RECLAMATION

Managing Water in the West

Report on Reclamation Workshop to Review Current Operations Practices

Focus on Communicating Risk, Uncertainty and Incorporating Climate Information

Science and Technology Program
Project Number 1077
Workshop held June 16-17, 2009

U.S. Department of the Interior
Bureau of Reclamation

November 2010

U.S. Department of the Interior
Bureau of Reclamation

November 2010

Report on Reclamation Workshop to Review Current Operations Practices

Focus on Communicating Risk, Uncertainty and Incorporating Climate Information

prepared by

Carly Jerla
Paul Miller
Thomas Scott
James Prairie

U.S. Department of the Interior
Bureau of Reclamation

November 2010

Contents

Page

Introduction 1
Background 1
Reservoir Operation 1
Outlook Types & Decisions 1
Stakeholders Involved 1
Workshop Objectives 2
Format 3
Basic Concepts & Definitions 3
Current Practices 3
Risk and Uncertainty in Operations Outlooks 3
Streamflow Forecast Uncertainty 4
Uncertainty Associated with Other Inputs 5
Operations Modeling and Related Tools 5
Communication of Risk and Uncertainty in Operations Outlooks 6
Stakeholder Type 6
2.3.2 Stakeholder Experiences and Perceptions 6
Describing Models and their Results 7
Current Gaps 8
Risk & Uncertainty in Operations Outlooks 8
Use of Information in Decision Making 8
Operations Modeling Tools 9
Communication of Risk & Uncertainty in Operations Outlooks 9
Common Risk & Uncertainty Language for Stakeholders 10
Common Approaches to Address Stakeholder Uncertainty Questions 10
Path Forward (Recommendations Based on Current Gaps) 12
Improved Information and its use in Improving Decision Making 12
Improved Information Strategy Implementation 13
Stakeholder Involvement 13
Sharing Strategies Among Stakeholders 13
Operations Modeling Tools Development & Modification 14
Development of a Common Language to Convey Risk & Uncertainty 14
Appendix A. Example of Published Results from Operations Outlooks for the Colorado and Truckee River Basins 16
Deterministic results from the Colorado River Basin 16
Probabilistic results from the Truckee River Basin 18
Appendix B. List of Participants 20
Appendix C: List of Presentations with Brief Descriptions 22

Introduction

Background

A common facet among Reclamation reservoir operations is that monthly to annual operations outlooks must be developed to support communication with stakeholders on how competing objectives will be satisfied in coming seasons. In several regions these outlook analyses are deterministic or based on a few planning scenarios. Stakeholders have become more skilled and more interested in understanding uncertainty and are requesting that Reclamation provide more information on outlook uncertainty and risk and convey these uncertainties in an accessible manner.

Uncertainty and risk are presently being handled in various ways throughout Reclamation. It would benefit Reclamation to understand the commonalities among these current strategies, the feasibility of sharing the more common ones more broadly within Reclamation, and the opportunity to enhance input uncertainty and outcome risk assessment and communication. These steps can foster a better relationship with operations stakeholders and thereby help Reclamation avoid potential conflicts that might interfere with Reclamation's mission to deliver water and generate power in an environmentally and economically efficient manner. A primary goal for this project is to improve communication of risk and uncertainty within and between Reclamation and its stakeholders. Achieving this goal will address stakeholders' requests to improve Reclamation's description of uncertain environmental systems and allow for more informed decisions by stakeholders.

Reservoir Operation

Outlook Types & Decisions

The focus of this paper is on risk and uncertainty related to future reservoir operations looking ahead from one month to 24 months time frame.   Stakeholders have various interests in reservoir operations including such items as: percentage of water deliveries for irrigation and M&I; reservoir storage for drought relief and recreations interests; in-stream flows for recreation, environmental and water quality purposes; flood control; and hydropower production. This paper will present the wide variation that Reclamation uses in addressing uncertainty and risks related to these stakeholders’ interest.

Stakeholders Involved

There was a wide variety of stakeholders attending the workshop interested in how Reclamation characterizes risk and uncertainty. These organizations included experts on risk and uncertainty, reservoir operations, weather and streamflow forecasting, climate change, irrigation, water supply for M&I, natural resources, and hydropower. Organizations attending the workshop were:

Utah State University
Colorado State University
USGS Fort Collins Science Center
CU-NOAA Western Water Assessment
Metropolitan Water District
USDA-Natural Resources Conservation Service
Western Area Power Administration
Colorado River District
USACE Hydrological Engineering Center
Colorado Water Conservation Board
Western Water Assessment
Colorado State University
Southern Nevada Water Authority
Reclamation
U.S. Army Corps of Engineers
USGS
University of Colorado (CADSWES)
NOAA

There also is a wide variety of stakeholders not present at the meeting that may have a high interest in risk and uncertainty related to reservoir operations including but not limited to:

Bureau of Land Management, US Fish & Wildlife Service, US Forest Service, US Dept of Energy National Renewable Energy Laboratory, States, Counties, Cities, M&I purveyors, irrigation districts, environmental groups, Public Utilities, hydropower purveyors, and the general public.

