

**U.S. Army Corps of Engineers  
Institute for Water Resources**

# **IWR Planning Suite II User's Guide**

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# Section 1

## Introduction

### History

The US Army Corps of Engineers Institute for Water Resources has developed IWR Planning Suite II Decision Support Software to assist with the formulation and comparison of alternative plans. IWR Planning Suite II builds upon previous versions of IWR-Plan, and upon the basic plan formulation and comparison framework of the original DOS program *ECO-EASY: Cost Effectiveness and Incremental Cost Analyses for Environmental Planning*, developed within the Corps Evaluation of Environmental Investments Research Program. IWR-Plan transformed ECO-EASY to a Windows operating environment, while IWR Planning Suite transformed that into a new paradigm with flexible “planning sets.”

IWR Planning Suite II builds on this history and adds new functionality, flexibility, and reporting tools. IWR Planning Suite II can assist with plan formulation by combining solutions to planning problems and calculating the additive effects of each combination, or “plan.” IWR Planning Suite II can assist with plan comparison by conducting cost effectiveness and incremental cost analyses (CE/ICA), identifying the plans which are the best financial investments, and displaying the effects of each on a range of decision variables. In addition, IWR Planning Suite II extends the analyses into an uncertainty environment by allowing users to specify distributions to quantify costs and outputs as well as includes modules for annualization and conducting Multi-Criterion Decision Analysis (MCDA). The software is available for download via the IWR Planning Suite II website (<http://crbweb01.cdm.com/iwrplan>).

### Audience

Today’s environmental decision makers are faced with a complex dilemma. Many of our nation’s valued watersheds, ecosystems and habitats are degraded or threatened. At the same time, dwindling budgets at all levels of government are forcing some hard choices about how tax dollars can best be invested. When it comes to making decisions about how to invest limited dollars in solving increasingly critical problems, decision makers must answer some very tough questions: How much can we afford to invest in an environmental project? Is it worth potentially doubling a project’s cost, for example, to get a small increase in environmental benefits? What level of environmental benefits is worth it?

Traditional benefit cost analysis is not enough, or even useful, in answering many of these kinds of questions. While the costs of environmental investments can still be measured in dollars, there is no universally-acceptable method to measure environmental benefits using a single metric, dollars or otherwise. However, other tools, such as cost effectiveness and incremental cost analyses, can be used to give decision makers better information in making such choices.

### Purpose of Manual

This manual was developed to serve as a practical guide for applying and interpreting cost effectiveness and incremental cost analyses in environmental planning. It describes the analyses’ data requirements, step-by-step instructions for conducting the analyses, examples of the analyses’ application in different planning settings, decision making using the analyses’ results, a case study, and instructions in the use of the program, *IWR Planning Suite II*. The *IWR Planning Suite II* software was developed to perform the routine, and often

time-consuming, number crunching required by the analyses; thereby freeing planners to focus on the identification of solutions, the estimation of their environmental and economic effects, and the communication of information to support decision making.

While economists may be most comfortable with the procedures of cost effectiveness and incremental cost analyses, biologists, ecologists, and other environmental scientists will typically determine the environmental variables to be analyzed and the methods by which changes in those variables will be measured and communicated as environmental outputs. Staff from plan formulation, engineering, environmental, and other areas will formulate alternative plans to effect changes in those variables. Similarly, cost engineers, real estate specialists, economists and others must combine their expertise to estimate the financial and economic costs of those alternative plans. It is important that all members of a study team, regardless of their discipline, understand how their respective inputs are used in the analyses, and provide decision makers with their unique insights in interpreting the analyses' results.

Just as the manual is intended for readers from varied backgrounds, it is also intended for readers with varied interests. Environmental restoration and mitigation planning studies will typically involve non-Corps parties. This manual may provide an understanding of the rationale for, and application of, cost effectiveness and incremental cost analyses in planning to interested representatives of other groups and agencies as well as to local cost-sharing partners.

It should be noted by non-economist readers, that a learning curve lies ahead in gaining an understanding about cost effectiveness and incremental cost analyses and their uses in planning. The analyses require some of us to think about some new things, and to think about some familiar things in different ways. We have tried to help you through this learning curve with the explanations and examples provided throughout the manual. For some readers, the best way to really become familiar with the analyses may be to do a simple example application that can be worked out with a calculator, pencil and paper. For others, the IWR Planning Suite II software can be a valuable educational tool for working through example applications at the computer. In either case, you may wish to use the example exercise included in this manual to work through a test problem and develop your skills in doing the analyses.

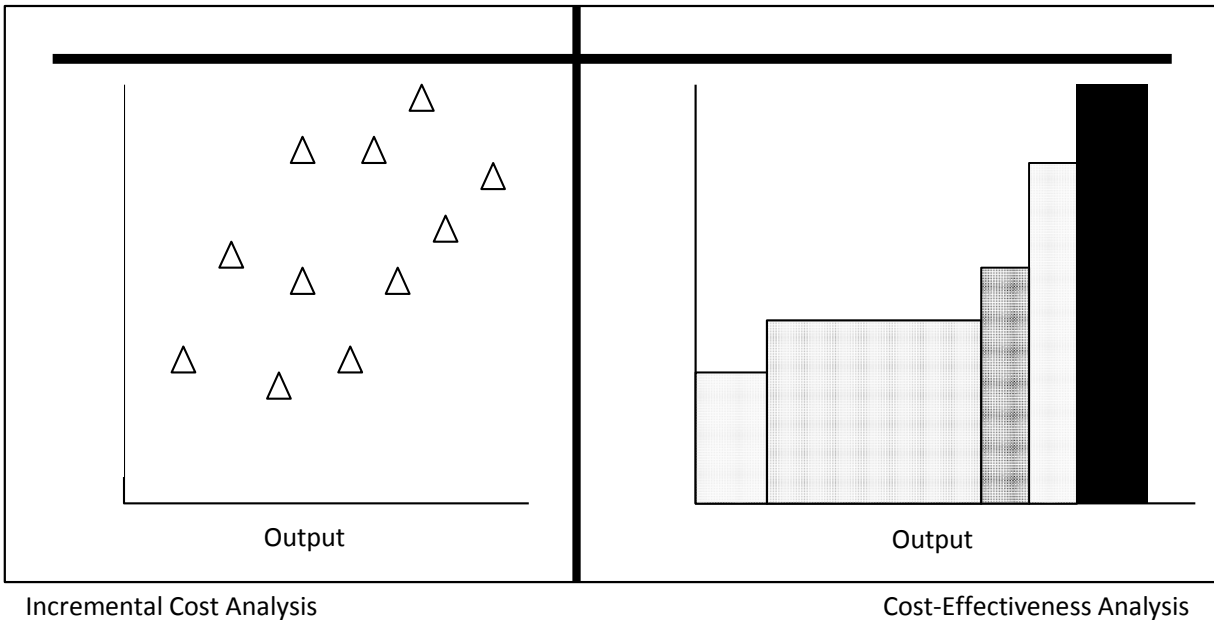
## What Are Cost Effectiveness and Incremental Cost Analysis?

The cost effectiveness and incremental cost procedures presented in this manual are based upon the planning framework established in Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (U.S. Water Resources Council 1983), referred to as the P&G. The P&G provides the instructions and rules for Federal water resource planning. The P&G require that, in developing alternative plans, Federal planners should include only increments that provide net NED [National Economic Development] benefits [for flood damage reduction, navigation, and other traditional benefit categories]... Increments that do not provide net NED benefits may be included...if they are cost effective.

For environmental planning, where traditional benefit-cost analysis is not possible because costs and benefits are expressed in different units, cost effectiveness and incremental cost analyses offer plan evaluation approaches that are consistent with the P&G paradigm. *Cost effectiveness analysis* is conducted to ensure that the least cost plan alternative is identified for each possible level of environmental output; and that for any level of investment, the maximum level of output is identified. Subsequent *incremental cost analysis* of the cost effective plans is conducted to reveal changes in costs as output levels are increased.



In the absence of a common measurement unit for comparing the non-monetary benefits with the monetary costs of environmental plans, cost effectiveness and incremental cost analyses are valuable tools to assist in decision making. The results of the analyses, which can be displayed as graphs of outputs against costs, permit decision makers to progressively compare alternative levels of environmental outputs and ask if the next level is worth it. In other words, is the additional environmental output in the next attainable level worth the additional cost? Typical examples of cost-effectiveness and incremental cost graphs are included in Figure 1.



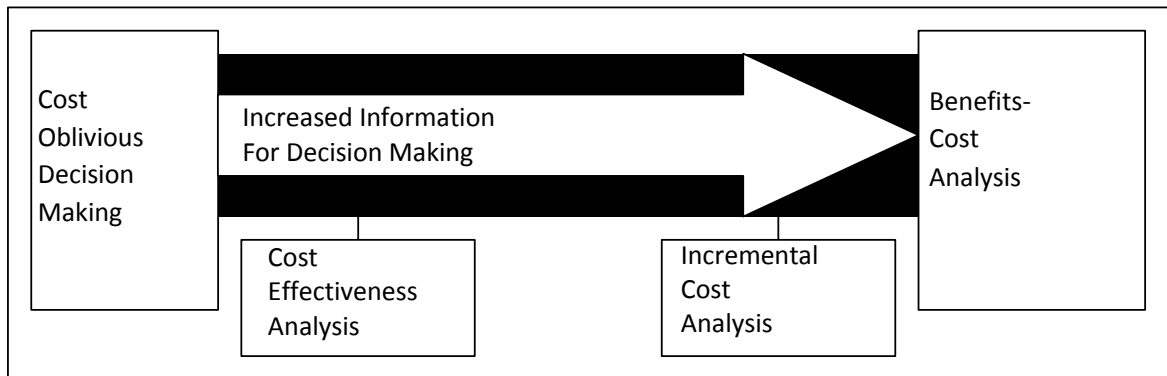
**Figure 1**  
*Examples of Typical Cost-Effectiveness and Incremental Cost Graphs*

## Incremental Cost Analysis

### Why Conduct Cost Effectiveness and Incremental Cost Analyses?

The planning paradigm in the P&G provides a rational and deliberate approach to solving problems and making decisions. Such decision-making requires information; for example, information about future environmental conditions with, and without, the implementation of each alternative plan under consideration. The cost effectiveness and incremental cost analyses procedures in this manual are intended to organize and communicate the types of information needed to support the decision making process.

Figure 2 shows some tools of economic analysis that can be used to provide varying levels of information to support decision-making. This decision-support continuum ranges from cost oblivious decision making (ignore all information about costs) to benefit-cost analysis (a mathematical comparison of benefits and costs). Between these two extremes, the economic tools of cost effectiveness analysis and incremental cost analysis can provide information to support decision making (Yoe 1992).



**Figure 2**  
**Economic Analysis Decision-Making Tools**

Benefit-cost analysis is generally considered the best-case scenario for Federal water resources decision-making. In benefit-cost analysis, the monetary cost of a plan is subtracted from the monetary value of the benefits to be provided by that plan to compute net dollar benefits. When there is a range of alternative plans, the plan that provides the most net benefits is considered optimal, and is typically the recommended plan.

When project benefits are not measured in dollars, cost effectiveness and incremental cost analyses offer next-best approaches. While the cost effectiveness and incremental cost analyses of alternative plans may not identify a unique or optimal solution, they can lead to more-informed choices from among alternatives by elevating the decision making process above cost oblivious decision making (Yoe 1992).

The value of this approach to environmental planning is recognized in the National Research Council's National Strategy for the Restoration of Aquatic Ecosystems. The Council's strategy states that, in lieu of benefit-cost analysis, the evaluation and ranking of restoration alternatives should be based upon a framework of incremental cost analysis. Continually questioning the value of restoration by asking whether an action is worth its cost is the most practical way to decide how much restoration is enough (NRC 1992). As an example, the National Research Council cites the Corps' approach where a justifiable level [of output] is chosen in recognition of the incremental costs of increasing [output] levels and as part of a negotiation process with effected interests and other federal agencies (NRC 1992).

Although cost effectiveness and incremental cost analyses will not, like benefit-cost analysis, usually lead us to a single solution, they will, at the very least, help us make *more informed* decisions. And, with some care and thought in interpreting and communicating the results, they may help us make *better-informed* decisions. In the long term, we hope that this will bring about *better decisions* about today's actions that will affect the environment of future generations.

## Applicability

The plan formulation and cost effectiveness and incremental cost analyses procedures in this manual were developed for both restoration and mitigation planning. They are useful for a wide range of problem and project sizes, and can be used for scoping solutions even at the earliest stages of planning. In addition, although these procedures were developed to meet Corps needs in restoration and mitigation planning, focusing on fish and wildlife habitat and watershed or ecosystem-related studies, they should be equally useful

in addressing many other planning applications both within and outside the Corps. For example, the procedures may be useful to address problems of dredged material disposal, natural resource management, and mitigation banking. Environmental planning and management applications outside the Corps might include studies addressing water and air pollution, hazardous waste, cultural resources, or mitigation planning in transportation alternatives analysis. Ultimately, applicability is limited only by analysts' ability to define and measure the output and cost of solutions to planning problems.

## How Do the Analyses Fit in the Planning Process?

Federal water resources planning is a formal choice process that integrates many perspectives. Engineering, economic, environmental, social, and political concerns are brought to the table and traded off as a number of alternative plans are formulated and evaluated. The P&G planning process consists of a series of steps that provide an orderly and systematic approach to selecting a recommended plan. The P&G planning process consists of the following major steps:

1. Identify problems and opportunities;
2. Inventory and forecast without-project conditions;
3. Formulate alternative plans;
4. Evaluate effects of alternative plans;
5. Compare alternative plans; and
6. Select a plan.

Though the numbering of the planning steps indicates the basic order in which they are conducted, planning is a dynamic process, the steps of which may be repeated, (or iterated) one or more times as steps of the process uncover new information, new alternatives are developed, or as objectives are reevaluated. The cost effectiveness and incremental cost analyses procedures in this manual can contribute to a planning study in a number of ways, both early on and later in the planning process.

Cost effectiveness and incremental cost analyses can be useful tools during even the earliest iterations of the planning process. As experience will show, the analyses can help you quickly formulate a very wide range and number of alternatives during reconnaissance or other early phases of work.

Cost effectiveness and incremental cost analyses are *comparisons* of the effects of alternative plans; more specifically, they involve comparisons between the outputs and costs of different solutions. As such, you must first develop at least preliminary information about alternative plans (planning step 3) and their effects (planning step 4) in order to conduct the cost effectiveness and incremental cost comparisons (planning step 5). In this sense, cost effectiveness and incremental cost analyses may be thought of as being “late” in the six-step planning process.

## Cost Effectiveness and Incremental Cost Analyses...What They Are Not

Prior to elaboration of what cost effectiveness and incremental cost analyses are, consider some things that the analyses are *not*. For example, cost effectiveness and incremental cost analyses are:

Not the planning process...

...but you have to understand the planning process to understand the role of the analyses;

Not a technique to measure or forecast environmental outputs...

...the analyses do not measure or forecast the environmental effects of plans; but that information, provided through other techniques, is required to conduct the analyses;

Not a technique for monetizing environmental outputs...

...the analyses will not place monetary values on measurements of environmental outputs; but rather the analyses will compare monetary costs against non-monetary outputs across solutions;

Not a way to reduce or eliminate environmental requirements...

...rather, the analyses can show how to meet requirements and keep costs down - or how to maximize output for a given expenditure level; and

Not a method that identifies a single right or optimal solution...

...unlike benefit-cost analysis, no single plan, like a National Economic Development (NED) plan, will emerge as the optimal selection; however, the analyses provide the types of information that will support the selection of a single plan.

And a final disclaimer: There is no single right way to conduct cost effectiveness and incremental cost analyses for every application. Planners and analysts need to look at each planning problem and determine the best way to proceed. The procedures in this manual provide a basic framework for plan formulation and evaluation. This framework is flexible enough to handle necessary modifications for its application to a wide variety of planning situations. The following chapters provide a number of examples, using the same analytical concepts in a variety of different planning applications. Again, once the learning curve has been overcome, and with some practice, the insights required to determine the best way to proceed will come with greater ease.

The development of the IWR Planning Suite II software may lead some to think of the analysis as a black box, where data is input and then, without requiring any knowledge of the analytical procedures being conducted, an answer is provided. Planners must recognize that uninformed dependence on the software's analysis results is inappropriate and misguided.

The capability to perform reality checks on the software's output, the insight required to use the software to handle different planning scenarios, and the ability to interpret results are important aspects of effectively utilizing IWR Planning Suite II. But they may all be applied for naught without a critical understanding of the procedures behind the software. Such an understanding will also provide valuable opportunities to consider new and different solutions that deliver more for less.

Herein you will find detailed, step-by-step, instructions in the procedures encoded into the software program. Understanding the procedures and the examples presented in the following chapters will assist analysts in achieving a comfort level with applying the analyses.

## History and Background

Benefit-cost analysis, incremental cost analysis and cost effectiveness analysis have long been integral to Federal water resources planning. Requirements for these types of economics-based analyses can be traced from the first Federal guidance in the Green Book (1950, 1958), through Senate Document 97 (1962), to the Principles and Standards (1973, 1980). Traditionally, these requirements have focused on projects' monetary costs and monetary benefits. Cost effectiveness analysis has been used to identify the least costly means to achieve a range of project benefits; subsequent incremental cost analysis has been used to scale project size by judging whether increasing economic benefits are worth their additional costs.

The evolution of economic analyses in Federal water resources planning was paralleled by the development of requirements and technologies for environmental evaluation. As the nation's first comprehensive environmental legislation, the National Environmental Policy Act of 1969 mandated, in Section 102 (2)(B):

All agencies of the Federal Government shall...identify and develop methods and procedures, in consultation with the Council on Environmental Quality established by Title II of the Act, which will ensure that presently unquantified environmental amenities and values may be given appropriate consideration in decision-making along with economic and technical considerations.

In 1983, the U.S. Water Resources Council replaced the Principles and Standards with the Principles and Guidelines (P&G), providing the instructions and rules for Federal water resources planning. The P&G requires that:

In general, in the formulation of alternative plans, an effort is made to include only increments that provide net National Economic Development (NED) benefits after accounting for appropriate mitigation costs. Increments that do not provide net NED benefits may be included, except in the NED plan, if they are cost effective measures for addressing specific concerns. (paragraph 1.6.2 (b))

While the P&G places emphasis on plans to achieve NED benefits, it does leave the door open for *cost-effective* plans to achieve other benefits, such as environmental benefits.

In the mid-1980's, the Corps adopted the principles of cost effectiveness and incremental cost analyses for use in planning and justifying mitigation for fish and wildlife habitat losses caused by projects for flood control, navigation, and other developmental purposes. Costs for mitigation are essentially the same types of financial costs that are incurred for other project purposes, including costs for: preconstruction engineering and design; real estate; construction; ongoing operation, maintenance, repair and rehabilitation; and monitoring.

Benefits for mitigation are more problematic since, unlike flood control, navigation and other developmental purposes, mitigation benefits are not measured monetarily. The analytical difficulty that this presents to justifying environmental projects is so pervasive that the Water Resources Development Act of 1986 sought to legislate a solution. Section 907 of that Act directs that:

*In the evaluation by the Secretary [of the Army] of benefits and costs of a water resources project, the benefits attributable to measures included in a project for the purpose of environmental quality...shall be deemed to be at least equal to the costs of such measures.*

Notwithstanding the intent of the Act, there remains no universally acceptable method to express environmental benefits in exclusively monetary or economic terms. Mitigation of environmental damage can, however, be expressed in other metrics, ranging from simple numbers of acres of a given habitat to more sophisticated indicators like habitat units. Therefore, although a traditional benefit-cost analysis cannot be conducted without monetary benefits, the costs of mitigation plans can be compared with their non-monetary effects. Such comparison is at the heart of cost effectiveness and incremental cost analyses, and is the basis for their application in environmental planning.

Initial Corps guidance on the application of incremental cost analysis in environmental planning, presented in engineering circular number 1105-2-185 (U.S. Army Corps of Engineers 1988), included:

*Incremental cost analysis is an investigation and characterization of how the costs of extra units of output increase as the level of output increases. In mitigation planning, such analyses will result in an array of implementable mitigation plan increments, ranked from most to least cost effective.*

This guidance was subsequently incorporated into the Corps engineering regulation number 1105-2-100, Guidance for Conducting Civil Works Planning Studies (U.S. Army Corps of Engineers 1990). This regulation, referred to as the Planning Guidance Notebook and revised in 2000, requires that:

*An incremental cost analysis shall be performed for all recommended mitigation plans. The purpose of incremental cost analysis is to discover and display variation in costs, and to identify and describe the least cost plan.*

The requirement of incremental cost analysis for the mitigation of adverse project impacts was extended to the *restoration* of fish and wildlife resources through Policy Guidance Letter #24, (U.S. Army Corps of Engineers, 1991).

In June 1995, the Corps released engineering circular number 1105-2-210, Ecosystem Restoration in the Civil Works Program. This guidance underscores the importance of cost effectiveness and incremental cost analysis in ecosystem restoration planning. The circular states that:

*Cost effectiveness analysis and incremental cost analysis are fundamental concepts in project formulation and evaluation. These analyses provide ways of thinking about outputs resulting from the various levels of expenditures. Ecosystem restoration studies differ from traditional studies only in that not all benefits are monetized.*

*A cost effectiveness analysis is conducted to ensure that least cost alternatives are identified for various levels of environmental output. After the cost effectiveness of the alternatives has been established, subsequent incremental cost analysis is conducted to reveal and evaluate changes in cost for increasing levels of environmental output.*

*Although incremental cost analysis does not provide a discrete decision criterion (such as the maximizing of net benefits in NED analysis), it provides for the explicit comparison of the relevant changes in costs and outputs on which such decisions should be made.*

The Planning Guidance Notebook, ER 1105-2-100, was revised in 2000 and contains the Corps' current policy regarding the requirement to conduct cost effectiveness and incremental cost analyses for ecosystem restoration projects. Paragraph E-36 states:

*Cost effectiveness and incremental cost analyses are two distinct analyses that must be conducted to evaluate the effects of alternative plans. First, it must be shown through cost effectiveness analysis that an alternative restoration plan's output cannot be produced more cost effectively by another alternative. "Cost effective" means that, for a given level of non-monetary output, no other plan costs less, and no other plans yields more output for less money. Subsequently, through incremental cost analysis, a variety of implementable alternatives and various-sized alternatives are evaluated to arrive at a "best" level of output within the limits of both the sponsor's and the Corps' capabilities. The subset of cost effective plans are examined sequentially (by increasing scale and increment of output) to ascertain which plans are most efficient in the production of environmental benefits. Those most efficient plans are called "Best Buys." They provide the greatest increase in output for the least increases in cost. They have the lowest incremental costs per unit of output. In most analyses, there will be a series of Best Buy plans, in which the relationship between the quantity of outputs and the unit cost is evident. As the scale of Best Buy plans increases (in terms of output produced), average costs per unit of output and incremental costs per unit of output will increase as well. Usually, the incremental analysis by itself will not point to the selection of any single plan. The results of incremental analysis must be synthesized with other decision-making criteria (for example, significance of outputs, acceptability, completeness, effectiveness, risk and uncertainty, reasonableness of costs) to help the planning team select and recommend a particular plan.*

Early Corps field applications of cost effectiveness and incremental cost analyses to environmental planning problems frequently consisted of an intuitive calculation and display of the average cost per unit of environmental output (benefit) for a set of alternative plans. In a 1989 survey of Corps planning staff titled *Effectiveness of Incremental Analysis for Mitigation Planning*, many respondents reported that incremental cost analysis was perceived as a hindrance to plan formulation and selection. The most common criticisms pointed to the analyses' time-intensive nature and to a lack of clear procedural guidance for their implementation (Reese 1989).

To address these criticisms, Corps Headquarters tasked the Institute for Water Resources to better define how cost effectiveness and incremental cost analyses could be accomplished. This resulted in an overview, entitled Economic and Environmental Considerations for Incremental Cost Analysis in Mitigation Planning (Greeley-Polhemus Group 1991), and a draft manual titled Incremental Cost Analysis Primer for Environmental Resources Planning (Yoe 1992). These studies provided background research that evolved into Cost Effectiveness Analysis for Environmental Planning: Nine EASY Steps (Orth 1994). Concurrent with this work, IWR supported a field demonstration to test the applicability of the *Nine EASY Steps* procedures and the resultant report, Bussey Lake: Demonstration Study of Incremental Cost Analysis in Environmental Planning (Carlson 1993) was produced. In May 1995, Evaluation of Environmental Investments Procedures Manual;

Interim: Cost Effectiveness and Incremental Cost Analyses (Robinson, et al. 1995) was released for review and comment. Accompanying the manual was the software, ECO-EASY, the predecessor to IWR-Plan and IWR Planning Suite II. In 2002 IWR also published Lessons Learned from Cost Effectiveness and Incremental Cost Analyses (Brandreth and Skaggs 2002) to document how well the procedures were being applied to Corps ecosystem restoration planning efforts and lessons learned that might improve their application.

The conversion of the approach to a Windows® operating system platform, and the addition of many new features, was carried out through the development of IWR-Plan, starting in July of 1996. As IWR-Plan became a standard tool for performing this type of analysis within USACE, a wealth of additional features were considered for incorporation within IWR-Plan. The underlying approaches identified by these explorations were kept in mind by the IWR Planning Suite II development and maintenance team for incorporation into the current design where appropriate.

Beginning in November of 2003, a complete redesign to incorporate desired features and new technologies was initiated, culminating in the current IWR Planning Suite II. This newly redesigned IWR Planning Suite II encapsulates the following fundamental design concepts. One concept is to consider plan descriptions as discrete entities, as opposed to the concept of a plan alternative solely as a derived aspect of a set of solution combinations. The *planning set editor* and *plan descriptions database* represent this concept. Yet another fundamental modification of the tool structure is a move from a single application to a modular approach consisting of an integrated suite of component modules. Such modules include a plan editor, plan generator, reporting tools, and analysis modules. These concepts are further explained in Section 5 of this User's Guide in "Software terms and Procedures."



## Section 2

### Plan Formulation

Let us assume that a planning investigation has been initiated concerning, for example, the degradation of a particular floodplain's ecosystem. Various problems and potential opportunities have been characterized and identified during the initial stages of the investigation. The objectives of the investigation and the constraints that are imposed upon it have been derived from the characterized problems and opportunities.

Further, during the investigation's information gathering process, the historic, existing, and future conditions of the site have been evaluated. Through this process, the problems and opportunities have become more fully and accurately described, as have the costs of various alternatives, protected resources, and other items deemed relevant to the investigation. At a relatively early stage, it will be possible to formulate plans and perform analyses, which can then be fed back into another, more detailed iteration of the planning cycle.

The specifics of the information needed to initially proceed with plan formulation and evaluation vary with each investigation, but will always include at least three kinds of data needed to formulate and evaluate plans. These types of information are:

1. Solutions,
2. The output of each solution, and
3. The cost of each solution.

This chapter provides an overview of solutions, outputs, and costs; and discusses how output and cost data can be manipulated to extract the types of information needed to support decision-making.

### What's a Solution?

A *solution* is a way to achieve, in whole or in part, one or more planning objectives. Every solution will provide some level of output at some cost. Cost effectiveness and incremental cost analyses examine the different cost and output levels provided by different *solutions*.

Solution is an umbrella term for three more familiar terms: management measure, alternative plan, and program. Throughout the remainder of this text, whenever we use the term "solution" it implies that the discussion applies to measures, plans and programs.

A *management measure* (or simply "measure") is either a feature or an activity, or some combination of the two that can be implemented at a specific geographic site to achieve desired effects. A *feature* is generally a "structural" element that requires site construction; for example, a levee. On the other hand, an *activity* is generally a "nonstructural" action; for example, vegetative planting. An activity might be a one-time occurrence, like planting; or it may be ongoing (continuing or periodic), such as harvesting aquatic vegetation. A *site* is a place on land or water (at, above or below the surface) in which there is a legal interest, through outright ownership or a right to use or act on it (flowage easement, grazing rights, etc.), for implementation of features or activities. Examples of management measures that may be used for restoration and mitigation are listed in Table 1.

**Table 1.**  
**Examples of Environmental Management Measures**

aerators	detention basins	revetments
algaeicide application	dredging	rock piles
bank overhangs	fencing	rock shoals
bank stabilization	fish ladders	rootwads
boulder deflectors	fish screens	rototilling
breakwaters	fish stocking	sedimentation basins
brush bundles	gabion baskets	stake beds
brush mattresses	gravel traps	stormwater treatment areas
brush piles	harvesting	substrate improvement
bulkheads	jetties	tree layering
chemical injection	log deflectors	water control structures
chemical precipitation	mowing	water dilution
concrete block piles	new channels	water pumps
contouring	planting	weirs
cribs	reservoirs	wing walls
dams	retention ponds	wood reefs

Management measures are the building blocks of alternative plans. An *alternative plan* (or simply “plan”) is one or more management measures. A management measure may or may not be able to stand alone as a plan; it depends on the characteristics of the measure. Most alternative plans are made up of more than one measure. And, just as management measures can be combined to form plans, so too can plans be combined to form programs. As we use it in this manual, a *program* is a set of one or more plans (or “projects”), usually located over a large geographic area. Some of the Corps current environmental programs are listed in Table 2.

**Table 2.**  
**Examples of Current Corps Environmental Programs**

<p>National Programs:</p> <ul style="list-style-type: none"> <li>▪ Section 1135 Program - Project Modifications for Improvement of the Environment</li> <li>▪ Coastal America Program</li> <li>▪ North American Waterfowl Management Plan</li> </ul>
<p>Regional Programs:</p> <ul style="list-style-type: none"> <li>▪ Upper Mississippi River System Environmental Management Program</li> <li>▪ Coastal Wetlands Planning, Protection, and Restoration Act Program ( Breaux Bill ; currently implemented in coastal Louisiana)</li> <li>▪ Comprehensive Everglades Restoration Plan (CERP)</li> </ul>

## Scales of Solutions

*Scales* are different and mutually exclusive properties of a solution. Scales are most typically thought of as different “sizes”, but they also apply to other dimensions. A management measure may be scaled by several different properties, such as:

- *Physical properties*, including different sizes, amounts, counts, etc. For example, size of a site (30 acres, 40 acres, 50 acres, etc.); number of plantings per acre; percent canopy cover of vegetation; water depth; discharge capacity of a pump.
- *Composition*, including different materials and methods that would accomplish the same purpose. For example, a fence may be constructed as a chain-link fence, or a barbed-wire fence, or a wooden slat fence. For the purpose of developing alternative plans, the different materials may be thought of as different scales of a fence.
- *Locations*, including different sites for the same solution.
- *Timing and duration*, including different start and stop times, and durations for the same solution. For example, low flow releases could be scheduled to last 6, 8, or 12 hours.

An alternative plan may be scaled in terms of the measures that make up the plan - which measures are included in the plan, and in what order would they be implemented? A program may be similarly scaled in terms of the alternative plans (or projects) that make up the program.

Scales are mutually exclusive; for example, we must decide upon one channel depth. Therefore, a plan may contain only one scale of a given characteristic of a measure, and a program may contain only one scale of each component plan.

Many of the variables used in habitat-based evaluation procedures (see below) can be used to define scales of management measures. For example, if “percent herbaceous canopy cover” is a variable for a target species, and if planting herbaceous vegetation is being considered as a measure, then the measure could be sized in increments of the variable, such as: 30 percent herbaceous canopy cover, 40 percent herbaceous canopy cover, 50 percent herbaceous canopy cover, and so forth.

## How Many Scales?

The number of possible solutions—and consequently the number of output and cost estimates—will rapidly increase as we consider increasing numbers of scales of measures. Therefore, the numbers of measures and their scales should be kept to a reasonable number to minimize study cost and time. There are no universal rules for determining the proper number of scales that should be considered in every case—the number that should be defined is a matter of judgment. In reaching that judgment, it is helpful to think about scales that are:

- *Meaningful*. For example, scales of a fenced-in area in increments of 0.01 of an acre, or in increments of 10,000 acres, are probably not correctly sized and would result in too many or too few solutions for most analyses. Also, there is no reason, beyond ease of comparisons and symmetry, that increments must be identical in size. For example, a scale of 10, 25, 50 and 100 units may be used in the same analysis if it makes sense to do so.

- *Practical.* Some solutions may be implementable over very few scales. Some measures may be “either-or” measures that are not possible, or reasonable, to size, and there is only one scale to consider. For example, although different sized areas may be considered, natural revegetation may be a single-scale measure (either it does or it doesn’t naturally revegetate). Administrative actions, such as requiring a permit or a license, may also be single-scale measures (for example, either a license is required or it isn’t). Equipment is often available in only a single size or relatively few sizes (for example: water pumps with fixed pumping capacities).

Minimum and maximum sizes could be a basis to bound a range of scales. For example, a bird may require a deciduous shrub cover between 1.0 foot and 3.0 feet in height. Planting schemes that would provide lesser or greater cover heights would not meet the requirement and need not be considered. Where a large number of scales is possible, the analyses could be initially limited to analyzing only the largest and smallest sizes (“high-low” analysis), or high-middle-low sizes, to bound and scope the range of costs and outputs; subsequent iterations could then be conducted for the more promising scales.

- *Revealing.* The number of scales should be adequate to reveal significant changes in outputs and costs. A cost effectiveness curve or an incremental cost graph reflecting only two points is usually not revealing, and therefore not helpful, for decision making.
- *Reasonable.* The number of scales should strike a reasonable balance between the needs and constraints of the analysis and the burdens (cost, time, and understanding) imposed by large numbers of scales that are not sufficiently differentiated to make a difference in decision-making. In many cases, only a few will be reasonable. Additional scales should not be artificially created simply for the sake of analysis.

The most important consideration in defining scales is that changes in scale should result in changes in output, or cost, or both.

## Interrelationships of Solutions: Combinability and Dependency

The ability to make plans from measures, and programs from plans, is governed by two types of relationships: combinability and dependency. In a typical Corps study, management measures may or may not be mutually exclusive, and it is the property of *combinability* that allows you to mix and match measures into different plans. Conversely, some measures may preclude others, and this will limit your ability to mix and match them. In thinking about combinability, you should consider whether two measures might be mutually exclusive because of:

- *Location*, where two different measures cannot occupy the same space at the same time. For example, at a particular stream site, you could create a calm slackwater area by either excavating the channel or by constructing a dam across the channel; you can do one or the other at the same site.
- *Function*, where two different measures may work against one another. For example, at Site A, it probably would not make sense to both build a retaining dike to hold water at the site and install drains to speed the removal of water from the site.

- “*Nested*” measures, where one measure is actually a smaller scale or a subset of another measure. For example, you could not combine a 4-acre wetland with a 5-acre wetland to produce a 9-acre wetland if the two wetlands are not physically separate and any part of the 4 acres is physically included—or “nested”—in the 5 acres.

While measures may or may not be combinable, alternative plans are mutually exclusive within a single planning study, and decision makers must ultimately select one plan. Within a single study, selection of a plan will preclude the selection of any other plan. However, at the program level, alternative plans (or “projects”) may or may not be mutually exclusive. Again, it is the property of combinability that, at the program level, allows us to develop different total programs based on different mixes of plans (or “projects”).

In addition to being combinable, many measures may be dependent on other measures in order to be implemented. *Dependency* relationships between two measures may exist for several reasons, including:

- *Necessary to function.* For example, the survival of willow tree plantings may be dependent upon an irrigation system; without irrigation the plantings will die. In this case, irrigation is necessary for the willows to function.
- *Reduce risk or uncertainty.* For example, we may wish to establish 50 willow trees per stream mile. However, because previous planting programs in the area have shown that about one-third of willow plants will not survive the first critical growing year, we elect to plant 75 trees per stream mile to account for the survival risk. The 50 trees per mile that we expect to survive are actually dependent on the additional 25 trees per mile that experience has shown are not likely to survive.
- *Improve performance.* For example, we may also elect to improve the growth rate of willow plantings by fertilizing them. The fertilizer is not necessary for the plants to function, nor will it reduce any risks or uncertainties of survival. However, it will improve the willows’ performance by producing more mature trees faster.

Dependencies can occur in at least two different ways. *Mutual dependency* exists where two or more measures must be implemented in combination or not at all. For example, consider the following two measures:

- Management Measure [A] = Vegetative Planting;
- Management Measure [B] = Irrigation System.

If [A] will not work without [B], then [A] cannot stand alone and cannot be a plan. Similarly, if [B] is only included because of the existence of [A], then [B] cannot stand alone as a plan. Here only the combination [A+B] is a viable plan. In cases where we have mutual dependency, it is best to group the two measures together and think of them as a single measure for the purposes of analysis. For example, in this case we could group management measures A and B together as a new measure C such that:

*Management Measure [C] = Planting & Irrigating*

A different type of dependency is where some measure(s) are dependent upon other measure(s) but the relationship is not reciprocal. We will refer to this type of dependency as *path dependency*. Understanding path dependency relationships can help to assure that time and resources are not wasted evaluating plans

that could not be implemented because they fail to meet a dependency path requirement. For example, consider a case where we have five management measures: A, B, C, D, and E. In this example, we must implement A before implementing B; if A and B are both present, we can then add C. Also, D must be present before we can add E.

Recognizing dependency relationships among management measures can assist in screening out plans that are not feasible because they fail to meet dependency requirements when using the “all combinations of management measures approach” to plan formulation. In our example, there are 32 possible combinations of the management measures A-E. However, many of these possible combinations are not functionally feasible because they violate the dependency requirements. Table 3 includes all combinations with shading over those plans that are not feasible because they do not meet dependency path requirements. Out of the initial 32 possible plans, only 12 meet dependency path requirements and are functionally feasible.

Situations may arise where we are faced with *either...or* dependencies. Either...or dependencies occur when a common measure may be added to more than one dependency path. For example, consider that on a common plot of land we have two measures: G—to plant one type of vegetation and T—to plant a second type of vegetation. Assume that we could plant either alone, or both in combination. If we were to add to either G or T (or both) planting measures a new measure: F—to fertilize; we would then put the same measure in two dependency paths.

Now, we can add measure F (fertilize) if *either* G or T is present. Similarly, F could be added if *both* G and T are present. In this case, we might only incur the cost of fertilizing once, but the effect of fertilizing on the planting may vary depending upon whether one or two types of planting are being affected. In such cases, the potential for improper estimates (either of cost, output, or both) is high. In situations where “either...or” dependencies occur between management measures, it is important to check the validity of the cost and output estimates of all combinations that include those measures to assure that costs or benefits are not being double-counted.

## Where Do Solutions Come From?

The process of building alternative plans from management measures (and programs from plans) is called *plan formulation*. Plan formulation occurs in three very general phases: identification of management measures, formulation of alternatives, and reformulation. In every study, these phases will overlap and be repeated (or “iterated”) again and again. For additional discussions about the plan formulation process, see the Planning Manual (IWR Report 96-R-21).

There are many plan formulation approaches, such as “ask an expert,” considering “plans of others,” and using brainstorming, HEP models, and checklists (see the Planning Manual). While any of these approaches may be used to develop solutions, a formulation approach known as “*all possible combinations*” is a viable approach frequently used during planning investigations. This approach begins with a list of individual management measures, defines combinability and dependency relationships among the measures, and finally derives every possible combination of the measures given the defined relationships. The resulting set of combinations is the entire set of alternative plans that can be generated from the measures under consideration—every plan possible will have been formulated. Once this set of all possible plans has been identified, they can be evaluated using the cost effectiveness and incremental cost analyses procedures.

<b>Table 3.</b> <b>All Combinations of Management Measures</b> <b>(with shading over plans which do not meet dependency path requirements)</b>			
NO COMBINATION	AD	ABC	BDE
A	AE	ABD	CDE
B	BC	ABE	ABCD
C	BD	ACD	ABCE
D	BE	ACE	ABDE
E	CD	ADE	ACDE
AB	CE	BCD	BCDE
AC	DE	BCE	ABCDE

The results of plan formulation—management measures, alternative plans, and programs—must be both “output-friendly” (you can estimate what outcomes or outputs you get from it) and “cost-friendly” (you can also estimate its costs).

## What’s an Output?

As we use it in this manual, the term output means an *intended, beneficial, nonmonetary effect*. Cost effectiveness and incremental cost analyses examine how *output levels*, and their respective costs, vary across different solutions.

An output is the means by which we measure how well we achieve a planning objective. Usually, we identify one type of output for each objective. For example, you may decide to measure progress in restoring a wetland in terms of changes in its habitat quality and quantity.

In some cases, it may be important to look at more than one aspect of an objective, and, therefore, you may use multiple outputs for a single objective (for example, habitat quality and the presence of a keystone species). In addition, if your study is addressing more than one planning objective, then you may use a different type of output for each objective. Using multiple outputs will complicate, but not necessarily overwhelm, your analysis. See Chapter Five for a discussion about how you can handle the “apples and oranges” problem of multiple outputs (called “commensuration”).

Outputs are the intended results of implementing solutions. In this sense, they are the analytical equivalent of traditional economic “benefits.” Outputs, like traditional dollar benefits, are a special type of what many of us refer to as “environmental impacts.” The difference is that “outputs” are the desired and intended effects of solutions (we’re trying to create them), while “impacts” usually refer to the full range of effects, both undesirable and desirable, and unintended and intended. Note that, although our primary concern here is with environmental outputs, the full range of effects, including other environmental and social impacts, must be assessed for environmental restoration and mitigation solutions. For example, the impacts of a wetland restoration project on lost upland habitat, displaced upland wildlife, relocated structures and utilities, and other impacts should also be assessed.

Although we have focused our discussions on fish and wildlife and ecosystem-related outputs, the procedures described in this manual can be applied to a wide range of other outputs. The basic questions posed in these procedures, culminating in the “Is it worth it?” analysis, are equally valid for problems related to water and air quality, hazardous and toxic wastes, aesthetic resources, cultural resources, and any other type of resource.

So long as the basic measurement requirements are met, any non-monetary output should be amenable to the essential analyses of these procedures.

## Measuring Outputs

Every output is measured using a technique that measures changes in terms of a metric, or “measurement unit”. There is no single, universal, all-purpose unit of environmental output, nor is there a single, universal, all-purpose measurement technique. Traditional metrics for measuring environmental outputs have included:

- *Physical dimensions*, such as acres, miles, days, etc.
- *Population counts* of a species or guild (number of wading birds, for example).
- *“Habitat units”* are a product of the “Habitat Evaluation Procedures” (U.S. Fish and Wildlife Service 1980; also referred to as “HEP”), as well as several other habitat-based evaluation methodologies similar to HEP. While the original HEP applications focused on single species, recent HEP-like procedures focus on communities and may measure “community units” or similar metrics.

Other less commonly used metrics include measurements of biodiversity, productivity and risk. Again, there is no one way to measure environmental outputs that will apply in all cases. Each study must determine the best way to measure outputs to meet its unique decision making needs.

Current Corps guidance provides flexibility in the measurement of outputs, but states that outputs that measure ecosystem value and productivity are preferred. According to ER 1105-2-100, paragraph 3-5, c (1):

*Ecosystem restoration outputs must be clearly identified and quantified in appropriate units. Although it is possible to evaluate various physical, chemical, and/or biological parameters that can be modified by management measures that would result in an increase in ecosystem quantity and quality in the project area, the use of units that measure an increase in “ecosystem” value and productivity are preferred. Some examples of possible metrics which may be used include habitat units, acres of increased spawning habitat for anadromous fish, stream miles restored to provide fish habitat, increases in numbers of breeding birds, increases in target species and diversity indices. Alternate measures of ecosystem value and productivity may be used upon approval by CECW-P. Monetary gains (e.g., incidental recreation or flood damage reduction) and losses (e.g., flood damage reduction or hydropower) associated with the project shall also be identified.*

Ideally, we should first define the output to be measured (based on a planning objective); then define the unit in which we will measure change in the output; and finally select the measurement technique that will provide values in terms of the selected unit. Selecting the technique first will, by definition, select the measurement unit, which may or may not be the best indicator for the output. Analysts should recognize linkages among outputs, units and techniques in developing measurement frameworks for their studies. Appendix C of Corps engineering circular 1105-2-210 (June 1, 1995) provides a good summary of current ecological measurement methods.



## What's a Cost?

Cost is a sacrifice that must be made in order to do or acquire something. Cost is frequently characterized as a monetary value for the purposes of planning investigations. The costs of environmental planning solutions have three components: *implementation costs*, *opportunity costs*, and *incidental benefits*. While all three components are discussed below, only implementation costs are to be included in the cost calculations for CE/ICA, per Corps policy. Opportunity costs and incidental benefits, if applicable, may be displayed in the comparison of alternative plans for trade-off analysis purposes, but are not to be included in CE/ICA procedures.

*Implementation costs* are what economists might refer to as explicit costs; they are the out-of-pocket, cash outlays for producing environmental outputs. Examples of implementation costs include outlays for preconstruction engineering and design, real estate, construction, OMRR&R (operation, maintenance, repair, relocation and rehabilitation), and monitoring. Implementation costs include what are typically thought of as the cost estimate and the real estate appraisal.

The level of detail appropriate for cost estimates and real estate appraisals will vary through different phases of planning. For the purposes of these analyses, a Corps M-CACES (Microcomputer-Aided Cost Estimating System) cost estimate, and a real estate appraisal, may not be needed, especially during early phases of planning. Professional judgment is needed in determining a level of detail that is appropriate for the phase of planning, project scale, and the level of detail in output measurements. Moreover, communication is required to inform staff from cost engineering and real estate about what types of decisions their estimates will support (for example, preliminary scoping of measures) so they can be comfortable with the appropriate level of detail.

*Opportunity costs of foregone benefits* are what economists might refer to as implicit costs; they don't cost us money we already have in pocket, but rather they cost us the opportunity to have done something else. For example, restoration of a riparian corridor may require removal of a levee, which would reduce flood damage reduction benefits provided by the levee. In Federal water resources planning, opportunity costs typically refer to foregone National Economic Development (NED) benefits. The P&G specifies the following goods and services as NED benefits:

- Municipal and industrial water supply;
- Agricultural floodwater, erosion and sedimentation reduction;
- Agricultural drainage;
- Agricultural irrigation;
- Urban flood damage reduction;
- Hydropower;
- Inland navigation;
- Deep draft navigation;
- Recreation;

- Commercial fishing; and
- Other categories of benefits.

See ER 1105-2-100 for a discussion of procedures for estimating these NED benefits. Additional Corps guidance for estimating many of these benefits can be found in the Corps National Economic Development Procedures Manual Series (see references).

*Incidental benefits* are monetary benefits that occur as unintended consequences of an environmental planning solution and incur no additional implementation costs. In some ways, they can be thought of as the opposite of opportunity costs. Incidental NED benefits are incidental benefits in the same eleven categories listed above. For example, restoration of a wetland, upstream from an urban center, may provide incidental flood damage reduction benefits to the urban area.

Although incidental benefits are not costs to be included in cost effectiveness and incremental cost analyses, they may nonetheless represent pertinent information for decision-making. If a solution provides significant incidental benefits, these benefits should be displayed in the comparison of alternative plans. A particular restoration alternative's incidental benefits may play an important role in plan selection.

## Total Cost

Summing all implementation costs produces the total cost of a solution to be used as the cost element in CE/ICA procedures. The formula for this calculation is shown in Figure 3.

$$\text{Total Cost} = \text{Implementation Costs}$$

**Figure 3**  
**Computing the Total Cost of a Plan Alternative**

## Section 3

# Plan Analysis

## Before You Start

Cost effectiveness and incremental cost analyses are tools for comparing alternative solutions to planning problems. The analyses should not require any additional data than what would otherwise be generated in a typical planning study. They examine how costs vary at different levels of output.

In cost effectiveness and incremental cost analyses, output values are added, subtracted, and divided. Therefore, ordinal units of measurement (1st, 2nd, 3rd...) cannot be used in these analyses. However, cardinal units of output measurement, such as population counts and habitat units, can be used.

Since the analyses are tools for making comparisons across alternative solutions, it is important to convert all data to comparable values. Specifically, all costs must be discounted to reflect the time value of money; and if costs are converted to average annual equivalent costs, outputs should also be computed on an average annual basis.

The remainder of this chapter will discuss calculations that are made in cost effectiveness and incremental cost analyses to extract information from the cost and output data. Perhaps the simplest such calculation is that of total cost.

## Average Cost

Average cost is calculated by dividing total cost by total output. The formula for this computation is shown in Figure 4. Average cost is altogether different than the concept of average annual cost. The average cost for a particular level of output is the cost per unit of output for that level. If a solution provides 100 units of output at a total cost of \$1000, the average cost is \$10 per unit for that alternative. Average costs can facilitate the comparison of production efficiencies across alternatives by placing each alternative plan in a common metric: dollars per unit of output. For example, a solution, which produces output at \$10 per unit, would be considered more efficient in production than a solution producing the same type of output at \$20 per unit.

$$\text{Average Cost} = \frac{[\text{Total Cost of Solution A}]}{[\text{Total Output of Solution A}]} = [\text{Cost per Unit Output of Solution A}]$$

**Figure 4**  
**Computing Average Cost**

## What's an Increment?

If you've been involved in planning studies, you've probably heard people talk about "increments". Unfortunately, like many other words in our business, the term increment has several different meanings, each of which are correct when used in the right context.

In general, "increment" is used in two different ways in Corps planning. First, and perhaps most commonly, increment is used in a design-sense to mean the size of a management measure or the composition or size of an alternative plan. For example, a levee's height may be sized in one-foot increments (4-feet high, 5-feet high, 6-feet high, etc.). Increments of a plan usually refer to additions of new measures to the plan (a levee plan; a levee and channel plan; a levee, channel and drop structure plan; etc.); or different sizes of a particular measure included in a plan (a levee and 2,000-foot channel plan; a levee and 2,500-foot channel plan; a levee and 3,000-foot channel plan; etc.). A "last-added increment" is the final size or measure included in a plan. In this manual, we use the term "scale" to mean this design-sense of increment.

## Incremental Cost and Incremental Output

When we use the term increment or incremental in discussing incremental cost analysis, we are using the term in its economic-sense to mean a *difference, or change*, between two solutions. The types of changes we are interested in are differences in cost and differences in output between solutions; these differences are referred to as incremental cost and incremental output.

*Incremental Cost* is the difference in total cost between two solutions, expressed in dollars. For example, if a 40-acre pond costs \$100,000, and a 50-acre pond costs \$175,000, the increment of cost (or change in cost) between the two ponds is \$75,000. This incremental cost information simply tells us that the 50-acre pond costs \$75,000 more than the 40-acre pond. Figure 5 contains the formula for incremental cost.

$$\text{Incremental Cost of Solution B} = [\text{Total Cost of Solution B}] - [\text{Total Cost of Solution A}]$$

**Figure 5**  
**Computing Incremental Cost**

*Incremental Output* is the difference in output between two solutions, expressed in the output's unit of measurement. Continuing with the pond example, if the 40-acre pond would produce 20 habitat units, and the 50-acre pond would produce 30 habitat units, the increment of output between the two ponds is 10 habitat units. In other words, the 50-acre pond provides 10 more habitat units than the 40-acre pond. Figure 6 contains the formula for incremental output.

$$\text{Incremental Output of Solution B} = [\text{Total Output of Solution B}] - [\text{Total Output of Solution A}]$$

**Figure 6**  
**Computing Incremental Output**

## Incremental Cost per Unit

Incremental cost analysis is an examination of the changes in both cost and output across alternative solutions. We can make this two-dimensional variation more apparent, helping us to make comparisons across solutions, by combining the concepts of incremental cost and average cost to compute *incremental cost per unit*; one number that reflects both types of change. Figure 7 contains the formula for incremental cost per unit.

$$\text{Incremental Cost per Unit of Solution B} = \frac{[[\text{Incremental Cost of Solution B}]]}{[\text{Incremental Output of Solution B}]}$$

**Figure 7**  
**Computing Incremental Cost per Unit**

Note: Figures 5, 6, and 7 refer to the incremental cost, incremental output, and incremental cost per unit, respectively, of *Solution B*. While saying these incremental values correspond to one solution simplifies the discussion, the incremental values in these formulas actually apply to *the decision to implement Solution B over Solution A*.

Examining the changes in incremental cost per unit across solutions is, in other words, examining how the cost per unit (or average cost) of incremental output changes as the level of output changes. Returning again to the pond example, the incremental cost per unit of the 50-acre ponds is \$7,500 per habitat unit, based on the following calculation:

$$(\$175,000 \text{ cost of 50 acre pond} - \$100,000 \text{ cost of 40 acre pond}) = \$75,000$$

$$= \$7,500/\text{HU}$$

$$(30 \text{ HU output of 50 acre pond} - 20 \text{ HU output of 40 acre pond}) = 10 \text{ HU}$$

This tells us that the 10 extra habitat units that the 50-acre pond can provide (over the 20 units provided by the 40-acre pond) cost \$7,500 each. Using the average cost equation in Figure 4, we find that the 20 habitat units provided by the 40-acre pond cost \$5,000 each. This information tells us that we can get the first 20 habitat units for \$5,000 each; if we want more we can get 10 additional units, but those will cost \$7,500 each. Now we have our cost and output data in a format that facilitates answering the “is it worth it?” question. Specifically, are 20-habitat units worth \$5,000 each? If so, are 10 more worth \$7,500 each?

The concepts of incremental cost, incremental output and incremental cost per unit are not difficult; but may be new, especially to non-economists. And, because they are unfamiliar, they are sometimes confused with average cost. Both types of cost measurements - incremental and average—play a role in our analyses, but they are different and cannot be used interchangeably.



## Section 4

# Case Study

### Introduction

In order to demonstrate how cost effectiveness and incremental cost analyses can be performed using IWR Planning Suite II software, the following case study is presented. Although the case study is based on an actual Corps ecosystem restoration feasibility study, the actual solutions, costs, and environmental outputs have been modified in this manual for illustration purposes. None of the cost and output figures used in this example represent real data from the feasibility study.

### Study Area Setting

The City of Phoenix and the Corps are studying means of restoring degraded riparian and riverine ecosystems in a seven-mile segment of the Salt River floodplain in the Phoenix metropolitan area. The Salt River channel downstream and south of the city is dry during most of the year, but the river and surrounding floodplain are subject to infrequent flood flows resulting from periodic flash flood events. The primary objective of the potential ecosystem restoration project is to restore the degraded ecological resources of the Salt River and associated floodplain. Incidental recreation benefits are expected. A planning constraint is that the proposed restoration measures should not increase flood damages to nearby residences and farms; if possible, the measures should contribute to the reduction of flood damages.

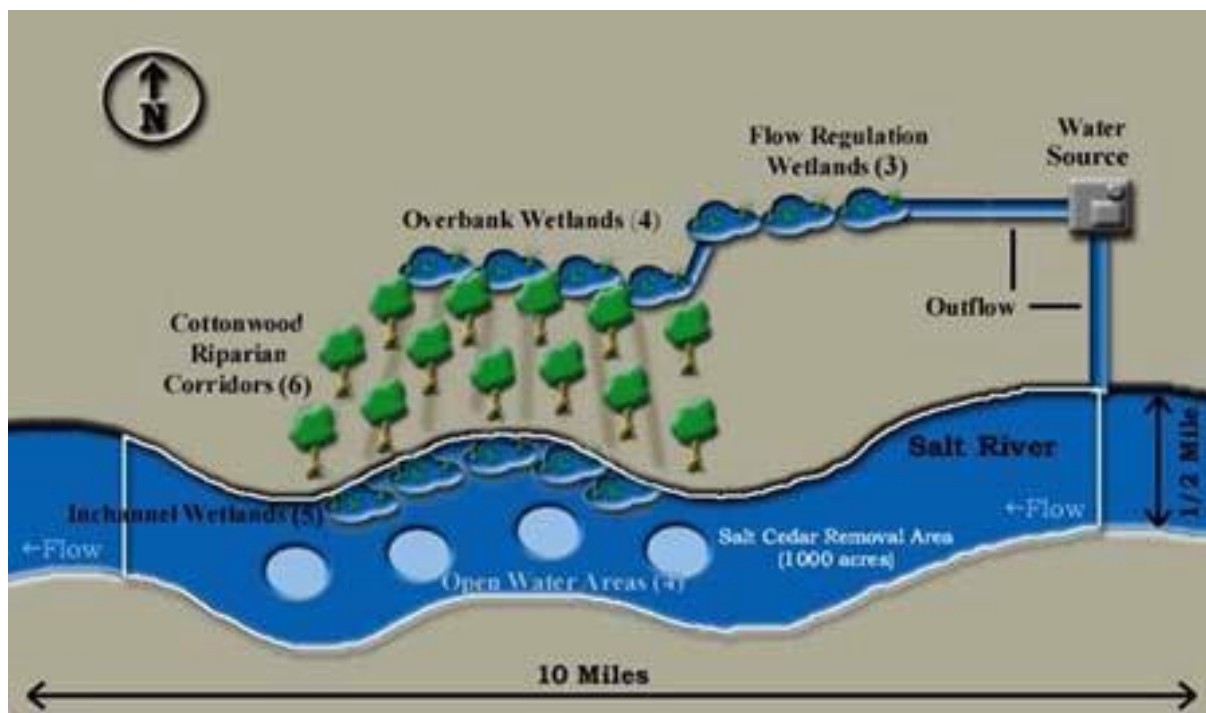
There are several manifestations of the degraded environment in this part of the Salt River floodplain. Riparian vegetation, including cottonwood-willow and mesquite vegetative covers, both native to the riparian zones of the study area, has been greatly reduced in aerial extent during the last 50 years. This is due primarily to the reduction of surface water flow volumes in the Salt River channel. Upstream water diversions and consumption are primarily responsible for the reduction in surface water flows in the study area. Reduced flow volumes have negatively impacted the availability of surface and groundwater to support the cottonwood-willow and mesquite vegetative cover types. As a result, approximately 1,000 acres of the previously mentioned cover types have been lost in the study area in the last 50 years. Both cottonwood-willow and mesquite riparian woodlands provide valuable habitat for many native Sonoran Desert bird and mammal species, including the Yuma clapper rail (a state-listed sensitive species) and the cactus wren. The former and existing riparian corridors also provide important resting and feeding sites for several Neo-tropical migratory species of birds.

Another sign of the degraded ecosystem is the virtual disappearance of riverine wetlands and open water areas within the study area. Again, due to reduced surface water flows, the open water sections of the channel have been reduced to a few seasonal pools (a loss of approximately 600 acres), while approximately 400 acres of former riverine and fringe wetlands in the floodplain have dried up. Much of the former river channel and riverine wetlands have been replaced by exposed rock, cobble, and sand. The loss of these ecosystems has resulted in the loss of habitat for such aquatic and wetland species as the snail darter, leopard frog, and blue heron.

Yet another manifestation of the degraded ecological conditions in the study area is the rampant growth of an exotic tree species called salt cedar. Salt cedar, a salt- and drought-tolerant invasive species, has thrived in dry Salt River riverbed, out-competing, and in many areas, replacing native vegetation. The leaves of salt cedar

trees exude a noxious compound that, upon decomposition in the soil, increases the salinity of the soil, thereby inhibiting the growth of other plant species. Stands of salt cedar therefore tend to be dense and monotypic, providing very low habitat values for native birds and mammals. In addition to their negative impacts on habitat quality, the density and roughness of salt cedar “forests” in the Salt River riverbed also contribute to flooding problems during episodic flash flood events (the trees retard passage of flood flows and contribute to increased sediment deposition). An estimated 1,000 acres of salt cedar now cover the floodplain in the study area.

An illustration of our sample study area is shown in Figure 8. (Note that this figure shows proposed solutions for the study area. A figure of the study area itself would not actually show proposed features, only existing conditions.)



**Figure 8**  
**Sample Study Area**



## Solutions

In cooperation with the local sponsor, state resource agencies, other Federal agencies, and local stakeholders, the Corps District office developed several solutions (various management measures at various sites) to the problem of degraded riparian and riverine ecosystems in the Salt River floodplain. Since lack of surface water in the Salt River channel was considered fundamental to all associated environmental problems, finding a source of water was a critical prerequisite to all proposed solutions. Fortunately, an underutilized source of water was available and acceptable to all the concerned parties: outflow from a nearby municipal wastewater treatment plant. Effluent from the plant is treated with secondary treatment processes, meeting all state water quality and EPA discharge criteria. All the proposed ecosystem restoration solutions make use of the wastewater treatment plant outflow. The individual sites and management measures (explained below) can be employed individually or in combination with each other to contribute to ecosystem restoration.

### Solution 1: Diurnal Flow Regulation Wetlands

Diurnal flow regulation wetlands would be created on the north bank of the Salt River and just west and downstream from the treatment plant outfall. They would be constructed at bank level above the 100-year floodplain. A pump would be required to move water from the wastewater treatment plant outflow discharge to the wetlands site. The wetlands would help to control and attenuate the diurnal pulses of water released from the plant, evening out the flows to more closely emulate a natural system. The wetlands would help to “polish” the effluent, thereby further improving water quality, as well as creating valuable habitat for the Yuma clapper rail, blue heron, and other bird species. It was estimated that a minimum of 50 acres would be required to handle and regulate the flow from the treatment plant. Therefore, 50 acres was considered the minimum scale for this solution. However, land is available to accommodate larger areas of diurnal flow regulation wetlands; these could be built linearly and further west of the initial 50-acre site. Larger wetland acreages of 100 and 150 acres would therefore be considered (corresponding to scales 2 and 3) of this first solution.

### Solution 2: Overbank Wetlands

Overbank wetlands would be created further west and downstream of the regulation wetlands and located, not in the Salt River channel itself, but at bank level. These wetlands would be supplied with water from the regulation wetlands. Their purpose is to provide similar habitat to what had historically existed for various aquatic, bird, amphibian, reptilian, and mammalian species. The overbank wetlands would also provide source water for downstream (and downhill or “downbank”) cottonwood and willow riparian corridors. Various scales and configurations of overbank wetlands are possible, but their general shape would be roughly linear along the top of the river bank, between approximately 100 to 200 yards wide, and covering areas of 25 to 150 acres (25 acres corresponding to scale 1; 75 acres to scale 2; 100 acres to scale 3; and 150 acres to scale 4). Because the overbank wetlands (solution 2) are supplied water through the diurnal flow regulation wetlands (solution 1), solution 2 is dependent on solution 1.

### Solution 3: Remove Salt Cedars from River Channel

This solution would entail removing all 1,000 acres of invasive salt cedar trees from the Salt River riverbed and the area between the overbank wetlands and the riverbed. The trees would be bulldozed, uprooted, and removed. Removing invasive salt cedar is a prerequisite to enabling native plant species to re-vegetate the area and would also improve the channel's capability to handle and pass flood flows. It was determined that removing all 1,000 acres would be required to effect any significant improvement in the local ecosystem. Complete removal would prevent the rapid re-population of salt cedar stands, which is able to out-compete native species due to its tolerance for high salt concentrations in the soil. Therefore only 1 scale would be considered for this solution. This solution is required before any of the other solutions involving re-vegetation of native species can be considered (i.e., solutions 4, 5, and 6 are dependent on solution 3.) No specific outputs are associated with the removal of salt cedar *per se*. Rather, this solution is a pre-requisite to the implementation of solutions 4-6 and the associated riparian, open water, and wetland habitats they would provide.

### Solution 4: Cottonwood-Willow Riparian Corridors

These 500- to 1,000-yard long corridors of planted cottonwood and willow trees would extend southwesterly from outflow points along the overbank wetlands, extending down the river bank toward the river channel itself. Water from the wetlands would feed excavated, shallow ditches, descending in elevation toward the river, with the banks along both sides of the ditches planted with cottonwood and willow trees and native bushes. Surface water and groundwater flow through the trench corridors would provide the required quantity of soil moisture to support tree growth. The cottonwood-willow riparian vegetative cover provides very high habitat values to a variety of bird and mammalian species. Enough water discharging from the overbank wetlands would be available to support up to six riparian corridors of approximately 50- to 100-yard widths and 500- to 1,000-yard lengths. These riparian corridors would correspond to scales 1 – 6 for this solution category (scale 1 = construct 1 riparian corridor, scale 2 = construct 2 riparian corridors, scale 3 = construct 3 riparian corridors, and so on). Because the cottonwood willow corridors (solution 4) are dependent on water flows from the overbank wetlands (solution 2), solution 4 is dependent on solution 2. Likewise, the establishment of cottonwoods and willows is dependent on the removal of salt cedar, so solution 4 is also dependent on solution 3.

### Solution 5: Create Open Water Areas in River Channel

This solution would consist of excavating and grading depressions or pits in the riverbed that would serve as deep water pools and open water areas to capture water from flood flows and some of the wastewater treatment plant outflow. The open water areas would provide habitat for various aquatic species, as well as provide food and water sources for various bird and terrestrial species. Various sizes and configurations of open water areas could be constructed. Four scales would be considered: 100, 200, 300, and 400 acres. Before this solution can be implemented, the existing stands of salt cedar must be removed, so solution 5 is dependent on solution 3. Creation of open water areas will also inhibit the re-establishment of salt cedar in the area.

## Solution 6: Create Riverine and Fringe Wetlands within River Channel

This solution would entail excavation and grading of sand and cobble areas to appropriate elevations within the river channel adjacent to open water areas and along the edge of the river channel to create riverine and fringe wetland areas. Water would be supplied from nearby open water areas and residual flow from riparian corridors. Wetland plants would be planted. These wetland areas would provide habitat for various aquatic, bird, amphibian, reptilian, and mammalian species. One to 5 wetland areas of 120 acres each would correspond to scales of 120, 240, 360, 480, and 600 acres. Before this solution can be implemented, the existing stands of salt cedar must be removed, so solution 6 is dependent on solution 3. Creation of wetlands within the river channel area will also inhibit the re-establishment of salt cedar.

## Costs and Outputs

The important variables that must be considered in any cost effectiveness and incremental cost analyses (CE/ICA) are the costs and outputs of the proposed solutions. In this study, the implementation and operation and maintenance costs in dollars of each proposed solution and scale were calculated by cost estimators and converted to an average annual equivalent amount by economists (presented in \$1000 in Table 4 below).

