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A Few Words from Editor

Dear SCCAEPA Online Journal Readers,

Enjoy the second issue of the Southern California Chinese American Environmental Protection Association (SCCAEPA) Online Journal (ISSN 1944-8945). In this issue, we have 2 peer reviewed articles. To sustain the journal, we need members' contributions. I invite you to submit your work and written materials from your experience. To make things easier, I would like to suggest short articles that can be modified from your conference presentations and slides. The Journal is also open to outside of our association.

Sincerely,

Yue Rong, Ph.D.
Editor-in-Chief
SCCAEPA Online Journal
June 2009
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USING A DECISION TREE APPROACH TO ESTIMATE ENVIRONMENTAL REMEDIAL COSTS – A CASE STUDY

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(Feburary 24, 2009) (Revised)

Abstract
This article discusses the use of a stochastic decision tree approach to estimate environmental remedial costs in a highly uncertain environment. The main advantage of this type of approach is that it is stochastic in nature and yields not just a number, but an entire distribution function of likely outcomes, allowing the user to quantify uncertainties. In the classical, deterministic approach, however, uncertainty is dealt with by calculating worst-case scenarios or ranges of values, but these are frequently of little practical use to the decision maker because they are often overly conservative. Because of its clear advantages, stochastic methods have been increasingly used in a variety of industries. This article will discuss the application, benefits, and limitations of this approach for cost estimation of environmental remedial activities.

Introduction
ENVIRON was asked to provide a cost estimate for a potential clean-up of a former mine site in the Western United States. Figure 1 shows a conceptual layout of the site.

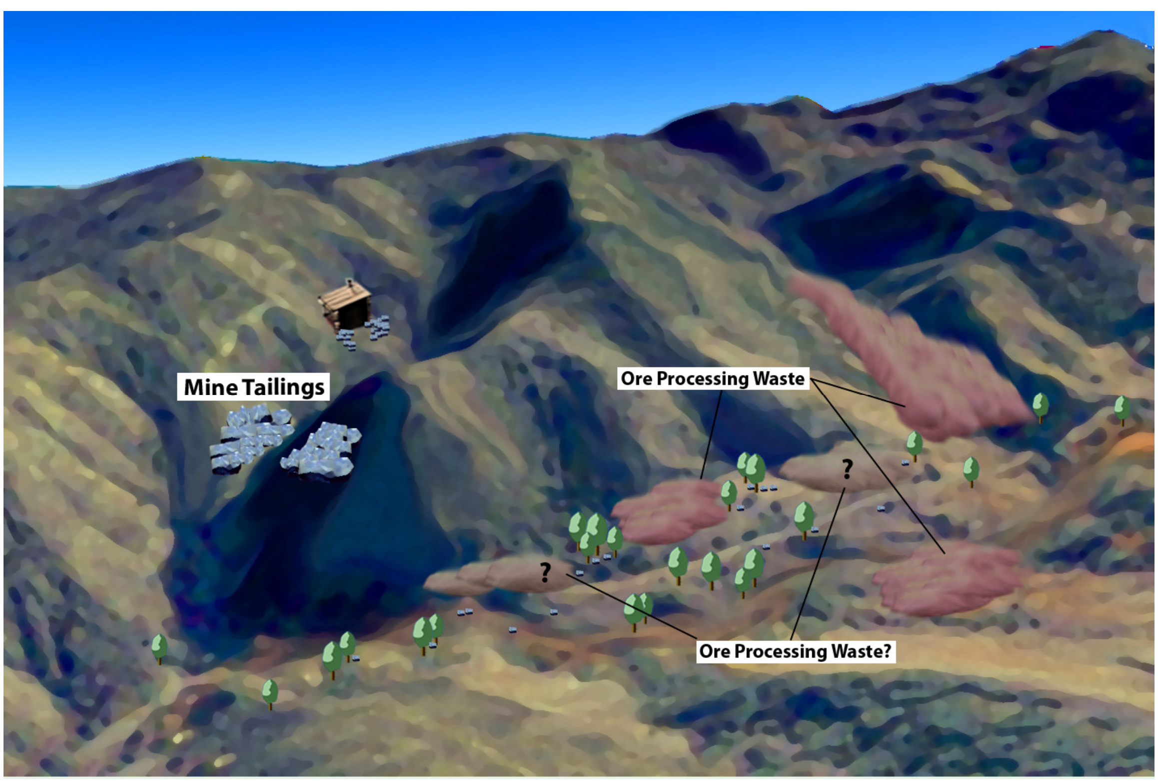

Figure 1: Conceptual Site Layout

In this case study, the main challenge in calculating a meaningful clean-up cost was the high number of uncertainties associated with the site. The main environmental concern at the site was the widespread presence of ore processing wastes, which can contain significant residual amounts of relatively mobile metal species. Clean-up of ore processing wastes at former mining sites typically entails stabilizing the wastes with caps and covers, or relocating them to a stabilized repository. The cost for doing so largely depends on the amount of material present, and the aerial extent over which the material is spread out, and therefore the distance over which it needs to be moved.

In the case of our Site, no specific requirements had been identified by the regulatory oversight agency with respect to contaminants of concern, clean-up levels, sampling, reporting, monitoring or remedial approaches. Furthermore, little information existed about the true extent and amount of ore processing wastes at the site.

Methodology

Due to the extensive list of uncertainties, it quickly became apparent that the typical approach to cost estimation, including a series of assumptions from which a single cost is calculated, would not yield a meaningful result in this case. Therefore, as an alternative method, ENVIRON opted for a decision tree approach. This approach allows the exploration of various scenarios and assigns costs and probabilities of occurrence to these scenarios. The software package used for this purpose was Precision Tree® from Palisade's Decision Tools Suite. The software calculates terminal costs and probabilities of the various scenarios by summing the user-defined costs, and multiplying the user-defined probabilities of the 'branches' leading to each terminal point on the decision tree. The decision tree for the ore processing waste issue is shown in Figure 2.

