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ECONOMIC VALUATION OF AIR FORCE ENVIRONMENTAL RESOURCES: A CONTINGENT VALUATION CASE STUDY

THESIS

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Presented to the Faculty of the Graduate School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Engineering and Environmental Management

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Member	Member
Member	Chairman

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Timothy P. Haynie

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Abstract

The Air Force spends $1 billion each year to preserve, maintain, and restore environmental resources under its control (Budget of the United States Government, 1994). Assessing the benefit of this spending is a central issue in federal environmental management. As federal environmental management moves from a "clean it up at any cost" mentality to one which carefully considers the costs and benefits of spending, a fundamental question arises: What value of environmental resources does our environmental spending provide? As in any rational economic exchange benefits must exceed costs; the value of an environmental resource which benefits from public spending must exceed the amount spent. This thesis explores a method to measure the value of environmental resources more completely and applies the method to measure the value of cleaning up two dormant landfills affecting a military housing area.

A technique known as the *contingent valuation method* has emerged in the field of economics as a means to measure environmental resource value. The Air Force has not yet applied contingent valuation, but could use the method to provide a more complete measure of environmental resource value and improve funding decisions involving $1 billion annually.

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I. Introduction

Air Force environmental management programs are critically linked to budgetary issues. Future-year programs are built to match expected funding profiles; current-year projects are prioritized and executed within current funding limits; and a central principle of the Air Force environmental program is to "make smart business decisions..." (Wallett, 1996). Though not unique to the environmental management field, the focus on budgetary issues indicates the basic purpose of federal environmental management: to achieve the most benefit possible with the funds available.

Ideally, the aim of any government program is to allocate money in such a way that any change in the allocation of spending would have a net negative effect on American society. Federal environmental managers must decide how to spend the limited funds available to achieve the best possible result. The net benefit derived from spending these environmental funds is measured by the difference in value of the output of the spending and the amount of money actually spent (Marshall, 1920). For instance, if the Air Force spends $10 million on a project that is worth $15 million, the project has a net benefit of $5 million for American society. Given a fixed budget, federal environmental managers maximize social welfare by maximizing the net benefit from federal environmental spending. The method used in measuring the value of environmental resources, therefore, is an issue of immense practical concern to federal environmental managers.

General Issue

Environmental resources under Air Force control can be categorized as having different types of "value." The land lying below restricted military air space has an *indirect* use value in flying training, an aquifer has a *direct* use value as a water supply, installation property has an *option* use value by being available for future development. Likewise, natural resources on military property have a non-use *existence* value simply because they exist as a public asset. Also, because they are available to future generations, natural resources have a non-use *bequest* value. Measuring the value of environmental resources is necessary if environmental managers are to make the best possible funding decisions.

Economic valuation of environmental resources may be useful in three decision-making situations: environmental impact analysis in which a future state of an ecosystem is being predicted, environmental damage assessment in which a degraded state of an ecosystem is being assessed, and cost-benefit analysis in which benefits of a proposed environmental policy are being assessed (Portney, 1994). In environmental impact analysis, economic valuation may indicate the expected value, or cost, of environmental impact from a new Air Force weapon system. Economic valuation in an environmental damage assessment may indicate the maximum reasonable amount that should be spent cleaning up a groundwater pollutant. Economic valuation could also indicate the equivalent monetary benefits of a new Air Force pollution prevention policy. In each setting, proper economic valuation could help measure the benefits of federal environmental action.

Problem Statement

Applying economic valuation techniques to environmental resources is an important and challenging task. Decision-makers can use the results of these techniques to allocate the federal budget more productively. In fact, there is a growing trend toward more careful consideration of how we spend limited environmental budgets to achieve the most benefit. Risk-based corrective action (RBCA), for instance, was recently developed by the American Society for Testing and Materials (ASTM) to help prioritize polluted sites according to urgency and type of corrective action needed to protect human health and the environment (Rapaport and Flesch, 1996). RBCA has gained widespread acceptance from the Environmental Protection Agency and state regulators and indicates a gentle shift away from strict cleanup standards toward a case-by-case approach to weighing benefits of environmental action against costs (Jones, 1996). There is, however, a question which complicates this issue: "What are the benefits of spending money on any given environmental resource?" There are many economic techniques available to answer this question, but which techniques can we trust? Particularly in cases where environmental conditions are linked to public health concerns, valuation techniques can yield conflicting or even contradictory results. The contingent valuation method (CVM) is emerging as a technique favored for making such value measurements. Contingent valuation has been used for decades in academic research and applied economics, but has not been widely studied for Air Force-specific applications.

Allocating environmental funds efficiently is the core purpose of federal environmental management. Air Force environmental programs may use economic valuation techniques to assess benefits more completely and transition to environmental management practices which consider costs and benefits of spending more carefully. The Air Force must explore the issues involved in applying economic valuation, and contingent valuation specifically, to Air Force environmental resources and adopt practices where warranted.

Research Objectives

The research centers on the measurement of the environmental resource value resulting from Air Force fund expenditures. To meet the research objectives, the research uses a case study involving restoration of two dormant landfills affecting a military housing area.

1. Determine the resource value provided by Air Force environmental fund expenditures as measured by the contingent valuation method (CVM).

2. Compare the CVM-estimated value of an environmental project with the actual cost and expected value of the project as measured by the additional lifetime income resulting from lower levels of health risk.

Scope of Research

Air Force programs which involve environmental impact assessment, environmental damage assessment, or environmental policy cost-benefit assessment could potentially use economic valuation techniques. This thesis, however, will apply the contingent valuation method to an environmental damage assessment involving two base landfills at Wright-Patterson AFB. The thesis will focus on a population of military housing residents living near the landfill as the respondent audience for a contingent valuation study. The results of the contingent valuation study will then be compared to actual project costs and the expected value of the project to assess the economic justification for Air Force environmental fund expenditures in this case. This thesis does not apply CVM in an impact assessment or policy cost-benefit analysis setting and does not apply CVM to other environmental damage cases. This thesis does not evaluate the accuracy of CVM. Instead, this thesis applies contingent valuation according to accepted guidelines to meet the research objectives of interest to the Air Force.

II. Literature Review

The environment bears the two major features of a public good: non-rival consumption and non-exclusive benefit. Non-rival consumption implies the environment may be enjoyed, or "consumed," by many individuals simultaneously. Non-exclusive benefit implies that even those who do not pay for sustaining environmental quality are able to enjoy, or "benefit from," the environment. As a public good, the environment is affected by market forces known as "externalities." An externality is a cost generated by an economic activity but for which the economic activity does not have to pay. For example, a coal-fired power plant produces air pollution which may result in acid rain. In most cases, the power plant does not have to pay the costs of dealing with acid rain and an externality exists—the power plant imposes an "external" cost on others who have to pay for dealing with acid rain. These externalities provide an incentive for agents operating in a free market to consume more of the public good and provide less in return than would ideally be the case. The collective effect of these externalities is widely known in the field of environmental management as the "tragedy of the commons" (Hardin, 1968). Hardin speaks of a pasture on which several herdsmen let their individual herds of cattle graze. Each herdsman finds an incentive to add more cattle to his herd because he alone benefits from the additional cattle, but he distributes the marginal damage done to the pasture among all other herdsmen. This incentive drives over-grazing of the pasture and depletes the resource to bring "ruin to all." This sort of failure in the private market is sufficient reason for the government to act on behalf of the collective good.

To allocate public environmental goods efficiently, the government must determine the quantity of each of the public goods it will provide and raise the necessary funds to finance its purchases of the public goods (Groves and Ledyard, 1977). For example, in designating national forests, the government must decide the amount of forest to set aside and raise money required to manage this amount of forest. To perform these tasks in a non-arbitrary manner, government must communicate with its citizens.

Some theoretical economic works (Malinvaud, 1971; Dreze and Poussin, 1971) have designed public policy mechanisms to elicit tax payments from individual citizens in a way to reach efficient allocation of public goods. The enormous complexity and high operating costs of these mechanisms, however, make them infeasible. More practical techniques solicit input from a representative sample of citizens (Ciriacy-Wantrup, 1947; Davis, 1964).

Meaningful communication between a sample of citizens and the government, though theoretically simple, is confounded by complex social, economic, and political issues. One such complexity was recognized in a 1958 report on federal economic analysis. The report recognized that not all effects of an environmental project or policy can be expressed in common terms (U.S. Federal Inter-agency River Basin Committee, 1958). It is difficult for government to make economic decisions based on non-economic public expressions of justice, quality of life, or personal values. Government must be able to translate various non-economic expressions into economic terms. To perform this task government may call on a number of economic valuation techniques documented in the literature.

Economic Valuation Techniques

Economists have developed techniques to understand public expressions of value for a wide range of environmental resources. Mitchell and Carson (1989) have proposed a classification system for these valuation techniques based on two dimensions. The first dimension is whether the data come from actual market transactions or from hypothetical sources such as a consumer's answer to a *what if* question. The second dimension is whether the technique measures monetary values directly or whether the technique measures attributes that must be converted to monetary values indirectly. Based on these two dimensions, each economic valuation technique may be classified as Observed Direct, Observed Indirect, Hypothetical Indirect, or Hypothetical Direct. Table 1 shows the techniques classified in this way. Each of these techniques must be considered for its ability to measure the value of a public resource and its ability to support public spending decisions. In fact, choosing an economic valuation technique is a critical step in making policy decisions (Barbier, 1994). The strengths and weaknesses of the technique used in this research—contingent valuation method—can best be illustrated by considering alternative techniques available to assess environmental benefits.

Table 1 - ECONOMIC VALUATION TECHNIQUES FOR PUBLIC GOODS
(Adapted from Mitchell and Carson, 1989)

	Direct Monetary Measure	**Indirect Monetary Measure**
	OBSERVED DIRECT	**OBSERVED INDIRECT**
Observed market behavior	Referenda Simulated markets Parallel private markets	Travel cost Hedonic pricing Expected value calculations
	HYPOTHETICAL DIRECT	**HYPOTHETICAL INDIRECT**
Responses to hypothetical markets	Spend more-same-less survey Contingent valuation	Contingent ranking Allocation game Indifference curve mapping

Observed Direct techniques are those that most closely follow actual market conditions. Consumers are free to make decisions involving real money and must live with the consequences of their decisions. The data reveal values in monetary units because choices are based on actual prices. In general, economists prefer these techniques because they involve actual market behavior—the traditional focus of economics—and these are the most articulate transactions to measure (Tunstall and Coker, 1992). Public goods provided through referendum such as a school bond levy (Nold, 1992) or public water supply protection policy (Powell and others, 1994) have used Observed Direct techniques. Voting actions, such as referenda, are analyzed through the median voter model to estimate the *majority-rule* level of public goods provision (Borcherding and Deacon, 1972; Bergstrom and Goodman, 1973). This method reveals an aggregate public demand function based on actual voting behavior.

Complementing the majority rule voting applications, Observed Direct techniques also use simulated markets in which actual dollars are available to individual citizens. In 1979, Bishop and Heberlein studied goose hunting permit holders in the state of Wisconsin. The state distributed less than one thousand permits on a lottery basis. Over two hundred permit holders were contacted with an actual cash offer to forfeit the permit. This simulated market was used to establish demand relationships for provision of the hunting permits and estimate a "market" price for the permits.

Along with voting actions and simulated markets, public goods may resemble a parallel private market. As such, the good in question is exclusive to those who pay and is no longer a pure public good. As a matter of local public policy the allocation of this sort of good is suited to Observed Direct techniques of valuation similar to actual market demand relationships.

The second category of market-based techniques are those classified as Observed Indirect. These techniques involve actual market behavior but do not directly reveal monetary values. As a marriage between theoretical and applied economics, these techniques have attracted a substantial amount of research. These techniques rely on assumptions to link a measurable feature of the market, such as price of a good, and immeasurable features of a public good, such as value of air quality. These methods study market behavior and estimate a value relationship to the non-marketed good. A technique that has been used to value site-specific recreation benefits is the travel cost method (Clawson, 1959; Knetsch, 1963). Survey data are collected to estimate the expenses borne by a person visiting the site of interest. The method accounts for travel time to and from the site, the distance traveled, and the amount of time spent at the site to estimate a travel cost for each survey respondent. These results are aggregated across all visitors to the site to develop a demand function. Some of the problems of this method are that recreation sites may not be substituted for each other as a market commodity and that the environmental resource of interest may be one of many reasons for the trip. Though progress has been made to address these problems (Binkley and Hanemann, 1978; Desvousges, Smith, and McGivney, 1983) and account for other variables (Calkins, Bishop, and Bouwes, 1986) the travel cost method still applies to a very small portion of public goods.

The hedonic price method indirectly measures the value of various characteristics associated with a market good (Rosen, 1974). Market behavior serves as an expression of consumer values and preferences. Freeman (1974) used the method to approximate the value of environmental characteristics. Consumption of a market good such as real estate indicates a value for environmental qualities associated with the good such as the value of a view of Lake Michigan (Blomquist, 1984), air visibility in San Francisco (Loehman, 1984), and air quality improvements in southern California (Brookshire and others, 1981). Real estate prices in areas of good environmental quality are expected to be higher than those in areas of poor environmental quality. Part of this price differential may be explained by consumer judgments on the value of environmental quality. The biggest problem with hedonic pricing is the need to account for relationships among all relevant characteristics: neighborhood environment, schools, taxes, services, and so on. Obtaining data on these characteristics is always difficult and frequently impossible. When data are available, hedonic pricing provides an indirect value estimate of environmental characteristics associated with a market good.

Another Observed Indirect valuation technique can be thought of as a specific form of the hedonic price method. Expected value calculation is based on the assumption that economic gains or losses associated with certain non-market conditions can reasonably be calculated. For instance, wrongful death statutes partially base lawsuit awards on an estimate of the value of lost life. This value is normally estimated by the amount of financial support deprived of the decedent's survivors. King and Smith (1988) published a detailed study to calculate wrongful death awards in the case of airline passenger fatalities. This approach has also been used to calculate the expected value of health risk reduction in the case of hazardous occupations (Viscusi, 1978), mandatory vehicle seat belt use (Blomquist, 1979), and residential smoke detector installation (Garbacz, 1989). Expected value calculations are useful in estimating the value of an environmental resource linked to a health risk—as in the case of a contaminated water supply or ozone depletion in the upper atmosphere.

