	0	0	0	0	0	0	20	20	20
Compressor plant	Urban	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rural	80	80	100	100	100	100	100	100	100	100	80	80	80
	Remote	20	20	0	0	0	0	0	0	0	0	20	20	20
Gas plant	Urban	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rural	80	80	100	100	100	100	100	100	100	100	80	80	80
	Remote	20	20	0	0	0	0	0	0	0	0	20	20	20
Service station	Urban	85	81	64	72	85	80	50	56	45	58	59	58	33
	Rural	15	19	36	28	15	20	50	44	55	42	41	42	67
	Remote	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulk plant	Urban	85	81	64	72	85	80	50	56	45	58	59	58	33
	Rural	15	19	36	28	15	20	50	44	55	42	41	42	67
	Remote	0	0	0	0	0	0	0	0	0	0	0	0	0
Commercial site	Urban	85	81	64	72	85	80	50	56	45	58	59	58	33
	Rural	15	19	36	28	15	20	50	44	55	42	41	42	67
	Remote	0	0	0	0	0	0	0	0	0	0	0	0	0
Government site	Urban	81	77	61	68	81	76	48	53	43	55	56	55	31
	Rural	14	18	34	27	14	19	48	42	52	40	39	40	64
	Remote	5	5	5	5	5	5	5	5	5	5	5	5	5
Home heating oil site	Urban	74	68	47	56	74	67	33	39	29	41	42	41	20
	Rural	26	32	53	44	26	33	67	61	71	59	58	59	80
	Remote	0	0	0	0	0	0	0	0	0	0	0	0	0

Table B.3: Estimated Applicability of Drinking Water Pathway by Facility and Province/Territory
(Values are percentages)

Facility Type	Drinking Water	BC	AB	SK	MN	ON	QC	NB	NS	PE	NL	YK	NT	NU
Wellsite	Y	85	70	79	72	100	92	89	69	100	54	67	41	16
	N	15	30	21	28	0	8	11	31	0	46	33	59	84
Battery/satellite	Y	85	70	79	72	100	92	89	69	100	54	67	41	16
	N	15	30	21	28	0	8	11	31	0	46	33	59	84
Compressor plant	Y	85	70	79	72	100	92	89	69	100	54	67	41	16
	N	15	30	21	28	0	8	11	31	0	46	33	59	84
Gas plant	Y	85	70	79	72	100	92	89	69	100	54	67	41	16
	N	15	30	21	28	0	8	11	31	0	46	33	59	84
Service station	Y	29	23	43	30	29	28	67	46	100	34	48	28	14
	N	72	77	57	70	72	72	34	54	0	66	52	72	86
Bulk plant	Y	29	23	43	30	29	28	67	46	100	34	48	28	14
	N	72	77	57	70	72	72	34	54	0	66	52	72	86
Commercial site	Y	29	23	43	30	29	28	67	46	100	34	48	28	14
	N	72	77	57	70	72	72	34	54	0	66	52	72	86
Government site	Y	28	23	42	30	28	28	64	45	96	33	47	28	15
	N	72	77	58	70	72	72	36	55	4	67	53	72	85
Home heating oil site	Y	38	32	52	39	38	38	74	53	100	40	57	33	14
	N	62	68	48	61	62	62	26	47	0	60	43	67	86

Table B.4: Estimated Applicability of Aquatic Life Pathway by Facility and Province/Territory

(Values are percentages)

Facility Type	Aquatic Life	BC	AB	SK	MN	ON	QC	NB	NS	PE	NL	YK	NT	NU
Wellsite	Y	75	75	75	75	75	75	75	75	75	75	75	75	75
	N	25	25	25	25	25	25	25	25	25	25	25	25	25
Battery/satellite	Y	75	75	75	75	75	75	75	75	75	75	75	75	75
	N	25	25	25	25	25	25	25	25	25	25	25	25	25
Compressor plant	Y	75	75	75	75	75	75	75	75	75	75	75	75	75
	N	25	25	25	25	25	25	25	25	25	25	25	25	25
Gas plant	Y	75	75	75	75	75	75	75	75	75	75	75	75	75
	N	25	25	25	25	25	25	25	25	25	25	25	25	25
Service station	Y	54	55	59	57	54	55	63	61	64	61	60	61	67
	N	46	45	41	43	46	45	38	39	36	40	40	40	33
Bulk plant	Y	54	55	59	57	54	55	63	61	64	61	60	61	67
	N	46	45	41	43	46	45	38	39	36	40	40	40	33
Commercial site	Y	54	55	59	57	54	55	63	61	64	61	60	61	67
	N	46	45	41	43	46	45	38	39	36	40	40	40	33
Government site	Y	55	56	60	58	55	56	63	62	64	61	61	61	67
	N	45	44	40	42	45	44	37	38	36	39	39	39	33
Home heating oil site	Y	57	58	63	61	57	58	67	65	68	65	65	65	70
	N	43	42	37	39	43	42	33	35	32	35	35	35	30

Table B.5: Soil Volume Adjustment Factors - Upstream

Volumes from Data Capture (m^3)

Facility	Scenario	Median	Mean
Wellsite	All A,B	1157	3595
Facility	All E,F	2879	8775
Gas plant	All M,N	9375	29120

Volumes from confidential data set provided by CAPP, 2007 (m^3)

Facility	Condition	Median	Mean
Wellsites	All	700	1660
Facilities	All	1671	4974

Volumes from Komex, 2000 (m^3)

Facility	Condition	Median	Mean
Oil well	Fine, GW	820	870
Gas well	Fine, GW	200	210
Oil battery/satellite	Fine, GW	940	1220
Gas satellite	Fine, GW	2070	2230
Compressor station	Fine, GW	2520	2570
Gas plant	Fine, no GW	2300	2390

Volume Adjustment Factors (based on data capture & CAPP data set)

Facility	Adjustment Factor
Oil well	0.743
Gas well	0.180
Oil battery/satellite	0.402
Gas satellite	0.731
Compressor station	0.731
Gas plant	0.462

Table B.6: Soil Volume Adjustment Factors - Downstream

Volumes from Data Capture (m^3)

Facility	Scenario	Median	Mean
Service station	D3	1775	2768
Bulk plant	H3	3702	3914
Residential oil tank	J3	9	9

Volumes from OAEI 1998 (m^3)

Facility	Condition	Median	Mean
Service station	All		1000

Volumes from Komex, 2000 (m^3)

Facility	Condition	Median	Mean
Service station	Coarse, no GW		938
Bulk plant	Coarse, no GW		1193
Government UST	Coarse, no GW		317
Commercial UST	Coarse, no GW		269
Residential oil tank	Coarse, GW		6

Volume Adjustment Factors (based on data capture & Komex data)

Facility	Adjustment Factor
Service station	0.339
Bulk plant	0.305
Government UST	0.339
Commercial UST	0.339
Residential oil tank	1.000

Table B.7: Inventory of Facilities by Province and Territory

Industry Sector	Scenario	Most Likely End Land Use	Number of Facilities by Province													Canada Total
			BC	AB	SK	MN	ON	QC	NB	NS	PE	NL	YK	NT	NU	
Upstream (# of sites)	Oil Well[b]	Agricultural	2,694	85,865[c]	47,390	3,337	581	NA	6	NA	NA	NA	NA	224	NA	140,097
	Gas Well[b]	Agricultural	8,364	131,085	19,857	5	2,046	5[t]	5[t]	5[t]	5[t]	5[t]	NA	139	NA	161,521
	Oil Battery or Satellite[d]	Agricultural	773	24,642[e]	13,600	958	167	NA	2	NA	NA	NA	NA	64	NA	40,206
	Gas Satellite[d]	Agricultural	514	8,060[e]	1,221	0	126	0	0	0	0	0	NA	9	NA	9,930
Midstream (# of sites)	Gas Compressor Station[d]	Agricultural	278	4372[q]	661	0	68	0	0	0	0	0	5	NA	NA	3,251
	Gas Plant[d]	Industrial	54	853[e]	129	0	13	0	0	0	0	0	1	NA	NA	1,050
Downstream (# of tanks)	Service Station[f]	Commercial	8,813	9,101	4,320	3,533	21,970	23,880	2,707	2,731	624	2,789	317	NA	200[g]	67,414
	Bulk Fuel	Commercial	792[e]	5,500[h]	2,272[e]	523[e]	883[e]	331[e]	1,105[e]	110[e]	43[e]	158[e]	125[e]	NA		11,942
Post-Consumer (# of tanks)	Government AST&UST Site[j]	Commercial	807	618	189	223	2,379	1,441	143	178	26	98	6	401[i]		6,308
	Commercial UST Site	Commercial	2,294[e]	5,000[k]	688[e]	526[e]	22,623[e]	20,426[l]	4,167[e]	4,095[e]	858[e]	4,534[e]	710[e]			66,121
	Residential Fuel Storage[v]	Residential	75,115	40,072	13,158	14,751	318,263	417,728	70,966	266,901	50,829	74,798	9,850	12,177	8,489	1,373,097
Downstream (# of sites)	Service Station[n,u]	Commercial	1,836	1,896	900	736	4,577	4,975	564	569	130	581	66	36	24	16,890
	Bulk Fuel[u]	Commercial	198[e]	401[e]	280[e]	131[e]	221[e]	83[e]	22[e]	28[e]	11[e]	40[e]	24[e]	70[o]	70[p]	1,576
Post-Consumer (# of sites)	Government AST&UST Site[r]	Commercial	807	618	189	223	2,379	1,441	143	178	26	98	6	8	6	6,122
	Commercial UST Site	Commercial	2,294[e]	2,506[e]	688[e]	526[e]	6,000[s]	8,918[l]	4,167[e]	4,095[e]	858[e]	4,534[e]	361[e]	965[e]	626[e]	36,538
	Residential Fuel Storage[v]	Residential	75,115	40072	13,158	14,751	318,263	417,728	70,966	266,901	50,829	74,798	9850	12,177	8,489	1,373,097