In building the decision tree for ore processing wastes, the first question we were faced with was the amount of waste material present at the site. Our research uncovered three references related to the amount of ore processing wastes potentially present at the site. Two references indicated 1,000,000 (1M) tons, while a third reference indicated the amount to be 10,000,000 (10M) tons. To independently evaluate the quantity of waste material present at the site, ENVIRON reviewed aerial photographs of the site. Based on the characteristic coloration of ore processing wastes, a visual assessment was made of the likely lateral extent of the material. To estimate the thickness of the waste piles, ENVIRON relied on publicly available site photographs taken from the ground and an interpretation of the natural topography in the vicinity of the piles. The amount of material calculated in this manner approximated 1M tons. Since ENVIRON's estimate was similar to two existing estimates, a probability of occurrence of 80% was given to the 1M ton scenario. Another result of ENVIRON's visual assessment, based on aerial imagery and site photos, was that 10M tons was an unrealistically high number (the entire site would need to be covered with a thick layer of ore processing wastes). However, in order to account for the possibility of higher than expected amounts of waste material at the site, a scenario of 5M tons was established and was assigned a probability of 20% (see Figure 2).

In the next step, we explored the need for additional site characterization and the associated investigation costs. For both the 1M and 5M ton ore processing waste scenarios, an assessment was made of possible site characterization costs ("Investigation Costs" in Figure 2). Depending on the number of analytes, the spacing of the sampling grids, the number of sampling rounds, and the amount of labor, investigation costs were placed into 'high', 'mid', or 'low' categories. Each of these scenarios is based on real world examples at other similar sites with varying regulatory requirements, and therefore varying degrees of investigation costs.

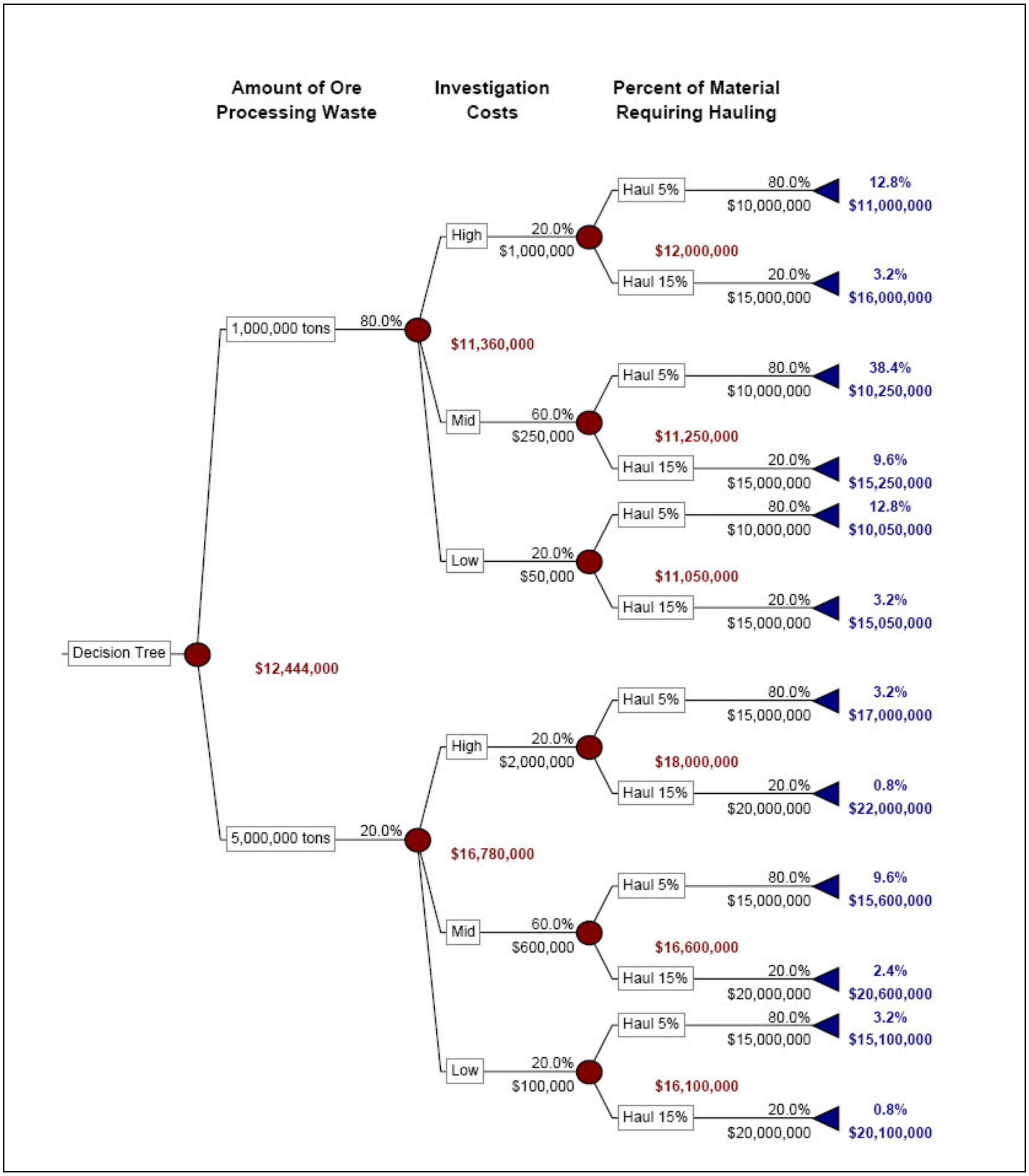

Figure 2: Ore Processing Waste Decision Tree with Costs and Probabilities

Finally, various remedial scenarios and associated costs for the ore processing waste material were evaluated. To narrow down the range of options for this step, a comprehensive review was conducted of other, similar mining sites in the same state as the site. A former mine with similar site conditions to the subject property was identified as a proxy for the site. At the proxy site, spread out areas of ore processing waste piles were either stabilized and capped in place, or hauled away and consolidated in one on-site location, which was subsequently capped, seeded, and drained. At our site, most but not all of the visible ore processing waste was already located in a central location (see Figure 1).