Moving away from observed valuation methods, hypothetical techniques are useful when assessing goods that are not bought and sold in a market. Such goods as potential recreation sites and protecting endangered species may not be well suited to observed techniques, but measurement of these goods is essential to public policy (Hanemann, 1994). Hypothetical Indirect methods present a consumer with a hypothetical market to yield an indirect value measure of a public good. Many of these techniques are similar to those of the Observed Indirect category. For instance, contingent ranking describes various characteristics of several hypothetical recreation sites (distance from respondent's home, environmental qualities, and so on). The respondent will rank-order the set of site descriptions and the results of this rank-order are analyzed to assess how a consumer would trade-off site characteristics. This technique, also known as *conjoint analysis*, has been used to measure the value of reduced motor vehicle emissions (Lareau and Rae, 1985) and water quality benefits in a river basin (Smith and Desvousges, 1986a). One advantage of contingent ranking is that consumers are asked to express their relative preferences rather than make an explicit estimate on the value of an environmental characteristic. The lower demand on the consumer places a higher demand on researchers to estimate environmental resource value indirectly. The ordinal-level of measurement used in contingent ranking requires a larger sample and more sophisticated statistical techniques than direct valuation methods (Mitchell and Carson, 1989). In cases where these features are acceptable, contingent ranking may be an appropriate technique.

Rather than ordinal-level ranking of environmental characteristics, allocation games provide a subject with a hypothetical budget to distribute among various public programs (Sinden and Worrell, 1979). The proportion allocated to a specific program of interest, such as wildlife preservation, would be an indication of the value of the program. This technique has been applied to the Maryland State Park Service's capital budget (Hardie and Strand, 1979). Advantages of an allocation game are that it yields an interval-level measure of indirect value and that it could be used to study a variety of public environmental resources. The primary disadvantage is that a subject's allocation of a hypothetical budget is still an indirect measure of value. The subject may have no interest in actually spending money on any of the public programs presented.

Another related Hypothetical Indirect technique is indifference curve mapping. This method asks a subject to express a trade-off relationship between two hypothetical experiences (Sinden, 1974). For instance, the subject would consider 10 days per year fishing at a beach front pier and express the equivalent number of days per year fishing in a public reservoir which would bring him the same benefit or satisfaction. This trade-off indicates an indifference curve of implied relative values for the resources presented. Like contingent ranking, this technique provides information on consumer preferences, but it shares the disadvantage of allocation games in that the subject may have no real desire to go fishing at all. Despite some limitations, hypothetical techniques are generally more flexible than observed techniques because they may be applied in conditions where real markets do not exist.

Hypothetical Direct methods form the last category of valuation techniques. These techniques take advantage of flexibility in the hypothetical approach, but seek a direct monetary value measure. Because direct value measures are sought, these methods eliminate the need for extensive assumptions and sophisticated analysis of indirect valuation methods. Most Hypothetical Direct methods are based on the assumption that consumers respond to hypothetical markets the same way they do to actual markets (Smith and Krutilla, 1982). One application of this assumption is the *spend more-same-less* survey. This type of survey asks respondents whether they believe the federal government is spending too much, too little, or about the right amount for various public programs (National Opinion Research Center, 1983). A response that says, for instance, *the federal government is spending too much money on new military weapons* indicates a preference for less spending on new weapons and lower federal taxes as a result. This method has been applied extensively to local school expenditures (Bergstrom and others, 1982; Langkford, 1985). The primary weakness in this method is the arbitrary nature of respondent answers. In most applications of the spend more-same-less survey, the respondent is not supplied with information on how much is currently being spent or the results of the spending. Further, the respondent is not asked, "How *much* more/less should government spend...?" For these reasons, the spend more-same-less survey has not been widely applied. Instead a much more dominant Hypothetical Direct technique has evolved: the contingent valuation method (CVM). CVM is designed to prevent problems associated with spend more-same-less surveys and weakness noted earlier for Observed Direct, Observed Indirect, and Hypothetical Indirect methods.

CVM seeks direct consumer responses to hypothetical markets. Because consumer responses are contingent on the hypothetical market presented, this method became known as the contingent valuation method (Brookshire and Eubanks, 1978). Cummings and Harrison (1994) summarize the method as follows:

> The CVM involves the use of surveys describing the good or resource injury to be valued, a rule that relates financial payments to the provision of the good or the avoidance of the injury, and a question that asks the subject to report a maximum willingness to pay some amount of money to see the good provided or the injury avoided.

CVM has been used in many environmental resource settings such as public recreation planning (Daubert and Young, 1981), public water quality improvements (Desvousges and others, 1987), and trees in a public park (Brookshire and Coursey, 1987). The method has been used in non-environmental settings to measure the value of improved information about grocery store prices (Devine and Marion, 1979) and reduced risk of respiratory disease (Krupnick and Cropper, 1992). The greatest strength of CVM is its flexibility to measure consumer responses to virtually any plausible, hypothetical market. This approach opens an entirely new world for gathering data on public benefits, "liberating us from the information shackles of the traditional [observed] approach" (Sen, 1977). The flexibility of a properly designed contingent valuation study allows CVM to measure economic value for a far larger range of environmental resources than either Observed Direct or Observed Indirect methods. The explicit willingness-to-pay responses gathered by a contingent valuation study also make CVM easier to apply and analyze than Hypothetical Indirect methods and other Hypothetical Direct methods. For these reasons, CVM is gaining favor in policy formulation. As Viscusi explains, "the appropriate value of a risk regulation policy is society's willingness to pay to reduce the risk" (Viscusi, 1996). No other economic technique measures willingness to pay as explicitly as CVM. Though CVM has limitations, it offers a flexible and direct method to measure public expressions of value concerning environmental resources. Indeed, "contingent valuation represents the most promising approach yet developed for determining the public's willingness to pay for public goods" (Mitchell and Carson, 1989). It is remarkable in light of this assessment that CVM has not been applied to environmental management in the Air Force. To properly apply CVM and analyze its results, one must understand the historical development and practical limitations of contingent valuation.

Contingent Valuation Method

Like other economic valuation methods, CVM is based on the economic assumptions that each consumer has preferences for some goods over others and that each consumer makes economic decisions to maximize his or her own well-being. Davis (1963) was the first to use contingent valuation to measure the value of a wilderness area in Maine. His doctoral dissertation research included interviews with a sample of 121 hunters and tourists. Davis recognized some limitations in his initial study, but advocated further research into contingent valuation (Knetsch and Davis, 1966). Economists began to see the need for contingent valuation when Krutilla (1967) published a paper introducing the concept of *existence value* for environmental resources. Krutilla argued that individuals may attach a value to the simple knowledge that a particular species or land feature exists even though the individual never expects to benefit directly from the resource. This and other developments of the time led economists to believe that observed valuation techniques in practice at the time weren't adequate to measure the full value of environmental resources and that contingent valuation showed promise as a survey approach (Schelling, 1968; Mishan 1971). For a discussion of the theoretical aspects of CVM see Appendix A: Theoretical Economic Basis of Contingent Valuation Method.

Environmental economists used contingent valuation surveys throughout the 1970s to measure value of pollution control (Eastman and others, 1974), non-congestion in a wilderness area (Cichetti and Smith, 1976), and wildlife hunting (Cocheba and Langford, 1978). Other fields used contingent valuation to measure the value of mobile coronary care units (Acton, 1973) and airline safety (Jones-Lee, 1976). Contingent valuation did not enter into the public policy arena, however, until the early 1980s when the federal government took two significant steps in environmental management: passage of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), and the widespread use of cost-benefit analysis prompted by Executive Order 12291 in 1981.

One of the provisions of CERCLA gave government agencies the power to seek restoration expenses from parties responsible for environmental damage. A full assessment of such damage considers both lost use-value—damage done to parties who are directly impacted by the pollution—and lost non-use value—damage done to society at large including lost existence value. In 1986, the Department of the Interior (DoI) created regulations endorsing contingent valuation (CV) as the preferred method to assess costs of environmental damage (Portney, 1994). In 1992, the National Oceanic and Atmospheric Administration (NOAA) sanctioned a panel headed by Nobel laureate economists Kenneth Arrow and Robert Solow to study the issue of contingent valuation. The panel concluded, "…that CV studies can produce estimates reliable enough to be the starting point of a judicial process of damage assessment" (58 Federal Register 4601, 15 Jan 93). In 1993 NOAA published regulations endorsing the use of contingent valuation in environmental damage assessment.

Along with CERCLA passed in 1980, contingent valuation gained further support with President Reagan's 1981 Executive Order 12291 requiring federal agencies such as the Environmental Protection Agency (EPA) to consider the benefits and costs of federal regulations and actions prior to their implementation (46 Federal Register 13, 17 Feb 81). To agencies such as the EPA, this executive order provided strong incentive to identify benefits attributable to public goods such as environmental improvements. The EPA adopted contingent valuation to cover the broad range of air quality and environmental safety issues of concern (Cummings and others, 1986).

The landmark DoI and NOAA regulations along with Executive Order 12291 called for a disciplined approach to contingent valuation. During the 1980s, a substantial amount of research was conducted to study and assess various features of CVM. Survey format and potential sources of bias have been dominant subjects in the CVM literature over the past 15 years.

An important part of each CVM survey is the way in which the respondent is asked to reveal a value, or willingness to pay. This "elicitation" can take many different forms depending on the contingent market, the audience, and the way in which the survey is administered. For instance, open-ended elicitation simply asks the respondent, "How much would you be willing to pay for...X?" without implying an answer. Without implying a value, the survey requires to respondent to think carefully about the value of the good, X. Open-ended elicitation is generally used for surveys which seek a distribution of values from a moderately-large audience (more than 50 respondents). An example of open-ended elicitation may be found in Desvousges and others, 1983.

Closed-ended elicitation, on the other hand, asks the respondent, "How much would you be willing to pay for...X?" and provides a set of value ranges such as "less than $50" or "between $50 and $100." This method may introduce a bias by implying a value rather than permitting the respondent full freedom in judging a value. Closed-ended elicitation is also not as useful as open-ended elicitation in seeking a distribution of values. For these reasons, the closed-ended elicitation format is used for surveys which seek a categorical distribution of values from a small audience (less than 50 respondents). An example of closed-ended elicitation may be found in Mitchell and Carson, 1984.

The third major type of elicitation used is the discrete choice format which asks the respondent, "Would you pay Y dollars for...X?" This method may also suffer from "implied value" bias, but is generally much easier for the respondent to answer than either open-ended or closed-ended elicitation. Because of the non-numerical answer, however, statistical analysis of discrete choice answers requires a relatively large audience (more than 300 respondents). An example of discrete choice elicitation may be found in Sellar and others, 1985.

The fourth, and final, major type of elicitation is the bidding game format which asks the respondent, "Would you pay Y dollars for...X?" If the response is, "Yes," the respondent is then asked if she would pay an incrementally higher amount for the good. This process continues until the respondent reaches her maximum willingness to pay. The bidding game works the same way when the first answer is, "No," except the payment is decremented rather than incremented. Like discrete choice elicitation, the bidding game demands little effort from the respondent. Like open-ended elicitation, the bidding game can reveal a distribution of values for a moderately large audience. Like closed-ended elicitation, however, the bidding game may suffer from "implied value" bias. Also, because of the direct involvement by the survey administrator, the bidding game is used only in a personal interview or telephone interview setting and is not used in mail or other written survey settings. An example of bidding game elicitation may be found in Randall and others, 1974.

The various elicitation methods have been studied (Boyle and others, 1985) and compared to each other (Johnson and others, 1986) to assess which method is appropriate for a given circumstance. The contingent market, the audience size, and the way the survey is administered are all important features in deciding which elicitation method is most appropriate.

Another major feature of CVM that has received attention in the literature is the issue of bias. A very thorough discussion of bias in CVM is given in Mitchell and Carson, 1989. As described above, elicitation methods which imply a value may suffer from many forms of "implied value" bias including question-order bias, range bias, and starting point bias. Question-order bias may exist when several goods are being valued sequentially. The respondent may be led to believe the first goods being valued are inherently more valuable than subsequent goods because the order in which questions are asked implies a higher value to those being asked first (Schuman and Presser, 1981). Range bias may exist in closed-ended elicitation in which a specific value "range" is being sought. If the highest range offered is less than the respondent's willingness to pay, the respondent may artificially lower his value to comply with the range offered (Schwarz and others, 1985). The final major type of implied value bias may occur in the bidding game elicitation format in which the initial value, or "starting point," serves as a strong indication of the expected value. Though follow-up questions allow the respondent to vary from the initial value, starting point bias has been shown in some cases to be substantial (Roberts and others, 1985).

In addition to implied value bias, many types of bias may be introduced by the hypothetical market of the survey. *Misspecification* bias refers to those sources of bias introduced by the way the hypothetical market is structured. For instance, a public recreation area owned and operated by the local city government may prompt a different willingness to pay response than the same park owned and operated by the federal government. This affect is known as "method of provision" bias. In the same way, a payment based on a local property tax may prompt a different willingness to pay than a federal income tax payment vehicle. This is known as "payment vehicle" bias and has been demonstrated in several studies (Rowe and others, 1980; Greenley and others, 1981). Regardless of the method of provision or payment vehicle, a "budget constraint" bias may occur in a hypothetical market when the respondent only considers his *willingness* to pay and not his *ability* to pay. The respondent must consider his budget constraint to avoid this sort of bias (Neill, 1995).

Another major form of bias in the hypothetical market is *misrepresentation* bias created when the respondent does not indicate his true willingness to pay. "Strategic behavior" bias occurs when a respondent deliberately understates or overstates his true willingness to pay. For instance, if the respondent believes that a high value response is likely to make the public good available and benefit him, there is a potential for the respondent to overstate his true willingness to pay. This potential is particularly strong in a hypothetical market where the respondent understands an actual future payment is not linked to the amount he states in the contingent valuation survey. Though some studies have found strategic behavior, most have concluded that it is a weak source of bias (Marwell and Ames, 1981; Bohm, 1984; Brubaker, 1984). Since the early 1980s, most CVM research concerning strategic behavior has focused on methods researchers can use to limit strategic behavior bias. Hoehn and Randall (1983, 1985, 1987) have found a correlation between strategic behavior bias and various elicitation formats, payment vehicles, and the amount of attention the respondent gives to the survey. Summarizing Hoehn and Randall, a contingent valuation survey will suffer less strategic behavior bias if it is structured in such a way that it demands little effort for the respondent to bid his true willingness to pay but demands a great deal of effort for the respondent to calculate an alternate, "strategic" bid. In many cases, the respondent does not put forth the effort required to calculate a strategic bid. Other studies have documented similar findings (Roberts and others, 1985). Past studies such as these have found ways to limit the amount of strategic behavior bias in CVM studies.

The second major type of misrepresentation bias is known as "compliance" bias. This occurs when the respondent is influenced in some way to state a willingness to pay that she believes would be consistent with what the survey sponsor or administrator would like. For instance, if a major oil company sponsors a contingent valuation survey assessing environmental damage resulting from an oil spill, a compliance bias may prompt a lower willingness to pay response than if the same survey was being conducted by an environmental group. Interviews conducted in-person or over the telephone are more prone to compliance bias because of a need in some respondents for feedback from the interviewer (Bishop and others, 1986).