a - includes mainland Territory, Mackenzie Delta and Beaufort Sea and the Arctic Islands
b - CAPP Statistical Handbook 2006
c - this includes project (bitumen) wells
d - values for provinces other than Alberta have been extrapolated from the well/satellite or well/compressor station ratio for Alberta
e - Komex, 2000
f - calculated based on an assumed tank/site ratio of 4.8 (Komex, 2000)
g - number of diesel,gas and jet A ASTs owned by the PPD, not incl. the Power Corp-owned tanks; service stn pumps for general population typically at location of bulk storage facilities
h - number of tanks, PTMAA, phone discussion
i - Office of the Fire Marshall-NWT, faxed database includes NU and NWT gover't and commercial USTs
j - estimated from an assumed ratio of tanks/site = 1
k - number of registered and active USTs-downstream sector only, sizes ranging from 3785 L to 18927 L; PTMAA, phone discussion
l - Quebec Ressources Naturelles et Faune. 2006. Liste des titulaires d'un permis d'utilisation d'equipments petroliers par region administrative. Viewed December 18, 2006.
m - number of registered and active ASTs-downstream sector only, sizes ranging from 2500 L to 100 000 L; PTMAA, phone discussion
n - MJ Ervin and Associates Inc. 2006
o - assumed a PPD-owned bulk fuel storage facility and a Power Corp-owned bulk fuel storage facility in each community (29 total)
p - assumed a PPD-owned bulk fuel storage facility and a Power Corp-owned bulk fuel storage facility in each community (29 total)
q - Alberta Energy and Utilities Board (EUB) 2005
r - 2002 Report of the Commissioner of the Environment and Sustainable Development, Office of the Auditor General of Canada (includes ASTs and USTs; determined national ratio for sites/people and used that to estimate number of sites/province; actual national total was reported as 6120 however, rounding values resulted in 2 additional sites).
s - Ontario Technical Standards and Safety Authority (TSSA). 2006. The State of Public Safety Reports 2005.
t - 25 gas wells in Eastern Canada split evenly between 5 provinces (Quebec, NB, NS, PEI and NF)
u - numbers increased by 20% to account for inactive sites
v - based on Statistics Canada 2005 and 2007c

APPENDIX C

PROBABILISTIC REMEDIATION COST MODEL REPORT

Crystal Ball Report - Full
Simulation started on 8/26/2007 at 12:02:37
Simulation stopped on 8/26/2007 at 12:02:57

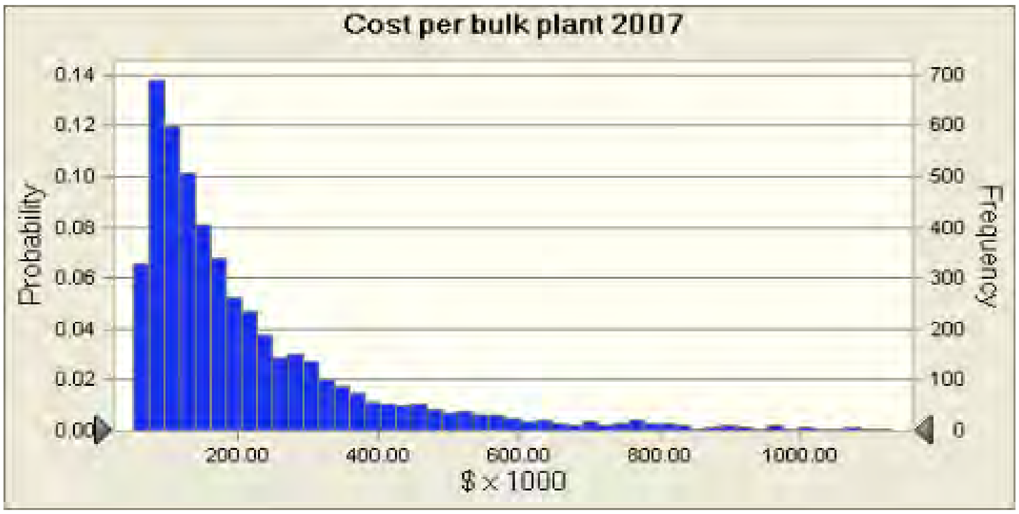
Run preferences:	
Number of trials run	5,000
Latin Hypercube (size)	500
Seed	109
Precision control on	
Confidence level	95.00%
Run statistics:	
Total running time (sec)	19.77
Trials/second (average)	253
Random numbers per sec	5,059
Crystal Ball data:	
Assumptions	20
Correlations	0
Correlated groups	0
Decision variables	0
Forecasts	15

Forecasts

Worksheet: [SEA Basic Remediation Cost Model - Revised final.xls]Aggregate Costs

Forecast: Cost per bulk plant 2007 **Cell: S37**

Summary:
Entire range is from 51.94 to 5928.05
Base case is 126.73
After 5,000 trials, the std. error of the mean is 4.43



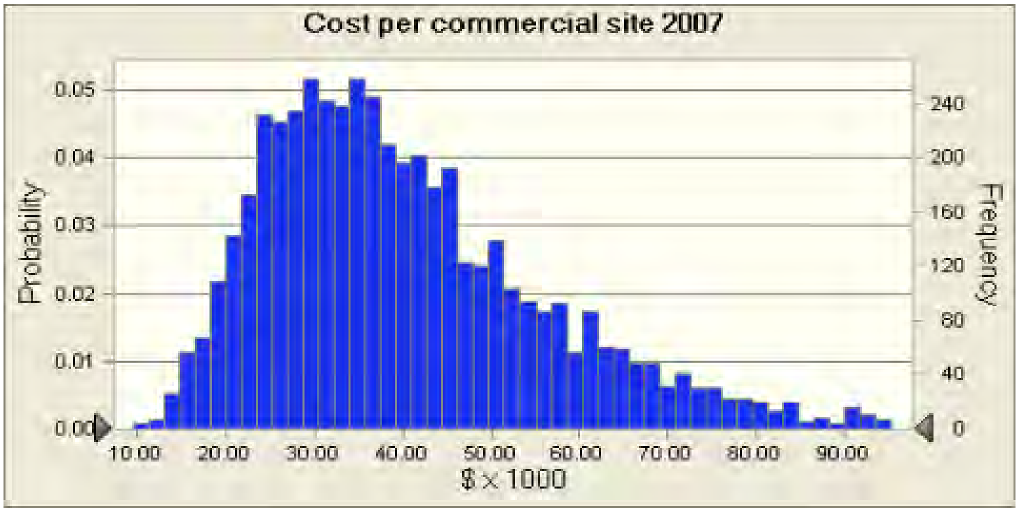
Statistics:	Forecast values
Trials	5,000
Mean	253.71
Median	160.47
Mode	---
Standard Deviation	313.14
Variance	98058.13
Skewness	6.10
Kurtosis	66.84
Coeff. of Variability	1.23
Minimum	51.94
Maximum	5928.05
Range Width	5876.11
Mean Std. Error	4.43

Forecast: Cost per bulk plant 2007 (cont'd) **Cell: S37**

Percentiles:	Forecast values
0%	51.94
10%	80.44
20%	95.23
30%	112.80
40%	134.63
50%	160.47
60%	195.37
70%	242.58
80%	320.36
90%	501.20
100%	5928.05

Forecast: Cost per commercial site 2007 **Cell: S39**

Summary:
Entire range is from 9.42 to 220.63
Base case is 41.56
After 5,000 trials, the std. error of the mean is 0.27



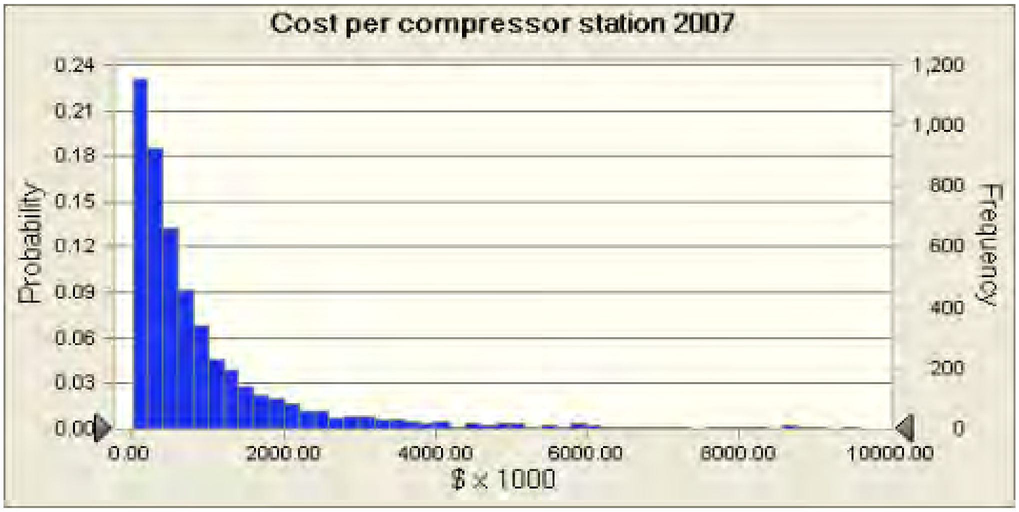
Statistics:	Forecast values
Trials	5,000
Mean	41.56
Median	37.36
Mode	---
Standard Deviation	19.20
Variance	368.67
Skewness	1.93
Kurtosis	10.45
Coeff. of Variability	0.4620
Minimum	9.42
Maximum	220.63
Range Width	211.21
Mean Std. Error	0.27