Workshop Objectives

The purpose of the workshop was to focus on communicating risk, uncertainty, and climate information among Reclamation and its stakeholders. The goals included:

- Documentation of critical risk questions asked by stakeholders, and their perceptions on planning uncertainties
- Documentation of current practices to access input uncertainties in operational outlook development at each Reclamation office represented at the workshop, focusing on the 1-month to 2-year look-ahead horizon for outlook development (monthly scheduling)
- Determine common types of uncertainty represented or absent in the analysis, and common methods for handling uncertainty
- Improve communication of risk and uncertainty with management and stakeholders
- Outline the next steps to improve uncertainty and risk representation and communication.

Format

Section 2 of this paper describes current Reclamation practices on risks and uncertainty, Section 3 discusses the current gaps, and Section 4 describes the recommendations on improving how Reclamation deals with risk and uncertainty.

Basic Concepts & Definitions

Risk and Uncertainty have different meanings to different people. In this paper risk is regarded as the probability of an event occurrence with an adverse or positive consequence. Using a baseline reservoir operation, an example of a risk is that a reservoir has a 10 percent chance of an unwanted spill. Uncertainty in this paper is generally regarded as lack of definitiveness or assuredness. There are two types of uncertainty, aleatory uncertainty which deals with natural variability and epistemic uncertainty which is knowledge deficiency. Examples of aleatory uncertainty are natural variations of temperature and precipitation. Examples of epistemic uncertainty are data input (measurements, instrumentation errors, random errors in measurement, systematic errors in instrumentation, recording, reporting), model uncertainty (parameter sensitivity, physical), climate change (long term and short term), and supply uncertainty (ESA demands, court orders, policy changes).

Current Practices

Current practices regarding risk and uncertainty can vary significantly between Reclamation and stakeholder offices; furthermore, the degree with which risk and uncertainty is incorporated into operations, models, and communication varies as well. The operation of reservoirs and incorporation of forecasts from outside agencies is addressed differently between Reclamation regions and offices; stakeholder groups often do not interpret Reclamation projections and reports uniformly. Reclamation and stakeholder agencies are currently working towards improving risk and uncertainty assessments that better take into account antecedent and projected conditions. Additionally, Reclamation is working towards defining a more focused and uniform approach regarding the implementation and application of risk and uncertainty practices.

Risk and Uncertainty in Operations Outlooks

Throughout Reclamation and stakeholder agencies, deterministic outlooks commonly yield or convey conservative, or what is perceived to be conservative, results or impacts. Weather and climate information are commonly used in the development of outlooks, often with some uncertainty. Precipitation and temperature are important to forecast water supply and demand, particularly in the mid-west and southwestern regions (e.g., CRWCD and Lower Colorado River Basin). In the Mid-Pacific Region, 7 to 30 day weather outlooks from the NWS and NRCS are used with forecasts of April through July runoff volumes to develop reservoir operational

outlooks. Recent hydroclimatic information is sometimes used to identify similar, historical inflow scenarios that can then be used to forecast reservoir operations.
Reclamation and stakeholder agency operational outlooks utilize models and publish outlooks with variable timesteps and may incorporate data and other outlooks that are not temporally consistent. Frequently, monthly and seasonal data are used in models operating at a daily timestep.

Projections of precipitation and streamflow are usually issued by the weather and river forecast agencies on a monthly timestep. Reclamation agencies incorporate this data into monthly operational models with minimal adjustment or deviation from the forecast provided. However, some Reclamation agencies will adjust monthly forecasts or projections through:

- The use of historical daily data to downscale monthly and seasonal projections to input into daily operational models (e.g., Lower Colorado Region).
- Adjustment of provided outlooks for modeling error and out of the ordinary circumstances, such as a change in operations or demand to the system. Stakeholders such as MWD and Western will augment outlooks to provide for an "operational buffer."
- Seasonal and monthly weather and climate outlooks are sometimes augmented through the use of additional, concurrent outlooks. These include, but are not limited to, longer-range weather forecasts, drought and flood monitoring, and real time snowpack and streamflow observations.

Additionally, some stakeholder agencies augment Reclamation deterministic outlooks and generate their own probabilistic outlooks. Much of the uncertainty observed in Reclamation reservoir projections is due to uncertainty in streamflow forecasts.

