RECLAMATION

Managing Water in the West

Placing an Economic Value on the Loss of Life – Value of Statistical Life Estimates that are Applicable to Reclamation Facilities

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U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Security, Safety and Law Enforcement
Denver, Colorado

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MEMORANDUM

To: Chief Security Officer, Security, Safety and Law Enforcement Office
Attention: 84-45000 (Taussig)

From: Steve Piper
Economist, Economics and Resource Planning Group

Subject: Report on Loss of Life Valuation

The Economics and Resource Planning Group in the Technical Service Center has completed an evaluation of the methodologies that are most appropriate for use in estimating the value of a statistical life. This evaluation also includes a recommended range of values of life that may be appropriate for use as part of a risk analysis of the Bureau of Reclamation facilities completed by Reclamation's SSLE Office.

The final report, *Placing an Economic Value on the Loss of Life – Value of Statistical Life Estimates that are Applicable to Reclamation Facilities*, is attached. The report is labeled and classified as FOR OFFICIAL USE ONLY (FOUO) and should be handled and stored in compliance with Reclamation guidelines.

If you have any questions, please do not hesitate to contact me. I can be reached at 303-445-2736.

Attachment

cc: 84-45000 (Duran)
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Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

BUREAU OF RECLAMATION
Technical Service Center, Denver, Colorado
Economics and Resource Planning Group, 86-68270

Placing an Economic Value on the Loss of Life – Value of Statistical Life Estimates that are Applicable to Reclamation Facilities

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Introduction

The concept of placing a value on human life for the purposes of aiding in the determination of government policies is not very attractive to many people. The initial feeling of some is that everything possible should be done to protect individuals from harm. An image that may come to mind is balancing the value of a person's life with the expenditures required to prolong that person's life, much like the debate occurring in the health care industry. However, there are several different types of approaches to measuring the value of lost lives which can avoid the philosophical dilemma of directly measuring the value of a specific human life.

Although measurement of the value of life may seem unreasonable at first, it is a necessary part of evaluating government programs and regulations aimed at improving or maintaining the health and safety of the general population. The primary reason it is necessary to provide a monetary measure for loss of life is due to limited budgets available for government programs, including programs that reduce the risks of illness, injury, or death. It is desirable from a public policy standpoint to spend public funds in a way that maximizes public benefits given a finite budget. Therefore, actions that prevent injury or death need to be measured in a way that the benefits from preventing injury or death can be compared to the benefits generated by another action that is not related to loss of life or injury. If a consistent comparison cannot be made between actions that generate very different types of outputs, then the potential exists for a misallocation of funds between projects and a loss in social welfare compared to the optimal allocation of limited funds.

Ideally, in addition to accounting for the economic benefits associated with reducing the loss of life and reducing injuries, methodologies that are consistent across all agencies should be used. Otherwise the situation could arise where a set of methods used by one agency shows that an action was economically justified while the very same action would be found to be unjustified by another agency using a different method. This could lead to a potentially inefficient set of regulations and an agency accepting an action that is not truly economically justified or rejection of an action that should be undertaken. Therefore, it is important to evaluate the methods used to measure the value associated with the loss of life for consistency and theoretical correctness.

The most widely used approaches to valuing the loss of life in a policy setting are discussed briefly below along with the theoretical and practical advantages and shortcomings of each. This includes a discussion of the difference between the "value of life" and the value of a statistical life. This paper then presents an analysis of the best approach for valuing the loss of life from the perspective of

Bureau of Reclamation safety and security. It is recognized that although consistency in approach across all Federal agencies would be desirable in theory, the differences in agency missions and activities they oversee may make it very difficult to come up with one desirable approach that can be applied by all agencies.

Assigning a value to life for policy analysis purposes

As mentioned in the introduction, people are very hesitant when asked to place a value on life. Most rational people, if asked, would be willing to pay essentially everything they have to avoid certain death. Therefore, we could say that there is a limitless value to life bounded by our maximum ability to pay. However, most people are willing to accept some small risk of death or injury that would be associated with an action in order to gain some benefit or utility associated with that action. In other words, we will take a small risk in order to gain a meaningful benefit that outweighs the risk. For example, driving a car entails some risk of injury or death and the benefit of driving a car is to get from one place to another fairly quickly. The person driving the car may have many choices that will affect the extent of the risk they are taking. If they drive fast, their risk of getting into an accident is likely to increase (increased cost) but they will arrive at their destination sooner (increased benefit). We can observe people driving fast, in many cases well over the speed limit, on any given day. The increased risk taken by an action combined with the benefit of that action is the basic idea behind the value of a statistical life (VSL). The VSL is based on the willingness of people to trade off wealth for a reduction in the probability of death or the willingness of people to accept an increase in wealth in exchange for an increase in the probability of death. The values associated with different probabilities of death are adjusted to represent a value that would correspond with a death. The value that corresponds to a death is a VSL.

There is a subtle but important difference between the VSL that can be used to help establish government policies and regulations and the "value of life" for a specific individual. The VSL is based on risks, usually relatively low risks, associated with various events and compensation individuals require to take that risk. Tradeoffs between the risk of death or injury and expenditures or income are commonly weighed by individuals. We may spend money on safety features for automobiles or homes that will decrease the risk of an accidental fatality or we may be willing to accept a higher risk of a fatality on the job if we are adequately compensated with a higher salary. In these cases we are defining the trade-off between wealth/income and the probability of death.

The above explanation of the difference between the "value of life" and the VSL identifies an important point. If the willingness to pay to avoid certain death is very high (essentially limitless if a person has endless resources) and the willingness to accept an incrementally small (essentially zero) increase in risk at relatively low levels of risk of death is low, then the VSL will be greatly influenced by the risk of death associated with a specific activity or situation.