Solution Number	Solution Description	Scale Number	Scale (Acres)	Costs (\$1,000)
1	Flow Regulation Wetlands	2	100	783
1	Flow Regulation Wetlands	3	150	849
2	Overbank Wetlands	1	25	415
2	Overbank Wetlands	2	75	620
2	Overbank Wetlands	3	100	815
2	Overbank Wetlands	4	150	1,010
3	Remove Salt Cedar	1	1,000	3,480
4	Riparian Corridors	1	15	144
4	Riparian Corridors	2	27	251
4	Riparian Corridors	3	47	370
4	Riparian Corridors	4	75	489
4	Riparian Corridors	5	101	560
4	Riparian Corridors	6	125	664
5	Open Water	1	100	2,150
5	Open Water	2	200	3,780
5	Open Water	3	300	5,777
5	Open Water	4	400	7,220
6	In-channel Wetlands	1	120	1,667
6	In-channel Wetlands	2	240	3,156
6	In-channel Wetlands	3	360	4,200
6	In-channel Wetlands	4	480	5,913
6	In-channel Wetlands	5	600	6,656

Note: Costs are expressed on an average annual equivalent basis.

In this study, the outputs of the proposed solutions are the changes in ecosystem values derived from the habitats produced by each solution. Some of the solutions use treated wastewater as a water source to produce wetlands and riparian habitats. Other solutions yield open water and wetlands habitats in the river channel, while another involves removal of a low-quality habitat associated with monotypic stands of an exotic species, which allows it to be replaced with higher-value native species. These wetlands, riparian, and

open water areas provide habitat for a variety of aquatic, wetland, terrestrial, and bird species. Rather than attempting to measure ecosystem outputs on a species-by-species basis, the interdisciplinary study team in this case decided to quantify outputs in terms of the acres and quality of those acres for each cover type or habitat produced by each solution. The output categories were therefore defined as wetland habitat, cottonwood-willow riparian habitat, and open water habitat. The quality of these habitat types was estimated by the biologists on the study team using available ecological models and best professional judgment. Quality Index values of 0.0 to 1.0, similar to Habitat Suitability Index (HSI) values, were estimated for each parcel of cover type to describe its overall quality for a variety of species' habitats under without project and with project conditions. Table 5 displays the acreage of various cover types produced by each of the solutions and scales, as well as the difference in Quality Index values between without project and with project conditions (i.e., the Quality Index value shown is the improvement or "lift" in habitat quality effected by implementation of a given solution). These quality index values were then multiplied by the acreage of each cover type restored or created to provide a quantity and quality measurement of the ecological output of each solution and scale (see Table 6 below). These "net" outputs are the output quantities to use for CE/ICA. The outputs displayed were calculated on an average annual basis over the 50-year project life.

The cost information from Table 4 and the output information from Table 6 for the various solutions and scales will be used in the IWR Planning Suite II software example in the following sections.

Solution Number	Solution Description	Scale Number	Scale (Ac)	Wetlands		C-W Riparian		Open Water	
				Ac	QI	Ac	QI	Ac	QI
1	Flow regulation wetlands	1	50	50	0.8				
1	Flow regulation wetlands	2	100	100	0.8				
1	Flow regulation wetlands	3	150	150	0.8				
2	Overbank Wetlands	1	25	25	0.85				
2	Overbank Wetlands	2	75	75	0.85				
2	Overbank Wetlands	3	100	100	0.85				
2	Overbank Wetlands	4	150	150	0.85				
3	Remove Salt Cedar	1	1,000	1,000	0				
4	Riparian Corridors	1	15			15	1.00		
4	Riparian Corridors	2	27			27	1.00		
4	Riparian Corridors	3	47			47	1.00		
4	Riparian Corridors	4	75			75	1.00		
4	Riparian Corridors	5	101			101	1.00		
4	Riparian Corridors	6	125			125	1.00		
5	Open Water	1	100					100	0.65
5	Open Water	2	200					200	0.65
5	Open Water	3	300					300	0.65
5	Open Water	4	400					400	0.65
6	In-Channel Wetlands	1	120	120	0.90				
6	In-Channel Wetlands	2	240	240	0.90				
6	In-Channel Wetlands	3	360	360	0.90				
6	In-Channel Wetlands	4	480	480	0.90				
6	In-Channel Wetlands	5	600	600	0.90				

Note: Ac – Acres; QI – Quality Index. Quality Index values shown are the difference (improvement) in QI between with project and without project conditions.

Table 6. Composite Outputs (Acres X Quality Index Values)			
Solution Number	Solution Description	Scale Number	Output
1	Flow Regulation Wetlands	1	40
1	Flow Regulation Wetlands	2	80
1	Flow Regulation Wetlands	3	120
2	Overbank Wetlands	1	21.25
2	Overbank Wetlands	2	63.75
2	Overbank Wetlands	3	85
2	Overbank Wetlands	4	127.5
3	Remove Salt Cedar	1	0
4	Riparian Corridors	1	15
4	Riparian Corridors	2	27
4	Riparian Corridors	3	47
4	Riparian Corridors	4	75
4	Riparian Corridors	5	101
4	Riparian Corridors	6	125
5	Open Water	1	65
5	Open Water	2	130
5	Open Water	3	195
5	Open Water	4	260
6	In-Channel Wetlands	1	108
6	In-Channel Wetlands	2	216
6	In-Channel Wetlands	3	324
6	In-Channel Wetlands	4	432
6	In-Channel Wetlands	5	540



## Section 5

# Software Terms and Procedures

The following sections describe terminology and procedures for using the IWR Planning Suite II software.

## Software Terminology

IWR Planning Suite II uses terms that have specific meanings within the context of the application to refer to various aspects of the planning process, and to refer to different entities associated with the planning investigation. Commonly used terms you will need to know in order to easily work through the example follow. These include such concepts as:

- Plan Alternatives
- Planning Sets
- Plan Studies
- Variables and Attributes
- Application Suite
- Plan Editor
- Plan Generator

There is also a glossary at the end of this guide which may be used as a quick reference for many common terms.

## Plan Alternative

A Plan Alternative, which may just be referred to as a “plan” or an “alternative,” is a set of one or more solutions (activities) of particular scales. Plan alternatives are created to address planning objectives. Each plan has a cost and one or more resulting outputs. Within IWR Planning Suite II, a plan consists of a plan name, a set of variables, and a set of attributes.

Plan alternatives are discrete entities, and need not necessarily be derived from a fixed set of solution and scale combinations. With such a configuration, the planner gains a great deal of leverage in the ability to define their own plan alternatives and scenario sets and to edit, combine or remove plans from both planning sets produced by the Plan Generator Module, and those that they enter themselves.

The same plan alternative can be a member of and shared by more than one planning set in a plan study simultaneously. This capability gives planners complete control over the planning sets used for analysis and removes any restrictions that would be imposed by a planning set generator that is tied directly to a plan scenario analysis. Prior to analysis, the plan alternatives can be described in exactly the format and subset most appropriate for the analysis that is to be undertaken.

## Planning Set

A planning set or “plan set” is a grouping of individual plan alternatives. There are different kinds of planning sets in IWR Planning Suite II, all having their own special use and purpose. There are generated planning sets, user-defined planning sets, constrained planning sets, and analysis planning sets. A description of each follows. The user may think of planning sets as similar to the term “scenario” as used under the IWR-PLAN version 3.33 nomenclature.

**Generated Planning Set:** A set of plan alternatives created with a plan generator from solutions (management measures) and scales.

**User-Defined Planning Set:** A set of plan alternatives entered by a user through the Plan Editor. Planners gain a great deal of leverage in the ability to define their own plan alternatives and scenario sets and to edit, combine or remove plans from both planning sets produced by IWR Planning Suite II’s plan generation capabilities and those produced by other means.

**Constrained Planning Set:** A set of plan alternatives created by applying limiting criteria to an existing planning set. Constraints may be defined within the plan editor to filter the planning set to only those plan alternatives that meet a set of predefined criteria. The criteria are minimum and maximum acceptable values for a particular variable. Derived variables (explained below) are not available for use by a constraint group. To define a constrained planning set, the planning set name is entered, along with one or more variables to constrain it by a minimum and maximum acceptable value for each variable. The application of a constraint to a planning set will generate a new planning set containing only the plan alternatives that meet the constraining criteria.

**Uncertainty Planning Set:** A set of plan alternatives created by a completion of a Monte Carlo Simulation where variable values are determined based on a random selection of values from a specified distribution for a set number of iterations along with defined tolerance rules and correlation amongst variables. The values of all iterations are then averaged to produce a final set of values for each plan in the planning set.

**Watershed Planning Set:** A set of plan alternatives that allows the user to consider multiple locations in the analysis. The user can define one plan per site, more than one plan per site or generate plans for each site based on their selections. Following that selection the user will be led through a series of steps to define solutions and scales, relationships and automated edits for each defined plan.

**Analysis Planning Set:** A set of plan alternatives created by performing an analysis on an existing planning set.

**Active Planning Set:** The planning set that is currently selected and visible in the Plan Editor. The active planning set is the one that component modules act upon. The user can easily change the active planning set to another planning set at any time, allowing a variety of planning sets to be operated on simultaneously.

## Plan Study

A “Plan Study” or “Planning Study” refers to a single database or data file in IWR Planning Suite II. It is a related group of planning sets derived from a common set of plan alternatives. It contains all of the plan alternatives and analysis results used to evaluate candidate plans for a specific planning task. In some cases, it may be considered to represent the plan formulation and analysis portion of the planning investigation. In other cases it may represent one portion or one iteration of these parts of a particular planning investigation.



## Plan Alternative Variable

A Plan Alternative Variable is a category used for comparative purposes in analyses. A “variable” describes some characteristic of the alternatives, or management measures comprising those alternatives, in a planning study. Some examples of variables are cost, output, habitat units, and other effects. Variables are the constituent components of “derived variables.” A Derived Variable is a variable, the value of which has been derived via a user-defined mathematical formula from the values of other variables in the plan alternative. Derived variables are described by formulae applied to component variables. Mathematical functions such as the additive, multiplicative, or exponential functions may be applied to these component variables, along with many other standard mathematical operations. They are thus added to the planning study and described in terms of a variable name, description, measurement units, and a calculation formula.

## Plan Alternative Attributes

The plan alternative representation is enhanced by the ability to internally associate data items other than solutions, scales, costs and outputs with plan alternatives. This new kind of plan alternative association is called a plan “attribute.”

An Attribute is a value or hierarchical structure of values associated with a plan alternative. It is distinguished from a variable in that it identifies a characteristic of the entire plan alternative, rather than being an intrinsic part of the plan alternative. An attribute is connected to a plan alternative associated with a particular planning set. In other words, two attributes of the same name connected to the same plan alternative may have two different values in two different planning sets.

In IWR Planning Suite II, an attribute is a named label with a textual or numeric value associated with it. Some examples of attributes are Cost Effective, Plan of Interest, and Rank.

Attributes applicable to the analysis may be defined, such as a *plan of interest* attribute, to be used by reporting and visualization modules. Then, once the rows of the planning set are created, individual *plans of interest* may be chosen. To do so, the *plan of interest* attribute of the row is marked in the planning set editor. At this time, if the planning set was generated by the Plan Generator Module, a more appropriate name for the plan (say, for example, than A1B0C4D2), may be entered and associated with a specific plan alternative.

For example, for a proposed Civil Works project, there may exist a *locally preferred plan*, which is a plan that is preferred by a non-Federal sponsor of a Civil Works project. In such a case, it would be desirable during analysis to take particular note of this plan and its relationship to various plan alternatives during analysis. This would be a case where designating the locally preferred plan as a *plan of interest* would be useful.

## Distinguishing Between a Variable and an Attribute

Here are some useful tips to help you to remember what a variable is used for as opposed to the use of an attribute. As previously stated, a variable is an intrinsic characteristic of a plan alternative, while an attribute identifies a characteristic that may change for a given alternative between different planning sets.

The result of this distinction is that variable values are the same for a particular plan alternative in any planning set in a plan study. For example, in the planning study “My Plan Study”, in all planning sets that use “Plan A”, the “Cost” variable of Plan A will have the same value.

However, attribute values may be different for a particular plan alternative in any planning set in a plan study. For example, Plan A's "Cost Effective" attribute may be "Yes" in one planning set, and "No" in another, because different analysis parameters may have been used to generate the two planning sets.

## Plan Generator

The Plan Generator is a wholly separate module which runs fully integrated within the IWR Planning Suite II Editor. It uses the previously described Solutions and Scales approach to plan generation to generate planning sets which may then be subjected to analysis.

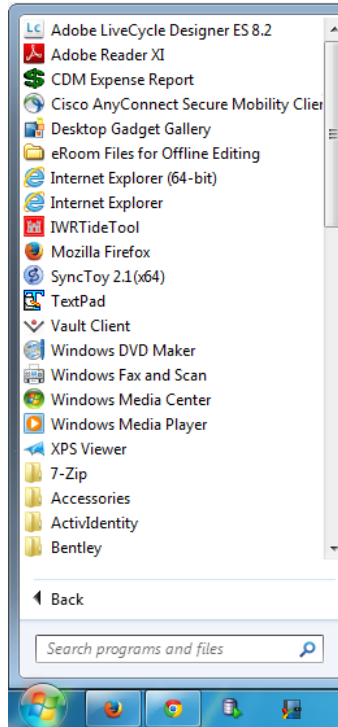
## Application Suite

IWR Planning Suite II is an application suite of software components. It is composed of the base Plan Editor component, to which other components can be readily added or removed. The modular "plug-and-play" ability to add or remove new components without re-installing IWR Planning Suite II lends itself to a more flexible architecture where you can pick and choose the modules that suit your needs. Current modules include a Plan Editor Component, which includes CE/ICA analysis and reporting, and a Plan Generator Component. An Uncertainty Planning Set Generation and Multi Criteria Decision Analysis (MCDA) modules were developed along with related reporting and graphing capabilities for each component. Also available is the Annualizer tool which allows the user to interpolate NER and NED benefits and costs over the period of analysis. The newest module addresses the ability to complete watershed analysis using multiple locations. New modules are easy to add to IWR Planning Suite II as needed.

## Software Procedures

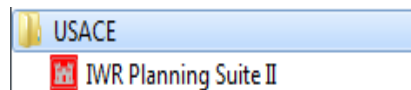
### Opening the Application

You will be working within the IWR Planning Suite II throughout the example scenario. Each Planning Study contains planning sets, and all IWR Planning Suite II functions are performed within Planning Studies. To open the application, click on the Windows Start button to open up the Start Menu and then select All Programs. A list of programs and folders will now appear.



**Figure 9**  
**Start Menu**

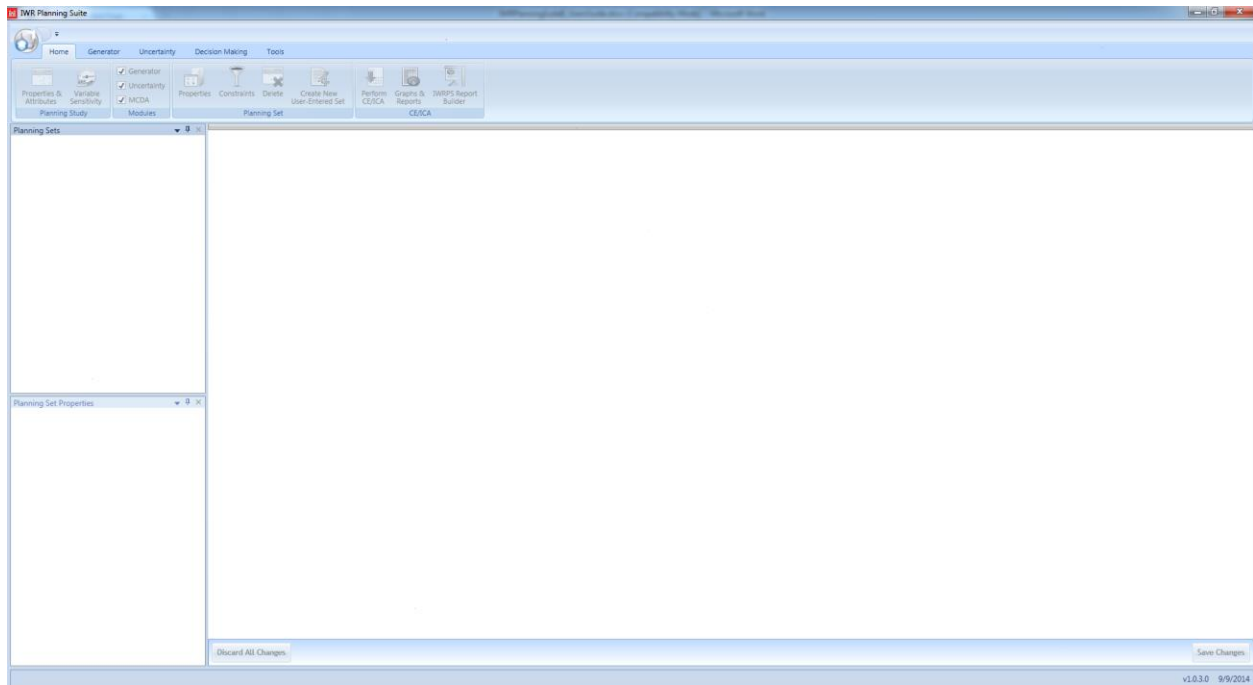
The user should scroll until they locate the USACE folder. Within that folder users will find IWR Planning Suite II.



**Figure 10**  
**Launching the Application**

The user should select this option to launch the application.


The IWR Planning Suite II Application will now open with a default view as shown below.



**Figure 11**  
**IWR Planning Suite II Application**

## Creating a New Plan Study

To follow along with the case study described in the previous chapter, simply create a new planning study following the procedures below. To create a new planning study, select the application button

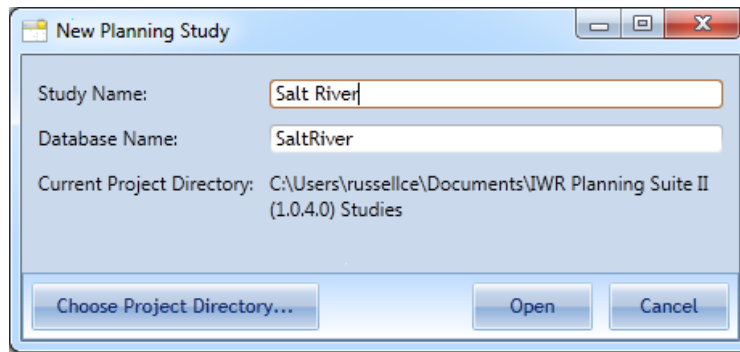
() and select New.



**Figure 12**  
**Launching Create New Planning Study**

After making this selection the New Planning Study form will open. A default study name is provided that can be used but it is recommended the user provide a more meaningful name for the planning study in order to be able to easily identify the planning study at a later date.

The user should provide a name for the planning study by replacing the text in the Study Name field as shown in the figure below. The name used in this example is “Salt River.”

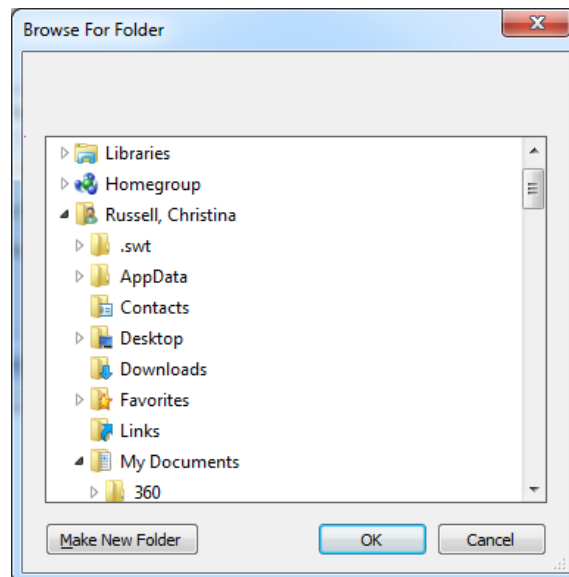


**Figure 13**  
**New Planning Study**

As the user types in the name of the planning study, the associated database name shown in the Database Name field is also updated. Any spaces or special characters are not included in the database name.

Once the user clicks the 'Open' button the planning study is created and a folder with the same name as the database is created within the directory identified under Current Project Directory.

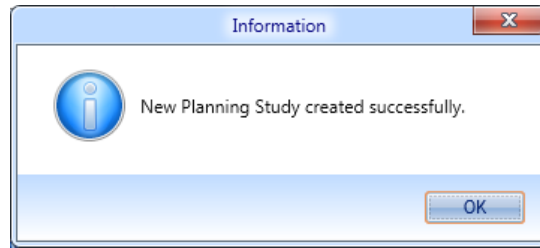
Alternatively, if the user would like to save the planning study to another location they should click the 'Choose Project Directory...' button. This will bring up a Browse for Folder dialog to allow the user to navigate to and select the directory in which they would like to save the planning study.



**Figure 14**  
**Browse for Folder**

Once the directory is chosen and the user clicks the 'OK' button they will return to the New Planning Study form. Note the Current Project Directory will update based on the location selected. The user can now click the 'Open' button to create the planning study.

At this point the user will receive a dialog verifying that the planning study was successfully created. The user should then click 'OK' to continue.

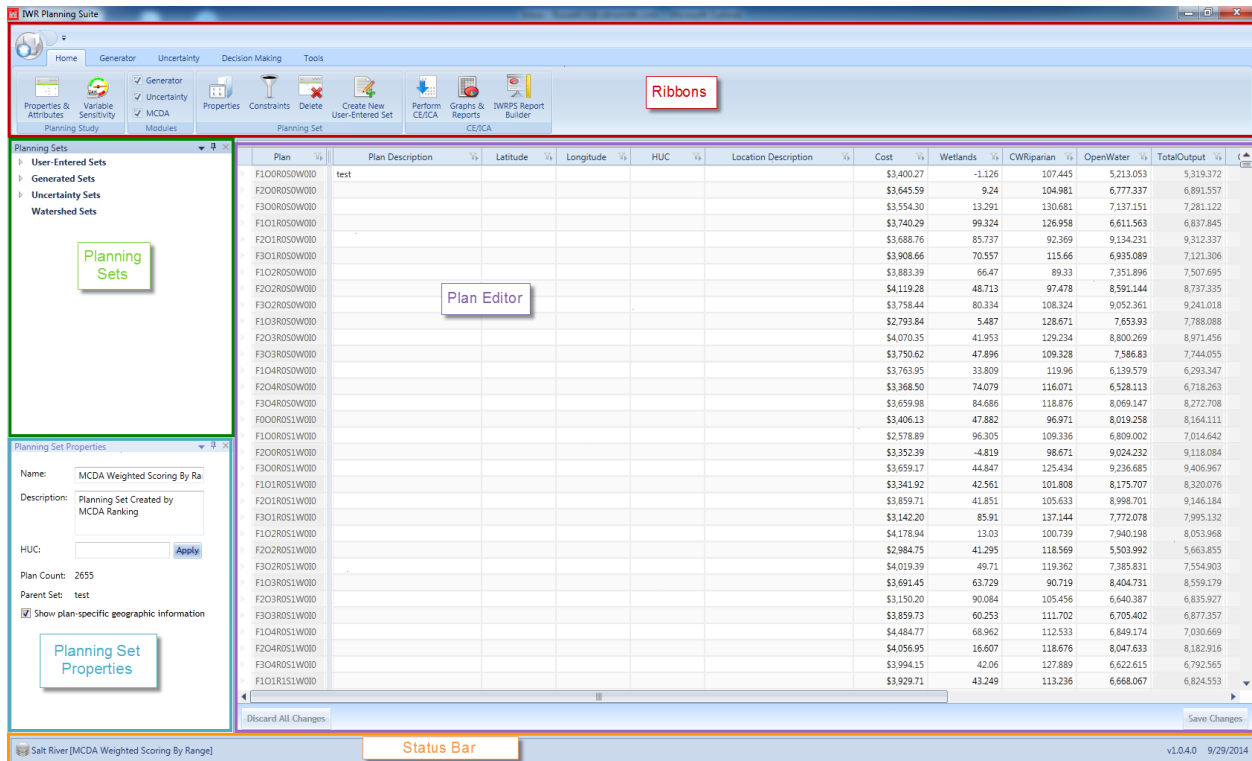


**Figure 15**  
**Planning Study Created Confirmation**

## General Application Use

Now that a planning study has been created the user has access to utilize most of the planning suite functionality. Please note that Planning Set Properties will not be enabled until a planning set has been created and then this area will display the properties of the currently selected planning set.

The application itself is broken into five main areas: ribbons, planning sets, planning set properties, plan editor and a status bar as shown below.



**Figure 16**  
**Application Areas**

## Ribbons

The application button and ribbons are a set of toolbars placed on several tabs that are filled with graphical buttons and other graphical control elements that allow the user to access controls that are grouped by functionality. For more information on ribbons please see the section on [Application Extras](#).

## Planning Sets

The Planning Sets area organizes the planning sets that are part of this planning study by type: [User-Entered Sets](#), [Generated Sets](#), [Uncertainty Sets](#) and [Watershed Sets](#). If sets of a given type are available then there will be a small arrow ( ▸ ) beside each type. Clicking on this arrow will expand the section and show all available planning sets of this type.



**Figure 17**  
**Planning Set Editor Organization**

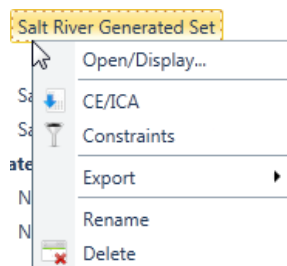
The user can click ▲ to collapse the area.

Clicking on a planning set highlights the planning set and displays the data for the plan alternatives in the Plan Editor to the right.

Plan	Plan Description	Latitude	Longitude	HUC	Location Description	Cost	Wetlands	CWRiparian	OpenWater	TotalOutput
F1OOROSOW00	test					\$3,400.27	-1.126	107.445	5,213.053	5,319.372
F2OOROSOW00						\$3,645.59	9.24	104.981	6,777.337	6,891.557
F3OOROSOW00						\$3,554.30	13.291	130.681	7,137.151	7,281.122
F1O1ROSOW00						\$3,740.29	99.324	126.958	6,611.563	6,837.845
F2O1ROSOW00						\$3,688.76	85.737	92.369	9,134.231	9,312.337
F3O1ROSOW00						\$3,908.66	70.557	115.66	6,935.089	7,121.306
F1O2ROSOW00						\$3,883.39	66.47	89.33	7,351.896	7,507.695
F2O2ROSOW00						\$4,119.28	48.713	97.478	8,591.144	8,737.335

**Figure 18**  
**Displaying Planning Set Details**

The user also has right click capabilities for each planning set. When the user right clicks on a planning set they will be presented with a menu of options. The options available to the user are: Open/Display..., CE/ICA, Constraints, Export to Excel, Rename and Delete.



**Figure 19**  
**Open a Planning Set**

**Open/Display...**

Selecting this option displays the selected planning sets data in the plan editor.

**CE/ICA**

Selecting this option launches the [Perform CE/ICA Analysis](#) form that allows the user to complete a CE/ICA Analysis on the selected set.

**Constraints**

Selecting this option launches the [Constrain Active Planning Set](#) form that allows the user to constrain an existing planning set.

**Export to Excel**

Selecting this option allows the user to export the selected planning set. Once the user selects this option they will be presented with a form to define a file name and select a location to save the file.

**Rename**

Selecting this option launches the Enter a New Name for the Planning Set dialog and displays the current planning set name. The user can update the planning set name as desired and then click the 'OK' button. Once the user clicks the 'OK' button the user will receive a confirmation that the planning set was successfully renamed. Clicking 'OK' on this confirmation updates the planning set name in both the Planning Sets, Planning Set Properties and Status Bar.

**Delete**

Selecting this option allows the user to delete the selected planning set. The user will receive a confirmation dialog to verify they do want to delete the planning set. Once a planning set has been deleted it is a permanent action and can't be undone.

**Planning Set Properties**

Planning set properties identify the name, description, [HUC](#) (Hydrologic Unit Code), plan count, parent set (when applicable) and an option for enabling and disabling the geographic fields. This information can be updated by the user and saved using the 'Save Changes' button available in the Plan Editor. If the user wishes to identify a HUC for a planning set and then apply that HUC to all plan alternatives within the planning set the user can click the 'Apply' button next to the HUC field. Likewise, the user can uncheck the box for Show plan-specific geographic information and all geographic fields will be removed from view in the Plan Editor. The geographic fields include the fields for latitude, longitude, HUC and location description.

**Plan Editor**

The Plan Editor displays the plans and the associated information related to each plan alternative for the planning set selected in the Planning Sets pane. The user can double click on a field to edit its value. The user can then use the tab or arrow keys to stay in edit mode and move to other fields and change their values. Note this is how all grids available on forms function within this application.



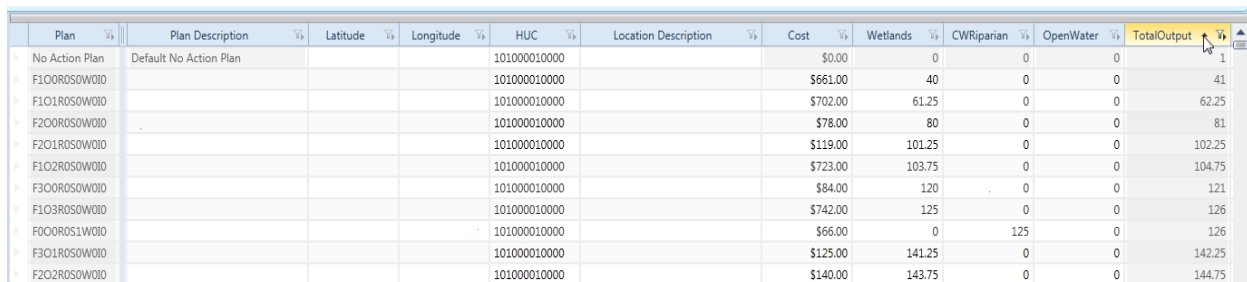
Once all changes are complete the user should click the 'Save Changes' button available in the bottom right corner of the Plan Editor to save their changes in both the Plan Editor and the Planning Set Properties window. Discard All Changes will discard all changes made in the Plan Editor or Planning Set Properties since the last save. Notice that derived variable values can't be edited by the user but are viewable in the editor. Since derived variable values are determined based on the formula provided in the Planning Study Properties form the user would need to modify the formula as necessary there and then the value for this derived variable will update for already created generated sets.

If the user wishes to see other attributes or variables in the plan editor that are not currently displayed they can modify the visibility settings in the Planning Study Properties form accessible by clicking the 'Properties & Attributes' button on the Home ribbon.

Users can also choose to copy and/or paste information into a spreadsheet from the plan editor to update or replace values in the Plan Editor with values from a spreadsheet. These same steps can be followed to complete copying and pasting into other forms as well.

To copy information from the Plan Editor the user should select (highlight) the values they wish to copy and use the key combination Ctrl+C to copy this information. The user can then click in a spreadsheet and use the key combination Ctrl+V to paste the copied information into the spreadsheet. Using these shortcut keys, it is possible to select an entire range of values (a grid of values) to copy or cut from the active planning set, and you may also paste an entire range of values from another source into the active planning set.

Users can elect to sort the plans shown by a given value. For instance if the user wants to sort all results by TotalOutput the user could click the heading of this field and the listed plans would then be displayed in ascending order by the value of the TotalOutput field. Notice the up arrow that displays beside TotalOutput now.



Plan	Plan Description	Latitude	Longitude	HUC	Location Description	Cost	Wetlands	CWRiparian	OpenWater	TotalOutput
No Action Plan	Default No Action Plan			101000010000		\$0.00	0	0	0	1
F100ROSOW00				101000010000		\$661.00	40	0	0	41
F101ROSOW00				101000010000		\$702.00	61.25	0	0	62.25
F200ROSOW00				101000010000		\$78.00	80	0	0	81
F201ROSOW00				101000010000		\$119.00	101.25	0	0	102.25
F102ROSOW00				101000010000		\$723.00	103.75	0	0	104.75
F300ROSOW00				101000010000		\$84.00	120	0	0	121
F103ROSOW00				101000010000		\$742.00	125	0	0	126
F000ROS1W00				101000010000		\$66.00	0	125	0	126
F301ROSOW00				101000010000		\$125.00	141.25	0	0	142.25
F202ROSOW00				101000010000		\$140.00	143.75	0	0	144.75

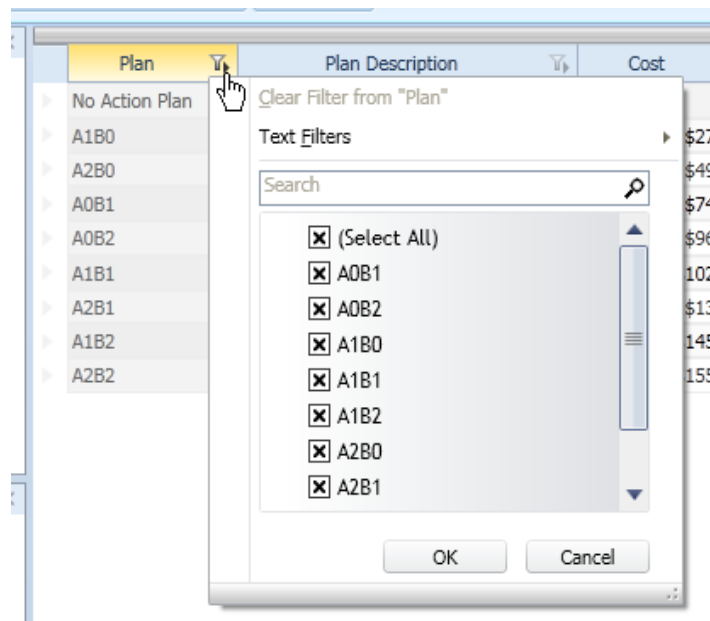
**Figure 20**  
**Planning Set Editor Sorting**

If the user wishes to sort in descending order they can simply press the TotalOutput heading again and it will re-sort in descending order and the arrow beside the field will now be pointing down. Grids on other forms can also be sorted in this way.

Plan	Plan Description	Latitude	Longitude	HUC	Location Description	Cost	Wetlands	CWRiparian	OpenWater	TotalOutput
F3O4R6S1W4I5				101000010000		\$1,401.50	787.5	200	260	1,248.5
F3O4R5S1W4I5				101000010000		\$1,379.50	787.5	172	260	1,220.5
F2O4R6S1W4I5				101000010000		\$1,395.50	747.5	200	260	1,208.5
F3O3R6S1W4I5				101000010000		\$1,381.50	745	200	260	1,206
F3O4R4S1W4I5				101000010000		\$1,355.50	787.5	152	260	1,200.5
F3O4R3S1W4I5				101000010000		\$1,333.50	787.5	140	260	1,188.5
F3O2R6S1W4I5				101000010000		\$1,362.50	723.75	200	260	1,184.75
F3O4R6S1W3I5				101000010000		\$1,256.50	787.5	200	195	1,183.5
F2O4R5S1W4I5				101000010000		\$1,373.50	747.5	172	260	1,180.5

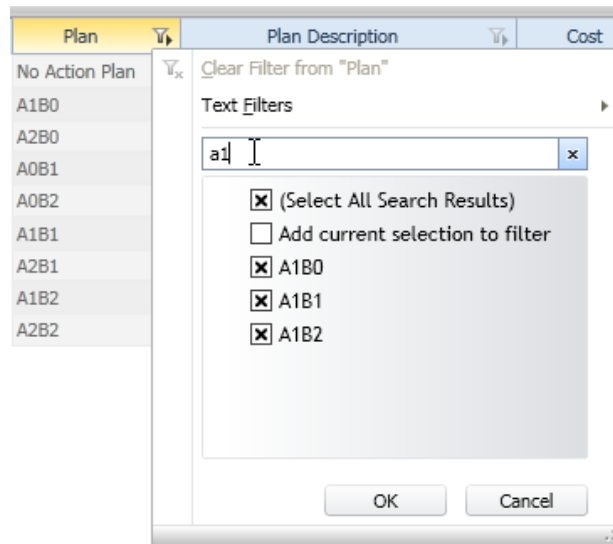
**Figure 21**  
**Planning Set Editor Sort Descending**

Users can elect to review all plans in a planning set at once or the user can filter the results to review a subset of the plans at one time. When a filter icon is clicked a multi-select panel appears where users can select one or more values from the list.



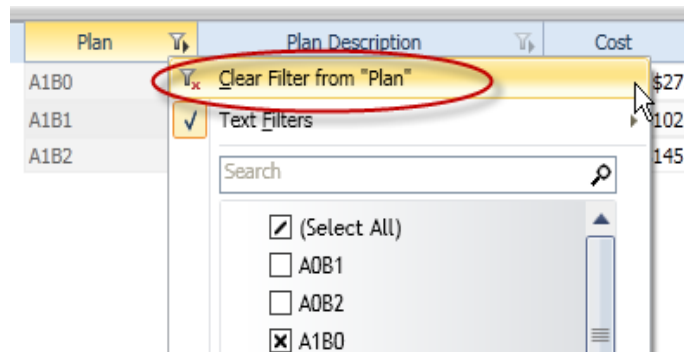
**Figure 22**  
**Filtering**

The text search box can be used to reduce the number of items in the checkbox list. So typing 'a1' would reduce the number of items in the list to only those beginning with 'A1' and clicking 'OK' would apply the filter.



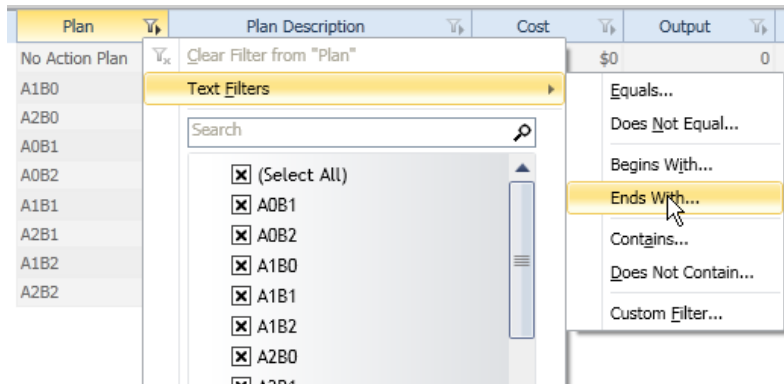
**Figure 23**  
**Filtering By Specific Value**

Users can tell what rows have an actively applied filter by looking at the filter icon. Filtered rows have a darker icon. To cancel a filter, users can click on the icon to bring up the filter panel and click on the Clear Filter from “field” option at the top.



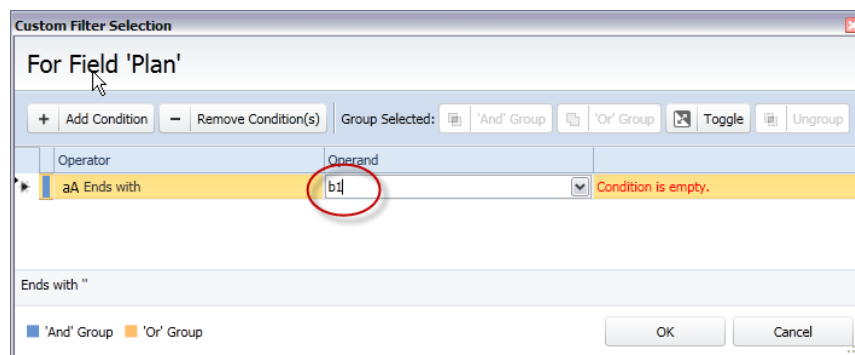
**Figure 24**  
**Clearing Filters**

Text searches still assume the default comparison type of ‘Starts with.’ If users would like to change the type of comparison used (i.e. ‘Ends with’) they could do so by expanding the ‘Text Filters’ selection.



**Figure 25**  
**Text Filtering Options**

Changing the default selection will bring up another window where users can specify more complicated rules.



**Figure 26**  
**Filtering Operands**

Typing 'b1' into the 'Operand' field and clicking the 'OK' button will filter the results to be all plan alternatives ending with 'B1.'

	Plan	Plan Description	Cost
▶	A0B1		\$74.74
▶	A1B1		\$102.94
▶	A2B1		\$138.9

**Figure 27**  
**Filtering Results**

Please note that other forms with grids throughout the application can also be filtered in this way as well.

## Status Bar

The status bar provides the user with information. The left portion of the status bar identifies which planning study the user is currently reviewing and which planning set is selected, if any, in brackets following the planning study name. The right hand portion of the status bar identifies the version of the IWR Planning Suite II application the user is using and the current date.

## Working with Planning Sets

The user now has four options available in order to create planning sets:

1. The user may define and manually enter a planning set.
2. The user can define attributes, variables, attributes, relationships and automated edits in order for the application to generate a planning set.
3. The user can create uncertainty sets using existing plan alternatives or by defining custom plans and assigning and applying distribution and correlation values to those plans where a Monte-Carlo Simulation is then utilized to determine the final planning set values.
4. The user can create watershed sets using the watershed wizard which leads the user through the process of defining locations, plans, solutions, and location dependencies for the purpose of completing a watershed analysis involving multiple locations.

Regardless of the method by which the planning sets are generated they do have some commonalities. The fields that are available for each plan are the same regardless of the method by which the set was created or generated. For each plan alternative a plan name, plan description, latitude, longitude, HUC, location description and user defined variables and attributes are displayed.

Plan	Plan Description	Latitude	Longitude	HUC	Location Description	Cost	Output	Cost Effective	test
No Action Plan	Default No Action Plan					\$0.00	0	Best Buy	<input type="checkbox"/>
A1B0						\$25.00	11,000	Cost Effective	<input type="checkbox"/>
A0B1						\$50.00	50,000	Best Buy	<input type="checkbox"/>
A1B1						\$75.00	61,000	Best Buy	<input type="checkbox"/>

**Figure 28**  
**Planning Set Editor Fields**

**Plan Name:** For user-defined planning sets the plan name is a user entered value and can be composed of alphanumeric characters. The user can define a plan name that includes a name of up to 255 characters. For generated planning sets the planning sets will be automatically named based on the solutions and scales set by the user at the time of generation.

**Plan Description:** The user can define a description of up to 500 characters for each plan. That value can be composed of any characters to include letters, numbers, spaces and special characters.

**Latitude and Longitude:** The latitude and longitude are to be entered in decimal degrees and up to 3 digits after the decimal value are allowed. The values for latitude are between -90 and 90 while the values for longitude range from -180 to 180.

**HUC:** Up to a 12-digit numeric Hydrologic Unit Code (HUC) value may be entered for each plan in whole numbers.

**Location Description:** The location description for each plan cannot exceed 500 characters.

**Variables:** All variables created prior to the creation or generation of a planning set will be listed (as long as they are set to visible in the Planning Study form. The values allowed for each variable depends on the variable type defined for each variable. For more information on [variable types](#) and their [constraints](#) please see those sections of the user guide. For generated planning sets the values for the variables will be set during plan generation.

The following will provide detailed guidance on how to create each type of planning set.

## User-Entered Planning Sets

The user should begin by defining which variables they anticipate using in relation to this planning set. The user can view the default variables and modify, remove or add new variables by clicking on the 'Properties & Attributes' button available on the Home ribbon.

Once the user makes this selection they will be presented with the Planning Study Properties form. Just below the description of the planning study, which defaults to the planning study name, is a section dedicated to defining variables for the planning study.

In this instance we will use the variables from the Salt River example as shown below.

Planning Study [Salt River] Properties

Name  
Salt River

Description  
Salt River

Variables

Name	Units	Description	Variable Type	Derived	Derived Function	Minimum	Maximum	Visible
Costs	Average Annual Equivalent Cost	\$1000	Currency	<input type="checkbox"/>				<input checked="" type="checkbox"/>
Wetlands	Wetland Habitat	AAHU's	Decimal	<input type="checkbox"/>				<input checked="" type="checkbox"/>
CWRiparian	Cottonwood-willow Riparian Habitat	AAHU's	Decimal	<input type="checkbox"/>				<input checked="" type="checkbox"/>
OpenWater	Open Water Habitat	AAHU's	Decimal	<input type="checkbox"/>				<input checked="" type="checkbox"/>

Add

Attributes

Name	Type	Description	Visible
Plan of Interest	Yes/No	Plan of Interest	Never
Cost Effective	Integer	Non-Cost Effective, Cost Effective, or Best Buy	CE/ICA Analysis
Rank	Double	MCDM Ranking	MCDA Ranked
Score	Double	MCDM Score from Ranking	MCDA Ranked
#CE	Integer	Number of Cost Effective Plans	Uncertainty CE/ICA Parent

Add

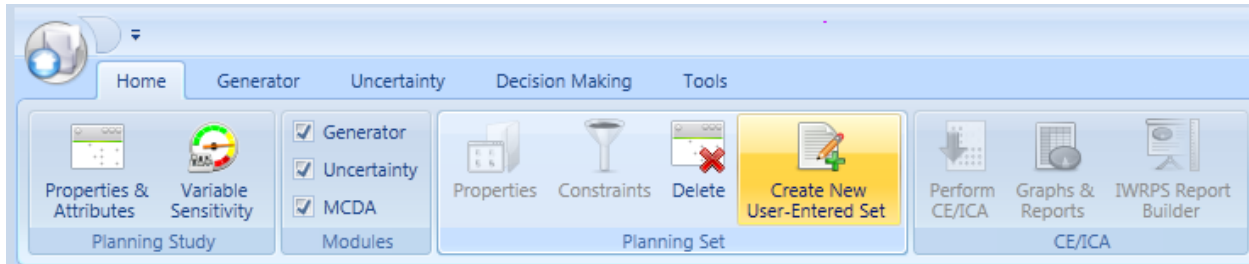
OK Cancel

**Figure 29**  
**Planning Study Properties**

Once the user has defined the costs and outputs they plan to use with this planning set the user can click the 'OK' button to close this form.

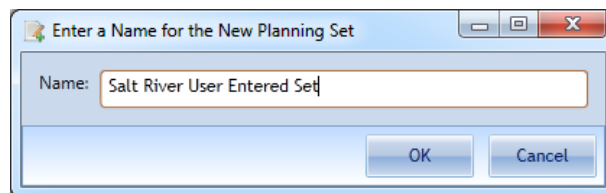
For more information on adding, deleting and modifying variables please see the [Costs and Outputs](#) section.

Now that the costs and outputs associated with this planning set have been defined the user can create their list of plans by clicking the 'Create New User-Entered Set' button available on the Home ribbon.



**Figure 30**  
**Launching Create New User-Entered Set**

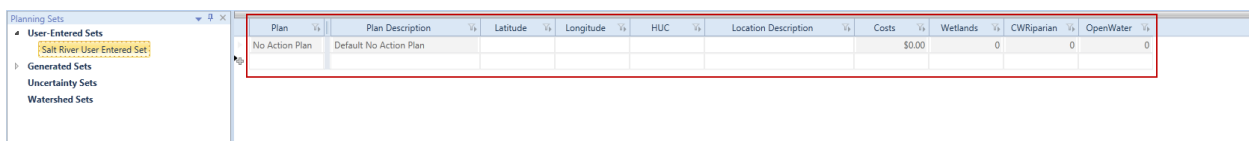
Once the user has made this selection the user will be prompted to enter a name for the new planning set.



**Figure 31**  
**Name New Planning Set**

The user can enter up to 255 alphanumeric characters in order to uniquely identify this planning set including spaces and special characters. Once the user has entered the name for the planning set they can click the 'OK' button to create the planning set or 'Cancel' to return to the main screen of the application.

Once the user clicks the 'OK' button to create a new user-entered planning set a grid becomes available in the Plan Editor to allow the user to enter their plans. Note the newly created planning set is categorized under User-Entered Sets in the Planning Sets pane.



**Figure 32**  
**Entering Planning Alternatives for User Entered Set**

The user may enter their information directly in the grid using the keyboard or may copy and paste information in this same format from a spreadsheet. To enter information directly into the grid the user should double click on the field and then use tab or the arrow keys to move between fields.

The user may copy and paste information using the standard copy and paste shortcuts available in Windows environment whereby Ctrl+C copies the selected rows and columns in a spreadsheet and then selecting the first cell you wish you paste the information into and using Ctrl+V on the keyboard to paste the information.

The user is able to enter for each plan a name (except for the no action plan), description, latitude, longitude, HUC, location description, and values for the variables and attributes the user defined in the previous step.

In this example only Flow Regulation Wetlands, Overbank Wetlands, and Remove Salt Cedar solutions are considered. The user may enter the information in the table below to create this planning set.

Table 7. Example User Entered Set				
Plan Name	Costs	Wetlands	CWRiparian	OpenWater
No Action Plan	0	0	0	0
F1O0S0	661	40	0	0
F2O0S0	78	80	0	0
F3O0S0	84	120	0	0
F1O1S0	702	61.25	0	0
F2O1S0	119	101.25	0	0
F3O1S0	125	141.25	0	0
F1O2S0	723	103.75	0	0
F2O2S0	140	143.75	0	0
F3O2S0	146	183.75	0	0
F1O3S0	742	125	0	0
F2O3S0	159	165	0	0
F3O3S0	165	205	0	0
F1O4S0	762	167.5	0	0
F2O4S0	179	207.5	0	0
F3O4S0	185	247.5	0	0

The user may now save the user entered set by clicking the 'Save Changes' button in the bottom right of the plan editor.

## Generated Planning Sets

Users can generate sets using the application. The user should work to define variables (costs and outputs), solutions and scales, relationships, constraints and sensitivities prior to generating a planning set. For our purposes we will utilize the case study for Salt River introduced in the earlier portion of the user guide.



The variables used in our Salt River example are shown below. The user can click the 'Properties & Attributes' button on the Home ribbon to enter the Planning Study Properties form and enter these variables.

<b>Table 8.</b> <b>Variable Names, Descriptions, and Units</b>			
Variable (Name)	Units	Description	Variable Type
Costs	\$1000	Average Annual Equivalent Cost	Currency
Wetlands	AAHU's	Wetland Habitat	Decimal
CWRiparian	AAHU's	Cottonwood-willow Riparian Habitat	Decimal
OpenWater	AAHU's	Open Water Habitat	Decimal

- For information on entering variables see [Costs and Outputs](#).
- Next the user should define the [solutions](#) to be used for this planning study. The user can define solutions by clicking the 'Solutions and Scales' button on the Generator ribbon. Selecting this option will launch the Solutions & Scales form.
- The solutions to be used in this example are shown below.

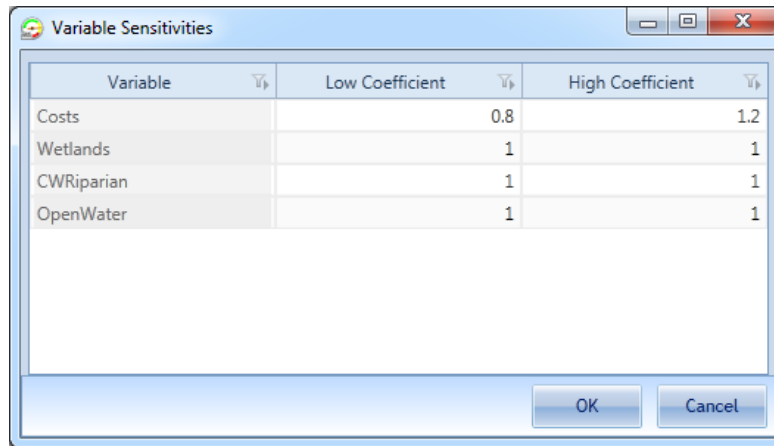
<b>Table 9.</b> <b>Solutions</b>		
Solution Description	Code	Number of Action Scales
Flow Regulation Wetlands	F	3
Overbank Wetlands	O	4
Riparian Corridors	R	6
Remove Salt Cedar	S	1
Open Water	W	4
In-channel Wetlands	I	5

- The scaled solution effects on variables can be entered in the bottom portion of the form. Please use the information below to assist you in completing this information.

<b>Table 10.</b> <b>Solutions and Effects</b>						
Code	Scale	Description	Costs (\$1000)	Wetlands (AAHU's)	CW Riparian (AAHU's)	Open Water (AAHU's)
F	0	No Action	0	0	0	0
F	1	50 Acres	661	40	0	0
F	2	100 Acres	78	80	0	0
F	3	150 Acres	84	120	0	0
O	0	No Action	0	0	0	0
O	1	25 Acres	41	21.25	0	0
O	2	75 Acres	62	63.75	0	0
O	3	100 Acres	81	85	0	0

Table 10. Solutions and Effects						
Code	Scale	Description	Costs (\$1000)	Wetlands (AAHU's)	CW Riparian (AAHU's)	Open Water (AAHU's)
O	4	150 Acres	1,01	127.5	0	0
S	0	No Action	0	0	0	0
S	1	1000 Acres	348	0	0	0
R	0	No Action	0	0	0	0
R	1	15 Acres	14	0	15	0
R	2	27 Acres	25	0	27	0
R	3	47 Acres	37	0	47	0
R	4	75 Acres	48	0	75	0
R	5	101 Acres	56	0	101	0
R	6	125 Acres	66	0	125	0
W	0	No Action	0	0	0	0
W	1	100 Acres	215	0	0	65
W	2	200 Acres	378	0	0	130
W	3	300 Acres	577	0	0	195
W	4	400 Acres	722	0	0	260
I	0	No Action	0	0	0	0
I	1	120 Acres	166	108	0	0
I	2	240 Acres	315	216	0	0
I	3	360 Acres	420	324	0	0
I	4	480 Acres	591	432	0	0
I	5	600 Acres	665	540	0	0

- For information on entering solutions and scales see the section on [Solutions and Scaled Effects](#).
- Next the user should define any constraints to be used when creating the planning set. In this example no constraints will be entered. For information on entering constraints see the section on [Constraints](#).
- Next the user should define any sensitivities that will apply to the given scenario.
- In this scenario variable sensitivities related to cost will be evaluated. Reviewing a range of potential costs from 80% of expected costs to 120% of costs will be reviewed. The user should click the 'Variable Sensitivity' button on the Home button to launch the Variable Sensitivities form. The user should modify the low coefficient for Costs to .8 and high coefficient to 1.2 as shown below.



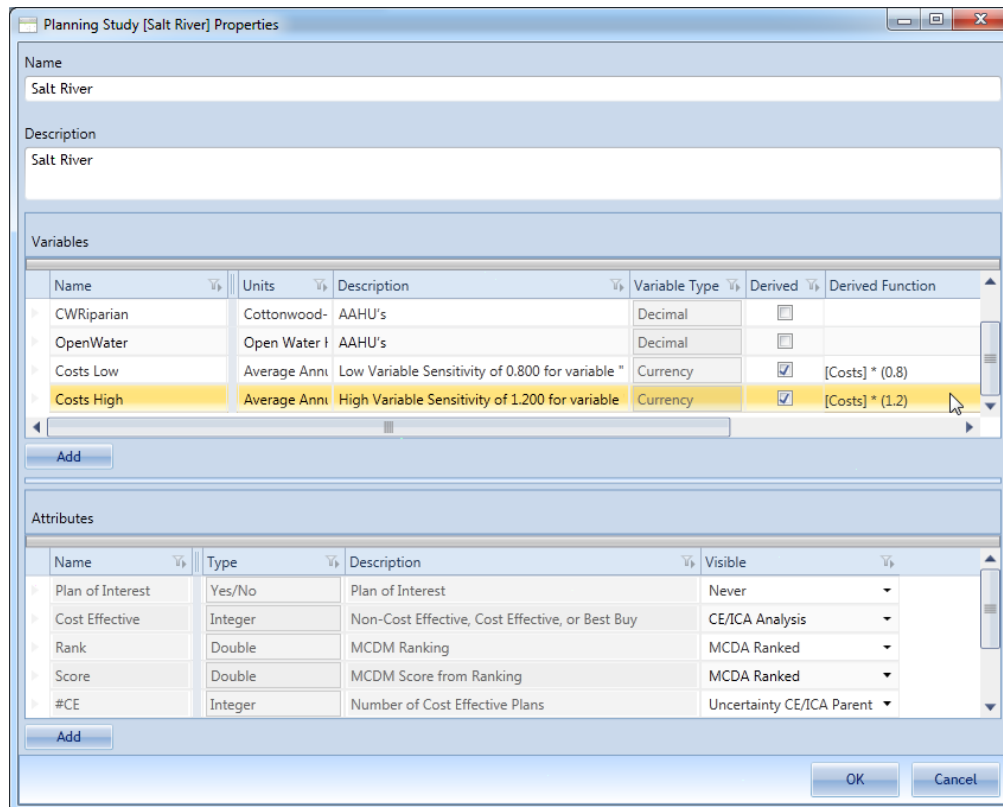
The 'Variable Sensitivities' dialog box contains a table with the following data:

Variable	Low Coefficient	High Coefficient
Costs	0.8	1.2
Wetlands	1	1
CWRiparian	1	1
OpenWater	1	1

Buttons: OK, Cancel

**Figure 33**  
**Variable Sensitivities**

- After this information is updated the user can click 'OK' to close the form. Two new variables will be created for Low Costs and High Costs. The user can view these newly created variables by clicking on the 'Properties & Attributes' button on the Home ribbon.



The 'Planning Study [Salt River] Properties' dialog box shows the following details:

Name: Salt River

Description: Salt River

**Variables**

Name	Units	Description	Variable Type	Derived	Derived Function
CWRiparian	Cottonwood-	AAHU's	Decimal	<input type="checkbox"/>	
OpenWater	Open Water	AAHU's	Decimal	<input type="checkbox"/>	
Costs Low	Average Annu	Low Variable Sensitivity of 0.800 for variable "	Currency	<input checked="" type="checkbox"/>	[Costs] * (0.8)
Costs High	Average Annu	High Variable Sensitivity of 1.200 for variable "	Currency	<input checked="" type="checkbox"/>	[Costs] * (1.2)

Buttons: Add, OK, Cancel

**Attributes**

Name	Type	Description	Visible
Plan of Interest	Yes/No	Plan of Interest	Never
Cost Effective	Integer	Non-Cost Effective, Cost Effective, or Best Buy	CE/ICA Analysis
Rank	Double	MCDM Ranking	MCDA Ranked
Score	Double	MCDM Score from Ranking	MCDA Ranked
#CE	Integer	Number of Cost Effective Plans	Uncertainty CE/ICA Parent

Buttons: Add, OK, Cancel

**Figure 34**  
**High and Low Variables**

- For information on entering variable sensitivities see the section on [variable sensitivity](#).

Next the user can define solution sensitivities. The user should select the 'Solution Sensitivities' button on the Generator ribbon to launch the Solution Sensitivity form. Through this dialog, you may enter uniform coefficients for computing all high and low values for any and every given variable and solution combination. As with variable coefficients, low coefficients must always be a real number less than or equal to one including negative numbers and high coefficients must be a real number greater than or equal to 1. Once the coefficients have been defined, clicking the 'OK' button will save the coefficients. Clicking the 'Cancel' button will discard any changes and close the form.

For this case study two variable and solution combinations have sensitivity that need to be defined. Enter the coefficients from Table 11 below now by the methods described above.

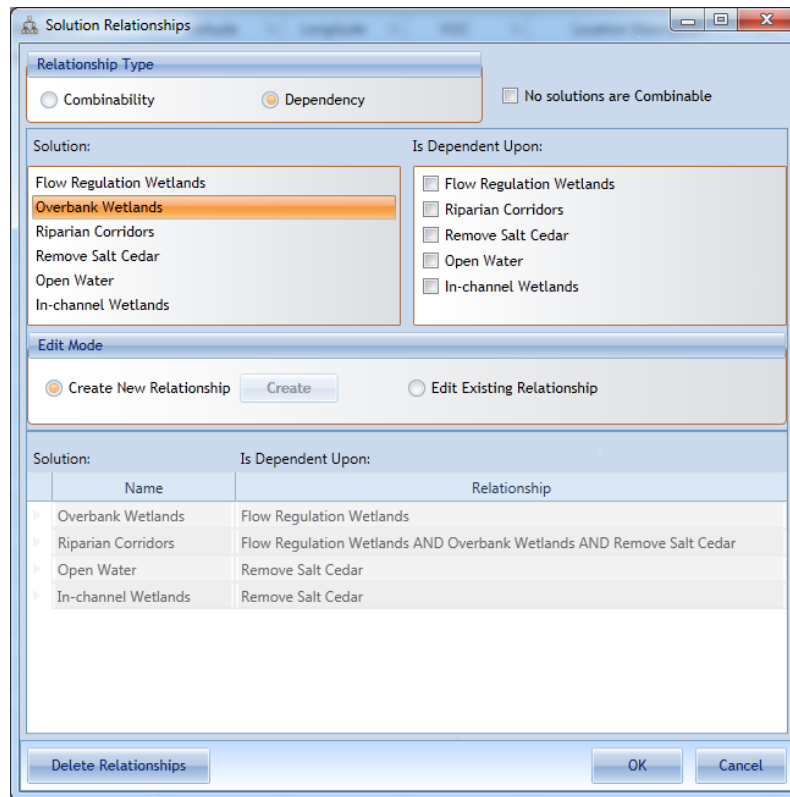
Table 11. Variable and Solution Combination Sensitivity			
Solution Code	Variable	Low Coefficient	High Coefficient
F	Cost	1	2
S	Cost	0.5	1

- For information on entering 'Solution Sensitivities' button see section on [solution sensitivity](#).

Finally, the user should define the needed relationship amongst solutions. In this example we will create the dependency [relationships](#) shown below.

Table 12. DependencyRelationships	
Solution	Dependent On
Overbank Wetlands (O)	Flow Regulation Wetlands (F)
Riparian Corridors (R)	Flow Regulation Wetlands (F), AND Overbank Wetlands (O), AND Remove Salt Cedar (S)
Open Water (W)	Remove Salt Cedar (S)
In-channel Wetlands (I)	Remove Salt Cedar (S)

Once these relationships have been established the form should appear as shown below.



**Figure 35**  
**Solution Relationships**

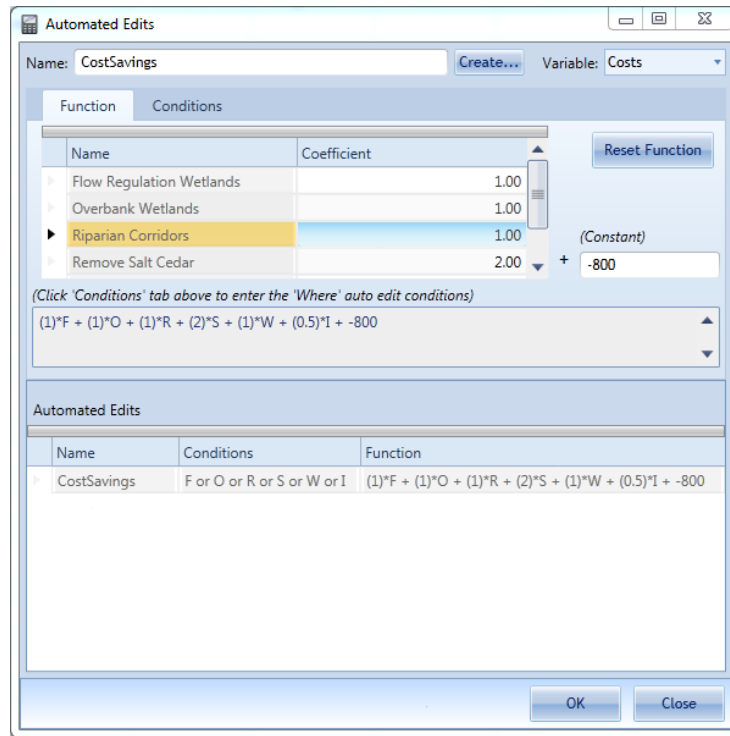
Finally, the [automated editing](#) feature allows users to automatically account for the fact that all plan effects may not be additive (IWR Planning Suite II's default assumption) when individual solutions are combined.

In this example we will create two automated edits. The first will be named "Cost Savings." The user can click the 'Create' button and then enter "CostSavings" as the group name and then click 'Save.'

This automated edit will be related to the variable Costs so that should be selected from the Variable field.

Next the user should update the coefficients for In-Channel Wetlands to .5, Remove Salt Cedar to 2 and then add a Constant of -800.

At this point it should look similar to what's shown below.



**Figure 36**  
**Automated Edits**

The defaults shown on the Conditions tab will be used in this example.

The user can now create the second automated edit, “Modoutput,” using the information shown in the table below.

Table 13. Automated Editing Function		
Group Name	Function	Where Condition
CostSavings	$(1) * F + (0.5) * I + (1) * O + (2) * R + (1) * S + (1) * W + -800$	F OR O OR R OR S OR W OR I (Default)
Modoutput	$(1) * F + (0.5) * I + (1) * O + (2) * R + (1) * S + (1) * W + (0)$	F OR I OR O OR R OR S OR W (Default)

Once these items have been entered the user should click the ‘Generate’ button available on the Generator ribbon.

The screenshot shows a window titled "Generate Planning Set". It has a "Planning Set Name" text box with "New Planning Set" entered. Below it is a "Description" text area with "New Generated Set" entered. A checkbox labeled "Remove inefficient plans during plan generation" is unchecked. Below the checkbox is a section labeled "Advanced Options" with a downward arrow. At the bottom right are "Generate" and "Cancel" buttons.

**Figure 37**  
**Generate Planning Set**

The user can now enter a name for the planning set to be generated. A default name will be provided but it is recommended it is updated to something more meaningful for the user. The user also has the option to enter a description for the planning set. The description can contain alphanumeric and special characters and can be up to 500 characters long.

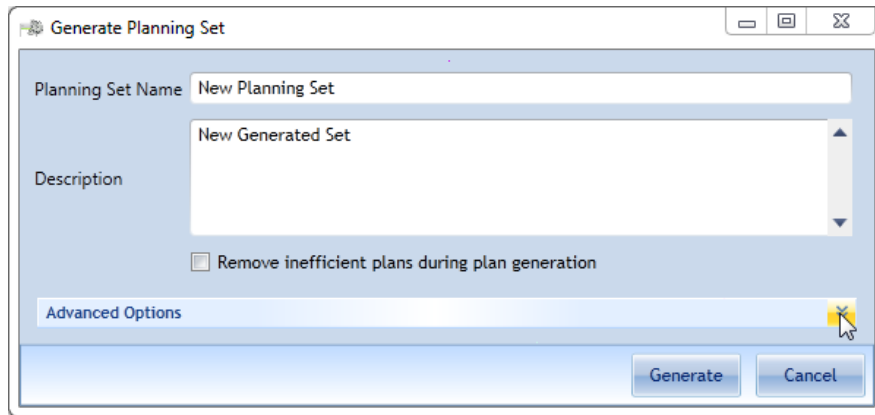
In this example the user should name the generated set Salt River Generated as shown below.

This screenshot is similar to Figure 37, but the "Planning Set Name" text box now contains "Salt River Generated". The "Description" text area still contains "New Generated Set". The checkbox and "Advanced Options" section are the same. The "Generate" and "Cancel" buttons are at the bottom right.