The potential for various forms of implied value, misspecification, and misrepresentation bias in CVM requires care in designing the study to limit or avoid these forms of bias. As a result of CVM research conducted during the 1980s, economists have developed general practices for conducting contingent valuation surveys. In 1986, for instance, Cummings, Brookshire, and Schulze issued a state-of-the-art report on contingent valuation in which they provided a set of reference operating conditions required for a valid contingent valuation survey (Cummings and others, 1986):

1. Subjects must understand and be familiar with the commodity to be valued.

2. Subjects must have had (or be allowed to obtain) prior valuation and choice experience with respect to consumption levels of the commodity.

In 1989 Mitchell and Carson published what has become the standard text on CVM. In it, CVM is divided into three general guidelines (Mitchell and Carson, 1989):

1. A detailed description of the good being valued and the hypothetical circumstance under which it is made available to the respondent.

2. Questions which elicit the respondents' willingness to pay for the good being valued.

3. Questions about respondents' characteristics, their preferences relevant to the good being valued, and their use of the good.

The NOAA guidelines issued in 1993 cover issues such as sample size, minimizing non-responses, conducting personal interviews, pre-testing interviewers, reporting results, and pre-testing the questionnaire (58 Federal Register 4601, 15 Jan 93).

Taken together, these guidelines form a framework for conducting a contingent valuation survey and are applied to this research as described in Chapter III. The need for this research, however, is motivated by limitations in past CVM studies of a similar nature.

Relevant CVM Studies

Contingent valuation has been used in studies ranging from market research to historic preservation. Among its most prominent environmental applications has been the valuation of environmental resources linked to public health. Smith and Desvousges (1986b) used contingent valuation to measure risk changes from exposure to hazardous waste. After interviewing 609 representative households in the Boston area, Smith and Desvousges concluded the willingness to pay for changes in risk is a function of how well the respondent is able to understand and discern the various risks presented as well as the level of the baseline, or initial, risk. Though one of the larger CVM studies in environmental economics, the Smith and Desvousges study was limited in its treatment in various kinds of risk and in a larger assessment of aggregate demand estimates yielded by CVM. Smith and Desvousges only presented mortality risk and not morbidity risk associated with the impact of environmental resources on human health. Environmental resources such as drinking water supply and ground level air quality are more an issue of maintaining quality of health than simply maintaining life. As such, a deeper understanding of the valuation of morbidity risk reduction is required in the field of environmental economics. Further, the Smith and Desvousges study did not independently assess the aggregate willingness to pay measure against other appropriate valuation techniques.

Particularly appropriate in this case is the expected value of reducing the health risk from exposure to hazardous waste. Such an alternate measure could be used to assess the validity of aggregate willingness to pay estimated by contingent valuation.

Later studies using CVM have incorporated a morbidity risk consideration (Berger and others, 1987; Evans and Viscusi, 1991), but the hypothetical markets presented in these studies are based in the healthcare field and are not directly linked to environmental resources. Taken together, most research using CVM has not fully considered the various forms of health risk citizens face in dealing with environmental issues. For federal environmental management, the relationship between environmental quality and various public health risks must be considered more thoroughly. CVM is the proper method to assess the value of reducing these risks in a hypothetical setting. The research documented in this report explores valuation issues of interest to Air Force environmental management and compares the results of a CVM study to the results of an alternate, market-based valuation technique used in the same setting.

III. Methodology

The purpose of this research was to apply and assess the contingent valuation method in an Air Force environmental management setting. This chapter describes the research objectives and the development, pre-testing, revision, and administration of a survey instrument to address the first research objective. This chapter concludes with a description of the analysis of actual costs and expected value to address the second research objective.

Research Objective 1

The first objective for this research was to determine the value provided by Air Force environmental fund expenditures as measured by the contingent valuation method. This research objective was used to develop research questions and select an appropriate case study.

Development of Survey Questions

The research objective was used to develop several research questions:

1. What respondent characteristics are expected to influence individual willingness to pay?
2. What is the consumer demand for an environmental resource which is linked directly to the consumer's health?
3. What is the consumer demand for environmental resources which are not linked directly to the consumer's health?
4. What demographic information is required to calculate aggregate willingness to pay?
5. What is the aggregate willingness to pay for the respondent population?

These research questions explored the aggregate willingness to pay for a health risk reduction associated with an environmental resource. Specific survey questions followed from each research question to establish household consumer demand and gather information required to estimate aggregate demand. For a full outline of research questions, survey questions, and survey answer formats see Appendix B: Research Development Plan.

Economic theory suggests consumer demand is a function of many things, foremost among these: tastes and preferences, prices of substitute and complementary goods, and income level. As standard practice in contingent valuation studies, consumer education and age were used as proxy variables for tastes and preferences, respondents were asked for their willingness to pay for substitute and complementary environmental resources, and respondents were asked for their household income. For a copy of the full survey see Appendix C: Environmental Resource Value Study Questionnaire

Development of Survey Instrument

To ensure the survey scenario was meaningful and credible and was appropriate for alternate forms of economic valuation (see Research Objective 2 below), a case study was chosen to form the basis of the survey instrument. Characteristics used to select a case study were numerous. The case had to represent a change in an environmental resource large enough to prompt a willingness to pay for the change. The details of the case had to be well documented to present a meaningful, credible scenario. The case had to present a significant health risk to properly motivate survey respondents. The case had to have actual costs to serve as a comparison to CVM results (see Research Objective 2 below). The case had to be well-suited to expected value calculation to serve as another comparison to CVM results (see Research Objective 2 below). Finally, the case had to be "typical" of other Air Force resources to allow generalization of research findings.

Environmental resources managed by Wright-Patterson AFB were considered first in fulfilling the desired case study characteristics. This selection minimized the administrative burden of developing, coordinating, and conducting the survey. A restoration project for two dormant landfills on base filled the characteristics of the case study.

Landfills 8 and 10 were used by the Air Force from the 1950s up until the late 1970s. They are on base property bordering the Woodland Hills military housing area. The housing area consists of approximately 350 family housing units with a total population of approximately 1300 military members, spouses, and dependent children. Risk assessments conducted in the 1980s found leachate and gas emissions from the landfills posed a cancer risk higher than federal Environmental Protection Agency (EPA) standards. The excess cancer risk to Woodland Hills residents was estimated to be 1-in-2,000 lifetime risk of developing cancer. This estimate was calculated using standard assumptions of risk assessment (30-year residence time and health-protective assumptions for exposure of residents to landfill pollution). The nature of these assumptions and the fact that mean residence time in Woodland Hills is 3 years—not 30—indicates that the excess cancer risk estimate of 1-in-2000 is probably a highly conservative estimate. Though actual risks may be lower, the 1-in-2000 estimate was used in a decision to proceed with a project to clean up Landfills 8 and 10.

A landfill restoration project was performed to reduce the cancer risk below the most stringent EPA standard (1-in-1,000,000 excess cancer risk). This project represented a significant change in the local environment; the cancer risk represented an impact sufficient to motivate respondents; the project's funding was well documented; the case was well-suited to expected value calculation; and the case was somewhat typical of other Air Force environmental resources. Further, Woodland Hills residents were the appropriate population over which to find an aggregate willingness to pay because the risk was isolated to Woodland Hills.

Before presenting information on the case study, the questionnaire asked respondents for their perception of how much they knew of the environmental impact of landfills 8 and 10 before completing the questionnaire. As shown in various contingent valuation studies the familiarity, or prior knowledge, of respondents can influence their willingness to pay for various programs (Bergstrom and others, 1990; Whitehead and others, 1995). The amount of prior knowledge was expected to have a similar impact on this study.

The questionnaire must develop and present a contingent market for the respondent. Respondents in this case study required the following information: proximity of the landfills to the respondent's dwelling, the excess cancer risk, the proposed payment vehicle, and the various levels of cleanup to consider. Based on data contained in a 1993 risk assessment, the physical dimensions of both landfills were described and accompanied by a map of the housing area. The scale on the map showed that some residents lived within 100 feet of the landfill and no residents lived more than 2000 feet away. Each resident was able to locate his dwelling on the map.

Information on excess cancer risk included a brief description of landfill leachate and gas production, the violation of EPA standards, the excess cancer risk estimated by the 1993 risk assessment, and the amount of time this risk would persist. In most contingent valuation studies respondents are frequently unfamiliar with estimating the value of a hypothetical good. The lack of comparison shopping and experience leave the respondent with a value judgment that is not well developed. To account for this, the excess cancer risk of this case study was presented in graphical form with other causes of cancer for which sufficient data exist (sun exposure, tobacco use, and alcohol use). The excess cancer risk posed by landfills 8 and 10 was considerably lower than all of these other indigenous causes of cancer. The graphical risk comparison would have included causes of cancer posing lower risk than landfills 8 and 10 if such data had been available. The lack of low-risk cancer data, the comparison of excess cancer risk with indigenous cancer risk, and the comparison of voluntary risk assumed by lifestyle patterns with involuntary risk assumed by dwelling assignment are all considered limitations to the research.

The payment vehicle chosen for this case study was the household federal income tax. This vehicle was considered plausible for three reasons: the property surrounding the landfill is managed by the federal government, the long-term nature of the remediation requires more than a one-time payment, and income taxes are an appropriate context for household spending decisions (58 Federal Register 4606, 15 Jan 93). Each household was asked for its willingness to pay higher federal income taxes for various levels of clean-up and correspondingly lower risks of developing cancer. The questionnaire presented information on federal income taxes spent on various public programs (interest on national debt, national defense, welfare programs, roads and highways, and the space program) by a household with an average annual income of $30,000 to $50,000. A comparison was made between the amount of federal taxes spent on these programs and the amount spent on environmental protection programs in general. Just as information on cancer risk filled the information gap on the good being valued, information on federal income tax payments filled the information gap on current spending patterns of the respondent.

The final set of information presented to the respondent was information on cleanup alternatives. To estimate consumer demand, three levels of cleanup were presented for valuation: cleanup all leachate and gas (*level A*), cleanup some leachate and gas (*level B*), and no cleanup at all (*level C*). Level A was associated with an excess health risk of 1-in-1,000,000 chance of developing cancer, level B was 1-in-100,000 chance of developing cancer, and level C was 1-in-2,000 chance of developing cancer. These levels were explained in graphical form in a landfill cleanup scale. Questions asking for willingness to pay referred to these separate cleanup levels.

After establishing the contingent market, the questionnaire asked open-ended questions on willingness to pay for cleanup level B and cleanup level A. The open-ended elicitation format was chosen because the population was too small for discrete choice elicitation (337 households), but large enough to avoid closed-ended elicitation. As a mail survey, bidding game elicitation was also judged to be an inappropriate elicitation format.

As recommended by the NOAA guidelines on CVM, respondents were asked to indicate the motive behind the stated willingness to pay (58 Federal Register 4606, 15 Jan 93). The questionnaire used several such opportunities to assess whether or not respondents took the contingent market as a rational economic exchange—the amount stated being the amount the respondent was actually willing to pay.

Respondents in this survey were asked to consider the portions of spending they would divert to pay the amount of income taxes they stated they were willing to pay. Budget constraint bias was not tested by this questionnaire, but respondents were asked to consider their budget in order to minimize any such bias.

Respondents were then presented with several substitute environmental programs for which they may be asked to pay. This is another recommendation from the NOAA guidelines on CVM: "if individuals fail to consider seriously the public or private goods that might be substitutes for the resources in question, their responses to questions in a contingent valuation survey may be unrealistically large" (58 Federal Register 4605, 15 Jan 93). This is one of many guidelines to ensure CVM results are conservative. One substitute commodity chosen for this questionnaire was a hypothetical landfill in California which posed a health risk to nearby residents similar to landfills 8 and 10. This resource was similar to landfills 8 and 10 but lacked the critical health risk implications for the Woodland Hills population. Another question asked for willingness to pay to protect natural salmon habitat in the Pacific Northwest. A stated willingness to pay for this commodity could be aggregated across the sample and compared to actual figures allocated in the federal budget. Another commodity, membership dues to a national environmental group, could be similarly compared to actual membership dues for the Sierra Club. The fourth substitute commodity was clean tap water funded by increased water rates. The stated willingness to pay for this commodity was compared against that for the fifth commodity: clean tap water funded by increased federal income tax rates. The comparison of the water rate payment vehicle and the federal income tax payment vehicle was another indication of the potential payment vehicle bias held by respondents.

After presenting substitute environmental resources, the questionnaire asked respondents if considering these substitute commodities had changed their original willingness to pay. If the respondent had changed his mind, he was asked to state his new willingness to pay for landfill cleanup. If considering substitutes had not changed his mind, his original stated willingness to pay was used.

The questionnaire concluded with a set of demographic responses including number of members of the household, education level of respondent, age of respondent, household income, and amount of time respondent expected to remain in Woodland Hills military housing. The number of members in the household was used for aggregation and, along with amount of time remaining in Woodland Hills, indicated the amount of resource use by the household. Like many other contingent valuation studies, education and age were used as proxy variables for tastes and preferences. Household income was also used as a variable directly affecting the stated willingness to pay.

After completing the survey, respondents were provided a landfill cleanup fact sheet describing the actual measures already taken to cleanup landfills 8 and 10. This fact sheet accompanied the survey but was marked, "Please read after completing and mailing questionnaire," to avoid creating a bias in the hypothetical market of the survey. This fact sheet was considered necessary to avoid undue alarm in the population and to inform the residents of the details withheld in the questionnaire.

Pre-Testing of Survey Instrument

Most contingent valuation questionnaires are pre-tested to identify response effects and wording difficulties before the actual survey is administered. NOAA guidelines advocate pre-testing to check how well respondents understand the sometimes complex and technical information presented in a contingent valuation questionnaire (58 Federal Register 4608, 15 Jan 93). Mitchell and Carson (1989) advocate pre-testing as a way to improve the reliability of survey results. Pre-testing the Woodland Hills questionnaire was necessary to meet several objectives:

1. Ensure sufficient information is provided to allow respondents to generate a meaningful expression of willingness to pay.

2. Ensure all information provided is relevant to respondent's willingness to pay.

3. Ensure sufficient indicators exist to determine forms of response bias (strategic bias, payment vehicle bias, budget constraint bias, and so on).

4. Ensure open-ended elicitation format provides appropriate willingness to pay expressions.

5. Ensure categorical answers to multiple choice questions are appropriate.

6. Ensure responses indicate potential to answer research questions.

7. Estimate the amount of time required to complete the questionnaire.

8. Estimate the percentage of responses which are valid.

As a result of pre-testing, several changes were made to the questionnaire: information such as the technical description of leachate and gas production was found not to affect the respondent's willingness to pay and was taken out of the survey; questions were reworded to be more concise; response categories were revised as appropriate to more closely match expected answers; and an expected valid response rate of approximately 70% was established.