Mirroring the approach taken at the proxy site, ENVIRON assumed that a limited amount of material would need to be removed from outlying areas, and areas bordering the main paths for rain water run-off, and relocated to the main dump site. To allow for varying amounts of material hauling, two scenarios were added to the tree: one requiring the hauling of 5% of the total amount of ore processing waste at the site, and another requiring 15% of material to be hauled to the main repository. Based on review of site imagery and analysis of the proxy site, the likelihood of the 'Haul 5%' scenario was deemed more probable than the 'Haul 15%' scenario, and an 80-20 split was assigned, respectively. Costs for the remedial approach were obtained from the proxy site, and adjusted for inflation and scale. In addition, costs were gathered from the RS Means Cost Works[1] which lists unit costs for grading, hauling, capping, etc.

Results

Once the decision tree has been constructed and populated with meaningful cost numbers and probabilities, the software was used to run a decision analysis report. Outputs include probability distribution functions (Figure 3), and cumulative distribution functions (Figure 4, Table 1). Figure 3 is a graphical representation of terminal costs and probabilities shown in blue at the end of the decision tree (see Figure 2). Figure 4, in turn, is constructed directly from Figure 3. To arrive at terminal costs shown in Figure 2, costs are added and probabilities multiplied. For example, for the scenario of 1M tons of ore processing waste ($0; 80%), low investigation costs ($50,000; 20%), and 5% hauling ($15,000,000; 20%), the terminal cost is the sum of all preceding branches, or $15,050,000; the terminal probability is the product of all preceding branches, 80% x 20% x 20% = 3.2%.

All costs used in this analysis were represented in present-day dollars, and ENVIRON conducted a cash flow analysis to provide the client with an estimated payment schedule for the potential remedial work.

From the model outputs for our ore processing waste cost estimating exercise, the most probable result (or mode) is $10,250,000 (Figure 3). The expected value, or mean, is $12,432,000 (Table 2). The cost estimate that will not be exceeded with a probability of 90% is $16,000,000 (Table 1). Having provided the end user with the results of this analysis, it is now their decision to select an appropriate cost estimate for budgetary purposes, commensurate with the end user's risk tolerance profile.

Sensitivity analyses can also be performed to gauge the effect of certain model assumptions on the estimated project cost. Figure 5 and Table 3 show the results of a two-way sensitivity analysis run for the entire model varying the probabilities assumed for the amount of material present at the site (1M tons vs. 5M tons) and the amount of material requiring hauling (Haul 5% vs Haul 15%). For both these nodes on the decision tree an 80-20 split was assumed. This two-way sensitivity analysis was performed to evaluate the impact of a change in these values on the expected value of the model ($12.4 Million). The 80-20 splits were simultaneously varied between 100-0 splits to 40-60 splits, and the expected value of the model was calculated for each combination, plotted on Figure 5, and tabulated in Table 3. The results of the two-way sensitivity analysis show that varying the assumed probabilities in this way results in a range of expected values from $10.4 - $16.6 Million.

As a means of verifying its estimated numbers, ENVIRON reviewed other mining sites in the United States with similar issues to those encountered at our site, i.e. the presence of unmanaged ore processing waste. After adjusting for inflation, and with a proper use of scaling factors to adjust for the magnitude of the problem at each site, these other sites were found to have incurred costs of the same order of magnitude as those estimated for the site by ENVIRON.

[1] http://www.meanscostworks.com/

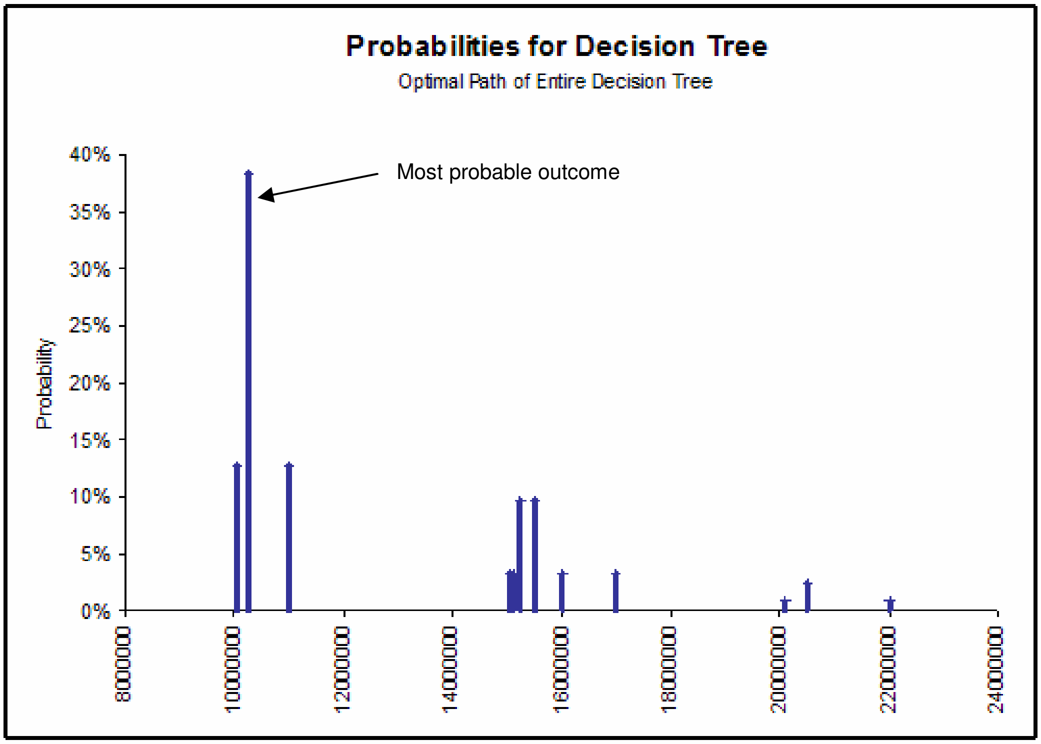

Figure 3: Probability Distribution Function for Costs from Ore Processing Waste Decision Tree