Forecast: Cost per commercial site 2007 (cont'd) **Cell: S39**

Percentiles:	Forecast values
0%	9.42
10%	22.62
20%	26.66
30%	30.16
40%	33.89
50%	37.36
60%	41.66
70%	46.29
80%	53.80
90%	65.11
100%	220.63

Forecast: Cost per compressor station 2007 **Cell: S34**

Summary:
Entire range is from 7.78 to 89721.15
Base case is 615.23
After 5,000 trials, the std. error of the mean is 43.09



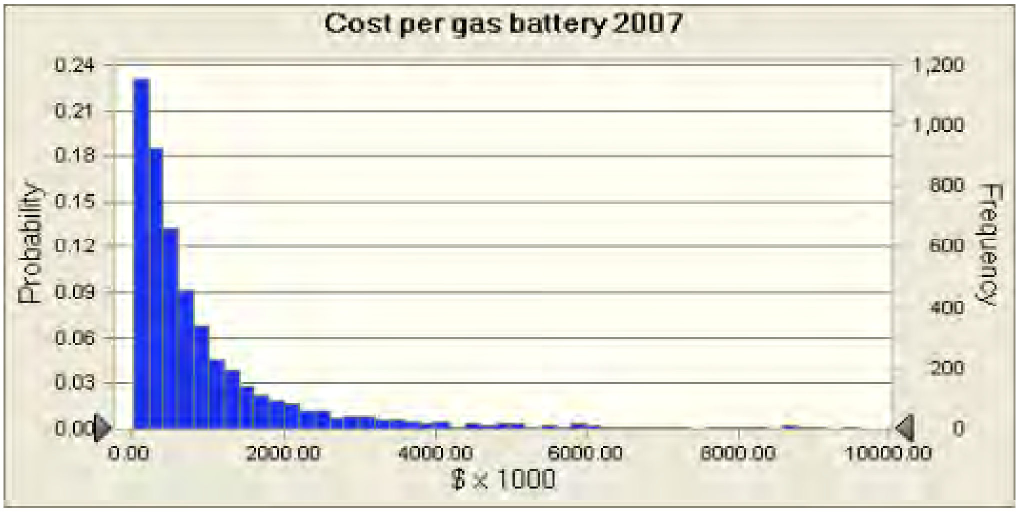
Statistics:	Forecast values
Trials	5,000
Mean	1236.14
Median	523.57
Mode	---
Standard Deviation	3047.18
Variance	9285317.72
Skewness	12.82
Kurtosis	260.44
Coeff. of Variability	2.47
Minimum	7.78
Maximum	89721.15
Range Width	89713.37
Mean Std. Error	43.09

Forecast: Cost per compressor station 2007 (cont'd) **Cell: S34**

Percentiles:	Forecast values
0%	7.78
10%	109.25
20%	182.50
30%	276.17
40%	386.55
50%	523.57
60%	709.61
70%	982.36
80%	1456.59
90%	2590.33
100%	89721.15

Forecast: Cost per gas battery 2007 **Cell: S33**

Summary:
Entire range is from 7.78 to 89727.50
Base case is 615.24
After 5,000 trials, the std. error of the mean is 43.10



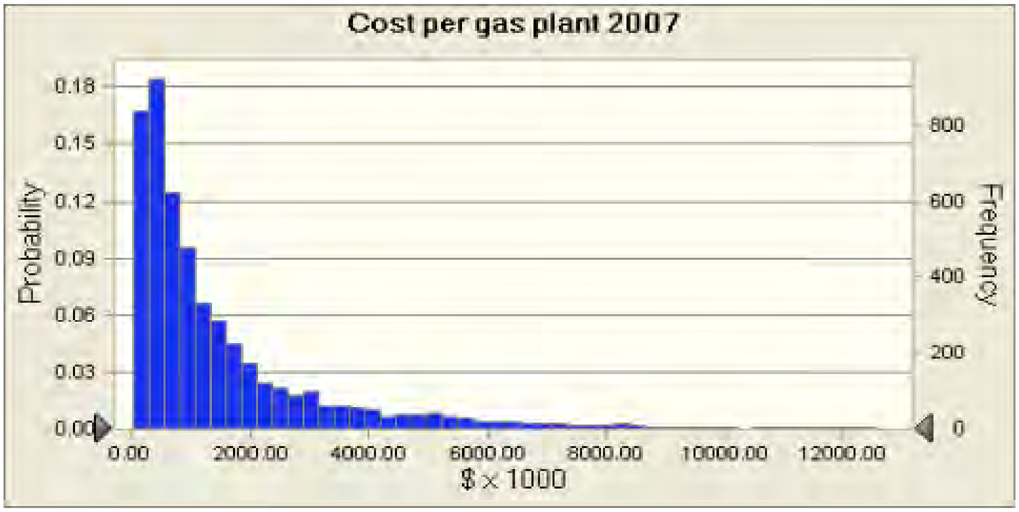
Statistics:	Forecast values
Trials	5,000
Mean	1236.19
Median	523.58
Mode	---
Standard Deviation	3047.38
Variance	9286507.96
Skewness	12.82
Kurtosis	260.45
Coeff. of Variability	2.47
Minimum	7.78
Maximum	89727.50
Range Width	89719.72
Mean Std. Error	43.10

Forecast: Cost per gas battery 2007 (cont'd) **Cell: S33**

Percentiles:	Forecast values
0%	7.78
10%	109.25
20%	182.51
30%	276.18
40%	386.55
50%	523.58
60%	709.53
70%	982.40
80%	1456.66
90%	2590.46
100%	89727.50

Forecast: Cost per gas plant 2007 **Cell: S35**

Summary:
Entire range is from 13.97 to 128718.28
Base case is 1209.39
After 5,000 trials, the std. error of the mean is 55.45



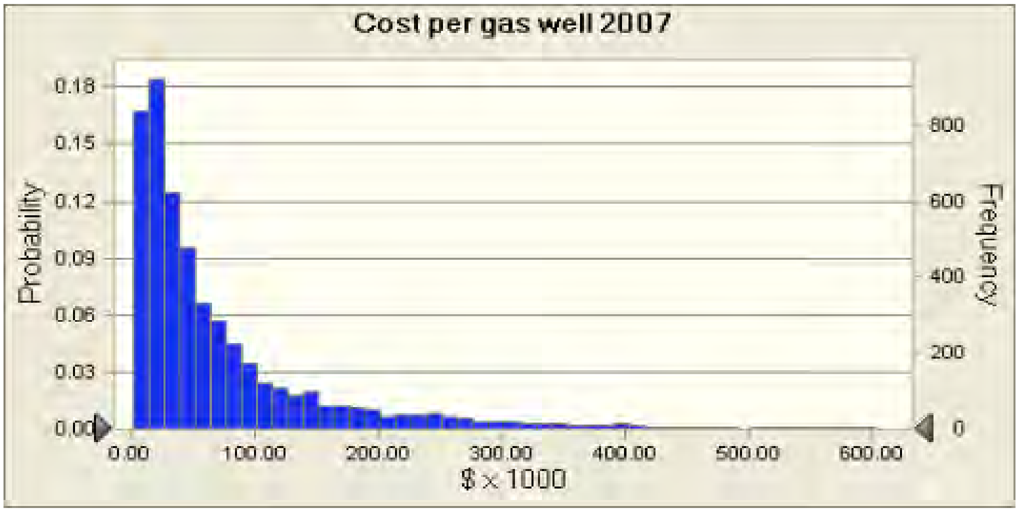
Statistics:	Forecast values
Trials	5,000
Mean	1827.27
Median	855.84
Mode	---
Standard Deviation	3921.19
Variance	15375753.64
Skewness	13.72
Kurtosis	321.14
Coeff. of Variability	2.15
Minimum	13.97
Maximum	128718.28
Range Width	128704.32
Mean Std. Error	55.45

Forecast: Cost per gas plant 2007 (cont'd) **Cell: S35**

Percentiles:	Forecast values
0%	13.97
10%	195.35
20%	317.05
30%	458.39
40%	626.11
50%	855.84
60%	1159.48
70%	1609.66
80%	2381.78
90%	4109.19
100%	128718.28

Forecast: Cost per gas well 2007 **Cell: S31**

Summary:
Entire range is from 0.67 to 6198.01
Base case is 58.24
After 5,000 trials, the std. error of the mean is 2.67