Coordination of Survey Instrument

Pre-testing showed the questionnaire had sufficient potential to answer the research questions. The next step in the survey effort was coordination with various agencies. Due to the nature of the audience and the contingent market the questionnaire was coordinated through the 88th Air Base Wing Environmental Management Directorate at Wright-Patterson AFB. This technical review led to revisions in the presentation of risk data to emphasize that the health risk is for developing any form of cancer, not necessarily *fatal* cancer.

To seek feedback from housing residents, the questionnaire was reviewed by two environmental management instructors at the Air Force Institute of Technology (AFIT) who also happen to live in Woodland Hills military housing. Technical comments from this review were plentiful and greatly improved the questionnaire. This review also gave a consensus view that the questionnaire would not cause undue alarm in the Woodland Hills population.

The questionnaire then proceeded to the 88th Air Base Wing Commander for approval to administer the survey in Woodland Hills military housing. The survey was also coordinated through the Air Force Personnel Center Survey Branch for official approval and was given an official Air Force Survey Control Number—SCN 96-59. For final review, the questionnaire was coordinated through the AFIT Commandant.

Administration of Survey Instrument

With final approval to administer the questionnaire, plans proceeded to distribute the questionnaire to all households in Woodland Hills. Mail administration was chosen because it ensured a larger number of useful responses than personal interviews and was better able to present the somewhat complex technical information better than telephone interviews. Judging from past contingent valuation mail surveys (Mitchell and Carson, 1989) a conservative return rate of 30 percent was assumed. With 70 percent of those returned expected to be valid, the total number of useful responses was expected to be 21 percent of all questionnaires distributed.

With approximately 350 housing units in Woodland Hills, fewer than 80 useful survey responses were expected.

Each Woodland Hills housing unit received a survey package containing the 8-page questionnaire; the fact sheet sealed with instructions "Please read after completing and mailing the questionnaire;" and a business reply mail envelope addressed to the AFIT Department of Engineering and Environmental Management. A sticker on the outside of the survey package stated, "Questionnaire enclosed. Please complete and mail by September 1st." This allowed respondents eight days to complete and mail the survey. The questionnaire was hand-delivered to all 337 occupied housing units in Woodland Hills.

Data Collection

Raw data were collected between 26 Aug and 13 Sep as individual questionnaires were returned by mail. Data from each questionnaire were recorded in an electronic spreadsheet. The raw data file is shown in Appendix D: Data Collected from Environmental Resource Value Study Questionnaire. A total of 113 questionnaires were received. Eight of the 113 questionnaires lacked sufficient information for further analysis and were eliminated. Approximately half of the remaining 105 questionnaires did not have a complete set of responses but contained sufficient information for further analysis. The actual response rate of 33.5 percent (113/337) was slightly higher than the 30 percent rate estimated before the survey.

During the time of questionnaire data collection, supplemental data were collected to help with interpreting and aggregating the questionnaire results. Information on the number and rank assignment of Woodland Hills housing was gathered from the Wright-Patterson military housing management office to help aggregate questionnaire results across all Woodland Hills households. This information was supplemented by military housing occupancy rates from the Air Force Statistical Digest (1995) to ensure only the *occupied* households of Woodland Hills were considered.

Data Analysis

The first step in analyzing data from a contingent valuation survey is to separate those responses which disclose a true willingness to pay from those which do not. For example, consider a person who stated a willingness to pay of zero dollars. If the rationale behind the bid was that the reduction in health risk simply wasn't worth any money, the person has made a reasonable judgment of monetary value and his response is valid. If, on the other hand, the person's rationale was that somebody else should clean up the pollution, the person is making a "protest" bid and his response is non-valid. For the question, "Is the amount you stated the amount you would actually be willing to pay, or is the amount you stated intended to communicate 'something else'?" responses which indicated an actual willingness to pay or other economic considerations were judged to be valid. Responses which were based on a "wild guess" or that the landfills should be cleaned up at any cost (or at the expense of other hypothetical "polluters") were judged to be non-valid. There were six questionnaires eliminated on this basis. This resulted in 99 valid responses. Further elimination based on indicated payment vehicle bias would have yielded fewer than 30 useful responses. Such a small response set was judged to be undesirable and the responses which indicated a potential payment vehicle bias were used in the analysis to maintain the full set of 99 useful responses.

The set of useful responses was used to estimate the mean annual willingness to pay from each Woodland Hills household for landfill cleanup level A. The mean value was chosen because the payment vehicle as described in the questionnaire was a *voluntary* federal income tax payment and not a *compulsory* payment for each household. Most contingent valuation studies using a compulsory payment will use the median willingness to pay—the value which the 50 percent majority would agree to pay. The willingness to pay for landfill cleanup level A was chosen because it coincided with the 1-in-1,000,000 EPA standard for excess cancer risk which served as the baseline for landfill 8 and 10 cleanup.

The mean annual willingness to pay was then aggregated across all Woodland Hills households. This method was chosen because the health risk was highly concentrated in the Woodland Hills housing area; landfills 8 and 10 present a very low risk of contaminating drinking water or surface water supplies for a larger population, a very low risk of spreading contamination through fugitive dust or air emissions, and a very low risk of contaminating food or wildlife which may move outside the Woodland Hills vicinity. Though one could argue residents of nearby communities may have a marginal willingness to pay for cleaning up landfills 8 and 10, this outside willingness to pay was discarded in favor of full aggregation across all Woodland Hills residents. On the one hand, limiting aggregation to Woodland Hills may underestimate the true aggregate willingness to pay. On the other hand, assuming those Woodland Hills residents who did not respond to the survey would be willing to pay an amount consistent with those who did respond may overestimate the willingness to pay aggregated across all Woodland Hills households. Though the relative error in these assumptions is not known, the assumptions were judged to be reasonable. Such an approach has been used in other contingent valuation studies (Walsh and others, 1984; Stoll and Johnson, 1984) in which a mean willingness to pay is generalized and aggregated across a relatively restricted population. The response rate of the Walsh study was 41 percent and that of the Stoll and Johnson study was 36 percent—very nearly the same response rate as this study.

The aggregate annual willingness to pay for landfill cleanup was then projected over the 30-year expected duration of the cleanup process. This annuity was discounted at a 3 percent real discount rate and expressed as a present value in 1996 dollars. A 3 percent real discount rate was chosen as the social expression of preference for the present rather than the future and is the rate advocated by King and Smith (1988) in calculating the expected value of health risk reduction. 1996 was chosen as the baseline for present value calculations because this study is determining the value of a decision to proceed with landfill cleanup as if that decision is presently being made. Economic calculations discussed in Research Objective 2 below are consistent with this approach.

The final expression of the aggregate willingness to pay for landfill cleanup is in the form of a *value per statistical life*. This is an accounting expression of the implicit value placed on a life by a decision to proceed with a health risk reduction. The measure is widely used in the field of risk analysis and management (Thaler and Rosen, 1976; Viscusi, 1978; Fisher and others, 1989) and serves as a baseline measure for comparison of the CVM results to the actual cleanup costs and the expected value of the health risk reduced by the cleanup.

Research Objective 2

The second objective for this research was to compare the value of the Woodland Hills environmental restoration project with the actual cost and expected value of the project. The difference between aggregate willingness to pay and actual project costs indicates the net benefit of this project and is a direct measure of the resource value provided by Air Force environmental funds in this case study. The difference between aggregate willingness to pay and expected value indicates the divergence between two techniques which attempt to measure the value of the environmental resource using separate economic methods. The Woodland Hills case provides an opportunity to compare the resource value measured by contingent valuation to the actual cost of an environmental project.

Actual Costs of Landfill Cleanup

The Woodland Hills restoration had progressed through the planning and execution stages to the point where actual budget projections existed for the long-term operation and maintenance of the project. Actual costs considered relevant to this estimate are the actual restoration project costs and the operation and maintenance costs estimated by the Wright-Patterson AFB Environmental Management Restoration Branch. These costs are documented in detail in Appendix E: Actual Costs of Woodland Hills Landfill 8 and 10 Restoration Project. Costs for site characterization, risk assessment, and remedial investigation studies were excluded from actual project costs. These preliminary studies are required in cases of environmental damage such as landfills 8 and 10 and the costs are unavoidable in the context of this research. Also, these were sunk costs at the time of the decision on whether or not to proceed with remediation; this is the point in the decision process at which the CVM study would be conducted. Further, the aggregate willingness to pay revealed by the questionnaire was for *cleaning up* landfills 8 and 10 not *studying* landfills 8 and 10. For these reasons, actual costs were considered relevant to this research only when they were directly linked to cleanup activities; all other costs were considered irrelevant to this research.

Once determined, the relevant project costs were then used to calculate the present value of the Woodland Hills restoration project. Like the aggregate willingness to pay calculations, a 3 percent discount rate was used to express the present value of actual costs in 1996 dollars. This dollar value was then converted to a final expression of value per statistical life for full comparison to the CVM-estimated value of the project.

Expected Value of Landfill Cleanup

As an observed valuation technique, expected value calculations are based on actual market behavior. In their detailed study of airline passenger fatalities, King and Smith (1988) developed a methodology to estimate the economic loss of victims in cases of wrongful death. The economic loss recognized by the legal system in such cases is the financial support deprived to the victim's survivors. Applying the methodology to the Woodland Hills case involves an adjustment for both mortality and morbidity health risk. Using this methodology, demographic information was collected for military members and spouses living in military family housing: mean age, mean base-year income, wage growth, female-to-male military member ratio, mean married rate, and mean years of service. Demographic information from the entire American population was also used for: expected worklife, death rates, number of non-market hours, and equivalent non-market wage. These demographics were assumed to represent the members of Woodland Hills and are shown in detail in Appendix F: Demographic Information for Expected Value Calculation.

The expected value methodology starts with adjusting base-year income for future years according to expected wage growth. This future expected income is then discounted for the probability that the individual will be alive and working in each future year. This discounted value is further added to the value of non-market duties which the victim would have performed in the future and for which the survivors deserve compensation: laundry, household maintenance, meal preparation, and child care. These total future earnings are then adjusted according to a discount rate—in this case 3 percent—and expressed as a present value in 1996 dollars. In all cases, the difference between future earnings based on a zero excess cancer risk and the future earnings based on the excess cancer mortality risk of landfills 8 and 10 was used as the expected lost income value due to the mortality risk.

Because the average age, life expectancy, and wage characteristics of Woodland Hills residents are different, it was necessary to calculate individual lost wages for each of twelve income groups: female enlisted military members, female enlisted spouses, male enlisted military members, male enlisted spouses, female officer military members, female officer spouses, male officer military members, male officer spouses, female enlisted children, male enlisted children, female officer children, and male officer children. In all cases, the expected lost income due to excess mortality cancer risk of landfills 8 and 10 was aggregated for each income group and added together as the expected value due to reduced *mortality* cancer risk.

The excess cancer risk also posed a morbidity risk for which the expected value was calculated separately. The methodology for this calculation was the assumption for each of the income groups that the individual would develop cancer at the midpoint of his or her remaining life. The individual would not die from the cancer, but would forfeit the equivalent of the succeeding five year's worth of income. This was based on the assumption that medical treatment, sick leave, and reduced earning potential would be roughly equivalent to a five-year income at the time cancer was discovered. Again this value was discounted at 3 percent and aggregated across each income group. The combined morbidity expected value of all income groups was added to the mortality expected value to reach the total expected value of health risk reduction. The total expected value was converted to a final expression of value per statistical life for full comparison to the CVM-estimated value of the project and the actual cost of the project.

IV. Findings and Analysis

This chapter reports the results of the contingent valuation study, the actual project costs, and the expected value of the landfill cleanup. The chapter compares each measure to assess how they may be used to make funding decisions affecting Air Force environmental resources. Unless explicitly stated in this chapter, the sources for assumptions made in this analysis are shown in Appendix G: Sources of Assumptions Made in Analysis. Also, unless explicitly stated, all dollar amounts are expressed in October 1996 dollars.

Research Objective 1

The 99 useful responses indicated a mean annual household willingness to pay for cleanup level A of $123.67 with a standard deviation of $148.41. The choice of using the mean rather than the median willingness to pay was not pivotal as the median was $100.00—only 19 percent less than the mean. Assuming 342 of the 350 Woodland Hills housing units are occupied at any time and that this mean payment would be collected from all occupied units, an annual payment of $42,294.00 would be collected. The present value of 30 years of such payments discounted at a 3 percent rate is $522,737.04 as shown in Table 2. In simple terms, this is how much a landfill cleanup project is worth to the residents of Woodland Hills if such a project was presently being considered. A project costing more than this would not be warranted when compared to the willingness to pay of Woodland Hills residents. A project costing less than $522,737.04 may be warranted if the surplus—the difference between what the project is worth and what the project costs—is the largest such surplus of all potential public expenditures.

Converting the aggregate willingness to pay into a value per statistical life requires a calculation of mortality risk, or "statistical lives" saved. The excess risk of developing cancer presented in the questionnaire was 1-in-2000. Without further information on the particular type of cancer, the gross cancer mortality rate must be used. In 1995 the US population developed an estimated 1,252,000 new cases of cancer. In the same year there were an estimated 547,000 cancer deaths. These rates were similar to rates in prior years. Without further time-series information this ratio was assumed to be steady state and revealed a gross cancer mortality rate of 43.7 percent (547,000 / 1,252,000). The gross cancer mortality rate was used to find the equivalent cancer mortality rate in the case of Woodland Hills: approximately 1-in-4600 (1-in-2000 x 0.437). A total of 1310 Woodland Hills residents would be exposed to this cancer mortality risk (342 households x 3.83 residents per household). The number of residents exposed to the landfills was not adjusted for residence turnover because the original cancer risk of 1-in-2000 assumed a 30-year residence time—an assumption of no residence turnover. The number of statistical lives saved is 0.286 (1310 / 4600). This results in a value per statistical life of $1.83 million ($522,737.04 / 0.286).

Table 2 - FINDINGS OF CONTINGENT VALUATION

Aggregate Willingness to Pay for Landfill Cleanup	
Mean household annual willingness to pay	$123.67
Mean number of households	342
Aggregate annual willingness to pay	$42,294.00
Life span of project	30 years
Discount rate	3 percent
Total Contingent Value	**$522,737.04**
Value Per Statistical Life	
Mortality risk per individual	0.00022
Mean number of individuals per household	3.83
Mean number of households	342
Statistical lives saved	0.28588
Value per statistical life	**$1,828,516.88**

For comparison to the field of risk analysis and management, Viscusi (1992) notes that for wage-risk trade-offs in the labor market, "most of the reasonable estimates of the value of life are clustered in the $3 to $7 million range [in 1990 dollars]." Miller (1990) reviewed 47 risk analysis studies to conclude a mean value per statistical life in CVM studies of $2.5 million (in 1988 dollars). Studies in the field of automobile accident risks calculate a value per statistical life between $2.9 million and $4.2 million (Atkinson and Halvorsen, 1990; Dreyfus and Viscusi, 1995). Adjusting to 1996 dollars, these studies indicate a mean "baseline" value per statistical life of approximately $4 million—slightly more than twice the value indicated in this study. The relative comparability between the value per statistical life indicated by this CVM study and that shown in the broader risk analysis field may indicate that respondents in this study did not tend to exaggerate the health risk posed by landfills 8 and 10. Indeed, the respondents indicated a concern for this somewhat unfamiliar health risk consistent with far more familiar health risks associated with occupation and automobile safety.