Assuming people are risk averse, the VSL associated with a very high risk situation is likely to lead to a high VSL estimate compared to the VSL in a very low risk situation. Therefore, a high risk activity will translate into a higher VSL than a low risk activity even though both VSL's represent one statistical life for the same individual. This situation is often referred to as the "dead-anyway" effect, where an individuals' willingness to pay for a small reduction in the risk of death increases with the initial level of the risk (Pratt and Zeckhauser, 1996). This is the result of differences in the marginal utility of wealth when an individual is alive or dead.

Another aspect that needs to be accounted for is the wealth effect. A VSL increases with wealth because the wealthy have greater material wealth to lose if they die and the loss in utility from spending when they are alive is smaller due to diminishing marginal utility with respect to wealth. As a result, the VSL increases as wealth increases. Therefore, it is important to evaluate the VSL at a level of risk and wealth that is appropriate for the situation under consideration.

Approaches that can be used to value loss of life

Four different approaches that are frequently used to measure the values associated with the cost of death, injury, or illness are described in this section. These approaches include: the willingness to pay or willingness to accept payment for a change in risk, cost of illness, cost effectiveness, and health-health analysis.

Measuring willingness to pay or willingness to accept payment associated with risk

The theoretically correct measure of the economic value associated with the benefits from reducing or avoiding the risk of death or injury or accepting risk is the willingness to pay (WTP) to reduce risk or the willingness to accept (WTA) payment for increased risk. Willingness to pay and the willingness to accept payment are based on individual demand curves and the idea that individuals can make rational decisions regarding the risk of death or injury. These decisions may be revealed through actual observed market based behavior or by the results of responses to hypothetical market situations. There are three general criticisms of the WTP and WTA approaches that are frequently mentioned. First, is it possible for individuals to accurately assess the risks of death or injury? In many cases we may rely on the judgment and information of others to assess our risk and we may not be aware of all the uncertainties involved. In addition, for risks that are very small, we may react as if the risk were actually zero. Second, do individuals fully understand the implications of all possible outcomes? While we may accept that death or injury is a possible result from a decision, we may not fully appreciate what will happen having not experienced the outcome before. Third, life is not a commodity in the typical sense, so it should not be treated in a traditional economic context.

The question regarding the ability to accurately assess risk is difficult to answer. There are many psychological and social factors that influence how people perceive risk. These factors include: simplifications that we use to make judgments about risk such as recent events discussed in the media or "common sense" in place of objective research and understanding, lack of interest in learning about risk, unrealistic optimism, difficulty understanding probabilities, the desire for certainty, unwillingness to change attitudes, how people judge the magnitude of risk, and the point at which people actually begin to worry about a risky event (Covello and Sandman , 2001). There are additional characteristics of an event that can influence the perceived risk, such as control, familiarity, reversibility, and nature versus human caused hazards. Generally, an event that a person has no control over, is unfamiliar and irreversible, and is human caused will be judged to be have a higher risk than an event that does not have these characteristics. As a result of the potential difficulty individuals have in assessing risk, the value derived from an analysis assigning a value to a risky outcome should be based on the perceived rather than actual risk because the perceived risk actually drives individual behavior. The value derived from the perceived risk can then be adjusted to reflect the value associated with the actual risk.

The second issue pertaining to not being able to fully understand all outcomes is similar to the first issue, except that it is directed at the value of the condition if an event occurs instead of the probability of the event occurring. Both the probability of an event and the value placed on an outcome are used to estimate the expected value associated with a particular event. Providing all available information regarding an event will help to accurately evaluate conditions associated with an event. If the perceived outcome is not the same as the actual event, then adjustments need to be made so the value of the actual outcome is represented.

Although life is not a typical economic good, the risk of injury or death is commonly recognized and compensated in actual economic market transactions. Assuming individuals are behaving rationally (maximizing utility) and that they are correctly perceiving and incorporating risk into their decisions, the compensation they receive for risk is a measure of the value of the risk of accepting an undesirable result. For example, high risk jobs receive "hazard pay" and individuals pay for safety devices that reduce the risk of injury or death. Therefore, even though life is not a typical commodity, individuals commonly make life-wealth tradeoff decisions in a market setting.

The cost of illness approach as a measure of the value of life

A method that has been used frequently in the health field to place a value on the benefits of health improvements is to estimate all the costs created by an illness or injury and to use those costs as a proxy for the benefits of avoiding illness or injury. The cost of illness (COI) approach includes two different types of costs: direct and indirect. Direct costs include expenditures for doctor visits, hospitals, medications, and any other out-of-pocket expenses. Indirect costs include the

present value of all wages lost due to illness, injury, or death. Theoretically indirect costs should also include costs associated with pain and suffering. However, the costs of pain and suffering are difficult to measure and are generally limited to legal proceedings when determining damages. The COI approach is frequently used in legal cases to help determine wrongful death awards.

The COI approach provides a monetary measure of how an injury or death affects spending patterns in the economy. These spending patterns are affected by the individual as a consumer (medical expenses) and as a producer (wages). This would theoretically represent the value of an individual as a part of the economy. Wages earned by an individual are considered representative of the value contributed by their labor to the economy. When an action creates extensive morbidity or premature death, indirect costs will represent a significant portion of the total cost of illness. When this is the case, using lost wages as the basis for estimating indirect costs becomes much more of a concern because of the potential for inaccurately estimating the value of life. There are many assumptions contained within the use of wages to measure the value of labor, including the assumption that an individual is working at a job that fully utilizes their skills. It is also assumed that medical expenses fully account for the cost of bringing an individual back to the same condition that they were before the event. Clearly, this is not the case for a death and is not likely to be true for an injury since there is no guarantee that the individual will be brought back to the pre-injury level of health.