**Figure 38**  
**Planning Set Name**

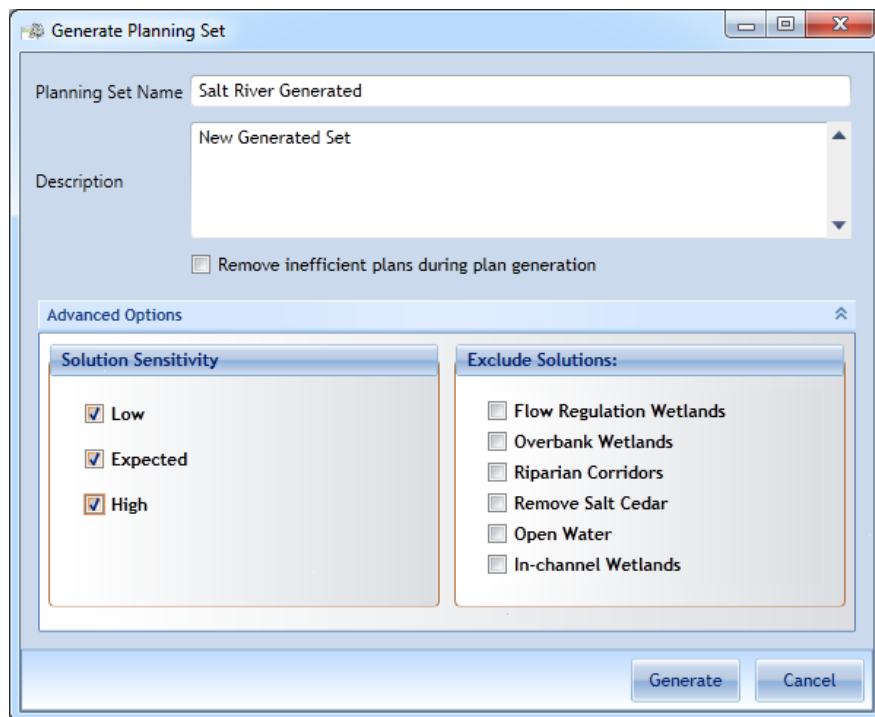
This form also includes an option to remove inefficient plans during plan generation. This can be done for large planning sets in order to reduce the number of plans that need to be reviewed but will not be used in this example.

Advanced options related to plan generation are also available by expanding this section of the form by clicking on the down arrows on the Advanced Options bar.



**Figure 39**  
**Expanding Advanced Options**

Expanding the Advanced Options section of the form provides the user will options for solution sensitivities and excluding solutions.



**Figure 40**  
**Advanced Options Expanded**

Since the user has defined solution sensitivities then the user can opt to select Low, Expected, and High options which will create three planning sets based on the defined solution sensitivities. For more information on solution sensitivities please see the section on [solution sensitivities](#).



If the user wishes to generate a set and exclude one or more solutions then they have the option to check the box beside each solution they wish to exclude during plan generation. No solutions will be excluded in our example.

Once all options have been set the user should click the 'Generate' button to [generate the planning set](#). The planning sets created by this method of generation will be named based on the planning set name entered and will displayed in the Planning Sets pane under Generated Sets.

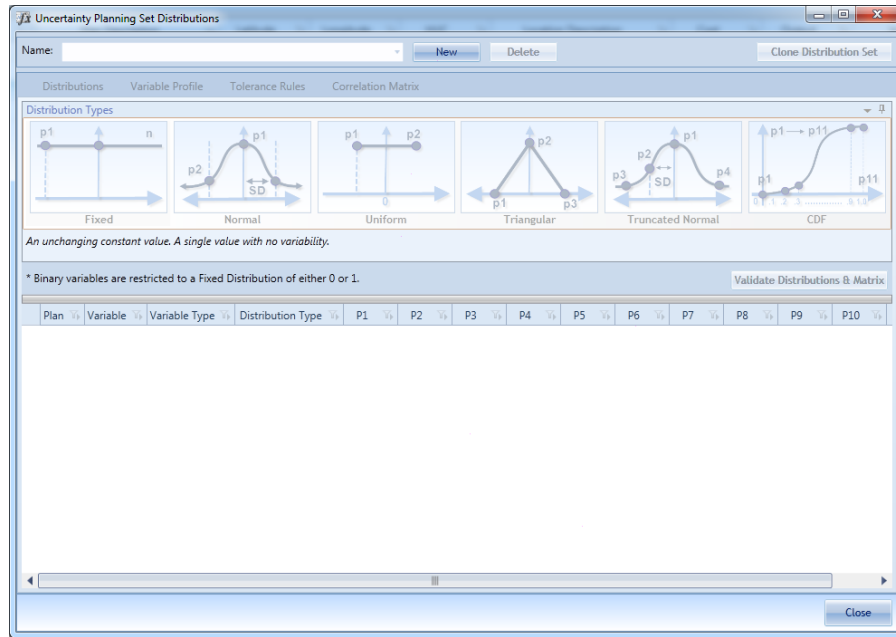
## Uncertainty Sets

Within IWR Planning Suite, each alternative plan has associated costs and outputs, such as a change in habitat units and the needed investment for obtaining them. The software derives the economic profiles of each alternative based on these parameters. The result of the analysis process is the identification of plans that pass proposal targets, are cost effective for current goals, and are incrementally justified for current goals. Additional results are calculated and stored, in particular the incremental cost data for “best buy” plans.

While this information is considered the current best available, there is still room to improve the quality of environmental investment decisions. Costs and outputs within the software reflect the best point estimates and a certain degree of certainty is implied because of that. The real world is of course, much more uncertain and there are a multitude of reasons why a particular alternative plan may cost more and produce less output than the best estimates provided at the time an analysis is performed. Further complicating this is the fact that, by its very nature, CE/ICA produces a “knife-edge” effect when using point estimates that can severely affect the cost effectiveness of any particular alternative. Cost and output estimates that are skewed even slightly can include plans that wouldn't in reality be cost-effective or entirely screen out an alternative that would otherwise be in the cost-effective set.

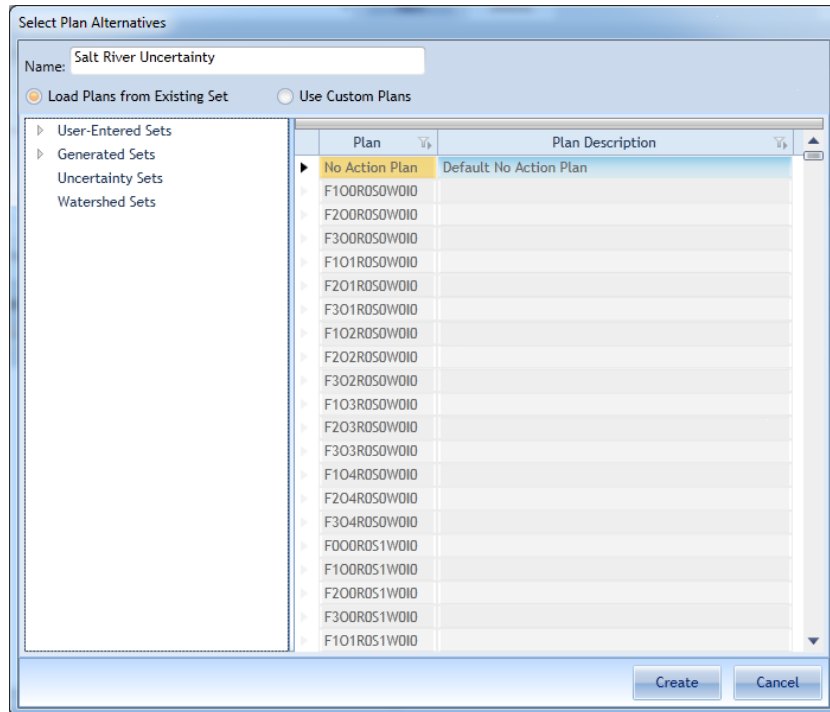
IWR Planning Suite incorporates the risk/uncertainty capability through use of an Uncertainty Set. Uncertainty sets allow the user to provide an additional set of information relating to variability/uncertainty surrounding the costs and outputs of each solution which can be quantified and added into the plan selection and decision-making process. As a result, a richer set of information for plan selection, incorporating the uncertainties associated with plan costs and outputs are available.

Uncertainty sets can be created by developing custom entered sets or using existing planning sets already in existence. To begin the user should click on the 'Uncertainty Planning Set Distributions' button on the Uncertainty ribbon. After making this selection the user will be presented with the Uncertainty Planning Set Distributions form.



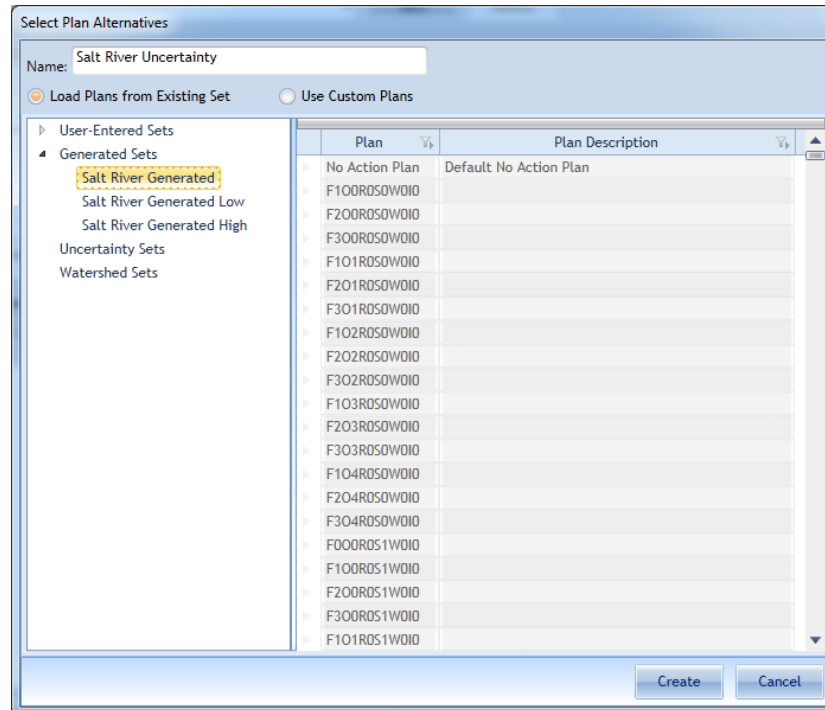
**Figure 41**  
**Uncertainty Planning Set Distributions**

To create a new uncertainty set the user should click the 'New' button and enter a name for this uncertainty set. The user can enter up to 255 characters to name this planning set.



**Figure 42**  
**Uncertainty Set Distribution Name**

After defining a name the user can select existing plans by selecting the radio button for Load Plans from Existing Set or select the Use Custom Plans radio button to create new custom plans that do not yet exist. If the user elects to use existing sets they can expand the planning set categories and planning sets within to locate and select the planning set they wish to utilize. In this example we will select the Salt River Generated set. Once selected, the available plans to select from will be displayed to the right.



**Figure 43**  
**Loading Plans from Existing Set**

If the user wishes to utilize all plans from an existing set they can simply select the planning set and then click the 'Create' button. In this example we will just select the planning set since all plans will be used.

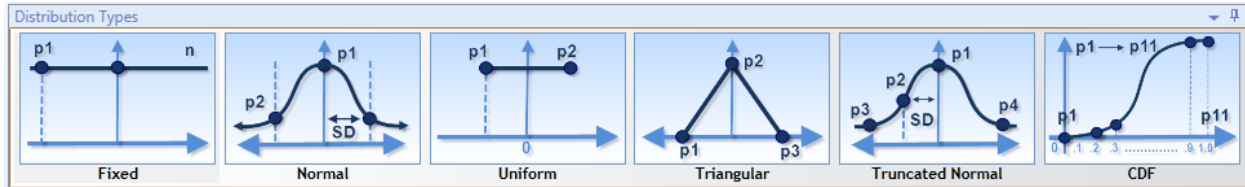
However, the user may only wish to use a specific selection of plans from an existing set. In this case the user may select one or more of these plans to use by clicking on the arrow in the beginning of that row. Selecting a plan on the list and then holding the Shift key down before clicking on another plan will select all plans between those selections. Selecting one plan and then holding down the Ctrl button on the keyboard while selecting other plans will select only those plans the user specifically selects.

Once all selections are made or custom plans are created the user can click the 'Create' button. Please note that the 'Create' button will remain disabled until the user enters a name for the uncertainty set and defines at least one plan.

Once all the plans the user would like to create are listed on the Uncertainty Planning Set Distributions form the user can define the distribution type to be used for each plan and variable. The user can accomplish this by setting the distribution type and values based on that distribution type on the Distributions tab of the form or they may select the Variable Profile tab to select a distribution type and associated values for each variable and then apply that profile to the plans on the Distribution tab.

If the user wishes to set each plan and variable combinations distribution type manually the user can select a distribution type from the Distribution Type field. Following that selection the appropriate number of value fields are enabled to the right. In the example below the selection of Triangular as the Distribution Type enabled P1, P2, and P3 as indicated with zero values and the white background of these fields.

The diagram at the top of the form indicates how many data points are required based on the selected distribution.



**Figure 44**  
**Distribution Types**

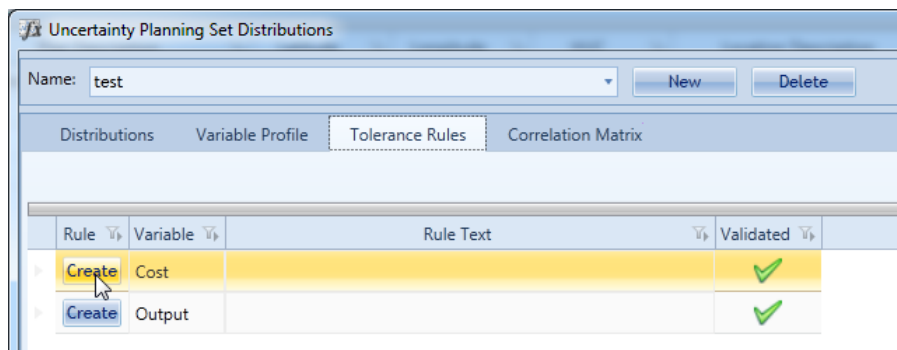
Please make the selections for the variables for this case study as shown below.

Selected	Variable	Variable Type	Distribution Type	P1	P2	P3
<input checked="" type="checkbox"/>	Costs	Currency	Normal	\$0.00	\$3,000.00	
<input checked="" type="checkbox"/>	Wetlands	Decimal	Triangular	0	450	800
<input checked="" type="checkbox"/>	CWRiparian	Decimal	Normal	0	200	
<input checked="" type="checkbox"/>	OpenWater	Decimal	Uniform	0	250	

**Figure 45**  
**Selecting Distribution Types**

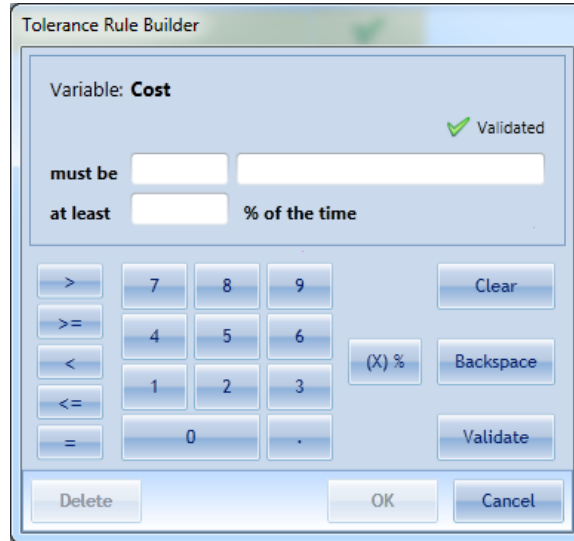
Once the user defines the distribution type and related values for each listed variable they can click the 'Apply Profile' button in order to update the values on the Distributions tab.

The user may also apply tolerance rules associated with this planning set using the Tolerance Rules tab. In order to create a tolerance rule for a variable the user can click the 'Create' button prior to the listed variable.



**Figure 46**  
**Creating Tolerance Rules**

After the user clicks the 'Create' button the Tolerance Rule Builder will be displayed.



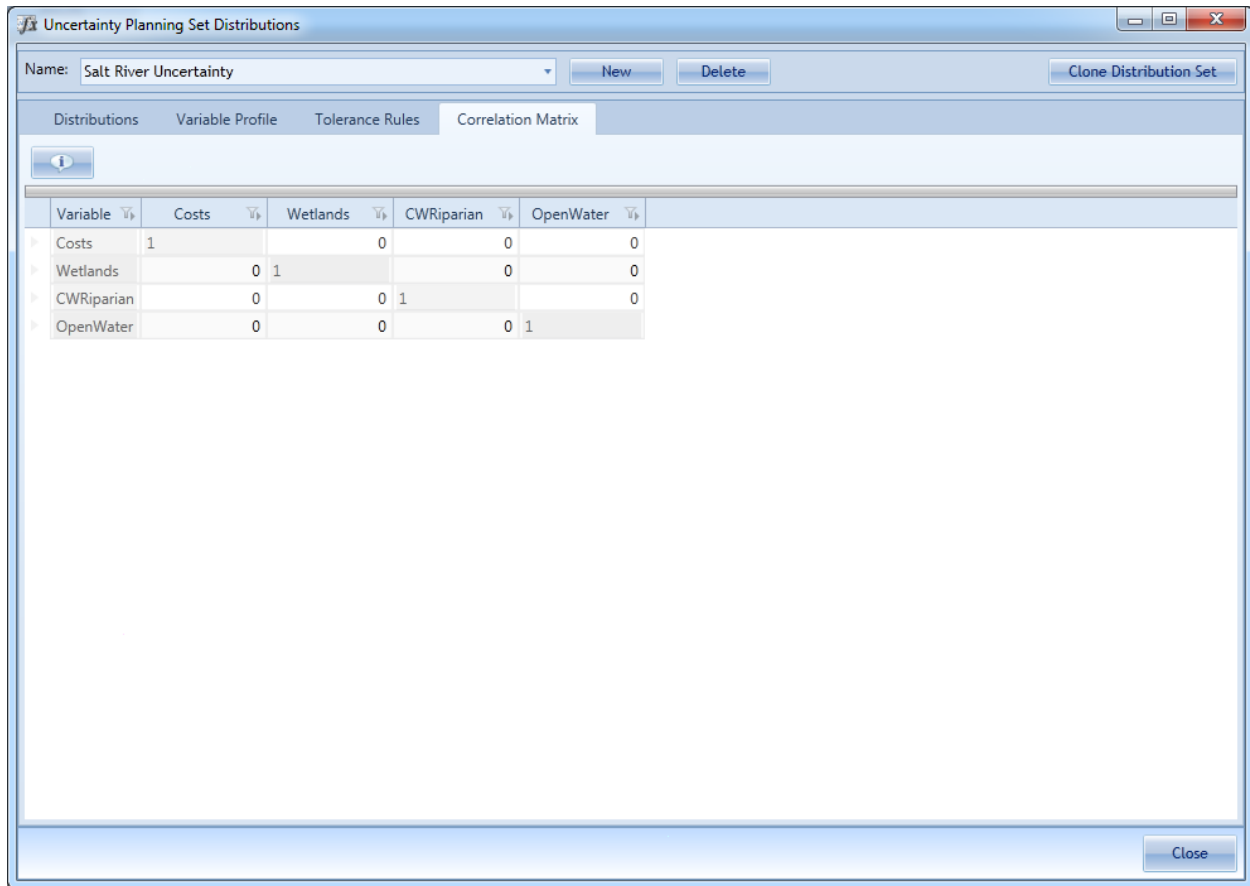
The screenshot shows a dialog box titled "Tolerance Rule Builder". At the top, it says "Variable: **Cost**". To the right of this is a green checkmark and the word "Validated". Below this, there are two rows of input fields. The first row is labeled "must be" and has two empty text boxes. The second row is labeled "at least" and has two empty text boxes, followed by the text "% of the time". Below these input fields is a numeric keypad with buttons for digits 0-9, a decimal point, and a percentage sign "(X) %". To the left of the keypad are comparison operators: ">", ">=", "<", "<=", and "=". To the right of the keypad are buttons for "Clear", "Backspace", and "Validate". At the bottom of the dialog are buttons for "Delete", "OK", and "Cancel".

**Figure 47**  
**Tolerance Rule Builder**

The user can specify an operand, value and percentage of the time the variable should fall within this range. The user can press the 'Validate' button following entry of this information to ensure the provided information is valid. The user can then click 'OK' to create the tolerance rule for this variable.

No tolerance rules will be used in this example.

The user can define the correlation between study variables on the Correlation tab.



**Figure 48**  
**Correlation Matrix**

Initially these values are set to zero indicating that the variables are independent of one another and no correlation amongst the variables exists. The matrix is disabled when the correlation between a variable and itself is shown as a variable is always perfectly correlated to itself. The user has the option to edit other relationships amongst variables with a value between negative one and one where one represents a perfect positive correlation and negative one represents a perfect negative correlation between variables.

In this example the variables will remain independent of one another and no correlation amongst variables will be defined.

The user can now validate the entered distributions & matrix by clicking the 'Validate Distributions & Matrix' button on the Distributions tab. If validations are passed a green checkbox will appear beside the button. If validations are not passed then a red x will be presented beside the validate field.

In our example it is expected that the distribution set will pass validation.

**Uncertainty Planning Set Distributions**

Name: Salt River Uncertainty

Buttons: New, Delete, Clone Distribution Set

Tabs: Distributions, Variable Profile, Tolerance Rules, Correlation Matrix

**Distribution Types**

Fixed: A horizontal line with two points p1 and p2.

Normal: A bell curve with mean p1 and standard deviation SD.

Uniform: A horizontal line with two points p1 and p2.

Triangular: A triangle with vertices p1, p2, and p3.

Truncated Normal: A bell curve with mean p1 and standard deviation SD, truncated at p2 and p4.

CDF: A cumulative distribution function curve with points p1, p2, p3, p4, p11, and p12.

The normal distribution is the standard statistical bell curve distribution. P1 is the Mean value and P2 is the Standard Deviation

\* Binary variables are restricted to a Fixed Distribution of either 0 or 1.

Validate Distributions & Matrix

Plan	Variable	Variable Type	Distribution Type	P1	P2	P3	P4	P5	P6	P7	P8	P9
No Action Plan	Costs	Currency	Fixed	0.00								
No Action Plan	Wetlands	Decimal	Fixed	0.00								
No Action Plan	CWRiparian	Decimal	Fixed	0.00								
No Action Plan	OpenWater	Decimal	Fixed	0.00								
F100R0S0W0I0	Costs	Currency	Normal	0.00	3,000.00							
F100R0S0W0I0	Wetlands	Decimal	Triangular	0.00	450.00	800.00						
F100R0S0W0I0	CWRiparian	Decimal	Normal	0.00	200.00							
F100R0S0W0I0	OpenWater	Decimal	Uniform	0.00	250.00							
F200R0S0W0I0	Costs	Currency	Normal	0.00	3,000.00							
F200R0S0W0I0	Wetlands	Decimal	Triangular	0.00	450.00	800.00						
F200R0S0W0I0	CWRiparian	Decimal	Normal	0.00	200.00							

Close

**Figure 49**  
**Validating Distributions and Matrix**

Once this information has been completed the user may close the Uncertainty Planning Set Distributions form by clicking the 'Close' button.

The user is now prepared to generate an uncertainty set. To do this the user should click on the 'Generate Uncertainty Set' button available on the Uncertainty ribbon. This will launch the Build Uncertainty Planning Sets form.

**Build Uncertainty Planning Sets**

Select Distribution Set: [Dropdown]

Planning Set Name: New Uncertainty Set 4

Description: [Text Area]

Max Iterations: 20

Seed: 7

Convergence Variables (Non-Derived): [Dropdown]

Derived Variables: [Dropdown]

OK Cancel

**Figure 50**  
**Building Uncertainty Sets**

The user can now select the distribution set from the Select Distribution Set list. The user is also required to enter a planning set name. The planning set name can include letters, numbers, spaces and special characters but should not exceed 255 characters in length. A description for the planning set can also be listed and should not exceed 500 characters in length.

In this example the user should select Salt River Uncertainty as the distribution list and should name the planning set Salt River Uncertainty Set.

The screenshot shows a Windows-style dialog box titled "Build Uncertainty Planning Sets". It contains several input fields: a dropdown menu for "Select Distribution Set" with "Salt River Uncertainty" selected; a text box for "Planning Set Name" containing "Salt River Uncertainty Set"; a larger text box for "Description" which is currently empty; a numeric spinner for "Max Iterations" set to 20; and another numeric spinner for "Seed" set to 7. Below these is an expandable section labeled "Convergence Variables" with a downward-pointing arrow. At the bottom right are "OK" and "Cancel" buttons.

**Figure 51**  
**Define Uncertainty Set Name**

As previously noted, the generated uncertainty sets utilizes a Monte Carlo Simulation whereby the distributions and distribution types are utilized to select random values within the defined ranges to use for the variables along with any tolerance rules and correlation described in the set. A set is then generated based on that random selection of values for variables within the defined limitations and within the constraints of the defined rules. The number of max iterations defines the number of times a planning set is created with randomly generated values. The values are then averaged to determine a final planning set which is listed under Uncertainty Sets in the Planning Sets pane.

The seed is the number used to initialize the number generator.

Convergence variables are available to set for each non-derived variable by expanding the Convergence Variables section of the Build Uncertainty Planning Sets form by clicking the down arrow on the right of the bar stating Convergence Variables. Derived variables (if any exist) are listed separately in the expandable Derived Variables section below the Convergence Variables section.



Build Uncertainty Planning Sets

Select Distribution Set: Salt River Uncertainty

Planning Set Name: Salt River Uncertainty Set

Description:

Max Iterations: 20

Seed: 7

Convergence Variables (Non-Derived)

Variable	Convergence	Threshold (%)	Threshold (Value)
Costs	<input type="checkbox"/>	0.00	0.00
Wetlands	<input type="checkbox"/>	0.00	0.00
CWRiparian	<input type="checkbox"/>	0.00	0.00
OpenWater	<input type="checkbox"/>	0.00	0.00

Derived Variables

Variable	Function
TotalOutput	[Wetlands]+ [CWRiparian]+ [OpenWater]

OK Cancel

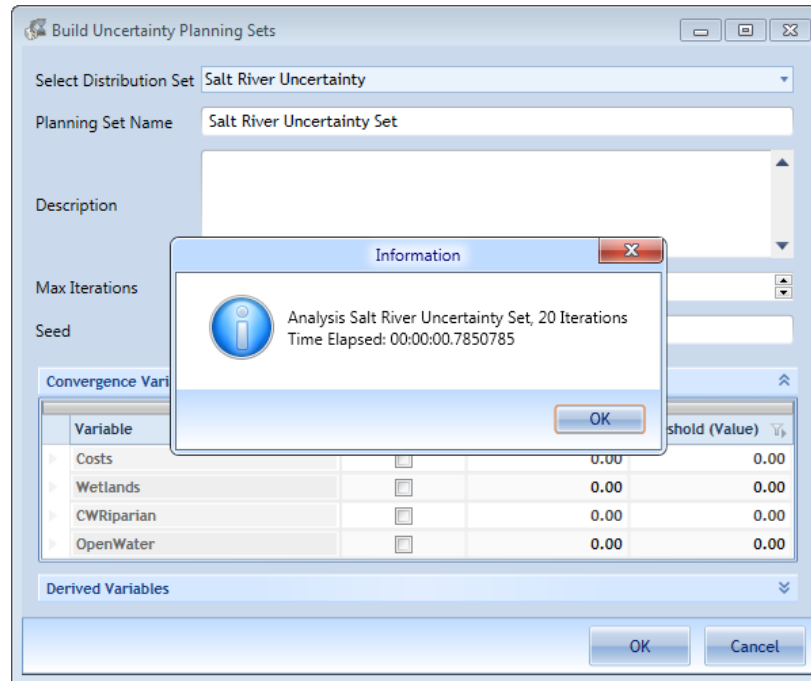
**Figure 52**  
**Convergence Variables**

Convergence variables allow the user to define what percentage of variation is anticipated in variable values before this variable is considered to have reached convergence. Once all variables in which convergence has been set then the simulation will complete regardless of whether the max number of iterations has been completed. If convergence is not set then all iterations defined will be completed.

Once all values are determined on the Build Uncertainty Planning Sets form the user can click the 'OK' button to generate the uncertainty set.

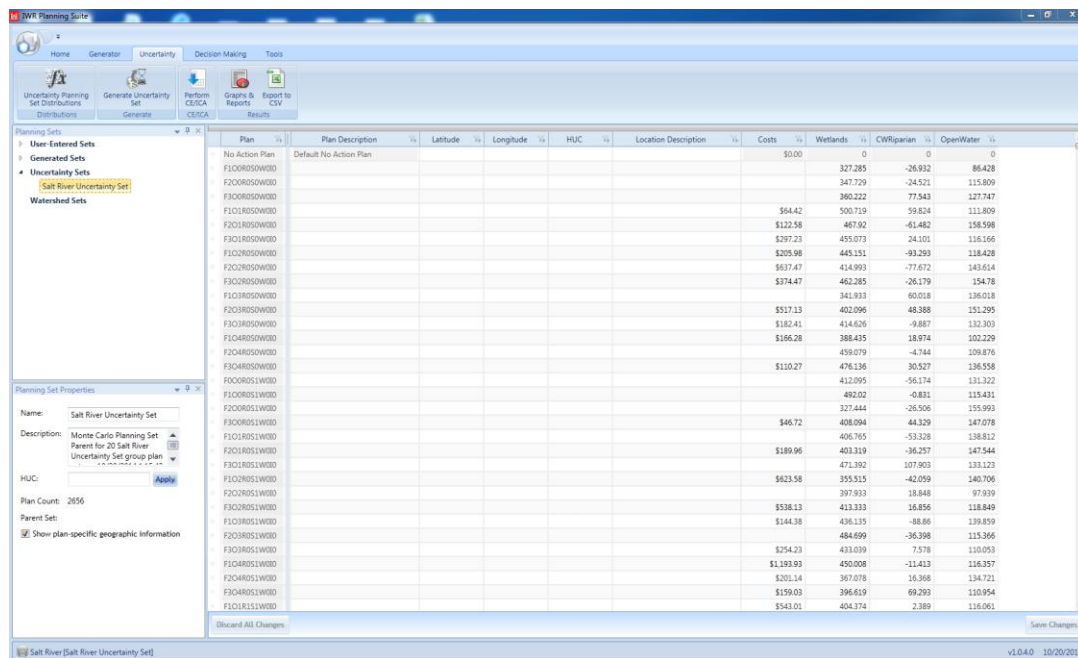
Please note the 'OK' button will be disabled until a distribution set has been selected and the user will receive a message indicating they need to enter a valid planning set name if they attempt to click 'OK' prior to creating one.

The user will receive a progress bar in the bottom right of the screen showing progress as the simulation is completed. Once the final planning set has been created the user will receive a message stating the time elapsed and number of iterations completed.



**Figure 53**  
**Uncertainty Set Statistics**

Once the user clicks 'OK' on this message the created planning set will be named Salt River Uncertainty Set and will appear under the Uncertainty Sets category in the Planning Sets pane.



**Figure 54**  
**Displaying Uncertainty Sets**

## Watershed Sets

The user can begin creation of a watershed set by selecting the 'Watershed Wizard' button on the Tools ribbon. The user is then asked to verify they are attempting to create an analysis for multiple locations. If the user selects No, they will be returned to the application to select entry of another type of planning set. If the user selects 'Yes,' they will enter into the watershed wizard where they will be led through a series of steps to create a watershed analysis. Users can either create a new watershed study (options a-c) or open an existing unfinished study for completion (option d). The options for creating a new study deal with how plans for each location will be created. Available options are whether users would like to enter one plan per site, more than one plan per site or generate plans for each site. Once a selection has been made and the user has entered a valid and unique study name, the user can click 'Next' to continue through the wizard.

**Figure 55**  
**Watershed Wizard**

Choosing option d will open a dialog window listing all existing watershed studies that were never fully completed. Users can select a record and select Open to continue through the wizard. The wizard will open the set at the last completed designated stage.

Name	Description	Study Type	Date Created	Date Last Saved	Delete
Watershed Set 1	Watershed Set 1	Watershed (N plans per site)	10/19/2016 3:10 PM	10/19/2016 3:57 PM	<input checked="" type="checkbox"/>
Watershed Set 2	Watershed Set 2	Watershed (N plans per site)	10/19/2016 3:57 PM	10/19/2016 3:57 PM	<input type="checkbox"/>

**Figure 56**  
**Open Existing Watershed Study**

Next the user will be asked to enter the locations in the form shown below.

**Figure 57**  
**Watershed Locations and Plans**

The user can enter a location name and a code will automatically be assigned but the generated code can be modified by the user. There is an option that is selected by default that will convert location code characters into special characters. Next the user defines the number of plans at that location (unless they selected one plan per location option in which case this field is disabled) and then can optionally enter a description, latitude and longitude for this location. The user can select the 'Add New' button to add additional locations. Once all locations are entered the user can enter values for each variable for each plan in the bottom portion of the form. The user may also elect to modify the name displayed for each plan as well. After entering all needed locations and variable values the user can select the 'OK' button to continue.

Next the user will be prompted to enter any relationships as shown below.

**Figure 58**  
**Watershed Location Relationships**

If the user has relationships that need to be defined they should select 'Yes' and then 'Next.' If the user doesn't have any relationships that need to be defined they should select 'No' and then click 'Next.' If the user selects 'Yes' they will be presented with a form to allow the user to define the relationships.

**Solution Relationships**

**Relationship Type**

☒ Combinability ☐ Dependency ☐ No solutions are Combinable

**Solution:**

- a
- b

**Is Not Combinable With:**

- ☐ b

**Edit Mode**

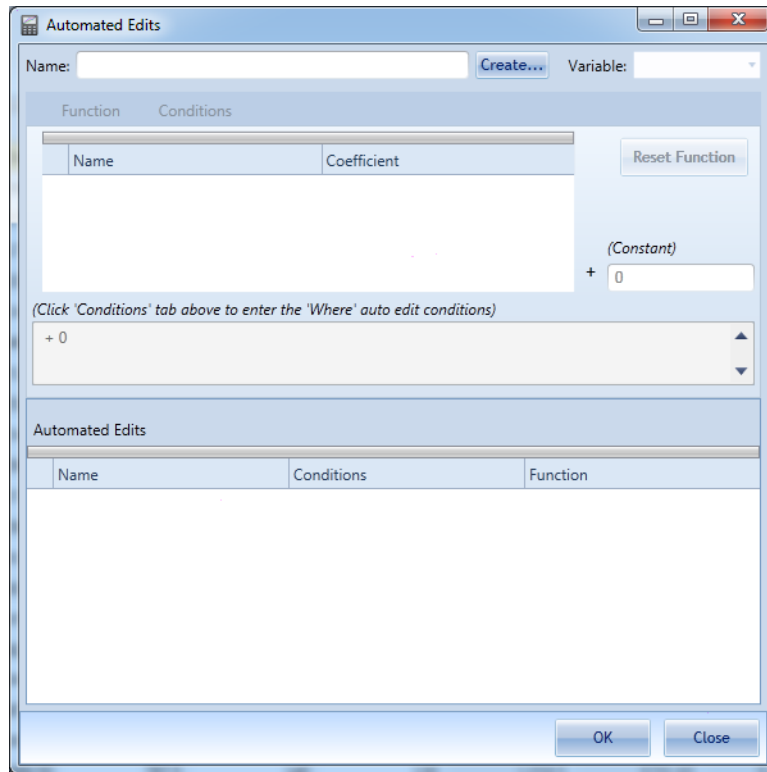
☒ Create New Relationship ☐ Edit Existing Relationship

Solution:	Is Not Combinable With:
Name	Relationship

**Figure 59**  
**Creating Relationships**

For more information on entering relationships please see the section on [relationships](#). After the needed relationships have been entered the user should click 'OK' to continue.

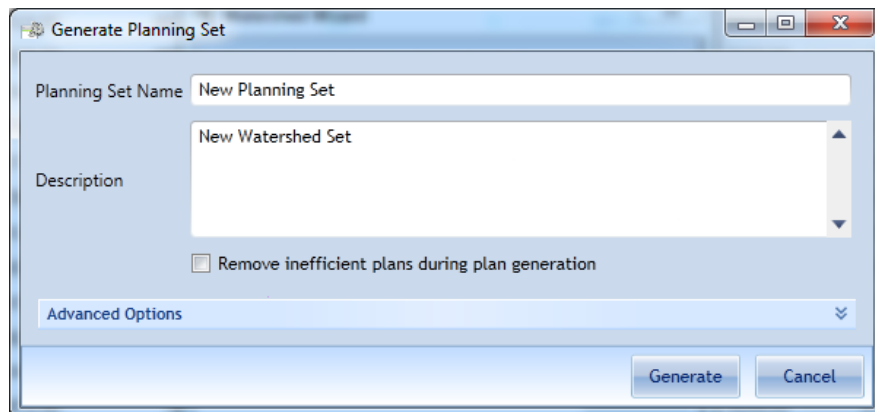
Next the user will be asked if the locations behave independently from one another. If the user selects 'Yes' they will continue through the wizard. If the user selects 'No' they will be presented with the Automated Edits form.



**Figure 60**  
**Automated Edits**

For more information on entering Automated Edits please see the [automated editing](#) section. After the user enters the appropriate dependencies between solutions the user can click the 'OK' button to continue.

At this point the user will be presented with a form that allows the user to generate plans based on the provided user selections.



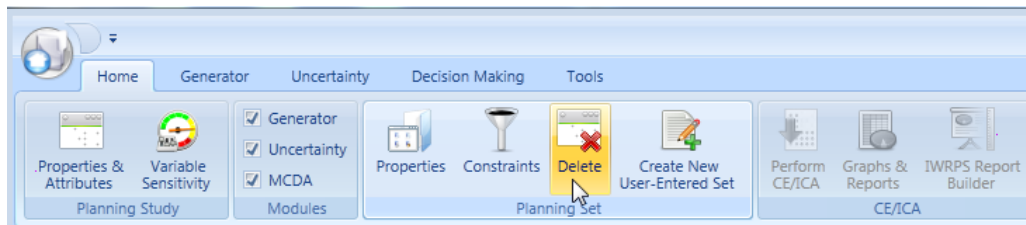
**Figure 61**  
**Generating Watershed Sets**

For more information on generating plans please see the section on [Plan Generation](#). After the user updates the planning set name and description as well as setting of any advanced features as applicable the user can click the 'Generate' button to generate the planning set.

It is important to note that if the user cancels out of the watershed wizard at any time that information will not be retrievable later and will require the user to re-enter the information.

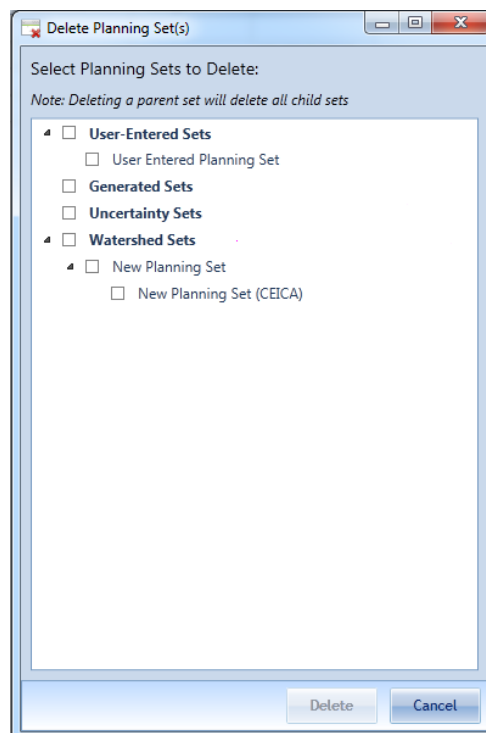
## Removing Planning Sets

Planning sets may be deleted, or removed from the plan study by clicking the 'Delete' button on the Home ribbon.



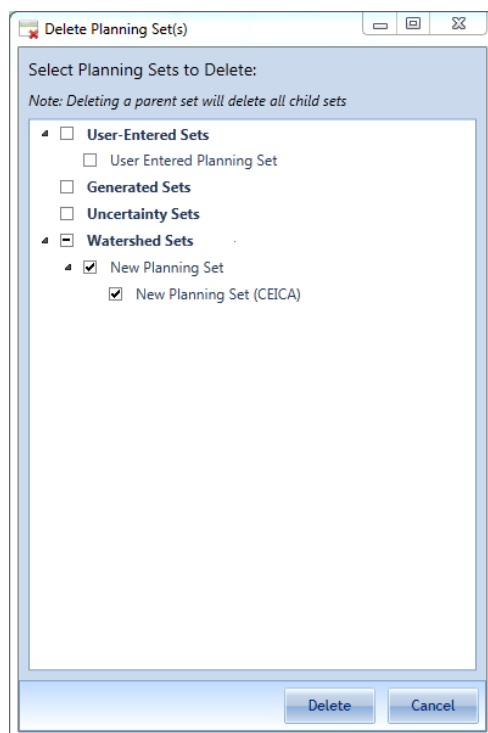
**Figure 62**  
**Launching Delete Planning Set(s)**

This will cause the Delete Planning Set form to appear.



**Figure 63**  
**Deleting Planning Sets**

You may select the planning set you wish to delete from the list of available plan sets, and press 'OK' to remove it from the planning study permanently. If the user elects to delete a parent set then they will be prompted that this will delete this set along with any child sets. When the user selects the parent set the child set(s) will also be selected.



**Figure 64**  
**Selecting Planning Sets for Deletion**

Please be aware that the operation cannot be undone once 'Delete' is pressed, and the planning set selected will be deleted and will not be recoverable by any means. Press 'Cancel' to exit the form without removing any planning sets from the planning study.

Planning Set removal may become necessary if a planning set analysis is performed with the incorrect cost and output variables, for example, or if a planning set is generated with an incorrect set of parameters. It may also be helpful to delete planning sets when the planning study has become "cluttered" with too many that are no longer current or no longer applicable.

## Costs and Outputs

The first step in performing incremental cost analyses for our sample ecosystem restoration study is to determine and define the costs and outputs to be used. Within the IWR Planning Suite II, we use the term *variables* to denote these costs and outputs. Variables are the categories upon which the effects of alternative plans will be compared and upon which cost effective and incremental cost analyses will be performed. A minimum of two variables must be defined for cost effectiveness and incremental cost analyses: a cost variable and an output variable. Examples of output variables might include: habitat units, acres of wetlands,

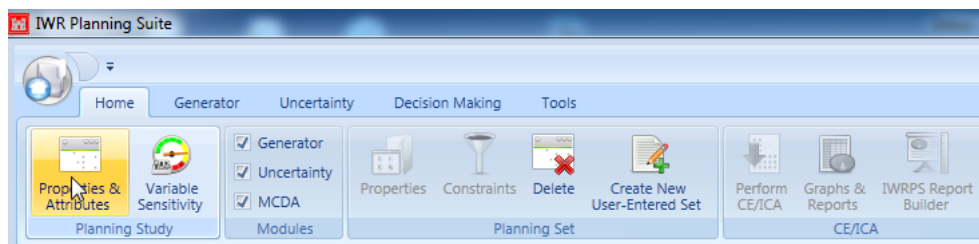


stream miles restored, number of salmon, diversity indices, etc. Due to processing time considerations, it is recommended that no more than ten variables be defined in an IWR Planning Suite II data file. The IWR Planning Suite II also allows for the definition of *derived variables*, which are included in the recommended count of ten or fewer variables. Derived variables will be discussed in more detail later in this chapter.

Plan variables may be created or removed from all the planning sets in a plan study through Planning Study Properties form which displays the available variables and attributes of the planning sets in the study. Once new attributes or variables have been added and defined via the Planning Studies Properties form, the new attribute values may be edited immediately to insert values manually through the Plan Editor. However, if the user wishes to have the newly added variable displayed they will need to generate a new planning set.

To begin the process, variables and derived variables for an analysis are defined within the Planning Study Properties form. The costs and outputs associated with the study are determined and defined. These variables are the categories used for comparative purposes during analysis. For example, if a given planning set was to be used as input data for subsequent CE/ICA analyses, then a cost and an output variable would need to be defined for that planning set. Variables are defined with a variable name, description, variable type and unit of measure. Additional types of variables would be needed for other kinds of analyses, such as multi-variable efficiency analysis.

To define these variables, navigate to the Planning Study Properties form by selecting the 'Properties & Attributes' button available on the Home ribbon.



**Figure 65**  
**Launching Properties and Attributes**

This will open the Planning Study Properties form which contains a Variables data entry table to allow for the addition, modification, and deletion of variables. Initially, this form displays default “Cost” and “Output” variables for your use. These default variables can be removed or renamed at your discretion to suit the needs of a particular planning study. As variables are defined, they will be added to the collection of variables, and will be available for review or modification.

New variables may be defined by clicking the ‘Add’ button under the Variables table on the Planning Study form.

Name	Units	Description	Variable Type	Derived	Derived Function	Minimum	Maximum	Visible
Cost	\$1000	Average Annual Cost in \$1000s	Currency	<input type="checkbox"/>				<input checked="" type="checkbox"/>
Output	AAHUs	Output in Average Annual Habitat Units	Decimal	<input type="checkbox"/>				<input checked="" type="checkbox"/>

Add

**Figure 66**  
**Adding Variables**

Doing so will create a new row in the table where you may enter properties in nine fields that define the variable. These properties are the variable’s name, units of measurement, description, whether it is a derived variable, the derived variable formula, minimum and maximum values, and whether the field is to be visible when displaying planning sets.

The variable name gives a name to the variable that the IWR Planning Suite II can use in analysis and reporting. This property is required to be entered and can be made up of any combination of alphanumeric or special characters up to 255 characters in length.

The description field describes the variable throughout the IWR Planning Suite II, specifically in reporting. This field can be up to 500 characters in length. Enter “Average Annual Equivalent Cost” in the space provided for the description now. The units field, or units of measure, is a quantitative representation of the unit used for each variable and can be up to 255 characters in length.

The variable type allows the user to define the type of output created for that variable. The options include:

- Decimal – A base 10 number that can extend to the thousands place after the decimal in this application
- Binary – A base two numeral system which is represented in this application as a checkbox that can be enabled or disabled
- Integer – A whole number
- Currency – A numeric value used to represent an output value in money

The derived checkbox will determine if this variable is a derived variable or not. A Derived Variable is a formulaic combination of two or more other variables already entered into the database. Derived Variables will be discussed later in this section. You may leave the “Visible” checkbox marked for all of the variables you will be entering.

The minimum field can be used to define a minimum acceptable value for this variable. If any plans that are generated create a value that falls below the defined minimum for that variable then those plans will not be listed.

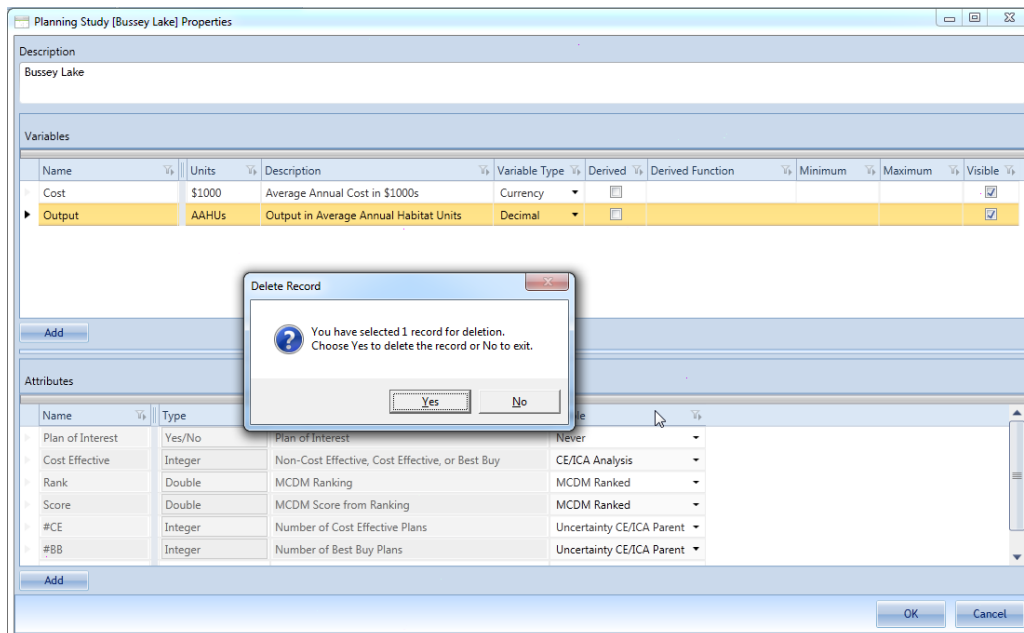
The maximum field can be used to define a maximum acceptable value for this variable. If any plans are generated that create values for this variable that exceed the defined maximum then those plans will not be listed.

It is highly recommended that the optional fields (“units” and “description”) be defined, as they will be used throughout the IWR Planning Suite II in reports and graphs. To add additional variables, simply click the ‘Add’ button and repeat the procedure defined above. The table below describes the four variables used in this case study.

<b>Table 14.</b> <b>Variable Names, Descriptions, and Units</b>		
Variable (Name)	Description	Units
Costs	Average Annual Equivalent Cost	\$1000
Wetlands	Wetland Habitat	AAHU's
CWRiparian	Cottonwood-willow Riparian Habitat	AAHU's
OpenWater	Open Water Habitat	AAHU's

The first variable that has just been defined is the cost variable for this study. The three remaining variables will be used as the output measures. Enter the three output variables defined in Table 14 now by following the above procedure.

Existing variables may be modified or deleted by clicking on the variable’s row in the grid to select it. When a specific variable is selected, it may either be modified or deleted. To modify the current variable, simply double click on the first value you would like to modify and then tab to and change the appropriate fields. Pressing the Delete or Del key on your keyboard will delete the current selected variable.



**Figure 67**  
**Deleting Variables**

Clicking the 'OK' button will save your changes and close the Planning Study Properties form, while clicking the 'Cancel' button will close the form without saving any changes.

## Derived Variables

Next we will define a derived variable. A derived variable is a formulaic combination of two or more other variables already entered into the database. Within a derived variable formula, other variables may be added, subtracted, multiplied, divided, or raised to a power. Square roots, natural logs, and absolute values may also be performed. Derived variables are also added to the planning study through the Planning Studies Properties form and described in terms of a variable name, description, measurement units, and a calculation formula.

If the planning study properties form has been closed, re-open the plan study form by clicking the 'Properties & Attributes' button on the Home ribbon. Clicking on the Derived checkbox on a variable's row will mark the checkbox indicating that the variable is derived and will cause the Formula Editor to appear with which to define the formula for computing a derived variable.

The screenshot shows the 'Planning Study [Bussey Lake] Properties' dialog box. The 'Variables' table has columns: Name, Units, Description, Variable Type, Derived, Derived Function, Minimum, Maximum, and Visible. The 'Output' variable is selected, and its 'Derived' checkbox is checked. The 'Formula Editor - Derived Variable 'Output'' dialog box is open, showing a blank formula field and a 'Select Variables' list containing 'Cost'. The 'Validated' checkbox is checked. The 'Attributes' table shows various attributes for the planning study.

Name	Units	Description	Variable Type	Derived	Derived Function	Minimum	Maximum	Visible
Cost	\$1000							<input checked="" type="checkbox"/>
Output	AAHUs			<input checked="" type="checkbox"/>				<input checked="" type="checkbox"/>

Name	Type	Description	Derived Function
Cost Effective	Integer		
Rank	Double		
Score	Double	MCDM Score from Ranking	MCDM Ranked
#CE	Integer	Number of Cost Effective Plans	Uncertainty CE/ICA Parent
#BB	Integer	Number of Best Buy Plans	Uncertainty CE/ICA Parent
test	Yes/No		Always

**Figure 68**  
**Derived Variable Formula Editor**

The Formula Editor contains a blank field in which the user defines the derived variable. The user cannot type variable information manually into the field but can enter numeric and operands manually. For variables the user must select (by clicking) functions and variables in sequence to define the derived variable formulation. Add a new variable by pressing the 'Add' button located below the Variables table. For the Name, enter "TotalOutput". Enter "AAHU" and "Total output of all habitat variables" as the unit and description. Now proceed to click on the derived checkbox for the variable. Enter the variable formula for "TotalOutput" now by using the Formula Editor sub-form. At this point, the user can click on the 'Validate' button to confirm that

the formula is logically valid (from a mathematical perspective, not a scientific one). Alternatively, when the user clicks 'OK' on the Formula Editor form, the IWR Planning Suite II will automatically check (validate) the derived variable for logical consistency.

Note that since the values of derived variables are not entered by the user, but rather are calculated directly by the IWR Planning Suite II, derived variables do not appear in the "Effects on Variables" columns on the Solutions and Scales form. Derived variables are automatically calculated by the program and can be selected as either Cost or Output Parameters to conduct cost effectiveness and incremental cost analyses. To see the calculated values of derived variables for a planning set, select the planning set in the Planning Sets pane of the application. Derived variables are labeled as such and their values are displayed.

## Attributes

Attributes are also displayed in the Planning Study Properties form accessible when the user clicks the 'Properties & Attributes' button on the Home tab. The default available attributes are listed for the user and are shown in grey text with a grey background to indicate these can't be modified or deleted by the user.

Attributes			
Name	Type	Description	Visible
Plan of Interest	Yes/No	Plan of Interest	Always
Cost Effective	Integer	Non-Cost Effective, Cost Effective, or Best Buy	CE/ICA Analysis
Rank	Double	MCDM Ranking	MCDA Ranked
Score	Double	MCDM Score from Ranking	MCDA Ranked
#CE	Integer	Number of Cost Effective Plans	Uncertainty CE/ICA Parent
#BB	Integer	Number of Best Buy Plans	Uncertainty CE/ICA Parent

**Figure 69**  
**Default Attributes**

However, the user can modify the visibility of the default attributes using the Visible column. The Visible column has the options listed below which describes when this attribute will be visible based on the user's selection.

- Always – This attribute will always be displayed
- Never – This attribute will never be displayed
- Plan Generator – This attribute will be displayed for generated sets
- CE/ICA Analysis – This attribute will be displayed for CE/ICA analysis sets
- Constrainer – This attribute will be displayed for constrained sets
- MCDA Ranked – This attribute will be displayed for ranked MCDA sets
- MCDA Imported – This attribute will be displayed for imported MCDA sets
- Uncertainty – This attribute will be displayed for uncertainty sets

- Uncertainty CE/ICA – This attribute will be displayed for CE/ICA uncertainty sets
- Uncertainty Parent – This attribute will be displayed for parent uncertainty sets
- Uncertainty CE/ICA Parent – This attribute will be displayed for CE/ICA parent uncertainty sets
- Watershed – This attribute will be displayed for all watershed sets
- Watershed (1 plan per site) – This attribute will be displayed for all 1-plan per site watershed sets
- Watershed (N plans per site) – This attribute will be displayed for all watershed sets where multiple plans per site exist
- Watershed (Generated per site) – This attribute will be displayed for all generated watershed sets
- Watershed CE/ICA (Generated per site) – This attribute will be displayed for all CE/ICA watershed sets

The user may also wish to create and display attributes of the user's own creation. The user can create additional attributes by clicking the 'Add' button available below the attributes section.

Attributes				
Name	Type	Description	Visible	
Plan of Interest	Yes/No	Plan of Interest	Plan Generator	
Cost Effective	Integer	Non-Cost Effective, Cost Effective, or Best Buy	CE/ICA Analysis	
Rank	Double	MCDM Ranking	MCDA Ranked	
Score	Double	MCDM Score from Ranking	MCDA Ranked	
#CE	Integer	Number of Cost Effective Plans	Uncertainty CE/ICA Parent	
#BB	Integer	Number of Best Buy Plans	Uncertainty CE/ICA Parent	

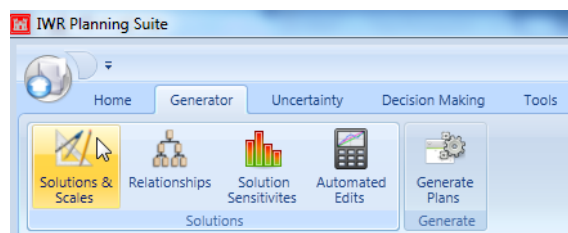
Add

**Figure 70**  
**Adding Attributes**

After the user clicks the 'Add' button a new row will be added to the bottom of the Attributes grid and the user can enter a Name, Type, Description, and select a visibility option from the list. The user should click the 'OK' button to save their changes and exit the form after entering this information.

## Solutions and Scaled Effects

The next step in performing incremental cost analyses is to define *solutions* and their effects on each variable. Solutions and their scaled effects are defined through a "Solutions and Scales" form which can be accessed by clicking on 'Solutions & Scales' button located on the Generator ribbon.



**Figure 71**  
**Launching Solutions and Scales**

A solution is a management measure or activity and there usually are many levels or sizes for a given solution. These different solution sizes are the scales at which the solution can be implemented. A solution description, solution code, and a number of action scales for the solution are entered to define each solution and scale.

Solutions and scales may be added, edited, or deleted through the Solutions & Scales form. Any solution and scale to be excluded from the set of generated plans may be removed through use of the Advanced Options available when generating a set. The Solutions & Scales form automatically generates a “No Action” scale for each solution.

To define solutions, navigate to the Solutions & Scales form shown below by clicking on ‘Solutions & Scales’ button on the Generator ribbon.

Solution	Code	# Scales
location 1	A	1
location 2	B	1

Code	Scale	Name	Cost	Output
A	0	No Action	\$0.00	0
A	1	location 1	\$25.00	11,000
B	0	No Action	\$0.00	0
B	1	location 2	\$50.00	50,000

**Figure 72**  
**Solutions and Scales**

Once the Solutions and Scales form is loaded solutions can be defined. One row is available for entry by default but users can add additional solutions by pressing the ‘Add New’ button. The solution description is a description of what action or measure is to be taken. Enter “Flow Regulation Wetlands” in the space provided for the solution description now. The solution code is a multi-letter code of up to ten characters that represents this solution. This code will be used in the naming of plan alternatives when planning sets are generated. A default code will be created for the user based on the first letter of the solution but if this default value results in duplicates or if the user wishes to utilize a different code it may be modified. In this instance “F” will be defined as the solution code and is appropriate in this case. The last field on this form represents the number of action scales this solution has. By default, a zero scale is added to each solution and represents no action taken. For example, Flow Regulation Wetlands has three action scales. This means that there are three possible scales at which Flow Regulation Wetlands can be implemented. Enter “3” in the

space provided for the number of action scales now. This scale will also be used in the plan code (automatically generated by the Plan Generator module) to represent which scale of action is being administered. Take the plan “F2O4R0S1W2I4” for example; the “F” represents the Flow Regulation Wetlands solutions.

Solution	Code	# Scales
Flow Regulation Wetlands	F	3
Overbank Wetlands	O	4

Code	Scale	Name	Cost	Output
F	0	No Action	\$0.00	0
F	1	Flow Regulation Wetlands	\$0.00	0
F	2	Flow Regulation Wetlands	\$0.00	0
F	3	Flow Regulation Wetlands	\$0.00	0
O	0	No Action	\$0.00	0
O	1	Overbank Wetlands	\$0.00	0
O	2	Overbank Wetlands	\$0.00	0
O	3	Overbank Wetlands	\$0.00	0
O	4	Overbank Wetlands	\$0.00	0

**Figure 73**  
**Creating Solutions**

Considering the example plan above, the “F2” portion indicates that the second action scale for Flow Regulation Wetlands is being used for this alternative plan. Once a solution or set of solutions are entered, clicking the ‘OK’ button will validate and save the new solutions. If the ‘OK’ button is not clicked, the solutions are not saved. The ‘Close’ button will close the form.

Table 15 below describes the solutions that are used in this case study. The first solution has just been defined for “Flow Regulation Wetlands.” Enter the five remaining solutions now. Please note that up to 52 solutions can be defined per planning study and up to 20 scales (including No Action) can be defined per solution.

Solution Description	Code	Number of Action Scales
Flow Regulation Wetlands	F	3
Overbank Wetlands	O	4
Riparian Corridors	R	6
Remove Salt Cedar	S	1
Open Water	W	4



In-channel Wetlands	1	5
---------------------	---	---

For reporting purposes, solutions are displayed in the Solutions & Scales form in the order they will be used to generate plan alternatives. By default, each new solution is given the next consecutive position for its order. To create a new solution, simply click the 'Add New' button which will add a new row into which the solution information may be entered. Clicking the Delete key on the keyboard after selecting a solution will permanently remove the selected solution. The 'OK' or 'Cancel' button will allow this form to be closed.

The Solutions and Scales form will also allow the entry of quantitative effects on each variable for every solution and scale through the "Scaled Solution Effects on Variables" grid.

Solutions		
Solution	Code	# Scales
Flow Regulation Wetlands	F	3
Overbank Wetlands	O	19

Scaled Solution Effects on Variables					
Code	Scale	Name	Cost	Output	
F	0	No Action	\$0.00	0	
F	1	Flow Regulation Wetlands	\$0.00	0	
F	2	Flow Regulation Wetlands	\$0.00	0	
F	3	Flow Regulation Wetlands	\$0.00	0	
O	0	No Action	\$0.00	0	
O	1	Overbank Wetlands	\$0.00	0	
O	2	Overbank Wetlands	\$0.00	0	
O	3	Overbank Wetlands	\$0.00	0	
O	4	Overbank Wetlands	\$0.00	0	
O	5	Overbank Wetlands	\$0.00	0	

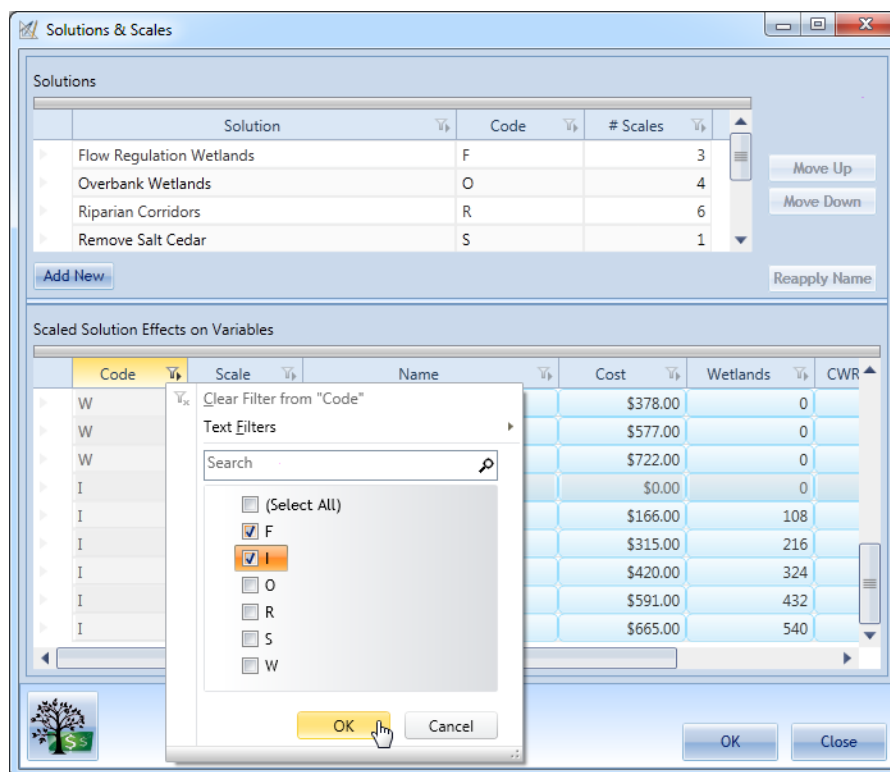
**Figure 74**  
**Scaled Solution Effects on Variables**

The first two columns of the data entry grid make up the solution code. The first column is the designator code for the respective solution (provided by the user); the second column is the scale counter. These code columns in the "Scaled Solution Effects on Variables" table are generated by the program and are not editable as indicated by a gray background. The third column is for entering a description for each solution-scale. This default description is editable. The entry of a description is not required, but is recommended. The description may be included in reports and is particularly useful for differentiating different scales of a given solution. Descriptions can be made up of any combination of alphanumeric or special characters and can be up to 500 characters in length. For example "F1" is described as Flow Regulation Wetlands on 50 acres. Therefore, 50 acres will be the description for "F1." Enter "50 Acres" in the space provided for the description of "F1" now. This particular action will cost \$661,000 and result in 40 habitat units of wetlands habitat being generated. These values are entered as follows: the "Costs" field has a value of 661 since the Costs variable is measured in \$1000. Enter "661" in the space provided for the Costs of "F1" now. The "Wetlands" field has a value of 40 for this solution and scale. Enter "40" in the space provided for Wetlands now. In this case, the solution "F1" does not have any output for CW Riparian or Open Water, so these fields may remain "0". This is how the effects that each solution and scale have on each variable are entered into IWR Planning Suite II.

Table 16 below defines the solutions and scales that are used in this case study. Repeat the procedure above for the 28 remaining solution-scales now.

Table 16. Solutions and Effects						
Code	Scale	Description	Costs (\$1000)	Wetlands (AAHU's)	CW Riparian (AAHU's)	Open Water (AAHU's)
F	0	No Action	0	0	0	0
F	1	50 Acres	661	40	0	0
F	2	100 Acres	78	80	0	0
F	3	150 Acres	84	120	0	0
O	0	No Action	0	0	0	0
O	1	25 Acres	41	21.25	0	0
O	2	75 Acres	62	63.75	0	0
O	3	100 Acres	81	85	0	0
O	4	150 Acres	1,01	127.5	0	0
S	0	No Action	0	0	0	0
S	1	1000 Acres	348	0	0	0
R	0	No Action	0	0	0	0
R	1	15 Acres	14	0	15	0
R	2	27 Acres	25	0	27	0
R	3	47 Acres	37	0	47	0
R	4	75 Acres	48	0	75	0
R	5	101 Acres	56	0	101	0
R	6	125 Acres	66	0	125	0
W	0	No Action	0	0	0	0
W	1	100 Acres	215	0	0	65
W	2	200 Acres	378	0	0	130
W	3	300 Acres	577	0	0	195
W	4	400 Acres	722	0	0	260
I	0	No Action	0	0	0	0
I	1	120 Acres	166	108	0	0
I	2	240 Acres	315	216	0	0
I	3	360 Acres	420	324	0	0
I	4	480 Acres	591	432	0	0
I	5	600 Acres	665	540	0	0

Note that specific solutions may be filtered for ease of data entry. To select which solutions will appear in the data entry/editing matrix, click on the funnel-shaped filter icon above the Code Header and uncheck "(Select All)" and then select the solutions you would like to display as shown below.