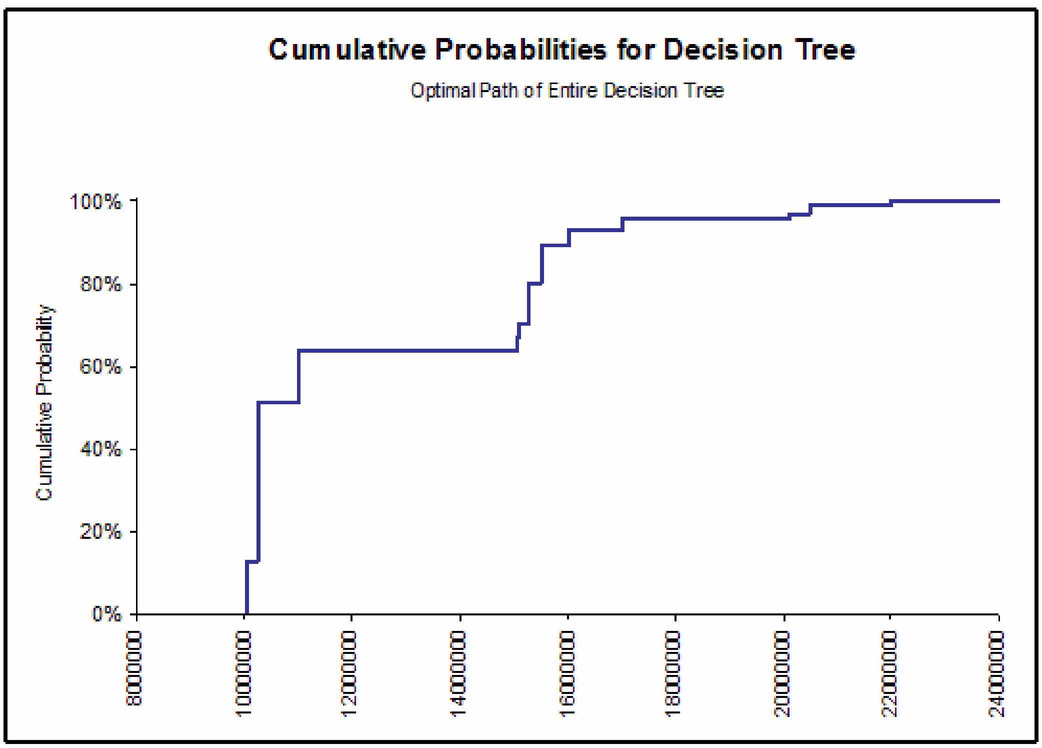

Figure 4: Cumulative Probability Distribution Function for Costs from Ore Processing Waste Decision Tree

Table 1: Tabular Cumulative Probability for Costs from Ore Processing Waste Decision Tree

Table 1		
	Optimal Path	
	Value	Probability
#1	-Infinity	0.00%
#2	$10,050,000	0.00%
#3	$10,050,000	12.80%
#4	$10,250,000	12.80%
#5	$10,250,000	51.20%
#6	$11,000,000	51.20%
#7	$11,000,000	64.00%
#8	$15,050,000	64.00%
#9	$15,050,000	67.20%
#10	$15,100,000	67.20%
#11	$15,100,000	70.40%
#12	$15,250,000	70.40%
#13	$15,250,000	80.00%
#14	$15,500,000	80.00%
#15	$15,500,000	89.60%
#16	$16,000,000	89.60%
#17	$16,000,000	92.80%
#18	$17,000,000	92.80%
#19	$17,000,000	96.00%
#20	$20,100,000	96.00%
#21	$20,100,000	96.80%
#22	$20,500,000	96.80%
#23	$20,500,000	99.20%
#24	$22,000,000	99.20%
#25	$22,000,000	100.00%
#26	Infinity	100.00%

Table 2: Model Statistics for Costs from Ore Processing Waste Decision Tree

Table 2	
Statistics	Optimal Path
Mean	12,432,000
Minimum	10,050,000
Maximum	22,000,000
Mode	10,250,000
Std. Deviation	2,961,448
Skewness[2]	1.0676
Kurtosis[3]	3.2056

[2] Skewness is a measure of a frequency distribution's lack of symmetry. Negative values for the skewness indicate that the left tail is long relative to the right tail. The converse is true for positive skewness values.

[3] Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution. Positive kurtosis indicates a "peaked" distribution and negative kurtosis indicates a "flat" distribution.