Streamflow Forecast Uncertainty

Reclamation offices are often dependant on streamflow forecasts issued by other governmental organizations (e.g., NOAA, NWS, RFC). The 24-Month Study, issued by Upper and Lower Colorado Regional offices and used by numerous stakeholders, is forced by unregulated streamflow forecasts provided by the CBRFC. Whereas the methodology through which these forecasts are determined provides an ensemble of potential streamflow traces, the CBRFC provides Reclamation with summary information that results in a deterministic, as opposed to probabilistic, forecast. Reclamation models have often been developed to accept and yield deterministic variables; current research efforts at various Reclamation offices include the development of stochastic approaches to these models.

Reclamation and stakeholder agencies have addressed uncertainty within streamflow forecasts by incorporating results from historic streamflow observations. For example, a current forecast may be compared to historic forecasts made under similar hydroclimatic conditions to develop an ensemble of resultant hydrologic scenarios. This allows modelers to take into account additional weather and climate indicators such as antecedent rainfall and snowpack conditions, historic forecast errors, and teleconnection indices. This also allows for outlook developers to weight past history such that the historical past is not treated equally. Reclamation and stakeholder agencies have traditionally assumed that past climate and operational records are representative of future climate conditions. However, with the onset of climate change, the past may not necessarily represent the future. Weighting past historical traces of climate and operations is a step towards improving traditional assumptions.

Reclamation and other governmental agencies routinely use the results of ensemble forecasts despite the fact that most Reclamation models are predominantly deterministic. Throughout Reclamation, this is typically reconciled through the use of the most probable, minimum probable, and maximum probable traces of the ensemble forecasts. The most probable trace is defined as median (50% exceedence) ensemble value. The minimum probable and maximum probable traces are defined as the 90% exceedence and 10% exceedence, respectively.

Uncertainty Associated with Other Inputs

Reclamation and stakeholder agencies utilize other outlooks when developing their own operational outlooks. Weather and climate projections of precipitation, temperature, and snowpack are commonly used by resource managers. Weather and climate information is often used at the discretion of the operator or modeler, and is inconsistent between Reclamation offices and stakeholder agencies. Information regarding short-term weather is often subject to qualitative analysis, and the quantitative impact to operational outlooks is variable based on agency and individuals. Environmental outlooks are occasionally used by Reclamation offices when accounting for operational impacts to endangered species or habitats.

Operational outlooks are not solely dependent on hydroclimatological projections. Reclamation operational projections are also dependent on demand outlooks. For example, in the Lower Colorado River Basin and CRWCD during peak agricultural use, irrigation demands are impacted by weather and gains or losses such as those due to tributary inflow or evaporation and can impact both water supply and demand. Stakeholder projections are generally more dependent on population and development outlooks. Based on these outlooks, alternative demand scenarios are often generated by Reclamation and stakeholder offices to account for best and worst case scenarios; alternative scenarios are typically not communicated with outside agencies.

While Reclamation and stakeholder agencies acknowledge uncertainty in policy, nearly all offices do not account or incorporate any knowledge of this uncertainty into outlooks or model projections. Accounting for political uncertainty has been strongly discouraged or not allowed by most agencies.

Operations Modeling and Related Tools

Reclamation and stakeholder agencies rely heavily on the results and projections of numerous models. While most offices agree that quantitative output from a model expressing uncertainty is desirable, most agencies tend to express uncertainty implicitly through a range of projections; for example, a probable minimum, probable maximum, and most probable inflow ensemble. Reclamation has expressed interest in the development of a tool or standard document to express or aid in the development of the expression of uncertainty in Reclamation models.

Reclamation offices internally utilize tools to assess risk and uncertainty. Most commonly, these are:

- Custom spreadsheets expressing exceedence probabilities regarding reservoirs filling or spilling (e.g., Pacific Northwest Region)
- Custom applications developed for specific cases (e.g., Army Corps of Engineers)
- Web-based applications (e.g., CPC and CBRFC)

Communication of Risk and Uncertainty in Operations Outlooks

Reclamation communicates risk and uncertainty to stakeholders through different means depending on stakeholder needs and target audience. Communication ranges from personal and conversational to official and technical. Presentations, reports, and graphs are all commonly used in communication with stakeholders. Current efforts focus on the communication of deterministic versus probabilistic results. Appendix A displays an example of deterministic results published for the Colorado River basin followed by probabilistic results published for the Truckee River basin.

Stakeholder Type

Reclamation interacts with a myriad of resource professionals and non-professionals with different levels of need and understanding, often within the same agency. Stakeholders typically fit into one or more of the following categories:

- Operators – This group includes control room and facility operators who often have a clear understanding of local and plant operations.
- Technical Staff – This group includes personnel who use and interpret model and model results. Technical staff often has an understanding of broad, system-wide characteristics, and provide upper management with information regarding model operations and results.
- Management – This group includes personnel who understand and influence policy decisions and typically convey information to management at other agencies
- General Public – This group include a broad range of individuals who may or may not have a technical understanding of system operations, but may be impacted or have a vested interest in local or system operations.