The use of labor income as a measure of lost benefit to the nation from injury or illness is based on the assumption that an individual's value is derived from their labor capital as part of the productive capacity of the economy. In other words, the economic contribution of an individual comes from their labor as a factor of production and its impact on national income. Therefore, accepting wage as a measure of the value of life requires not only accepting labor contribution as the determinant of human value but also that national income is an accurate measure of well-being. There is no reason to expect that national income is strongly correlated with social well-being. National income includes expenditures for goods and services that mitigate problems that otherwise would reduce well-being. As a result, the increase in national income may indicate an improvement in well-being while social well-being has not necessarily improved. In addition, the COI means that "non-productive" members of society (from the standpoint of contribution to the value of national income) do not have economic value. Therefore, the premature death of individuals who provide unpaid voluntary service or are stay-at-home parents would not be considered to have lost indirect benefits using the COI approach. This assumption is not realistic and is not acceptable for accurately valuing the loss of life.

Despite the shortcomings of the COI approach, it is frequently used in the health economics and legal fields. The primary reason for its use has been the relative

ease of obtaining data and estimating the cost of illness or death, especially compared to estimating willingness to pay.

Cost effectiveness of reducing loss of life or illness

This approach is not very useful for establishing values associated with a loss of life. Cost effectiveness is simply an evaluation of the costs required under different alternatives to meet a loss of life reduction goal and it does not require the actual measurement of benefits. It is assumed in a cost effectiveness analysis that the benefits from reducing the risk of death are worth the cost. For example, a cost effectiveness analysis could theoretically look at a range of costs for alternatives that would reduce the risk of death or injury associated with an event to zero. The least costly alternative would be most cost effective and would be chosen in a cost effectiveness analysis. However, if individuals are willing to accept some risk in order to avoid the cost of attaining zero risk, then the most cost effective alternative would not be a measure of the benefit from avoiding a loss of life or injury. Cost effectiveness cannot tell us what level of risk and the associated value of the life-risk trade-off is optimal. As a result, cost effectiveness analysis does not provide a measure of welfare and cannot be used to establish a value associated with loss of life.

Health-Health Analysis

Health-health analysis is generally used in the regulatory area to evaluate the number of deaths that could occur as a result of lost income to households that is used instead to fund a program intended to save lives. The cost of complying with the regulations will, at least in part, be passed on to individuals. One possible effect of reduced disposable income is reduced spending on health and safety items, which increases the risk of death. A reduction in individual purchases of health promoting goods and services will lead to increased mortality and morbidity. Therefore, the cost of implementing a regulation intended to save lives can actually contribute to a loss of life. Health-health analysis is based on the idea that risk reduction is a normal good (higher income means we want more of it) and that health and safety programs have to be publicly financed. Money for those programs has to come from individuals and thus paying for programs reduces individuals' ability to pay for private risk reduction.

The most important, and the most difficult, part of a health-health analysis is correlating income losses with mortality. Lost income leads to a potential increase in the risk of death or injury from a source other than the source that is being targeted by a regulation. This secondary cost must be accounted for in order to accurately assess the value of life saved. In order to complete a health-health analysis, dollars (income) must be translated into health effects. There is a distinct cost from implementing a regulation in terms of lost income to households and support for this type of regulation indicates a willingness of households to spend to avoid the risk of injury or death. However, the relationship between income and mortality/morbidity needs to be better understood in order to reliably estimate benefits when the loss of life is a major

impact associated with an action. This difficulty needs to be addressed before it can be useful for evaluating the value of life.

Health-health analysis has other drawbacks that limit its usefulness for valuing loss of life. First, the methodology treats small costs (income related losses) incurred by many people equivalently to large costs (lost lives) incurred by a few people. The sum of all small costs is considered to be an accurate measure of changes in utility. However, small costs may have little or no actual impact on individual utility while a large cost is likely to have a significant impact on utility. Second, there is no way of knowing if the costs of the regulation were the costs that actually lead to a reduction in household spending that affected the risk of injury or death. It may be that the cost of the regulation was inconsequential and that some other increase in unrelated spending actually lead to increased risks. Although the health-health approach is useful for understanding the net impacts of regulation on the risk of death or injury, the lack of a quantifiable relationship between income and health is most problematic.

Potentially Viable Methods for Estimating a Range of Values for Loss of Life

The WTP/WTA and COI approaches have the greatest potential for evaluating the value associated with the loss of life. The cost effectiveness and health-health types of analyses do not provide theoretically valid measures of economic benefit under any circumstances. The WTP and COI approaches are based on very different assumptions. WTP is based on measurement of benefit as needed to compensate for risk while COI is based on reduced cost as a proxy for benefits. In order for the COI approach to be a valid measure of the value of loss of life, the costs associated with death or injury must correlate with the "value of life." WTP would be considered an accurate measure of the value associated with loss of life if an approach can be implemented that reliably estimates the benefits/costs associated with risk.

There is no direct link between benefits and costs that supports the use of COI as a proxy measure of the value of life. If an individual were asked how much they would be willing to pay to eliminate the probability of death for a specific condition, their response would probably not be influenced only by the present value of their earnings from that point forward. From the standpoint of that individual, lost earnings and increased medical expenses are only two factors figured into the value of reducing the risk of death. Individual welfare losses would also include disutility associated with pain and suffering as well as non-market consumption and production activities.

According to Linnerooth (1979), there is no useful relationship between the value of an individual's risk of death and their lifetime earnings. This means that using a value based on COI in an economic feasibility framework will not necessarily result in an economically desirable choice. As a lower bound value of loss of life, the COI approach will always underestimate the value of reducing the risk of death and would therefore undervalue estimates of the VSL (Linnerooth, 1979).

Given the lack of a one-to-one relationship between COI and WTP, we cannot even say that COI will consistently and unambiguously lead to a lower bound of WTP. Therefore, COI based studies cannot be used as a reliable estimate of even a lower bound value associated with loss of life. It is stated in Kuchler and Golan (1999) that "any attempt to find a middle ground between WTP and COI seems to reduce, not improve, the theoretical justification of either approach." Therefore, only studies based on a WTP type of approach are recommended for evaluating the value associated with a loss of life.