Research Objective 2

Findings of Actual Project Costs

The two major components of actual project costs were the short-term construction costs of the landfill cap and leachate treatment system and the long-term operation and maintenance costs of the leachate treatment system. The present value of construction costs totaled $12.7 million and the present value of operation and maintenance costs totaled $20.3 million to bring the total actual project cost up to $33.0 million as shown in Table 3. It is worth mentioning that the operation and maintenance costs are approximately $162,000 per quarter for the 30-year duration of the project and these costs are, therefore, highly influenced by the chosen discount rate. The present value of actual project costs is roughly 63 times the aggregate willingness to pay determined by the contingent valuation study. In economic terms, this project has zero consumer surplus. In fact, costs outweigh economic benefits 63-to-1.

Table 3 - FINDINGS OF ACTUAL COST

Actual Costs	
Landfill cap construction	$12,052,931.62
Leachate treatment plant construction	$708,727.76
Leachate treatment plant operation & maintenance	20,284,664.71
Total Actual Cost	**$33,046,324.09**
Value Per Statistical Life	
Statistical lives saved	0.28588
Value per statistical life	**$115,594,949.04**

For an actual cost of $33.0 million, the value per statistical life of the landfill 8 and 10 cleanup project is $115.6 million. This value far exceeds the $1.83 million of the contingent valuation study and the $4 million baseline value found in the risk analysis field. For the sake of illustration, a higher cancer risk would equate to more lives being saved by this project. To bring the value per statistical life of the project down to the $1.83 million value found by the study, the excess cancer risk would have to increase from 1-in-2000 to 1-in-32. In summary, the cancer risk of landfills 8 and 10 would have to increase roughly two orders of magnitude for the project to make economic sense when compared to the aggregate willingness to pay for the project.

The $115.6 million value per statistical life of this case may be compared with other federal environmental policies. For instance, EPA regulations on uranium mill tailings imply a value per statistical life of $100.2 million and EPA guidelines on asbestos imply a value per statistical life of $160.3 million (Viscusi, 1996). In fact, many of the public programs which have such an inflated value per statistical life are environmental programs managed by the EPA and not occupation or transportation risk management programs of other federal agencies. Though the landfill 8 and 10 value per statistical life is not consistent with the contingent valuation results or the $4 million baseline, it is consistent with some of the higher values associated with federal environmental programs.

Findings of Expected Value

The expected lost income for each of the twelve income groups is shown in Table 4. The aggregate expected lost income is $253,039.12. In simple terms, this is how much a landfill cleanup project is worth to society in order to avoid compensating victims who develop cancer from their exposure to landfills 8 and 10. On many accounts, this amount may be seen as the lower bound of value. First of all, this methodology considers only lost income and not pain or suffering of the victim or his family. Second, this methodology does not account for risk aversion—the desire most people have to limit their exposure to significant risk. Despite these limitations, the expected value methodology is accepted in court cases of a similar nature and serves as a societal measure of the value of cleaning up landfills 8 and 10.

Table 4 - FINDINGS OF EXPECTED VALUE

Expected Lost Income (by income group)			
Female enlisted military member		**Female officer military member**	
Mortality lost income	$60.44	Mortality lost income	$109.00
Morbidity lost income	$57.32	Morbidity lost income	$119.22
Number in income group	12.66	Number in income group	40.63
Aggregate lost income	$1,491.17	Aggregate lost income	$9,272.27
Female enlisted spouse		**Female officer spouse**	
Mortality lost income	$49.17	Mortality lost income	$60.22
Morbidity lost income	$37.64	Morbidity lost income	$51.71
Number in income group	61.58	Number in income group	218.73
Aggregate lost income	$5,345.91	Aggregate lost income	$24,483.06
Male enlisted military member		**Male officer military member**	
Mortality lost income	$93.57	Mortality lost income	$169.86
Morbidity lost income	$57.32	Morbidity lost income	$119.22
Number in income group	65.51	Number in income group	223.20
Aggregate lost income	$9,884.39	Aggregate lost income	$64,523.25
Male enlisted spouse		**Male officer spouse**	
Mortality lost income	$71.83	Mortality lost income	$89.18
Morbidity lost income	$37.64	Morbidity lost income	$51.71
Number in income group	11.90	Number in income group	39.82
Aggregate lost income	$1,303.12	Aggregate lost income	$5,609.70
Female enlisted child		**Female officer child**	
Mortality lost income	$52.41	Mortality lost income	$82.22
Morbidity lost income	$61.49	Morbidity lost income	$79.10
Number in income group	73.87	Number in income group	244.04
Aggregate lost income	$8,414.10	Aggregate lost income	$39,369.56
Male enlisted child		**Male officer child**	
Mortality lost income	$108.82	Mortality lost income	$199.12
Morbidity lost income	$58.31	Morbidity lost income	$91.80
Number in income group	73.87	Number in income group	244.04
Aggregate lost income	$12,345.90	Aggregate lost income	$70,996.68
Total expected lost income		**$253,039.12**	
Value Per Statistical Life			
Statistical lives saved		0.28588	
Value per statistical life		**$885,122.49**	

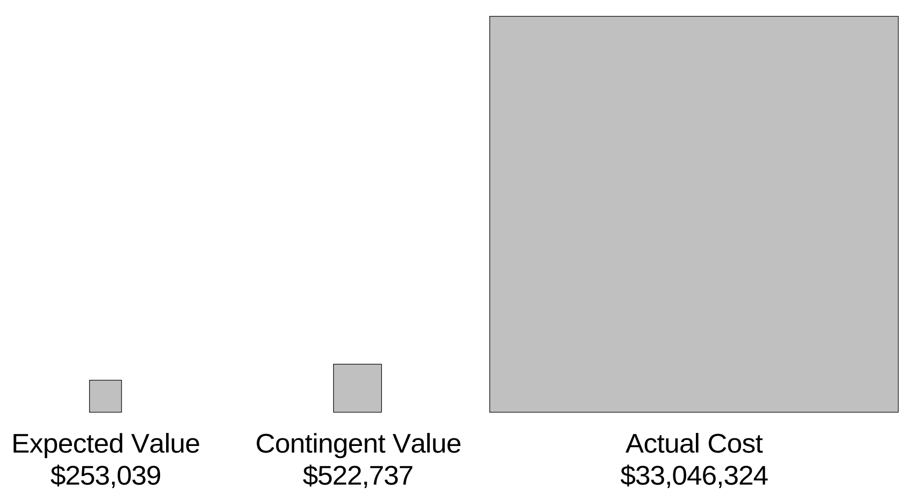
Converting the expected value yields a value per statistical life of $885,122.49. Though considered a lower bound and substantially below the $1.83 million figure indicated by the study, this value is consistent with some non-environmental public risk management programs. For instance, federal alcohol and drug control programs imply a value per statistical life of $640,000 and automobile regulations governing passive restraints and seat belts imply a value per statistical life of $556,000 (Viscusi, 1996). Though it may be difficult to draw extensive conclusions about the implied value per statistical life in this case, studies conducted in other fields of public risk analysis have shown results consistent with this case.

The difference between results of the contingent value study and the expected value methodology may be largely explained by the concept of risk aversion. Residents of Woodland Hills will naturally be more conservative in dealing with health risk affecting themselves and would tend to inflate their willingness to pay over that expressed by society at large in the expected value calculation.

Comparison of Values

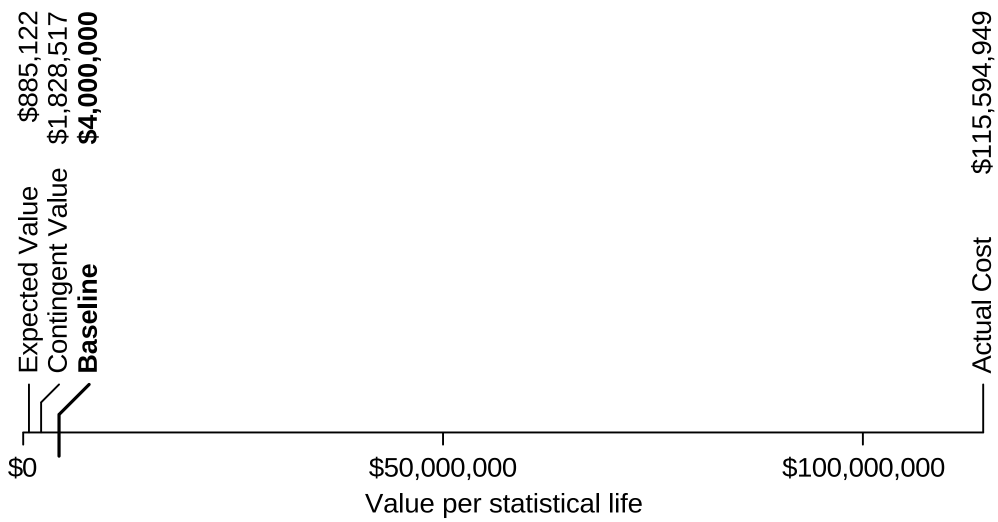
The three measures of value for landfill 8 and 10 cleanup are compared in Figure 1 on the basis of present value. The expected value is roughly 50% of the contingent value and less than 1% of the actual cost.

Figure 1 - PRESENT VALUE COMPARISON



The three values are shown in Figure 2 on the basis of value per statistical life. In this comparison, the contingent value is comparable to the $4 million baseline established by a wide range of other risk analysis and management studies. Though the expected value serves as a reasonable lower bound on the value of landfill cleanup, the actual costs of cleanup far exceed any reasonable economic measure of value.

Figure 2 - VALUE PER STATISTICAL LIFE COMPARISON



V. Conclusions and Recommendations

This chapter presents the conclusions of this research and recommendations for using the results of this study. The first four chapters of this study are summarized and conclusions drawn concerning how this study could be used to improve Air Force environmental management. Finally, recommendations for further research beyond this study are presented.

Summary of Previous Chapters

The purpose of this research was to measure the economic value of Air Force environmental resources using a case study approach. Chapter 1 briefly described the issue of economic value and how it applies to Air Force environmental management. The two research objectives were: 1) determine the resource value provided by Air Force environmental fund expenditures as measured by the contingent valuation method (CVM) and 2) compare the CVM-estimated value of an environmental project with the actual cost and expected value of the project. Chapter 2 presented literature describing the purpose and techniques of measuring the economic value of environmental resources. The technique given particular emphasis in this discussion was CVM. Chapter 3 described the methodology used to meet the research objectives including the processes of data collection and analysis. Chapter 4 discussed the findings for each research objective. The value of cleaning up landfills 8 and 10 as measured by the contingent valuation study, actual project costs, and the expected value of health risk reduction were presented and discussed. When compared on the basis of implied value per statistical life, the contingent valuation measure was the most comparable to values found in the wider risk analysis and management field. Though the expected value calculation serves as a reasonable lower bound on the value of cleanup, the actual costs of the project far exceed any reasonable economic measure of value.

Conclusions

In the course of spending $1 billion annually on environmental programs, the Air Force must consider the relative benefit of each potential expenditure. In the case of landfills 8 and 10 at

Wright-Patterson Air Force Base, for instance, the pertinent question should be, "How much is it worth to clean up these landfills?" The worth may be measured by many economic valuation techniques, but the contingent valuation technique is uniquely suited to measuring the value of goods in a hypothetical market. The result of contingent valuation—the willingness to pay—is also the appropriate measure of public support for managing risks such as the human health impact of landfills 8 and 10. Treating the case of landfills 8 and 10 as a purely economic decision, contingent valuation indicated a cleanup project may be worth just over $500,000. In contrast, the actual project cost totaled over $33,000,000. On the economic grounds presented in this research, this project should not have proceeded. Using contingent valuation to measure the benefits of this project may have indicated that the Air Force could spend its environmental funds more productively elsewhere. Given the fact that the project proceeded may indicate a non-economic rationale behind the funding decision. Perhaps political considerations such as future Air Force liability or current public relations were part of the rationale. Perhaps regulatory considerations to "clean it up at any cost" were part of the rationale. In fact a case can be made that because the original excess cancer risk exceeded EPA standards, the project was justified as a risk-reduction requirement rather than a net benefit. At any rate, when assessing the purely economic basis for proceeding with this or other similar Air Force environmental expenditures, the contingent valuation method may allow decision-makers to make funding decisions that are many millions of dollars more productive. For this reason, future decisions based on a case-by-case assessment of health risk and net benefit rather than strict cleanup standards may use contingent valuation extensively.

On the basis of this case study, contingent valuation should be considered a useful tool in cost-benefit analysis for similar environmental restoration projects. Judging from the costs of other contingent valuation studies, a contract to conduct such a study in this case would have cost more than $30,000. Clearly, such a study is not warranted for projects involving relatively small costs—less than $100,000. On the other hand, a contingent valuation study may be warranted for projects involving over $1,000,000 and certainly would have been warranted for this $30,000,000 project. It is difficult to say without further information how productive CVM would be in cases of environmental policy cost-benefit analysis or environmental impact assessment, but this research has demonstrated a proper place for CVM in environmental restoration management.

Further Research

This study established CVM as a viable policy tool in some Air Force environmental funding decisions—specifically, large-scale restoration projects. Many prominent questions still remain:

1. How productive would CVM be for other types of analysis (policy cost-benefit analysis, environmental impact analysis)? For instance, can the Air Force use results of CVM to make better policy or more meaningful environmental impact analysis?

2. How productive would CVM be for issues involving a different respondent audience (local civilians, non-local civilians)? For instance, does the willingness to pay for an Air Force environmental resource differ with the audience?

3. How could the results of CVM be used by the Air Force to support discussions with state and federal environmental regulators? For instance, if CVM indicates an environmental resource is worth X dollars to clean up, will regulators allow the Air Force to limit its spending to X dollars?

4. What practical steps would be required to fully incorporate CVM into current Air Force environmental management practices? For instance, would the Air Force have to develop its own guidance of when and where to apply CVM?

5. What is the change in social utility if the Air Force bases its funding decisions on CVM? For instance, if the Air Force prioritizes its funding based on consumer surplus indicated by CVM, how much would society gain over the way funding decisions are currently based?