Stakeholder Experiences and Perceptions

Stakeholders have expressed various degrees of satisfaction with Reclamation communication regarding risk and uncertainty; however, nearly all stakeholders have requested and continue to request more information regarding uncertainty in Reclamation outlooks. Reclamation outlooks primarily impact stakeholders financially, as water and power are frequently bought or sold depending on Reclamation, and internal stakeholder, projections.

Municipalities develop water resource and management plans based on Reclamation outlooks. Increased certainty in outlooks would allow for more aggressive water management and decrease the likelihood of unanticipated shortages on water customers. Improved and expanded communication of uncertainty and risk in reservoir operations would allow for more informed resource management decisions. The customers of municipalities, as well as the municipalities themselves, would like to understand and communicate the levels of risk more clearly.

Western Area Power Authorities would like more communication regarding planned and unplanned maintenance on generation units at Reclamation power plants. Western has noted that Reclamation tends to provide a range of hydrologic and consumptive use demands that is too large; a narrower range or increased certainty of demands is desired. Increased certainty in projections would reduce the frequency of electric power rate increases.

Describing Models and their Results

Reclamation and stakeholder agencies continue to work on improved methods of communicating input, output, and general model uncertainties. Stakeholders tend to be most dependent on operational outlooks that describe:

- Reservoir storage and elevation
- Streamflow forecasts
- Reservoir operations
- Probabilistic operations

Reclamation consistently receives requests from stakeholders to produce more probabilistic output similar to that of ensemble streamflow prediction models used by the RFC. Stakeholders would like to see increased communication regarding near-term, mid-term, and long-term uncertainty. Most stakeholders find the information regarding forecast uncertainty on RFC websites to be very helpful.

In the past, stakeholders typically required a single, deterministic value or projection from Reclamation; however, as resources become scarcer, more stakeholders would like to see probabilistic projections. Stakeholders increasingly want to answer questions using probability amounts; for example, what is the percent probability that a reservoir will fill or hit a target elevation? In general, resource managers and stakeholders are more interested than the general public in risk and uncertainty incorporation and uncertainty.

Current Gaps

Risk & Uncertainty in Operations Outlooks

Section 2 describes current practices in terms of the incorporation of risk and uncertainty in seasonal to annual operations outlooks. This Section looks at those practices and describes gaps based on feedback from the workshop.

The most common gap expressed by workshop attendees in the incorporation of risk and uncertainty in operations outlooks is the use of probabilistic information and expressing the results in probabilistic terms.

Use of Information in Decision Making

Many operational outlooks incorporate uncertainty through analyses that utilize the minimum, maximum and most probable forecast. Some Regions utilize these forecasts on a monthly basis and some make use of these forecasts only during certain months of the year. For the rest of the years, they rely on the most probable forecast or climatology. Other percentiles, such as the 25^{th} or 75^{th}, are not often utilized. The main reason being there is a lack of models available capable of processing probabilistic input. Water resource planners have asked for operations outlooks that use other percentiles, in the case of the Colorado River Basin, and have expressed that although it is useful to understand the worst and best case (indicated by the maximum and minimum or usually the 10^{th} and 90^{th} percentiles), rarely is planning done based on those extremes.

The reliance on the most probable forecast is also problematic because it does not necessarily translate into the most probable reservoir operation or resulting elevation. A simulation of the forecast ensemble would be required to determine the most probable resulting elevation and then compute a probability for that operation. As stated by Professor David Bowles, best estimate inputs do not necessarily lead to best estimate outputs, so it is unrealistic to think of incorporating uncertainty as simply adding confidence limits to a deterministic model output (due to the non-linearities inherent in the way the system works).

The degree of risk and uncertainty typically varies throughout the forecast cycle. For example, the risk of different outcomes may be wider in January than March. Stakeholders have requested Reclamation better covey the impact of these risk variations on operations outlooks throughout the forecast cycle.

Another gap is the availability of a forecast for the duration of the operations outlook. In the case of the 24-Month Study, a 2-year outlook developed every month jointly by the Upper and Lower Colorado Regions, a forecast is generally only available through the first 12 months. Beyond that, a statistical average of the 1976-2005 inflows is used. Ideally, a forecast extending 2 to 5-year range is needed. When looking at this extended period beyond 12 months, a technique to express hydrology rather than assuming a climatological average would be preferred given the importance of decadal variability in 2-5 year hydrology outlooks.

For the most part, climate change information, e.g., shift in timing of spring runoff, has not yet been factored into forecasts. Many regions employ the strategy of using history to predict the future, e.g. apply historic hydrographs to seasonal forecast volume to project timing. Although the need to incorporate climate information is realized, there is a perception that the incorporation of this information will lead to increased uncertainty.