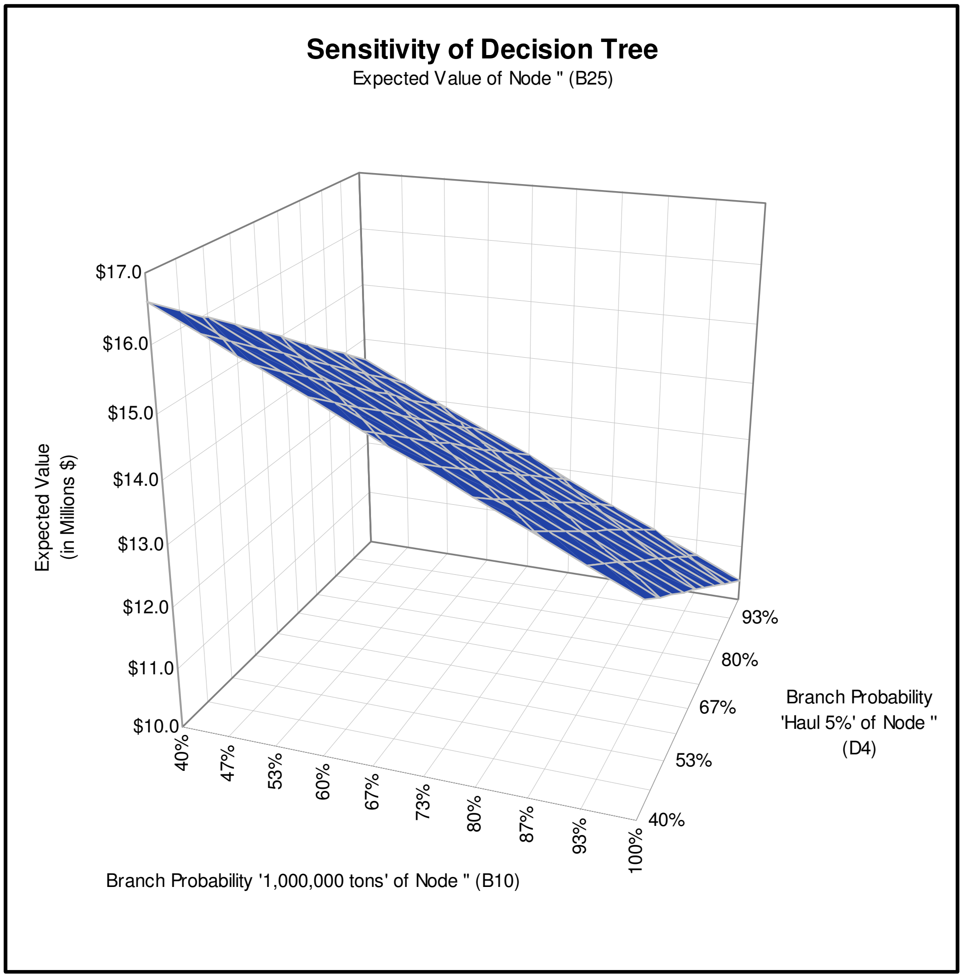

Figure 5: Two-way Sensitivity Plot of Decision Tree With Variation of Branch Probability '1,000,000 tons', and Branch Probability 'Haul 5%'

Table 3: Two-way Sensitivity Data of Decision Tree With Variation of Branch Probability '1,000,000 tons', and Branch Probability 'Haul 5%'

		Branch Probability '1,000,000 tons'									
		40%	47%	53%	60%	67%	73%	80%	87%	93%	100%
Branch Probability 'Haul 5%'	40%	$16.6	$16.3	$15.9	$15.5	$15.2	$14.8	$14.4	$14.1	$13.7	$13.4
	47%	$16.3	$15.9	$15.6	$15.2	$14.8	$14.5	$14.1	$13.7	$13.4	$13.0
	53%	$15.9	$15.6	$15.2	$14.9	$14.5	$14.1	$13.8	$13.4	$13.1	$12.7
	60%	$15.6	$15.3	$14.9	$14.5	$14.2	$13.8	$13.4	$13.1	$12.7	$12.4
	67%	$15.3	$14.9	$14.6	$14.2	$13.8	$13.5	$13.1	$12.7	$12.4	$12.0
	73%	$14.9	$14.6	$14.2	$13.9	$13.5	$13.1	$12.8	$12.4	$12.1	$11.7
	80%	$14.6	$14.3	$13.9	$13.5	$13.2	$12.8	$12.4	$12.1	$11.7	$11.4
	87%	$14.3	$13.9	$13.6	$13.2	$12.8	$12.5	$12.1	$11.7	$11.4	$11.0
	93%	$13.9	$13.6	$13.2	$12.9	$12.5	$12.1	$11.8	$11.4	$11.1	$10.7
	100%	$13.6	$13.3	$12.9	$12.5	$12.2	$11.8	$11.4	$11.1	$10.7	$10.4

Discussion

The results of the decision analysis are far more informative than what a deterministic cost estimating approach would have provided. The key difference between the two approaches is that the user not only gets a "best estimate" cost number, but also gets a sense of the level of confidence associated with that number.

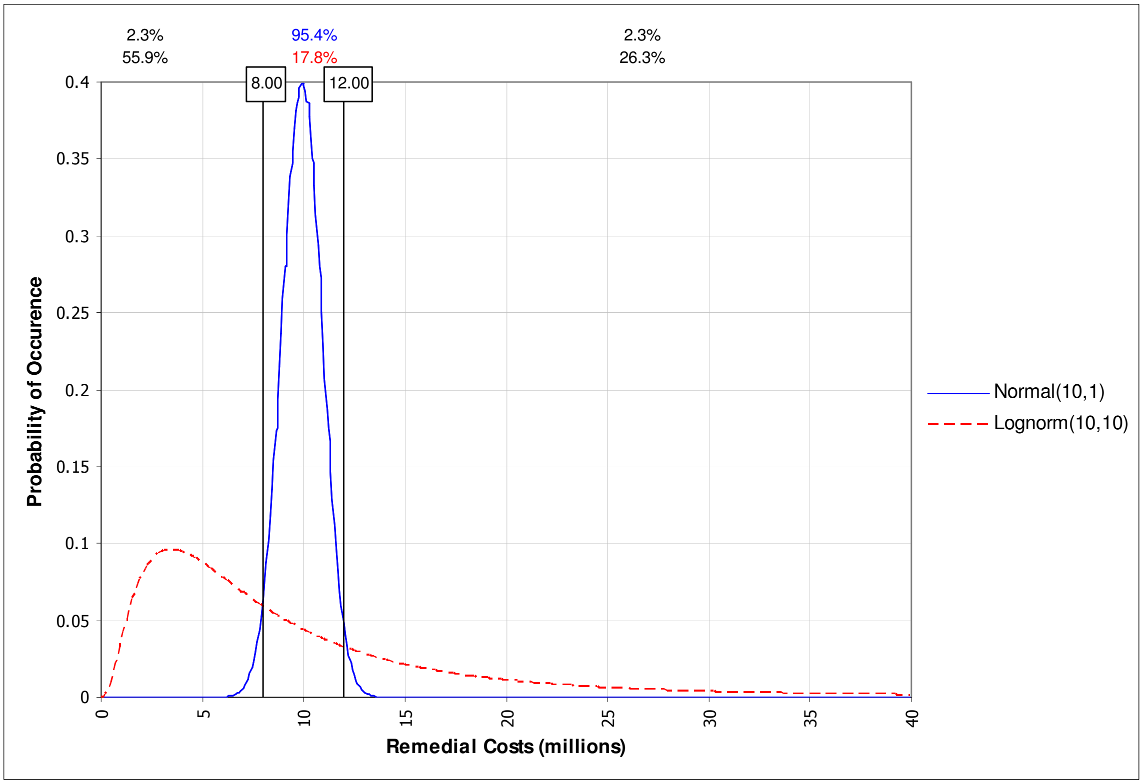

Figure 6: Illustration of the Importance of Stochastic Outputs for the Decision Making Process