**Figure 75**  
**Filtering Scaled Solution Effects on Variables**

This does not delete any solution or any associated effects data from the database; it simply will not appear in the data entry/editing matrix under Solutions and Effects until the filter is turned off by selecting “(Select All)” from the filter icon combo box.

At this point, solutions may be added or deleted by clicking the ‘Add’ button on the Solutions & Scales form or selecting a solution and pressing the Delete key on your keyboard. Following deletion the user will be presented with a confirmation dialog. Clicking ‘Yes’ will delete the solution, and clicking ‘No’ will cancel the action.

Scales may be added to or removed from a solution by entering a new number in the # Scales column of the Solutions table of the Solutions & Scales form.

If the Delete action was selected, deleted scale(s) will no longer appear on the Solutions & Scales form.

If the user determines they would like to rename a solution they may do so at any time. If the user desires the related Names of the Scaled Solution Effects on Variables to be updated as well the user can select a solution row and then click the ‘Reapply Name’ button. This action is not performed by default in order to preserve possible previously defined Names in the bottom portion of the form.

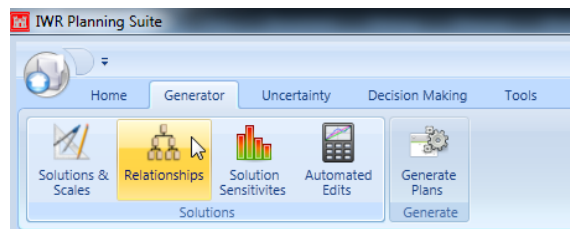
After all desired solutions have been selected clicking the ‘OK’ button to save your changes and exit the form. If the user wishes to exit the form without saving their changes the ‘Close’ button should be used.

## Solution Relationships

The set of rules regarding which solution and scale combinations are dependent upon one another, also known as “dependency relationships,” may be defined as appropriate before plan generation. These relationships occur between solutions when the implementation of one solution is dependent on the implementation of one or more other solutions. Dependencies are entered by stating the dependent solution and the set of solutions upon which it depends.

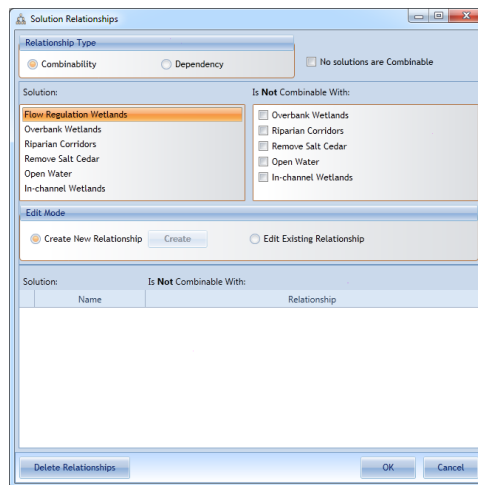
The rules for defining combinability relationships between solutions may also be defined, as appropriate. Such relationships occur between solutions when the implementation of one solution cannot be combined with the implementation of other solutions. Combinability is declared by selecting the solution and selecting those solutions with which it is not combinable.

Dependency and combinability relationships may be defined at this time by clicking the ‘Relationships’ button on the Generator ribbon as shown below.



**Figure 76**  
**Launch Relationships**

This will open the Solution Relationships form shown below.



**Figure 77**  
**Solution Relationships**

## Dependencies

First we will define dependency relationships. Dependency relationships occur between solutions when the implementation of one solution is dependent on the implementation of one or more other solutions. Click the Dependency radio button under the Relationship Type group box in order to specify dependency relationships for the solution currently displayed on the form.

The screenshot shows the 'Solution Relationships' dialog box. It has a 'Relationship Type' section with 'Combinability' and 'Dependency' radio buttons. Below is a 'Solution' list box containing 'Flow Regulation Wetlands', 'Overbank Wetlands', 'Riparian Corridors', 'Remove Salt Cedar', 'Open Water', and 'In-channel Wetlands'. To the right is an 'Is Dependent Upon' list box with checkboxes for the same solutions. At the bottom is an 'Edit Mode' section with 'Create New Relationship' (with a 'Create' button) and 'Edit Existing Relationship' radio buttons. A table at the bottom is empty, with columns for 'Solution' (Name) and 'Is Dependent Upon' (Relationship). Buttons for 'Delete Relationships', 'OK', and 'Cancel' are at the bottom.

**Figure 78**  
**Steps to Creating Dependency Relationships**

“And...” relationships (for example, A is dependent on B AND C) are entered across rows in the table, either...or” relationships are entered using multiple rows. Relationship rows are created by pressing the “Create” button. For example, to define the dependency relationship for “Overbank Wetlands,” click on the Overbank Wetlands solution in the Solution list box. Next, select the Flow Regulation Wetlands checkbox to the right and then click the ‘Create’ button. The solution “Overbank Wetlands” is now dependent on “Flow Regulation Wetlands.”

Select the solution you want to define a non-combinability relationship for (Step 2), check the solutions it is not combinable with (Step 3), and, then click the ‘Create’ button (Step 4). When done creating relationships the user can press the ‘OK’ button to save their changes and exit the form.

Note, if there were multiple solutions required, they would all be checked and would appear across the first row of the “Solution Is Dependent Upon:” table as shown below.

The 'Solution Relationships' dialog box is shown with the 'Dependency' radio button selected. The 'Relationship Type' section has 'Combinability' and 'Dependency' radio buttons, and a checkbox 'No solutions are Combinable'. The 'Solution:' list on the left includes 'Flow Regulation Wetlands', 'Overbank Wetlands' (highlighted), 'Riparian Corridors', 'Remove Salt Cedar', 'Open Water', and 'In-channel Wetlands'. The 'Is Dependent Upon:' list on the right includes checkboxes for 'Flow Regulation Wetlands', 'Riparian Corridors', 'Remove Salt Cedar', 'Open Water', and 'In-channel Wetlands'. The 'Edit Mode' section has 'Create New Relationship' (selected) and 'Edit Existing Relationship' radio buttons, with a 'Create' button next to the first. Below is a table showing the created relationships:

Solution:	Name	Is Dependent Upon:	Relationship
	Overbank Wetlands		Flow Regulation Wetlands
	Riparian Corridors		Flow Regulation Wetlands AND Overbank Wetlands AND Remove Salt Cedar
	Open Water		Remove Salt Cedar
	In-channel Wetlands		Remove Salt Cedar

At the bottom are buttons for 'Delete Relationships', 'OK', and 'Cancel'.

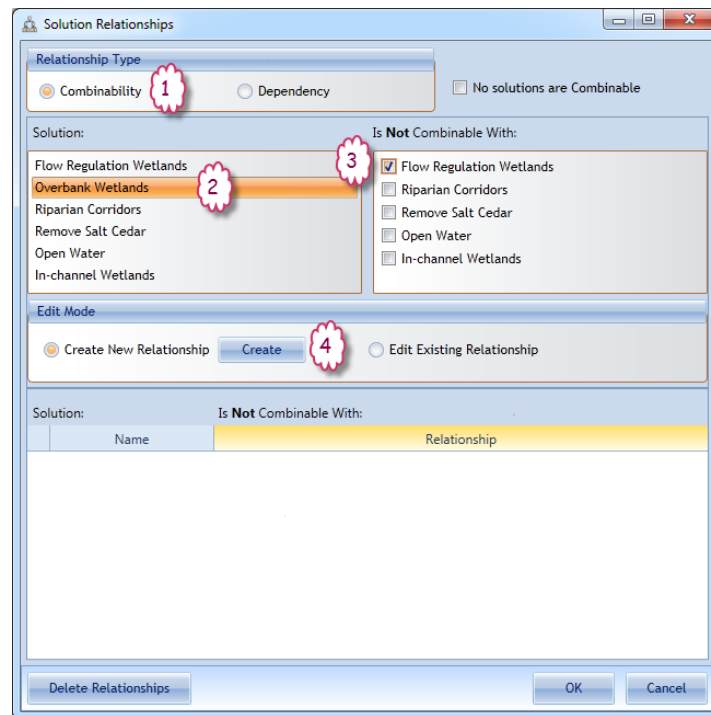
**Figure 79**  
**Created Relationships**

You will notice that when a dependency is defined by pressing the 'Add' button, a new row appears below the current row. This will allow the "either...or" dependency relationships to be defined.

### Combinability Relationships

Next we will define the combinability relationships. Combinability relationships occur between solutions when the implementation of one solution cannot be combined with the implementation of one or more other solutions. Click the Combinability relationship type radio button in order to specify non-combinable relationships for the solution currently displayed on the form (Step 1). "And..." relationships (for example, A is not combinable with B and C together) are entered across rows in the sub-form, "either...or" relationships are entered using multiple rows.

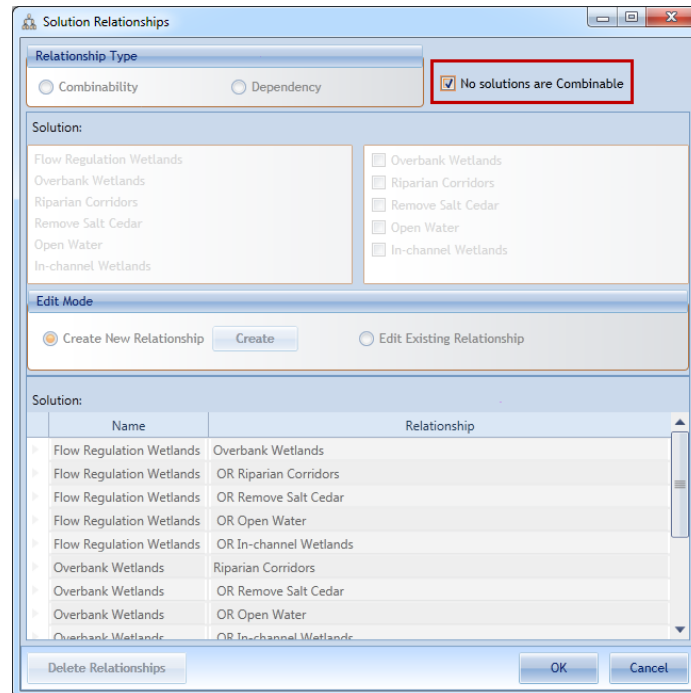
As with dependency relationships, click the solution you want to define a non-combinability relationship for (Step 2), check the solutions it is not combinable with (Step 3), and, then click the 'Create' button (Step 4). When done the user can press the 'OK' button.



**Figure 80**  
**Steps to Creating Combinability Relationships**

However, if no solutions are combinable with each other (for example, each solution represents a fully formulated, discrete alternative plan), a shortcut to specifying individual non-combinability relationships between solutions is to click on the checkbox in the upper-right-hand corner of the Solution Relationships form marked “No Solutions Are Combinable.” When this box is checked, the IWR Planning Suite II will automatically prevent any solution from being combined with another.





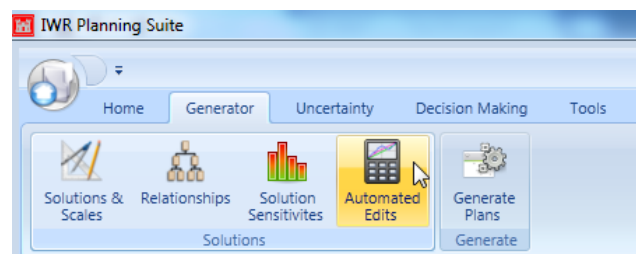
**Figure 81**  
**No Solutions Are Combinable**

When finished defining relationships, click the 'OK' button to save the defined relationships.

## Automated Editing

Automated editing is a feature which allows the planner to automatically account for the fact that a group of plan effects to be generated may not be a matter of simple addition of solution effects. A mathematical function is entered to describe complex additive effects for a set of solution combinations. To define an automated edit, an edit group name, applicable variable, additive function and logical condition for application of the edit are entered in an automated edit group entry form. During plan generation, the automated edit entries are used in place of simple addition for applicable solution and scale combinations.

Next we will define automated edits. Clicking the 'Automated Edits' button on the Generator ribbon will open the Automated Edits form.



**Figure 82**  
**Launching Automated Edits**

The automated editing feature allows users to automatically account for the fact that all plan effects may not be additive (IWR Planning Suite II's default assumption) when individual solutions are combined. Alternatively, the user has the ability to edit the effects of plan combinations manually on a plan by plan basis directly within the Plan Editor.

Automated editing can make the editing process more efficient and time-saving by enabling the user to specify multiple non-additive effects when the edit can be described by some logical statement such as, "When solution A and solution B are combined, reduce the sum of the cost of (A+B) by \$1000." These edits to account for non-additive effects will take place as plan combinations are being built.

To perform an automated edit, see the figures below, the user must complete the following information on the Automated Editing form:

**Figure 83**  
**Creating Function for Automated Edits**

Automated Edits

Name: CostSavings Create... Variable: Cost

Function Conditions

Name	Code
Flow Regulation Wetlands	F
Overbank Wetlands	O
Riparian Corridors	R
Remove Salt Cedar	S

( ) Clear

And Or Not

Validate Validated

Where: A or B or C or ... n = All Action Plans (Default)

F or O or R or S or W or I

Automated Edits

Name	Conditions	Function
CostSavings	F or O or R or S or W or I	(1)*F + (1)*O + (1)*R + (1)*S + (1)

OK Close

**Figure 84**  
**Creating Conditions for Automated Edits**

1. **Edit Group Name (Required)** - The user must provide a unique edit group name for each individual automated edit he/she wishes to perform.
2. **Variable (Required)** - The user must specify the variable on which the automated editing will be performed by clicking to select from the pull-down list next to the variable field. Select "Cost" from the pull-down list.
3. **Function (Required)** - In this field the user specifies the editing function to be performed on the variable. The default function that first appears in the Function field displays IWR Planning Suite II's additive assumption, i.e., each solution's value for that variable is added together to yield that combination of solutions' value for that variable. (In the default case, the "1's" indicate that a coefficient of 1 will be multiplied by each of the solution's values, and the constant of "0" indicates that no additional constant will be added to the solutions' values; thereby adhering to the program's additive assumption.)

To edit the default function, the user can change the coefficients as appropriate by clicking in the Coefficient column and typing in a new value; and can change the constant as appropriate by clicking in the Constant field and typing in a new value. Solution values are multiplied by coefficients; to divide a solution value, a decimal coefficient (<1) must be used in the Coefficient column. Similarly, constants are added to solution values; to subtract a constant, a negative value must be typed in the Constant field.

4. All the solution coefficients can remain as 1; however a constant can also be added to this formula.
5. Conditions (Not required, but usually necessary) - In this field the user specifies under what conditions (i.e., where) the editing function is to be performed on the variable to be edited. The default function that first appears in the Where: field is “under all conditions” or for all action plan combinations. Unless you want the automated edit function to be applied to all plan combinations, you will need to change the statement in this field.

To change the Where: conditions, first click on the ‘Clear’ button to delete the default statement in the Where: field. Then double-click on the appropriate solution code in the “Solution/Description” box to insert that solution code into the Where: condition field. Next, select a Boolean operator (AND or OR; NOT may be used in conjunction with AND or OR) by clicking on the appropriate button to place that operator after the first solution code in the Where: condition statement. Next, select another solution code by double clicking on the appropriate code to place it in the Where: field statement. Repeat this process of selecting solution codes and Boolean operators until the desired conditions appropriate to the automated edit function are specified in the Where: field. Use the parentheses buttons ( ) as appropriate. In defining Where: condition statements, those specified within parentheses are performed first. Operations are performed in the following order of precedence: NOT statements first, followed by AND statements, then OR statements. If you make a mistake, use the backspace button (<) to delete the preceding term or use the ‘Clear’ button to start over.

6. Click on the ‘Validate’ button to validate the logical consistency of the Where: condition statement.
7. The IWR Planning Suite II will automatically verify the validity of the Where: condition statement when the user presses ‘OK’ to close the Automated Edits form.

You may add or delete groups at this time by clicking the ‘Create’ button to add or selecting an automated edit and pressing the Delete key on the keyboard to delete. Clicking the ‘OK’ button will save the automated edits you have defined.

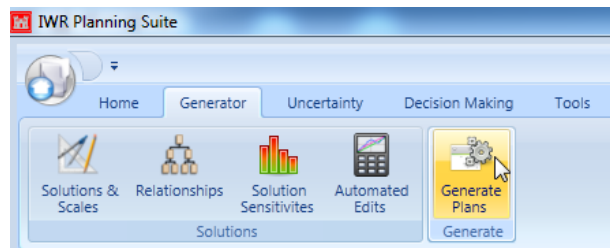
## Plan Generation

Once a planning study comprised of variables, derived variables, and attributes has been defined by the user, the plan generation module is used to populate a new planning set with plan alternatives. The plan generation module will automatically generate a Planning Set from a set of solutions and scales using the same mechanisms available in the current IWR Planning Suite II application. It generates a planning set directly to the IWR Planning Suite II database and, like all the default IWR Planning Suite II modules, this active planning set in the database is associated with the current plan study.

The solutions, scales, combinability and dependency relationships which together determine the full set of plan alternatives which may be generated are defined by the user. Additionally, automated edits, constraint groups, and solution sensitivities are defined.

Generated planning sets will be displayed with some information that will assist planners in managing them and keeping them in context. For example, planning sets will include the name of the planning study to which they belong.

Click on the 'Generate Plans' button available on the Generator ribbon as shown below to launch the Generate Planning Set form.

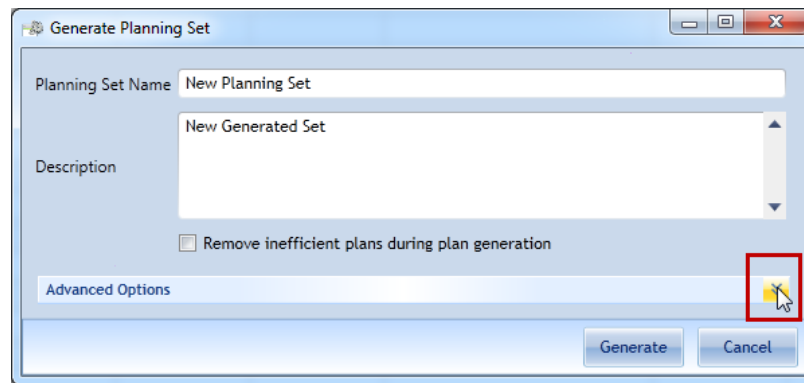


**Figure 85**  
**Launching Generate Plans**

This will launch the “Generate Planning Set” form shown below.

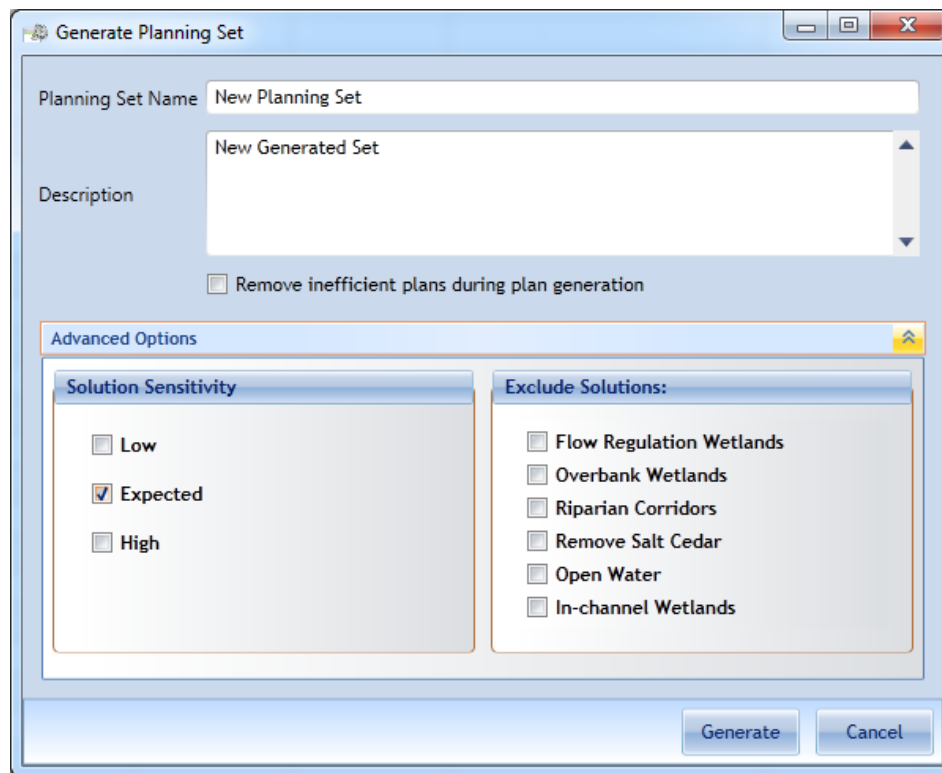
**Figure 86**  
**Generate Planning Set**

You may take the default settings of this form and just press 'OK,' and plans will be generated. You may, if you wish, define the planning set's name and description as well as remove any inefficient plans during generation to reduce the number of overall plans generated. You may also expand the Advanced Options section of the form to define solution sensitivities sets to be generated and any solutions you wish to exclude by clicking the down arrow next to Advanced Options.



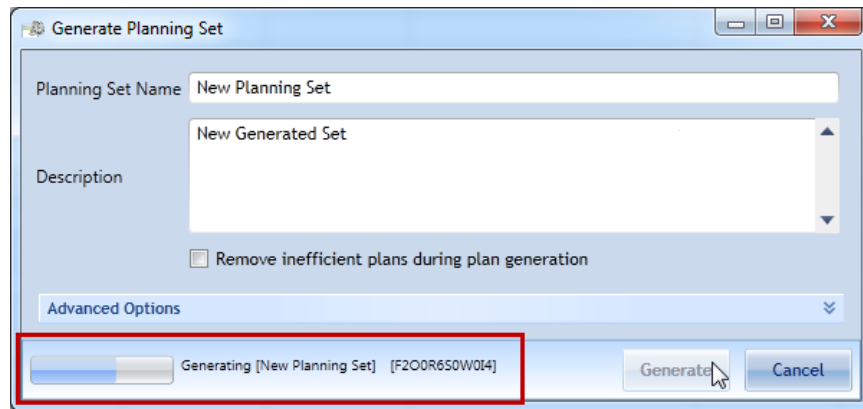
**Figure 87**  
**Expanding Advanced Options for Generating Planning Set**

The user may now make these advanced options selections and then click 'Generate' to generate the planning sets.



**Figure 88**  
**Advanced Options for Generating Planning Set**

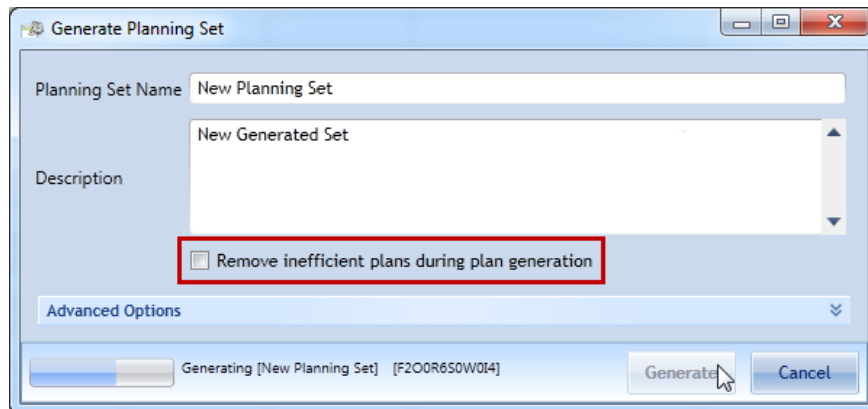
When you press 'Generate', the planning set is generated. If there are many solutions and scales defined, this may take from several minutes to many hours. A progress bar at the bottom of the Generate Planning Set form will display the percentage of plans that have been generated.



**Figure 89**  
*Progress of Generating a Planning Set*

### Inefficient Plan Removal

Inefficient Plan Removal, the filtering of all plans except cost-effective plan alternatives, may be applied as an option when generating the planning set. To enable inefficient plan removal, check the “Remove inefficient plans during generation” checkbox available on the Generate Planning Set form prior to generation.



**Figure 90**  
*Removing Inefficient Plans During Generation*

This option is of value in cases where numerous solutions and scales have been defined, which would result in an extremely large set of solution combinations, which may exceed the limits of the database. When this option is selected, plan generation only saves cost-effective plans to the database. Further detail on what constitutes a cost-effective plan definition may be found in the description of the CE/ICA component.

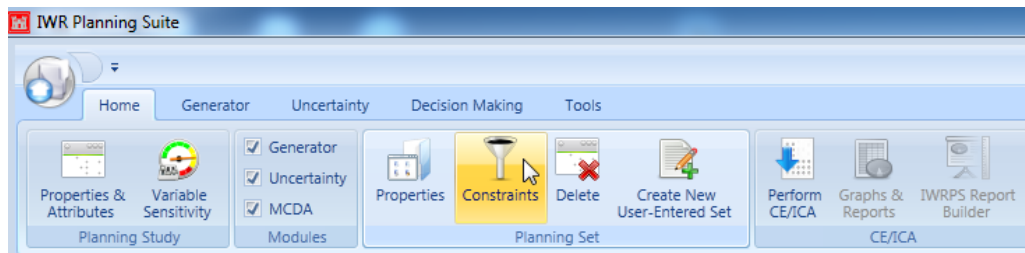
## Constraints

Constraints may be defined to filter a planning set to only those plan alternatives that meet a set of predefined criteria. The criteria are minimum and maximum acceptable values for a particular variable. Note that, constraints may not be applied to derived variables.

To constrain a planning set, a planning set name is entered, along with one or more variables to be constrained and a minimum and maximum acceptable value for each variable. The application of constraints to a planning set will generate a new planning set containing only the plan alternatives that meet the constraining criteria.

Constraints can be defined to limit the a planning set's alternatives to only those plan alternatives from a parent planning set that meet the criteria defined by the constraints. In defining a constrained planning set, the user can select any non-derived variables for inclusion in the group. The user then can enter in minimum and maximum acceptable values for each variable in which the user would like to constrain. The user can leave the fields blank for any variables they do not wish to constrain.

Click on the 'Constraints' button on the Home ribbon to launch the Constrain Active Planning Set form.



**Figure 91**  
**Launching Constraints**

After clicking this button the Constrain Active Planning Set form shown below will open.

Variable	Description	Minimum Value	Maximum Value
CWRiparian			
Cost	Average Annual Cost		
OpenWater			
Wetlands	Output in Average Ai		

Constrained Planning Set Name:

**Figure 92**  
**Constrain Active Planning Set**



When defining constraints, a default name is provided for the planning set but it is recommended you specify a more meaningful name to be used for the constrained planning set. The Constrained Planning Set Name can be comprised of any combination of alphanumeric or special characters and can be up to 255 characters in length. Next, you would enter a minimum and maximum value for each variable the user wishes to constrain. To have multiple variables constrained, simply enter minimum and maximum for the other variables. If the user doesn't wish to constrain the planning set by a particular variable the minimum and maximum values can be left blank.

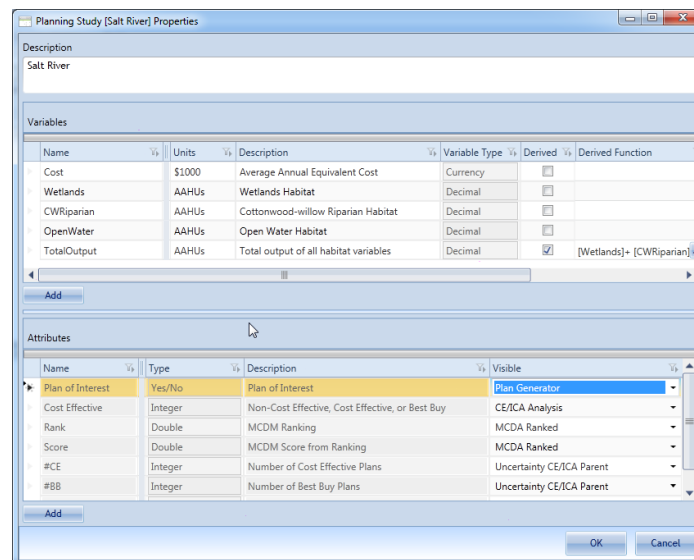
## Plans of Interest

Plans of interest are defined as plans that are deemed interesting, and therefore the user desires to keep track of them, for some purpose.

Certain different types of variables or attributes must be associated with a planning alternative and given values, either during the manual creation of the planning set, or by the planning set generator, before the set may be subjected to subsequent analysis. For example, in order to be processed by the CE/ICA module, each plan alternative must have variables, which represent the cost and output measures of the plan. The CE/ICA analysis will allow the user to specify which variables of the planning set represent the cost and output measures for analysis purposes.

In the Planning Study Properties form, attributes applicable to the analysis may be defined, such as a *plan of interest* attribute, to be used by reporting and visualization modules. Then, once the rows of the planning set are created, individual *plans of interest* may be chosen. To do so, the *plan of interest* visibility of the row is marked as Plan Generator.

Plans of interest are defined by marking the Plan of Interest checkbox in the Plan Editor for each plan deemed to be interesting. Each plan alternative has a Plan of Interest attribute, but this attribute is hidden by default. It may be displayed by bringing up the Planning Study Properties form, and selecting Plan Generator from the Visibility property of the Plan of Interest Attribute.



**Figure 93**  
**Setting Plan of Interest Visibility**

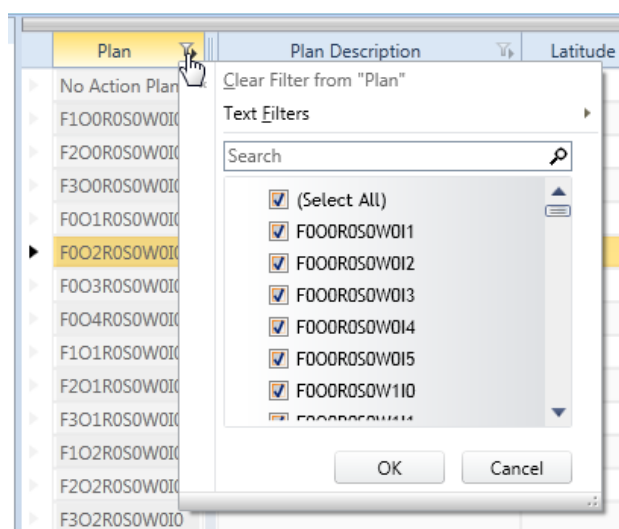
The Plans of Interest attribute allows the user to specify particular plans as plans of interest. Initially when the Plan Editor displays a planning set, the Plan of Interest column will appear blank since no plans of interest have yet been defined.

To enter a plan as a plan of interest, click the Plan of Interest Checkbox on the plan alternative deemed to be of interest as shown below.

Plan	Plan Description	Latitude	Longitude	HUC	Location Description	Cost	Wetlands	CWRiparian	OpenWater	Plan of Interest
No Action Plan	Default No Action Plan					\$0.00	0	0	0	<input type="checkbox"/>
F100R0S0W0I0							40	0	0	<input type="checkbox"/>
F200R0S0W0I0							80	0	0	<input type="checkbox"/>
F300R0S0W0I0							120	0	0	<input type="checkbox"/>
F001R0S0W0I0							21.25	0	0	<input type="checkbox"/>
F002R0S0W0I0							63.75	0	0	<input type="checkbox"/>
F003R0S0W0I0							85	0	0	<input type="checkbox"/>
F004R0S0W0I0							127.5	0	0	<input type="checkbox"/>

**Figure 94**  
**Identifying Plans of Interest**

To find a particular plan to mark as of interest in a large planning set, click on the funnel-shaped filter icon beside the Plan field header and enter the plan name in the Search field and press Enter on the keyboard.

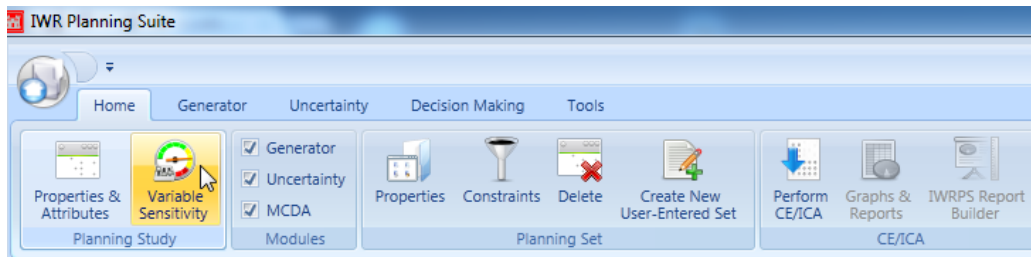


**Figure 95**  
**Filtering Planning Sets by Plan Name**

Once all plans of interest have been identified as such the user can click the 'Save Changes' button in the Plan Editor to save their changes.

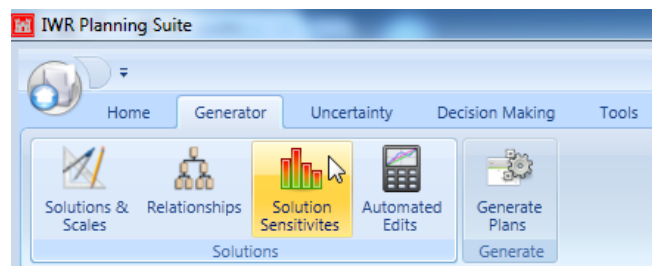
## Sensitivity

Sensitivity values can be entered at one of two levels – variable sensitivity and solution sensitivity. Variable sensitivity allows the user to enter uniform coefficients for computing all high and low values for a given variable (for example, evaluate all cost estimates by +/- 20%). Variable sensitivity values can be changed by clicking on the 'Variable Sensitivity' button located on the Home ribbon.



**Figure 96**  
**Launching Variable Sensitivity**

Solution sensitivity allows the user to enter uniform coefficients for computing all high and low values for a given variable and solution combination (for example, evaluate all cost estimates for the solution “dredging” at +/- 20% but all cost estimates for the solution “aquatic plant harvesting” at +/- 40%). Solution sensitivity values can be changed by clicking on the ‘Solution Sensitivities’ button located on the Generator ribbon.

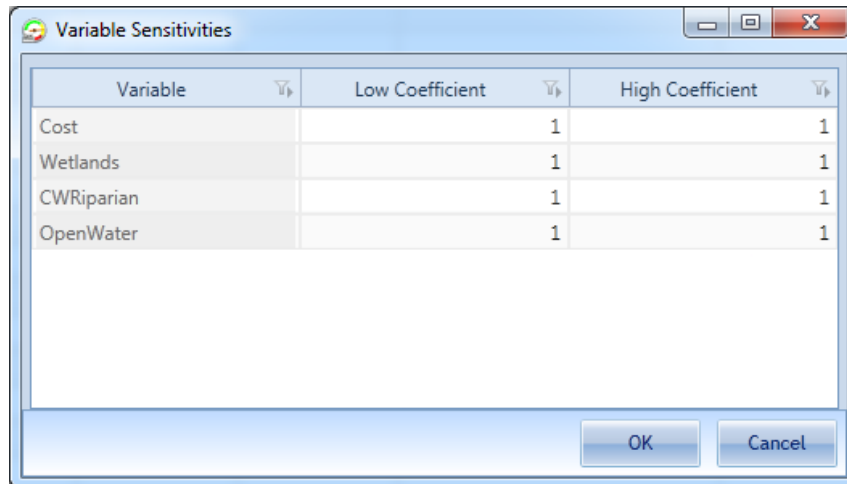


**Figure 97**  
**Launch Solution Sensitivities**

## Variable Sensitivity

For variable sensitivity, the high and low variable values entered are uniform coefficients used for computing the high and low values for the selected variable. This creates a value range result for that variable.

If ‘Variable Sensitivity’ button is selected on the Home ribbon, the Variable Sensitivities form shown below will be opened.



The image shows a software dialog box titled "Variable Sensitivities". It contains a table with three columns: "Variable", "Low Coefficient", and "High Coefficient". Each column has a small downward arrow icon next to its header. The table lists four variables: "Cost", "Wetlands", "CWRiparian", and "OpenWater". For each variable, both the "Low Coefficient" and "High Coefficient" are set to the value "1". Below the table, there are two buttons: "OK" and "Cancel".

Variable	Low Coefficient	High Coefficient
Cost	1	1
Wetlands	1	1
CWRiparian	1	1
OpenWater	1	1

**Figure 98**  
**Variable Sensitivities**

Next you will enter uniform coefficients for computing all high and low values for the corresponding variable. Note that low coefficients must always be a real number less than or equal to one including negative numbers and high coefficients must be a real number greater than or equal to 1. Once the coefficients have been defined, simply click the 'OK' button to save the coefficients. Clicking the 'Cancel' button will simply discard any changes and close the form.

Variable Sensitivity causes the creation of two derived variables—a high value and low value -- to be added to the planning study for each variable. In the resulting planning set, these new variables are filled with the respective high and low values indicating the sensitivity range for the variable. In addition to this ability to set all the plan alternative variable sensitivities in a study at one time by using high and low coefficients, the capability exists through the Planning Study Properties form to change the visibility of low and high variables. By default the high and low variable alternatives will be set to visible.

**Planning Study [Salt River] Properties**

Description  
Salt River

Variables

Name	Units	Description	Variable Type	Derived	Derived Function
CWRiparian	AAHUs	Cottonwood-willow Riparian Habitat	Decimal	<input type="checkbox"/>	
OpenWater	AAHUs	Open Water Habitat	Decimal	<input type="checkbox"/>	
TotalOutput	AAHUs	Total output of all habitat variables	Decimal	<input checked="" type="checkbox"/>	[Wetlands]+ [CWRiparian]
Cost Low	\$1000	Low Variable Sensitivity of 0.800 for variable "	Currency	<input checked="" type="checkbox"/>	[Cost] * (0.800)
Cost High	\$1000	High Variable Sensitivity of 1.200 for variable "	Currency	<input checked="" type="checkbox"/>	[Cost] * (1.200)

Add

Attributes

Name	Type	Description	Visible
Plan of Interest	Yes/No	Plan of Interest	Always
Cost Effective	Integer	Non-Cost Effective, Cost Effective, or Best Buy	CE/ICA Analysis
Rank	Double	MCDM Ranking	MCDM Ranked
Score	Double	MCDM Score from Ranking	MCDM Ranked
#CE	Integer	Number of Cost Effective Plans	Uncertainty CE/ICA Parent
#BB	Integer	Number of Best Buy Plans	Uncertainty CE/ICA Parent

Add

OK Cancel

**Figure 99**  
**Viewing Low and High Variables**

## Solution Sensitivity

Similar to variable sensitivity, the high and low values entered for solution sensitivity are uniform coefficients used for computing the high and low values for the selected solution combination. This creates a value range result for that solution. When a planning set is then generated to the plan study, hidden high and low value variables are added for each variable of each plan alternative in the generated planning set.

When the 'Solution Sensitivity' button on the Generator ribbon is clicked, the Solution Sensitivity form shown below will be opened.

Code	Solution	Variable	Low Coefficient	High Coefficient
F	Flow Regulation \	Cost	1	1
F	Flow Regulation \	Wetlands	1	1
F	Flow Regulation \	CWRiparian	1	1
F	Flow Regulation \	OpenWater	1	1
O	Overbank Wetlan	Cost	1	1
O	Overbank Wetlan	Wetlands	1	1
O	Overbank Wetlan	CWRiparian	1	1
O	Overbank Wetlan	OpenWater	1	1
R	Riparian Corridor	Cost	1	1
R	Riparian Corridor	Wetlands	1	1
R	Riparian Corridor	CWRiparian	1	1
R	Riparian Corridor	OpenWater	1	1
S	Remove Salt Cedi	Cost	1	1
S	Remove Salt Cedi	Wetlands	1	1
S	Remove Salt Cedi	CWRiparian	1	1

**Figure 100**  
**Solution Sensitivity**

Through this dialog, you may enter uniform coefficients for computing all high and low values for any and every given variable and solution combination. As with variable coefficients, low coefficients must always be a real number less than or equal to one including negative numbers and high coefficients must be a real number greater than or equal to 1. Once the coefficients have been defined, clicking the 'OK' button will save the coefficients. Clicking the 'Cancel' button will discard any changes and close the form.

## CE/ICA Analysis

Cost Effectiveness and Incremental Cost Analysis is described in detail in Section III, "[Plan Analysis](#)." Here is an overview of how it is applied within the IWR Planning Suite II application.

Cost Effectiveness is a method of identifying least-cost solutions for different levels of outputs or benefits. It is utilized in planning situations where dollar values are not used to measure outputs. In the absence of economic valuation of effects, then, it can lead to more informed and supportable decisions than might cost-oblivious decision making.

In a planning set comprised of many plan alternatives, cost effectiveness can support decision-making by filtering out and eliminating many plan alternatives that are ineffective and inefficient. Plan alternatives that cost the same amount or more compared to plan alternatives that produce the same or more outputs can be reasonably discarded, thereby significantly reducing the number of plan alternative options to a more manageable subset from which the most viable plan alternative may be chosen.

**Incremental Cost Analysis** is performed by determining the incremental cost per unit between successively larger (i.e., more output) plan alternatives, and identifying best buy plans as those plans for which the incremental cost per unit is lowest for a particular output level. Incremental cost per unit is defined as the plan alternative's incremental cost divided by its incremental output.

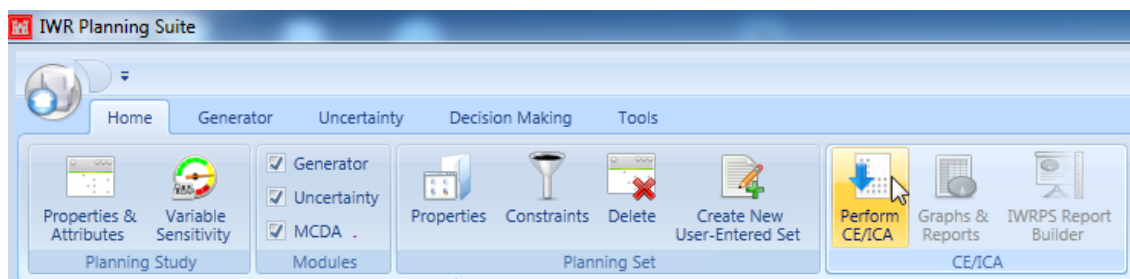
**Incremental Cost** is the difference in cost between the costs of two plan alternatives. It is determined by subtracting the cost of the less expensive plan alternative from the cost of the more expensive plan alternative. Incremental output is the difference between the outputs of two plan alternatives. It is determined by subtracting the output of the smaller output plan alternative from the output of the larger plan alternative.

The CE/ICA module performs CE/ICA on an active plan set. The existing planning set data will be evaluated to generate results, which may be filtered down to a preferred set of plans.

The CE/ICA analysis module is capable of processing plans from any of the planning sets in the current plan study in the IWR Planning Suite II database. Results may be generated as a planning set directly to the IWR Planning Suite II database, from which they may be edited, reported on or graphed, printed, used as input to additional analyses, or exported to a file.

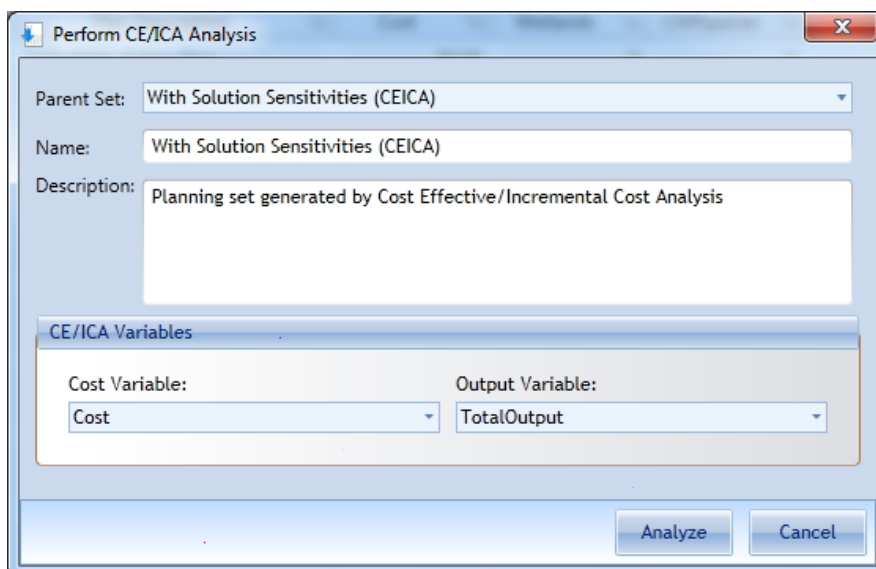
The CE/ICA analysis form will accept active planning sets in the IWR Planning Suite II database, those generated by the plan generator or using user-entered sets, watershed sets and uncertainty sets. The analysis results will be output as an active planning set to the IWR Planning Suite II database, from which it may be exported if desired. The default "Cost Effective" attribute is made visible in the resulting planning set to indicate the cost-effectiveness or "best buy" status of each of the plan alternatives from the analyzed planning set.

Open the CE/ICA Analysis form now by clicking on the 'Perform CE/ICA' button on the Home ribbon to generate a new analysis planning set from the current generated planning set. The same steps may be followed to perform an analysis on User-Entered planning sets that were manually entered through the plan editor.



**Figure 101**  
**Launching CE/ICA**

The CE/ICA analysis will be completed automatically for Watershed Analysis following generation of the planning set. Once the set has been generated then the form to complete the CE/ICA will display for the user. The user can select the Cost and Output variables to be used and then click the 'Analyze' button to continue with the CE/ICA Analysis.

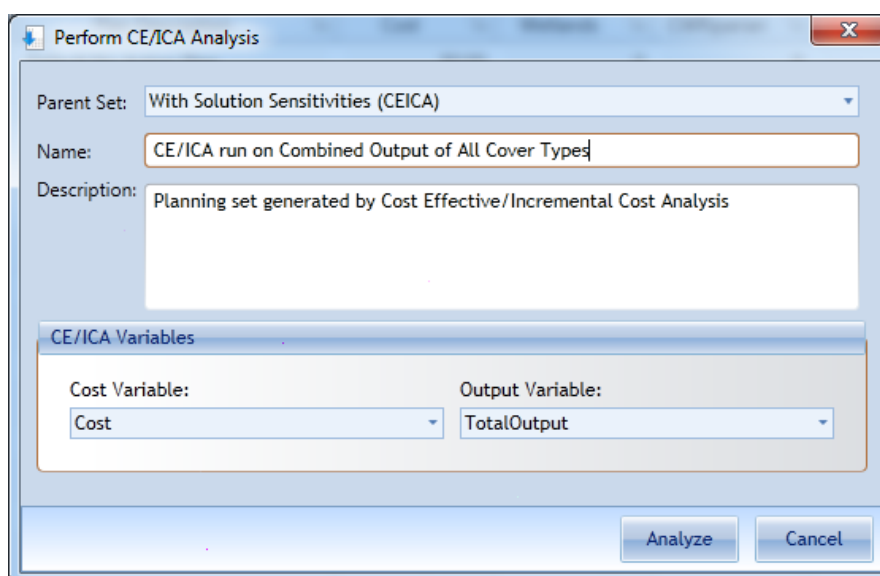


The dialog box titled "Perform CE/ICA Analysis" contains the following fields:

- Parent Set:** A dropdown menu showing "With Solution Sensitivities (CEICA)".
- Name:** A text field containing "With Solution Sensitivities (CEICA)".
- Description:** A text area containing "Planning set generated by Cost Effective/Incremental Cost Analysis".
- CE/ICA Variables:** A section containing two dropdown menus:
  - Cost Variable:** A dropdown menu showing "Cost".
  - Output Variable:** A dropdown menu showing "TotalOutput".
- Buttons:** "Analyze" and "Cancel" buttons at the bottom right.

**Figure 102**  
**Performing CE/ICA for Watershed Analysis**

The description field is an optional field that allows the user to give a better description of the CE/ICA set. Note that the description can be up to 500 characters in length. Enter "CE/ICA run on Combined Output of All Cover Types" in the space provided for the Plan Study description now. The cost parameter field is a drop-down list populated with the defined variables. IWR Planning Suite II will use the selected cost variable as the Y-axis variable for all analyses. The cost parameter is what is used in all cost effectiveness and incremental cost calculations. Select "Cost" as the cost parameter now. As with the cost parameter, the output parameter field is a drop-down list populated with the defined variables. IWR Planning Suite II will use the selected variable as the X-axis variable for all analyses. The output parameter is also used in all cost effectiveness and incremental cost (incremental cost per unit of output) calculations. Select "TotalOutput" as the output parameter as shown below.



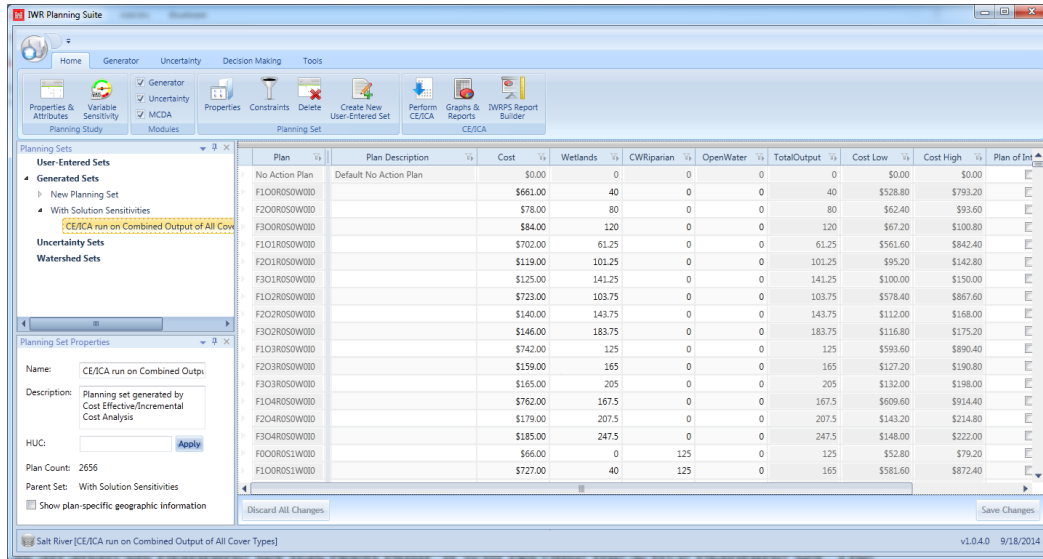
The dialog box titled "Perform CE/ICA Analysis" contains the following fields:

- Parent Set:** A dropdown menu showing "With Solution Sensitivities (CEICA)".
- Name:** A text field containing "CE/ICA run on Combined Output of All Cover Types".
- Description:** A text area containing "Planning set generated by Cost Effective/Incremental Cost Analysis".
- CE/ICA Variables:** A section containing two dropdown menus:
  - Cost Variable:** A dropdown menu showing "Cost".
  - Output Variable:** A dropdown menu showing "TotalOutput".
- Buttons:** "Analyze" and "Cancel" buttons at the bottom right.



**Figure 103**  
**Selecting Cost and Output Variables**

As soon as an analysis planning set has been built, it will become the active planning set. The active planning set is selected in the Planning Sets pane and displayed in the Plan Editor.

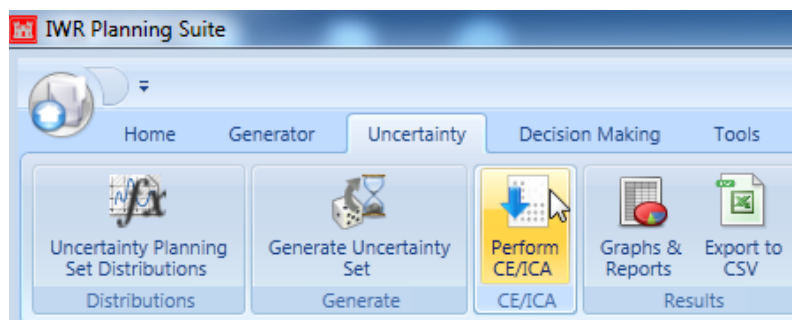


**Figure 104**  
**Viewing CE/ICA Results**

A particular analysis module will usually require certain variables or attributes, such as cost and value attributes, which are prerequisite components of every plan alternative in the planning set. A default “Cost” and “Output” variable are automatically created for new plan studies to support the intrinsic CE/ICA analysis module.

## Uncertainty CE/ICA Analysis

For Uncertainty Analysis the CE/ICA will be completed through use of the ‘Perform CE/ICA’ button located on the Uncertainty ribbon. Please note that the ‘Perform CE/ICA’ button on the Uncertainty ribbon will remain disabled until an uncertainty set has been generated.



**Figure 105**  
**Launching CE/ICA for Uncertainty Sets**

CE/ICA is performed for each iteration of the uncertainty planning set with the final planning set displaying counts of the number of times each plan alternative was calculated to be a Cost Effective or Best Buy alternative.

The CE/ICA form for uncertainty sets looks almost identical to the CE/ICA for non-uncertainty planning sets. The only difference is an additional option to perform Data Envelopment Analysis which is selected by default.

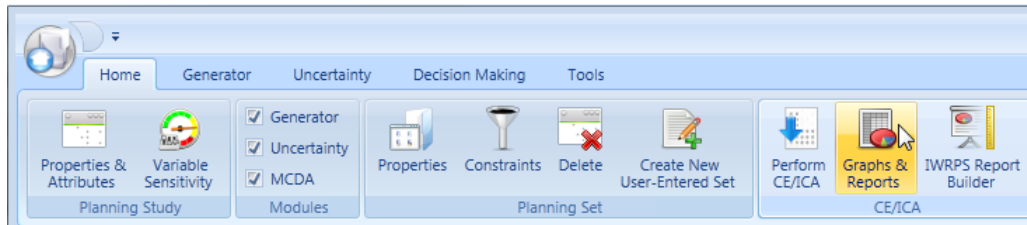
The screenshot shows a software dialog box titled "Perform Uncertainty CE/ICA Analysis". It contains several input fields and checkboxes. The "Planning Set" is a dropdown menu showing "Salt River Uncertainty Set". The "Name" field contains "CE/ICA run on Salt River Uncertainty Set". The "Description" field contains "Planning set generated by Cost Effective/Incremental Cost Analysis". Below this is a section titled "CE/ICA Analysis" which contains two dropdown menus: "Cost Variable" set to "Costs" and "Output Variable" set to "TotalOutput". There are two checkboxes: "Perform Data Envelopment Analysis" which is checked, and "Exclude plans in violation of tolerance rules" which is also checked. A text field for "Near Cost Effective Threshold (0-1)" is set to "0.9". At the bottom right are "Analyze" and "Cancel" buttons.

**Figure 106**  
**Uncertainty CE/ICA Form**

If selected, Data Envelopment Analysis is performed at each iteration to determine how close plan alternatives are to the calculated efficient frontier and store quantitative metrics of this distance. In order to declare a plan alternative to be 'Near Cost Effective', the plan alternative must not exceed the user-specified threshold (0 – 1 with 1 being on the efficient frontier) for both cost and output values. As with CE/ICA, the final planning set will display total counts for the number of times each alternative was calculated to be 'Near Cost Effective'.

## Analysis Results

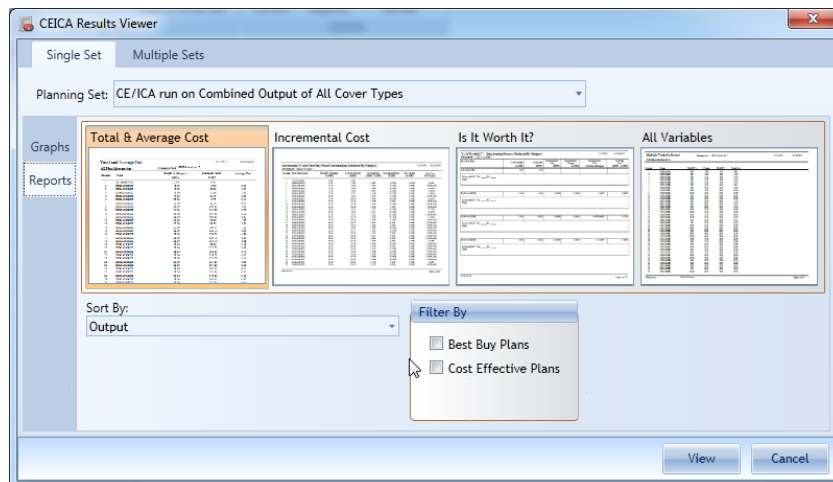
The Analysis Results function of IWR Planning Suite II provides a variety of graphical and textual reports for the planner to assist in the evaluation of plan alternatives. Reports can be generated from the IWR Planning Suite II database of the active planning set, or selected from the entire set of analysis results for multi-planning set reports. Users can access the available reports and graphs related to the CEICA analysis by clicking on the 'Graphs & Reports' button on the Home ribbon.



**Figure 107**  
**Launching Graphs & Reports**

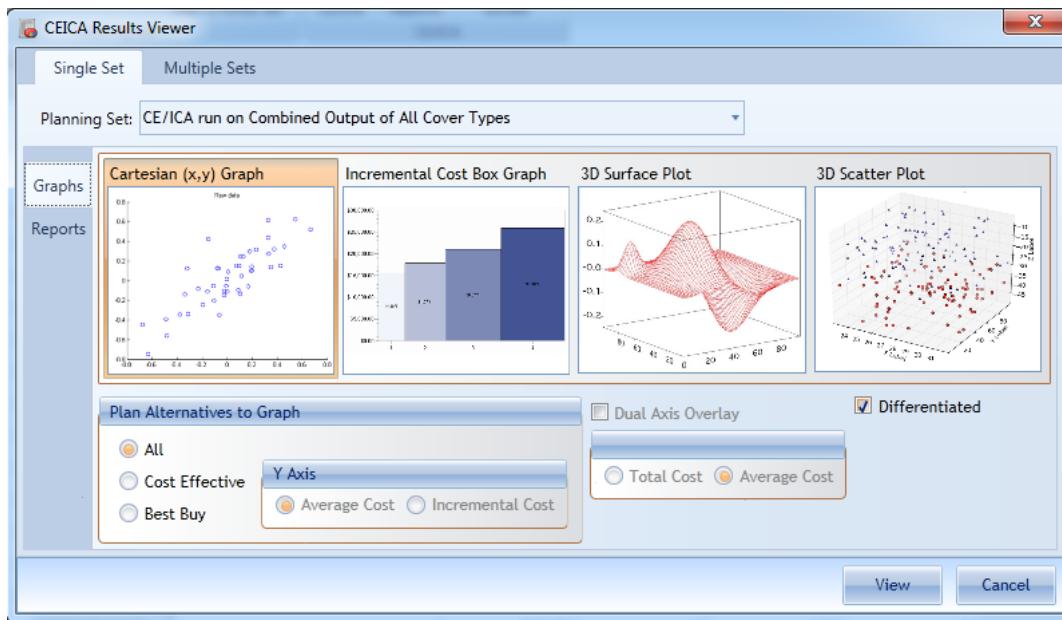
The reporting and graphing capabilities are intended to be performed on the results of a CE/ICA analysis. However, these reports are more broadly applicable to any analytic technique that associates appropriate output variables and attributes to the plan alternatives. When a report or graph is chosen for display, the user will be asked to select the appropriate parameters, such as filtering by cost effective plans, needed to generate the report or graph.

Available reports include a total and average cost report, an incremental cost analysis report, an “Is it worth it?” report, and an “All Variables” report.



**Figure 108**  
**Viewing Single Set Reports**

Graph options include graphs of All Plans, Cost Effective and Best Buy plans. All plans and cost effective plans may also be graphed in a differentiated format (i.e., differentiated between non-cost effective, cost effective, and best buy plans). The best buy plans graph is viewable as a Cartesian (x,y) coordinates graph, as a box graph, and other formats including three dimensional visualization graphs.



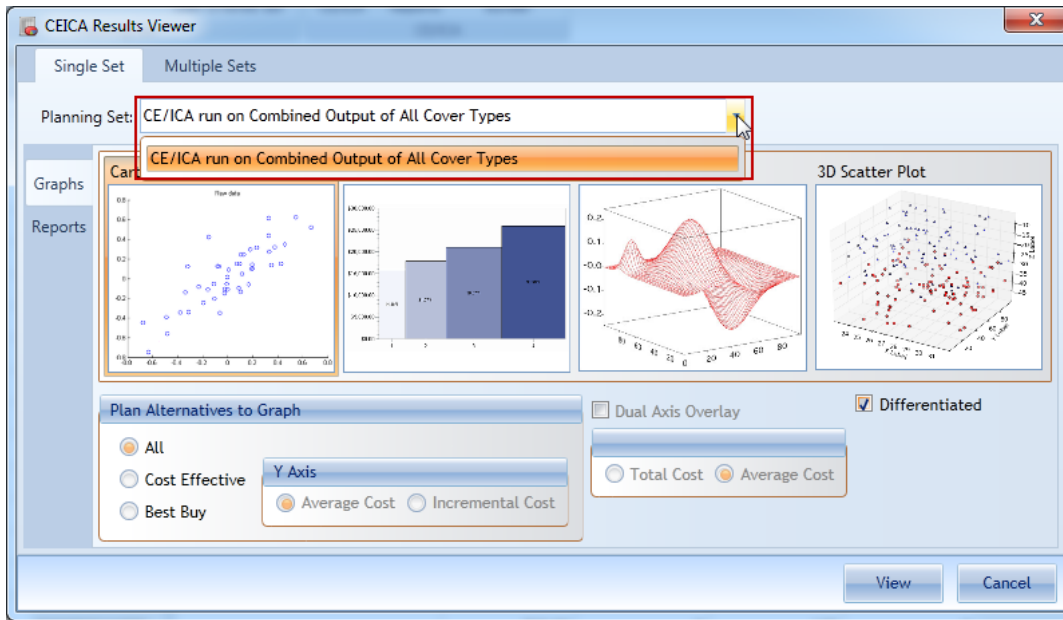
**Figure 109**  
**Viewing Single Set Results**

## Single Planning Set Results

Once at least one planning set has been analyzed, you may view the analysis results. Such results are called “Single Planning Set Results.” The available single planning set graphs are displayed by default when the CEICA Results Viewer is opened.

## Graph Single Planning Set Results

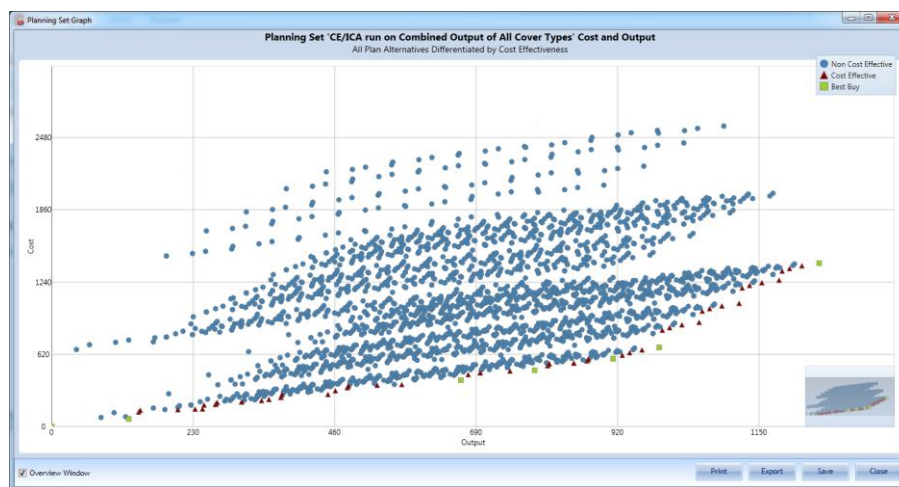
The first step in selecting a graph to view is to specify which analysis planning set to graph. To do this, select the desired planning set from the “Planning Set” dropdown list.



**Figure 110**  
**Selecting a Planning Set for Graphing and Reporting**

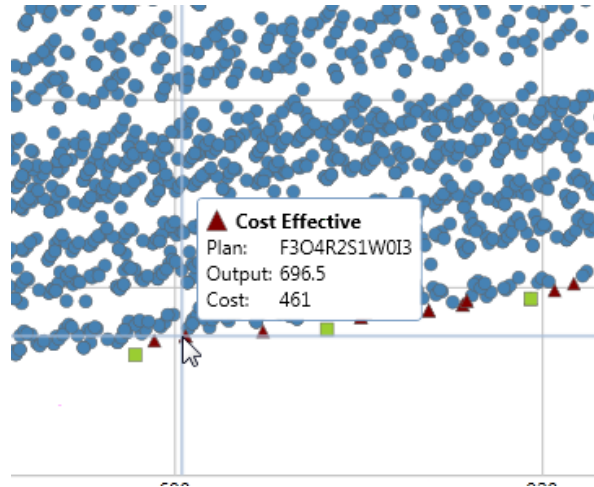
Next, the user must specify which type of graph to view by clicking the corresponding Graph Type. For some reports, the user may also select a subset of analysis results to graph by clicking appropriate options in the “Plan Alternatives to Graph” group. For some reports, the Differentiated checkbox may also be checked, indicating that non-cost effective, cost effective, and best buy plans will be indicated on the graph by different symbols and colors. Once the analysis set, graph type, and the other desired options have been selected, clicking the ‘View’ button will display the graph.

An example of a Cartesian (x, y) All Plans Differentiated graph for a CE/ICA analysis planning set is shown below.