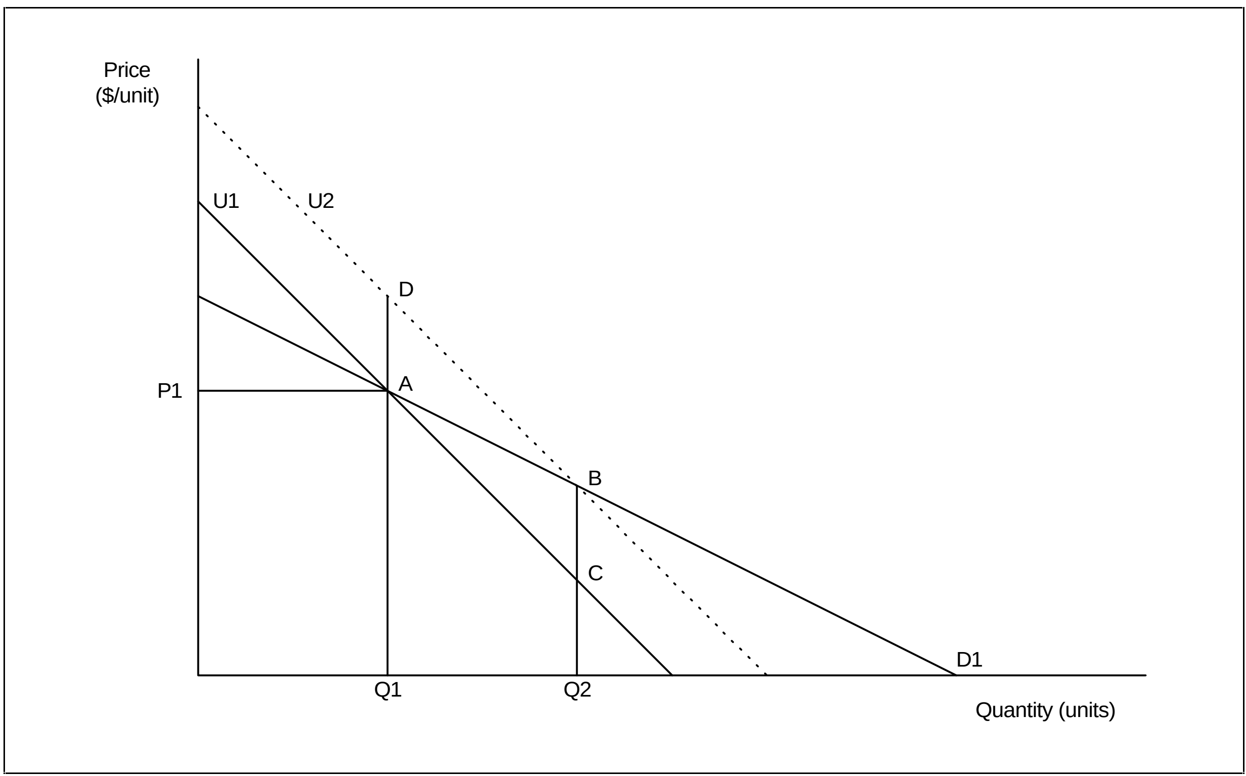
6. How could the Air Force apply CVM to non-environmental resources? For instance, national defense or socio-economic impact on a local community are public goods of interest to the Air Force that could be studied by CVM.

This study indicates CVM has a place in Air Force environmental management. The common theme of these new research questions is to find the proper place and time at which to apply CVM. Further research is needed and warranted.

Appendix A: Theoretical Economic Basis of Contingent Valuation Method

A contingent valuation survey indicates the public's constant-utility (Hicksian) demand curve for a public good. Illustrated in Figure 3 below, a Hicksian demand curve (U1) represents the quantity of a good consumed for a given price at a given utility, or level of satisfaction. The same figure also illustrates a constant-budget (Marshallian) demand curve (D1) which represents the quantity of a good consumed for a given price at a given budget. Because actual consumer behavior follows Marshallian demand curves, a researcher must consider the relationship between behavior revealed in the contingent valuation survey (Hicksian) and behavior expected in the actual marketplace (Marshallian). For a given quantity and price of an economic good, there is a single Hicksian curve that coincides with this point. This Hicksian curve represents the level of utility derived from the consumption of the good at that quantity and price. At this same point, there is a single Marshallian curve that coincides. This Marshallian curve represents the level of budget a consumer would need to support the consumption of the good at that quantity and price. In Figure 3 this point of coincidence for U1-D1 is represented by point A. At this

Figure 3 - HICKSIAN-MARSHALLIAN DEMAND CURVES



point, Q1 of the good is being consumed at price P1 producing a utility represented by U1 for a consumer with a budget represented by D1.

Since the consumer is willing to spend money to consume this good at point A, the value of the good to the consumer must be greater than or equal to the amount of money paid. The total money paid is the quantity (Q1) multiplied by the price per unit (P1). In Figure 3 this amount is the area under P1-A to the left of Q1-A. The amount of money the consumer would be willing to pay in excess of this amount is the *consumer surplus* and represents the benefit derived by the consumer (Morey, 1984). For instance, if the good is gasoline, Q1 is 10 gallons, and P1 is $1.00, this consumer would spend $10 on gasoline (10 gallons x $1.00 per gallon) represented by point A. If the consumer would be *willing* to spend $3.00 per gallon for the same 10 gallons, there is a consumer surplus of $20 ($30 - $10). This is a measure of benefit experienced by the consumer. Apart from most goods in the marketplace, however, environmental resources are a special case of benefit estimation.

Most environmental resources are provided free of charge. There is generally no market price set for consumption of clean air or existence of national forests. With a price of zero, the benefit represented by consumer surplus is the entire area under the demand curve. Since we have both Hicksian and Marshallian demand curves, consumer surplus has a slightly different meaning in each case. Figure 3 represents an increase in an environmental good (for instance, better visibility or more public parks) from Q1 to Q2. Under the Marshallian curve (D1), this change equates to the area under the D1 curve between point A and point B. This is the *ordinary* consumer surplus. Under the Hicksian curve (U1), this change equates to the area under the U1 curve between point A and point C. This is the *compensating* surplus and is revealed in a contingent valuation as a willingness to pay for increasing the environmental resource from Q1 to Q2. In the case of decreasing an environmental resource, for instance from Q2 to Q1, the area under the Hicksian curve (U2) between point B and point D is the *equivalence* surplus. This is revealed in a contingent valuation as a willingness to accept compensation. In simple terms, when asked, "How much would you be willing to pay to increase environmental good X from Q1 to Q2?" a consumer will assume she ends up with the same level of utility she currently has. The consumer references a Hicksian demand curve in this hypothetical market. Since the utility before an increase is lower than utility before a decrease, willingness to *pay* is expected to be lower than willingness to *accept compensation* in a contingent valuation survey. Further, as shown in Figure 3, ordinary consumer surplus (under A-B) will be higher than compensating surplus (under A-C) but lower than equivalence surplus (under D-B).

In cases of public policy, Hicksian measures are more appropriate than Marshallian measures (Mishan, 1976; Brookshire and others, 1980). As a measure of utility, Hicksian surplus indicates whether a change in provision of a public good is Pareto-improving whereas Marshallian measures do not indicate full utility. CVM is able to capture Hicksian welfare measures better than other valuation techniques because CVM measures include both use-value and non-use value of the hypothetical good. In practice, however, the difference between Hicksian and Marshallian measures is small for small changes in the level of provision of the public good (Willig, 1976). For this reason, CVM studies seek a single demand function to represent surplus for the public good of interest.

When using surplus to measure benefits, there is an important distinction between public goods and market goods exchanged in the economy. Individual demand curves for public goods are added vertically (an aggregate price is paid by many for a fixed quantity); individual demand curves for market goods are added horizontally (a separate quantity is received by many for a fixed price). In aggregating these individual demand curves for a public good, it is reasonable to expect some variation among individual citizens. Factors such as income, education, tastes and preferences all influence the amount an individual is willing to pay for a public good. These same factors can vary widely among different citizen groups. Public officials in a position to make these decisions must properly aggregate the results of individual demand functions into a representative social demand function. Air Force environmental managers, for example, must consider the aggregate demand for funding its environmental programs. The aggregate demand function is the final product of CVM.

Appendix B: Research Development Plan

<u>Research Objective</u>: Determine the value provided by Air Force environmental fund expenditures as measured by CVM.
Research Question: What respondent characteristics are expected to influence individual willingness to pay?
Survey Question: If you add together the income (wages, dividends, interest income) for every member of your household, how much would that amount be?
Answer Format: Multiple choice of $10,000 intervals (< $10,000, $10,000-$20,000, etc, > $70,000)
Survey Question: How much longer do you expect to live in Woodland Hills?
Answer Format: Multiple choice of 1 year intervals (< 1 year, 1-2 years, etc, > 7 years)
Survey Question: How much did you know about landfills 8 and 10 before taking this survey?
Answer Format: Multiple choice of discrete values (nothing, very little, etc, very much)
Research Question: What is the consumer demand for an environmental resource which is linked directly to the consumer's health?
Survey Question: How much would your household be willing to pay per year in increased federal income taxes to reduce the risk of developing cancer from living next to landfills 8, 10?
Answer Format: Open answer
Survey Question: How did you decide on the amount you stated?
Answer Format: Short answer with potential reasons listed (wild guess, prior knowledge, etc)
Survey Question: What portions of your current spending would you sacrifice in order to pay the amount you stated?
Answer Format: Multiple choice of discrete categories with option for open answer (transportation, food, entertainment, charitable donations, etc)
Research Question: What is the consumer demand for environmental resources which are not linked directly to the consumer's health?
Survey Question: How much would your household be willing to pay per year in increased federal income taxes to reduce the risk of developing cancer for residents living next to a landfill in California?
Answer Format: Open answer
Survey Question: How did you decide on the amount you stated?
Answer Format: Short answer with potential reasons listed (wild guess, prior knowledge, etc)
Survey Question: How much would your household be willing to pay per year in increased federal income taxes to preserve habitat for salmon in the Pacific Northwest?
Answer Format: Open answer
Survey Question: How much would you, yourself, be willing to pay per year in membership dues to belong to a national environmental group such as the Sierra Club?
Answer Format: Open answer
Survey Question: How much would your household be willing to pay per year in increased water rates to ensure tap water in your home is as clean as bottled water?
Answer Format: Open answer
Survey Question: How much would your household be willing to pay per year in increased federal income taxes to ensure tap water in your home is as clean as bottled water?
Answer Format: Open answer
Survey Question: After considering these other programs, have you changed your mind about how much your household would be willing to pay to lower the health risk posed by landfills 8, 10? If so, how much is your household willing to pay now?
Answer Format: Open answer
Research Question: What demographic information is required to calculate aggregate willingness to pay?
Survey Question: How many members currently live in your household?
Answer Format: Multiple choice of discrete values (1 person, 2 people, etc, > 8 people)
Survey Question: What is the highest level of education you have received?
Answer Format: Multiple choice of discrete values (some high school, etc, post-graduate)
Survey Question: What is your age?
Answer Format: Multiple choice of 5 year intervals (< 20, 20-25, etc, > 50)
Research Question: What is the aggregate willingness to pay for the respondent population?
Detail Question: What is the mean household willingness to pay?
Detail Question: What is the aggregate willingness to pay?
<u>Research Objective</u>: Compare the CVM-estimated value of an environmental resource health risk reduction with the calculated expected value of the health risk reduction and the actual cost of the health risk reduction.
Research Question: What is the total cost for the case study project?
Detail Question: What is the present value equivalent cost of the case study project (capital cost, maintenance)?
Research Question: What is the expected value of the health risk reduction associated with the project?
Detail Question: What is the expected value of mortality health risk reduction?
Detail Question: What is the expected value of morbidity health risk reduction?

Appendix C: Environmental Resource Value Study Questionnaire

ENVIRONMENTAL RESOURCE VALUE STUDY: INFORMATION SHEET

WHO IS DOING THE STUDY? The study is being conducted by Captain Tim Haynie, a student in the Department of Engineering and Environmental Management at the Air Force Institute of Technology.

WHO IS SPONSORING THE STUDY? The Air Force Institute of Technology is sponsoring the study.

WHAT IS THE PURPOSE OF THE STUDY? The purpose of the study is to sample households like yours to measure the value of certain environmental features. This study is part of the research for a master's degree thesis. It will give federal environmental managers better information about the value of environmental resources under their control.

WHAT KINDS OF QUESTIONS WILL BE ASKED? Questions about specific environmental resources and programs.

HOW DID YOU GET MY NAME? All residents of Woodland Hills military family housing are being polled because some of the environmental resources discussed in the survey are the landfills which border your housing area.

DO I HAVE TO PARTICIPATE? No, participation is voluntary. However, if you don't choose to participate, we will lose the benefit of your experience and lower the accuracy of the study. **If there are any questions you prefer not to answer, you can skip those questions**.

HOW LONG WILL IT TAKE? The length depends somewhat on your answers. Some people have more to say than others. However, the average time to complete the questionnaire is about 15 minutes.

ARE MY ANSWERS CONFIDENTIAL? Yes. You won't even be asked your name. Your answers will be combined with answers from other respondents to make a statistical report. Your honest opinions, whether favorable or unfavorable, are very necessary to be sure that federal environmental managers serve the public as effectively as possible.

HOW WILL THE DATA BE REPORTED? The research results will be reported in Captain Haynie's graduate student thesis and will provide important data for funding decisions affecting environmental resources managed by the federal government.

WHAT DO I DO WITH THE SURVEY WHEN I'M DONE? Place the survey in the envelope provided and send it in the mail. Please complete and return the survey right away. Again, thank you for your help.

---

1. Before turning the page, how much do you know about the environmental impact of landfills near Woodland Hills military family housing?

   A great deal

   A little

   Nothing

We would like for you to consider the environment surrounding your neighborhood. Woodland Hills military housing is bordered by two areas which once served as landfills for Wright-Patterson AFB. You can locate your house and the landfills on the map in Figure 1. Landfill 8 was used from the late 1940s to the early 1970s and has a 10-foot thick layer of garbage covered by 6 feet of soil. Landfill 10 was used from the middle 1960s to the early 1970s and has a 20-foot thick layer of garbage covered by 2 feet of soil. Both landfills were operated by the Air Force within the laws in effect at the time.

Figure 4 - Map of Woodland Hills Military Housing and Landfills 8 and 10

Like any other landfill, Landfills 8 and 10 generate chemicals that dissolve into water flowing through the ground. "Garbage juice" coming out of a landfill is formally known as "leachate." In addition, Landfills 8 and 10 produce gases that work up through the ground and are released into the atmosphere.

In the 1980s the Air Force found chemicals in the leachate and gases of landfills 8 and 10 which slightly exceeded standards set by the federal Environmental Protection Agency (EPA). The health risk of living next to the landfills was estimated to be about a 1-in-2,000 chance of any given Woodland Hills resident developing cancer in his or her lifetime who would not have developed cancer otherwise. As a comparison, figure 2 shows a person's risk of developing cancer from several other sources.