Other specific needs that were voiced during the workshop include: a better understanding of antecedent conditions affect on forecasts, greater spatial and temporal resolution in forecasts, improved documentation of metadata relating to forecast generation, and better information regarding physical processes in reservoirs (e.g., evaporation).,.

Operations Modeling Tools

Modeling tool development is a common gap among all Regions. The use of operations modeling tools is critical in order to process probabilistic information. However, many regions have not yet developed the modeling tools needed to fully incorporate probabilistic input into operations outlooks. Some Regions, such as the UC and LC Regions are working towards enhancing their mid-term operations model to handle probabilistic inputs.

In addition to the need to develop better modeling tools, there is also a need to link existing models together so that there is better and more efficient communication amongst the models. This would enhance automation which is needed to make the incorporation of probabilistic data more efficient.

Communication of Risk & Uncertainty in Operations Outlooks

There is a chain of uncertainty from science to decision-makers and communication is imperative (moving both ways) down the line, e.g. science agencies learn from the operators what forecasts and tools are useful, operators learn from water managers who learn from decision makers, what types of output are useful.

Reclamation operators and managers frequently work in systems that entail competing objectives. To help attain an equitable balance of these objectives, e.g. provide higher fish flows, provide better chance of refilling reservoir and prevent or minimize the occurrence of water shortages, operators and managers are motivated to incorporate risk and uncertainty through the use of operations models and probabilistic operations analysis. Communicating the use of these tools and the resulting analysis that aid Reclamation’s decision-making process is a critical step that supports decisions impacting the stakeholder community under competing objectives.

Improved communication with stakeholders is needed to understand their needs and better tailor outlooks to those needs. This could be as simple as providing figures of reservoir elevations as opposed to storages to stakeholders who think in terms of elevations. In the partnership with stakeholders Reclamation must ensure communication of risk and uncertainty is meeting stakeholder needs. If it is not, listening to stakeholders requests and meeting these requests to the best of our ability is essential.

Operators have expressed difficulty in communicating the use of forecast to stakeholders with wide ranging expertise when forecasts are not consistent between sources. In the case of the

Boise Basin in the PN Region, the coordinated forecast, NWS ESP forecast and the Region's forecast are not always in-sync. Explanations of why forecast may not be in-sync that are tailored to a range of audiences would help stakeholders grapple with conflicting information.

Common Risk & Uncertainty Language for Stakeholders

In order to convey the complete picture of risk and uncertainty, consider the following format: the probability of event Y in the time period T is X1 to X2 considering the uncertainty in factors a1 through ai and not considering the uncertainty in factors b1 through bi. Thus the risk of the event along with the uncertainty associated with factors associated with quantifying the risk is communicated. Generally, some part of the picture is conveyed to stakeholders but rarely is the entire picture communicated. Reasons vary by Region and range from technical limitations to limited stakeholder interest. (UC and LC Regions have expressed that they would like to convey their many operational triggers in a probabilistic framework, but do not currently have the technical capability. As a path forward, they are working with the NWS to identify the probability of reaching a defined trigger that is important as identified in the operations outlook, i.e. probability of equalization in 2010).

Another gap is the failure of operational outlook producers to provide or display data in a way that is most meaningful to stakeholders. Operations outlooks that are regularly produced and relied on by stakeholders should incorporate stakeholder input regarding display of results. Many regions, the PN Region for example, have considered using probabilistic forecasts in the form of ESP provided by the NWS, and have encountered two problems that are similar across regions. The first problem being, certain stakeholders prefer the "best shot" or a single value. Another is significant staff time is required (in part due to the lack of tools available to process probabilistic input quickly) to run probabilistic information through their existing model. In contrast, the UC and LC Region stakeholders are requesting probabilistic forecasts be used to produce probabilistic operations outlooks.

Common Approaches to Address Stakeholder Uncertainty Questions

Instead of providing "best guess" answers to stakeholder uncertainty questions, Regions need to encourage stakeholders to ask risk-based questions. For example- What is the probability of equalization (an event) occurring? As opposed to, what is your best guess for what Powell's elevation will be on September 30? In other words, consider thresholds that are important as decision points and convey uncertainty around those decision points. Some stakeholders like to be rooted in reality and sometimes ask "what year in history is this like? How is this like something we've seen before?" In communicating uncertainty to stakeholders it is useful to keep the responses and explanations simple, but to be careful to not over-simplify.

It is not always clear to decision makers how to use risk and uncertainty information. Some decision makers avoid uncertainty information because having that information puts the decision makers on the line. They do not want to be accountable for a number that they do not really understand. Providing a range of possible actions based on a range of possible outcomes is more helpful, which also encourages an analysis and discussion of the tradeoffs.

Operator experience has shown personal interaction with stakeholders and developing partnerships with stakeholder groups that go beyond less interactive means of communication (such as a website) is critical. Once established, the interaction should become a constant stream of education so that stakeholders are knowledgeable and thus prepared when operations can shift due to forecast changes.