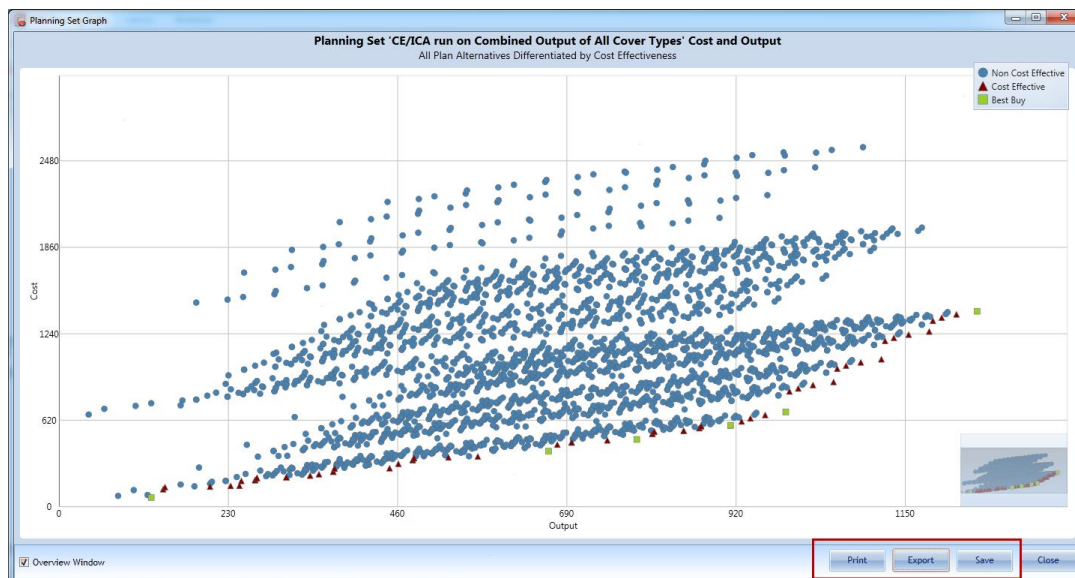
**Figure 111**  
**Example Cartesian Graph Following CE/ICA**

In this example, all plans are graphed by Cost and Output, with the cost effectiveness status of each plan alternative differentiated by different colors and symbols. The graphing tool allows the user many ways to customize the way in which the data is displayed. The user may zoom in by holding the left mouse button down and dragging the rectangle to the area of interest. Likewise, the user may hover the mouse pointer over a point on the graph to see the data pertaining to that point as shown below.



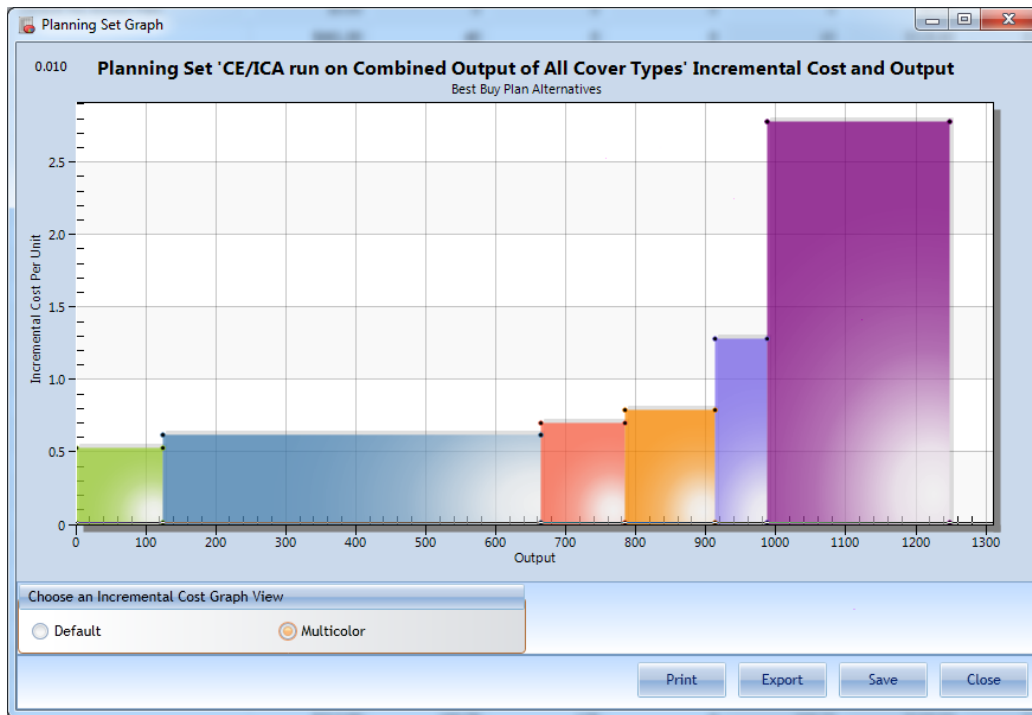
**Figure 112**  
**Viewing Information About Data Points**

The graph tool also allows the user to print, export or save the graph using the options available at the bottom of the graph.

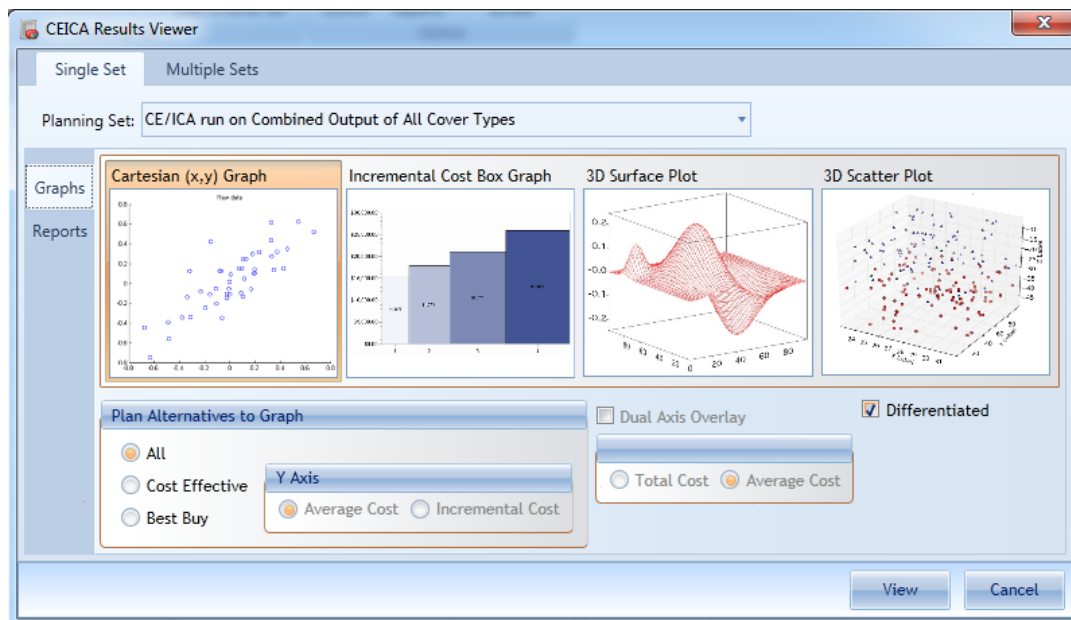


**Figure 113**  
**Printing, Exporting and Saving Graphs**

The Incremental Cost Box Graph option allows the user to display the Best Buy plans resulting from incremental cost analyses.

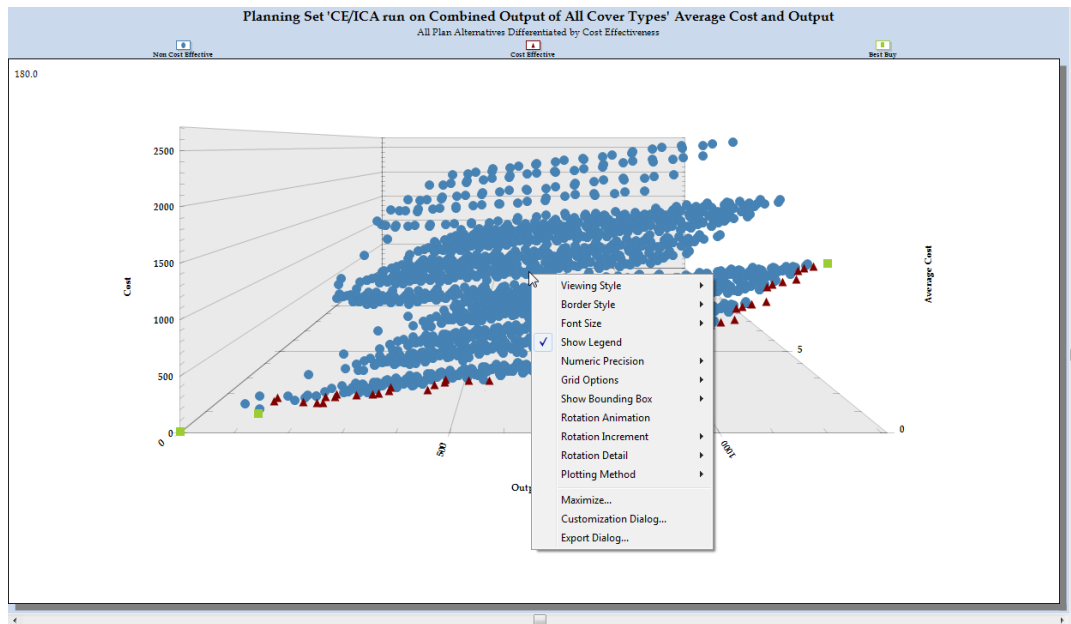


**Figure 114**  
**Incremental Box Graph Options**



**Figure 115**  
**CE/ICA Results Viewer Options**

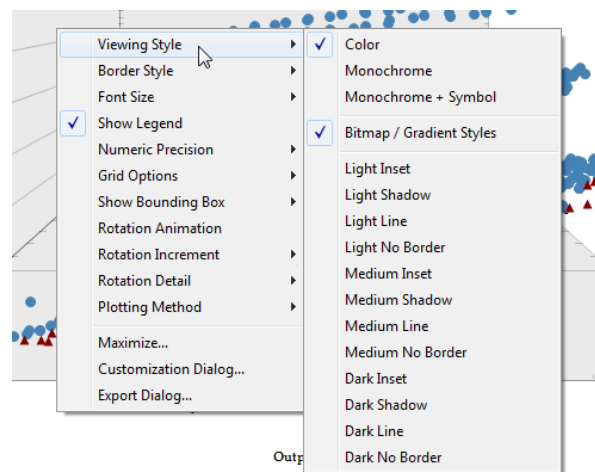
The Incremental Cost Box Graph, 3D Surface Plot, and 3D Scatter Plot were developed using a third party tool Gigasoft ProEssentials. This allows these reports to have additional options to modify the graphs that are available when the user right clicks on the resulting graph.



**Figure 116**  
**Right Click Options for Graphs**

A few of the more commonly used options are described below.

- Viewing Style – Right clicking on a graph and selecting Viewing Style provides the user the options shown below. These options allow the user to color scheme used in the graph using and in the background of the graph.



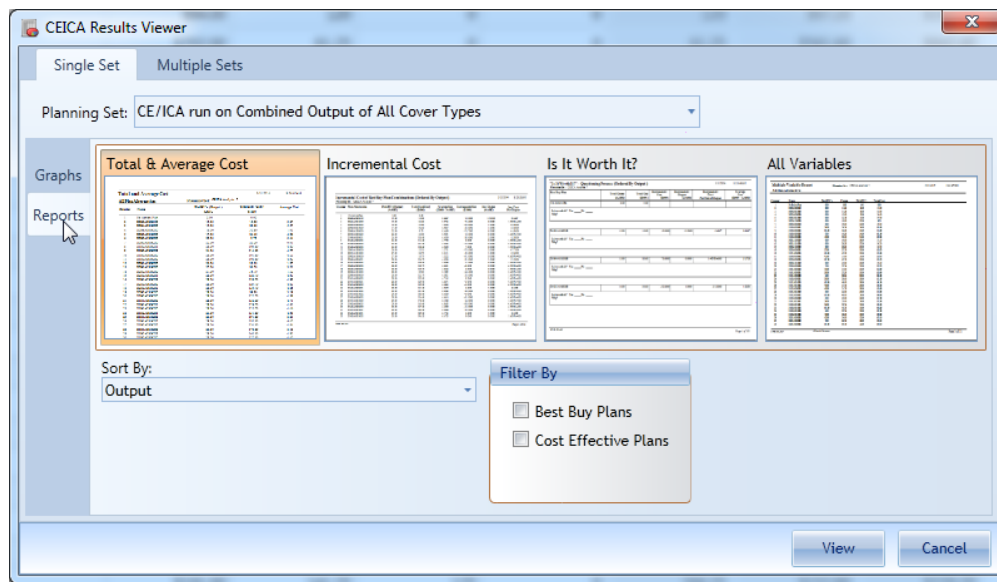
**Figure 117**  
**Viewing Style Options**



- **Border Style** – This option allows the user to modify the style of the border around the graph
- **Font Size** – This option allows the user to modify size of the text shown on the graph
- **Show Legend** – This option allows the user to hide and show the legend if they do not wish to include it on the report. By default the legend is visible on the graph.
- **Grid Options** – This option allows the user to show one, both or no grid lines on the graph.

For more information on Gigasoft ProEssentials please see their website at <http://www.gigasoft.com/netchart/controlcomponentslibrary.htm>.

The user can view the available Single Planning Set Reports by clicking the Reports selection along the left side of the form as shown below.



**Figure 118**  
**Single Planning Set Reports**

The first step in selecting a report to view is to specify which of the planning set analyses to report on. To do this, simply select the name of the analysis planning set from the “Planning Set” dropdown list. Next, Reports may be sorted in different ways. Simply select the desired sort in the “Sort by:” dropdown list to sort the results on the desired field.

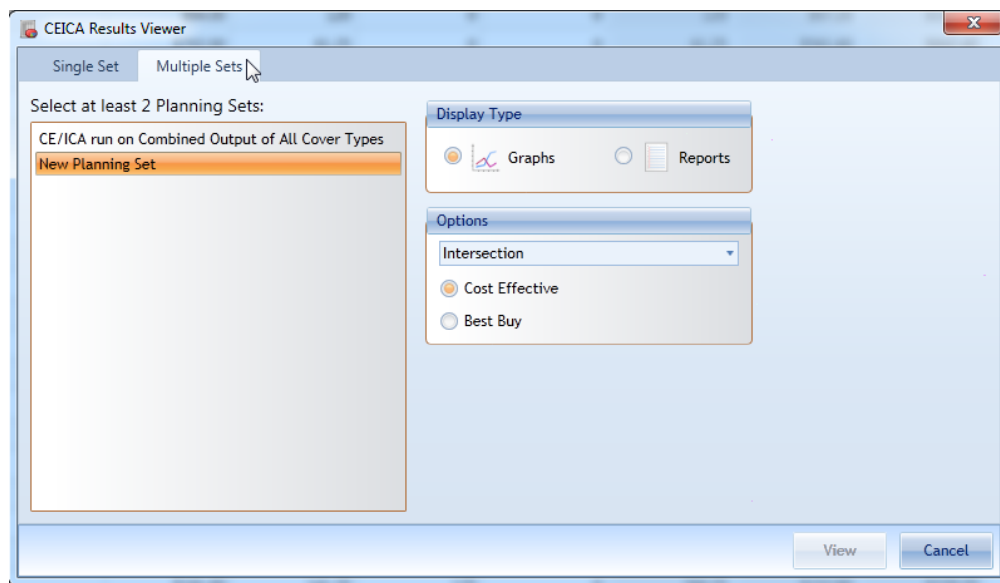
Next, specify which type of report to view by clicking the corresponding report type. Some reports have the option of displaying multiple sets or subsets of data. The “Filter By” checkboxes will allow selection of the possible sets of data that the selected report type may display. For example, the Average Cost report by default displays All Plans, but checking the appropriate “Filter By” checkbox can allow you to report only on Cost Effective Plans or Best Buy Plans. Once all of the desired options have been set, clicking the ‘View’ button will display the report.

## Multiple Planning Set Results

Reporting may be performed across multiple planning sets. An intersection report will display all plans that are cost effective or best buy plans in common to the various planning sets selected. A union report shows all plans that are cost effective or best buy in any one of the selected planning sets.

Intersection and union graphs will also be available for viewing, similar in graphical representation to the text reports just described.

When at least two CE/ICA analysis planning sets have been processed, you may view the results for a combination of analysis planning sets. Such results are called “Multiple Planning Set Results.” The multiple planning set Graphs & Reports options are displayed when the user clicks the Multiple Sets option along the top of the CEICA Results Viewer form accessed by clicking the ‘Graphs & Reports’ button on the Home ribbon.



**Figure 119**  
**Multiple Set CEICA Result Views**

The Multi Planning Set Results tab displays all of the CE/ICA Planning Sets in the Planning Sets list box. Desired planning sets can be selected using the <Shift>-Click to select sets contiguous to one another in the list, and <Control>-Click to select non-contiguous sets (separated in the list from one another by one or more intervening sets).

Next, select the Display Type to view either Graphs or Reports.

Selecting the various result Options is the next step in viewing multiple analysis results. In the Options group box dropdown list, two types of **Reports** can be selected: **Intersection or Union**.

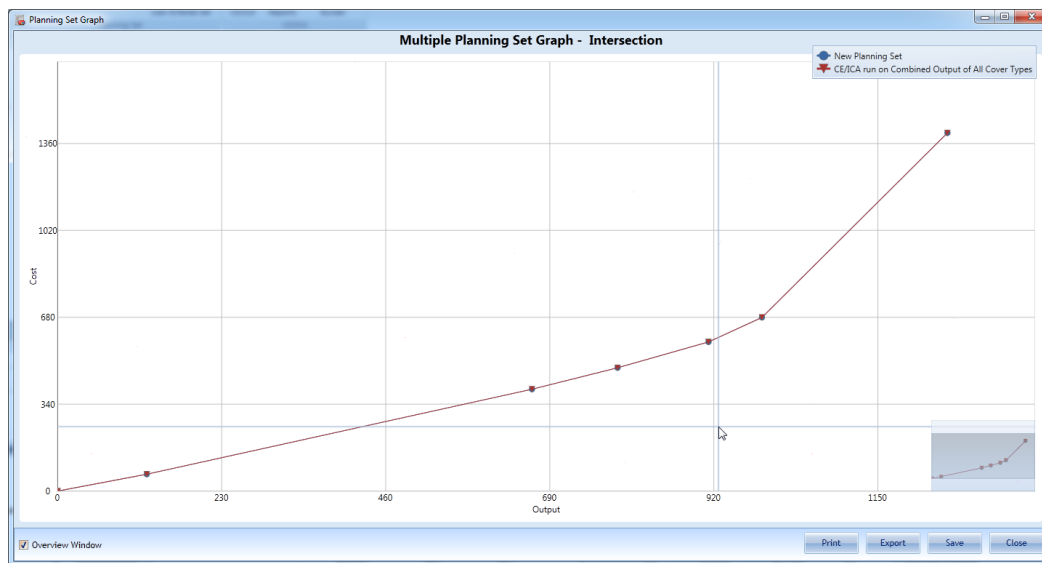
- The **Intersection** report displays all plans that are consistently cost effective or Best Buy plans in each of the planning sets selected. For either cost effective or Best Buy plans (user selects), the report shows, the plan combination code, the total output, total cost, and average cost by planning set for each plan.

- The **Union** report shows all plans that are cost effective or Best Buy plans in any of the selected planning sets. For either cost effective or Best Buy plans (user selects), the report shows for each planning set the plan combination code, total output, total cost, and average cost by plan.

For **Graphs**, either of two types of results can be selected: **Intersection** and **Union**.

- The **Intersection** graph displays the cost effective or Best Buy plans in common to each of the planning sets selected. Since the selected planning sets may use different cost and output parameters, the axes are merely labeled "y-axis variable" for the specified cost parameters and "x-axis variable" for the specified output parameters. Each plan is plotted by its total cost and total output.
- The **Union** graph shows all plans that are cost effective or Best Buy plans in any of the selected planning sets. Since the selected planning sets may use different cost and output parameters, the axes are merely labeled "y-axis variable" for the specified cost parameters and "x-axis variable" for the specified output parameters. Each plan is plotted by its total cost and total output.

The other option in the Options group box the user must specify is the selection of either the Cost Effective or Best Buy subset as the result set to view. Finally, clicking the 'View' button will display the appropriate multi planning set graph or report. An example multi planning set graph is shown below.



**Figure 120**  
**Multiple Planning Set Graph**

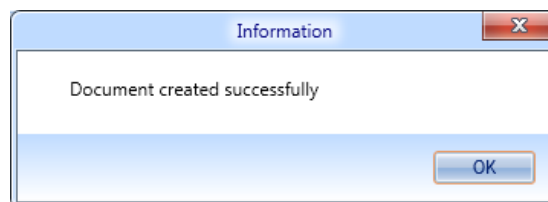
## Report Builder

The Report Builder develops a comprehensive report concerning the selected planning set. The report includes selecting the 'Report Builder' button on the Home ribbon launches the Report Builder form as shown below.

**Figure 121**  
**Reports Builder**

The user can then select an existing planning set and define a title for the report. The user also has additional options available on this form to modify whether the metadata, tabular CE/ICA data and which charts if any are included along with filtering options. Note that the while the study name and description are included on this form they are not editable by the user and therefore have a gray background and gray text to indicate such.

Once the user has selected the options they wish to utilize they can click the 'Create' button to create the report. The user will be prompted to select a name and location to save the resulting report. Following creation of the report the user will receive a notification the report has been created and selecting 'OK' on this dialog will open the resulting report on the machine's defined software for viewing PDFs such as Adobe Reader.



**Figure 122**  
**Document Created Verification Message**

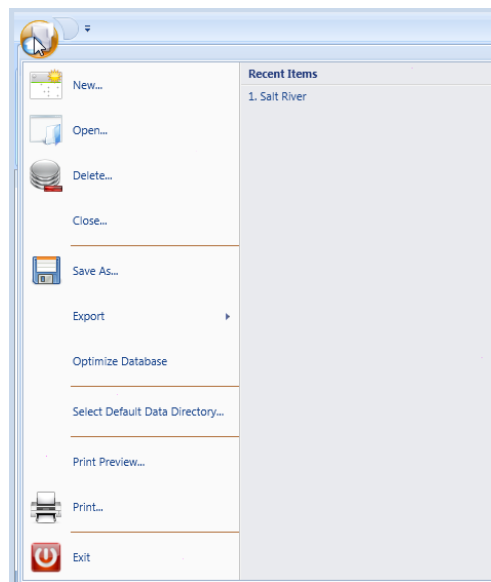
Depending on the options selected prior to running the report the report will contain the following sections:

- Metadata
- References
- Benefit-Cost Analysis Variables Definitions
- Cost and Benefits Summary
- Incremental Costs and Benefit Summary
- Chart of Alternatives
- Chart of Cost-Effective Alternatives
- Chart of Incremental Costs and Benefits of Alternatives

## Application Extras

### Application Button

IWR Planning Suite II provides many additional features that can be found under the Application button.



**Figure 123**  
**Application Button Options**

### New...

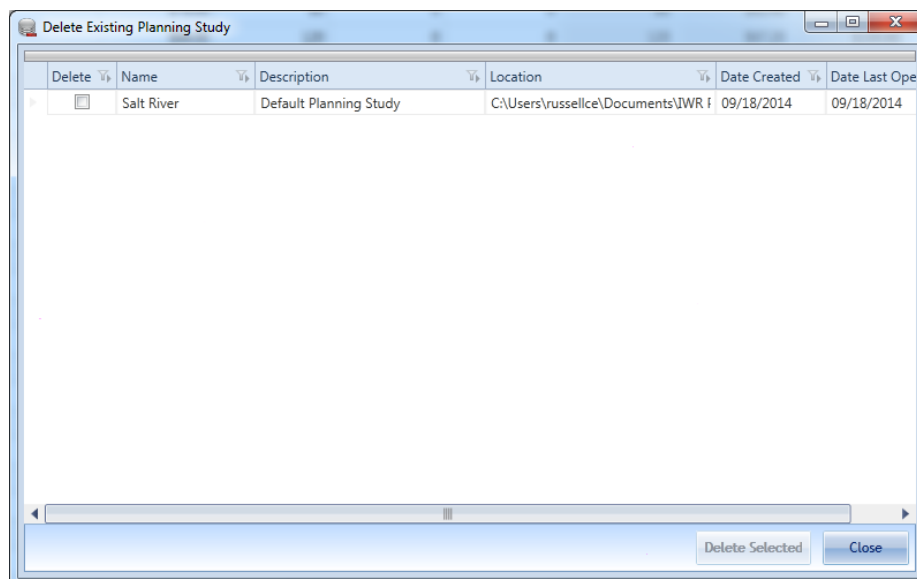
Use New to create a new IWR Planning Suite II database and planning study. The current study will be saved and closed, and a new, empty default database will be created for you to begin working in. You may choose to create any one of the four types of planning sets at this time.

### Open...

Use Open to open an existing IWR Planning Suite II database and planning study. Any currently open plan study and database will be saved and closed, and the selected database will be opened in IWR Planning Suite II, ready for editing or analysis.

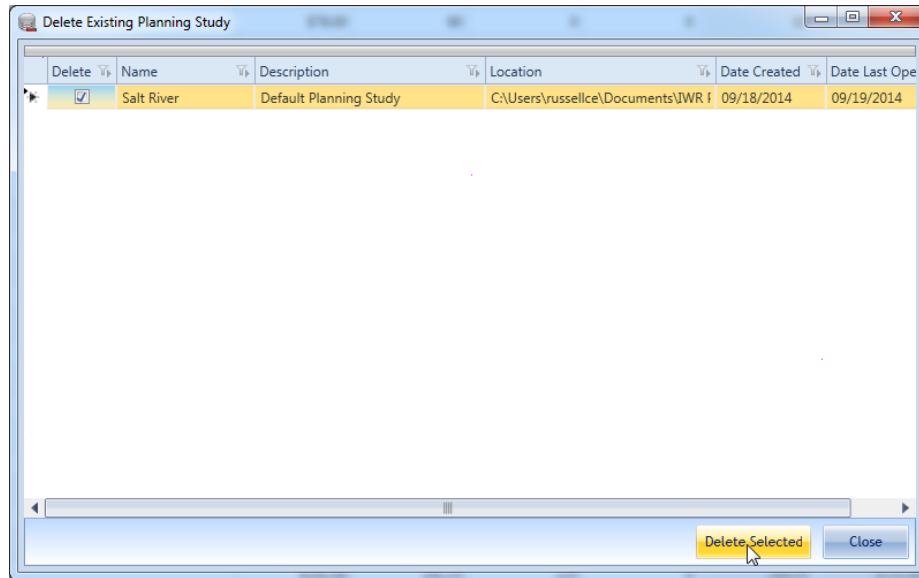
### Delete...

The Delete menu item will launch the Delete Existing Planning Study form shown below.



**Figure 124**  
**Deleting Planning Studies**

Users should check the checkbox beside each planning study they wish to delete and then click the 'Delete Selected' button to delete existing planning studies. Note that the 'Delete Selected' button will not be enabled until at least one planning study is selected for deletion.



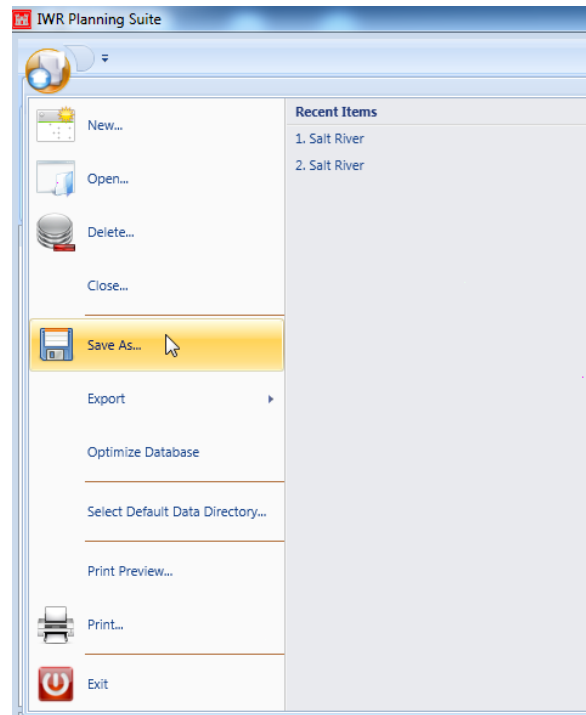
**Figure 125**  
*Selecting Planning Studies for Deletion*

### **Close...**

The Close menu item, when selected, will close the current planning study and database. Many menu items will become unavailable when the plan study is closed, because there is no open plan study for them to act upon. The “New” and “Open” and “Delete” and “Set Default Directory” and “Exit” items will remain available so that another planning study may be created or opened for editing and analysis.

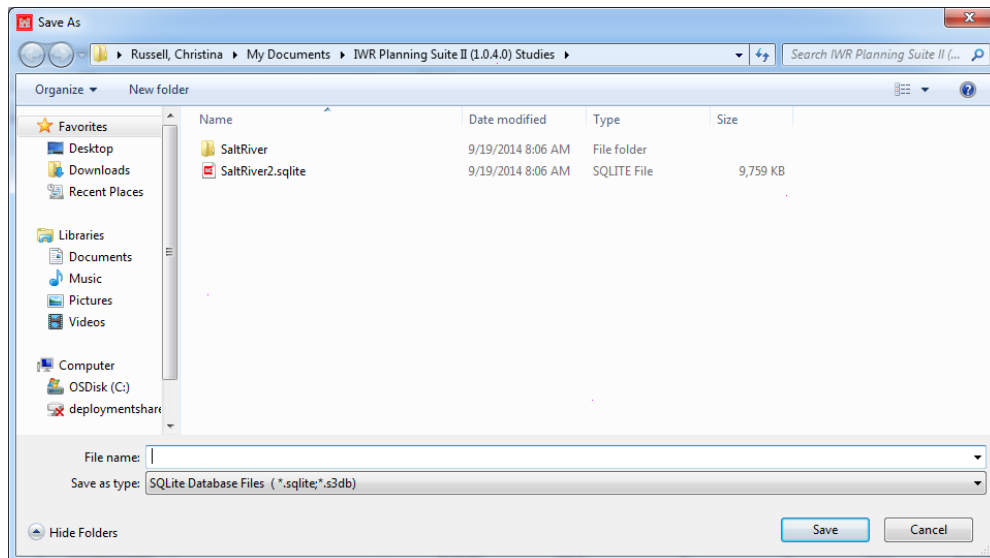
### **Save As...**

Select “Save As...” to save a copy of the currently opened planning study with an alternate name to a location of the user’s choosing.



**Figure 126**  
**Save As**

The currently open planning study will be the planning study copied by this action. The “Save As” form will appear and the user should type in a new name in the File name. Click on ‘Save’ to rename the database and possibly modify its saved location. The database the user will be working with within the application is the renamed version of the planning study. The original planning study database will not be altered by any changes made going forward.

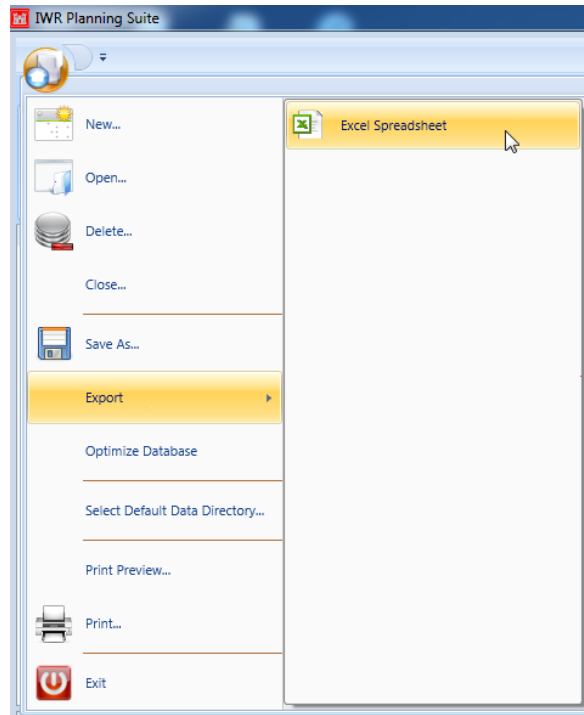




**Figure 127**  
**Save As Dialog**

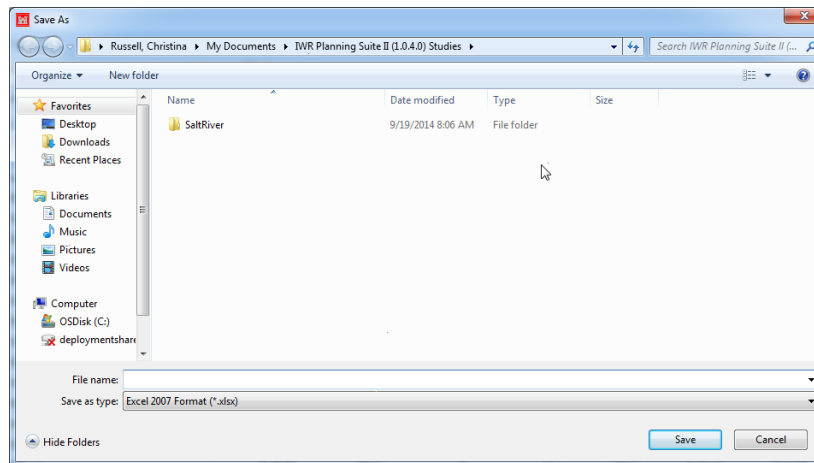
## Export

To export IWR Planning Suite II data to an Excel document, navigate to the Export popup menu from the application main menu and then select Excel Spreadsheet.



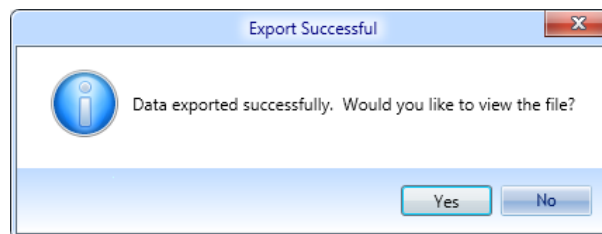
**Figure 128**  
**Export Options**

Then select the format in which you wish to export (currently only Excel file formats are supported from the “Export” function). An Export form will appear as shown below. Note the user has an option to select which format the Excel spreadsheet will be saved in by modifying the Save As Type.



**Figure 129**  
**Define Export File Name and Location**

Select the directory you wish to save the exported planning set to and then in the File name enter the name of the new file to which you wish to export the current planning set. The file will be created and the current planning set will be exported as a sheet in an Excel spreadsheet file. The user will receive a message, “Data exported successfully. Would you like to view the file?” The user should select ‘Yes’ if they wish for the resulting file to be opened in Microsoft Excel. The user should select ‘No’ if they wish for the resulting file not to be opened at this time.

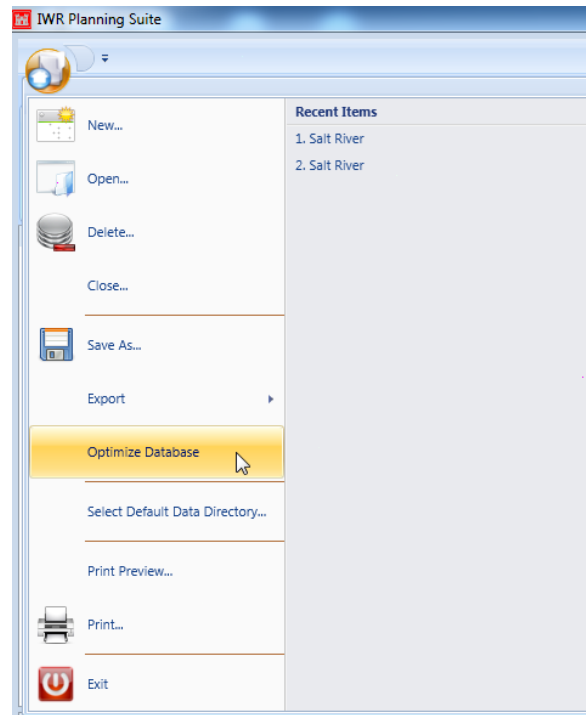


**Figure 130**  
**Data Exported Verification Message**

The active planning set is then exported to Microsoft Excel and includes the Plan Name, Description, HUC, Location Description, Latitude, and Longitude along with variable and attribute information.

### **Optimize Database**

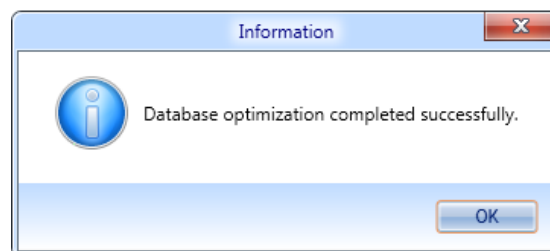
Choose “Optimize Database” from the application menu to de-fragment, repair, and compact existing database files.



**Figure 131**  
**Optimize Database**

This is an optional operation. However, periodic compacting/repairing of data files is recommended to speed processing times and reduce file size.

When selected, the database is closed and optimized, and the following dialog is shown when optimization is completed.

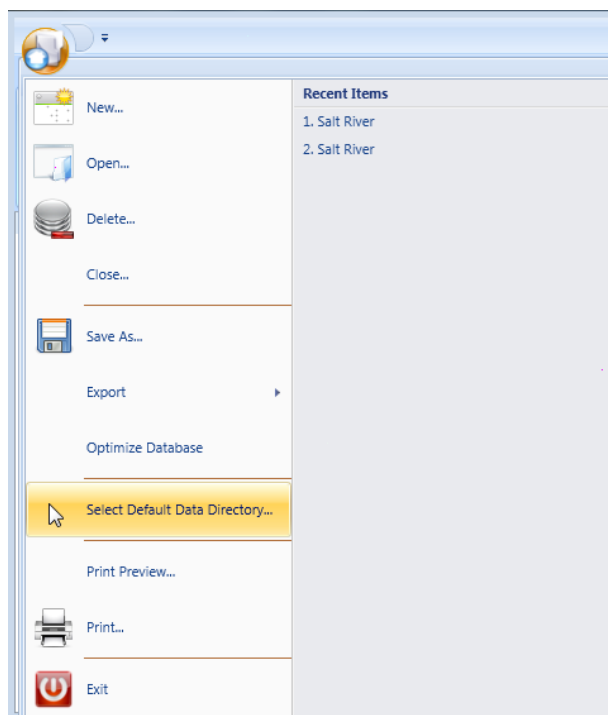


**Figure 132**  
**Optimize Database Verification Message**

The database is then automatically re-opened so that you can continue working in it.

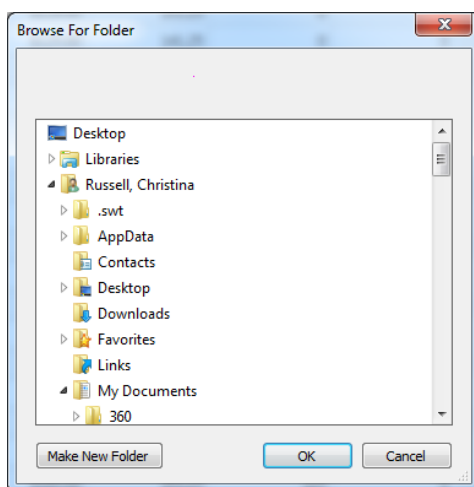
### **Select Default Directory...**

The “Select Default Directory...” option available on the application menu allows the user to select a default directory where planning studies that are created will be stored.



**Figure 133**  
**Selecting Default Data Directory**

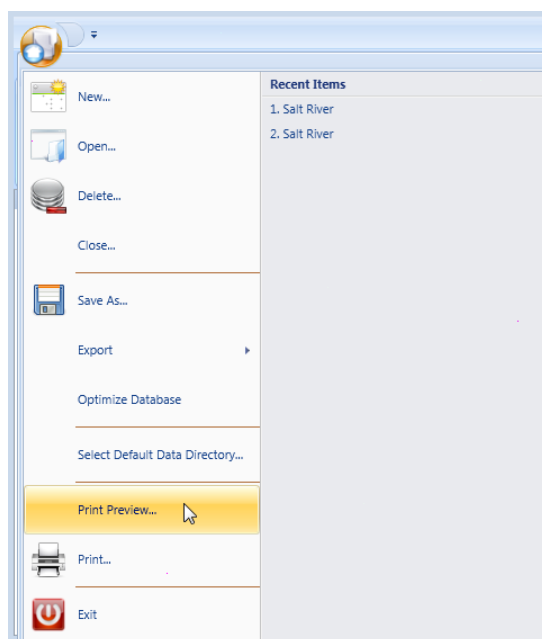
After selecting this option the Browse for Folder dialog will open and allow the user to select a folder where planning studies will be stored. By default new planning studies will be stored in the user's My Documents folder in a folder titled IWR Planning Suite II (application version) Studies. If the folder the user wishes to save to does not yet exist, the 'Make New Folder' button can be utilized.



**Figure 134**  
**Browse for Default Data Directory**

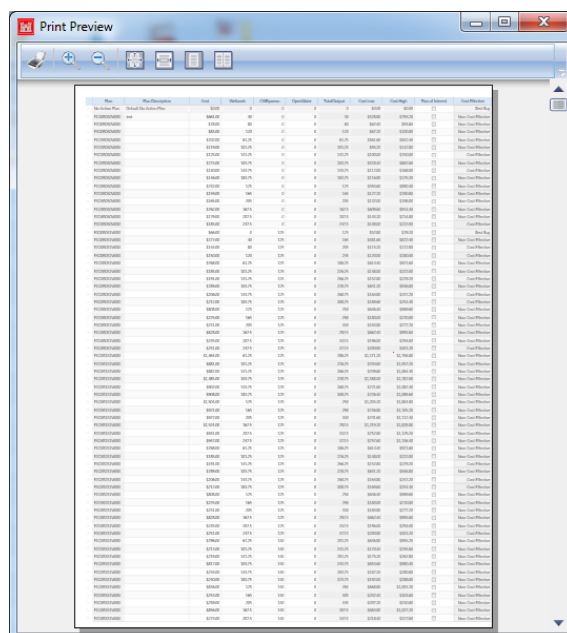
**Print Preview...**

The “Print Preview” option available on the application menu displays a preview of how the current planning set will appear when it is printed out to the selected printer.



**Figure 135**  
**Print Preview**

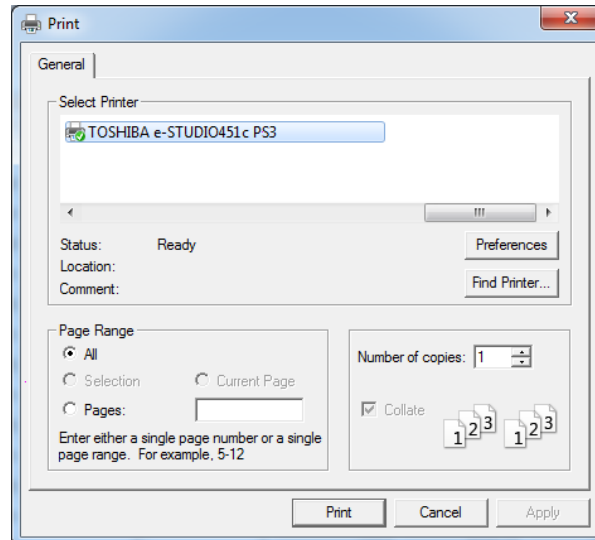
The Print preview form shown below allows the user to then print the planning set to the printer, to zoom in on the print image, or to select several different single or multi-page views of the printed planning set. Pressing the 'Close' button will close the preview form without printing the planning set.



**Figure 136**  
**Print Preview Form**

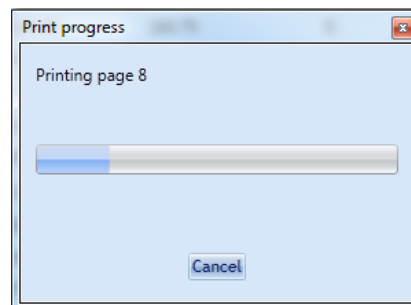
**Print...**

Selecting “Print” from the application menu will print the current planning set to the default printer but that can be changed prior to selecting the ‘Print’ button.



**Figure 137**  
**Print**

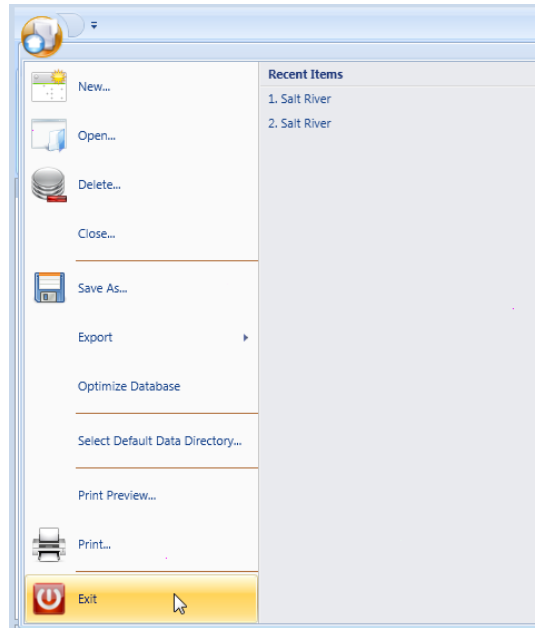
During the printing process, the page being printed will be displayed in a dialog with the option to cancel the printing process as shown below.



**Figure 138**  
**Printing Progress**

**Exit**

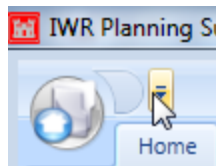
To quit the IWR Planning Suite II application, select the “Exit” option from the Application button as shown below.



**Figure 139**  
**Exit Application**

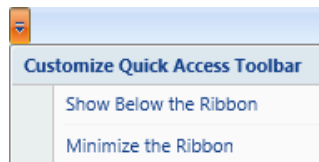
## Quick Access Toolbar

The Quick Access Toolbar can be accessed by the user by clicking the down arrow beside the application button as shown below.



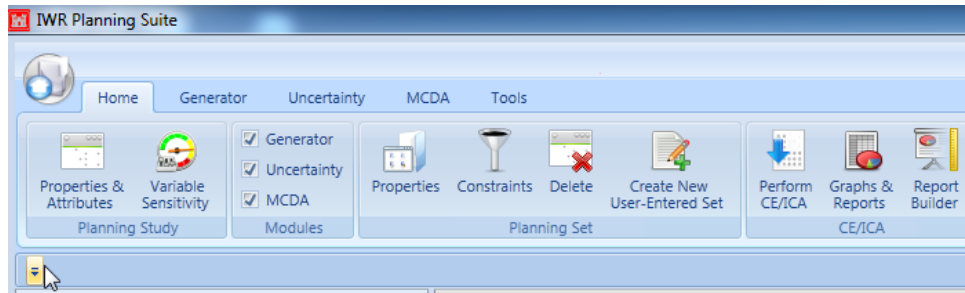
**Figure 140**  
**Quick Access Toolbar Location**

Once this menu is selected the user will be provided with options to move the Quick Access Toolbar below the ribbons or minimize the ribbon.



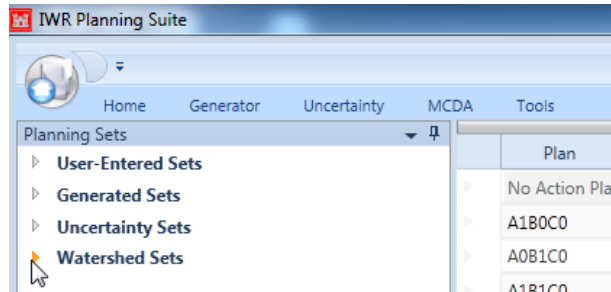
**Figure 141**  
**Quick Access Toolbar Options**

If the user selects “Show Below the Ribbon” the Quick Access Toolbar will be moved below the ribbons as shown below.



**Figure 142**  
**Showing Quick Access Toolbar Below Ribbons**

If the user selects “Minimize the Ribbon” from the Quick Access Toolbar then the ribbons will be minimized so that the user can only see the titles of each ribbon as shown below.

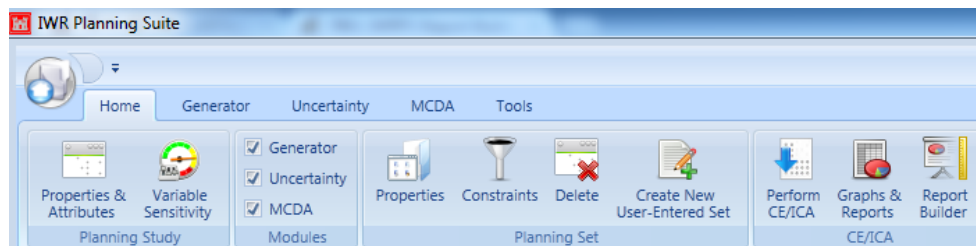


**Figure 143**  
**Minimized Ribbons**

Clicking on any of the ribbons will expand the ribbon so that all user controls are viewable for the selected ribbon. Clicking further down in the application on Planning Sets, Plan Editor, or Planning Set Properties will minimize the ribbons once again. The user can permanently maximize the ribbons once again by selecting the “Minimize the Ribbons” option again so that a check mark no longer displays beside that option.

## Home Ribbon

The Home ribbon has capabilities available to modify the properties and attributes, variable sensitivity values, properties of a planning set, constraints, delete planning sets, create user entered sets, perform CE/ICA analysis and create reports and graphs related to that analysis.



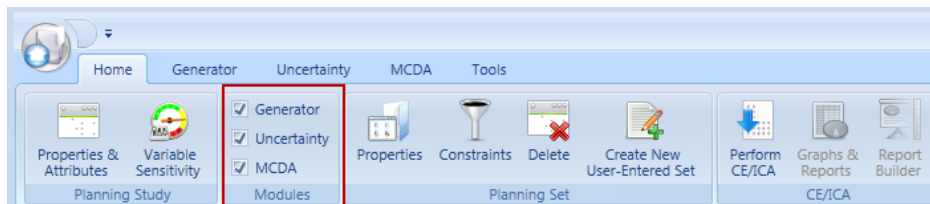


**Figure 144**  
**Home Ribbon**

“Properties & Attributes” will allow the user the ability to modify the variables and attributes of a planning study. Clicking on the ‘Properties & Attributes’ button on the Home ribbon will launch the Planning Study Properties form where the user will have the ability to modify the description of the planning study; add, modify or delete variables, and create or delete user create attributes as well as modify the visibility of default attributes. Default attributes can’t be deleted by the user but can control their visibility based on the value selected for the Visible field.

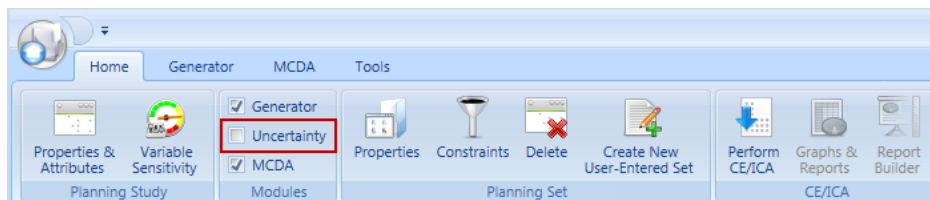
“Variable Sensitivity” will allow the user to set low and high coefficients for each variable included in the planning set for all non-derived variables. Clicking on the ‘Variable Sensitivity’ button on the Home ribbon will launch the Variable Sensitivities form. Creating low and high coefficients for a variable will create new Low and/or High variables and make them visible by default. For more information on variable sensitivity please see the section on [Variable Sensitivity](#).

Module enabling and disabling is available on the Home ribbon. If the user wishes to disable the Generator, Uncertainty or MCDA ribbons then the user can uncheck the corresponding box from the modules section of the Home ribbon.



**Figure 145**  
**Module Enabling**

If the user unchecks the Uncertainty checkbox then the Uncertainty ribbon will no longer be displayed as shown below.



**Figure 146**  
**Disabling Modules**

“Properties” will allow the user to modify the properties of the selected planning set and view the parameters that were utilized when this planning set was generated. Once the user selects the ‘Properties’ button the Planning Set Properties form will launch. The user has the ability to modify the planning set name, description, HUC fields from this form. The user can also specify whether they would like to view the optional geographic information fields related to the planning set in the planning set editor on this form. If this option is selected the planning set editor will allow the user to specify a latitude, longitude, HUC and location description for each plan included in the planning set.

The Planning Set Properties form also has a ‘Historical Information’ button when that information is available. If the user selects this option they will be able to identify what information was utilized in the generation of a planning set. This information is for display purposes only and can’t be modified since it is intended to provide the user with the details on what information was used during generation of this planning set. The form has tabs across the top to provide the user with information on Solutions & Scales, Relationships, Solution Sensitivities and Automated Edits. The user can click on each tab to display the information. While this information can’t be modified it can be copied and pasted for use in reports or for reuse purposes on other planning studies.

Planning Set Historical Information (Read-only)

Solutions & Scales Relationships Solution Sensitivities Automated Edits

Solutions:

Solution	Code	# Scales
Flow Regulation Wetlands	F	3
Overbank Wetlands	O	4
Riparian Corridors	R	6
Remove Salt Cedar	S	1
Open Water	W	4
In-channel Wetlands	I	5

Scaled Solution Effects on Variables:

Code	Scale	Name	Costs	Wetlands	CWR/Riparian	OpenWater
S	1	1000 Acres	\$348.00	0	0	0
W	0	No Action	\$0.00	0	0	0
W	1	100 Acres	\$215.00	0	0	65
W	2	200 Acres	\$378.00	0	0	130
W	3	300 Acres	\$577.00	0	0	195
W	4	400 Acres	\$722.00	0	0	260
I	0	No Action	\$0.00	0	0	0
I	1	120 Acres	\$166.00	108	0	0
I	2	240 Acres	\$315.00	216	0	0
I	3	360 Acres	\$420.00	324	0	0
I	4	480 Acres	\$591.00	432	0	0
I	5	600 Acres	\$665.00	540	0	0

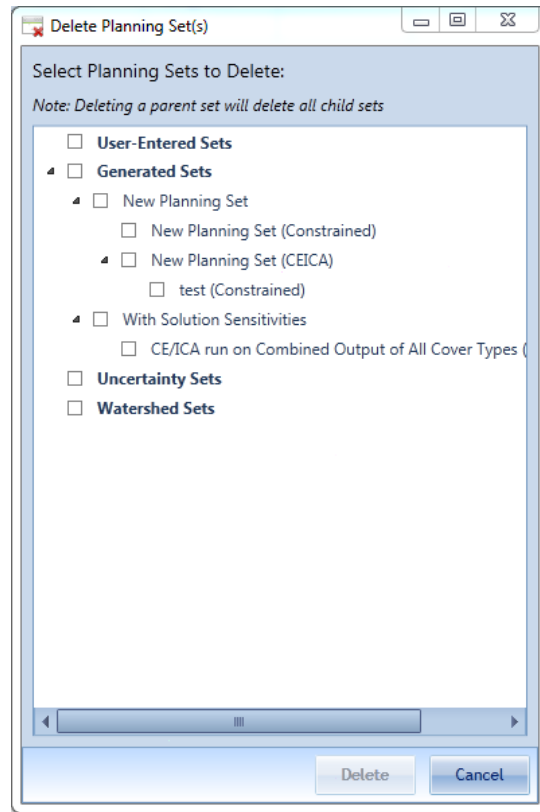
Close

**Figure 147**  
**Display of Historical Information**

“Constraints” allows the user to define minimum and maximum values for each defined variable that is not derived in nature along with a name for the to be generated constrained planning set. When the user selects the ‘Constraints’ button, the Constrain Active Planning Set form will open. Once the user enters the appropriate values and name for the planning set and selects the ‘Constrain’ button then a new planning set will be generated and listed as a child set to the selected set. “(Constrained)” will be appended to the defined name of the planning set in order to differentiate that this set was constrained. All plans that have variable values outside the constraints identified by the user will not be included in the new constrained set. For more information on constraining a planning set, please see the section on [Constraints](#).

“Delete” allows the user to delete one or more existing planning sets from the currently loaded planning study. When the user selects the ‘Delete’ button the Delete Planning Set(s) form will be launched.

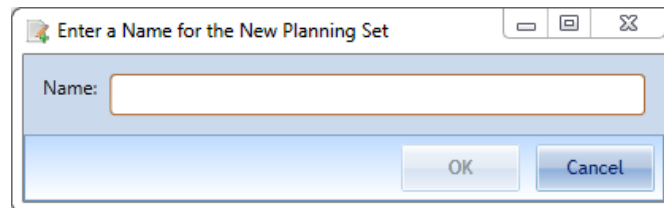
The user can check the box beside one or more planning sets. If the user opts to delete a parent planning set then all child planning sets will also be deleted.



**Figure 148**  
**Selecting Planning Sets for Deletion**

Please note that the 'Delete' button will remain disabled until at least one planning set is selected for deletion.

"Create User-Entered Set" allows the user to create a planning set and all associated variable values without using the generator. Once the user clicks the 'Create New User-Entered Set' button a form will open to allow the user to specify a name for the new planning set.



**Figure 149**  
**New Planning Set Name**

After the user enters a unique name for the planning set comprised of alphanumeric characters not to exceed 255 characters the user can click 'OK' to continue. At this point the user can begin entry of their plans into the Plan Editor. For more information see the section on [User-Entered Planning Sets](#).

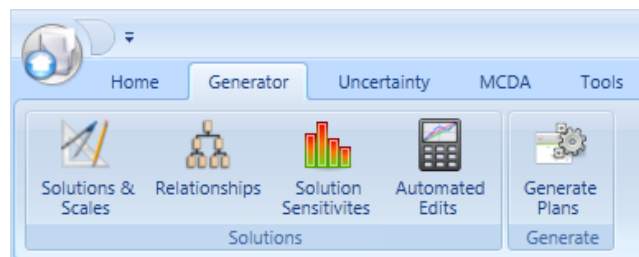
“Perform CE/ICA” allows the user to perform Cost Effective and Incremental Cost Analysis on a planning set. After the user selects the ‘Perform CE/ICA’ button on the Home ribbon the Perform CE/ICA Analysis form will launch. The user can then specify a name and description for the CE/ICA Analysis along with specifying which variables should be used as the cost and output variables during the analysis. Please see the section on [CE/ICA Analysis](#) for more information.

“Graphs & Reports” allows the user to create Graphs & Reports based on the CE/ICA Analysis results. When the user selects the ‘Graphs & Reports’ button the CEICA Results Viewer form will launch. The user can generate reports and graphs for a single analysis or create graphs and reports that compare the results of multiple analyses. Please see the section on [Analysis Results](#) for more information.

“Report Builder” allows the user the ability to create a report of the CE/ICA results in a formatted PDF report that includes the metadata, tabular CEICA information as well as charts. When the user selects the Report Builder the Report Builder form will open and the user can select the report options they wish to utilize in generation of the report. Please see the section on [Report Builder](#) for more information.

## Generator Ribbon

The Generator Ribbon has tools available to create solutions and scales, to define dependability and combinability relationships between solutions, set low and high coefficients for each solution and variable combination, and allows users to automatically account for the fact that all plan effects may not be additive (IWR Planning Suite II’s default assumption) when individual solutions are combined.



**Figure 150**  
**Generator Ribbon**

“Solutions & Scales” allows the user to define solutions and scales for those solutions along with values for all defined (non-derived) variables. After the user selects the ‘Solutions & Scales’ button the Solutions & Scales form will launch. For more information on defining solutions and scales the user can review the section [Solutions and Scaled Effects](#).

“Relationships” allows the user to define combinability and dependency relationships between solutions. After the user selects the ‘Relationships’ button the Solution Relationships form will launch. The user can review the section [Solution Relationships](#) for more information.

‘Solution Sensitivities’ button allows the user to define low and high coefficients for solution and variable combinations. After the user selects the ‘Solution Sensitivities’ button the Solution Sensitivity form will launch. The user can review the section on [Solution Sensitivity](#) for more information.

“Automated Edits” allows users to automatically account for the fact that all plan effects may not be additive (IWR Planning Suite II’s default assumption) when individual solutions are combined. After the user selects

the 'Automated Edits' button the Automated Edits form will launch. The user can review the section on [Automated Editing](#) for more information.

"Generate Plans" allows the user to generate plans based on the user provided information. After the user selects the 'Generate Plans' button the Generate Planning Set form will launch. The user can review the section on [Plan Generation](#) for more information.

## Uncertainty Ribbon

The Uncertainty Ribbon has capabilities to develop uncertainty planning set distributions, generate uncertainty sets and perform CE/ICA analysis on these sets and to review output based on the results of this analysis.

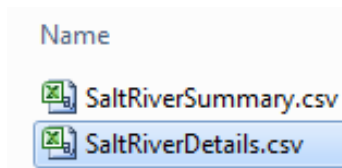
"Uncertainty Planning Set Distributions" allows the user to create plans and to define values for the variables for these plans based on a distribution type as well as tolerance rules and to specify the correlation of study variables. After the user selects the 'Uncertainty Planning Set Distributions' button the Uncertainty Planning Set Distributions form will launch. The user can review the section on [Uncertainty Sets](#) for more information.

"Generate Uncertainty Set" allows the user to generate uncertainty sets based on the plans, distributions, tolerance rules and specified correlation between study variables. After the user selects the 'Generate Uncertainty Set' button the Build Uncertainty Planning Sets form will launch and the user can specify the distribution list, planning set name, descriptions, max iterations and seed to be utilized in development of the uncertainty set. The user can review the section on [Uncertainty Sets](#) for more information.

"Perform CE/ICA" allows the user to perform Cost Effective and Incremental Cost Analysis on an uncertainty set. After the user selects the 'Perform CE/ICA' button on the Uncertainty ribbon the Perform CE/ICA Analysis form will launch. The user can then specify a name and description for the CE/ICA Analysis along with specifying which variables should be used as the cost and output variables during the analysis. Please see the section on [CE/ICA Analysis](#) for more information.

"Graphs & Reports" allows the user to create Graphs & Reports based on the CE/ICA Analysis results. When the user selects the 'Graphs & Reports' button the CEICA Results Viewer will launch. The user can generate reports and graphs for a single analysis or create graphs and reports that compare the results of multiple analyses. Please see the section on [Analysis Results](#) for more information.

"Export to CSV" allows the user to export the uncertainty planning set to CSV format after selecting a location and file name for the file. This export will create both a detailed and a summary file. These files will both be located in the directory designated by the user with the name the user designated with the word Details and Summary appended to the file name.



**Figure 151**  
**Summary and Detail Export Files**

The summary csv file contains the final planning set developed and viewable within the IWR Planning Suite II application. The detail csv file contains all planning sets created for every iteration during the Monte Carlo Simulation. Note this option will not be available until CE/ICA analysis has been completed on at least one uncertainty set.

### **MCDA Ribbon**

The MCDA ribbon has capabilities for multi-criterion decision making and the associated graphs and reports.

“Weights, Ranking & Analysis” allows the user the ability to complete multi-criterion decisions making. When the user selects the Weights, Ranking & Analysis the Multi-Criterion Decision Analysis form opens. For more information on see the section [Multi-Criterion Decision Making](#).

“Graphs & Reports” allows the user to create graphs and reports based on the CE/ICA results. When the user selects the ‘Graphs & Reports’ button the MCDA Results Viewer form will launch. The user can generate reports and graphs for a single analysis or create graphs and reports that compare the results of multiple analyses. Please see the section on [Analysis Results](#) for more information.

### **Tools Ribbon**

“Annualizer” is a tool that allows the user the ability to annualize costs over the period of the project. When the user selects the ‘Annualizer’ button the Annualization Calculator form will launch. The user can enter cost, NED benefits, and NER Output information to utilize in performing these calculations. Please see the section on the [Annualizer](#) for more information.

“Watershed Wizard” allows the user to complete a watershed analysis based on multiple calculations. The user is led through a series of steps where the user can define the locations, relationships, additive effect between proposed plans and generate a set of plans to represent this scenario. Please see the section on the [Watershed Wizard](#) for more information.

## Section 6

### Annualizer

Annualizing ecosystem costs and outputs is required by U.S. Army Corps of Engineers (Corps) planning guidance. While annualizing costs is typically performed by economists, annualizing ecosystem outputs requires knowledge on the part of biologists or ecologists in terms of ecosystem response rates for various project alternatives. Responses over the period of analysis are compared to future without project conditions to estimate the “lift” or “benefit” provided by project alternatives. While the process and calculations may sound simple, they are fraught with error. Miscalculations or failure to even consider average annual outputs are frequently cited as problems by higher level reviewers. The annualizer utility allows users to interpolate NED and NER benefits and costs over the period of analysis.

The utility also estimates average annual equivalent NED costs and benefits and net present values, and estimates the average annual NER outputs. While there are many interpolation techniques for non-monetary units of cost and benefit, the NER annualizer provides users with options for estimating values between point measurements. The two options presently available to users of the annualizer module include linear interpolation, rate of growth, and user input at each point. While the annualizer is intended to serve as an aid to planners and economists, it remains the user’s responsibility to apply annualization techniques appropriate to the level of accuracy and fidelity of the benefits and costs quantification effort.

In order to demonstrate the newly added Annualizer, the Cedar Lake, Indiana Feasibility Study (referred to as Cedar Lake Study) is provided as a case study application. In this document, the Annualizer Case Study Background below provides background on the Cedar Lake Study including relevant data on the costs and environmental outputs. The remainder of Section 6 provides a step-by-step user guide for the Annualizer module using data from the Cedar Lake Study as a case example.

The user is encouraged to review the following references and Corps guidance for further information:

- The Planning Guidance Notebook (ER 1105-2-100), April 2000
- Principles and Guidelines, March 1982
- Economic Guidance Memorandum on the Federal Interest Rate, Published Yearly
- The National Economic Development Manuals Website (<http://www.iwr.usace.army.mil/ned/>)

### Annualizer Case Study Background

The Town of Cedar Lake, Indiana and the U.S. Army Corps of Engineers (Corps) have partnered to investigate the feasibility of an aquatic ecosystem restoration project at Cedar Lake. Historically, Cedar Lake supported a biologically diverse ecosystem with native flora and fauna characteristics of glacial lakes. Since the late 1800’s, alterations to Cedar Lake have caused major adverse impacts to its fringe wetland habitat, littoral zone habitat, lake-bottom substrate, and water quality. The primary objective of this potential ecosystem restoration project is to:

- Restore Cedar Lake to mesotrophic or eutrophic status and reduce turbidity in the water column by achieving water quality standards. Incidental recreation benefits are expected.
- Restore the lacustrine habitat of Cedar Lake by restoring fringe wetlands, the littoral zone, and confluent streams and wetlands.
- Gain outputs of native lacustrine biodiversity through increases in diversity and abundance of aquatic macrophytes, increases in diversity and abundance of macroinvertebrates, increases in diversity and abundance of native glacial lake fishes, and reduced abundance of non-native common carp and whiter perch.

Several restoration measures were considered in the Cedar Lake Study including sediment removal, nutrient inactivation, dilution and flushing, creation of in-lake structures, littoral zone creation, shoreline restoration, institutional controls, fish community management and aquatic invasive species control, bank stabilization of tributaries, storm water management, farmland improvements, woodland management, and creation of filtration wetlands. These measures were evaluated for cost effectiveness based on habitat output and implementation costs. Combinations of restoration measures are formulated into alternatives for evaluation.