It is important to note that the use of VSL's allows for completion of a benefit-cost type of analysis rather than just a cost-effectiveness analysis. Cost effectiveness analysis avoids placing a monetary value on health by comparing the incremental cost of the intervention to the incremental health effect achieved. The problem with cost effectiveness analysis is that it doesn't actually answer the question if the benefits of improving/extending life are greater than the costs. It is assumed that an end goal is desirable enough (generates large benefits) to justify the expenditures necessary to improve/extend the life. Cost effectiveness will always result in a selected alternative.

Methods that can be used to estimate willingness to pay or willingness to accept payment

The willingness to pay/accept payment approach in estimating the VSL is essentially an attempt to apply a private market decision making process for risk to a public sector good or service. Therefore, results from the application of this approach can be used in a benefit-cost framework to help determine the economically efficient level of risk associated with a particular event.

There are two general methods that can be used to estimate the willingness to pay for increased safety or the willingness to accept payment for increased risk, revealed preference and stated preference. The revealed preference approach is based on observed behavior while the stated preference approach is based on what individuals say they will do. These approaches can be applied in a variety of ways, including:

- Revealed preferences in the labor market – Using actual behavior in the labor market to infer the VSL. The risk of death is one variable among many that would characterize a particular job. The influence of risk, holding other variables constant, on wage can be used to infer the value placed on a statistical life. Labor market behavior reveals the value individuals place on their perceived risk of death.
- Revealed preferences in the consumer market – Based on the choices consumers make regarding goods and services that could reduce the risk of death or injury. The amount individuals are willing to pay for products that lower the probability of death can be used to infer the value of a statistical life.

- Stated Preference – Using contingent valuation techniques where individuals indicate the amount they would be willing to accept as compensation for increased risk of injury or death or the amount they would be willing to pay to reduce risk in a survey setting. The respondents' answer is contingent upon the hypothetical result occurring.
- Meta-Analysis – Using the results of previously completed revealed or stated preference studies to estimate a representative value for a VSL. A meta-analysis can control for exogenous factors that can affect the VSL. For example, different studies will likely be based on a range of risks and a variety of situations. The risks can be accounted for to adjust representative values of a statistical life.

The conceptual foundation of both the revealed preference and stated preference approaches in estimating the VSL is that societal WTP and WTA for changes in risk should reflect individuals' risk valuations, whether elicited directly through surveys or revealed in their labor or consumer market decisions.

Revealed Preference

The revealed preference approach to measuring the VSL is based on actual observed behavior in situations with different levels of risk. Decisions made in different situations reflect how individuals value tradeoffs between changes in risk and the benefits/costs associated with the possible outcomes. These tradeoffs can be used to value government policies and regulations that influence the risk of death, injury, or illness. The value of the risk reduction can then be compared to the cost of the risk reducing policy to evaluate the desirability of a policy or regulation. For example, the wage associated with a job that is very dangerous can be compared to the wage associated with a job that is not as dangerous to infer the wage needed to compensate an individual to accept the higher risk of a more dangerous job. The wage would represent the minimum amount needed to compensate for taking greater risk. This can then be used to derive a VSL.

In the revealed preference approach the household has choices over many market goods and services, some of which affect the risk of a fatality or injury, and the household maximizes its utility with respect to these goods and services given exogenous factors such as environmental quality, market prices, and a budget constraint. The analyst estimates a health related production function where different levels of risk are associated with different levels of utility. In a simple household model, the willingness to pay for a reduction in the risk of a fatality would be equal to the reduction in household expenditures that would lead to the household being at the same level of utility after a reduction in fatality risk as before the risk reduction. The revealed preference approach assumes that choices related to the risk of a fatality or injury lead to optimization of individual preference functions that include fatal outcomes and injuries in a health related production function. It is also assumed that individuals have the ability to choose among a range of factors that are part of a health production function and a budget constraint.

The primary advantages of the use of revealed preference to place values on risk and an associated VSL are:

- Revealed preference is based on actual observed behavior. Supports the argument that we are more likely to get valid measures of value based on what we see people do rather than from what people tell us they would do. There may be complications that individuals do not consider that will keep them from doing what they say. However, individuals who are actually doing something we observe have actually dealt with those complications.
- Since revealed preference is based on actual choices, these choices reflect the perceptions and experience of individuals which actually influence willingness to pay or willingness to accept payment.

There are also several shortcomings associated with the use of revealed preference. These shortcomings include:

- The true underlying household production function and household preferences from which utility is derived is unknown.
- Individuals have subjective perceptions of what can actually be done to protect themselves from risk or to reduce risk, but these perceptions may be incorrect.
- It is assumed in revealed preference that observed choice and utility maximization are synonymous. However, there may be unknown constraints that are driving decisions that otherwise would not be made. For example, a person may accept a high risk job because they need to stay in an area for family reasons rather than because they are evaluating the trade-off between wage and risk.
- Revealed preference is based on historical data, which may not be applicable to conditions when a new policy is implemented.

Stated Preference

Another approach that can be used to evaluate the VSL is the stated preference approach, where individuals are surveyed and asked how they would react in different risk situations. The stated preference approach is very similar to the revealed preference in that both approaches assume that there is an underlying household production function and preferences that include risk of a fatality or injury and consumption of other goods and services that determine utility. The difference is that stated preference is based on household responses to specific risk questions in a hypothetical market rather than observed behavior in a market that may not be comparable to the situation under consideration.

Stated-preference (SP) surveys are based on the hedonic principle that commodities have value because of their attributes. For example, a car has value because of specific characteristics such as size, color, comfort, body style, handling, gas mileage, and price. People have preferences among these attributes and are willing to accept tradeoffs among them. SP surveys are designed to measure the underlying utility function that is consistent with respondents stated

willingness to accept such tradeoffs. By including a cost attribute, the implicit marginal utility of money can be used to rescale utility values in monetary terms.