Path Forward (Recommendations Based on Current Gaps)

Section 3 identified current gaps in the implementation and communication of risk and uncertainty in Reclamation projections and in communication with stakeholder groups. It is essential to consider and act upon a path forward in which Reclamation, with associated agencies and stakeholder groups, improve the way in which information regarding risk and uncertainty is implemented in water and resource management practices.

Improved Information and its use in Improving Decision Making

Improvements to existing datasets and new information have been made available to Reclamation and stakeholder groups, particularly with respect to weather and climate information. This includes, but is not limited to:

- Increased accuracy in short-term forecasts (i.e., less than two weeks)
- Mid-term operational projections (i.e., greater than a year)
- Statistical forecasts of temperature and precipitation
- A better understanding of Potential and Actual Evapotranspiration

Additional improvements to information that is not necessarily climate related include, but is not limited to:

- Flood control requirements as defined by the USACE
- Timing and magnitude of agricultural and irrigation demands
- Municipal demands for water
- Economic impacts

Whereas there is some concern that some advanced stochastic techniques may be too difficult to communicate broadly and effectively, there is optimism that Reclamation and stakeholders have elevated the general knowledge base such that this information and new, more advanced, techniques for expressing and quantifying risk and uncertainty can be effectively integrated. Probabilistic volumetric forecasts are currently being generated by the NRCS and RFC; however, most Reclamation offices use a single trace for use in a deterministic model. Reclamation is currently working towards integrating ESP results and longer range water supply forecasts (i.e., two to five years).

Reclamation is currently incorporating projected climate information into its models, as the past may not necessarily be representative of the future under changing climate conditions. While these projections have not been incorporated into published reports, Reclamation is currently working to understand the impacts of changing climate scenarios to operations.

Improved Information Strategy Implementation

Reclamation is committed to addressing Stakeholder needs for improved strategy information, although Stakeholder demands often vary between Stakeholder groups and Reclamation offices. Reclamation stakeholders differ in their needs with respect to risk and uncertainty. Some stakeholders require a most probable or average scenario that is essentially deterministic as the basis for decision. Most stakeholders have an increased interest in probabilistic output and uncertainty. To meet these needs Reclamation needs to:

- Incorporate improved forecasts
- Develop models able to accept and provide probabilistic input and output
- Maintain flexibility
- Continue effective communication strategies
- Develop new ways to effectively communicate new information
- Continue to solicit feedback from stakeholder community regarding evolving needs

Stakeholder Involvement

Reclamation and stakeholders agree that it is in the best interest for all parties to be partners in the development and implementation of improved strategies regarding risk and uncertainty. While continued education is important to both Reclamation and Stakeholders, education tends to imply that one agency would be imparting knowledge on another, and suggests more formal, impersonal training and exercises.

It is Reclamation's intent to involve Stakeholders to the fullest extent possible not just continued education. Communication and accessibility are paramount, and may be accomplished through face-to-face meetings, sharing and communication of beta products, and frequent reviews and informal consultations. For example, the state of Colorado has developed a "Climate Road Show" which travels to various groups and invites them to participate in a discussion of climate change and different ways to address the impacts of climate change to water resource availability. The focus of the effort should center on personal communication, rather than on the development of educational materials.

Sharing Strategies Among Stakeholders

Several concepts under consideration to share strategies between Reclamation and other stakeholders include, but are not limited to:

- Development of a Reclamation website to act as a source for current and developing practices regarding risk and uncertainty
- Creation of a listserv to which questions and ideas can be shared and discussed informally between those concerned with the implementation and communication of risk and uncertainty
- Reclamation offices can continue to submit for Science and Technology funds through the Technical Service Center in pursuit of improved tools that better incorporate uncertainty.
- Periodic meetings with Reclamation and Stakeholders to discuss current practices regarding risk and uncertainty and listen to stakeholder needs.

Operations Modeling Tools Development & Modification

There exists a gap in information regarding complimentary tools that quantify risk and uncertainty in current Reclamation models. Often times, the extent of quantification is limited to exceedence probabilities or the investigation of hindcast modeling. New models and tools based on a common set of understanding and needs are desirable. New tools could be run in parallel with existing tools to develop a better understanding of operational effects. The concurrent running of models also allows for the opportunity to develop products that effectively communicate information regarding associated risks and uncertainties from these new models.

Development of a Common Language to Convey Risk & Uncertainty

Risk and uncertainty is defined differently between researchers, agencies, within Stakeholder groups, and within Reclamation. From this workshop, it was identified that the development of a common language with agreed upon definitions and metrics would be immensely useful. With respect to the communication of uncertainty, it was stated that those involved should, "…keep it simple, but not simpler than it should be." As stated previously, with the development of a common language it is important to focus on personal communication and interaction, as opposed to formal training and non-personal communication via websites and documentation (although those may compliment personal interactions).