Since implementation time can vary depending on the measure, construction costs and operation and maintenance costs were distributed appropriately over the entire 50-year project life. Implementation costs were brought to present value based on federal discount rate of 4.875 percent.

Note the discount rate is representative of the example. The federal discount rate as of FY15 is 3.375 percent.

Once all implementation distributed costs were converted to present values, the annual equivalent cost of implementing each measure was determined.

Habitat outputs were estimated over the entire project life. In order to restore the aquatic ecosystem of Cedar Lake, both ecosystem function and structure must be addressed. The level of habitat suitability, which takes into account the function and structure of the ecosystem, is calculated by developing a habitat suitability index (HIS). The HIS is an algebraic function that uses various indicators of the quality of habitat function and structure. Several species-specific HSIs were developed by the U.S. Fish and Wildlife Service. There are limitations to using a species-specific index when the goal is to restore the overall natural habitat because outputs are focused on one species and other species may be overlooked or negatively impacted. Unfortunately, there is not an established HIS for lacustrine habitats; therefore one was developed for Cedar Lake. Total habitat outputs, in terms of habitat units (Hus) were calculated by multiplying the habitat suitability index times the area of habitat affected.

For purposes of this document, two measures developed for the Cedar Lake Study were selected for input into the Annualization module: Measure A.3 and Measure B.2.

Measure A.3 involves physical removal of bottom sediments aimed at reducing both the internal nutrient loading as well as turbidity caused by resuspension. This scenario only dredges areas that contain elevated levels of phosphorus, which is approximately 83 acres total to a depth of 2.7 feet.

Measure B.2 applies Aluminum Sulfate (Alum) to 83 acres that contain elevated levels of phosphorus to reduce the internal nutrient loading caused by the interaction between nutrient rich sediments and the water column.



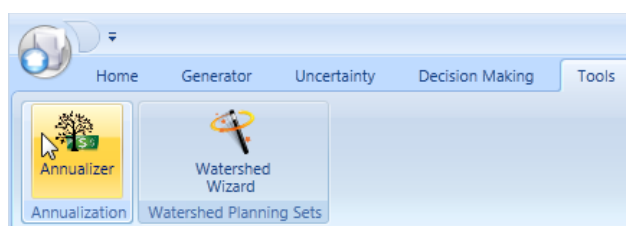
The release of phosphorus from bottom sediments to the water column has been shown to be the major contributor to water quality degradation in Cedar Lake.

In the remainder of this section provides step-by-step instructions for using the Annualizer module. The Cedar Lake Study data for Measure A3 and Measure B2 are used in the examples.

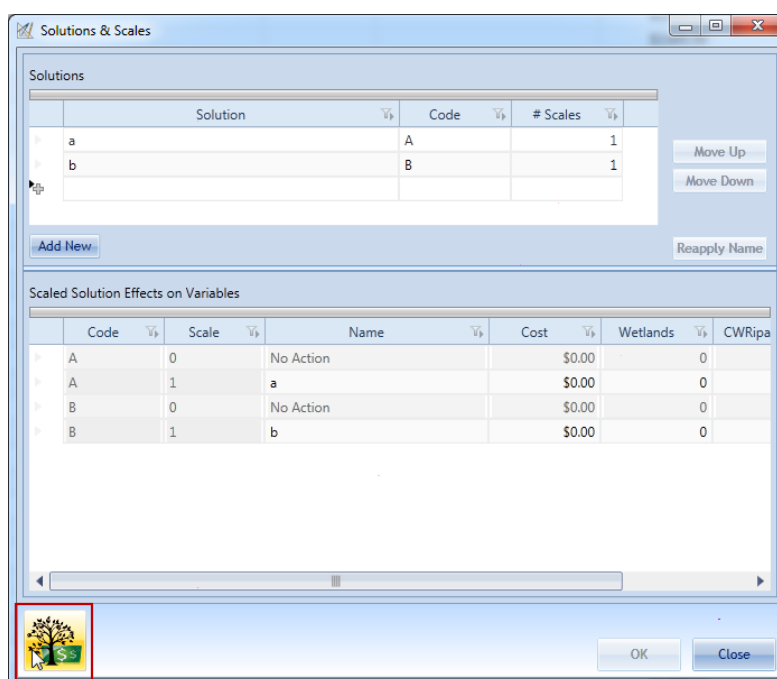
The overall process for the Annualizer is to first open the calculator; save measures needed for the study; input cost, NED, and NER data; print graphics and tables as needed; and create graphics of the measures to be compared. Each of these steps is described in detail. For reference, a list of definitions is provided in the [Glossary](#).

## Open Annualizer

Open the IWR Planning Suite II. Open a planning study or create a new one. To open the Annualizer, click on the 'Annualizer' button located on the Tools ribbon or click on the 'Solutions & Scales' button on the Generator ribbon and click on the 'Annualizer' button in the bottom left corner of this form.



**Figure 152**  
**Launching the Annualizer**



**Figure 153**  
**Launching the Annualizer from Solutions and Scales**

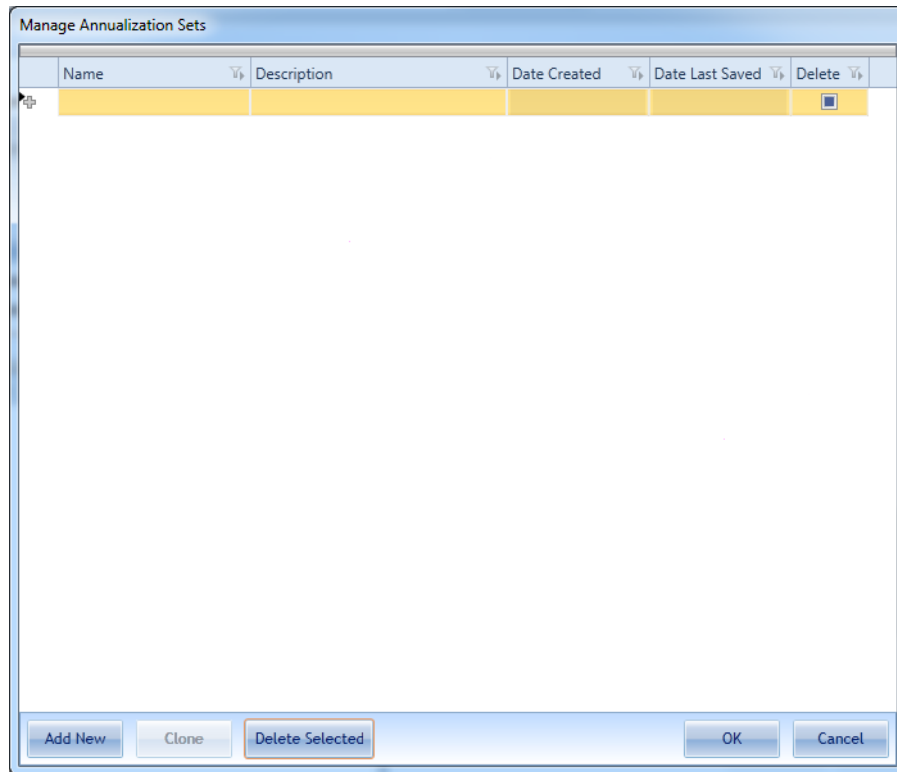
Once the user clicks the 'Annualizer' button the Annualization Calculator will open as shown below.

**Figure 154**  
**Annualizer Calculator**

If no Annualizer data are saved in the opened planning set, all data entry fields are set to default values upon creation of an annualization set. By default, the base year is set to the current year, the discount rate is set to 0 percent, period of analysis is set to 50 years, and all other values are set to zero.

The Annualizer module has three “Tabs” that can be selected for data input, Cost, NED Benefits, and NER Outputs. The Cost, NED Benefits, and NER Outputs tabs are where data are entered and calculations are computed.

Users may save multiple Annualization sets. New sets can be created and existing sets managed by clicking the ‘Create/Manage’ button on this form. Once the user clicks the ‘Create/Manage’ button the Manage Annualization Sets form will launch as shown below.

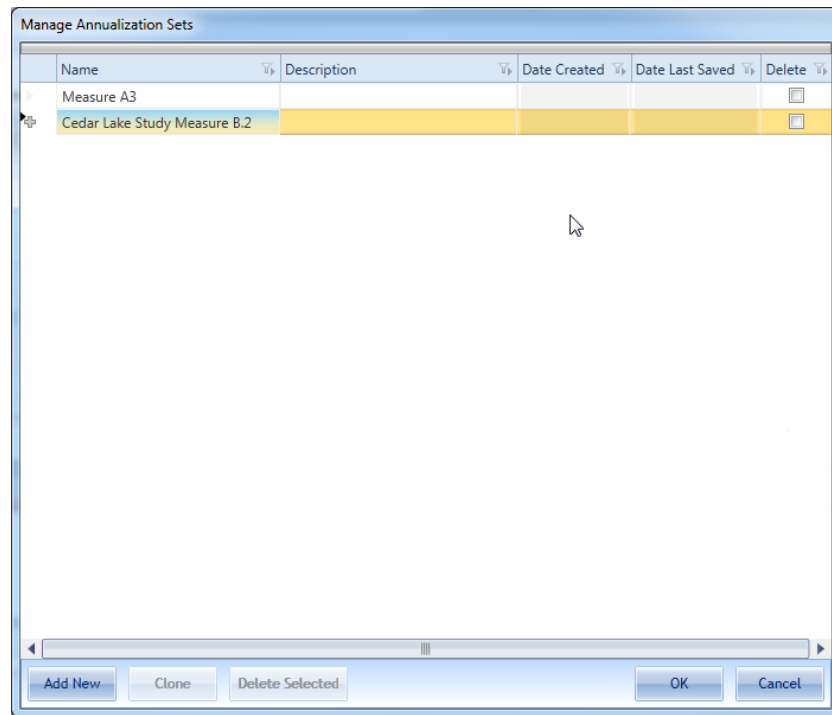


**Figure 155**  
**Managing Annualization Sets**

The user can enter a new annualization set by entering a name in the name field. Click the 'Add New' button if you wish to add another new annualization set. The user can delete existing annualization sets by clicking the Delete checkbox for the annualization sets you wish to delete and then clicking the 'Delete Selected' button. The user can update the Name or Description for an annualization set by updating the listed name or description. The application will set the Date Created and Date Last Saved for the user so no action is required by the user for these fields which is indicated by a grey background

## Add New Measures

To begin, click the 'Create/Manage' button. To add a new annualization set enter the desired name for the measure and a description and then click the 'OK' button. In the example, the measure is named "MeasureA3." Click the 'Add New' button to add additional measures. In the example, Cedar Lake Study Measure B.2 is added as well.



**Figure 156**  
**Creating New Annualization Sets**

Click 'OK' after creating these two new sets. Select Measure A.3 From the Annualization Set drop down list to begin entering data for this annualization set.

Annualization Calculator

Annualization Set: Measure A3 [Create / Manage](#)

Initial Terms: Cedar Lake Study Measure B.2

Base Year: Measure A3

Period of Analysis (years): 50

Discount Rate %: 0.0%

Capital Recovery Factor: 0.0

Cost NED Benefits NER Outputs

Initial Cost Details

Total Initial Cost - \$0.00

Construction	Real Estate	Pre-construction Monitoring	PED	Other	
\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00

Total Investment Cost - \$0.00

Total Initial Cost: \$0.00 + IDC: \$0.00 = \$0.00

Initial Investment

Total Investment Cost	PV Factor	Present Value
\$0.00	1.0	\$0.00

Cost Annualizer

Year	Total Future Costs	PV Factor	Present Value
2016	\$0.00	1.0	\$0.00
2017	\$0.00	1.0	\$0.00
2018	\$0.00	1.0	\$0.00

Net Totals

Total Cost:	Present Value:	Average Annual Equivalent Cost:
\$0.00	\$0.00	\$0.00

[Export Table To Excel](#) [View & Print Report](#) [Save](#) [Close](#)

**Figure 157**  
**Selecting Annualization Set**

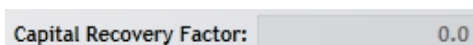
## Add Cost Data

Next, add data to the Cost tab which is the default tab that is shown. There are fields that are expecting user input and there are also calculated fields. For fields where the user will enter the values will have a white background. An example is shown below.



**Figure 158**  
**Editable Fields**

Fields that are calculated and do not require user entry have a grey background and do not accept user input. An example is shown below.



**Figure 159**  
**Non Editable Fields**

This pattern is also true for the NED Benefits and NER Outputs tabs.

There are seven main areas of the Cost tab. Each are briefly described below and then further discussed:

1. Initial Terms—in this area enter the base year, project discount rate and the period of analysis; the capital recovery factor is automatically calculated.
2. Total Initial Cost—input areas for initial construction, real estate, monitoring, and other initial costs; the total initial costs are automatically calculated.
3. Total Investment Cost—total initial costs are carried from above and input boxes are provided for PED and IDC; calculator for IDC; total investment costs are automatically calculated.
4. Initial Investment—here the total investment cost, present value (PV) factor, and present value (in dollars) are automatically calculated as data are entered.
5. Cost Annualizer Table—in this table, enter all annual costs in column “Total Future Costs”, the PV factor and present value are automatically updated.
6. Net Totals—automatically provides summary of Total Initial Cost, Total Investment Cost and Total Future Costs in total cost, present value, and the average annual cost of the management measure.
7. Action Buttons—these are the buttons that allow the user to export the table to excel, view and print the report, save changes to the measure, and close the Annualizer.

The diagram below identifies each area of the form.

**Figure 160**  
**Areas of the Annualizer**

## Initial Terms

The *Initial Terms* area is shown in detail in figure below. Enter the discount rate for the project and the period of analysis. The capital recovery factor automatically calculates and the 'Cost Annualizer' table automatically adds the number of years. Inputting the base year, discount rate and period of analysis should be completed before adding data to the 'Cost Annualizer' table. In the example, data for Measure A.3 of the Cedar Lake Study is entered. The discount rate is 4.875 percent and the period of analysis is 50 years.

Initial Terms	
Base Year:	2016
Period of Analysis (years):	50
Discount Rate %:	4.875%
Capital Recovery Factor:	0.053722

**Figure 161**  
**Initial Terms**

## Total Initial Cost

The *Total Initial Cost* area is shown in detail below. Enter the initial costs for the project. The input boxes are labeled as Construction, Real Estate, Pre-construction Monitoring, and Other. These boxes are for costs incurred during year zero of the project. To enter a value, click in the box, enter the desired value, and click somewhere else on the calculator. The total is automatically updated. The input boxes are designed to be general, as all projects do not have these exact categories. Use them as needed but be sure to only enter costs incurred in year zero in these cells. For the Cedar Lake Study Measure A.3, there are no initial construction costs or real estate costs but there are initial pre-construction monitoring costs in the amount of \$32,500 and PED costs of \$682,500.

Total Initial Cost - \$715,000.00						
Construction	Real Estate	Pre-construction Monitoring	PED	Other		
\$0.00	\$0.00	\$32,500.00	\$682,500.00	\$0.00	=	\$715,000.00

**Figure 162**  
**Initial Cost**

## Total Investment Cost

The *Total Investment Cost* area is shown in detail below. The total initial costs are carried down and added to the Interest During Construction Costs (IDC) to calculate the total investment cost. There is a calculator for the IDC input box, as described below. The user can enter an IDC value or use the calculator to compute IDC. In this example, the project's IDC costs are zero.

Total Investment Cost - \$715,000.00	
<div>Total Initial Cost</div> <div>\$715,000.00</div>	<div>IDC</div> <div>\$0.00</div>
+ = \$715,000.00	

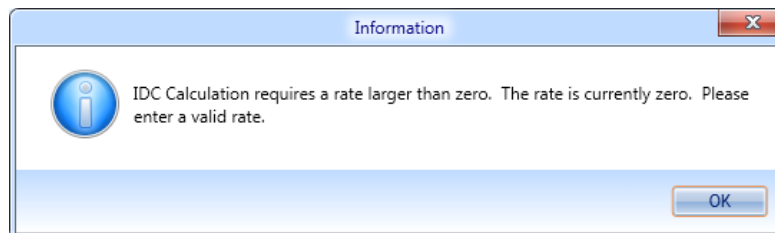
**Figure 163**  
**Total Investment Cost**

As shown above, the Total Investment Cost area has an input box for IDC. Also shown in the figure is a button with the ellipsis mark (three periods). Clicking on this button opens an IDC calculator.

Total Investment Cost - \$715,000.00	
<div>Total Initial Cost</div> <div>\$715,000.00</div>	<div>IDC</div> <div>\$0.00</div> <div>...</div>
+ = \$715,000.00	

**Figure 164**  
**Launching the IDC Calculator**

To open the IDC calculator left click with the mouse once on the button. The 'Interest During Construction Calculator' will appear, as shown below. Because the interest rate is carried from the Cost tab, *Initial Terms* section, the IDC calculator will not open if a discount rate has not been entered. Instead the user will receive a message indicating that the user must enter a valid rate prior to using the IDC Calculator.



**Figure 165**  
**IDC Calculation Prerequisite**

The screenshot shows the 'Interest During Construction Calculator' window. The 'Initial Terms' section at the top has the following inputs: 'Total Construction Periods' set to 10, 'Discount Rate %' set to 4.875%, and 'Number of Construction Periods Per Year' set to 12. A 'Calculate Interest at Period' button is present, with radio buttons for 'Start', 'Middle' (selected), and 'End'. Below this is a table with 5 columns: 'Construction Period', 'Cost', 'Interest Factor', and 'Interest'. The table contains 10 rows, all with a 'Cost' of \$0.00. The 'Interest Factor' values decrease from 0.038404 in period 1 to 0.001987 in period 10. The 'Interest' column shows \$0 for all periods. At the bottom right, 'IDC =' is displayed as \$0.00. At the bottom left is an 'Export Table To Excel' button, and at the bottom right are 'Save' and 'Close' buttons.

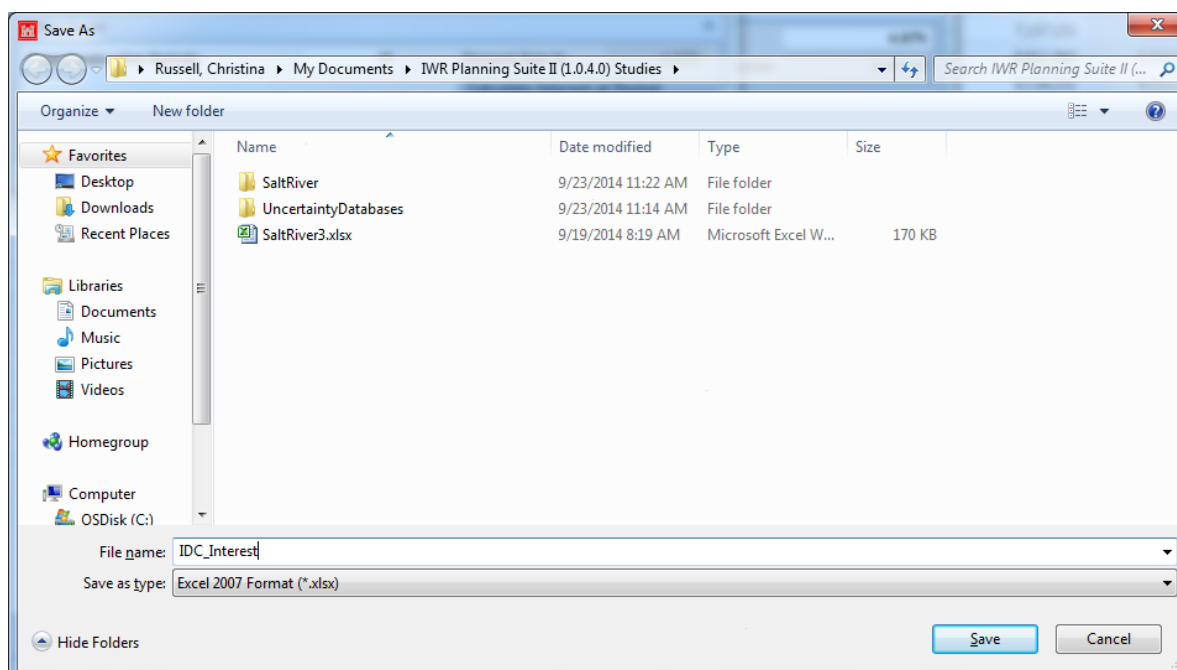
Construction Period	Cost	Interest Factor	Interest
1	\$0.00	0.038404	\$0
2	\$0.00	0.034293	\$0
3	\$0.00	0.030198	\$0
4	\$0.00	0.02612	\$0
5	\$0.00	0.022058	\$0
6	\$0.00	0.018012	\$0
7	\$0.00	0.013982	\$0
8	\$0.00	0.009968	\$0
9	\$0.00	0.00597	\$0
10	\$0.00	0.001987	\$0

**Figure 166**  
**Interest During Construction Calculator**

Within the IDC calculator, the user inputs the construction period and can indicate the number of periods per year. This section should be completed before entering the annual construction costs. To enter an annual construction cost, click in the box adjacent to the given year, enter the value, and click out. To move from year to year use the UP and DOWN arrow keys on the keyboard. As annual construction costs are entered, the IDC (shown at the bottom of the calculator tool) is automatically computed.

To export the Construction Interest table to an Excel workbook, click the 'Export Table to Excel' button, located at the bottom left-hand of the calculator. For more information on exporting to Excel see the section on [Exporting to Excel](#).





**Figure 167**  
**Export IDC Calculations**

Once the IDC table has been exported to Excel (if desired) and all values are correct in the IDC calculator, click 'OK' to close the IDC calculator. The IDC value is automatically carried to the IDC box in the *Total Investment Cost* area.

## Initial Investment

The *Initial Investment* area is shown in detail below. There are three values calculated in this area: total investment cost, present value factor, and present value. These values represent a sum of the total investment cost. These values change as data are entered into the *Initial Terms*, *Total Initial Cost*, and *Total Investment Cost* sections. For Measure A3 of the Cedar Lake Study, initial investment costs equal \$715,000.

Initial Investment		
Total Investment Cost	PV Factor	Present Value
\$715,000.00	1.0	\$715,000.00

**Figure 168**  
**Initial Investment**

## Cost Annualizer Table

The *Cost Annualizer Table* is shown in detail below. There are four columns to the table: Year, Total Future Costs, PV Factor, and Present Value. The Year column is automatically calculated based on the value input into the 'period of analysis' box. In the Cedar Lake Study example, the period of analysis is 50 years so the Cost Annualizer Table has 50 rows, one for each year. In the Total Future Cost column, input the total costs incurred for a given year in the corresponding box. These costs could include any construction costs,

engineering and design during construction (EDDC) costs, project management costs, and any OMRR&R costs. All the costs incurred in a given year should be summed and then entered into the table. Values should be entered in future value. The table then converts the future value of the costs to present value and updates the Present Value Column. NED costs are discounted mid-period. The present value of NED costs at year 1 would be the entire first year cost discounted at 6 months. The present value of year 2 costs would be all of the second year costs discounted at 18 months. Users are allowed to enter a total future cost value for the base year. However, these should be additional costs that are not already included in the total initial costs section of the form. For Measure A3 of the Cedar Lake Study, cost incur every year for OMR&R in the amount of \$23,800 for mowing and fence repair. Costs also occur in the first two years for dredging.

Year	Total Future Costs	PV Factor	Present Value
2016	\$0.00	1.0	\$0.00
2017	\$6,487,677.00	0.976481	\$6,335,096.47
2018	\$6,487,677.00	0.931091	\$6,040,616.42
2019	\$23,800.00	0.88781	\$21,129.88
2020	\$23,800.00	0.846541	\$20,147.68
2021	\$23,800.00	0.807191	\$19,211.14
2022	\$23,800.00	0.769669	\$18,318.13
2023	\$23,800.00	0.733892	\$17,466.63
2024	\$23,800.00	0.699778	\$16,654.71
2025	\$23,800.00	0.667249	\$15,880.54
2026	\$23,800.00	0.636233	\$15,142.35
2027	\$23,800.00	0.606658	\$14,438.47
2028	\$23,800.00	0.578459	\$13,767.32

**Figure 169**  
**Cost Annualizer Table**

## Net Totals


Once the initial costs, investment costs, and annual costs are entered into the Cost tab, the construction and O&M costs (in future dollars and present dollars), and average annual costs are automatically calculated and the totals are shown in the Net Totals area, as shown below. For the Cedar Lake Study, construction and O&M costs in future value equal \$14.8 million, and \$13.4 million in present value. The average annual cost is \$725.1 thousand.

<b>Total Cost:</b>	<b>Present Value:</b>	<b>Average Annual Equivalent Cost:</b>
\$14,832,754.00	\$13,499,001.92	\$725,197.19

**Figure 170**  
**Net Totals**

## Add NED Benefits Data

Next, add data to the NED Benefits tab (Note: data can be input to the Cost, NED Benefits, and NER Outputs tabs in any order). To move from the Cost tab to the NED Benefits tab, left click on the NED Benefits tab with the mouse. The image below displays the NED Benefits tab.

Cost		NED Benefits		NER Outputs	
# Years Before Base Year:		0		Benefit Annualizer 	
	Year	Benefit	PV Factor	Present Value	
▶	2016	\$0.00	1.0	\$0.00	
▶	2017	\$0.00	0.976481	\$0.00	
▶	2018	\$0.00	0.931091	\$0.00	
▶	2019	\$0.00	0.88781	\$0.00	
▶	2020	\$0.00	0.846541	\$0.00	
▶	2021	\$0.00	0.807191	\$0.00	
▶	2022	\$0.00	0.769669	\$0.00	
▶	2023	\$0.00	0.733892	\$0.00	
▶	2024	\$0.00	0.699778	\$0.00	
▶	2025	\$0.00	0.667249	\$0.00	
▶	2026	\$0.00	0.636233	\$0.00	
▶	2027	\$0.00	0.606658	\$0.00	
▶	2028	\$0.00	0.578459	\$0.00	
▶	2029	\$0.00	0.55157	\$0.00	
▶	2030	\$0.00	0.52593	\$0.00	
▶	2031	\$0.00	0.501483	\$0.00	
▶	2032	\$0.00	0.478172	\$0.00	
▶	2033	\$0.00	0.455945	\$0.00	

**Figure 171**  
**NED Benefits Tab**

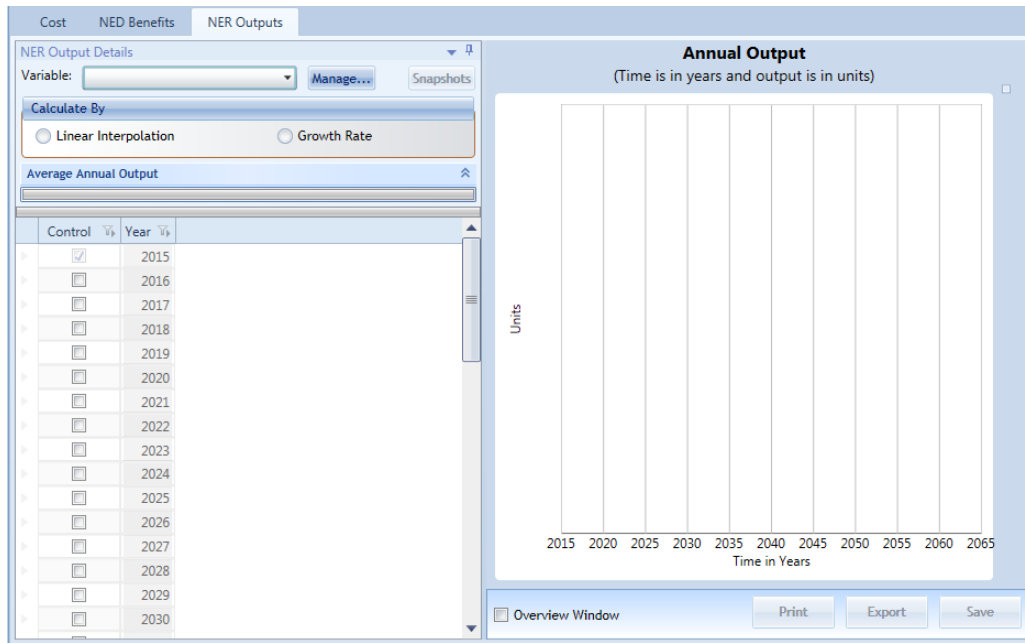
Similar to the cost data, the NED benefit tab has a table for entering benefits for each year of the project for annualization. The benefits are entered in future value and the table converts them to present value. Like NED costs, benefits are discounted mid-period. To enter a value in the 'Benefit' column of the table, double click in the 'Benefit' cell in the row that corresponds to the given year and enter the value. To move to the next year press either the tab or down arrow button on the keyboard. In our example, Measure A3 does not have NED benefits.

Similar to the Cost tab, the Net Totals are calculated for NED Benefits. Net totals include the total cost of benefits in future value, total cost of benefits in present value, and the average annual cost. The NED Benefits Annualizer table can be exported to Excel by clicking the 'Export Table to Excel' button located at the bottom left-hand of the NED Benefits tab. For more information, see the section on Export Table to Excel.

Also located at the bottom left-hand of the NED Benefits tab is an icon to view/print the NED Benefits report. Click this button to view the NED Benefits report. A window appears with the report identical to for the Costs tab, only data are for the NED Benefits.

## Add NER Outputs Data

Next, add data to the NER Outputs tab (Note: data can be input to the Cost, NED Benefits, and NER Outputs tabs in any order). To move from the NED Benefits tab to the NER Outputs tab, left click on the NER Outputs tab with the mouse. The image below displays the NER Outputs tab with default settings.



**Figure 172**  
**NER Outputs tab**

As shown, there are six main areas of the NER Outputs tab. Each is briefly described below. To best explain how to use the functions of the NER Outputs tab, this section is organized by calculation type. First discussed is how to perform linear interpolation of NER Outputs. This is followed by a discussion of how to calculate NER Outputs based on specified growth rates. While these two techniques are presently the only featured by IWR Planning Suite II's annualizer module, users should be aware that other annualization techniques exist and might be used where higher levels of accuracy and precisions are known and sought. At the end of this section, table and report functions are discussed, as they are applicable to both options.

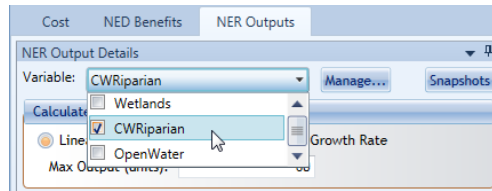
**Note:** The Corps does not discount non-monetary outputs; therefore, no technique for discounting non-monetary benefits exists in the annualizer module at this time.

The user should begin by choosing the variables they are interested in. This is done by clicking on the 'Manage...' button to bring up the Manage NER Output Variables form. The form lists all non-currency variables that exist for the planning study. The user can select one or more variables from the grid by checking the 'Include?' checkbox and clicking the 'OK'.

Include?	Name	Units	Description	Variable Type	Derived	Derived Function	Minimum	Maximum
<input checked="" type="checkbox"/>	Wetlands	Wetland Habi	AAHU's	Decimal	False			
<input checked="" type="checkbox"/>	CWRiparian	Cottonwood-	AAHU's	Decimal	False			
<input checked="" type="checkbox"/>	OpenWater	Open Water I	AAHU's	Decimal	False			
<input type="checkbox"/>	TotalOutput	AAHU's	AAHU's	Decimal	True	[Wetlands] + [CWRiparian] + [OpenWater]		

**Figure 173**  
**Adding Planning Study Variables**

Once variables have been selected they will show up in the Variable drop down list. At least one variable must be selected to edit and view output, but multiple variables can be selected at the same time.



**Figure 174**  
**Selecting Working Variable Set**

## Calculate by Linear Interpolation

The Annualization Calculator allows the user to calculate NER outputs using linear interpolation. This is a method of curve fitting using linear polynomials. Use this type of calculation method when NER output values are known for two or more years, but not all years. The values for the unknown years will be calculated using linear interpolation. Also, select this option if the NER output values for all years are calculated elsewhere, thus known, and simply need to be input. The latter is the case for the simplified example below and for the Cedar Lake Study Measure A3, where values are known for the beginning of the project and the outputs max out at year six.

**Simplified Example:** The start of the period of analysis has 0 output lift. At the end of year 1, there are 500 units and at the end of year 2 there is an additional 500-unit lift. To simplify, the project only has 2 years of life. The inputs would be as shown on the left.

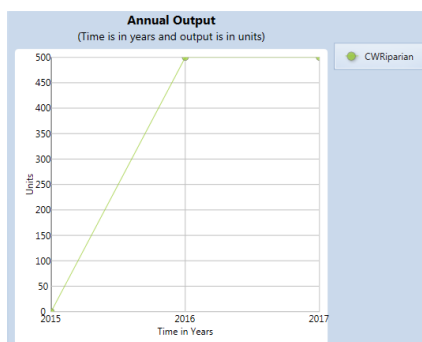
	Control	Year	CWRiparian
▶	<input checked="" type="checkbox"/>	2015	0
▶	<input checked="" type="checkbox"/>	2016	500
▶	<input checked="" type="checkbox"/>	2017	500

**Figure 175**  
**Simplified Example**

The sample calculations to find the average annual output are:

Step 1:  $[(500 \times 1)/2] + [500 \times 1] = 750$

Step 2:  $750/2 \text{ years} = 375 \text{ average annual output}$



**Figure 176**  
**Annual Output Graph**

The model finds the area under the curve and divides that area by the period of analysis.

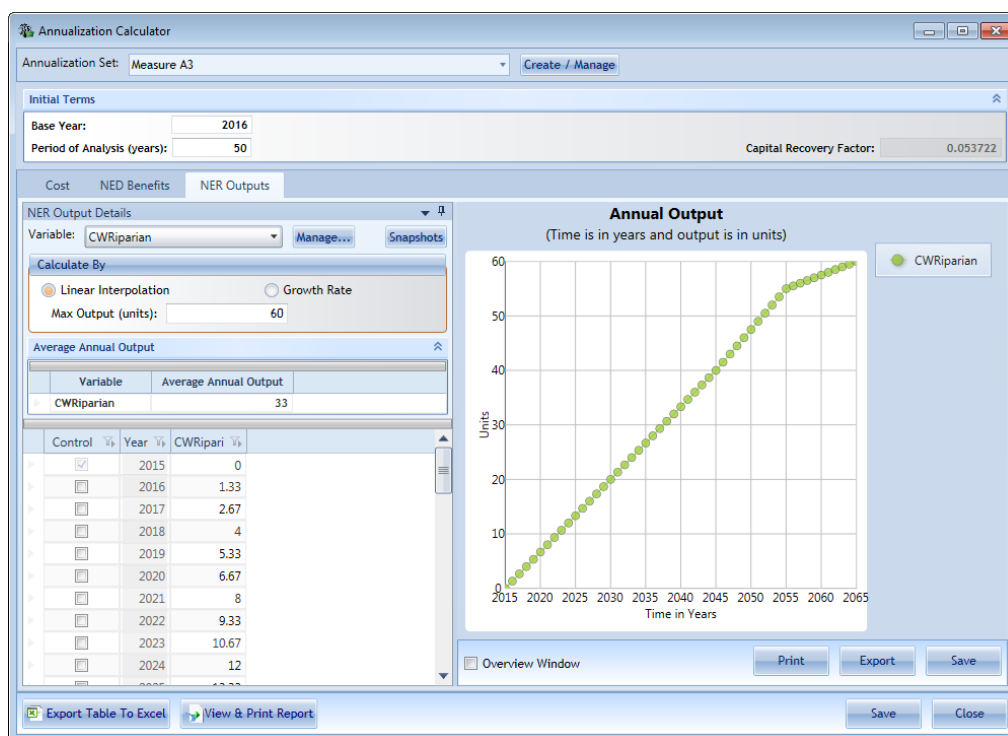
To illustrate how to employ the tool for either scenario, an arbitrary example is provided that highlights the functionality of the linear interpolation option. Data for the example is provided in Table 17. After the linear interpolation tool is explained, the Cedar Lake Study Measure A3 data entry methodology is demonstrated.

<b>Table 17.</b> <b>Data for Linear Interpolation Example</b>	
Max Output	60
Period of Analysis	50
Known Control Points	
Year	Value
2015	0
2045	40
2055	55
2065	60

To begin using the NER Outputs tab when linear interpolation is desired, after selecting one or more variables ensure that 'Linear Interpolation' radio button is selected.

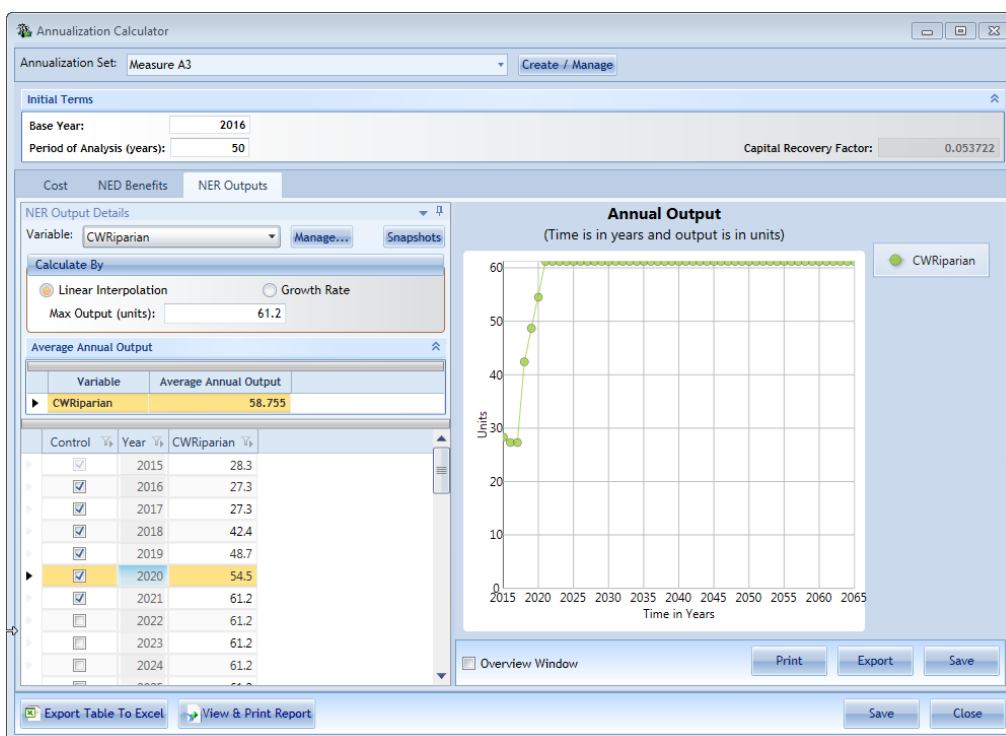
Once 'Linear Interpolation' is selected, the initial terms of the NER outputs can be set. Next set the max output. In the example, max output is set to 60 units.

Next, add the remaining data from Table 17 to the Annual NER Output Table. For each year with known outputs, the 'Control Point' box will be selected as a value is entered for Output next to the corresponding year. In the 'Output' box for the corresponding year, enter the desired output by clicking twice in the box and entering the new value. For year 2035 enter 40 for the output; for year 2045 enter 55 for the output and 2065 should be 60. Linear interpolation is automatically employed to reconfigure the in-between years. Notice the graphic automatically updates as well as the average annual outputs.



**Figure 177**  
**Linear Interpolation Example**

The linear interpolation tool is designed with flexibility so that the user can enter project specific NER outputs as well. The average annual output for the period between two user-provided control points is calculated to yield the average annual output for the period. For the Cedar Lake Study Measure A3, NER outputs are specified for the beginning years of the project and reach a max output of 61.2 at year 2021. To enter these into the NER Outputs Table on the Annualizer, set the max output to 61.2 units and the period of analysis to 50 years, as shown below. Next, enter the output for each year in the Output column. Again, notice the graphic and average annual output is automatically updated.



**Figure 178**  
*Expanded Linear Interpolation Example*

## Calculate by Growth Rate

The NER Outputs tab also allows to user to calculate NER outputs based on specified growth rates. Because the Cedar Lake Study does not have any measures with NER outputs calculated solely on growth rates, an arbitrary example is provided to demonstrate the use of this option. The criterion for this example follows:

- The period of analysis for the project is 50 years.
- NER output at year 2013 is 20 units.
- This grows 3 percent each year until year 2034, where the growth rate slows to 2 percent.
- At year 2044, the growth rate slows again to 1 percent.

To begin, select the “Growth Rate” radio. A column appears in the Annual Output table labeled

“**Growth Rate Percent.**” Next, change the period of analysis to 50 years. Select the year 2013 and set the Output column to 20. Next, set the growth rate at year zero to 3 percent by clicking in the corresponding growth rate cell for year zero and entering “3.”



NER Output Details

Variable: CWRiparian Manage ...

Calculate By

☐ Linear Interpolation ☒ Growth Rate

Max Output (units): 0.5

**Average Annual Output = 28.996**

Control Point	Year	Output	Growth Rate %
<input checked="" type="checkbox"/>	2013	20.00	3.0%

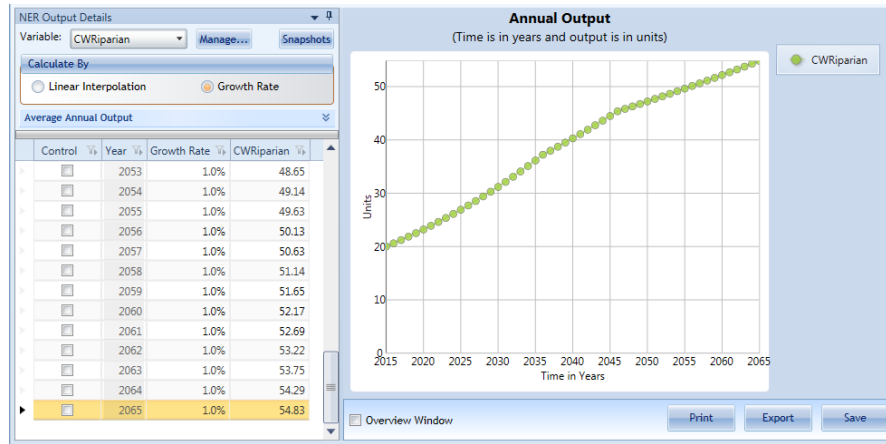
**Figure 179**  
**Growth Rate Example**

Repeat this process for year 2034 by clicking the control point box and changing the growth rate to “2”. Again, repeat this process for year 2044, clicking the control point box changing the growth rate to “1.”

	Control	Year	Growth Rate	CWRiparian
>	<input type="checkbox"/>	2035	3.0%	36.15
▶	<input checked="" type="checkbox"/>	2036	2.0%	37.23
>	<input type="checkbox"/>	2037	2.0%	37.97
>	<input type="checkbox"/>	2038	2.0%	38.73
>	<input type="checkbox"/>	2039	2.0%	39.5
>	<input type="checkbox"/>	2040	2.0%	40.29
>	<input type="checkbox"/>	2041	2.0%	41.1
>	<input type="checkbox"/>	2042	2.0%	41.92
>	<input type="checkbox"/>	2043	2.0%	42.76
>	<input type="checkbox"/>	2044	2.0%	43.62
>	<input type="checkbox"/>	2045	2.0%	44.49
>	<input checked="" type="checkbox"/>	2046	1.0%	45.38
>	<input type="checkbox"/>	2047	1.0%	45.83
>	<input type="checkbox"/>	2048	1.0%	46.29

**Figure 180**  
**Setting Control Points**

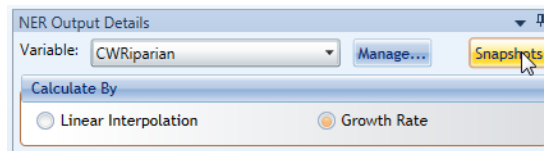
In this scenario the output reached in year 50 is 54.83.



**Figure 181**  
**Growth Rate Example Output**

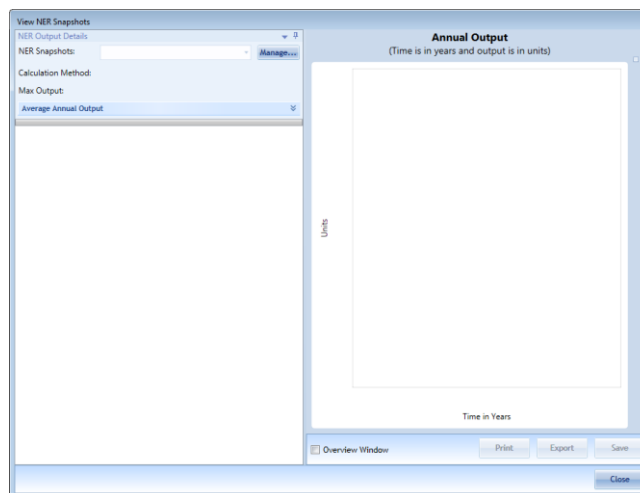
## NER Snapshots

It is possible for users to save different read-only snapshots of their output configurations and associated graphs for comparison purposes by clicking on the 'Snapshots' button in the NER Output Details panel as shown in Figure 181.



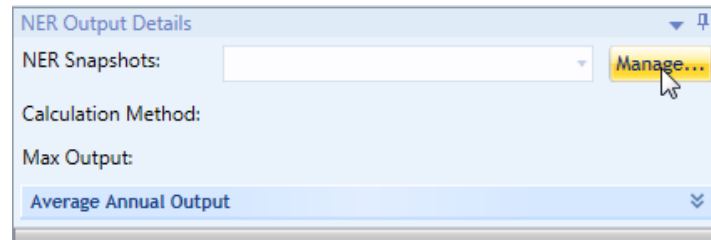
**Figure 182**  
**NER Output Snapshots**

This will bring up the View NER Snapshots screen as shown below.



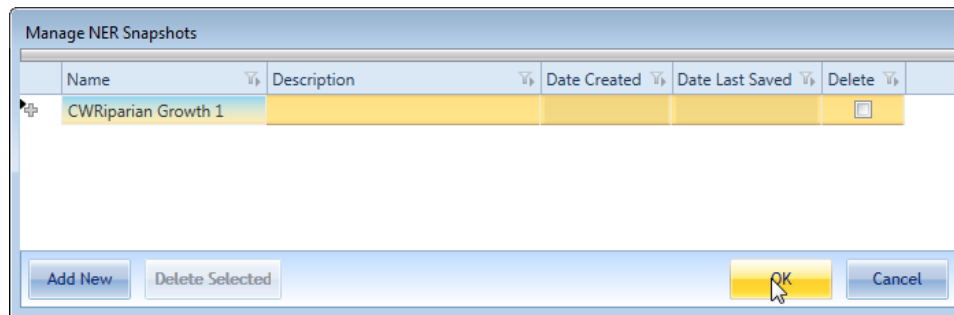
**Figure 183**  
**NER Snapshots Form**

If any snapshots have been created they will be available for selection in the drop down list. Snapshots can be created or deleted by selecting the 'Manage...' button.



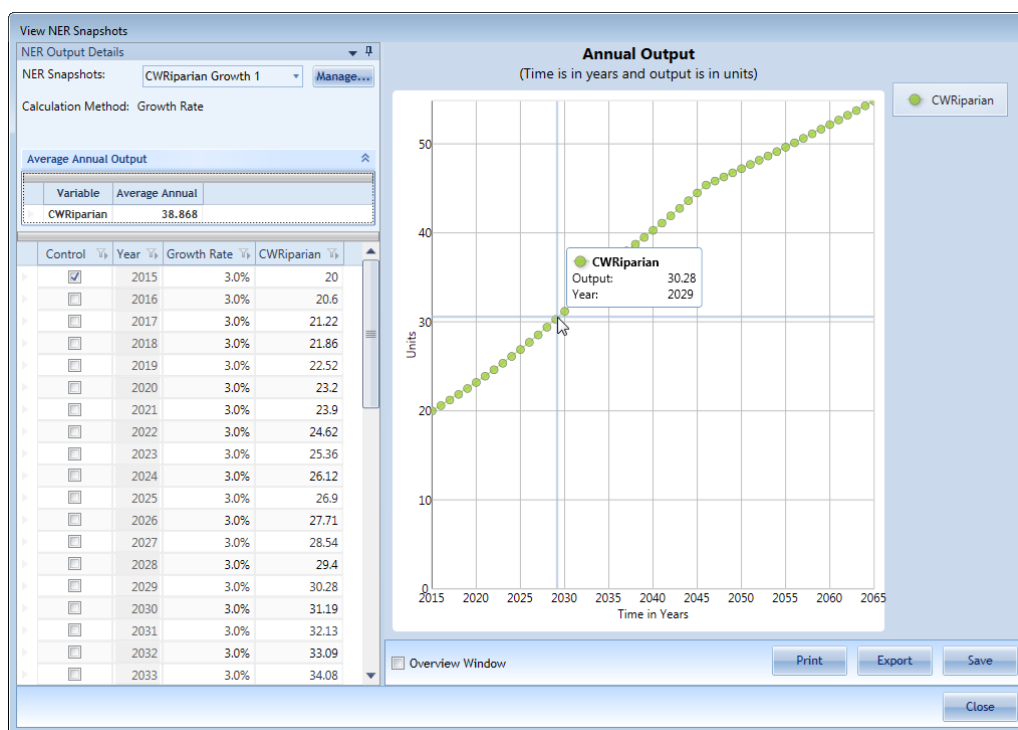
**Figure 184**  
**Manage NER Snapshots**

This will bring up the Manage NER Snapshots form which will list any existing snapshots. Users can create new snapshots, edit the name or description of existing snapshots, or choose to delete existing snapshots. In this example, create a new snapshot by entering a name for the new snapshot and clicking the 'OK' button.



**Figure 185**  
**Creating a New NER Snapshot**

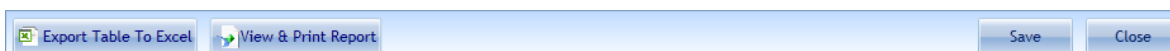
The created snapshot is displayed in the viewer and includes a read-only copy of the all the data that was generated in the previous Growth Rate example. While snapshot information cannot be edited, it is displayed in the same kind of interactive view as the main NER Outputs editor.



**Figure 186**  
**Viewing NER Snapshot**

## Annualizer Action Buttons

The final area of the Annualizer Cost tab is where the “action buttons” are located. These are buttons that initiate an action when clicked. The action buttons are as follows: (1) Export Cost Annualizer Table to Excel, (2) View & Print Report, (3) Save, and (4) Close. The buttons are shown and described below. These options are available on all three tables of the Annualization Calculator: Costs, NED Benefits, and NER Outputs. The data that is exported or viewed in the report depends on which tab the user has selected at the time the button is selected.

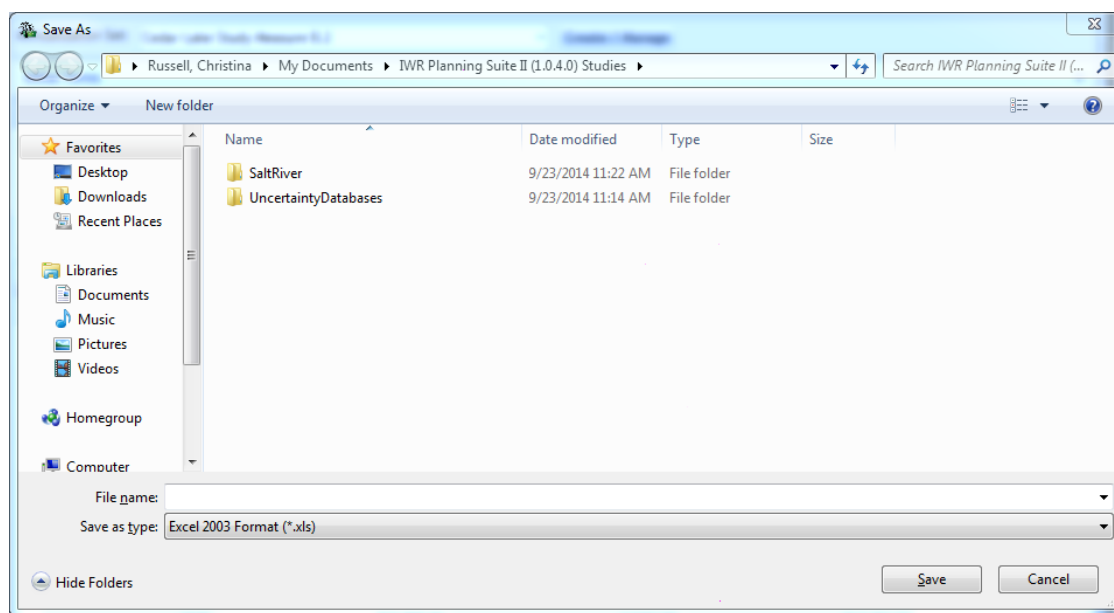


**Figure 187**  
**Annualizer Action Buttons**

## Export Table to Excel

Click this button to export only the data from the selected tab to an Excel workbook. If the user has the Cost tab selected then the information viewable to the user when this tab is selected is displayed. Likewise if you have the NED Outputs or NER Benefits tab selected when the export is completed then the information viewable from these tabs will be exported.

After selecting the ‘Export Table to Excel’ button the form that appears is shown below.

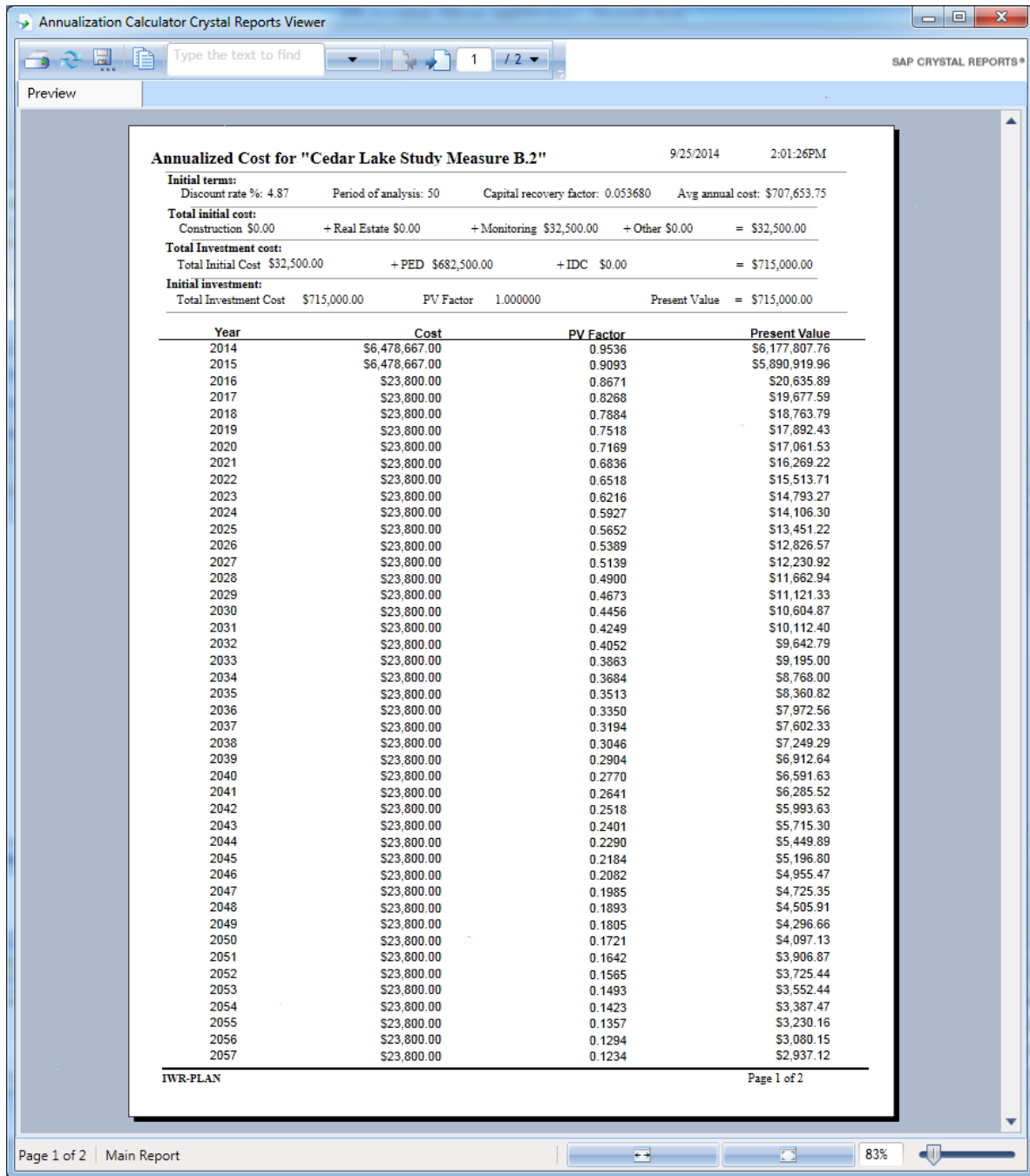


**Figure 188**  
**Export Table to Excel**

Click in the file name box to specify a name for the file. Navigate to the desired folder and click the 'Save' button, located at the bottom right-hand of the dialog box, to save the file. To cancel the action, click the 'Cancel' button, located at the bottom right-hand of the dialog box.

## View & Print Report

Click the 'View & Print Report' button to view the annualized report. The tab the user has selected at the time they press the 'View & Print Report' button will determine the report the user is provided. If the user presses the 'View & Print Report' button while the user is on the costs tab the annualized cost report will be displayed. If the user selects the 'View & Print Report' button while on the NED Benefits tab then the annualized benefits report will be displayed. Lastly, if the user selects the 'View & Print Report' button while on the NER Outputs tab then the annualized NER outputs report will be displayed. An example of the annualized cost report is shown below.

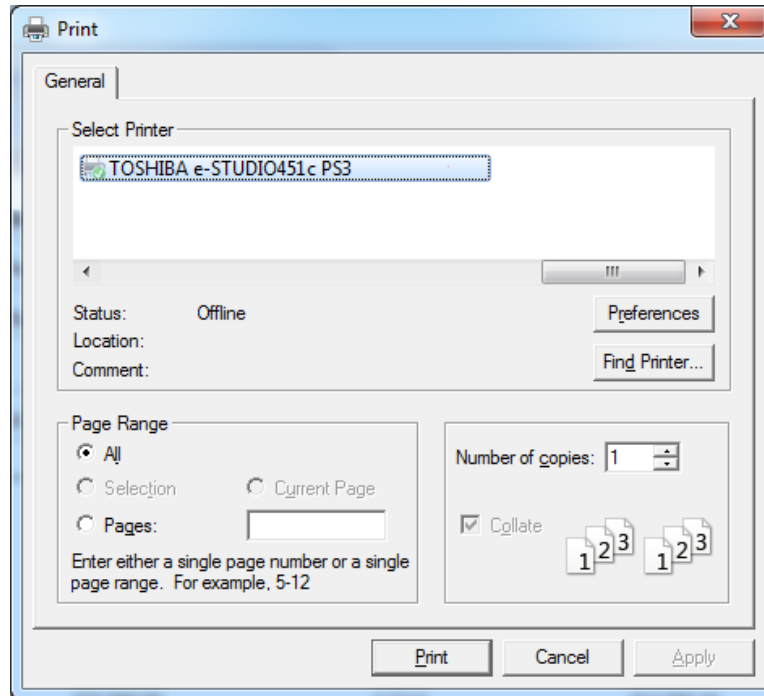


**Figure 189**  
**View and Print Annualizer Report**

There are many options on the report dialog. Each button is briefly described below.



This option allows the user to print the report. Clicking on this button will launch the print form and allow the user to define which printer to use, pages to print, number of copies as well as modify other standard print preferences.



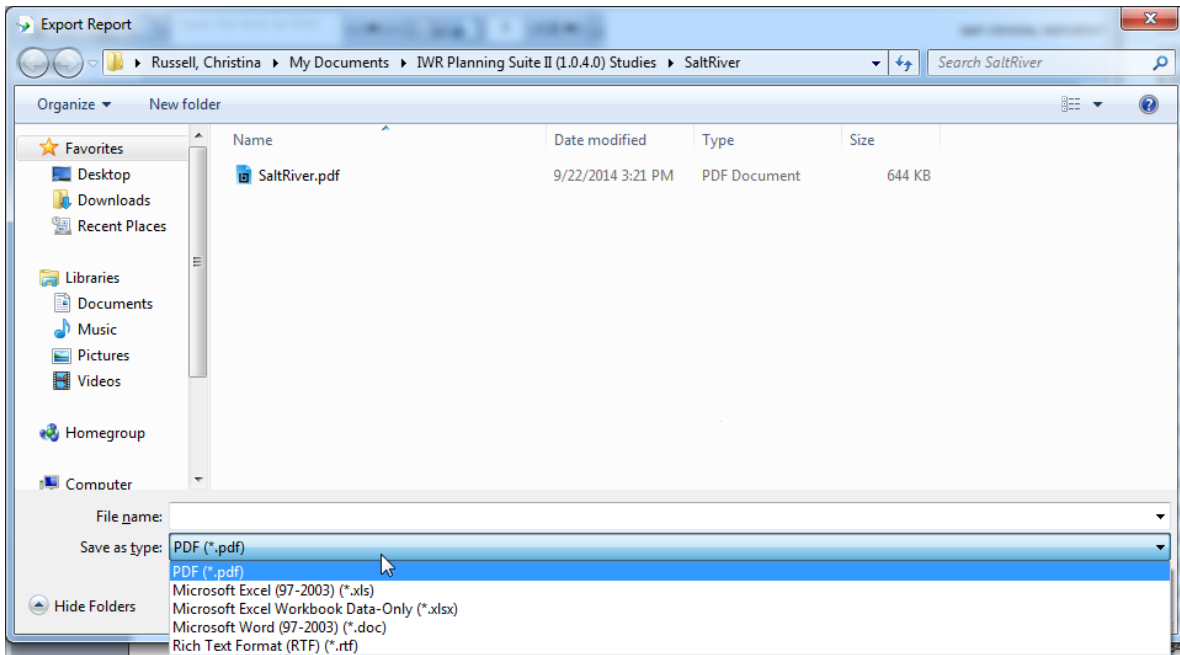
**Figure 190**  
**Annualizer Report Print Options**



The refresh button allows the user to refresh the data shown in the report.



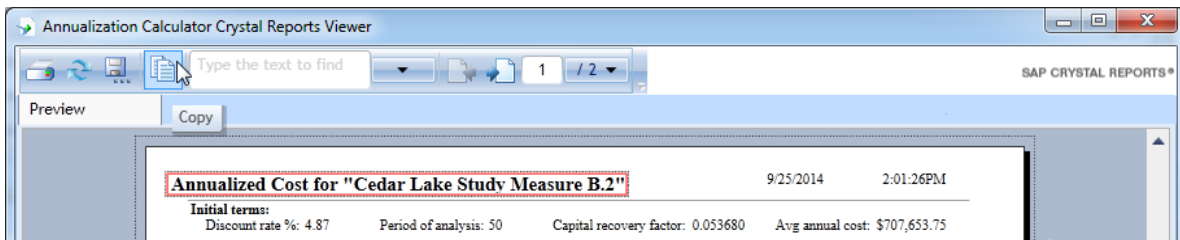
The export report button allows the user to export the report to PDF, XLS, XLSX, DOC, or RTF format depending on the option selected. The user should select a location to save the report, define a name for the exported report and a format for the exported report.



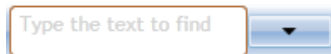
**Figure 191**  
**Annualizer Report Format**



The copy button allows the user to copy a selected value and paste it in another application. The user can select a field such as the report title. After selection it will be surrounded by a red outline. Then the user can click the Copy button to copy that text. It will now be available in the clipboard for pasting in another application.



**Figure 192**  
**Copying and Pasting from Annualizer Report**



This field and options allow the user to search the report. If the user enters text into the “Type the text to find” box and then presses the Enter key the value entered will be highlighted in the report.



Annualization Calculator Crystal Reports Viewer

2015

Preview

SAP CRYSTAL REPORTS\*

**Annualized Cost for "Cedar Lake Study Measure B.2"** 9/25/2014 2:01:26PM

**Initial terms:**  
Discount rate %: 4.87    Period of analysis: 50    Capital recovery factor: 0.053680    Avg annual cost: \$707,653.75

**Total initial cost:**  
Construction \$0.00    + Real Estate \$0.00    + Monitoring \$32,500.00    + Other \$0.00    = \$32,500.00

**Total Investment cost:**  
Total Initial Cost \$32,500.00    + PED \$682,500.00    + IDC \$0.00    = \$715,000.00

**Initial investment:**  
Total Investment Cost \$715,000.00    PV Factor 1.000000    Present Value = \$715,000.00

Year	Cost	PV Factor	Present Value
2014	\$6,478,667.00	0.9536	\$6,177,807.76
2015	\$6,478,667.00	0.9093	\$5,890,919.96
2016	\$23,800.00	0.8671	\$20,635.89

Figure 193

Finding Text in Annualizer Report

If the user clicks the down arrow next to the search field they will be presented with two search options: Match Case and Match Whole Word.

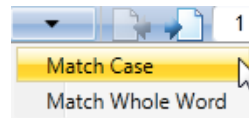


Figure 194

Text Search Options

By default the search will identify the search entered information even if it is a partial word or in the document in a different case. These two options can limit the results of the search by only returning those values that are in the same case or only if the entered search criteria appears in the resulting report as a whole word.

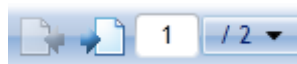
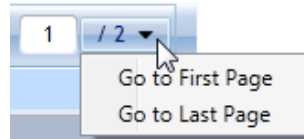


Figure 195

Page Navigation

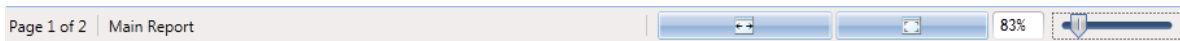
These options allow the user to navigate through the report pages. The page icon with the right arrow moves forward one page. The page icon with a left arrow will navigate one page back. Note that the previous page option is disabled for the user if they are on the first page of the report and the next page option will be disabled if the user is viewing the last page of the report. Alternately, the user may enter a specific page number in the available field and click the Enter key to navigate to a specific page of the report. The down arrow beside the page number allows the user to select "Go to First Page" or "Go to Last Page" options.



**Figure 196**  
**Page Navigation Options**

To close the report, click the “X” button, located in the upper right-hand of the report.

There are also options available on the bottom status bar of the report viewer as shown below.