To illustrate the importance of stochastic outputs for the decision making process, Figure 6 is included as a hypothetical example. The solid blue line is normally distributed with a mean of $10M and a standard deviation of $1M. The dashed red line is log-normally distributed with a mean of $10M and a standard deviation of $10M. Basing a decision on a single number, without any idea of the underlying uncertainty can be problematic. In this hypothetical example, the deterministic cost estimating approach would have resulted in the same answer for both scenarios, namely $10M. However, it is clear from Figure 5, that the additional information provided by stochastic approaches to cost estimation are essential to the decision making process. In the case of the solid blue line the decision maker is 95.4% confident that the final cost will fall between $8M and $12M (as indicated near the top of the graph[4]). In contrast, in the case of the dashed red line, the level of confidence of the cost falling between $8M and $12M, is reduced to only 17.8%, with a 55.9% chance it will be less than $8M, and a 26.3% chance the cost will be greater than $12M.

This hypothetical example illustrates the importance of stochastic outputs to the decision making process. In contrast to the typical deterministic approach, a stochastic, decision-tree approach provides not just a single number, but an entire distribution function, which can be used to make better decisions.

[4] Approximately 95.4% of normally-distributed observations lie within two standard deviations of the mean.

Summary

This article has laid out a process used to provide a stochastic cost estimate. There are multiple advantages to selecting this approach, including increased transparency in assumptions through use of a decision tree structure, more informative outputs than deterministic methods, and the ability for the end user (and not the technical consultant) to select an appropriate risk-level to use in budgeting a likely cost. As a cautionary note, as is the case with all models, results are only meaningful when care is taken to provide meaningful inputs to the model. To this end, a lot of our time was spent gathering real-world cost information, and reviewing other mining sites in the area to find comparable conditions.

As an additional advantage to this type of approach, it can be used as a cost-tracking and update tool. As a project progresses and more information is obtained, a decision tree may be refined and updated with the most current information available. In doing so the range of expected outcomes will invariably narrow as the project progresses, providing more specific estimates of final remedial costs.

Finally, this approach can be very helpful in multi-party discussions with project stakeholders. Because a decision tree is transparent in nature, negotiations can focus on specific assumptions, and appropriate costs and probabilities, to arrive at a mutually agreeable conclusion. Overall, we believe this approach has yielded superior results to our client, especially given the many uncertainties associated with the site.

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Precision Tree, The DecisionTools Suite (software), Palisade Corporation

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US STRATEGIES FOR WATER QUALITY PROTECTION

Charles Cheng, Ph.D.[5]

(March 12, 2009) (Revised)

ABSTRACT

Pollution control and water resource protection is a fundamental strategy to protect water quality and designated beneficial uses of the nation's waters, including safe drinking water supply. This strategy, through sound regulatory programs and policies, has been shown effective in protecting and restoring water resources in the U.S. The objective of this paper is to introduce core regulatory programs, implementation and enforcement policies in the U.S. The paper provides an overview of relevant federal and state water laws and policies, core regulatory programs, and strategies of water quality protection. Discussions are focused on controls of point source and nonpoint source discharges, as well as remediation of groundwater pollution. The paper concludes that pollution control and water resource protection is a fundamental strategy to protect water quality, and that effective regulatory programs and policies are necessary to achieve the goal.

1. INTRODUCTION

As a result of global warming and climate change, population growth and human pollution, water resources around the world become increasingly limited in quantity and quality. At the same time, there is a great need to balance competing beneficial uses for the increasingly limited water resources. It is critical that government authorities recognize and establish fundamental strategies to protect limited water resources for balanced and sustainable beneficial uses. For example, as frequently reported around the world especially in developing countries, shortage and pollution of drinking water supply is becoming an alarming issue that threatens the wellbeing of human society. In China, chemical spill along the Songhua River and algae bloom in the Tai Lake caused not only serious problems and panicking situations with drinking water supply in metropolitan cities, but also damages to the ecology and the environment. Yet, the government placed emphasis only on treatment of polluted waters rather than the protection of water resources. Treatment at water plants may not remove all harmful chemicals - some of which have accumulative effects on human health that are not well understood, and treatment process can produce harmful by-products such as trihalomethanes. Therefore, it is essential that pollution control and protection of water resources be the fundamental strategy of protecting water beneficial uses, including drinking water safety. Strong regulatory programs and policies are vital to implement protective water quality standards for surface and ground waters, to regulate improper waste management practices, to control and reduce pollution sources, and to restore impaired waterbodies. The purpose of this paper is to introduce some of the strategies used in the U.S. that, in author's opinion, are critical and effective in pollution control and water resources protection and restoration.

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2. CONTROL OF POINT SOURCE POLLUTANTS

Point source discharges are from discrete conveyance systems at well-defined locations. Examples include municipal and industrial wastewater treatment facilities. Point source wastes can be generated by residential, commercial, industrial, agricultural, and other human activities. Because point source discharges are direct and "controllable" water quality factors, Clean Water Act (CWA)[1] included point source permitting program as the centerpiece of national water pollution control efforts.