It is clear that stakeholders and Reclamation offices need answers to, and need to be able to answer practical questions such as:

- What is the probability of a reservoir filling?
- What is the probability of flood control releases?
- What is the probability of equalization?
- What is the probability or surplus, shortage, or normal conditions?
- Approximately how much snowpack is necessary to see an amount of inflow?

- How likely is an environmental release?
- What is the likelihood of reaching a certain reservoir elevation?
- What range of elevations can be expected over a particular time?
- What is the probability of triggering operational thresholds (e.g. specific reservoir elevations)?

Risk and uncertainty practices need to be developed with the goal of answering these types of questions readily, uniformly, and effectively.

Appendix A. Example of Published Results from Operations Outlooks for the Colorado and Truckee River Basins

Deterministic results from the Colorado River Basin

O P E R A T I O N   P L A N   F O R   C O L O R A D O   R I V E R   S Y S T E M   R E S E R V O I R S

Bureau of Reclamation - CRFS 4/2009 Most Prob Water Supply   06-apr-2009 14:41:28

Lake Powell

	Unreg Inflow 1000 Ac-Ft	Regulated Inflow 1000 Ac-Ft	Evap Losses 1000 Ac-Ft	PowerPlant Release 1000 Ac-Ft	Bypass Release 1000 Ac-Ft	Total Release 1000 Ac-Ft	Reservoir Elevation EOM Feet	Bank Storage 1000 Ac-Ft	EOM Storage 1000 Ac-Ft	Lees Ferry 1000 Ac-Ft
* Apr 2008	1003	1004	21	678	0	678	3594.09	18151	11195	691
H May 2008	2644	2365	27	790	0	790	3610.81	18082	12812	807
I Jun 2008	3585	3330	49	791	0	791	3631.05	18413	14971	810
S Jul 2008	1709	1430	63	865	0	865	3633.00	18694	15192	887
T Aug 2008	489	596	62	890	0	890	3629.55	18727	14803	914
O Sep 2008	390	555	56	723	0	723	3626.90	18797	14509	738
WY 2008	12420	12474	396	8885	93	8978				9164
R Oct 2008	382	498	38	749	0	749	3623.82	18844	14172	762
I Nov 2008	418	455	36	603	0	603	3621.90	18866	13966	612
C Dec 2008	311	385	28	801	0	801	3617.89	18847	13541	818
A Jan 2009	329	394	9	802	0	802	3614.17	18816	13155	822
L Feb 2009	328	382	9	602	0	602	3612.05	18803	12938	612
* Mar 2009	468	442	16	626	0	626	3610.43	18768	12774	632
Apr 2009	900	778	27	600	0	600	3611.81	18779	12913	600
May 2009	2400	2066	38	600	0	600	3624.41	18885	14236	600
Jun 2009	2800	2430	46	625	0	625	3638.82	19015	15864	625
Jul 2009	1100	1034	55	815	0	815	3640.11	19028	16016	815
Aug 2009	497	592	56	813	0	813	3637.93	19007	15759	813
Sep 2009	431	543	48	595	0	595	3637.13	19000	15666	595
WY 2009	10364	9997	407	8230	0	8230				8306
Oct 2009	506	574	44	615	0	615	3636.45	18993	15588	615
Nov 2009	523	566	36	600	0	600	3635.89	18988	15523	600
Dec 2009	418	503	30	800	0	800	3633.25	18964	15220	800
Jan 2010	384	481	22	900	0	900	3629.63	18931	14812	900
Feb 2010	395	460	21	800	0	800	3626.62	18904	14477	800
Mar 2010	628	581	25	800	0	800	3624.55	18886	14252	800
Apr 2010	952	770	29	950	0	950	3622.77	18871	14059	950
May 2010	2161	1878	39	1000	0	1000	3629.84	18933	14835	1000
Jun 2010	2808	2421	47	1178	0	1178	3639.48	19022	15942	1178
Jul 2010	1345	1234	55	1175	0	1175	3639.51	19022	15946	1175
Aug 2010	566	672	56	1125	0	1125	3635.47	18984	15475	1125
Sep 2010	459	597	48	595	0	595	3635.11	18981	15432	595
WY 2010	11147	10737	452	10538	0	10538				10538
Oct 2010	506	603	43	615	0	615	3634.66	18977	15382	615
Nov 2010	523	597	36	600	0	600	3634.35	18974	15345	600
Dec 2010	418	548	30	800	0	800	3632.06	18953	15085	800
Jan 2011	384	514	22	800	0	800	3629.52	18930	14800	800
Feb 2011	395	489	21	700	0	700	3627.60	18913	14585	700
Mar 2011	628	614	26	700	0	700	3626.66	18905	14482	700