Statistics:	Forecast values
Trials	5,000
Mean	87.99
Median	41.21
Mode	---
Standard Deviation	188.81
Variance	35650.23
Skewness	13.72
Kurtosis	321.13
Coeff. of Variability	2.15
Minimum	0.67
Maximum	6198.01
Range Width	6197.34
Mean Std. Error	2.67

Forecast: Cost per gas well 2007 (cont'd) **Cell: S31**

Percentiles:	Forecast values
0%	0.67
10%	9.41
20%	15.27
30%	22.07
40%	30.15
50%	41.21
60%	55.84
70%	77.52
80%	114.68
90%	197.88
100%	6198.01

Forecast: Cost per gov't site 2007 **Cell: S38**

Summary:
Entire range is from 11.19 to 279.93
Base case is 48.54
After 5,000 trials, the std. error of the mean is 0.33

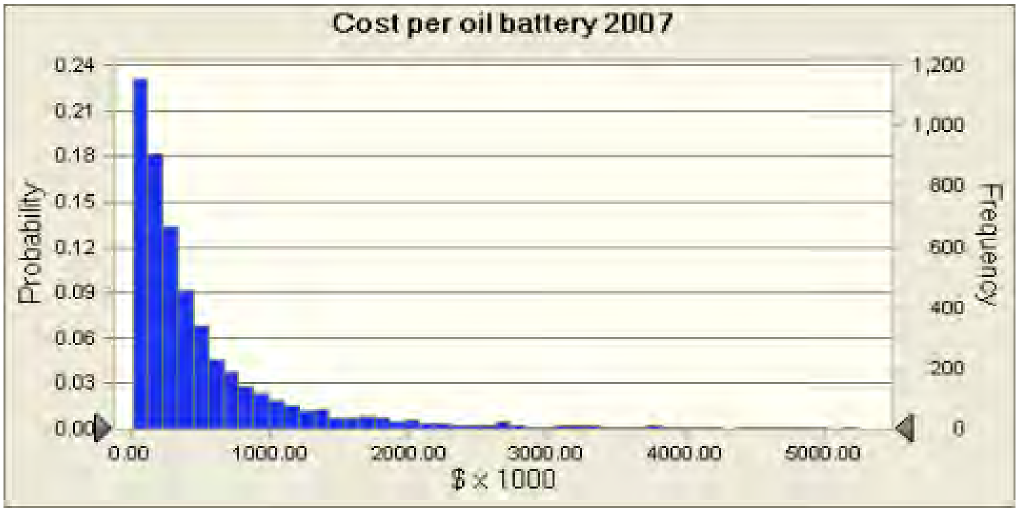
Statistics:	Forecast values
Trials	5,000
Mean	48.52
Median	43.46
Mode	---
Standard Deviation	23.23
Variance	539.57
Skewness	2.14
Kurtosis	12.45
Coeff. of Variability	0.4787
Minimum	11.19
Maximum	279.93
Range Width	268.74
Mean Std. Error	0.33

Forecast: Cost per gov't site 2007 (cont'd) **Cell: S38**

Percentiles:	Forecast values
0%	11.19
10%	25.92
20%	30.80
30%	35.08
40%	39.13
50%	43.46
60%	48.35
70%	54.21
80%	62.68
90%	76.19
100%	279.93

Forecast: Cost per oil battery 2007 **Cell: S32**

Summary:
Entire range is from 4.29 to 48957.24
Base case is 340.82
After 5,000 trials, the std. error of the mean is 23.63



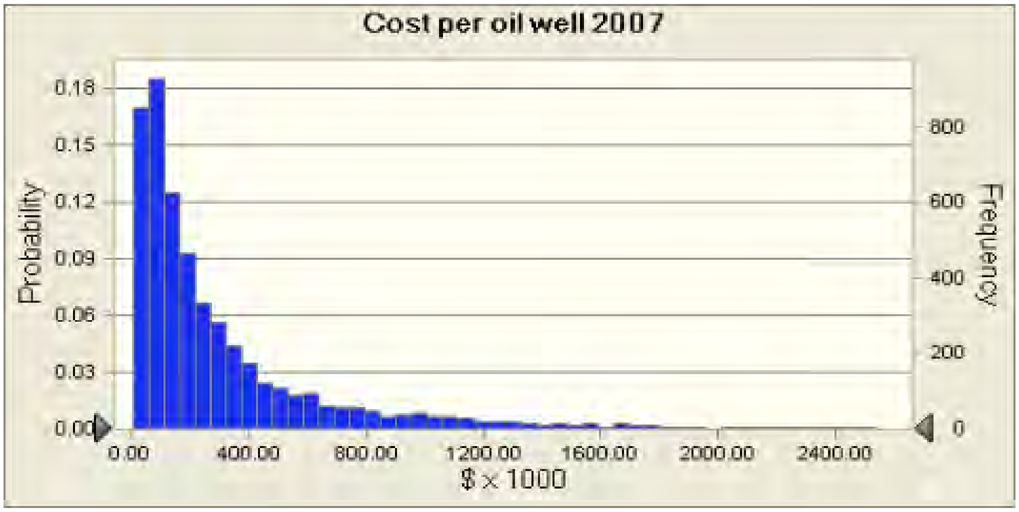
Statistics:	Forecast values
Trials	5,000
Mean	680.85
Median	288.70
Mode	---
Standard Deviation	1670.61
Variance	2790948.26
Skewness	12.70
Kurtosis	256.00
Coeff. of Variability	2.45
Minimum	4.29
Maximum	48957.24
Range Width	48952.95
Mean Std. Error	23.63

Forecast: Cost per oil battery 2007 (cont'd) **Cell: S32**

Percentiles:	Forecast values
0%	4.29
10%	60.10
20%	100.55
30%	150.75
40%	212.96
50%	288.70
60%	391.22
70%	539.80
80%	805.80
90%	1427.31
100%	48957.24

Forecast: Cost per oil well 2007 **Cell: S30**

Summary:
Entire range is from 2.76 to 26138.67
Base case is 243.32
After 5,000 trials, the std. error of the mean is 11.24



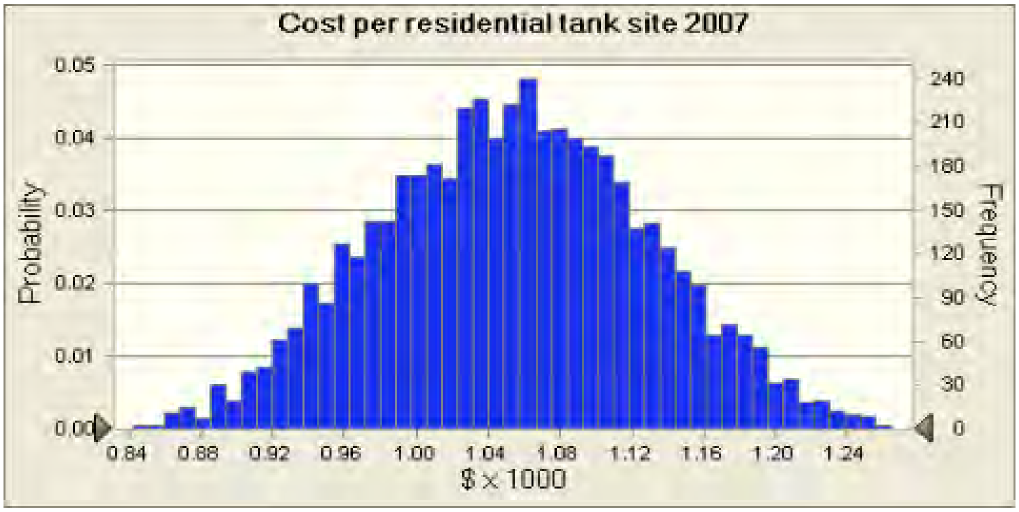
Statistics:	Forecast values
Trials	5,000
Mean	367.69
Median	171.47
Mode	---
Standard Deviation	794.86
Variance	631803.69
Skewness	13.81
Kurtosis	324.06
Coeff. of Variability	2.16
Minimum	2.76
Maximum	26138.67
Range Width	26135.90
Mean Std. Error	11.24

Forecast: Cost per oil well 2007 (cont'd) **Cell: S30**

Percentiles:	Forecast values
0%	2.76
10%	39.19
20%	63.27
30%	91.46
40%	125.42
50%	171.47
60%	232.12
70%	322.87
80%	479.71
90%	829.36
100%	26138.67

Forecast: Cost per residential tank site 2007 **Cell: S40**

Summary:
Entire range is from 0.83 to 1.27
Base case is 1.05
After 5,000 trials, the std. error of the mean is 0.00