2.1. Waste Discharge Prohibition

Certain types of wastes or certain areas are not allowed to discharge. Examples include discharges of waste, including reclaimed water, into lakes or reservoirs used for drinking water supply; discharges of waste that cause or threaten to cause pollution; discharges of waste that exceed receiving water quality objectives; dumping waste directly into waters or adjacent to waters; discharges of waste into storm water conveyance systems; discharges of any radiological, chemical, or biological warfare agent into waters; discharges of sand, silt, clay, or other earthen materials which cause deleterious bottom deposits, turbidity, or discoloration in waters. "No Discharge Zone" in bays and harbors prohibits waste discharges from marine vessels. Waste discharge prohibitions are established in permits and Regional Boards' water quality control plans (the Basin Plan[2]), and are enforceable.

2.2. Control of Waste Discharges to Surface Water

The prominent strategy in controlling point source waste discharge to surface waters of the U.S. is the National Pollutant Discharge Elimination System (NPDES) permitting program. It is authorized under Section 402 of the CWA (40 CFR 122)[3], and is administered by USEPA or authorized States. Any person or entity who discharges or proposes to discharge wastes to surface waters of the U.S. must apply for an NPDES permit - it is illegal to discharge wastes without an NPDES permit. NPDES permits establish discharge limits, prohibitions, provisions and conditions to ensure that applicable water quality objectives and beneficial uses are protected. The basic elements in the NPDES permits include a) effluent limitations on the quality and quantity of the waste discharge; b) standard and special provisions and discharge prohibitions; and c) monitoring and reporting program. NPDES program has evolved from controlling conventional pollutants (BOD, TSS, pH, fecal coliform and oil and grease), to controlling toxic discharges (priority pollutants) plus emerging chemicals (such as endocrine disrupting chemicals); from using technology-based effluent limits to imposing water quality-based effluent limits (federal and California water quality objectives, antidegradation policy, drinking water standards, California Toxics Rule[4], California Ocean Plan[5], etc.).

Dischargers shall pay annual fees according to its discharge volume, pretreatment program, threat to water quality (Category I through III) and operational complexity (Category a through c)[6]. Dischargers are required to self-monitor its compliance with NPDES permit by collecting and analyzing effluent (sometimes the receiving water) samples, and reporting results to the oversight agency. Dischargers are required to report and take corrective actions when not in compliance with the permit. The oversight agency conducts periodic inspections and compliance monitoring, and takes necessary enforcement actions to ensure compliance.

According to USEPA[7] , since the implementation of NPDES permitting program in 1972, US has spent $77 billion in construction of Publicly Owned Treatment Works (POTWs), the nation has reached 45% reduction in effluent BOD while POTW loading increased by 35%; water bodies meeting standards increased from 37% to 53%.

2.3. Control of Waste Discharges to Groundwater

Because NPDES permits only regulate waste discharges to surface water, waste discharges to land and groundwater are regulated by State or local governments. In California, the Waste Discharge Requirements (WDRs) are issued under the authority of Porter-Cologne Act[8] to regulate waste discharges to land, such as use of reclaimed water, landfill, septic tank system, dairy, nursery, industrial and sewage treatment plans. WDRs are similar to NPDES permits in most aspects, but are authorized by state laws and administered by state or local agencies.

2.4. Pretreatment Program

As a component of the NPDES permitting grogram, the CWA in Section 122 (40 CFR 403)[3] also included a National Pretreatment Program (NPP) for "indirect discharges" from industries into municipal wastewater treatment plants (POTWs). Certain industrial discharges interfere with the operation POTWs; some are not compatible with biological treatment and pass through POTWs without treatment. In 1986, more than one-third of all toxic pollutants entered the nation's waters from POTWs through industrial discharges into public sewers[9]. The goal of the NPP is to protect municipal treatment plants and the environment from hazardous or toxic wastes. Industrial and commercial dischargers are required to treat or control pollutants in their wastewaters prior to discharging into POTWs. USEPA has established Pretreatment Standards for 51 industrial categories and 126 priority pollutants[2]. The objectives of the NPP are achieved by applying and enforcing three types of discharge standards: prohibited discharge standards, categorical standards and local limits. Major POTWs (> 5MGD), or minor POTWs with significant industrial users (SIUs), are required to develop and implement pretreatment programs to regulate all industrial users (IUs). Unlike NPDES program that rely on federal and state governments, the NPP places responsibilities to local municipalities (Control Authorities) to implement and enforce specific requirements. The federal or state government agencies (Approval Authorities) oversee Control Authorities' implementation of pretreatment programs via receiving annual reports, conducting periodic audits and inspections. Since 1983, the NPP has made great advance in reducing the discharge of toxic pollutants to sewer systems and to the environment; it is a notable success story as a partnership between EPA, States and POTWs.

2.5. Control of Sanitary Sewer Overflow (SSO)

Sanitary sewer overflows (SSOs) become significant sources of water pollution. SSOs consist of varying mixtures of domestic sewage, industrial and commercial wastewater. SSOs often contain high levels of suspended solids, pathogenic organisms, toxic pollutants, nutrients, oxygen demanding organic compounds, oil and grease and other pollutants. SSOs can cause exceedances of applicable water quality objectives, pose a threat to the public health, adversely affect aquatic life, and impair the public recreational use and aesthetic enjoyment of surface waters. The main causes of SSOs include blockages from grease, root, and debris; damages of sewer lines and manholes from flood, construction and vandalism; mechanical failures of pumps and valves; power outages; storm or ground water inflow/infiltration, etc. In San Diego, approximately 50 million gallons of SSOs were reported in a one-year survey period, resulted in considerable surface water pollution and numerous beach closures. In California, a statewide WDR[10] was adopted prohibiting sanitary sewer overflow, establishing requirements for maintenance, prevention, emergency response and reporting, in order to minimize SSO impact to water quality.