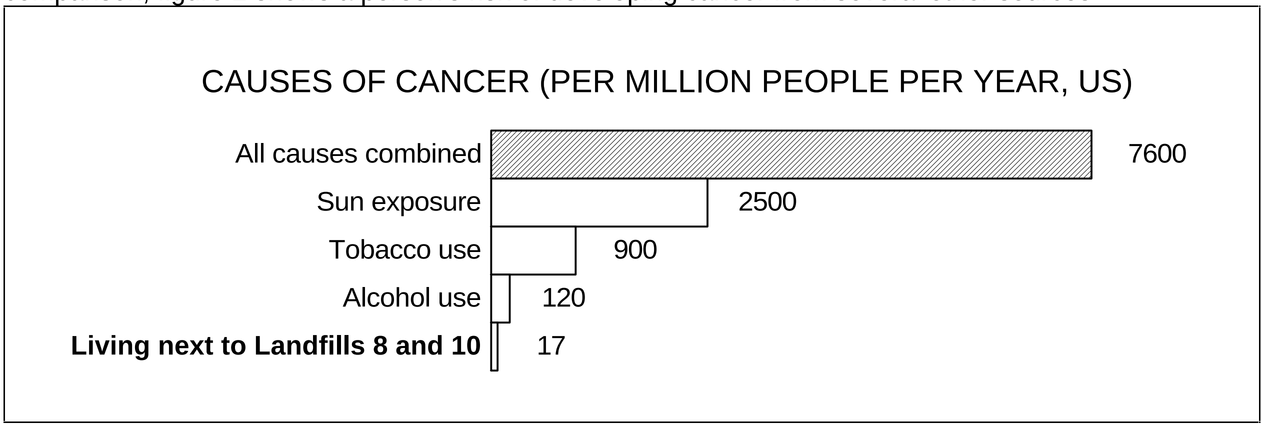


Figure 5 - Risk Comparison

If left untreated, Landfills 8 and 10 would produce leachate and gases over a period of 20-30 years. During this period Woodland Hills residents would experience the health risk shown in Figure 2.

We would like for you to think about the relationship between improving the quality of the environment and the money we all pay each year as taxpayers. We all pay for cleaning up pollution through local, state, and federal taxes. You will be asked questions about the amount of money your household is willing to pay in higher federal income taxes for cleaning up Landfills 8 and 10. For reference, you may want to consider the spending levels in Figure 3. These are federal income taxes spent each year for various public programs by an average household with income between $30,000 and $50,000. If your household has income less than $30,000 you would pay less in taxes; if your income is higher $50,000 you would pay more in taxes.

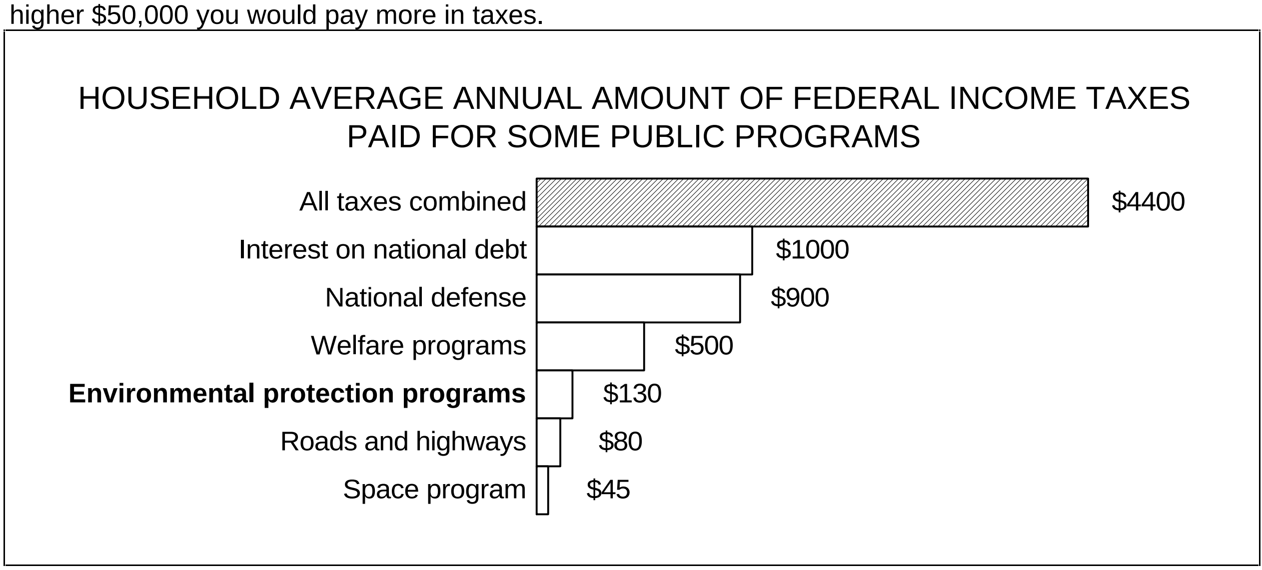


Figure 6 - Average Federal Income Tax Amounts (household income $30,000 - $50,000)

As you complete the survey, please remember there are no right or wrong answers. Your honest response to each question is the absolute best answer you can give.

Imagine that every household in the country, including yours, has the opportunity to say how much they are willing to pay for each environmental program. In this imaginary setting, money that you and all other taxpayers are willing to pay is collected and goes directly toward the program described in the question. Keep in mind other taxpayers may be willing to pay more for some programs than you and others may want to pay less than you.

By cleaning up landfill pollution, we can lower the health risks discussed earlier. When asked about your willingness to pay for cleaning up pollution at landfills 8 and 10, consider the cleanup levels in Figure 4. At the bottom is cleanup level C where the landfills would just be left alone (no cleanup).

Cleaning up and containing some of the leachate and gas would help reduce the health risk to 1-in-100,000 chance of developing cancer. This is cleanup level B. A person's risk of developing cancer from landfill pollution at this cleanup level would be about equal to the risk of developing cancer from smoking 1 cigarette per month.

Cleaning up and containing all of the leachate and gas would help reduce the health risk to 1-in-1,000,000 chance of developing cancer. This is cleanup level A. A person's risk of developing cancer from landfill pollution at this cleanup level would be about equal to the risk of developing cancer from smoking 1 cigarette per year.

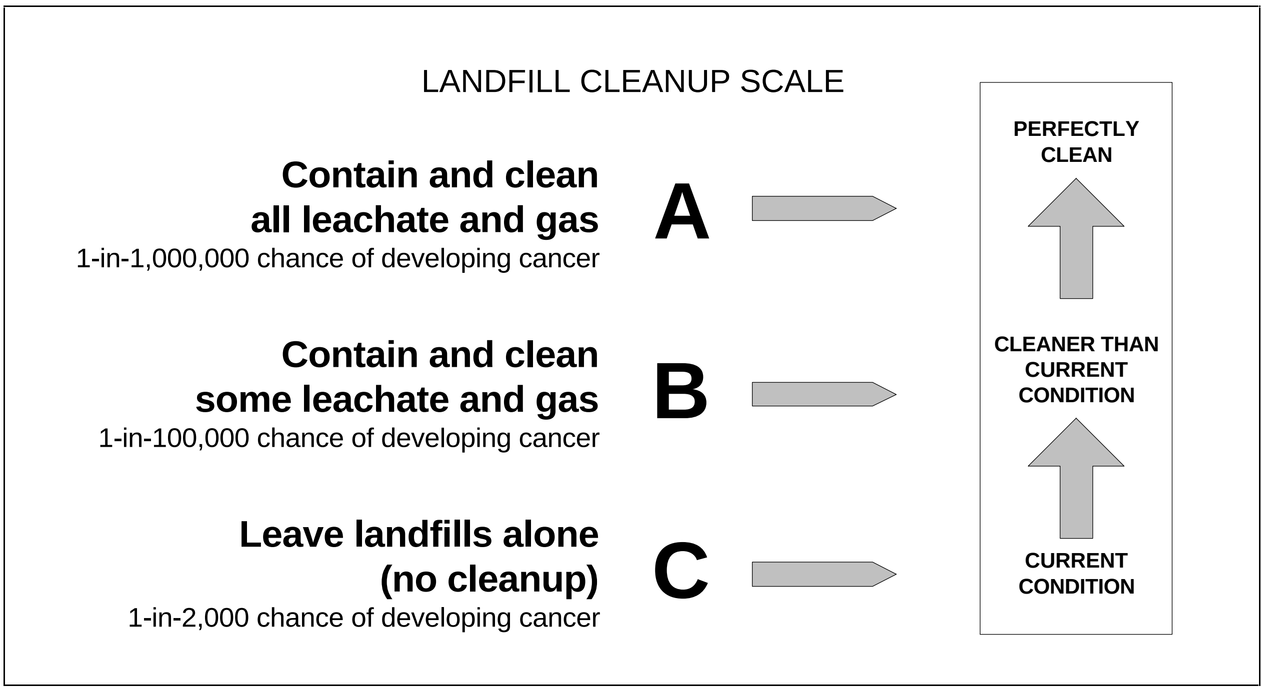


Figure 7 - Landfill Cleanup Scale

2. What is the maximum amount your household would be willing to pay per year in higher federal income taxes to treat leachate and gases from Landfills 8 and 10 to lower the health risk for people living near the landfills from 1-in-2,000 to **1-in-100,000** chance of developing cancer? In other words, what is the highest amount your household would be willing to pay for **cleanup level B** each year before you would feel you are spending more than it's really worth to you and all members of your household?

I would be willing to pay ________________ dollars per year in higher federal income taxes.

No answer

3. What is the maximum amount your household would be willing to pay per year in higher federal income taxes to lower the health risk for people living near Landfills 8 and 10 from 1-in-2,000 to **1-in-1,000,000** chance of developing cancer? In other words, what is the highest amount your household would be willing to pay for **cleanup level A** each year before you would feel you are spending more than it's really worth to you and all members of your household?

I would be willing to pay ________________ dollars per year in higher federal income taxes.

No answer

4. When answering this type of question, some people consider how much they already pay in taxes, some consider the benefits of paying for the program, and some consider other things. Is the amount you stated the amount you would actually be willing to pay, or is the amount you stated intended to communicate "something else"?

I reported the amount I'm actually willing to pay (go to question 5)

The amount I reported is intended to communicate "something else"

What is your reported amount communicating? (Check all that apply)

Wild guess (no idea how much I'd be willing to pay)

Contributing money to an environmental program makes me feel good

I already pay too much money in federal income tax

I think Landfills 8 and 10 should be cleaned up at any cost

Other reason(s) (please specify) ____

____

5. If you said you would pay an amount greater than 0 for cleaning up Landfills 8 and 10, what portions of your current spending would you take money away from in order to pay the amount you stated?

Check all that apply

Food (restaurant dining, quantity of groceries, quality of groceries)

Entertainment (sporting events, theater/art events, movie rentals, cable television subscription)

Savings/Investment (individual retirement account, certificates of deposit, mutual funds, stocks)

Civic activities (group/club memberships, charitable donations)

Other

6. There is a landfill in California that is identical to Landfills 8 and 10 and poses the same health risk to residents living nearby. What is the maximum amount your household would be willing to pay per year in higher federal income taxes to lower the health risk for people living near Landfills 8 and 10 **and** people living near the California landfill from 1-in-2,000 to **1-in-100,000** chance of developing cancer? This would be for **cleanup level B** at Landfills 8 and 10 **and** the landfill in California.

I would be willing to pay ________________ dollars per year in higher federal income taxes.

No answer

7. Again, keep in mind the landfill in California. What is the maximum amount your household would be willing to pay per year in higher federal income taxes to lower the health risk for people living near Landfills 8 and 10 **and** people living near the California landfill from 1-in-2,000 to **1-in-1,000,000** chance of developing cancer? This would be for **cleanup level A** at Landfills 8 and 10 **and** the landfill in California.

I would be willing to pay ________________ dollars per year in higher federal income taxes.

No answer

8. Is the amount you stated the amount you would actually be willing to pay, or is the amount you stated intended to communicate "something else"?

I reported the amount I'm actually willing to pay (go to question 9)

The amount I reported is intended to communicate "something else"

What is your reported amount communicating? (Check all that apply)

Wild guess (no idea how much I'd be willing to pay)

Contributing money to an environmental program makes me feel good

I already pay too much money in federal income tax

I think Landfills 8 and 10 should be cleaned up at any cost

Other reason(s) (please specify) ____

____

9. If you said you would pay an amount greater than 0 for cleaning up both the landfill in California **and** Landfills 8 and 10, what portions of your current spending would you take money away from in order to pay the amount you stated?

Check all that apply

Food (restaurant dining, quantity of groceries, quality of groceries)

Entertainment (sporting events, theater/art events, movie rentals, cable television subscription)

Savings/Investment (individual retirement account, certificates of deposit, mutual funds, stocks)

Civic activities (group/club memberships, charitable donations)

Other

Apart from the case of cleaning up landfill pollution, we would like you to consider some other environmental programs. When considering how much you would be willing to pay for each of these programs, please remember you would have to pay the amount you state for each program listed here and the nation's other environmental programs such as conservation and pollution cleanup.

10. What is the maximum amount your household would be willing to pay per year in higher federal income taxes to preserve the natural habitat for the salmon population in the Pacific Northwest?

I would be willing to pay ________________ dollars per year in higher federal income taxes.

No answer

11. What is the maximum amount you, yourself, would be willing to pay per year in membership dues to belong to a national environmental group such as the Sierra Club?

I would be willing to pay ________________ dollars per year in membership dues.

No answer

12. What is the maximum amount your household would be willing to pay per year in higher **water rates** to ensure tap water in your home is as clean as bottled water?

I would be willing to pay ________________ dollars per year in higher water rates.

No answer

13. Keeping your water rates the same as they are now, what is the maximum amount your household would be willing to pay per year in higher **federal income taxes** to ensure tap water in your home is as clean as bottled water?

I would be willing to pay ________________ dollars per year in higher federal income taxes.

No answer

14. After considering your willingness to pay for these other programs, have you changed your mind about how much your household would be willing to pay per year to cleanup Landfills 8 and 10?

Yes, I have changed my mind (go to question 15)

No, I haven't changed my mind (go to the next page)

15. After considering other environmental programs, what is the maximum amount your household would be willing to pay per year in higher federal income taxes to lower the health risk for people living near Landfills 8 and 10 from 1-in-2,000 to **1-in-100,000** chance of developing cancer?

I would be willing to pay ________________ dollars per year in higher federal income taxes.

No answer

16. After considering other environmental programs, what is the maximum amount your household would be willing to pay per year in higher federal income taxes to lower the health risk for people living near Landfills 8 and 10 from 1-in-2,000 to **1-in-1,000,000** chance of developing cancer?

I would be willing to pay ________________ dollars per year in higher federal income taxes.

No answer

To compare your answers to those of other people answering these questions, we would like to know a little about you and your household. Once again, we'd like to remind you that this questionnaire is completely confidential.