There are two primary advantages associated with using the SP approach to estimate the VSL, including:

- Allows an analyst to create a hypothetical market that represents risk tradeoffs for the specific situation of interest.
- The use of surveys allows an analyst to control specification of the trade-off between risk and household utility, which limits the number of unknowns in estimation of the respondent's preferences. The benefits or costs from changes in the risk of death or injury of can then be estimated directly.

However, there are also concerns with the use of the SP approach (surveys) for estimating the willingness to pay for improved safety or the willingness to accept payment for increased risk. These concerns include:

- The hypothetical nature of the market. People will not react to a hypothetical situation in the same way as an actual market situation because the hypothetical decision is not enforceable. There may be a fundamental difference in the way people make hypothetical decisions compared to how they make actual decisions. Hypothetical decisions are not likely to be as serious as actual decisions, particularly when it pertains to safety.
- The assumption that people understand the "good" in question and will reveal their preferences in the hypothetical market just as they would in a real market may not be correct
- The answers provided to a willingness to pay (willingness to accept payment) question in a contingent valuation format may be biased because the respondent is actually answering a different question than intended. Never certain that the respondent understands the question.
- Survey responses may express what individuals would like to have happen rather than their true valuation of an actual market.
- Strategic bias is possible, where a respondent provides a biased answer in order to influence a particular outcome.
- Information bias may arise whenever respondents are forced to value attributes with which they have little or no experience.
- Non-response bias is a concern because individuals who do not respond are likely to have different values than individuals who do respond.

Which approach is best, revealed preference or stated preference?

There are advantages and disadvantages to both revealed preference and stated preference approaches. The ability to precisely define a relationship between risk preferences and monetary impacts in a hypothetical framework must be weighed against the ability to use data based on presumably rational decisions made in an actual market requiring assumptions about the risk-income relationship. The SP approach requires respondents to understand the hypothetical market presented to

them, to be able to correctly interpret the risk and monetary impacts in the hypothetical market, and to state a response where an exchange of money isn't required that is identical to what they would actually have to pay. The revealed preference approach assumes that people are well informed, understand the risks and outcomes, and behave in a rational economic way. Therefore, the primary question that needs to be answered is this: is the potential bias associated with the hypothetical nature of stated preference greater than or less than the potential bias associated with an incorrect perception of risk and less than perfect knowledge of the household production function?

There have been several studies that have compared the value of real economic commitments with hypothetical contingent valuation responses. These studies indicate that the stated preference approach generally overvalues the willingness to pay for environmental goods. A few of these studies are briefly mentioned below.

A 2005 study by Duffield, et al. (2005) evaluated the difference between hypothetical and actual donations to benefit instream flows for Montana fisheries. The analysis estimated that the simple mean cash transaction was about 50% lower than the mean for contingent donations. Another study of the willingness to pay for environmental goods in Norway indicated that there was a large discrepancy between the stated maximum willingness to pay in a hypothetical market setting and actual payment (Seip and Strand, 1992). The actual payment was much lower than the hypothetical amount. The percentage stating they were willing to pay a membership fee for an environmental fund was about 10 times higher than the number that actually paid the fee. The possible reasons for the differences may be due to confusion about what good is actually being measured or unfamiliarity with the market.

An analysis by MacMillan (2005) reviewed over 30 different studies that compared stated preference based willingness to pay estimates with actual cash transaction based values. The MacMillan analysis found that the hypothetical market based values were consistently higher than actual contributions in experimental settings, ranging from 50% to 500% greater than actual contributions. The analysis concluded that there was hypothetical bias associated with the stated preference approach. The analysis included a meta-analysis looking at the influence of different study characteristics on the magnitude of difference between stated preference values and actual values. The meta-analysis indicated that the hypothetical bias was less for well defined private goods than for public goods that are not typically traded in a market setting.

Another study by Champ, et al, (1997) indicated that contingent donations badly overestimated the actual willingness to donate of Wisconsin residents toward a road removal project in Grand Canyon National Park. The study also indicated some promise in methods for reducing the potential for overestimating willingness to pay.

The general finding in the literature is that hypothetical payments generally exceed actual payments, providing evidence of significant hypothetical bias. Given the hypothetical bias of stated preference, especially for non-market goods and services, and the fact that revealed preference is based on actual decisions, the preferred basis for estimating the VSL for safety and security functions within the Bureau of Reclamation is revealed preference.

Potential problems in applications measuring the VSL

It needs to be recognized that there are some potential problems in accurately measuring the VSL based on revealed preference. First is the problem of endogeneity of risks. This problem can best be explained with an example. The choice of speed driven by an individual will influence travel time. Other things equal, a driver will prefer shorter travel times because time represents a cost of travel. However, higher speeds generally increase the risk of a fatality. We could look at the relationship between speed and fatalities across different roads to understand the trade-off between benefits (reduced travel time) and the risk of a fatality. However, road conditions and traffic congestion are exogenous (outside the system) factors that will have a major influence on both fatalities and speed. Therefore, increased speed may cause more fatalities but at the same time speeds may be higher when there are fewer exogenous fatality risks. The result is that the net effect of a change in speed is unknown and without some additional assumptions the resulting relationship between speed and risk cannot be used to estimate a range of VSL.

Another problem is associated with the commonly used revealed preference approach of measuring the VSL using the relationship between wages and fatality risks on jobs. While it would appear that the relationship would be fairly simple to estimate, it is rarely the case that identical jobs can be compared which have different fatality risks. The relationship between wages and fatality risks contains both a causal effect due to higher wage demanded to compensate for higher fatality risks and the result of other factors (skill, working conditions, etc.) that affect pay and are correlated with fatality risks across job types. Therefore, the net effect between wage and fatality risk is unclear.