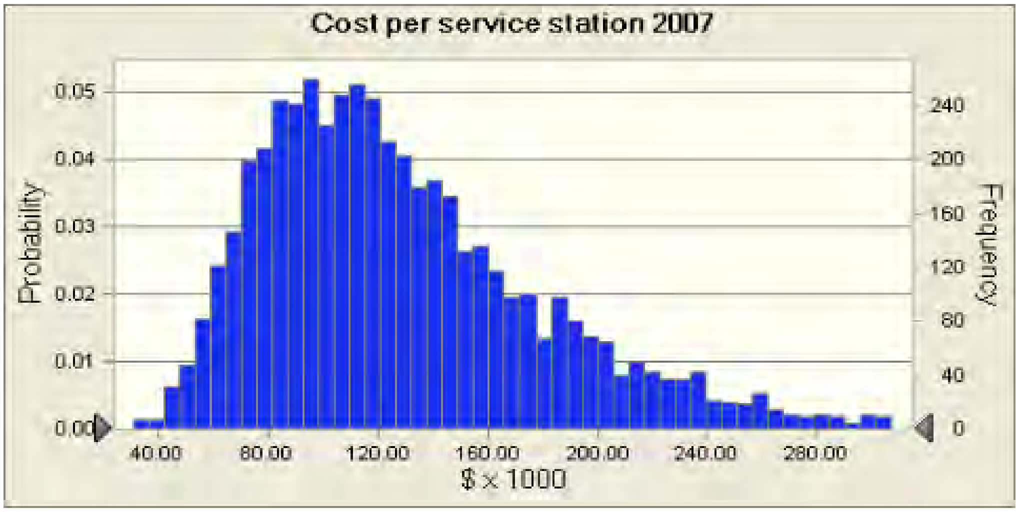
Statistics:	Forecast values
Trials	5,000
Mean	1.05
Median	1.05
Mode	---
Standard Deviation	0.08
Variance	0.01
Skewness	0.0031
Kurtosis	2.67
Coeff. of Variability	0.0716
Minimum	0.83
Maximum	1.27
Range Width	0.44
Mean Std. Error	0.00

Forecast: Cost per residential tank site 2007 (cont'd) **Cell: S40**

Percentiles:	Forecast values
0%	0.83
10%	0.95
20%	0.99
30%	1.01
40%	1.03
50%	1.05
60%	1.07
70%	1.09
80%	1.12
90%	1.15
100%	1.27

Forecast: Cost per service station 2007 **Cell: S36**

Summary:
Entire range is from 30.45 to 700.26
Base case is 133.03
After 5,000 trials, the std. error of the mean is 0.88



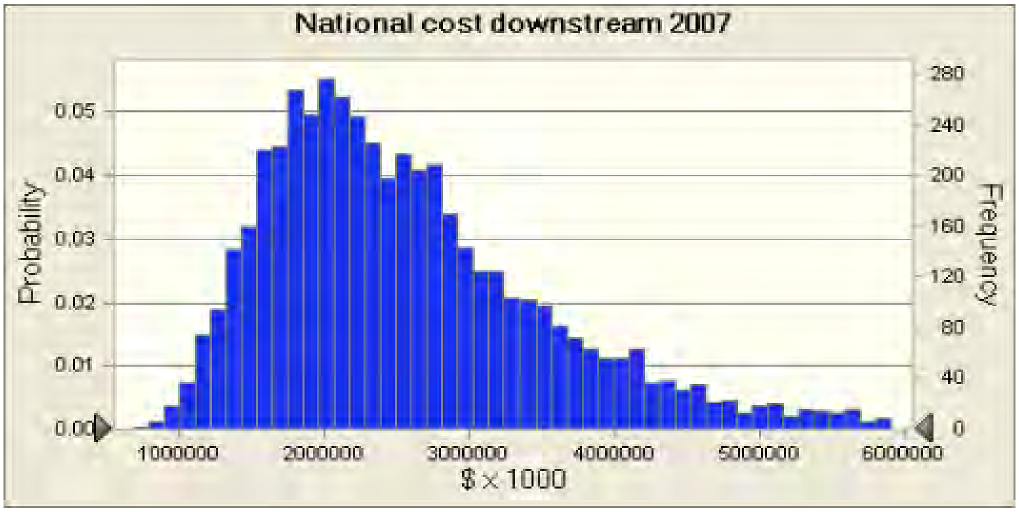
Statistics:	Forecast values
Trials	5,000
Mean	133.00
Median	118.95
Mode	---
Standard Deviation	62.31
Variance	3882.40
Skewness	1.96
Kurtosis	10.47
Coeff. of Variability	0.4685
Minimum	30.45
Maximum	700.26
Range Width	669.82
Mean Std. Error	0.88

Forecast: Cost per service station 2007 (cont'd) **Cell: S36**

Percentiles:	Forecast values
0%	30.45
10%	71.89
20%	85.08
30%	95.97
40%	108.24
50%	118.95
60%	132.76
70%	148.49
80%	171.68
90%	208.71
100%	700.26

Forecast: National cost downstream 2007 **Cell: R37**

Summary:
Entire range is from 683058 to 11913021
Base case is 2446350
After 5,000 trials, the std. error of the mean is 16474



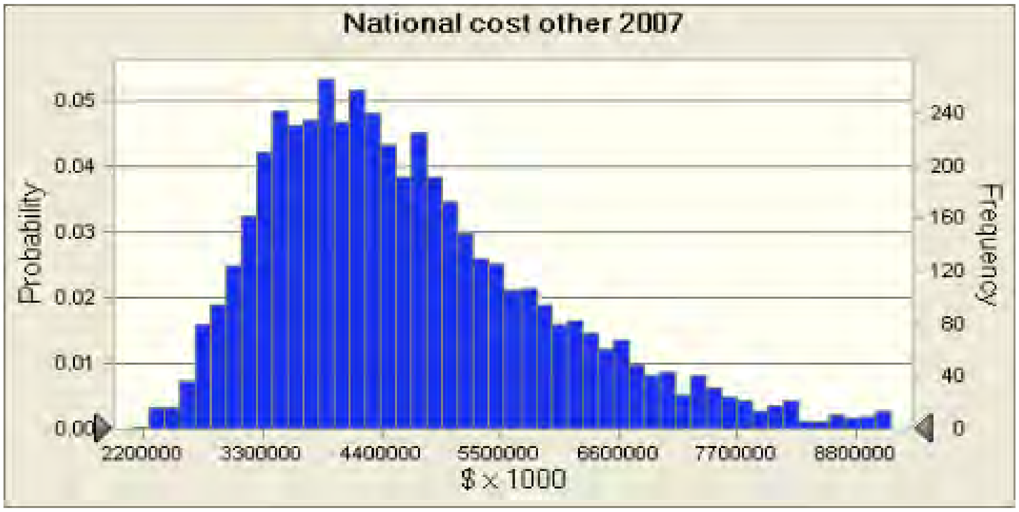
Statistics:	Forecast values
Trials	5,000
Mean	2646032
Median	2389953
Mode	---
Standard Deviation	1164870
Variance	1356921597461
Skewness	1.99
Kurtosis	10.22
Coeff. of Variability	0.4402
Minimum	683058
Maximum	11913021
Range Width	11229963
Mean Std. Error	16474

Forecast: National cost downstream 2007 (cont'd) **Cell: R37**

Percentiles:	Forecast values
0%	683058
10%	1515947
20%	1763628
30%	1967291
40%	2162237
50%	2389953
60%	2647163
70%	2924686
80%	3363679
90%	4063686
100%	11913021

Forecast: National cost other 2007 **Cell: R40**

Summary:
Entire range is from 2099070 to 19475874
Base case is 4762551
After 5,000 trials, the std. error of the mean is 22059



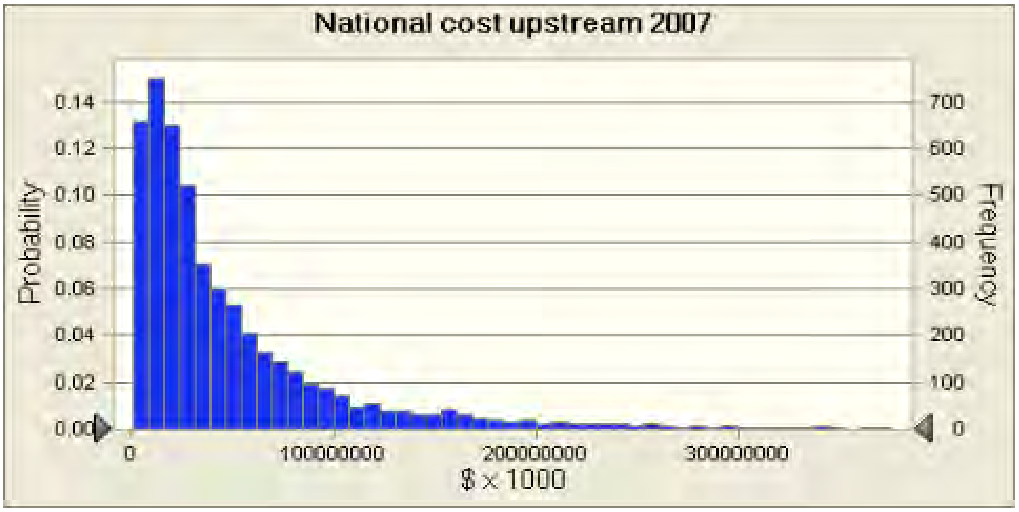
Statistics:	Forecast values
Trials	5,000
Mean	4762134
Median	4423614
Mode	---
Standard Deviation	1559840
Variance	2433101872148
Skewness	1.92
Kurtosis	10.50
Coeff. of Variability	0.3276
Minimum	2099070
Maximum	19475874
Range Width	17376804
Mean Std. Error	22059

Forecast: National cost other 2007 (cont'd) **Cell: R40**

Percentiles:	Forecast values
0%	2099070
10%	3219730
20%	3548687
30%	3851390
40%	4142701
50%	4423614
60%	4771831
70%	5164562
80%	5749624
90%	6662696
100%	19475874