**Figure 197**  
**Report Status Bar**

**Page 1 of 2** The first block of information identifies which page of the report that the user is viewing out of the total number of pages.



This button widens the report to fit the width of the report viewer screen.



This button modifies the size of a page displayed in the report so that the entire page is viewable in the report viewer screen.



This option allows the user to zoom in and out of the report using the sliding bar. The percentage the report is zoomed will be displayed to the left. In this example the report is zoomed out to 49%.

## Save

This buttons saves the changes made to the current measure. This option is available from all tabs on the Annualization Calculator.

## Close

This buttons closes the Annualization Calculator. This option is available from all tabs on the Annualization Calculator. If changes have been made to the annualization set but were not saved, a dialog box will appear asking if you would like to save the changes to the current measure.



## Section 7

# MCDA Introduction and History

*...seek balance and synergy among human development activities and natural systems by designing economic and environmental solutions that support and reinforce one another.” (USACE Environmental Operating Principles)*

Multiple-criteria decision analysis (MCDA) is a technique to assist decision-makers in clarifying and conveying the tradeoffs across multiple criteria. Since most decisions involve more than one criteria or objective, MCDA is a decision-aiding tool to sort this out. However, it is NOT a decision-making technique. It is a logical, consistent framework that provides clarity and transparency. In the case of ecosystem restoration studies, MCDA is a helpful tool to weigh off various habitat types or ecosystem measures. MCDA can also be used to analyze multiple accounts; however, Corps teams must take great care in doing this to ensure policy is followed and avoid double counting variables. **Teams should consult their vertical team and the appropriate Planning Center of Expertise prior to pursuing this path.** It is very important to have the decision makers become a part of the MCDA process.

Why should one use MCDA?

- It's technically defensible and easily understandable
- It can improve the quality and consistency of individual judgments
- It produces results that can help to focus deliberation in productive ways
- Shifts discussion away from positions and toward performance-based dialogue
- To support Civil Works Planning processes with additional tools and techniques to better assess and make decisions toward arriving at a preferred alternative
- To provide enhanced understanding of the nature of the tradeoffs across the alternatives in terms of impacts to the criteria identified
- To deliver transparency and convey the rationale behind the selection of a preferred alternative
- It provides clarity on trade-offs between alternatives.

According to the Corps Planning Principles and Guidance, four accounts are established to help the decision maker recommend a plan at the end of the feasibility phase.

- a) The National Economic Development (NED) account displays changes in the economic value of the national output of goods and services.
- b) The Environmental Quality (EQ) account displays non-monetary effects on significant natural and cultural resources.

- c) The Regional Economic Development (RED) account registers changes in the distribution of regional economic activity that result from each alternative plan. Evaluations of regional effects are to be carried out using nationally consistent projections of income, employment, output and population.
- d) The Other Social Effects (OSE) account registers plan effects from perspectives that are relevant to the planning process, but are not reflected in the other three accounts. (ER 1105-2-100, 1-3)

All of the criteria used to evaluate the projects will fall under one or two of these accounts. In each of the plans chosen for evaluation, national economic development, environmental quality, regional economic development and social well-being should be addressed. It is easy to quantify the NED account because it is based on dollars, but the other accounts are more difficult to quantify. In 1999, the National Research Council (NRC) recommended “that further decision analysis tools be implemented to aid in the comparison and quantification of environmental benefits from restoration, flood damage reduction and navigation projects.” (Linkov et al., 11)

MCDA helps the decision maker balance a set of criteria (acres of wetland restored, habitat units created and number of jobs created) against a given set of solutions. It gives the decision maker a way to quantify how each alternative considered meets a set of existing criteria. The MCDA process can even be used to measure qualitative units such as socioeconomic factors or cultural resources using a user defined scale or a commonly accepted scale such as Saaty Analytical Hierarchy Process (AHP) scale.

Using MCDA the user can weigh the importance of different criteria by assigning numerical weights to each criterion. By maximizing or minimizing criteria, the study manager can reduce harmful effects and increase benefits of a given criteria in a particular alternative.

MCDA provides a framework for stakeholders to voice their opinions and, in the best- case scenario, come up with a consensus on the set of objectives/criteria for the project. Even if a consensus on the set of objectives cannot be achieved; the stakeholders are aware of the objectives of the other stakeholders. In a worst-case scenario, the stakeholders walk away from the process with a better understanding of one another, a benefit derived from allowing the process to act as a type of mediation.

## History of MCDA

MCDA arose as an area of specialization within the arena of Operations Research (OR). Operations Research is dedicated to advancing the science of decision making.

Initial applications of OR were in support of military activities. Around 1937, Operational Research analysis was initiated by the British Royal Air Force in a seminal study of the network of radar operators and how the decisions they made affected the results gained from their radar operations.

The Naval Ordnance Laboratory brought the science, renamed operations research, in as a formal program into the United States in 1942. Eventually this resulted in the inclusion of OR groups in all Air Force command units.

Research has moved forward rapidly over the past sixty years. Significant advances continue to be made in OR and in multi-criteria decision analysis (MCDA), specifically. Advances are to some degree correlated to increases in computing power and availability, as the greater majority of OR analyses are computationally intensive in nature.

MCDA is applied to decision making problems in a variety of areas, such as economics, production and project planning, the statistics and management sciences, engineering design, and in several areas within the field of environmental analysis. MCDA methodologies have been developed around a variety of theoretical frameworks like outranking, optimization, goal aspiration, and the combining of different methods.

In the 1960's, the first methods of evaluation that used matrices for selection of plan alternatives were developed. These methods, collectively referred to as weighted summation analyses, were constrained solely to the evaluation of quantitative numeric criteria where all criteria were expressed in the same units of measure (for example, all criteria values expressed in dollars). These constraints severely limited the potential complexity of the analysis often necessitated by the vagaries of real-world problems.

As such, subsequent research focused on the expansion of MCDA to include criteria measured with different units. Seminal work by French researcher Bernard Roy resulted in the ELECTRE methods. Research during this period culminated in the development of Morris Hill's Weighted Ranking method by means of the Goals Achievement Matrix in 1968, wherein normalized scores provided the key to the resolution of different criteria measurement units, and its widespread dissemination and use in the 1970's.

Research and new developments in MCDA have continued at a prodigious rate through to the present day, spawning new methods that further expand the applicability of the discipline to decision making. Compromise Programming, Outranking methods such as PROMETHEE, the ELECTRE MCDA methods, Concordance/Discordance analysis, Analytic Hierarchy Process, and non-dominant, or Efficient Frontier analysis are all outgrowths of MCDA research that continue to be used, developed, and refined to this day.

Information on specific Corps projects where MCDA has been used is difficult to find. Most literature linking MCDA and the Corps examine environmental cleanup of contaminants and consider MCDA in a more abstract way, suggesting that it was a good thing for the Corps to use. One example is the Missouri River Recovery Program Management Plan and draft EIS released Dec 2016 used a MCDA process to structure criteria and their metrics using stakeholder input, assessed impacts of alternatives to those criteria, and qualitatively displayed the tradeoffs in a consequences table on p. 2-77. The Corps undertook this process in response to a recommendation from the Missouri River Recovery Implementation Committee's Independent Science Advisory Panel. It indicated that due to the multiple interests, values, and concerns within the Basin, the planning process would benefit from using structured methods to quantitatively describe impacts to the concerns of interest. There are situations where going through those steps and then showing the tradeoffs provides sufficient clarity to select a preferred alternative, without necessarily conducting a weighting or other analytic activity to quantify the tradeoffs.

URL: <http://moriverrecovery.usace.army.mil/mrrp/f?p=136:70:0::NO::>

## Things to Remember When Using MCDA

It is important to remember that MCDA is a decision aiding tool and not an instrument to actually make the decision for the planning professional. As with all models and computer programs, the answers returned need to be reviewed.

Great care shall be taken when deciding which criteria should be used to evaluate a project to ensure that the appropriate process is being used. Weighting heavily or choosing many criteria out of particular business line will focus the analysis toward that business line or aspect unless they are appropriately nested into an objectives/criteria hierarchy. Likewise leaving out a criteria that matters to decision-makers or stakeholders

may result in missed opportunities to improve or select the best preferred alternative, as well as to communicate the impacts of alternatives on the criteria. It is important for the study team to remember the project purposes, scope of what can be affected, and the criteria chosen needs to accurately reflect them.

The Corps has built into the planning process a way for the data used for MCDA analysis to be internally and sometimes externally peer reviewed. The study managers, in cooperation with the project team, currently determine project effects, both positive and negative, in the formal study and NEPA processes. Vertical team integration throughout the study process (including the Feasibility Scoping meeting, Alternative Formulation Briefings and other review meetings) adds a level of assurance the study team is following guidance.

Using MCDA, the study or project team can clearly demonstrate how they assigned weights to each of the criteria and how those choices led them to selecting a given plan. The use of the MCDA tool provides transparency on the vertical team's decision making process. The use of weights will help the stakeholders realize where the emphasis for the project really lies. The use of MCDA is beneficial to stakeholders because it allows items that are not easily quantifiable, such as recreation and cultural resources, to be openly reflected in the decision making process (if these are desired objectives).

## MCDA Basic Constructs & Definitions

### What is a Criterion?

A criterion represents a measured quantity in an MCDA decision matrix. In the IWR Planning Suite II MCDA module, criteria are synonymous with variables in a MCDA planning set. They may alternatively also be the Cost Effective attribute of a particular planning set. Criteria can either be maximized or minimized. For example, one would want to minimize cost while maximizing habitat units achieved by a particular plan.

The data to be ranked may be quantitative (cardinal) or qualitative (ordinal). Quantitative data is data that can be described in physical units with a real number. Cost is a quantitative criterion. Habitat Units, Acres, Water Depth, and Pump discharge capacity are all quantitative values. Qualitative data is data that cannot be described in physical units, but must be described by a set of discrete, ordered identifiers. This can happen in cases where robust, quantitative data is not available for a particular criterion. If such is the case, then more general identifiers that represent qualitatively the criteria in question may be used.

Qualitative data can be assigned a quantitative number in a ranking system. Some example identifiers representing potential qualitative data sets are:

Table 18. Quantitative to Qualitative Criteria		
Type of Criterion	Qualitative Value	Potential Quantitative Value
Habitat Units	Ordinal Values (Low to High)	3 = Low 5 = Middle 7 = High
Improve Substrate	True or False	1 = True 0 = False
Public Agreement	(None, Few, Average, Many)	0 = None 2 = Few 4 = Average 6 = Many

Distance	(Near, Middle, Far)	3 = Near 4 = Middle 5 = Far
Risk of Failure	(Low, Medium, High, Critical)	9 = Low 7 = Medium 5 = High 2 = Critical

It is important to remember to look at the scaling of your criteria. In the example for habitat units, the medium ranking is assigned almost twice the weight of the low ranking. Improper scaling will skew your final answer.

## What is a Decision Matrix?

A decision matrix is the foundational structure from which all IWR Planning Suite II MCDA work is performed. Simply, it is a matrix of alternatives and their impact on the criteria. Specifically, it corresponds to an IWR Planning Suite II MCDA Planning Set, where each Plan Alternative is a row in the decision matrix, and each criterion is a column in the decision matrix.

## What are Criterion Weights?

Criterion weights are the mechanism for determining relative importance of each criterion. When analyzing alternatives, we may wish to consider one criterion as relatively more important than another criterion. For example, if a scale from 1 to 20 is used to indicate importance and habitat units are given a 20 and cost is assigned a 1, then habitat units are 20 times more important than total cost. One should also consider the spread of values across alternatives and how these values impact the analysis in light of these weights. For example, having multiple plans with values of 17, 18, and 19 versus 5, 10, and 15 will impact these weights differently. It may also be that no plan scores an “optimum” value.

Analytic Hierarchy Process (AHP) is a method for simplifying the determination of the relative importance of criteria using plain English terms that is described in further detail in section 3. AHP is included within the IWR Planning Suite II MCDA tool as an optional weighting scheme.

## What is Criteria Optimization?

The attempt to evaluate rows of the decision matrix based on criteria values is an optimization problem. In saying that we are attempting to find optimal solutions, we mean the best solutions based on criteria that involve some values being as low or high as possible (minimized or maximized).

### Criteria Minimization

When smaller values of criteria are more desirable, the criteria are minimized. Cost is a criteria for which minimization is often selected, as the lowest possible cost is usually considered part of an optimal solution. Other criteria that may be minimized included habitat disturbed, endangered species taken, cultural resources affected and houses destroyed. The minimization of criteria within the context of a MCDA analysis is the attempt to identify those rows with the smallest criteria values for the criteria being evaluated.



## Criteria Maximization

Criteria should be maximized when the larger values are more desirable. For example, Habitat Units are maximized on an ecosystem restoration project. The maximization of criteria is the attempt to identify decision matrix rows with the largest criteria values for the criteria under consideration.

## What is Ranking?

Decision matrix ranking is the evaluation of rows in a decision matrix (a planning set). The ranking methodology attempts to find the relative minimum and maximum criteria for all of the rows in order to rank the rows of the decision matrix from the optimal solution row (the least desirable plan alternative) to the least optimal solution row (the least desirable plan alternative). The weights play a factor in ranking by assigning more importance to particular criteria.

## MCDA Plan Alternative Attributes

Attributes are associated with a plan alternative in a particular planning set. They contain the results of a particular analysis. Specifically, the Score and Rank of each Plan Alternative is maintained in Score and Rank attributes associated with the plan alternative. The distinction between attributes and variables is that while variables are consistent within a plan alternative, attributes may vary. For example, the cost of Plan A will always be the same but the MCDA score or rank can be different depending upon the type of analysis using a different method, different weights, or different analysis parameters.

## MCDA Module

The MCDA Module is a plug-and-play module of the IWR Planning Suite II that provides the ability to perform Multi Criteria Decision Analysis using a variety of methods and techniques.

## Reducing the Decision Matrix

MCDA Decision Matrix rows may be reduced by applying filtering techniques to them. In some cases it is appropriate to the needs of the analysis being conducted to reduce the size of the MCDA planning set, or to eliminate those plan alternatives that do not meet the minimum requirements set for an analysis or exceed an established threshold, such as a cost limitation.

Decision Matrix reduction is performed by applying maximum and minimum criteria value tests to each decision matrix row (plan alternative). These criteria value tests act as constraining limits which remove rows from the decision matrix which fail to pass the constraint test. A new planning set is created at this time to contain the constrained decision matrix so that the original set of alternatives is accessible simply by changing the working planning set. For example, if a maximum value for cost is set to \$1,000,000 then any plan alternatives that have a total cost which exceeds this maximum value are removed from the decision matrix and a new planning set is created which contains all alternatives which passed the constraint tests. This reduction in the decision matrix is a function of the IWR-Planning Suite and is not exclusive to the MCDA module.

## Weighting Criteria

MCDA allows the user to assign weights to each criterion by assigning user defined values or by using the Analytic Hierarchy Process (AHP).

When the user is defining weights, it is important to remember how the weights will scale the criteria. If the user defined weights are 1, 2, 3, and 4, the criteria weighted with a 4 is four times more important than the criteria weighted with a 1.

## AHP Weighting

Additionally, MCDA provides an alternative to the user defined weights called Saaty's Analytic Hierarchy Process (AHP). AHP is a methodology for decision-making that utilizes relative importance descriptions in a pair-wise comparison analysis to set criteria weights. This technique requires the decision maker to consider each single criterion against every other criterion in pairs. In AHP weighting the user selects the phrase describing the relative importance of each criterion combination. There are nine different levels of importance to choose from:

- Equally Important (1)
- Slightly More Important (3)
- Strongly More Important (5)
- Demonstrably More Important (7)
- Absolutely More Important (9)
- Slightly Less Important (-3)
- Strongly Less Important (-5)
- Demonstrably Less Important (-7)
- Absolutely Less Important (-9)

Selecting from these plain English phrases allows the planner to set the weights for each criterion using an easily understandable comparison method. All that is needed is to set how important each criterion is compared to the other criteria, and the weighting will then be automatically calculated based on your selections.

Relative importance will vary with the specifics of each MCDA study and the manner of framing the planning study. For example, a project planner may assume that total cost is more important than the effect on the deer population in a project area, because there is a specific limitation to the total investment that can be made. Conversely, if the project had no cost limitations, the planner might consider the effect on the deer population equally or even more important than total project cost. It is important to consider the scales and range of values across criteria – not just the criteria themselves.

As you can see from this example, comparisons of criteria are by their nature very dependent on the individual decision makers' view of their relative importance. One person may feel that a criteria is Strongly More Important than another, whereas someone else may feel that the relationship is one of only slightly more importance.

In a group setting, individuals can come to a mutually agreed upon consensus on the importance through a method such as facilitated conflict resolution. The MCDA tool supports these types of activities by allowing

participants to rapidly change inputs to reflect preferences and produce alternative ranking scenarios for discussion. Often the most valuable insights come from comparing outcomes of ranked alternatives across different criteria weights because this helps to provide clarity about the decision and related tradeoffs.

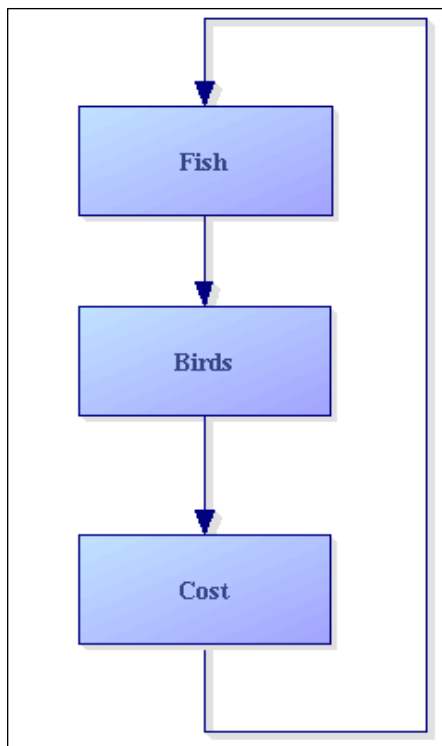
### The AHP Inconsistency Ratio

It is important to pay careful attention to the Inconsistency Ratio calculated as part of the AHP weighting methodology. It serves to indicate the degree of inconsistency in the relative importance chosen for criteria. The AHP Inconsistency Ratio is a number between zero and one indicating how inconsistent the relative criteria importance selections are. Zero indicates there is no inconsistency, and one indicates complete inconsistency. The Inconsistency Ratio should be kept as close to zero as possible, the higher the value the more inconsistent the selection.

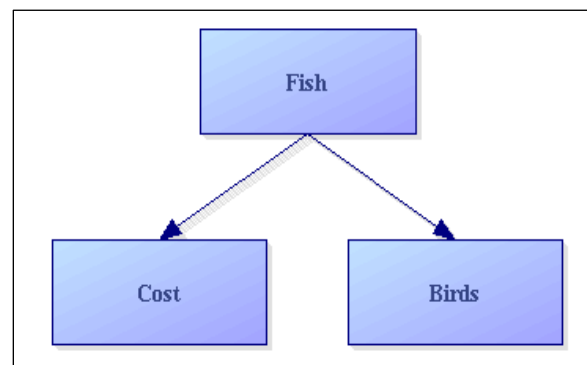
Once the Inconsistency Ratio reaches 0.1 or above, the dialog box will become red. Once this value becomes greater than 0.1 you should examine your rankings for any inconsistencies and attempt to eliminate them.

Consider the following example of inconsistent choices: Suppose we have three criteria: Fish, Birds, and Cost. Then, further suppose these criteria were described in the following manner:

- Fish are Strongly More Important than Birds.
- Birds are Strongly More Important than Cost.
- Cost is Strongly More Important Than Fish.



**Figure 199**  
*Circular Reasoning*



**Figure 198**  
*Consistent Preferences*

There is a subtle but important problem with the description of the relative importance of Fish, Birds, and Cost in this example – it is not logically consistent. We have stated that Fish are more important than Birds, which are more important than Cost, which is more important than Fish, an example of false circular reasoning. These cases need to be considered carefully and examined on an individual basis to avoid creating problems in the analysis.

A diagram representing this can be seen in Figure 192. Note the arrows indicating the circular reasoning; such inconsistencies need to be avoided in order to determine meaningful criteria weights. Using the same three criteria, a consistent set of preferences is also shown in Figure 193.

## Available Ranking Methods

The IWR Planning Suite II MCDA Module provides several ranking methods, with important variations that need to be understood for each. The ranking methodologies include:

1. Weighted Scoring,
2. Compromise Programming,
3. Outranking (Promethee II).

Efficient Frontier method is also included in the methodologies, but it does not give a ranking. Efficient Frontier helps you determine if your solution is dominated or non-dominated. More about dominated and non-dominated appears in the explanation below about Efficient Frontier.

The result is a robust toolset of ranking algorithms which may be used by the planner to evaluate planning sets using multiple criteria. The different ranking algorithms will most certainly produce different results and care should be taken when choosing a final ranking algorithm. Transparency in understanding is extremely important, so selecting an algorithm that the team understands and is comfortable with is a good place to start. One of the benefits of providing alternative ranking algorithms is that different techniques can be used on the same problem and the results analyzed to find commonalities amongst the final rankings. Plans that rank highly regardless of the algorithm chosen can provide the team with confidence that the solution set has been analyzed robustly, and the resulting choice is not sensitive to the algorithm selected.

### Weighted Scoring

The weighted scoring technique is the most common technique used in MCDA and is the simplest algorithm to understand. The algorithm compares plans to one another and assumes higher end values result in more desirable plan. Because of that assumption, the values are normalized to not artificially weight the plans.

Weighted Scoring is a methodology for evaluating plan alternatives within a decision matrix. Weighted scoring of a planning set is performed as follows:

1. Criteria values are normalized by one of three methods: by range, by percent of the maximum, or by percent of the total.
2. Criteria values for maximized criteria are multiplied by their associated weights to obtain raw weighted scores for each maximized criteria.

3. Weights of the minimized criteria are converted to negative and multiplied by the criteria values to obtain raw weighted scores for each minimized criteria.
4. Raw weighted values for alternatives are produced by summing the raw weighted criteria score values for a particular row.
5. Raw weighted scores are again normalized to produce scores that fall between 0 and 1.

Normalization allows criteria comprised of different units, such as dollars and habitat units to be compared with meaningful results. Weighted Scores may be evaluated by a variety of means, including normalization by percentage of maximum criteria value, by range, or by mean values.

Weighted scoring uses a matrix multiplication to arrive at a single score for each alternative. Weighted scoring has three different possible normalization methods that can be applied:

- Normalization to maximum:

$$v = \frac{a}{\max a}$$

- Normalization to range:

$$v = \frac{a - \min a}{\max a - \min a}$$

- Normalization to percent of total: v

$$v = \frac{a}{a + a_1 + a_2 + \dots + a_n}$$

Where

- a = "raw" value of criterion for alternative
- v = normalized value of criterion i for alternative
- n = number of alternatives

All of these techniques are variations on a single normalization method. The choice in a particular normalization technique to use is primarily a matter of judgement by the team. Different techniques will produce different results and the team should take care in selecting a technique that is appropriate for the problem being analyzed and the data that is being used. The measurements used for criterion values will in many cases drive the normalization technique that is most appropriate. While some techniques will perform well when dealing with zero or null values for instance, others will not.

Normalization by range guarantees that each normalized criterion value, whether maximized or minimized, will be in the range of zero to one. The other methods of normalization do not provide this. For this reason, range should be mostly used. Care should be taken in developing the appropriate scale or range to deliver the appropriate proportionality. Normalization by range also introduces a complexity where criteria minimization cannot be handled by simply negating the normalized criterion. So in this method, minimized criteria are no longer converted through multiplying by -1, but the weights of these criteria are taken as negative, thus reducing the score contribution for minimized criteria. This type of normalization does not retain proportionality. Proportionality of scores is retained when normalization by maximum and normalization by percent of total are used.

At the end of each process, "Raw" scores exist, which are then normalized to fall between zero and one.

For more information on normalization methods, the "Trade-Off Analysis Planning and Procedures Guidebook", IWR 02-R-2 contains a good discussion of the topic. The report can be found at:

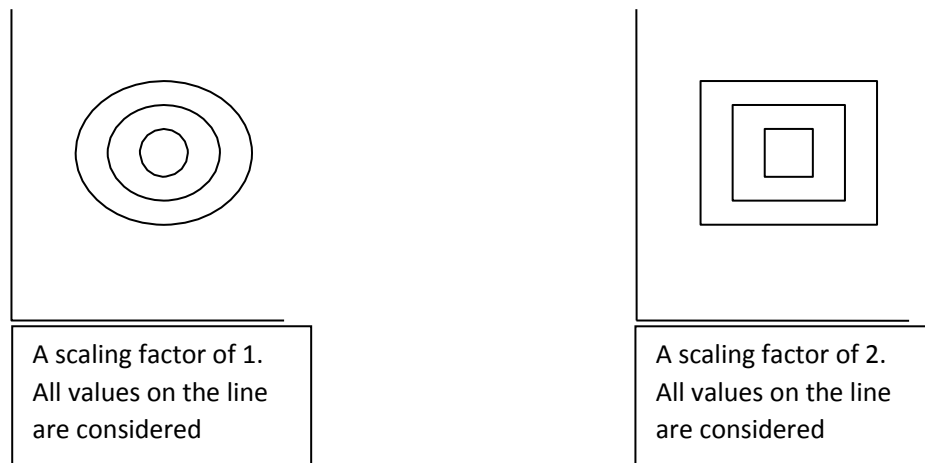
<<http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/02-R-2.pdf>

## Compromise Programming

In this method, an ideal point is defined as the "best" that any criterion in the decision matrix can achieve. Then a "distance metric" is developed for each of the actual plans relative to the ideal point. The closer a plan is to the ideal point, and the higher its rank. The algorithm is called compromise programming because it offers a compromise between multiple solutions. The solutions are not necessarily optimal or non-dominated solutions; rather, they are solutions that fit the preferences of the stakeholders. Compromise programming is a goal aspiration technique.

In its simplest form, the distance metric is taken as the weighted sum of the individual distance metrics for each criterion. However, the literature on compromise programming provides for alternative distance metrics using to express absolute deviation or distance from the ideal point.

For compromise programming a scaling factor can be used to normalize the values. The scaling factor is usually 1, 2, or infinity. The three scaling factors offer different ways to measure the distance from the ideal point or aspiration criteria to the point being measured. In this program the scaling factors used are 1 and 2. The users can choose the scaling factors by checking the appropriate bubble in the "Deviation from Ideal" portion on the ranking screen. In the program, a scaling factor of 1 is referred to as being "weighted equally." A scaling factor of 2 is referred to as "weighted proportional to magnitude." A graphical representation of how the scaling factors measure distance appears in Figure 193. The scaling factors cannot be compared to one another because they measure distance in a different way.



**Figure 200**  
**Compromise Programming Scaling Factors**

The final equation for each of the alternatives is below:

$$I f w(i)^p x \frac{(f(i^*) - f(i))^{1/p}}{f(i^*) - f(i^-)}$$

- $w(i)$  = weight for the criteria  $i$
- $f(i^*)$  = optimal value or the maximum or minimum value in the existing
- criteria depending on if the criteria is maximized or minimized.
- $f(i)$  = least optimal value or the minimum if the criteria is maximized and the maximum if the criteria is minimized
- $f(i)$  = criteria for the alternative being evaluated
- $p$  = scaling factor. In this program either 1 or 2.

The criteria are summed across the plans being evaluated. The plans are then ranked according to how close they are to the ideal with a minimum value being the most desirable.

For absolute deviation, all deviations are weighted equally. For pythagorean distance, the deviations are weighted in proportion to their magnitude. As such, use of the pythagorean distance places a greater emphasis on being closer - there is a larger penalty for deviations from the ideal point.

## Outranking

The Outranking method used by the MCDA Module is PROMETHEE II. Promethee stands for Preference Ranking Organization METHod for Enrichment Evaluations II. Outranking methods compare variables

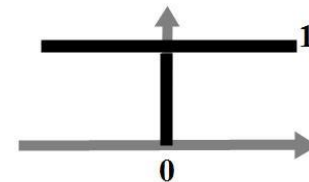
pairwise, developing a numerical matrix showing the degree to which each alternative is preferred over another alternative. The numbers in this matrix are used to develop an ordering which shows the strength of preference of one alternative over another. PROMETHEE II does not give a clear preference as the weighted scoring method and compromise programming do; rather, it gives preorders (changes in rank) and shows preference for plans based on how they compare to the criteria of other plans.

Each criteria can be assigned its own Preference Function, from the choices of Strict, Threshold, Linear Over Range, Stair-Step, and Linear with Threshold.

## Preference Functions:

### Strict

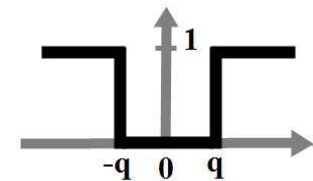
There is a strict preference for alternative A over alternative B at any level by which the rating of absolute value of A exceeds the rating of absolute value of B. Neither the Absolute Preference nor Indifference Value need be identified for this preference function. When they are equal there is no preference and the value is zero.



$$H(d) = \begin{cases} 0 & \text{if } d = 0 \\ 1 & \text{if } |d| > 0 \end{cases}$$

### Threshold

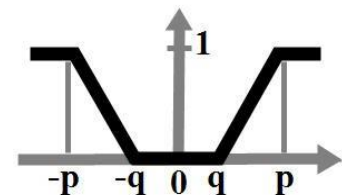
For this method an Indifference Value must be identified. Alternative A must exceed Alternative B by an amount q greater than or equal to the indifference value (q) to be preferred over B. The user defines the indifference threshold.



$$H(d) = \begin{cases} 0 & \text{if } d = 0 \\ 1 & \text{if } |d| > q \end{cases}$$

### Linear With Threshold

For this method an Absolute Preference value, p, and an Indifference Value, q, must be identified. This says that any two alternatives that differ by the Indifference value or less cannot be distinguished among one another. As the difference grows closer to the Absolute Preference one alternative can be said to be better than the other alternative. Once the difference reaches the Absolute Preference, one alternative can be said to be absolutely better than another alternative.

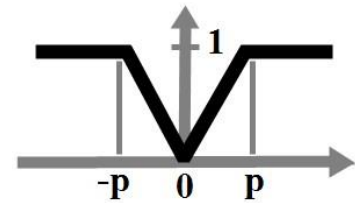




$$H(d) = \begin{cases} 0 & \text{if } |d| \leq q \\ \frac{|d| - q}{p - q} & \text{if } q < |d| \leq p \\ 1 & \text{if } |d| > p \end{cases}$$

### Linear Over Range

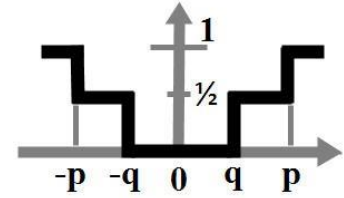
For this method an Indifference Value must be identified. This indicates that as the difference between A and B moves from a value 0 to a value p, the preference function increases linearly from zero to one over that range of differences. That is, the greater the difference past the threshold value of 0, the more A is preferred to B.



$$H(d) = \begin{cases} \frac{|d|}{p} & \text{if } |d| \leq p \\ 1 & \text{if } |d| > p \end{cases}$$

### Stairstep (Level Criterion)

For this method an Absolute Preference value,  $q$ , and an Indifference Value,  $p$ , must be identified. This says that a difference less than  $q$  gives a preference of zero, a difference between  $q$  and  $p$  gives a preference of one half, and a difference greater than  $p$  gives a preference of one.



The PROMETHEE II functions rely on four variables within this program.

$d$  = Difference between the two criterion. Each criterion is compared to every other criterion.

$q$  = Absolute preference. If the absolute value of the difference of the two criteria being compared is greater than  $q$ , then a preference can be shown for one criterion over another, either absolute or in decimal form.  $q$  marks the bottom boundary of the user's preference.

$p$  = Indifference. If the absolute value of the difference of the two values being compared exceeds this number, then an absolute preference can be shown for one preference over another. Below this number, the preference is less than 1.  $p$  marks the top boundary of the user's preference.

$H$  = preference function for the two criterion being compared. This value will range between 0 and 1.

The user chooses a performance function for each of the criteria used in the study. Each preference function has a corresponding set of equations to figure the  $H$  variable. Each of the plan's individual criterions is compared against each other in a preference table. For example, if you want to look at the cost of construction for a set of plans, one would set up a table similar to Table 19.

Table 19. Comparing Plans			
	Plan 1	Plan 2	Plan n
Plan 1	0	$H(d)$ for Plan 2 compared to Plan 1	$H(d)$ for Plan n compared to Plan 1
Plan 2	$H(d)$ for Plan 1 compared to plan 2	0	$H(d)$ for Plan n compared to Plan 2
Plan n	$H(d)$ for Plan 1 compared to Plan n	$H(d)$ for Plan 2 compared to Plan n	0

If there is a preference, the preference function assigned to the criteria is used to determine  $H$ . The  $H$  variable comparing each of the plans is used to populate the preference table. After all of the criteria have been compared, the  $H$  values are added for each of the criteria into an absolute preference table.

To determine the complete preorder, the  $\Phi$  ( $\Phi$ ) values need to be determined from the absolute preference table.

$$\Phi(a) = \Phi^+(a) - \Phi^-(a)$$

$\Phi(a)$  = net outranking flow. Referred to as the score in the program

$\Phi^+(a)$  = positive outranking flow. In the previous chart, this is the sum down a column.

$\Phi^-(a)$  = negative outranking flow. In the previous chart, this is the sum across a row.

Sorting the plans by the net outranking flow gives a complete preorder of the plans. The preorder in the program gives the decision maker an idea of the plan with the stronger preference. It does not give the decision maker a gauge for determining how close the higher ranked plans are to an optimal plan. By design, PROMETHEE gives a measure of tolerances as determined by comparing every plan to another.

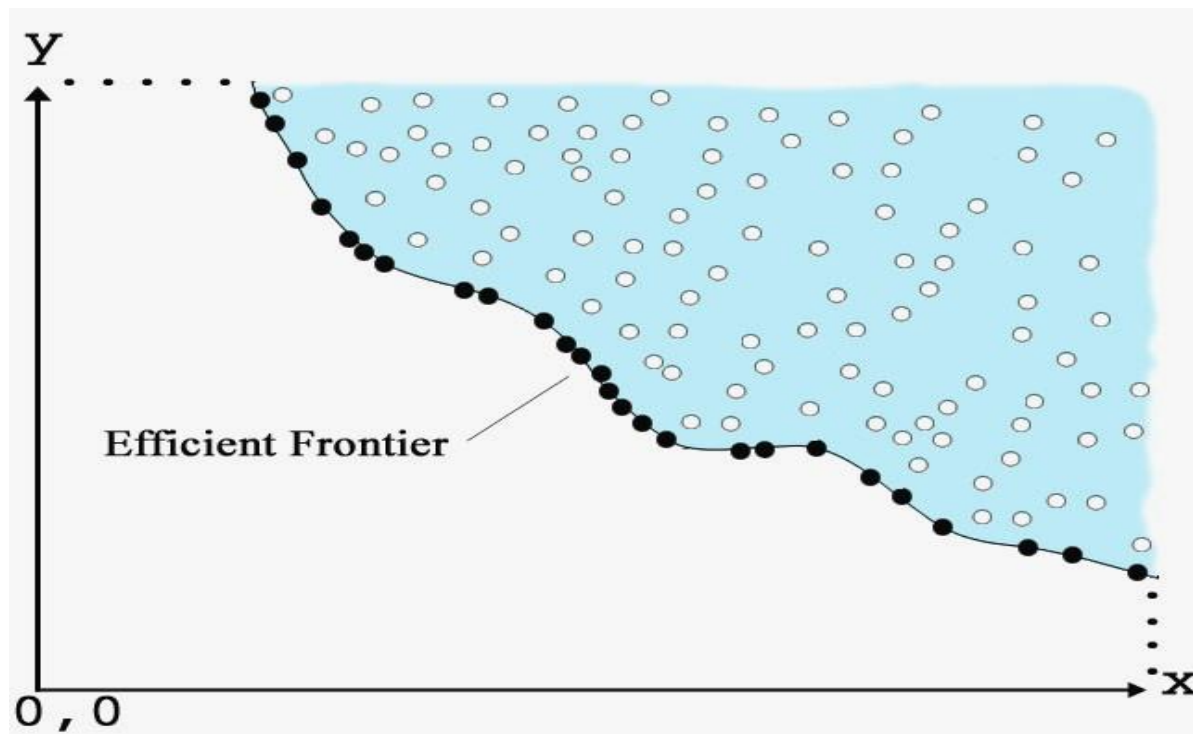
PROMETHEE is a useful method for setting restrictions or tolerances for error; however, it is not a tool for setting optimal limits. PROMETHEE helps the decision maker take into account variances in limitations. With this added flexibility there is, however, also more room for error.

The decision maker will rely on her team, but even with expert knowledge, the decision to use a particular parameter or criteria may be arbitrary. According to Brans et al., small deviations in the parameters used can lead to deviations in the reorder. The model can be calibrated to find the most reasonable values for the parameters, but this will add additional time and cost.

## Efficient Frontier

The Efficient Frontier method is so named because it identifies a multi-dimensional frontier of cost-efficient points. The method identifies those plan alternatives that are non-dominated, meaning that there is no plan that provides more of all outputs for less of all inputs. This is a traditional step in screening alternatives in multi-criterion decision tasks. The plans that are considered dominated can be eliminated from consideration. See Figure 194 for an illustration of the Efficient Frontier. The dark dots on the lines are those solutions considered non-dominate.

Note that the concept of dominance does not imply any valuation of the inputs or outputs, only an attempt to find those plans that are unambiguously “better” than other candidate plans from the point of view of giving more output for fewer (or the same) inputs, or the same output for less input. The relative value of input and output is not considered, nor does the concept of incremental cost analysis come into play at this step.



**Figure 201**  
**The Efficient Frontier of Dominant Plans**

Efficient frontier is not used to rank a set of plans. It simply determines dominance in a solution set. The output is a set of solutions to be further evaluated.

The problem is easily understood in two dimensions, with an input (cost) and an output variable (Environmental Quality or EQ). Plan B is dominated by Plan A because Plan B costs more, and it results in less output. There is no dominance relationship between plans A and C. Plan C costs more, but gives more output, so it is not dominated. If all plans are plotted, then the non-dominated plans are those shown below: Plans A, C, D, E, and F.

**Table 20.**  
**Ex. of Dominate Solution**

Plan	Cost	EQ Output
A	100	30
B	200	25
C	145	40
D	150	60
E	250	65
F	350	75
G	300	10
H	175	53

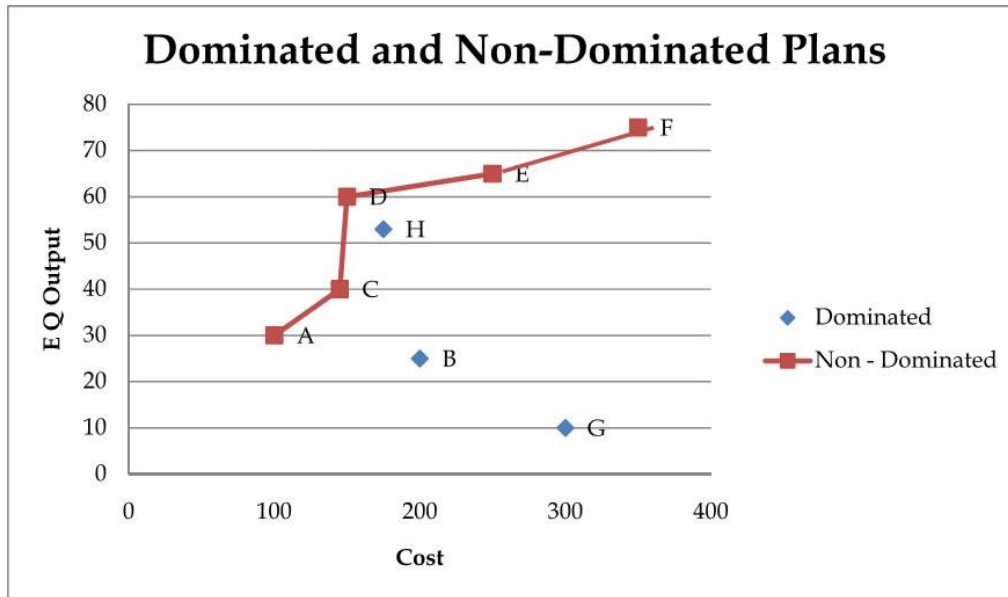


Figure 202

Graph of Dominated and Non-Dominated Plans

For multiple variables, the general concept can be extrapolated from the single-variable example outlined. That is, a pairwise comparison of plan alternatives is performed, determining which plans are dominated with the resultant non-dominated plans comprise the efficient frontier.

The program runs an algorithm developed using R Statistical package. The algorithm works by comparing pairs in each of the different columns as follows:

1. Pre-process the decision matrix, by multiplying all output values by  $-1$ . This simplifies the definition of the dominance relationship between two rows. Row A dominates row B if, for all variables,  $A[i] \leq B[i]$ .
  2. Sort the decision matrix by all columns, in ascending order.
  3. Initialize all rows to "non-dominated".
  4. Start at the first row of the sorted decision matrix, and check for dominance of that row against all other rows. If a row is dominated, flag it as dominated. Continue for all rows of the matrix. This constitutes one pass through the matrix.
  5. Proceed to the next non-dominated row after the 1<sup>st</sup> pass. Repeat the same process but check only those rows that have not yet been flagged as dominated.
  6. Continue until the decision matrix has been completely processed, i.e. until there is no further remaining non-dominated row below the row currently being processed.
  7. The resulting set of rows that remain flagged as non-dominated (i.e. have not been flagged as dominated) represent the complete non-dominated set.
  8. The output columns are again multiplied by  $-1$  to restore their original values.
- (R. Males, 9)

## Section 8

# MCDA Software Procedures

## Adding New Criteria

The user needs to identify the criteria that will be used to rank these plans by other criteria deemed appropriate to assist us in choosing the ‘best of the best.’

Suppose, just for example, that a new study has been conducted which concludes there to be a measurable area deer population increase related to flood damage reduction. The study also predicts that any work in the area would have an effect on that population. So, we want to add a new criterion, which will demonstrate the effect on the deer population. DeerPopIndex is a calculated value demonstrating the effect on the Deer population. We also want to add the criteria Acceptability, which is a value between 1 and 5 representing the acceptability of the particular alternative, 1 being unacceptable and 5 being most acceptable.

MCDA Criteria correspond to Plan Study variables, so we would add these new criteria as Plan Variables through the Planning Study Properties form as shown below.

Planning Study [Planning Study 5] Properties

Name: Planning Study

Description: Planning Study

Variables

Name	Units	Description	Variable Type	Derived	Derived Function	Minimum	Maximum	Visible
AAHU	AAHU	AAHU	Decimal	<input type="checkbox"/>				<input checked="" type="checkbox"/>
Acceptability		Acceptability	Decimal	<input type="checkbox"/>				<input checked="" type="checkbox"/>
DeerPopIndex		DeerPopIndex	Decimal	<input type="checkbox"/>				<input checked="" type="checkbox"/>
FDRBEN		FDRBEN	Decimal	<input type="checkbox"/>				<input checked="" type="checkbox"/>
TOTCOST		TOTCOST	Decimal	<input type="checkbox"/>				<input checked="" type="checkbox"/>

Add

Attributes

Name	Type	Description	Visible
Cost Effective	Integer	Non-Cost Effective, Cost Effective, or Best Buy	CE/ICA Analysis
Rank	Double	MCDM Ranking	MCDM Ranked
Score	Double	MCDM Score from Ranking	MCDM Ranked
Plan of Interest	Yes/No	Plan of Interest	Never
#CE	Integer	Number of Cost Effective Plans	Uncertainty CE/ICA Parent
#BB	Integer	Number of Best Buy Plans	Uncertainty CE/ICA Parent

Add

OK Cancel

**Figure 203**  
**Adding New Criteria**

Add these variables as new criteria, by pressing the Planning Study Properties form 'OK' button to [add the new variables](#) to the plan study as MCDA criteria. Note that when Variables and Attributes are initially entered, they are listed in their input order.

However, when the Planning Study form is opened the next time, the Variables and Attributes are reorganized into alphabetical order.

## Entering Criteria Values

After defining the criteria that will be used in the analysis, we now need to add some values to our new criteria to make them useful. Currently our new criteria DeerPopIndex and Acceptability have no values associated with them for each alternative. Therefore, it has no real effect on our ranking method. Enter the following information as a [user-entered set](#) as shown below.

Plan	Plan Description	AAHU	FDRBEN	TOTCOST	DeerPopIndex	Acceptability
No Action Plan	Default No Action Plan	0	0	0	0	0
1 - Local Setback		783	10	1,000	53	2
2 - Intermediate Setback		795	15	1,200	56	1
3 - Ring Levee		895	30	2,700	47	4
4 - Local Setback Up/Inter Setback Down		642	35	2,750	61	1
5 - Inter Setback Up/Local Setback Down		937	70	3,048	49	3
6 - Inter Setback Up 32/Local Setback Down 32		888	75	3,687	37	5

**Figure 204**  
**Entering Criteria Values**

Once these values are entered the user should click the 'Save Changes' button available in the bottom right corner of the Plan Editor to save the changes.

**Figure 205**  
**Entering Criteria Values**

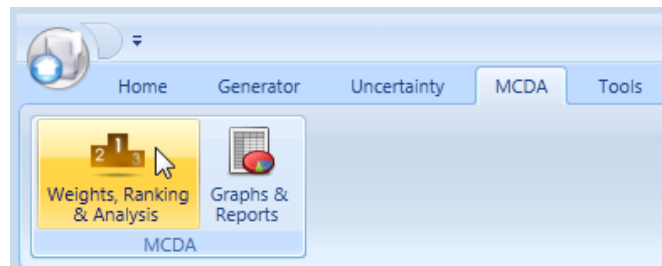
## Excluding Existing Criteria

We also need to exclude some variables as criteria from evaluation. MCDA criteria correspond to planning study variables, so we would identify the criteria to exclude as plan variables through the Planning Study Properties form and use the Visible property to designate which variables will be used in ranking as shown below. Those variables that will not be utilized in the ranking will be unchecked in order for them not to be displayed in the MCDA module.

Ensure that the Visible checkbox in the Variables table is not checked for the variables AAHU and FDRBEN. Marking the checkboxes as hidden will remove the variables from the list of MCDA criteria, and we do not want these variables to be available as MCDA criteria.

## Launching the MCDA Module

The IWR Planning Suite II MCDA Module may be launched from the MCDA ribbon. Select the 'Weights, Ranking and Analysis' button as shown below.

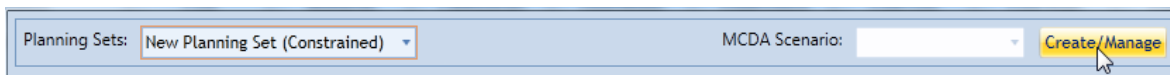


**Figure 206**  
**Launching the MCDA Module**

## Working from Existing Planning Set Data

You can use data from existing planning sets in the currently opened planning study.

To begin the user should select a planning set from the list and then create a MCDA Scenario using the 'Create/Manage' button.



**Figure 207**  
**Launching Create/Manage MCDA Scenarios**

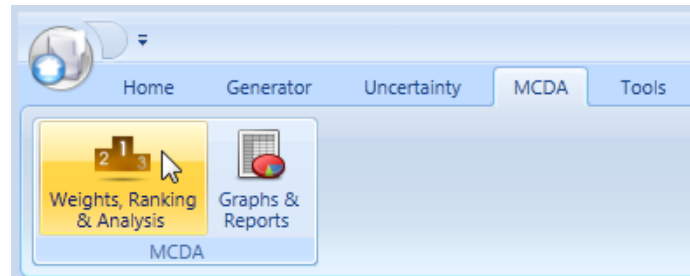
Clicking on the 'Create/Manage' button launches the Manage MCDA Scenarios for planning set '*planning set name*.' The user can simply enter a name and description and click 'OK' if they would like to create one new MCDA scenario at this time. However, this form also has capabilities to create additional MCDA scenarios using the 'Add New' button, clone an existing MCDA scenario by selecting the appropriate scenario and clicking the 'Clone' button, or delete MCDA scenarios by checking the Delete check box for the appropriate scenario and selecting the 'Delete Selected' button. Note the 'Clone' button will remain disabled until an



MCDA scenario is selected and the 'Delete Selected' button will remain disabled until one or more rows have the checkbox for Delete selected.

## Ranking Planning Sets

Once criteria are set up properly, we can rank the planning set. Click on the 'Weights, Ranking & Analysis' button on the MCDA ribbon as shown below.



**Figure 208**  
**Launching Weights, Ranking & Analysis**

The Multi-Criteria Decision Analysis form shown below will now launch.

Multi-Criteria Decision Analysis

Planning Sets: MCDM Example (Generated) MCDA Scenario: MCDM Example Create/Manage

Ranking Weights

Rank Method

☒ Weighted Scoring ☐ Outranking ☐ Efficient Frontier ☐ Compromise Programming

Criterion	Weight	Min/Max
DeerPopIndex	1	Maximize
FDRBEN	1	Maximize
TOTCOST	1	Maximize

Normalization Methods

☒ By Range ☐ By Percent of Max ☐ By Percent of Total

Discard All Changes Save Changes

Perform MCDA

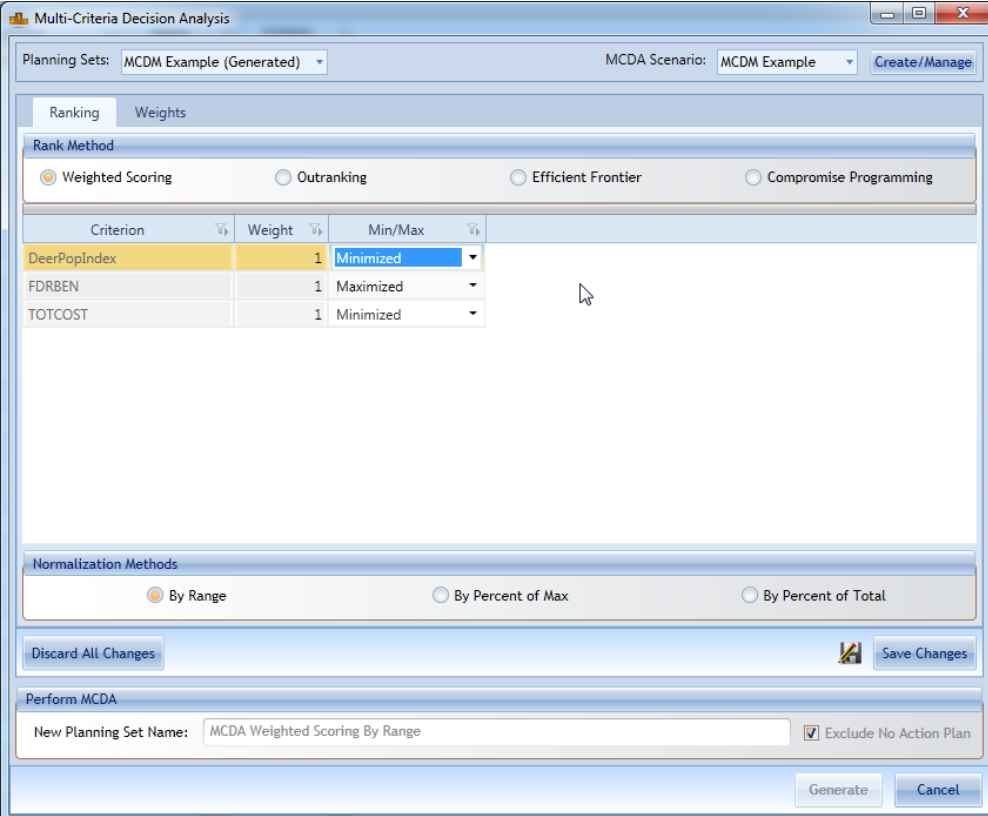
New Planning Set Name: MCDA Weighted Scoring By Range ☒ Exclude No Action Plan

Generate Cancel

**Figure 209**  
**Multi-Criteria Decision Analysis**

You will notice the word Maximized to the right of each of the criteria. Maximized tells the program that higher values are more desirable. Minimized tells the program that lower values are more desirable. These min/max are optimization options. For more information refer to the [Criteria Optimization](#) section.

TotalCost should be set to Minimized, because we want the optimal alternative to have the lowest possible cost. Please recall from the initial description of the scenario that the values we entered for DeerPopIndex indicate negative effects on the Deer population, so it too is optimal when minimized. For Acceptability, the higher the number, the higher the level of acceptability, which means it should be set to Maximized. Set the optimization, labeled Min/Max, for each Criterion as shown in the form below. Click 'Save Changes' when complete.



Multi-Criteria Decision Analysis

Planning Sets: MCDM Example (Generated) MCDA Scenario: MCDM Example Create/Manage

Ranking Weights

Rank Method

☒ Weighted Scoring ☐ Outranking ☐ Efficient Frontier ☐ Compromise Programming

Criterion	Weight	Min/Max
DeerPopIndex	1	Minimized
FDRBEN	1	Maximized
TOTCOST	1	Minimized

Normalization Methods

☒ By Range ☐ By Percent of Max ☐ By Percent of Total

Discard All Changes Save Changes

Perform MCDA

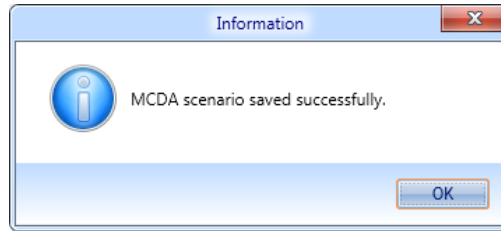
New Planning Set Name: MCDA Weighted Scoring By Range ☒ Exclude No Action Plan

Generate Cancel

**Figure 210**  
**Minimize or Maximize Variable Selections**

Notice that the criteria weights are by default all one. This will become important later on when we change the weights.

Click 'OK' on the dialog that states the MCDA scenario saved successfully.



**Figure 211**  
**MCDA Scenario Saving Verification Message**

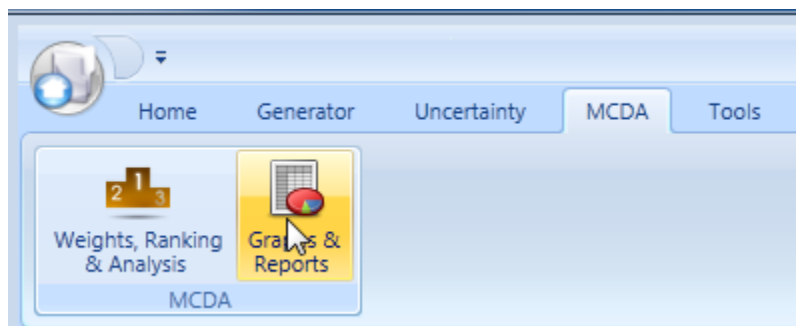
The normalization method defaults to By Range, and the “Exclude No Action Plan” checkbox is selected by default and will be the values used in this example. The default values will usually be appropriate for each ranking method for optimization and No Action plan exclusion. While a default planning set name is provided automatically based on the rank method and options selected, you can rename the MCDA set. From the New Planning Set Name field, you may rename the default planning set name to a more specific name. Then press ‘Generate’ to generate a new ranked planning set according to the ranking and optimization methods defined. The resulting set will look similar to that shown below.

Plan	Plan Description	Acceptability	DeerPopIndex	TOTCOST	Rank	Score
1 - Local Setback		2	53	1,000	3	0.527
2 - Intermediate Setback		1	56	1,200	5	0.378
3 - Ring Levee		4	47	2,700	2	0.566
4 - Local Setback Up/Inter Setback Down		1	61	2,750	6	0.116
5 - Inter Setback Up/Local Setback Down		3	49	3,048	4	0.412
6 - Inter Setback Up 32/Local Setback Down 32		5	37	3,687	1	0.666

**Figure 212**  
**Example MCDA Set**

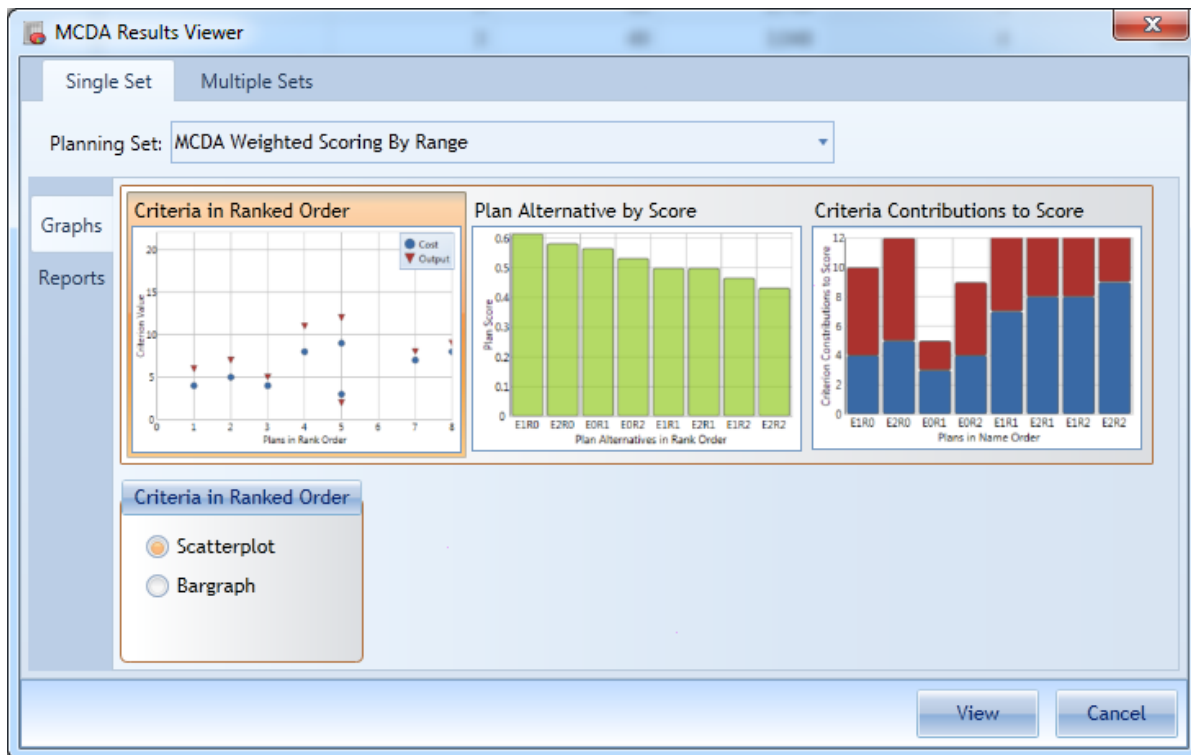
## Graph Ranked MCDA Planning Set Results as Bar Graph

To graph the MCDA results, click on the ‘Graphs & Reports’ button on the MCDA ribbon as shown below.



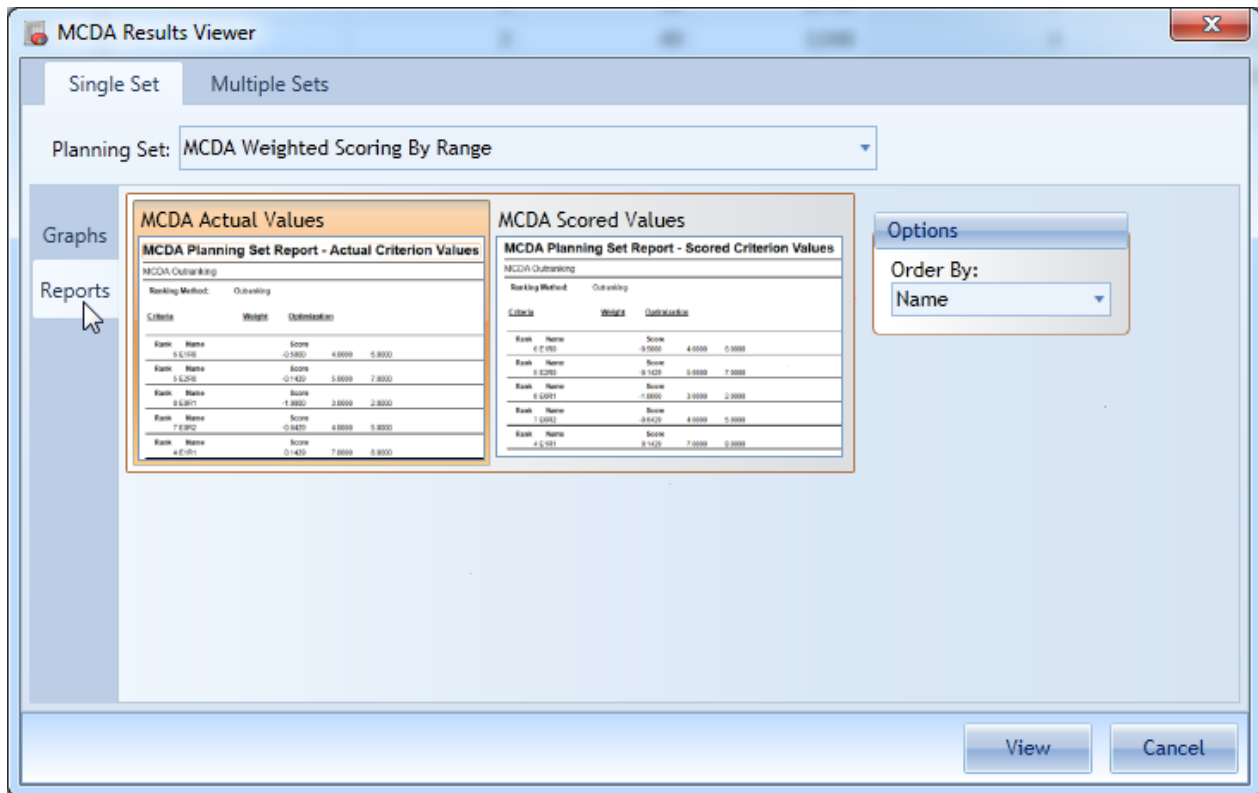
**Figure 213**  
**Launching MCDA Graphs & Reports**

After selecting the ‘Graphs & Reports’ button the MCDA Results Viewer will launch as shown below.



**Figure 214**  
**MCDA Single Set Graphing Options**

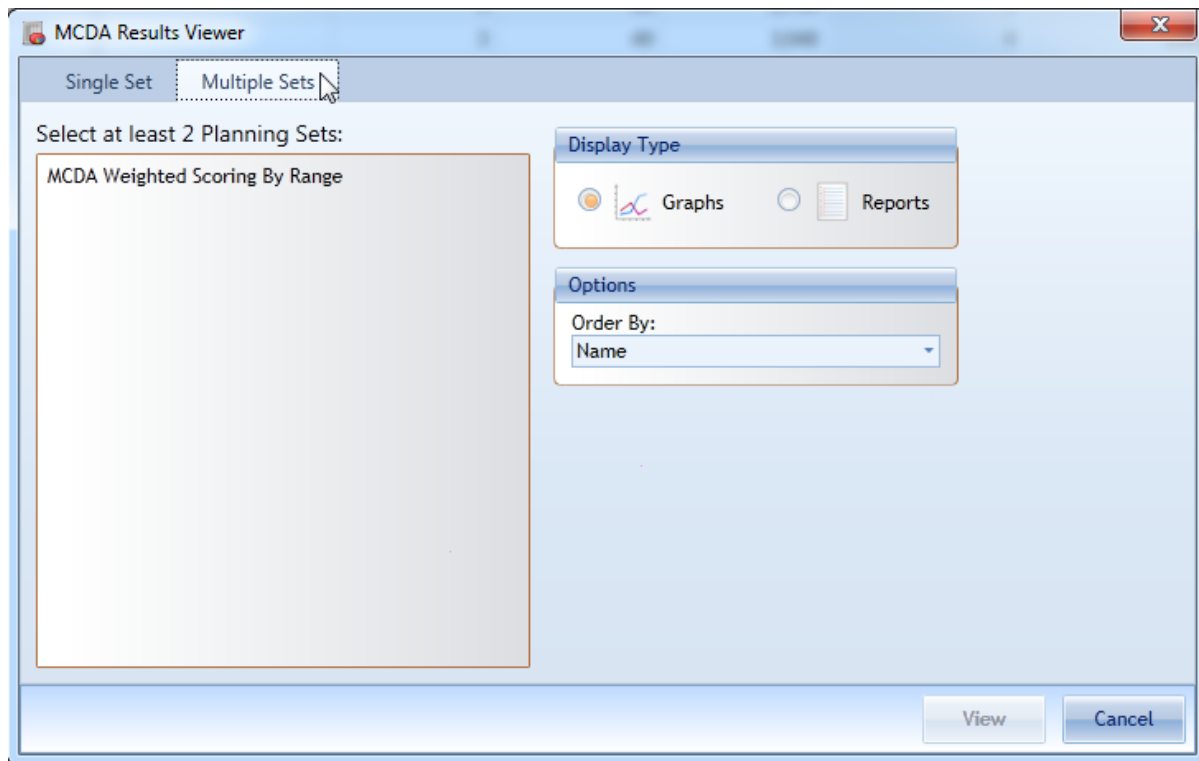
If the user wishes to run a graph over a single set of MCDA results they can select the Planning Set from the list and then select the graph they would like to view. The user has the option to view a Criteria in Ranked Order, Plan Alternative by Score, or Criteria Contributions to Score.



**Figure 215**  
**MCDA Single Set Reporting Options**

If the user wishes to run a report they should select the Reports option as shown below. The user will then have the option to view a MCDA Actual Values or MCDA Scores Values report.