A third problem involves whose preferences we are measuring. The VSL would be expected to vary across people with different preferences, income levels, and ages. Whose preferences are we actually measuring and whose do we want to measure? Variation depends on risk acceptance behavior and there is no way of knowing if the data used to estimate the VSL is representative of the general population. We may tend to measure at the two extremes of risk taking behavior (those who are not willing to take any risk regardless of the potential benefits from taking risk and those who are willing to take a risk for a very small benefit), leading to a very wide range in the VSL which may not be very useful in a benefit-cost framework.

Last, do individuals actually know all of the risks and can fully informed decisions be made? Some activities, such as driving, people have some feeling for the risks involved because of their familiarity with the activity. However, risks in other areas such as health (medicine or exposure to toxic substances, for example), people must rely on the advise of others more knowledgeable about the risk (but not individual preferences) to make choices. There is the potential for misperceptions and inaccurately assessing or describing risk. Therefore, the VSL must be based on the translated risk.

These potential problems must be considered when evaluating the most appropriate values to place on a potential loss of life. In other words, revealed preference based study results associated with outcomes that are prone to problems of endogeneity and have very difficult to understand or uncertain risks should be considered much less reliable than results that are based on studies with well defined and well understood risks.

Factors that need to be considered when determining the most appropriate VSL to apply to a BOR loss of life evaluation

Consistency of Risk Measured

Consistency of risk measured basically refers to measurement of the willingness to pay to reduce risk or the willingness to accept payment for increased risk. Although theoretically these two measures should provide the same measure of the VSL, assuming individuals correctly perceive risk and react to risk consistently, in actual application the two measures may be very different. Willingness to pay may be limited by budget constraints and implies an individual is obtaining something that they currently do not have. Willingness to accept payment is not budget constrained and implies that an individual is giving something up that they currently have. Other things equal, a study based on willingness to accept payment will likely have higher values than a study based on willingness to pay. The VSL used to value loss of life should be representative of the actual situation imposed on the individual.

Risk Characteristics

The characterization of risk includes items such as control, event outcome, expectation of the event, and the characteristics of the population affected. The control characteristic refers to the extent that an individual has control over an event or the risk of an event occurring. For example, an individual may place a greater perceived risk on the chance of being involved in an airplane accident and a lower perceived risk on being in an automobile accident because they have no control over the airplane but some control over their automobile. Therefore, the ability to have an affect on the outcome of an event can affect the estimated VSL.

The expectation of the event does not refer to the risk of an event, but relates to the timing of an event. For example, a death from a long term illness allows more time to prepare for the outcome both financially and psychologically than an

unexpected death. Death from an automobile accident or some other unexpected event does not allow for any preparation or time to get personal affairs in order. This difference in expectations could influence the associated VSL.
The characteristics of the population may also affect the estimated VSL. For example, low income households may be willing to take more job related risks because the benefit of the extra income from a higher risk job is very high compared to a high income family that doesn't need the higher income of the higher risk job. The higher threshold for unacceptable risk for a low income household could result in lower VSL estimates for low income households. Other population characteristics that could influence the VSL include age, urban or rural setting, region where the individual lives, marital status/number of dependents, and others.

Application of a VSL estimated from a previously completed study to an analysis of the value associated with a loss of life at a site of interest (BOR facilities) requires the risk characteristics of the completed study area to be similar to the site of interest. Greater similarity will improve the reliability of the value estimate due to similarity of the underlying risk-VSL relationships.

Perception of Risk and Comparability of Outcome
The perception of risk refers to how an individual or household actually sees the risk they are taking regardless of the actual risk involved. This may be very closely related to the issue of who controls the risk, the source of information regarding the risk, and if the individual is risk seeking or risk averse. A lack of control may be perceived as a greater risk or at least a more unacceptable risk compared to a situation where an individual has some control. Information provided by experts in the area of risk assessment may carry more weight and influence perceived risk much more than a lay person, or vice versa. A risk seeking individual may actually get some satisfaction from the risk taking itself, compared to a risk averse person who seeks out ways of avoiding an adverse risky outcome. A risk seeker will not pay to reduce risk and may in fact pay to take a risk to attain a beneficial result. The revealed preference approach would indicate a risk seeker has a low VSL. Unfortunately, the perception of risk at previously completed study sites and the area of interest will be difficult to evaluate, except possibly for the amount of control that individuals have over the event under consideration. However, risk perception should be consistent between the study sites and the site of interest to the extent possible.

VSL's estimated in previous studies that are applicable to the evaluation of BOR loss of life

A summary of previous value of life studies was reviewed in "Summary of Valuation of Statistical Life Estimation Policies and Methods" which was completed for the Bureau of Reclamation Security, Safety and Law Enforcement Office in 2007. The 2007 review provided a description of the techniques that have been used to place a value on life, but did not provide an analysis of most appropriate methodology or applicable VSL's for use by the Bureau of

Reclamation for estimating the value associated with a loss of life. The most applicable VSL must be comparable to an outcome that could be associated with Bureau of Reclamation facilities.

The comparability of outcome refers to the situation that ultimately leads to a death, since the ultimate outcome is always the same. A death from a long term illness related to risks from exposure to some type of environmental factor may not be comparable to a death from an unexpected accident, even though the outcome of death is the same. Therefore, the characteristics of the outcome between a previously completed study site and the site of interest should be similar in order to estimate a representative value for loss of life at the site of interest.

There were no studies found from which a VSL was estimated based on a flooding event, which would be the most obvious case applicable to a loss of life associated with Bureau of Reclamation facilities. The lack of these studies may be due to the existence of "de minimis" risk. De minimis risk essentially describes a risk beyond which the risk is so small as to be inconsequential. Examples of these risks in Adler (2007) included an incremental $1X10^{-6}$ lifetime cancer risk from pollution, a 100 year flood, or a 475 year earthquake. Therefore, other studies that meet the revealed preference methodology and risk characteristic criterion were evaluated. Studies that meet these criteria can then be used as a basis for estimating a value associated with the loss of life.