17. How many members, counting yourself, currently live in your household full-time?

__________________ members

18. What is the highest level of education you, yourself, have received?

Some high school

High school graduate

Some college

College graduate (4-year degree)

Post-graduate

No answer

19. What was your age on your last birthday?

Less than 20

20-25

26-30

31-35

36-40

41-45

More than 45

20. What is the combined annual income (wages, dividends, interest income) for members of your household?

Less than $10,000

$10,000 - $19,999

$20,000 - $29,999

$30,000 - $39,999

$40,000 - $49,999

$50,000 - $59,999

$60,000 or more

21. How many more years do you expect to live in Woodland Hills military housing?

______________ years

This completes the questionnaire. **Please mail it immediately in the envelope provided**. Thank you again for your time and attention.

LANDFILL CLEANUP FACT SHEET

This survey was based on an imaginary assumption that Landfills 8 and 10 were not being cleaned up. The federal government has actually spent a great deal of time, money, and effort cleaning up Landfills 8 and 10. This sheet describes what the federal government has actually done to clean up these landfills:

In 1981 Wright-Patterson AFB conducted an assessment of potential hazardous waste contamination issues to identify sites on base which may pose environmental problems. During these initial record searches, Landfills 8 and 10 were identified as high priority sites requiring further investigation.

In 1984, the Air Force conducted a field investigation of the landfill sites. During this investigation, wells were drilled into the landfill surface to monitor and test leachate and gases. Tests were also conducted on soil and surface water samples. Results of the 1984 investigation led to a follow-on investigation in 1986 which included installation of additional monitoring wells, further sampling of groundwater, shallow borings to excavate small quantities of landfill cover and material, and testing for specific chemicals in landfill gas emissions.

In 1988, a Remedial Investigation/Feasibility Study (RI/FS) was performed to characterize and define the extent of environmental contamination and the potential risk to human health and the environment. This study served as the initial link between what existed in the landfill and how it might be harmful to the environment. The public, including Woodland Hills residents, was asked for comment and input during the RI/FS. The final RI/FS was used to develop a cleanup solution for Landfills 8 and 10.

In 1992, a long-term engineering design was ready for public comment. The "Record of Decision" describing the cleanup strategy was jointly approved by the Air Force, the US Environmental Protection Agency, and the Ohio Environmental Protection Agency in 1993. The cleanup solution reduces the health risk due to the landfills below 1-in-1,000,000 chance of developing cancer. The Record of Decision calls for the following measures:

1. Restricting access to the site and future development of the site.
2. Placing an impermeable cap over each landfill to reduce the amount of rainwater seeping into the ground.
3. Installing wells and pipes through the landfill to collect and completely treat leachate and gas.
4. Providing public water supply to homes previously using well water from the area.
5. Air, gas, and groundwater monitoring.
6. Long-term operation and maintenance plan for the remedy.

As of May 1996 the status of the site is as follows:

1. Access and development of the site have been restricted.
2. The landfill caps are nearly 100% complete.
3. Wells and pipes are nearly complete.
4. Public water supplies have been established.
5. Air, gas, and groundwater monitoring is being done.
6. The long-term operation and maintenance plan is in place to operate the cleanup solution for the next 30 years.

In general, the Air Force no longer operates large landfill operations to collect refuse. Some Air Force bases may have a small operation to compost yard waste or to recycle various materials, but most solid waste generated by an Air Force base is placed in municipal landfills operated by the local city or county. Today these landfill operations are governed by federal laws passed the 1970s and 1980s to prevent the type of environmental impact we see with Landfills 8 and 10.

If you have questions concerning the condition of landfills 8 and 10 you may call the 88th Air Base Wing Environmental Management Restoration Branch at 257-2201.

Appendix D: Data Collected from Environmental Resource Value Study Questionnaire

#	WTP	WTP	MEM	EDU	AGE	INC	YRS
1	0	0	4	5	5	6	1
2	100	200	4	3	2	2	2
3	10	10	4	3	4	2	3
4	50	100	5	4	6	5	1
5	100	100	5	3	4	3	2
7	75	100	7	4	4	5	3.5
8	250	500	4	3	4	2	2
9	50	80	4	4	3	1	3
10	0	0	5	4	3	3	1
11	75	100	3	3	3	3	1
12	250	320	3	5	4	5	1
13	0	400	6	2	4	2	2
14	0	0	2	4	6	6	3
17	0	0	4	4	5	4	2
18	0	0	4	4	4	4	3
19	0	0	4	5	4	4	1
20	20	25	3	5	5	6	2
21	300	400	4	3	5	2	3
22	0	0	3	5	5	5	
23	0	0	4	3	6	3	3
25	0	0	2	4	4	4	0
26	0	0	4	5	4	6	1
27	10	15	4	3	3	3	1
28	0	85	6	5	4	6	0.5
29	75	100	6	5	4	5	5
30	100	100	4	4	3	4	2.5
31	0	250	5	4	5	3	2
33	50	75	4	5	3	4	0.5
34	0	300	2	3	5	3	4.5
35	200	260	4	4	3	3	2
36	0	100	4	3	4	3	1
37	0	100	4	5	6	5	2
38	50	50	4	3	5	3	1
39	0	250	4	5	4	4	4
40	250	400	4	5	3	4	0.1
41	300	750	5	5	6	6	0.8
42	500	520	3	5	5	6	2
43	20	20	4	3	3	5	1
44	0	0	4	3	4	2	3
45	0	80	5	5	4	5	2
46	60	60	4	5	5	5	1
47	0	150	4	5	4	5	2
48	100	110	3	5	5	5	3
49	5	10	4	5	4	4	2
50	5	5	4	5	4	4	1
51	0	0	4	5	6	6	0.5
52	120	170	2	3	6	4	2
54	30	100	2	4	2	3	2
55	200	400	4	5	3	3	1
57	0	200	5	5	6	6	1.5
58	130	136	4	5	6	5	1
59	5	5	3	5			1
60	0	0	4	3	4	2	

#	WTP	WTP	MEM	EDU	AGE	INC	YRS
62	0	0	3	5	4	4	1.5
64	0	0	4	4	3	3	1
65	0	200	4	3	4	4	2
66	200	200	4	3	4	4	3
67	70	75	4	5	5	3	3.5
68	40	500	4	5	4	3	1.5
69	300	400	2	4	2	3	1
70	100	175		4	5	4	2
71	50	50	4	5	5	4	3
72	0	0	4	5	4	4	2.5
73	0	0	3	5	4	5	0.5
74	0	170	2	3	2	3	3
75	100	100	4	3	4	3	3
76	0	100	3	4	7	6	1
77	100	500	3	3	3	1	3
78	200	252	3	5	4	4	1.5
79	50	50	2	5	6	6	1
80	0	0	3	4	5	6	2
81	0	0	5	5	5	4	3
83	0	0	4	3	5	3	0.5
84	0	0	4	5	3	5	0.5
85	0	200	4	5	7	6	2.5
86	100	150	3	5	5	2	2
87	100	100	2	3	7	5	1
88	75	75	4	3	2	2	1.5
89	100	100	4	4	4	5	3
90	0	20	5	4	6	5	2
91	10	10	2	5	2	2	4
92	0	70	3	5	6	5	1.5
94	45	45	2	5	2	3	2
95	0	200	7	5	4		1
96	150	200	2	5	2	2	0.5
97	50	50	4	5	4	4	2.5
99	0	0	4	4	3	4	2
101	0	0	4	5	5	3	4
102	0	0	4	4	6	6	1.5
103	0	300	6	3	6	5	2
105	200	200	4	3	4	3	3
106	0	0	3	5	6	4	2
107	0	150	4	4	6	5	2
108	100	125	3	3	3	2	3.5
109	100	140	4	5	3	4	1
110	20	100	4	5	6	6	1
111	100	100	5	5	3	4	3
112	0	0	4	5	3	4	1.5
113	0	0	4	5	4	6	2
Sample size	99						
Mean	$59.09	$123.67	3.83	4.22	4.29	4.00	1.91
Median	$10.00	$100.00	4.00	5.00	4.00	4.00	2.00
Standard deviation	$90.36	$148.41	1.05	0.88	1.27	1.34	1.03

Appendix E: Actual Costs of Woodland Hills Landfill 8 and 10 Restoration Project

Capital Costs				
Landfill Cap	Total Cost	Months	Cost/Month	Present Value
Documentation	$31,422.08	2	$15,453.48	$33,350.15
Site Preparation	$1,693,918.14	4	$416,537.25	$1,793,305.21
Pre-construction Tests	$174,766.69	2	$85,950.83	$185,490.43
Landfill 10N	$2,199,079.93	16	$134,912.88	$2,247,246.82
Landfill 10S	$1,520,766.57	16	$93,298.56	$1,554,076.22
Landfill 8	$4,132,698.97	12	$338,745.82	$4,266,367.27
Off-Landfill Construction	$1,303,865.34	16	$79,991.74	$1,332,424.16
O&M During Construction	$138,830.69	6	$22,635.44	$140,073.91
Post-construction Tests	$465,157.08	6	$75,840.83	$469,322.52
Change Orders	$30,526.44	18	$1,665.08	$31,274.93
			Subtotal	$12,052,931.62
Leachate Treatment Plant	$698,000.00	9	$76,423.36	$708,727.76
			Subtotal	$708,727.76
Operations and Maintenance (O&M) Costs		Quarters	Cost/Quarter	
Leachate Treatment Plant		360	$162,000.00	$20,284,664.71
			Subtotal	$20,284,664.71
			Grand Total	$33,046,324.09

Appendix F: Demographic Information for Expected Value Calculation

Mean number occupied households in Woodland Hills	342	Total number housing units in Woodland Hills	350
Mean number occupied enlisted households	78	Total number enlisted housing units	80
Mean number occupied officer households	263	Total number officer housing units	270
Mean number residents per household	3.83	Mean residence time in Woodland Hills	1.91 years
Enlisted female-to-male military ratio	0.162	Officer female-to-male military ratio	0.154
Mean enlisted spouse rate	0.94	Mean officer spouse rate	0.98
Mean enlisted member age	31.12	Mean officer member age	33.34
Mean enlisted spouse age	30.21	Mean officer spouse age	32.20
Mean Enlisted Member Income	$21,000.00	Mean Officer Member Income	$37,000.00
Mean Enlisted Spouse Income	$22,000.00	Mean Officer Spouse Income	$27,000.00
Mean number enlisted children	1.89	Mean number officer children	1.85
Mean age enlisted children	12.06	Mean age officer children	12.25
Female enlisted military member		Female officer military member	
Base-period income	$105,000.00	Base-period income	$185,000.00
Wage growth rate (per five-year period)	0.18	Wage growth rate (per five-year period)	0.23
Non-market hours (per five-year period)	7830	Non-market hours (per five-year period)	7830
Non-market wage	$8.72	Non-market wage	$8.72
Female enlisted spouse		Female officer spouse	
Base-period income	$110,000.00	Base-period income	$135,000.00
Wage growth rate (per five-year period)	0.05	Wage growth rate (per five-year period)	0.08
Non-market hours (per five-year period)	9915	Non-market hours (per five-year period)	9915
Non-market wage	$8.72	Non-market wage	$8.72
Male enlisted military member		Male officer military member	
Base-period income	$105,000.00	Base-period income	$185,000.00
Wage growth rate (per five-year period)	0.18	Wage growth rate (per five-year period)	0.23
Non-market hours (per five-year period)	3480	Non-market hours (per five-year period)	3480
Non-market wage	$18.31	Non-market wage	$18.31
Male enlisted spouse		Male officer spouse	
Base-period income	$110,000.00	Base-period income	$135,000.00
Wage growth rate (per five-year period)	0.05	Wage growth rate (per five-year period)	0.08
Non-market hours (per five-year period)	3835	Non-market hours (per five-year period)	3835
Non-market wage	$18.31	Non-market wage	$18.31
Female enlisted child		Female officer child	
Base-period income	$100,000.00	Base-period income	$160,000.00
Wage growth rate (per five-year period)	0.07	Wage growth rate (per five-year period)	0.10
Non-market hours (per five-year period)	9559	Non-market hours (per five-year period)	9588
Non-market wage	$8.72	Non-market wage	$8.72
Male enlisted child		Male officer child	
Base-period income	$100,000.00	Base-period income	$160,000.00
Wage growth rate (per five-year period)	0.16	Wage growth rate (per five-year period)	0.21
Non-market hours (per five-year period)	3535	Non-market hours (per five-year period)	3534
Non-market wage	$18.31	Non-market wage	$18.31

Male		
Age	Death Rate (per 1000 alive)	Life Expectancy
30	10.55	43.73
35	13.29	39.20
40	16.52	34.78
45	23.90	30.37
50	37.53	26.07
55	61.58	21.98
60	99.29	18.28
65	159.81	14.90
70	244.84	11.89
75	373.70	9.28
80	577.56	7.04
85	1,000	5.17

Female		
Age	Death Rate (per 1000 alive)	Life Expectancy
30	4.13	49.90
35	5.74	45.13
40	8.56	40.37
45	14.32	35.63
50	23.52	31.09
55	37.70	26.75
60	60.34	22.63
65	97.62	18.82
70	152.58	15.21
75	243.00	11.88
80	377.52	8.94
85	1,000	6.39

Appendix G: Sources of Assumptions Made in Analysis

ID #	Assumption	Data Source
1	Woodland Hills housing occupancy rates are equal to the Air Force mean of 98%	United States Air Force Statistical Digest, 1995
2	Woodland Hills residents follow the same distribution of female-to-male military member ratio as the Air Force mean of 0.162 (enlisted) and 0.154 (officer)	United States Air Force Statistical Digest, 1995
3	Spouse rates can be inferred by comparing the mean number of children to the mean number of residents per household (94% for enlisted, 98% for officer)	Woodland Hills contingent valuation study (mean residents per household); H. Leroy Gill (mean number of children per household)
4	Woodland Hills residents follow the mean military member and spouse age, income, and wage growth for all Air Force military housing residents	H. Leroy Gill
5	Woodland Hills residents follow the mean non-market time and wage for all US adult population	King and Smith, 1988
6	Woodland Hills residents follow the mean death rate and life expectancy for all US adult population	Statistical Abstract of the United States, 1994
7	Woodland Hills excess cancer health risk follows mortality/morbidity ratio of cancer rates for all US population	National Institutes of Health, 1995
8	Woodland Hills remediation project will operate for 30 years	88th Air Base Wing, Environmental Restoration Branch
9	Treatment of non-fatal cancer follows mean values for all US population	Epstein, 1978 (cost of treatment and reduced earning potential); Statistical Abstract of the United States, 1994 (duration of treatment)
10	Wages of Woodland Hills residents do not continue to grow in real dollars after age 50	H. Leroy Gill
11	Non-market income of Woodland Hills residents remains constant throughout their lifetime	King and Smith, 1988

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