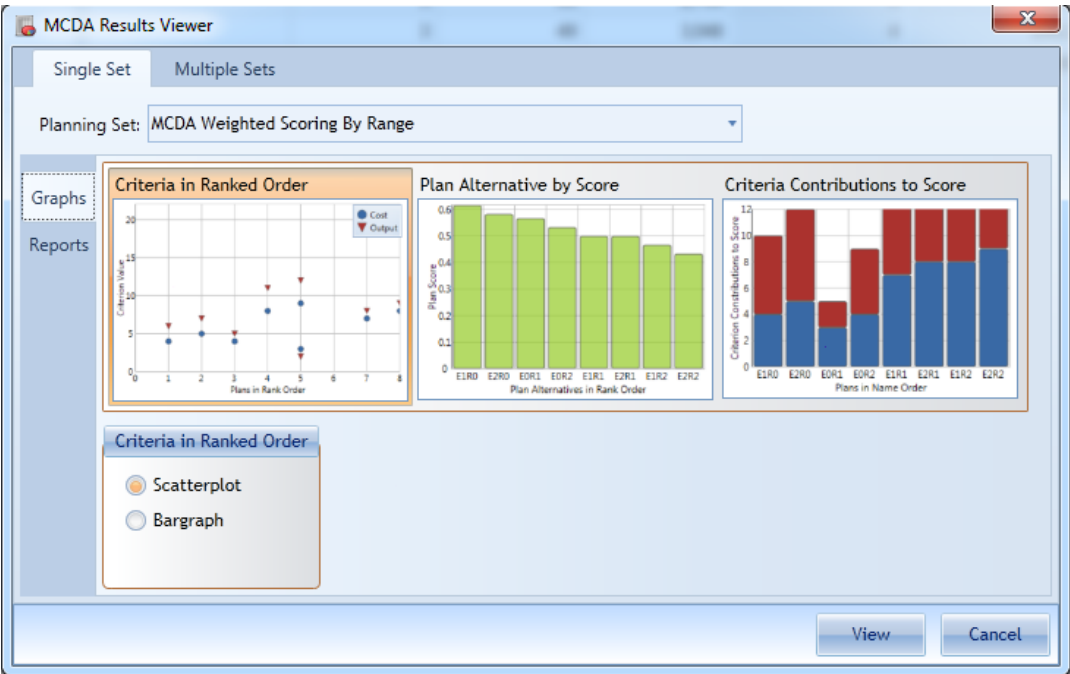
If the user wishes to view a graph or report that compares the results of two MCDA sets they should select the Multiple Sets tab as shown below.



**Figure 216**  
**MCDA Multiple Set Comparison Options**

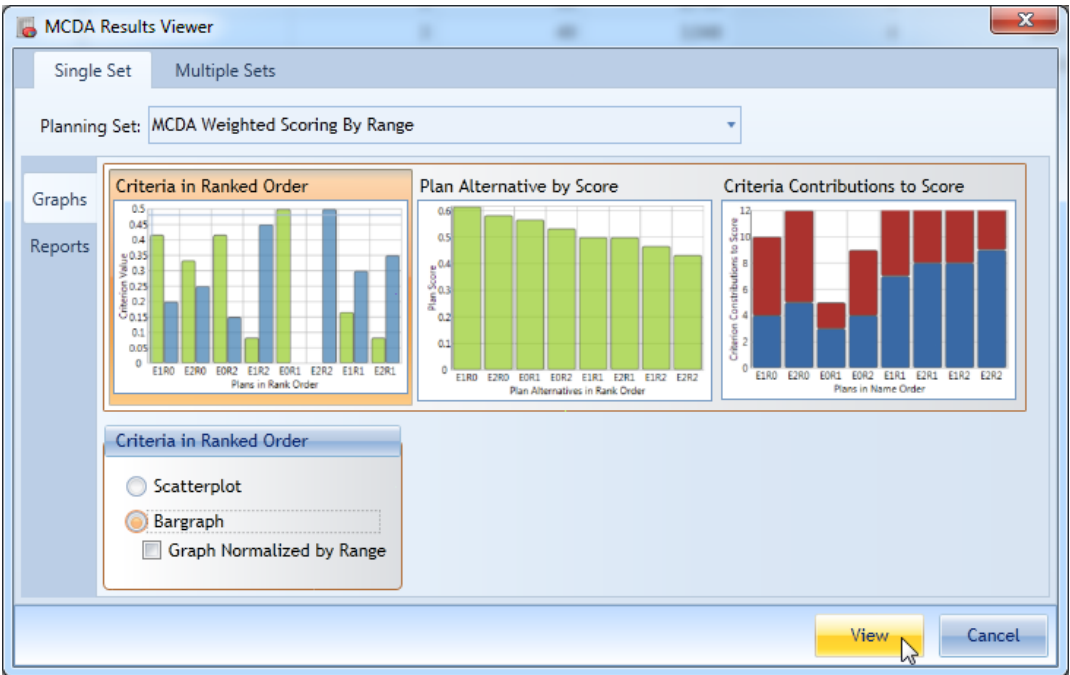
The user can then select whether they wish to view a graph or reports after selecting their planning sets.

In this example we are going to create a 'Criteria in Ranked Order' graph. The user should start by selecting the planning set, such as "MCDA Weighted by Range" from the Planning Set field and then ensure 'Criteria in Ranked Order' is selected as the graph as shown below.



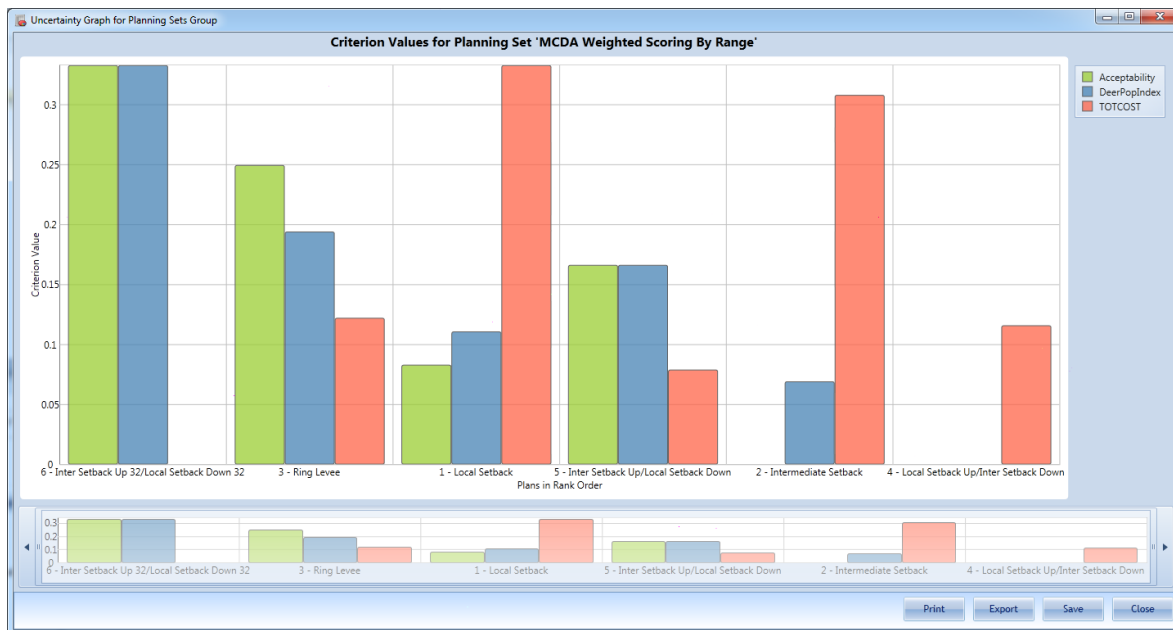
**Figure 217**  
**Selecting MCDA Planning Set**

Once the selections have been made the user can select Bargraph in the Criteria in Ranked Order options below the graph and then click 'View' to view the resulting graph.



**Figure 218**  
**Graphing Options**

The bar graph for the currently selected planning set could look like the one shown below, for example.

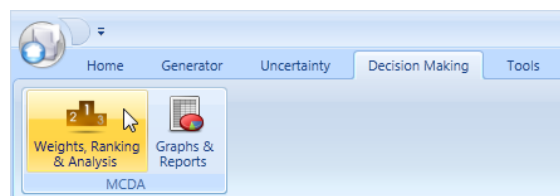


**Figure 219**  
**Example Criteria in Ranked Order Graph**

The graph tool also allows the user to print, export or save the graph using the options available at the bottom of the graph.

## Assigning Weights Manually

We are now going to add some weights to our criteria. Weights will represent the importance of each criterion and are used in the ranking process to determine the alternative scores and ranks. Changing the weights on criteria affects the scores and therefore the rankings assigned to different plan alternatives. From the MCDA ribbon select **Weights, Ranking & Analysis**.

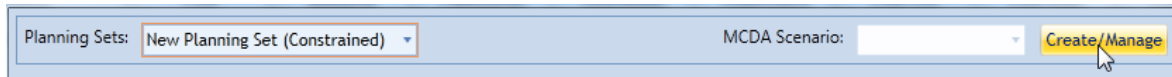


**Figure 220**  
**Launching Weights, Ranking & Analysis**

You can use data from existing planning sets in the currently opened planning study.

To begin the user should select a planning set from the list and then create a MCDA Scenario using the 'Create/Manage' button.





**Figure 221**  
**Launching Create/Manage MCDA Scenarios**

Clicking on the 'Create/Manage' button launches the Manage MCDA Scenarios for planning set '*planning set name*.' The user can simply enter a name and description and click 'OK' if they would like to create one new MCDA scenario.

Next the user should select the Weights tab on the form as shown below.

Criterion	Weight	Normalized Value
Acceptability	1	0.333
DeerPopIndex	1	0.333
TOTCOST	1	0.333

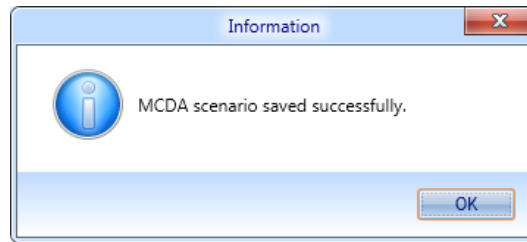
**Figure 222**  
**Multi-Criteria Decision Analysis Weights**

On the Manual Creation of Weights form, you will see each of the criteria used in our study. Notice that each criterion has a weight of one. This means that all the criteria are of equal importance to the scenario. Change your weights to match the values shown below, and then click "Save Changes."

Criterion	Weight	Normalized Value
Acceptability	0.85	0.34
DeerPopIndex	0.75	0.3
TOTCOST	0.9	0.36

**Figure 223**  
**Assigning Weights**

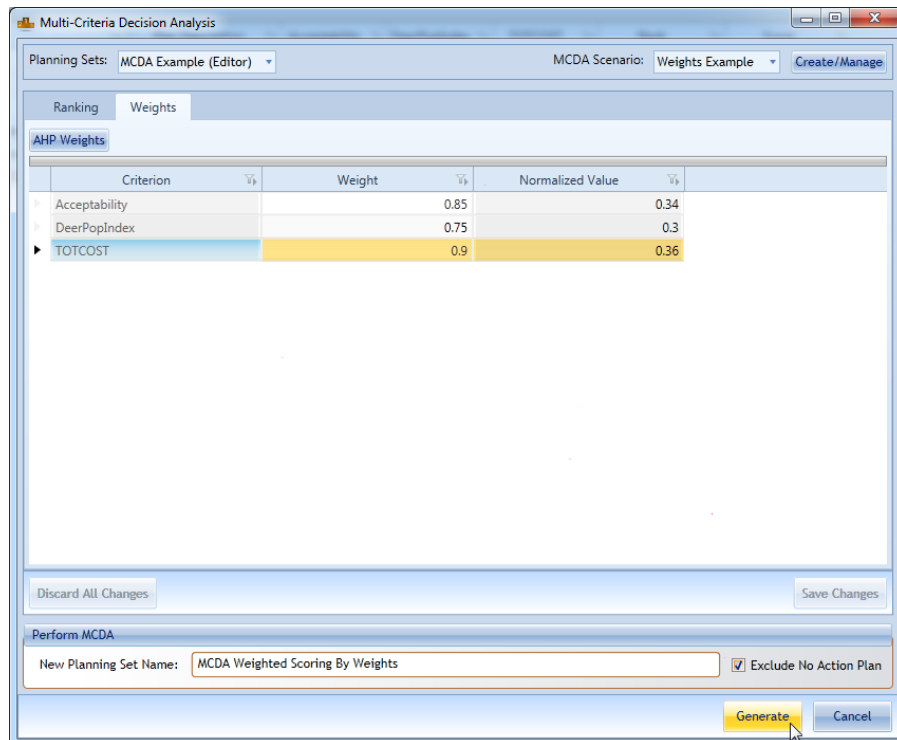
The user can click the 'OK' button on the dialog indicating that the MCDA Scenario was saved successfully.



**Figure 224**  
**MCDA Scenario Saved Verification Message**

Any relative weights can be entered for the various criterion and the weights will be normalized to a standard value in the range from zero to one. This value is represented in the non-editable "Normalized Value" field.

Click the 'Generate' button to generate a set using the entered weights.

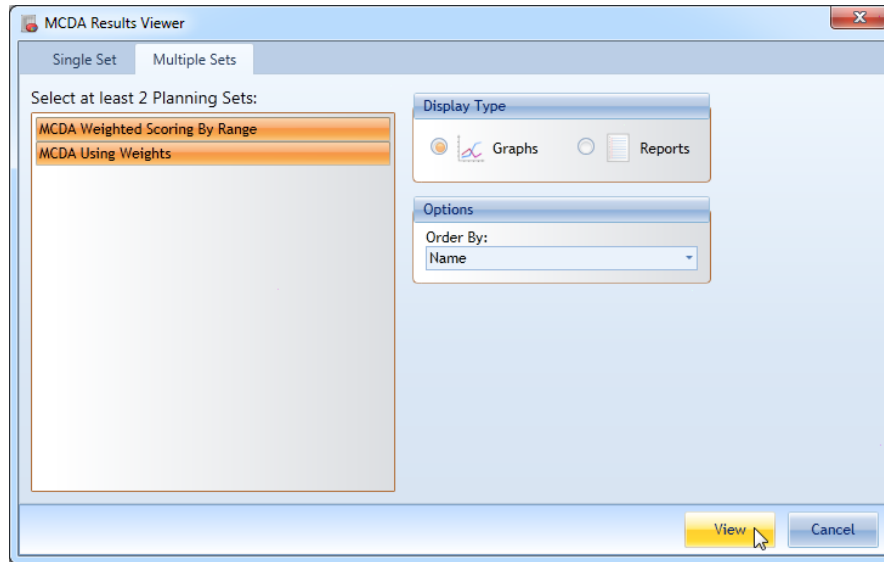


**Figure 225**  
**Generating MCDA Set**

Try re-ranking the original planning set using the weights and compare it to the equally weighted ranking by selecting the two planning sets and looking at their "Rank" attribute.

## Graph Comparison of Multiple Planning Sets

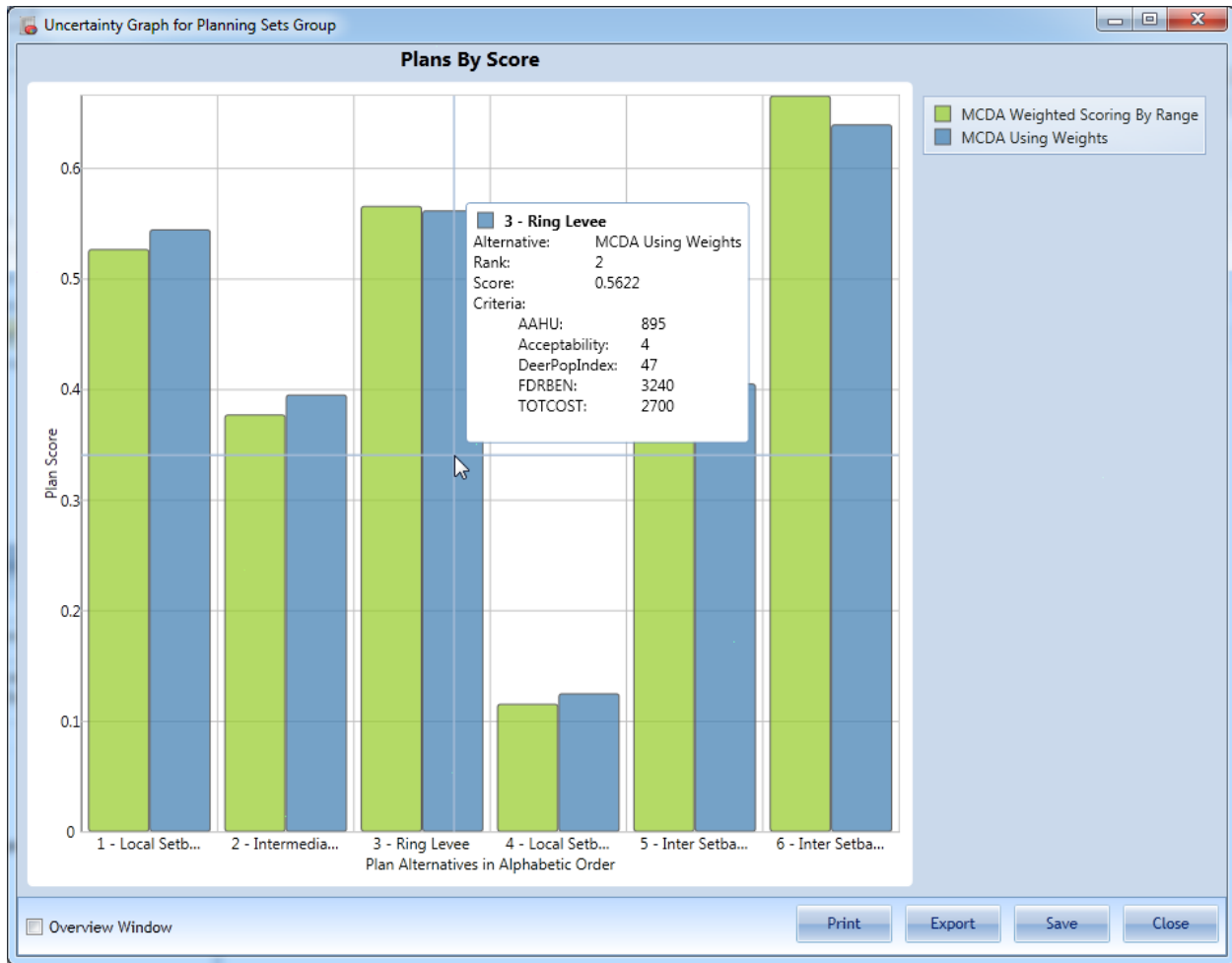
If the user would like to compare the two MCDA planning sets they can use a multiple planning set graph or report. The user should click the 'Graphs & Reports' button available on the MCDA ribbon to launch the MCDA Results Viewer. Next the user should select the graph option on the Multiple Planning Sets tab, and select both MCDA sets.



**Figure 226**  
**Graph Comparison of Multiple MCDA Sets**

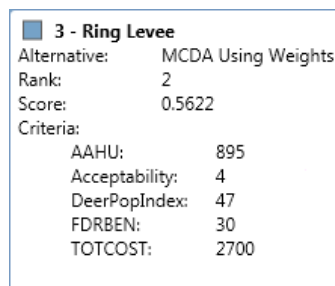
Next the user can click the 'View' button to see a graph that compares the two result sets.

Examine the plan scores and rankings. Then, hover the mouse over the bars of plan alternatives so that the mouse pointer changes from an arrow to a pointing hand icon as shown on the multi-scenario Plans By Score graph.



**Figure 227**  
**Multi-Scenario Plans by Score Graph**

Hover on the bars to bring up an information dialog that shows which plans made which ranks. It should look something like what is shown below, although the specific values shown may be different from those shown here.



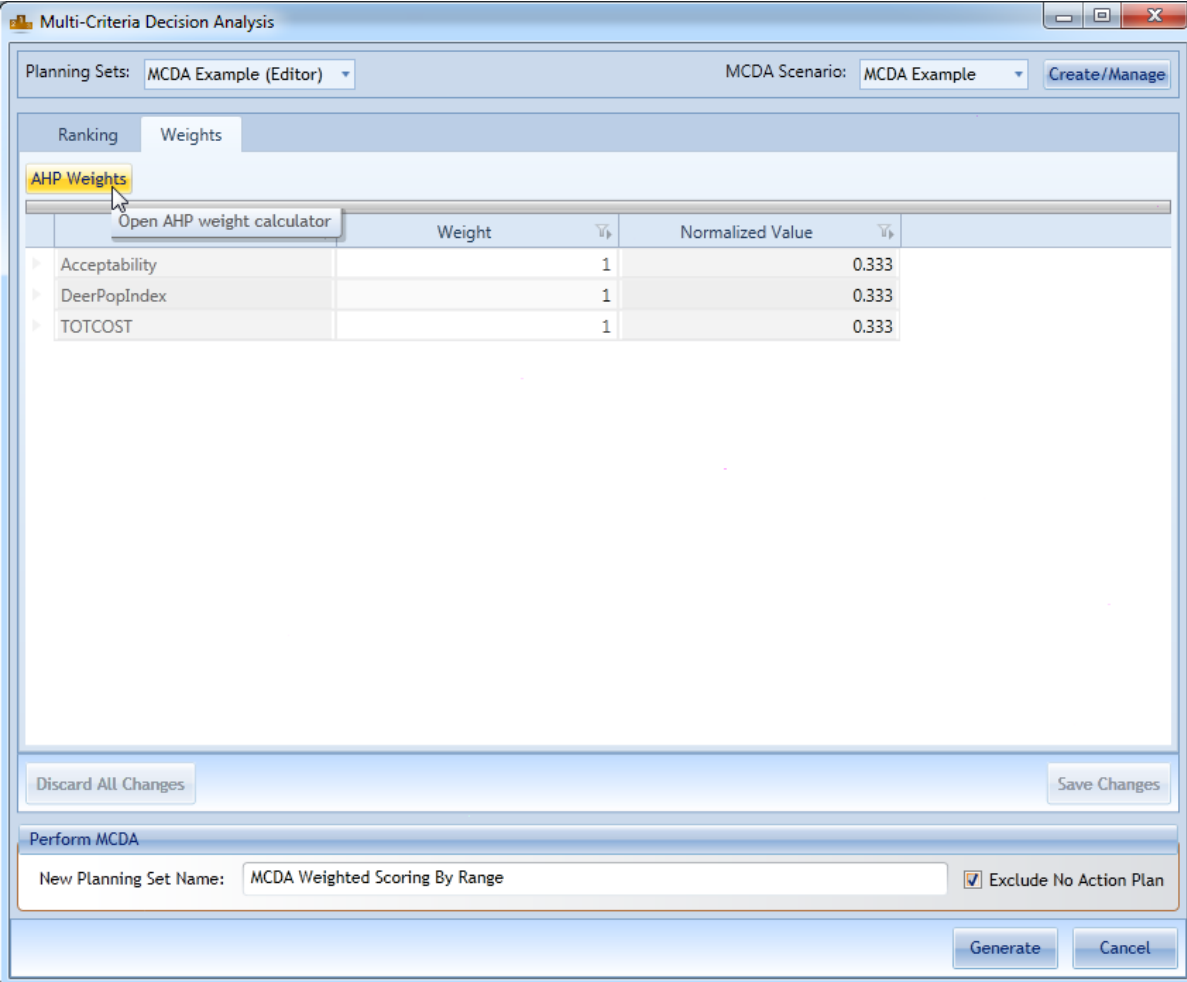
**Figure 228**  
**Graphing Hover Dialog**

## Assigning Weights with AHP

MCDA has a method of automatically assigning weights to criteria using standard English evaluative phrases. The method is called Analytical Hierarchy Process (AHP), and it uses a comparison matrix that compares the relative importance of all the criteria to one another.

When an evaluation process includes many criteria, the process of assigning appropriate weights can become confusing and unwieldy. AHP Weighting is an approach that is intended to address such situations by making the process more intuitive. AHP weighting is a useful method of involving public stakeholders in the weighting process. Because it is the product of accepted, well-established research efforts, the validity of the weighting produced by AHP may be more readily defended.

On the Weights tab of the Multi-Criteria Decision Analysis form click the 'AHP Weights' button.



Multi-Criteria Decision Analysis

Planning Sets: MCDA Example (Editor) MCDA Scenario: MCDA Example Create/Manage

Ranking Weights

AHP Weights

Open AHP weight calculator

	Weight	Normalized Value
Acceptability	1	0.333
DeerPopIndex	1	0.333
TOTCOST	1	0.333

Discard All Changes Save Changes

Perform MCDA

New Planning Set Name: MCDA Weighted Scoring By Range ☒ Exclude No Action Plan

Generate Cancel

**Figure 229**  
**Selecting AHP Weights**

Clicking on the 'AHP Weights' button will launch the AHP Weights form as shown below.

	Acceptability	DeerPopIndex	TOTCOST
Acceptability	N/A	(1) Equally Important	(1) Equally Important
DeerPopIndex	(1) Equally Important	N/A	(1) Equally Important
TOTCOST	(1) Equally Important	(1) Equally Important	N/A
Weight	33.333	33.333	33.333

Statistics		
Inconsistency Ratio:	Dominant Eigen Value:	Consistency Index Value:
0	3	0

Reset Apply Weights Cancel

**Figure 230**  
**AHP Weights**

Identify how important a row heading (criteria) is compared to the column heading (another criteria). For example if deer were included as a criteria in the analysis, the decision might be made that total cost is more important than the effect of Flood control on the Deer population in the project area because budgeted resources are severely limited and the impact on the size of the total deer population affected is minimal. Conversely, if financial resources were not a constraining factor and the percentage of the deer population affected were large, the effect on the Deer population might be considered more important than that of total cost.

The levels of importance you can choose from are natural language English phrases. See below for the phrases and their associated weights:

- Equally Important (1)
- Slightly More Important (3)
- Strongly More Important (5)
- Demonstrably More Important (7)
- Absolutely More Important (9)
- Slightly Less Important (-3)

- Strongly Less Important (-5)
- Demonstrably Less Important (-7)
- Absolutely Less Important (-9)

For the purposes of this example, fill out your table with the same selections as shown in the example AHP Weight form shown below.

The screenshot shows the 'AHP Weights' dialog box. It contains a table for comparing criteria: Acceptability, DeerPopIndex, and TOTCOST. The 'Weight' row shows values 8.017, 23.441, and 68.542. Below the table is a 'Statistics' section with three fields: Inconsistency Ratio (0.253, highlighted in red), Dominant Eigen Value (3.295), and Consistency Index Value (0.147). At the bottom are 'Reset', 'Apply Weights', and 'Cancel' buttons.

	Acceptability	DeerPopIndex	TOTCOST
Acceptability	N/A	(-5) Strongly Less Important	(-5) Strongly Less Important
DeerPopIndex	(5) Strongly More Important	N/A	(-5) Strongly Less Important
TOTCOST	(5) Strongly More Important	(5) Strongly More Important	N/A
Weight	8.017	23.441	68.542

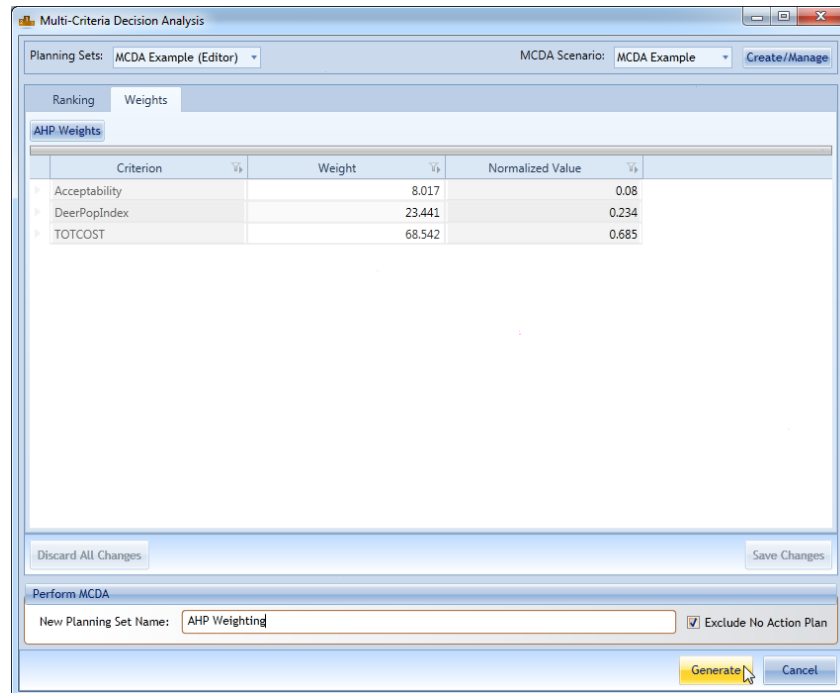
Statistics		
Inconsistency Ratio:	Dominant Eigen Value:	Consistency Index Value:
0.253	3.295	0.147

**Figure 231**  
**Example AHP Weight Form**

It is important to pay careful attention to the Inconsistency Ratio in the lower left corner of the form. Once the Inconsistency Ratio reaches 0.10 or above the box will become red. If this should occur, the user should examine the rankings for any inconsistencies.

Once all comparisons have been selected, click the 'Apply Weights' button to update the MCDA module to use the weights displayed in the matrix when ranking. We are now ready to see the effects of our new weighting method. Re-rank the original planning set. Examine its graphs and compare them to other MCDA planning set graphs. Notice the new rankings assigned to the plan alternatives based on the AHP Weight changes.

Now rank using the newly entered weight values for the criteria as shown below, rename the planning set name to indicate AHP Weighting and click 'Generate.'



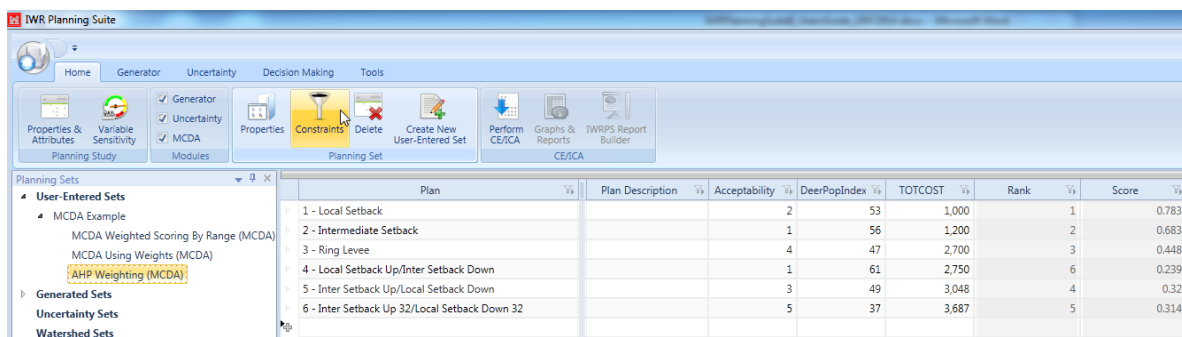
**Figure 232**  
**Generating a MCDA Set**

Examine the resulting graphs and see how the ranking has been changed by the AHP Weighting selections.

## Reducing Alternatives

In some cases it is necessary to reduce the size of the planning set or to eliminate those plan alternatives that do not meet the minimum requirements set for the project. This is done with the [Constraints](#) feature.

Here is an example of how the constraints filter might be used to reduce a planning set for MCDA. First, select the planning set you want to constrain from the Plan Editor and then click the 'Constraints' button on the Home ribbon.



**Figure 233**  
**Launching Constraints**

A form is displayed similar to the one below.



Variable	Description	Minimum Value	Maximum Value
AAHU	AAHU		
Acceptability	Acceptability		
DeerPopIndex	DeerPopIndex		
FDRBEN	FDRBEN		
TOTCOST	TOTCOST		

Constrained Planning Set Name: AHP Weighting

Constrain Cancel

**Figure 234**  
**Constrain Active Planning Set**

Now we will set the minimum and maximum values for our criteria. Change the minimum for Totalcost to 100, this means that alternatives total cost value must be at least 100 to be included in the scenario. Assume we also have a \$260,000 budget that we cannot exceed. For Total cost, you would set maximum to 260000 as shown, then click “OK” to generate the reduced plan set and close the Constrain Active Planning Set form.

In the text field “Constrained Planning Set Name” please enter the new plan set name “Reduced Example Matrix.” (If you would like, after the constrained plan set has been generated, you may change its description to “Exclude inappropriate plan alternatives” in the [Planning Set Properties](#).) This process allows us to make changes without altering the existing MCDA planning set. Press the ‘Constrain’ button to close the form and generate the constrained set.

Variable	Description	Minimum Value	Maximum Value
AAHU	AAHU		
Acceptability	Acceptability		
DeerPopIndex	DeerPopIndex		
FDRBEN	FDRBEN		
TOTCOST	TOTCOST	100	260,000

Constrained Planning Set Name: Reduced Example Matrix

Constrain Cancel

**Figure 235**  
**Creating a Constrained Planning Set**

Then select the ‘Weights, Ranking & Analysis’ button on the MCDA Ribbon and the user should select the Reduced Example Matrix planning set. The user can then click the ‘Create/Manage’ button to create a new

scenario. Once the scenario has been created the user can update the Min/Max values for the listed variables and then 'Save Changes.' Once this has been done the user can click 'Generate' to re-rank the alternatives after constraining them.

Multi-Criteria Decision Analysis

Planning Sets: Reduced Example Matrix (Constrained) MCDA Scenario: Reduced Example Matrix Create/Manage

Ranking Weights

Rank Method

☒ Weighted Scoring ☐ Outranking ☐ Efficient Frontier ☐ Compromise Programming

Criterion	Weight	Min/Max
Acceptability	1	Maximize
DeerPopIndex	1	Minimize
TOTCOST	1	Minimize

Normalization Methods

☒ By Range ☐ By Percent of Max ☐ By Percent of Total

Discard All Changes Save Changes

Perform MCDA

New Planning Set Name: Reduced Example Matrix Ranked ☒ Exclude No Action Plan

Generate Cancel

**Figure 236**  
**Generating a MCDA Set**

## Change Ranking Method

Select the 'Weights, Ranking & Analysis' button on the MCDA ribbon and then select the original MCDA Example planning set. Click the 'Create/Manage' button and create a new scenario named Outranking. Once the new scenario has been created and selected on the Multi-Decision Criteria Analysis form the user can select the Outranking radio button.

Multi-Criteria Decision Analysis

Planning Sets: MCDA Example (Editor) MCDA Scenario: Outranking Example Create/Manage

Ranking Weights

Rank Method

☐ Weighted Scoring ☒ Outranking ☐ Efficient Frontier ☐ Compromise Programming

Outranking Criterion Types

There is a strict preference for alternative A over alternative B at any level by which the rating of A exceeds the rating of B

Criterion	Weight	Min/Max	Criterion Type	Indifference Value	Absolute Preference
Acceptability	1	Maximize	Strict	0	0
DeerPopIndex	1	Maximize	Strict	0	0
TOTCOST	1	Maximize	Strict	0	0

Discard All Changes Save Changes

Perform MCDA

New Planning Set Name: MCDA Outranking

Generate Cancel

**Figure 237**  
**Selecting the Rank Method**

A frame containing Outranking Criterion Types will appear on the form. These are all of the different preference functions you can choose for Promethee. Selecting any of the types will bring up a brief definition for that particular preference function definition.

Set the Criterion Type for DeerPopIndex to Strict. Set the Criterion Type for Totalcost to Linear With Threshold. Then set the Absolute Preference= 1 and Indifference Value=0.1. Using the Linear with Threshold performance function, an alternative (alternative A) is absolutely better than another alternative (alternative B) if its TotalCost differs by the absolute value of 1. However, as the difference between alternative A and B grows from the Indifference Value to the Absolute Value there is a linear preference for alternative A.

Set the Acceptability Criterion Type to Threshold. Set the Indifference Value to 0.75. If alternative A and Alternative B differ by only .75 then there is no preference for either A or B. Once the Acceptability differs by a value greater than 0.75 then a preference is shown.

Multi-Criteria Decision Analysis

Planning Sets: MCDA Example (Editor) MCDA Scenario: Outranking Example Create/Manage

Ranking Weights

Rank Method

☐ Weighted Scoring ☒ Outranking ☐ Efficient Frontier ☐ Compromise Programming

Outranking Criterion Types

Strict Threshold Linear Over Range Stair-Step Linear With Threshold

There is a strict preference for alternative A over alternative B at any level by which the rating of A exceeds the rating of B

Criterion	Weight	Min/Max	Criterion Type	Indifference Value	Absolute Preference
Acceptability	1	Maximize	Threshold	0.75	0
DeerPopIndex	1	Maximize	Strict	0	0
TOTCOST	1	Maximize	Linear With Threshold	0.1	1

Discard All Changes Save Changes

Perform MCDA

New Planning Set Name: MCDA Outranking Example

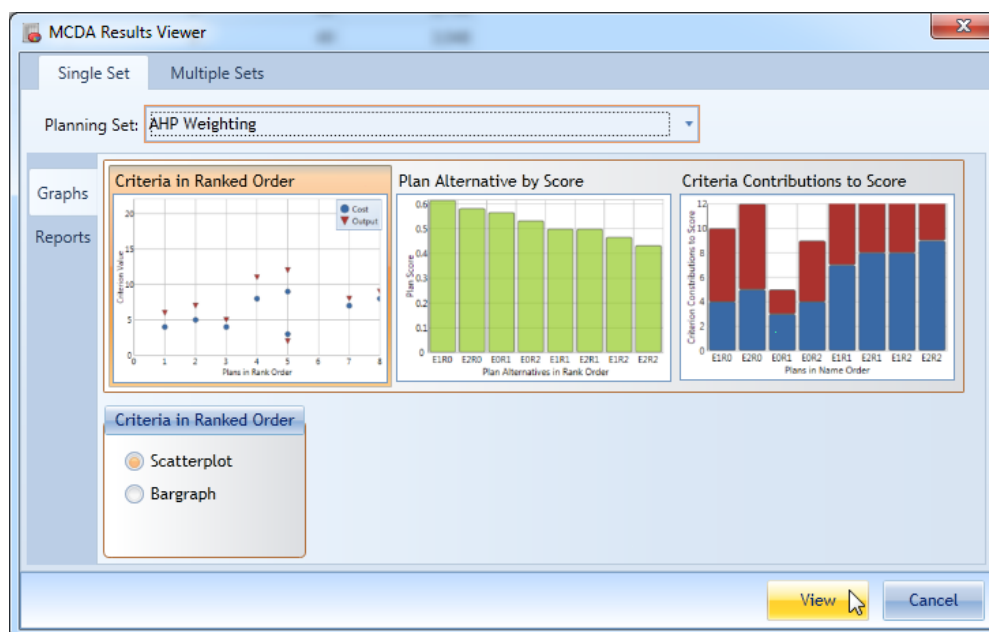
Generate Cancel

**Figure 238**  
**Setting Indifferences Values**

We are ready to enter a name and click “Save Changes” and then “Generate” to rank the scenario and view the result of our ranking.

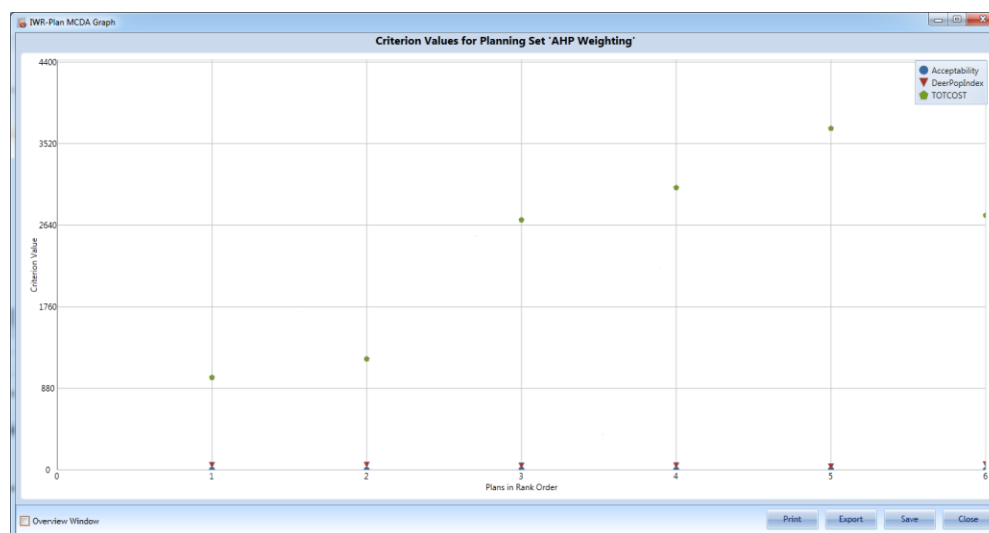
## Viewing MCDA Scatterplot Graphs

View the results via the MCDA Graphs & Reports. Select the ‘Graphs & Reports’ button on the MCDA ribbon. Select a planning set and then under Graphs choose Criteria in Ranked Order, ensure Scatterplot is selected and then click “View” as shown below.



**Figure 239**  
**MCDA Results Viewer**

The graph shown below will be created.

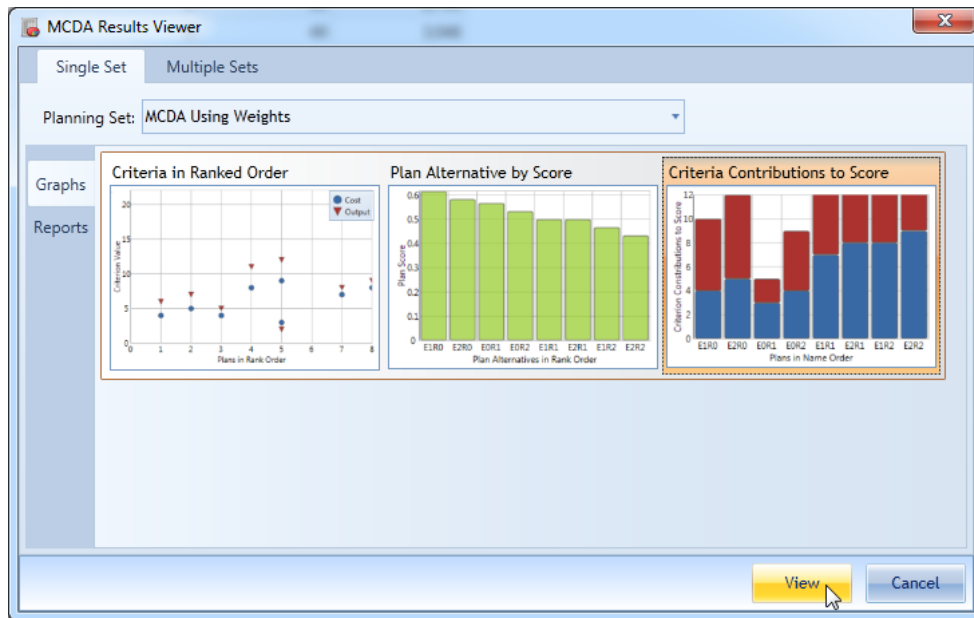


**Figure 240**  
**MCDA Graph Example**

Let's look at some of MCDA's additional graphing options. We'll use scenarios that we have already run.

Since we've processed the MCDA Using Weights, let's use it.

Now let's display the Criterion Contribution to Score bar graph. Please select the MCDA Using Weights planning set on the MCDA Results Viewer form on the Single Set tab. The user can now click on the 'View' button to create the graph.



**Figure 241**  
**Launching the MCDA Graph**

A graph like the one below will be displayed.



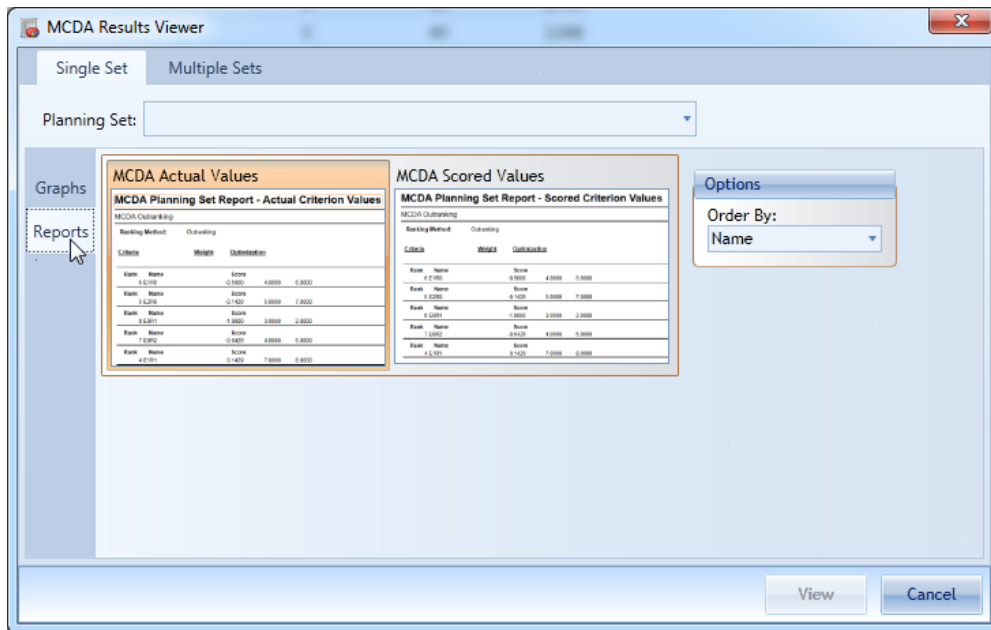
**Figure 242**  
**MCDA Graph Example**

This graph shows how each criterion contributes to the total score for that alternative.

## Generating MCDA Reports

There are also several reports that can be generated. The user can create reports which sort the alternatives by plan name and by the rank after running one of the algorithms. The order of plans can also be compared across planning sets to determine if a particular set of plans rise to the top under a variety of circumstances.

Click on the 'Graphs & Reports' button on the MCDA ribbon and then select the Reports option along the left as shown below.



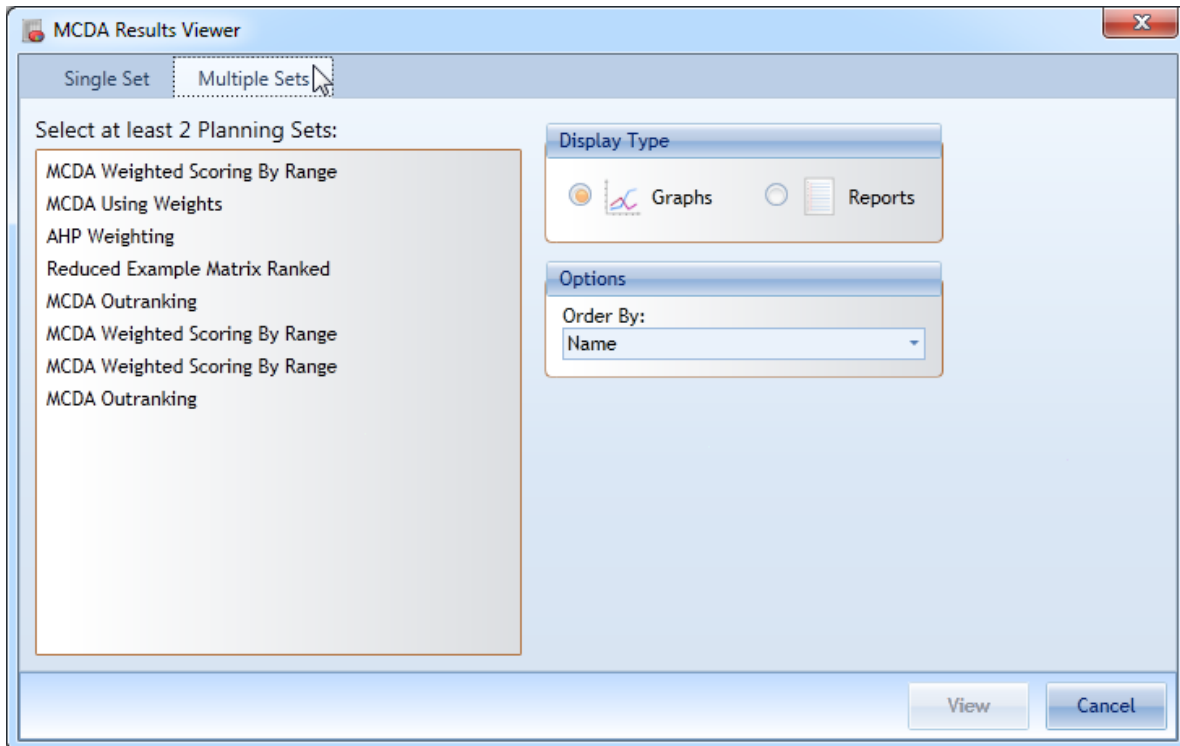
**Figure 243**  
**Generating MCDA Reports**

This will cause the MCDA report options to display. Select the planning set and either select the MCDA Actual Values or MCDA Scored Values report and then click the 'View' button. The Criteria Values and Actual Values will display the values for the individual criteria input by the user.

MCDA Planning Set Report - Actual Criterion Values						10/13/2014
MCDA Outranking						
Ranking Method:						
Criteria	Weight	Optimization	Criterion Type	Indifference Value	Absolute Preference	
Acceptability	1.00	Maximized	Strict	0.00	0.00	
DeerPopIndex	1.00	Maximized	Strict	0.00	0.00	
TOTCOST	1.00	Maximized	Strict	0.00	0.00	
Rank	Name	Score	Acceptability	DeerPopIndex	TOTCOST	
6	1 - Local Setback	-0.3333	2.0000	53.0000	1000.0000	
Rank	Name	Score	Acceptability	DeerPopIndex	TOTCOST	
5	2 - Intermediate Setback	-0.2667	1.0000	56.0000	1200.0000	
Rank	Name	Score	Acceptability	DeerPopIndex	TOTCOST	
4	3 - Ring Levee	-0.0667	4.0000	47.0000	2700.0000	
Rank	Name	Score	Acceptability	DeerPopIndex	TOTCOST	
3	4 - Local Setback Up/Inter Setb.	0.1333	1.0000	61.0000	2750.0000	
Rank	Name	Score	Acceptability	DeerPopIndex	TOTCOST	
2	5 - Inter Setback Up/Local Setb.	0.2000	3.0000	49.0000	3048.0000	
Rank	Name	Score	Acceptability	DeerPopIndex	TOTCOST	
1	6 - Inter Setback Up 32/Local S	0.3333	5.0000	37.0000	3687.0000	

**Figure 244**  
**MCDA Planning Set Report Example**

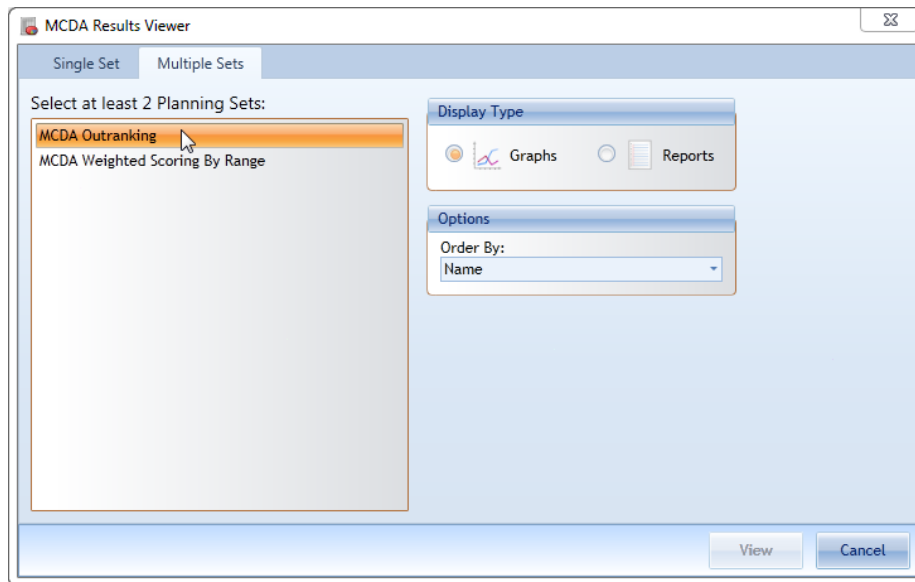
There is also a report that allows for the comparison of multiple planning sets. This report can be accessed by selecting Multiple Sets at the top of the MCDA Results Viewer form.



**Figure 245**  
**MCDA Multiple Set Output Options**

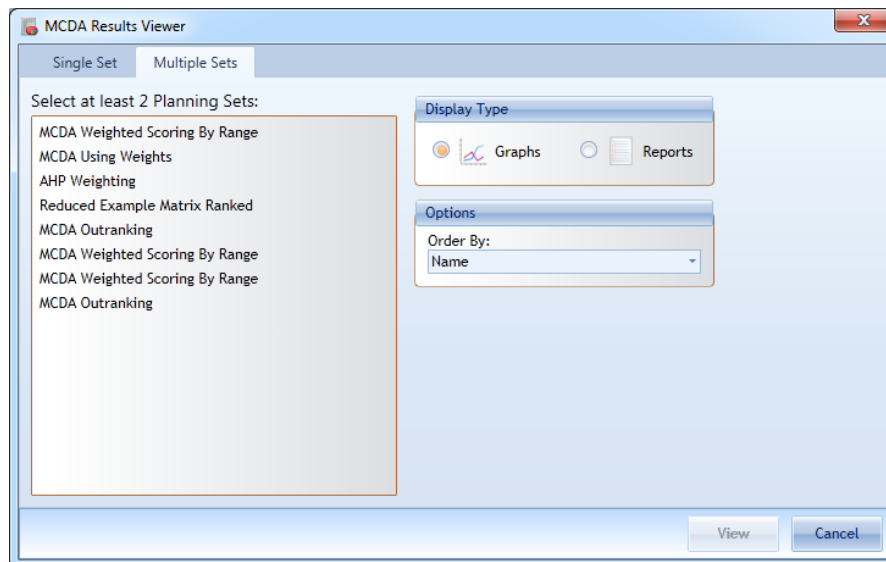


This report requires that the planning sets that are compared be derived from the same parent planning set. Once the user selects a planning set the display will limit to show only those other planning sets that have the same parent.



**Figure 246**  
*Selecting MCDA Planning Sets with Same Parent*

Clicking on the selected set again will unselect the set and bring back the entire list of available planning sets.



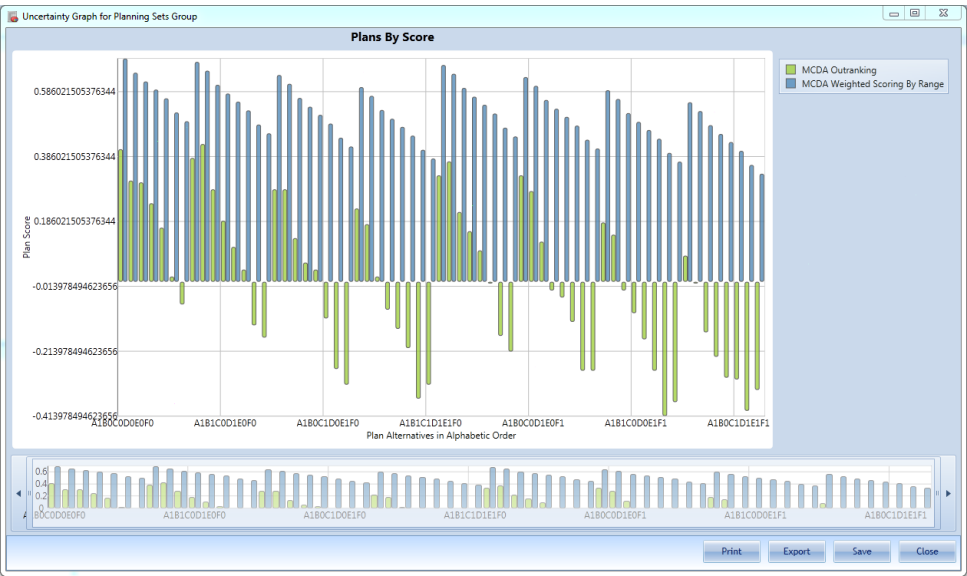
**Figure 247**  
*Deselecting a MCDA Planning Set*

Once two planning sets have been selected the user can click the radio button next to Reports and then click 'View' to view the report. Comparing the Outranking and Weighted scoring planning sets produce a report similar in format to the one shown below.

MCDA Multiple Planning Set Plan Alternative Ranking Report										
10/13/2014										
<b>Planning Sets</b>										
MCDA Outranking										
Ranking Method Outranking										
MCDA Criterion										
MCDA Criterion										
MCDA Criterion										
MCDA Weighted Scoring By Range										
Ranking Method Weighted										
Weighting Method By Range										
MCDA Criterion										
MCDA Criterion										
MCDA Criterion										
PlanName	MCDA Outranking	MCDA Weighted Scoring By Range	PS3	PS4	PS5	PS6	PS7	PS8	PS9	PS10
A1B0C0D0E0F0	5	3	0	0	0	0	0	0.00	0	0
A0B1C0D0E0F0	11	7	0	0	0	0	0	0.00	0	0
A1B1C0D0E0F0	17	16	0	0	0	0	0	0.00	0	0
A0B0C1D0E0F0	3	2	0	0	0	0	0	0.00	0	0
A1B0C1D0E0F0	6	8	0	0	0	0	0	0.00	0	0
A0B1C1D0E0F0	14	13	0	0	0	0	0	0.00	0	0
A1B1C1D0E0F0	26	25	0	0	0	0	0	0.00	0	0
A0B0C0D1E0F0	13	15	0	0	0	0	0	0.00	0	0
A1B0C0D1E0F0	25	26	0	0	0	0	0	0.00	0	0
A0B1C0D1E0F0	28	35	0	0	0	0	0	0.00	0	0
A1B1C0D1E0F0	47	46	0	0	0	0	0	0.00	0	0
A0B0C1D1E0F0	24	24	0	0	0	0	0	0.00	0	0
A1B0C1D1E0F0	36	36	0	0	0	0	0	0.00	0	0
A0B1C1D1E0F0	43	44	0	0	0	0	0	0.00	0	0
A1B1C1D1E0F0	55	54	0	0	0	0	0	0.00	0	0
IWR Planning Suite MCDM Module Report - Multiple Planning Set Plan Alternative Rankings										Page 1 of 3

**Figure 248**  
**Example MCDA Multiple Set Report**

Similarly if the user selects the radio button for Graphs prior to clicking 'View' then this provide the user with a graphical way to compare the results of two MCDA planning sets.



**Figure 249**  
**Graphical MCDA Set Comparison**

## Section 9

# Bibliography

Saaty, Thomas L., Luis G. Vargas. Models, Methods, Concepts and Applications of the Analytic Hierarchy Process. Kluwer Academic Publishers, University of Pittsburgh 2001.

Mendoza, G.A. and H. Martins. "Multi-criteria decision analysis in natural resource management: A critical review of methods and new modeling paradigms". *Forest Ecology and Management* 230 (2006) 1-22.

Sprague, Ralph H., Eric D. Carlson. *Building Effective Decision Support Models*. Prentice-Hall, Inc. 1982.

Sadjadi, Seyed Jafar. "An Application of Efficient Frontier in Transportation of Hazardous Material". *Computers & Industrial Engineering*. 53 (2007) 357 – 360. 15, June 2007.

[Polasky S](#), E. [Nelson](#), E. [Lonsdorf](#), P. [Fackler](#), A. [Starfield](#). "Conserving Species in the Biological Landscape" *Ecological Applications*. 15(4), 2005, pp 1387 – 1401.

Hyde, Kyle, Holger Maier, and Chris Colby, "Reliability-Based Approach to Multi- Criteria Decision Analysis for Water Resources" *Journal of Water Resources Planning and Management ASCE*, 0733-9496(2004) 130:6(429).

Xenarios S., I Tziritis. "Improving pluralism in Multi Criteria Decision Aid approach through Focus Group Technique and Content Analysis." *Ecological Economics*. 62 (2007) 692-703.

Brans, Jean-Pierre and Bertrand Mareschal. "How to Decide with PROMETHEE". *European Journal of Operational Research*. 24 (1986) 228-238. 28 September 2006.  
<<http://homepages.ulb.ac.be/~bmaresc/PromWeb.htm>>

Prato, Tony. "Multiple Attribute Evaluation of Management Alternatives for the Missouri River System." *Using Multi-Criteria Decision Analysis in Natural Resource Management*. Ashgate Publishing Company 2006. 75-92.

Linkov, I. and A. Ramadan. eds " Multi-Criteria Decision Analysis: A Framework For Structuring Remedial Decisions At Contaminated Sites" *Comparative Risk Assessment and Environmental Decision Making*. Kluwer, 2004.

U.S. Army Corps of Engineers, 2003a. USACE Environmental Operating Principles and Implementation Guidance..<<http://www.hq.usace.army.mil/cepa/envprinciples.htm>>

U.S. Army Corps of Engineers, 2002. Civil Works Program Strategic Plan.  
<<http://www.iwr.usace.army.mil/iwr/strategicplan.htm>>

U.S. Army Corps of Engineers, 2003b. Planning Civil Works Projects under the Environmental Operating Principles. Circular 1105-2-404. <<http://www.usace.army.mil/inet/usace-docs/engcirculars/ec1105-2-404/entire.pdf>>

Flood Control Act, 1936, 74th CONGRESS. SESS. II. CHS. 651, 688. JUNE 20, 22, 1936,  
<<http://www.ccrh.org/comm/cottage/primary/1936.htm>>

US Army Corps of Engineers, Planning Principles, Engineering Regulation 1105-2-100, April 22, 2000  
<<http://www.usace.army.mil/publications/eng-regs/er1105-2-100/c-1.pdf>>

Pictet, Jacques and Dominique Bollinger. "The Silent Negotiation or How to Elicit Collective Information for Group MCDA Without Excessive Discussion". *Journal of Multi-Criteria Decision Analysis*. 13: 199-211 (2005).

Yoe, C. "Trade-Off Analysis Planning and Procedures Guidebook", IWR 02-R-2, April 2002,  
<<http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/02-R-2.pdf>>

## Used in the Program

"A Class of Solutions for Group Decision Problems", Yu, P.L. *Management Science*, Vol. 19, No. 8, Application Series. (Apr., 1973), pp. 936-946.

Prodanovic, Predrag and Slobodan P. Simonovic. "Comparison of fuzzy set ranking methods for implementation in water resources decision-making". *Canadian Journal of Civil Engineering*. 29: 692-701 (2002).

R. Males. "Calculation of Non-Dominated Points in Multiple Dimensions DRAFT". Policy Paper from CDM. September 22, 2003

Davide, Christophe, Decide PROMETHEE,  
<<http://www.christophedavid.org/w/c/w.php/DECIDE/ReferencePromethee>>

Brans, J.P., Vincke, Ph. and Mareschal, B. "How to select and how to rank projects: The PROMETHEE Method". *European Journal of Operational Research* 24 (1986) 228-238. North Holland.

# Appendix

## Glossary

Attribute	A value or hierarchical structure of values associated with a plan alternative which identifies a characteristic of the entire alternative. In IWR Planning Suite II, a text label with a textual or numeric value associated with it.
Capital Recovery Factor (CFR)	The ratio of a constant annuity to the present value receiving that annuity for a given length of time. The CFR is calculated using the interest rate.
Construction Costs	These costs are the direct cost of installing project measures. They should be based on the market value of goods and services required to install project measures. They should include the cost of purchased materials; equipment rental or purchase; construction wages or salaries; and contractors' management, supervision, overhead, and profit. These costs will be based on current contract bid items in the project area or on the current market value of purchased materials and services, etc.
Derived Variable	A variable associated with a plan alternative, and described by formulae applied to component variables. Mathematical functions are applied to component variables to define a derived variable.
Discount Rate	The rate established annually for use in evaluating Federal water projects.
Hydrologic Unit Code (HUC)	A hierarchical classification of hydrologic drainage basins in the United States consisting of 2 to 12 digits based on the levels of classification in the hydrologic unit system. A hydrologic unit describes the area of land upstream from a specific point on the stream (generally the mouth or outlet) that contributes surface water runoff directly to this outlet point. Another term for this concept is drainage area. It is delineated by starting at a designated outlet point (usually the river mouth) and proceeding to follow the highest elevation of land that divides the direction of surface water flow (usually referred to as the ridge line). This boundary will follow the basin ridges until connected back at the outlet point.
Interest During Construction (IDC)	This represents the opportunity cost of capital incurred during the construction period. The cost of a project to be amortized is the investment incurred up to the beginning of the period of analysis. The investment cost at that time is the sum of construction and other initial cost plus interest during construction. Cost incurred during the construction period should be increased by adding compound interest at the applicable project discount rate from the date the expenditures are incurred to the beginning of the period of analysis.
MCDA Plan Alternative	A Plan Alternative in MCDA is equivalent to a decision matrix alternative.
MCDA Plan Study	A MCDA Plan Study is a group of Planning Sets which contain the decision matrix on which the analyses are performed, and the results of all of the different types of analyses performed upon the decision matrix.
MCDA Plan Study Variables	An IWR Planning Suite II Variable is equivalent to a MCDA criteria.
MCDA Planning Set	A MCDA Planning Set stores an MCDA decision matrix. It may also contain the results of an MCDA performed on the decision matrix.

National Economic Development Cost (NED Costs)	Project measures require the use of various resources. NED costs are the opportunity costs of resource use. Proper NED analysis requires that project NED costs and benefits be compared at a common point in time. Costs are calculated in annualized terms and converted to an annual equivalent value over the period of analysis.
Net Ecosystem Restoration Benefits (NER Benefits)	These are the non-monetized outputs of ecosystem restoration projects.
OMRR&R Costs	The expected costs over a period of analysis for operation, maintenance, repair, rehabilitation, and replacement necessary to maintain the benefit stream and agreed-upon levels of mitigation of losses to fish and wildlife habitats.
Period of Analysis	The time horizon for project benefits, deferred installation costs, and operation, maintenance, repair, rehabilitation, and replacement (OMRR&R) costs. The same period of analysis should be used for all alternative plans. Appropriate consideration should be given to environmental factors that may extend beyond the period of analysis.
Plan alternative	A set of one or more management measures (activities) of particular scales. Comprised to address planning objectives.
Plan study schema	A named set of variable and attribute definitions held in common by a planning study. Within IWR Planning Suite II, describes a particular planning study.
Planning set	Any group of plan alternatives.
Planning study	The plan alternatives and analysis results, maintained in planning sets, used to evaluate candidate plans for a specific planning task. A related group of planning sets derived from a common set of plan alternatives.
Preconstruction, Engineering and Design Cost (PED)	These costs are the direct costs for investigations, field surveys, planning, design, and preparation of specifications and construction drawings for project measures.
Scale	A discrete feature magnitude or level of activity applied to a solution.
Scenario	A specific analysis to be performed upon a planning set, or the results of that analysis.
Sensitivity	A basic method of indicating the analytic uncertainty of a plan alternative variable through the mechanism of assigning low and high values to describe the variable's value as a range.
Solution	A feature or activity that can be implemented to address one or more planning objectives. A planning task management measure.
Variable	One of the constituent components of a plan alternative. A category used for comparative purposes during analysis. A representation of the combined measures of a study, such as cost and output. The constituent components of a derived variable.