2.6. Control of Stormwater Discharges

The distinction between point and nonpoint sources is not always clear. The most important example of such an overlap involves urban runoff and stormwater which are clearly diffuse and nonpoint in origin, but become channelized and ultimately discharge through discrete point source conveyance systems to receiving waters. As such, stormwater is considered point source discharge and is regulated through NPDES permit under the authority of CWA Section 402(p)[1] (40 CFR 122)[3]. Stormwater discharges often contain pollutants include sediment, nutrients, oxygen-demanding substances, bacteria, viruses, heavy metals, synthetic organics, pesticides, and other toxics. These pollutants severely degrade the beneficial uses of surface water, and threaten the health of both human and aquatic organisms. There are currently three types of stormwater permits: municipal[11], industry and construction[12]. The CWA established different performance standards for municipal and industrial discharges. Unlike the other NPDES permits, stormwater permits do not contain numerical effluent limits; instead contain prohibitions and narrative receiving water limitations. The permit objectives are achieved by pollution prevention and source control Best Management Practices (BMPs). BMPs include structural and behavioral activities intended to prevent or reduce pollutant discharge and to improve water quality.

3. CONTROL OF NONPOINT SOURCE POLLUTANTS

Although great efforts have been made to control waste discharges from point sources under the federal NPDES permitting program, significant portions of U.S. waterbodies are still impaired. Nonpoint source (NPS) pollution has become the single largest factor causing the impairment. Over 45% of the nation's rivers and streams, 47% of the nation’s lakes, ponds and reserviors are impaired due mainly to sediments, and nutrients, pathogens and metals from NPS discharges[13]. It becomes increasingly clear that control and reduction of NPS pollution is needed in order to restore and protect the nation's waters.

3.1 Watershed Management

A watershed is the land area where it drains into a creek, river, lake, bay, ocean, or other waterbodies. Watershed management (WM) involves the integration and coordination of activities that affect the watershed's natural resources and water quality. To protect water resources in a watershed, the important relationships between point and nonpoint source discharges, ground and surface water interactions, water quality and water quantity must be considered. The underlying principle of WM is that many water quality and ecosystem problems can be best prioritized, addressed, and solved at the watershed level rather than at the individual waterbody or discharger level. The WM approach identifies critical areas and problems, assesses cumulative effects, targets priority problems, creates and implements unique solutions for each watershed. Moving from facility-specific controls to watershed-based water quality management, WM approach formulates a new strategy to more effectively coordinate and implement measures to control both point and nonpoint sources, and to protect and restore natural resources. Efforts are currently being made to implement the WM approach in the U.S.

3.2 Total Maximum Daily Loads (TMDLs)

Section 303(d) of CWA requires that states, territories, and authorized tribes list impaired waters and develop total maximum daily loads (TMDLs) for these impaired waters[1,3]. A TMDL is a quantitative assessment of water quality problems, contributing sources, and load reductions or control actions needed to restore and protect waterbodies. A TMDL specifies the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and allocates pollutant loadings among point and nonpoint sources. The following are basic elements of a TMDL: identification of waterbody, pollutant of concern, pollutant sources, and priority ranking; description of the applicable water quality standards and numeric water quality target; loading capacity - linking water quality and pollutant sources; load allocations (LAs) and wasteload allocations (WLAs); margin of safety (MOS); seasonal variation; reasonable assurances; monitoring plan to track TMDL effectiveness; implementation and public participation. Developed TMDLs are implemented through incorporation into NPDES permits and Basin Plans.

3.3 Control of Urban Area NPS Pollutants

The National Urban Runoff Program study has shown that in the United State, urban runoff contains significant loadings and relatively high levels of sediment, nutrients, heavy metals, petroleum hydrocarbons, oxygen-demanding substances, salts, bacteria and viruses. Two primary strategies are used in U.S. to control urban NPS pollution: prevention of pollutant loadings and treatment of unavoidable loadings. In California, urban management measures are organized to parallel land use development process to address NPS pollution loadings during all phases of urbanization[14]; this strategy focuses on pollution prevention or source reduction practices. Pollution prevention and source reduction practices are favored over treatment practices because conducting education and incorporating pollution prevention practices into project planning and design activities are generally more effective, require less maintenance, and are more cost-effective in the long term than treatment strategies.

3.4 Control of Agricultural NPS Pollutants

Recent studies have identified agriculture as the greatest source of water pollution in the U.S[14]. The primary agricultural NPS pollutants are nutrients, sediment, animal wastes, pesticides, and salts, causing eutrophication, turbidity, temperature increases, toxicity, and decreased oxygen. In California, the following seven management measures were developed to control agricultural NPS pollution: erosion and sediment control; contain wastewater and runoff from confined animal facilities; nutrient management; pesticide management; grazing management; irrigation water management; and education/outreach.

4. REMEDIATION OF POLLUTION

Groundwater pollution by industrial, agricultural and military activities has impaired many groundwater resources in the U.S. Common pollutants include nitrate, benzene, MTBE, solvents, and perchlorate. In Californian, groundwater accounts for up to 40 percent of the state's water supply. Substantial resources are allocated to the investigation and remediation of polluted groundwater to restore water quality. Specific remediation programs include Underground Storage Tanks Program (UST); Spills, Leaks, Investigation and Cleanup Program (SLIC); Department of Defense (DoD) and Department of Energy (DoE) Sites; Well Investigation Program (WIP); Bay Protection and Toxic Cleanup; Groundwater Ambient Monitoring Assessment Program (GAMA). The high cost of remediation proves that pollution prevention and source reduction are the best strategies in water resource protection.

5. CONCLUSIONS

Water quality protection in the United States is an important government function and task, under the authorities ofthe federal Clean Water Act, federal regulations, as well as state water laws and regulations. In the US, the strategy to protect water quality and designated uses of the nation's waters is to protect water resources by controlling both point source and nonpoint source pollution discharges, by pollution prevention, and by clean up and restoration of impaired waterbodies. The core regulatory programs, implementation and enforcement policies introduced in this paper represent important elements of the strategy to effectively achieve the goal of protecting nation's waters, as set forth in the Clean Water Act.

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