A large number of the studies estimating VSL's have evaluated the costs associated with health risks from environmental degradation. These environmental health effects will typically occur due to exposure over a relatively long period of time and will not be comparable to the loss of life associated with an unexpected flood event, as discussed earlier in this paper. In addition, many of these environmental degradation studies are based on cost of illness or stated preference approaches.

Revealed preference VSL studies based on the risks of a traffic fatality are likely to be the most applicable to a loss of life from flooding. There are similarities in the short and sudden time period of the death or injury, the lack of complete control over the outcome, and familiarity with the events. To some extent we have some control over a flood related fatality in that we can have emergency evaluation plans, we can locate outside of a flood plain, or we can take some other action to avoid adverse consequences. We have control over a traffic accident by driving safely, but a lack of control over the outcome when the other person at fault. A somewhat better application of a VSL could be the risks associated with air transportation due to the larger number of people typically involved in a single air transportation accident and similar control aspects in that a person could decide not to fly or could decide not to live in a flood plain. Only one study of the value associated with air transport safety was found and that study was based on a contingent valuation survey (Carlsson, et al., 2004). However, it is useful to note

that the value of life estimated in the Carlsson study for air transportation was more than twice the value for travelling by taxi. As a result, application of a traffic fatality based VSL for Bureau of Reclamation loss of life could potentially be a lower-bound value for large flood events.

Several studies have estimated the willingness to pay for safety features of new automobiles and used those models to estimate the VSL associated with that willingness to pay. A study by Winston and Mannering (1984) estimated the value of various safety attributes with automobiles such as air bags, passive restraints, and manual lap and shoulder belts. Using household data on vehicle choices and the traits of various new vehicles the estimated VSL was slightly less than one million dollars. A similar type of analysis was completed by Atkinson and Halvorsen (1990) using the purchase of new car models with various safety options to value the trade-off between safety risk and the cost of various options. Atkinson and Halvorsen estimated a VSL of about $3.36 million. Dreyfus and Viscusi (1995) estimated a hedonic price model for automobiles, where several different attributes were included (for example: weight, year, size, cargo capacity, horsepower) which influence fatality risks and vehicle price. Dreyfus and Viscusi estimated a VSL of $2.6 million to $3.7 million.

Another method that has been used to estimate VSL's is the measurement of costs and risk reductions associated with seat belt use. The value of life saving behavior as reflected by seat belt usage was estimated in a study by Blomquist (1979). The study incorporated a life-cycle model, where individuals maximize their expected lifetime utility given estimated costs and benefits of a life-saving activity, in this case seat belt use. The disutility associated with seat belt use included discomfort associated with use, resistance due to habit, and the time involved with buckling and unbuckling. The estimated "most reasonable" value of life was $368,000. A value of life based on foregone earnings was estimated to be less than one-half of the estimated change in utility.

In a paper by Blomquist, et al. (1996) the value of the loss of life was estimated through the use of seat-belt use, child restraints, and motorcycle helmets. The estimates included an adjustment for under-estimating the true risk. Before adjusting for risk the estimated VSL was about $2 million. After adjusting for risk misperceptions, the VSL in Blomquist, et al. is estimated to be $3.6 million. Another study by Hakes and Viscusi (2007) also used seat belt use and associated risk-cost trade-offs to estimate a VSL. The study included three cost and benefit categories associated with seat belt use: the time cost of buckling up, disutility of restricted range of motion when seat belts are used, and the reduction in expected legal penalties from not buckling up when there are mandatory seatbelt laws. The estimated VSL ranged from $1.91 million to $8.36 million. The relatively wide range was the result of different disutility estimates assumed for seat belt use.

The purchase of bicycle helmets to reduce the risk of a fatal or serious accident was used by Jenkins, et al. (2001) to estimate a VSL. The Jenkins, et al. study

estimated the VSL for different ages based on the amount paid for helmets and the number of helmets purchased. The estimated VSL range was $1.1 million to $4.0 million, with the value for children at the lower end of the range and adults at the higher end.

Finally, a study by Ashenfelter and Greenstone (2002) looked at the tradeoff between speed and the risk of a fatal accident to estimate a VSL. The study evaluated the change in speed limits allowed by the federal government in 1987. The study indicated that a 3.5% increase in speed translated into a 35% increase in fatality rates. Valuing the time saved at the average hourly wage, the VSL was estimated to be $1.54 million.

The results of the transportation based VSL studies described above are summarized in Table 1. The ranges of VSL estimates for each of these studies were converted to 2008 dollars and the results are presented in Table 2.

Table 1 – Summary of transportation based VSL studies

Study Authors	Year of Study	Activity that risk based VSL is based on	Year of data	Estimated VSL in data year dollars (millions)
Ashenfelter & Greenstone	2002	Speed and fatality risk on highways	1997	$1.54
Atkinson & Halvorsen	1990	The purchase of different car models	1986	$3.36
Blomquist	1979	Seat belt use	1972	$0.37
Blomquist, Miller, & Levy	1996	Seat belt, child seat, helmet use	1991	$3.60
Dreyfus and Viscusi	1995	Purchase of cars with various fatality risks	1988	$2.6 - $3.7
Hakes and Viscusi	2007	Seat belt use	1998	$2.2 - $7.9
Jenkins, Owens, & Wiggins	2001	Bicycle helmet use	1997	$1.1 - $4.0
Winston & Mannering	1984	Seat belt use/air bags	1980	$0.98

Table 2 – Transportation based VSL estimates indexed to 2008 dollars

Study Authors	Price Index*	Index factor to convert to 2008 $'s	Lower VSL estimate (millions)	Upper VSL estimate (millions)	Midpoint VSL estimate (millions)
Ashenfelter & Greenstone	93.2	1.365	$2.10	-	$2.10
Atkinson & Halvorsen	63.7	1.997	$6.71	-	$6.71
Blomquist	24.3	5.235	$1.94	-	$1.94
Blomquist, Miller, & Levy	79.1	1.608	$5.79	-	$5.79
Dreyfus and Viscusi	68.7	1.852	$4.81	$6.85	$5.83
Hakes and Viscusi	94.7	1.343	$2.96	$10.61	$6.78
Jenkins, Owens, & Wiggins	93.2	1.365	$1.50	$5.46	$3.48
Winston & Mannering	47.9	2.656	$2.60	$2.60	$2.60

* Consumer price indices obtained from Organisation for Economic Co-Operation and Development. Year 2000 = 100 and August 2008 = 127.2.