Forecast: National cost upstream 2007 **Cell: R35**

Summary:
Entire range is from 950425 to 2622433188
Base case is 33424083
After 5,000 trials, the std. error of the mean is 1597402



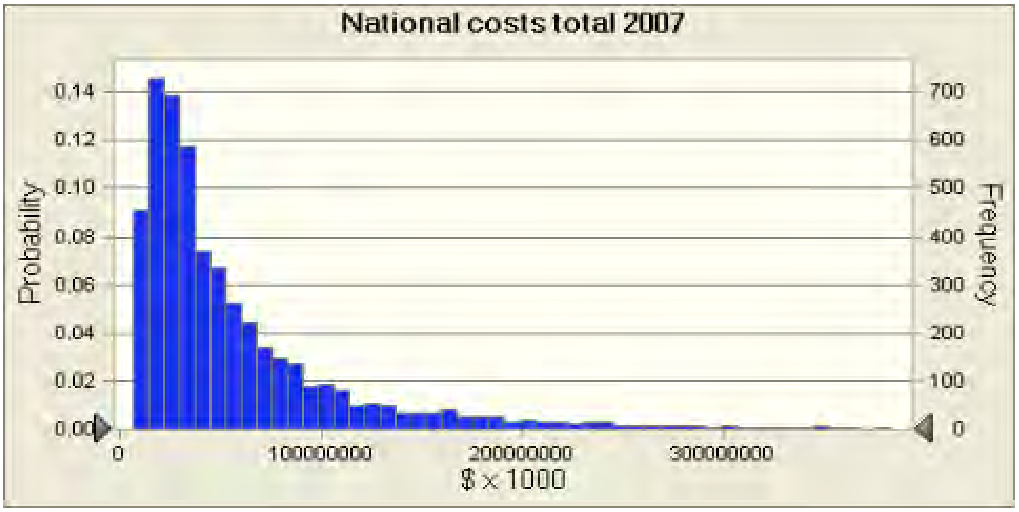
Statistics:	Forecast values
Trials	5,000
Mean	59528093
Median	30390177
Mode	---
Standard Deviation	112953390
Variance	###############
Skewness	9.31
Kurtosis	137.26
Coeff. of Variability	1.90
Minimum	950425
Maximum	2622433188
Range Width	2621482763
Mean Std. Error	1597402

Forecast: National cost upstream 2007 (cont'd) **Cell: R35**

Percentiles:	Forecast values
0%	950425
10%	7317722
20%	12214257
30%	17324050
40%	23148270
50%	30390177
60%	40782782
70%	54696564
80%	77373219
90%	126308937
100%	2622433188

Forecast: National costs total 2007 **Cell: Q42**

Summary:
Entire range is from 6202875 to 2630416093
Base case is 40632983
After 5,000 trials, the std. error of the mean is 1597220



Statistics:	Forecast values
Trials	5,000
Mean	66936259
Median	37775948
Mode	---
Standard Deviation	112940513
Variance	###############
Skewness	9.31
Kurtosis	137.17
Coeff. of Variability	1.69
Minimum	6202875
Maximum	2630416093
Range Width	2624213217
Mean Std. Error	1597220

Forecast: National costs total 2007 (cont'd) **Cell: Q42**

Percentiles:	Forecast values
0%	6202875
10%	14379641
20%	19635045
30%	24890785
40%	30682064
50%	37775948
60%	48473053
70%	62419402
80%	84677892
90%	134123451
100%	2630416093

End of Forecasts

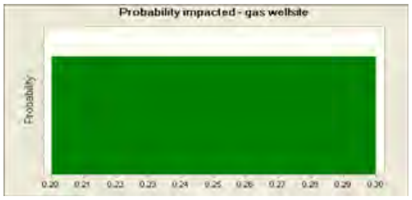
Assumptions

Worksheet: [SEA Basic Remediation Cost Model - Revised final.xls]Numbers of Facilities

Assumption: Probability impacted - gas wellsite **Cell: Q9**

Uniform distribution with parameters:

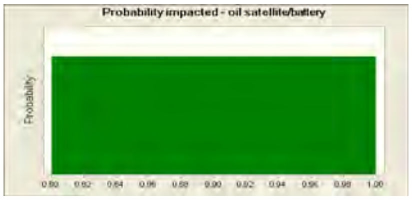
Minimum	0.20
Maximum	0.30



Assumption: Probability impacted - oil satellite/battery **Cell: Q10**

Uniform distribution with parameters:

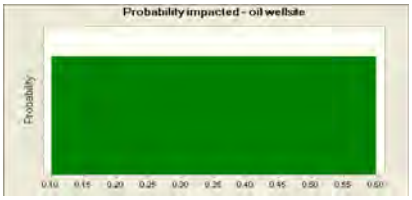
Minimum	0.80
Maximum	1.00



Assumption: Probability impacted - oil wellsite **Cell: Q8**

Uniform distribution with parameters:

Minimum	0.10
Maximum	0.60



Worksheet: [SEA Basic Remediation Cost Model - Revised final.xls]Remediation Unit Costs

Assumption: Downstream unit cost - Atlantic $/m3 **Cell: I20**

Triangular distribution with parameters:

Minimum	120.00
Likeliest	160.00
Maximum	200.00

Assumption: Downstream unit cost - BC $/m3 **Cell: I17**

Triangular distribution with parameters:

Minimum	90.00
Likeliest	120.00
Maximum	150.00

Assumption: Downstream unit cost - Central $/m3 **Cell: I19**

Triangular distribution with parameters:

Minimum	100.00
Likeliest	140.00
Maximum	180.00

Assumption: Downstream unit cost - North $/m3 **Cell: I21**

Triangular distribution with parameters:

Minimum	160.00
Likeliest	200.00
Maximum	240.00

Assumption: Downstream unit cost - Prairies $/m3 **Cell: I18**

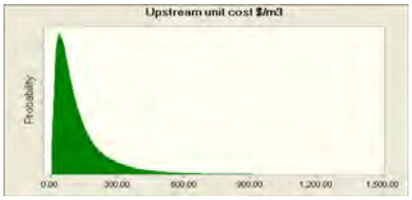
Triangular distribution with parameters:

Minimum	90.00
Likeliest	120.00
Maximum	150.00

Assumption: Upstream unit cost $/m3 **Cell: I9**

Lognormal distribution with parameters:

Mean	90.90
90%	288.10

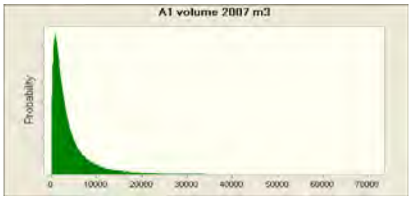


Worksheet: [SEA Basic Remediation Cost Model - Revised final.xls]Scenario Volumes & Costs

Assumption: A1 volume 2007 m3 **Cell: P8**

Lognormal distribution with parameters:

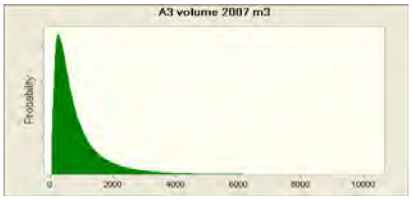
Mean	4627
Std. Dev.	6813



Assumption: A3 volume 2007 m3 **Cell: P10**

Lognormal distribution with parameters:

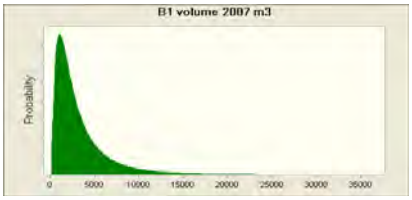
Mean	901
Std. Dev.	1059



Assumption: B1 volume 2007 m3 **Cell: P15**

Lognormal distribution with parameters:

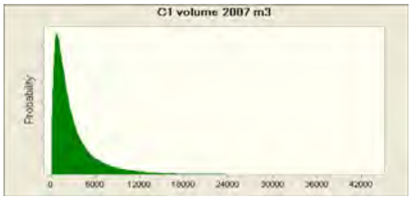
Mean	3460
Std. Dev.	3826



Assumption: C1 volume 2007 m3 **Cell: P22**

Lognormal distribution with parameters:

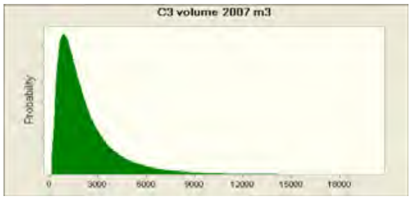
Mean	3334
Std. Dev.	4333



Assumption: C3 volume 2007 m3 **Cell: P24**

Lognormal distribution with parameters:

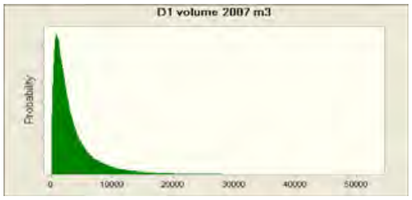
Mean	2310
Std. Dev.	2217



Assumption: D1 volume 2007 m3 **Cell: P29**

Lognormal distribution with parameters:

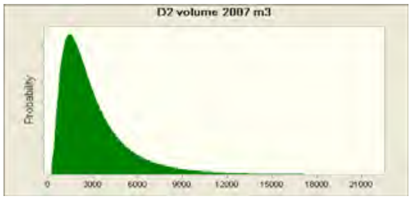
Mean	3959
Std. Dev.	5217



Assumption: D2 volume 2007 m3 **Cell: P30**

Lognormal distribution with parameters:

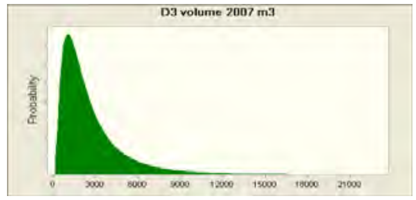
Mean	3100
Std. Dev.	2539



Assumption: D3 volume 2007 m3 **Cell: P31**

Lognormal distribution with parameters:

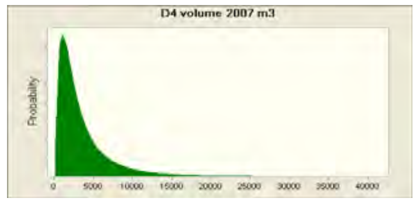
Mean	2719
Std. Dev.	2553



Assumption: D4 volume 2007 m3 **Cell: P32**

Lognormal distribution with parameters:

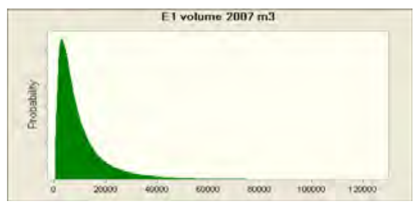
Mean	3767
Std. Dev.	4286



Assumption: E1 volume 2007 m3 **Cell: P36**

Lognormal distribution with parameters:

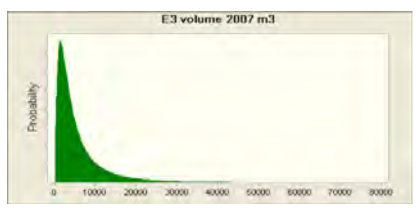
Mean	10897
Std. Dev.	12877



Assumption: E3 volume 2007 m3 **Cell: P38**

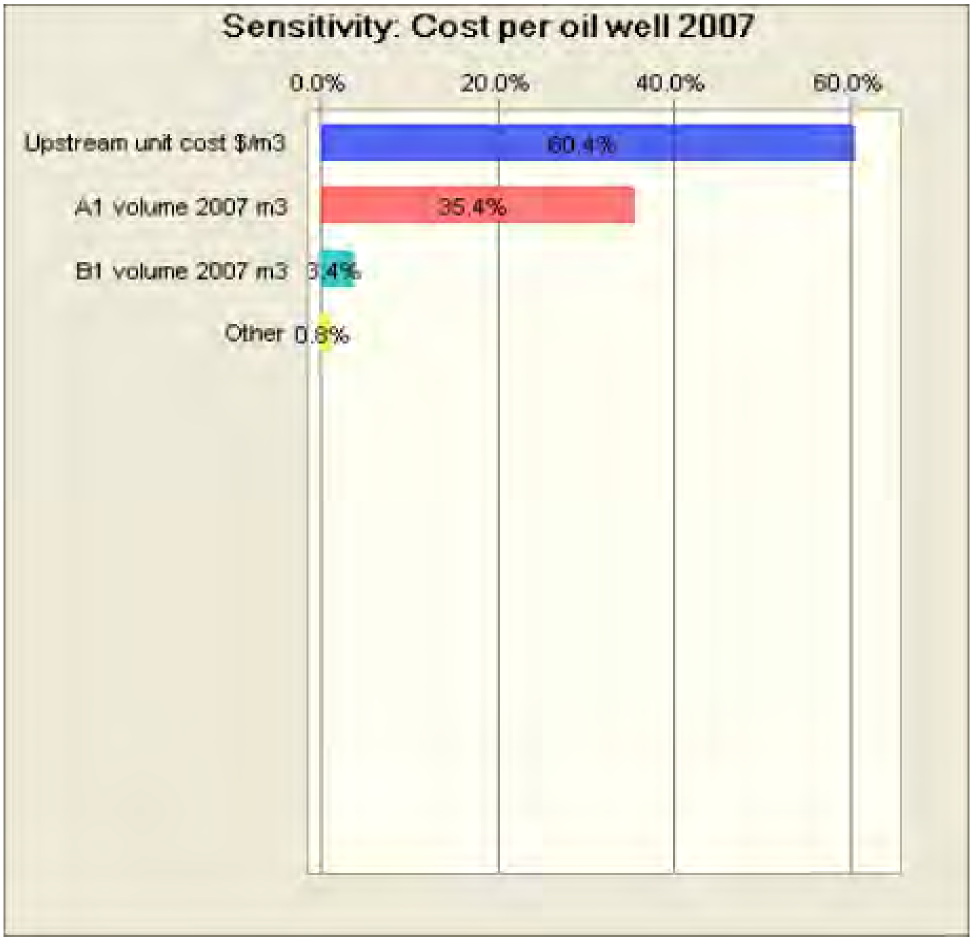
Lognormal distribution with parameters:

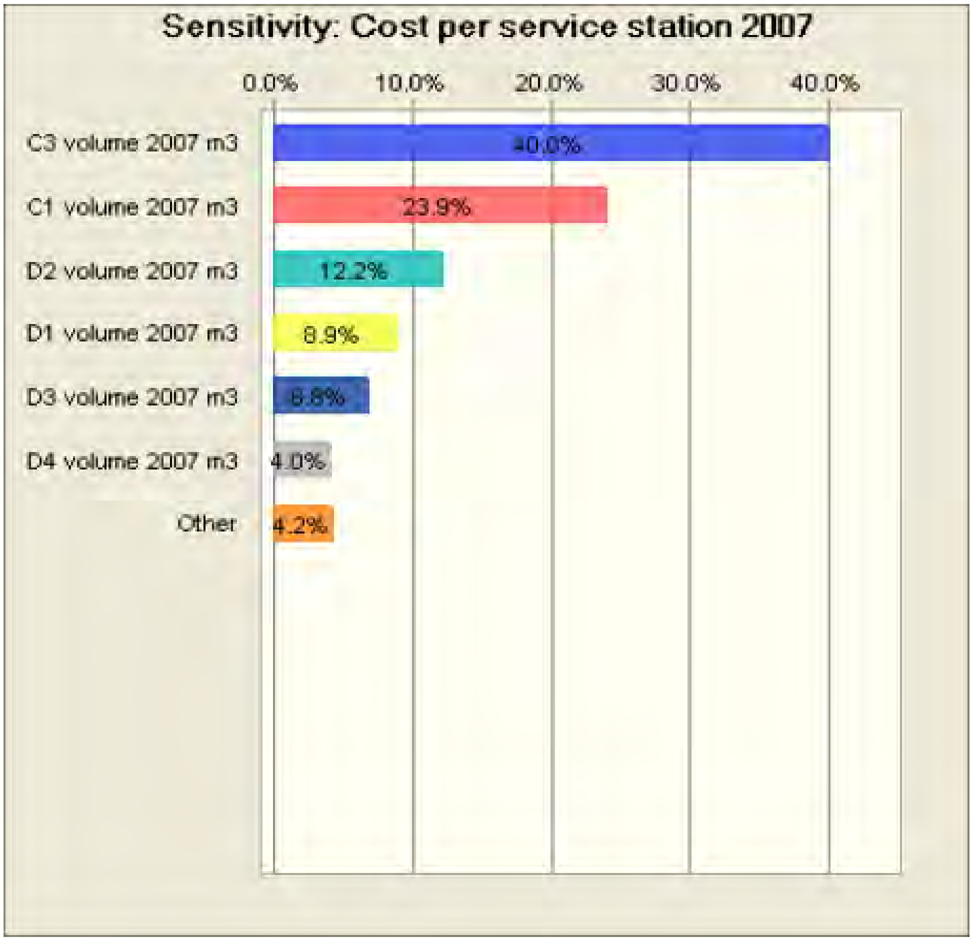
Mean	6064
Std. Dev.	7854

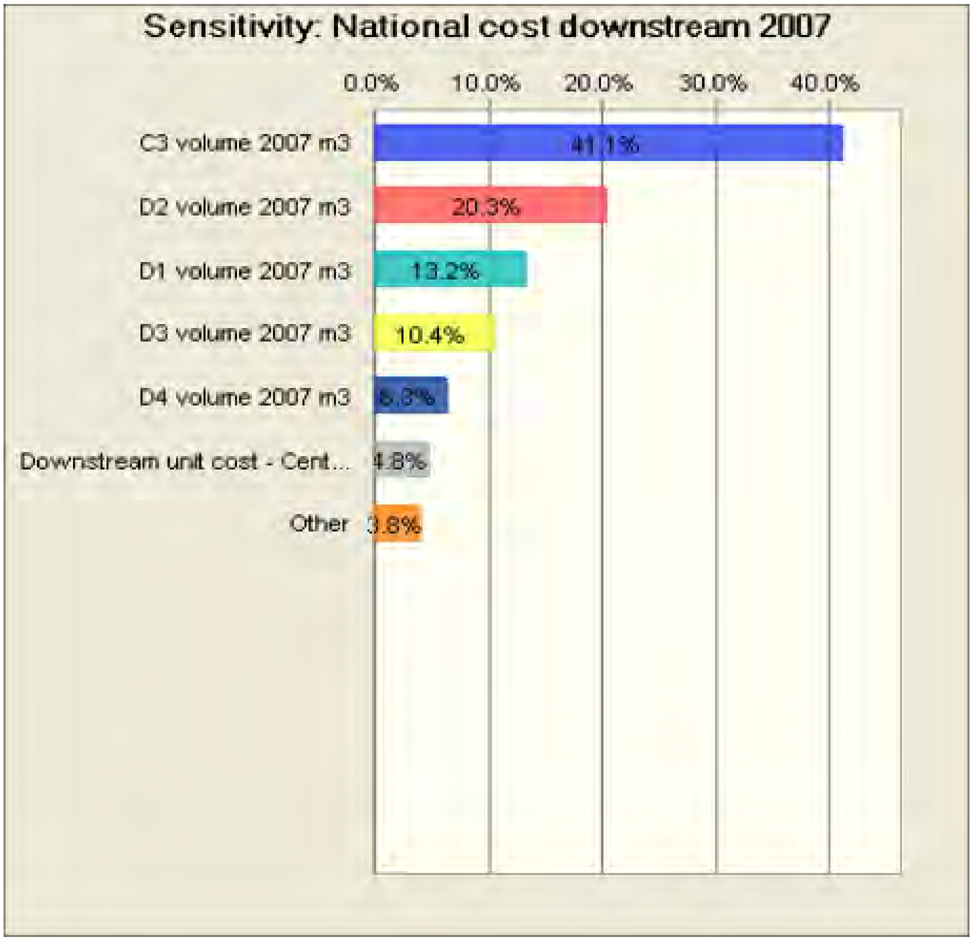


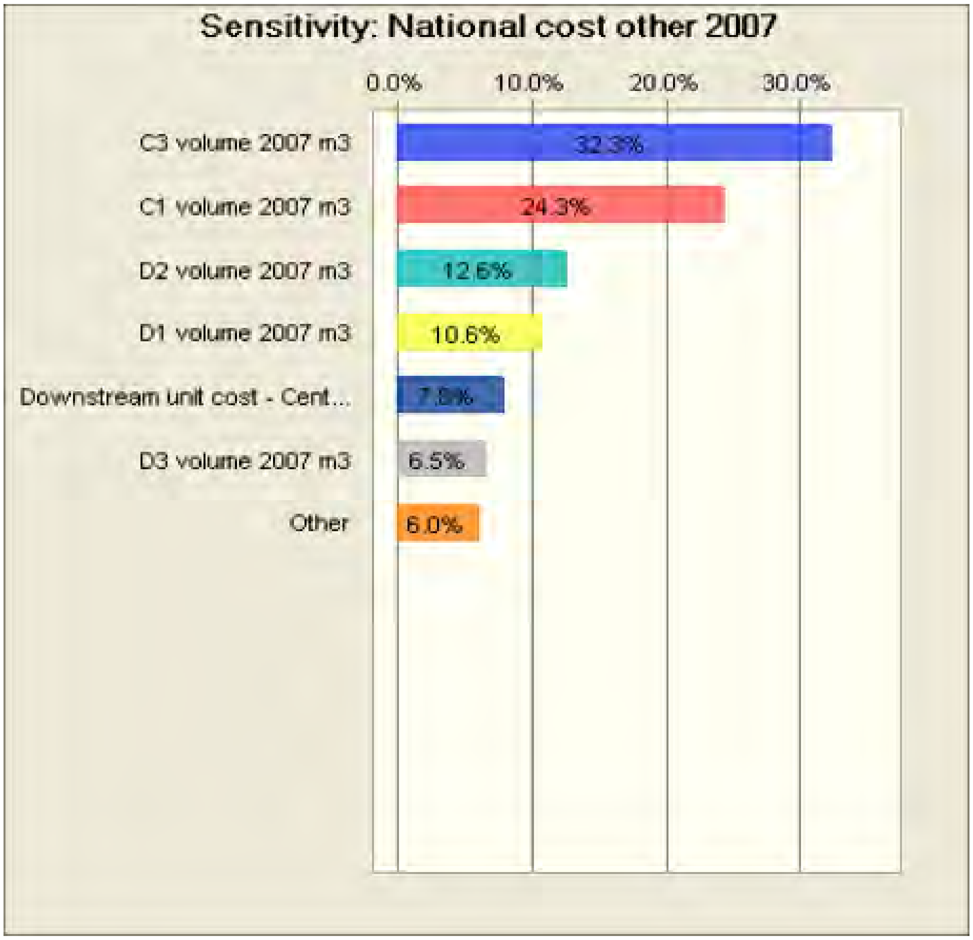
End of Assumptions

Sensitivity Charts

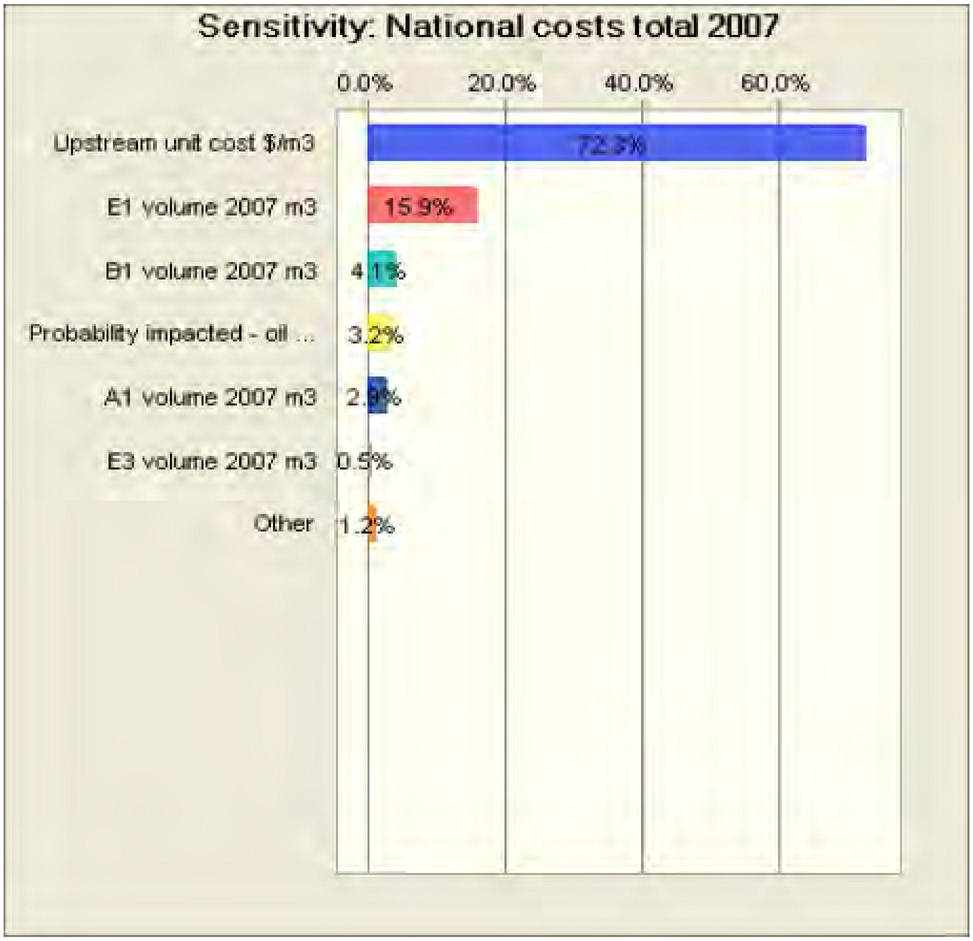



Sensitivity: Cost per service station 2007
0.0%
10.0%
20.0%
30.0%
40.0%
C3 volume 2007 m3
40.0%
C1 volume 2007 m3
23.9%
D2 volume 2007 m3
12.2%
D1 volume 2007 m3
8.9%
D3 volume 2007 m3
6.8%
D4 volume 2007 m3
4.0%
Other
4.2%


Sensitivity: National cost downstream 2007
0.0%
10.0%
20.0%
30.0%
40.0%
C3 volume 2007 m3
41.1%
D2 volume 2007 m3
20.3%
D1 volume 2007 m3
13.2%
D3 volume 2007 m3
10.4%
D4 volume 2007 m3
6.3%
Downstream unit cost - Cent...
4.8%
Other
3.8%


Sensitivity: National cost other 2007
0.0%
10.0%
20.0%
30.0%
C3 volume 2007 m3
32.3%
C1 volume 2007 m3
24.3%
D2 volume 2007 m3
12.6%
D1 volume 2007 m3
10.6%
Downstream unit cost - Cent...
7.9%
D3 volume 2007 m3
6.5%
Other
6.0%


Sensitivity: National cost upstream 2007
0.0%
20.0%
40.0%
60.0%
Upstream unit cost $/m3
73.0%
E1 volume 2007 m3
15.9%
B1 volume 2007 m3
4.1%
Probability impacted - oil ...
3.2%
A1 volume 2007 m3
2.8%
E3 volume 2007 m3
0.5%
A3 volume 2007 m3
0.2%
Downstream unit cost - BC $/m3
-0.1%
Other
0.2%



End of Sensitivity Charts