The average for all eight revealed preference based studies in Table 2 is $4.4 million. This can be used as a representative base value for the loss of life in Bureau of Reclamation analyses. However, considering the possibility that a flood event could involve a large number of people and the air transportation study by Carlsson, et al. (2004) indicated the VSL for events involving more people is higher than for an event affecting a small number of people, the VSL for

a flood event may be closer to the upper end of the range shown in Table 2 or $6.8 million.

The results presented in Table 2 are similar to the results presented by Blomquist (2004) in a review of VSL studies. The Blomquist review indicated a VSL best estimate of about $4.0 million in 2000 dollars ($5.08 million in 2008 dollars). The Blomquist best estimate is within the $4.4 million to $6.8 million range indicated in the analysis presented in this paper. The Table 2 results are somewhat higher but similar to U.S. Department of Transportation (DOT) guidance on the value of life and injuries (2004). According to DOT the appropriate VSL is $3.0 million in 2004 dollars ($3.48 million in 2008 dollars).

An Environmental Protection Agency analysis (1997) reviewed 26 studies estimating VSL under different circumstances and indicated that a defensible estimate of the mean VSL was $4.8 million. EPA's review included 21 studies that estimated the value of risk reductions based on workers' willingness to accept riskier jobs in return for higher wages and 5 studies used contingent valuation. Another analysis by Andersson and Treich (2008) showed a very wide range of VSL estimates using both revealed and stated preference techniques of $261,000 to $36.4 million in 2005 dollars.

Summary

Given the amount of funding available for programs that improve health, reduce the risk of dying, or provide some other benefits to society is limited, some evaluation of the benefit from reduced fatalities and injuries is necessary. The benefit evaluation must, therefore, include a measure that is comparable to the benefits measured for other desirable effects. As a result, a monetary value for life must be estimated in order to determine the outcome that generates the greatest benefit per dollar spent.

The value of life should be included in any project evaluation where the result of an action will influence the potential risk of death or injury because this risk represents a real economic benefit or cost. Ignoring this risk ignores real project effects and is not a viable option for an accurate project analysis. The best way to measure the value of life for project analysis is through the VSL approach.

Generally, the VSL should approximate the value that people place on their lives in their unrestrained decisions in a market setting. People make decisions every day that carry some risk of harm or death but also provide some benefit. It is through these actual market decisions that WTP/WTA studies can be used in a revealed preference framework to infer the VSL. Studies evaluated in this paper included the use of seat belts, paying more for crash tolerant automobiles, the use of bicycle helmets, and driving speeds. Each of these situations represent trade-offs between a monetary gain (loss) and an increase (decrease) in risk. If an individual is willing to pay the price (the cost associated with a risk) to get a

benefit (such as decreased travel time or less time spent buckling up) the consumer is implicitly revealing the value they place on life.

Market behavior indicates that there is a willingness by individuals to accept risk. Consumers do not show that they are willing to pay an infinite amount of their income for safety in their own private market decision making. Private markets indicate that consumers do trade-off safety for other variables such as time and money.

This paper concludes that the studies most similar to the conditions of a loss of life due to a failure of Bureau of Reclamation facilities, in terms of the type of risk situation, are most likely transportation related studies using a revealed preference based estimate of willingness to pay. A review of these studies indicates that a likely range of VSL's for Bureau of Reclamation facilities is $4.4 million to $6.8 million in 2008 dollars. This is somewhat higher than the value used by the U.S. Department of Transportation, but is well within the range that has been estimated by the U.S. Environmental Protection Agency and other reviews of VSL studies.

Glossary

Economic feasibility – The comparison of the economic benefits and costs of a project or action. If the benefits of a project or action are greater than the costs, then it is considered to be economically feasible.

Household production function – The transformation of commodities purchased by a household into goods and services that generate utility for a household.

Marginal utility of wealth – The rate at which an individual's utility increases with a small increase in wealth.

Revealed preference – The use of observed changes in consumer buying behavior that result from changes in price and/or income to infer characteristics about an individual demand curve for a good or service.

Risk aversion – The willingness of an individual to forgo a potential return in order to avoid an adverse outcome or the need for a very high return in order to accept a risk.

Risk seeker – An individual that is willing to accept a relatively high level of risk for a given expected return.

Stated preference – The use of data obtained from household surveys indicating preferences for a hypothetical situation to derive a household demand curve for the good or service described in the hypothetical situation.

Utility – A measure of individual or household satisfaction or welfare associated with a good or service or combination of goods and services.

Value of a statistical life (VSL) – A value based on the willingness of people to trade off wealth for a reduction in the probability of death or the willingness to accept an increase in wealth for an increase in the probability of death.
Wealth effect – The influence of wealth or income on expenditures for goods and services. In the context of value of life, greater wealth increases the cost associated with a loss of life.

Willingness to accept payment (WTA) – The monetary value an individual places on a good or service they currently posses and the amount they would be willing to accept in payment in order to give up that good or service.

Willingness to pay (WTP) – The monetary value an individual places on a good or service they desire and as a result the amount they are willing to spend in order to obtain that good or service.

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