O P E R A T I O N   P L A N   F O R   C O L O R A D O   R I V E R   S Y S T E M   R E S E R V O I R S

Bureau of Reclamation - CRFS 4/2009 Most Prob Water Supply   06-apr-2009 14:41:28

Hoover Dam - Lake Mead

	Glen Release 1000 Ac-Ft	Side Inflow 1000 Ac-Ft	Evap Losses 1000 Ac-Ft	Total Release 1000 Ac-Ft	Total Release 1000 CFS	SNWP Use 1000 Ac-Ft	Dwnstrm Reqmnts 1000 Ac-Ft	Bank Storage 1000 Ac-Ft	Reservoir Elevation EOM Feet	EOM Storage 1000 Ac-Ft
* Apr 2008	678	40	44	1159	19.5	24	1155	810	1110.61	12463
H May 2008	790	49	49	1113	18.1	30	1110	789	1107.05	12132
I Jun 2008	791	44	59	949	15.9	30	949	776	1104.98	11941
S Jul 2008	865	63	73	876	14.2	33	874	773	1104.42	11890
T Aug 2008	890	95	78	804	13.1	34	789	777	1105.13	11955
O Sep 2008	723	77	64	652	11.0	22	642	781	1105.76	12013
WY 2008	8978	912	606	9531		278	9468			
R Oct 2008	749	47	47	508	8.3	26	498	794	1107.94	12213
I Nov 2008	603	74	47	675	11.3	15	659	790	1107.33	12157
C Dec 2008	801	62	41	453	7.4	8	432	812	1110.97	12496
A Jan 2009	802	63	34	741	12.1	9	739	817	1111.78	12572
L Feb 2009	602	82	31	679	12.2	9	669	815	1111.43	12539
* Mar 2009	626	63	34	1037	16.9	18	1035	791	1107.40	12164
Apr 2009	600	75	42	1191	20.0	26	1191	755	1101.40	11616
May 2009	600	70	47	1018	16.6	35	1018	729	1096.86	11212
Jun 2009	625	24	56	882	14.8	33	882	709	1093.42	10910
Jul 2009	815	61	69	909	14.8	35	909	701	1091.93	10781
Aug 2009	813	110	73	794	12.9	36	794	702	1092.15	10800
Sep 2009	595	78	61	593	10.0	31	593	701	1092.04	10790
WY 2009	8230	809	583	9480		278	9418			
Oct 2009	615	73	44	490	8.0	39	490	708	1093.27	10897
Nov 2009	600	73	44	542	9.1	28	542	712	1093.90	10952
Dec 2009	800	65	39	561	9.1	23	561	727	1096.50	11180
Jan 2010	900	131	32	678	11.0	19	678	745	1099.70	11464
Feb 2010	800	134	30	667	12.0	18	667	759	1101.99	11670
Mar 2010	800	96	33	1013	16.5	25	1013	748	1100.16	11505
Apr 2010	950	75	41	1136	19.1	23	1136	737	1098.32	11341
May 2010	1000	70	47	1009	16.4	32	1009	736	1098.13	11324
Jun 2010	1178	24	57	902	15.2	30	902	749	1100.37	11524
Jul 2010	1175	61	72	902	14.7	32	902	763	1102.77	11740
Aug 2010	1125	110	78	811	13.2	33	811	782	1105.99	12035
Sep 2010	595	78	64	679	11.4	28	679	776	1105.00	11943
WY 2010	10538	990	581	9390		329	9390			
Oct 2010	615	73	47	453	7.4	36	453	786	1106.54	12085
Nov 2010	600	73	47	515	8.7	25	515	791	1107.41	12165
Dec 2010	800	65	41	531	8.6	20	531	807	1110.17	12422
Jan 2011	800	131	34	677	11.0	19	677	820	1112.19	12611
Feb 2011	700	134	31	661	11.9	18	661	827	1113.42	12728
Mar 2011	700	96	35	1014	16.5	25	1014	810	1110.66	12467

Probabilistic results from the Truckee River Basin

Forecast Date: 4/20/2009

TRUCKEE RIVER OPERATION STUDY ***50% EXCEEDENCE FORECAST***

	Tahoe Inflow (1000 AF)	Tahoe EOM Storage (1000 AF)	Tahoe EOM Elevation (feet)	Truckee River at Tahoe City (1000 AF)	Truckee River nr Truckee (1000 AF)	Donner Inflow (1000 AF)	Donner EOM Storage (1000 AF)	Donner EOM Elevation (feet)	Don Cr at Donner (1000 AF)	Don Cr at Hwy 89 (1000 AF)	Martis Cr blw Martis (1000 AF)	Prosser Inflow (1000 AF)	Prosser EOM Storage (1000 AF)	Prosser EOM Elevation (feet)	Pross Cr blw Prosser (1000 AF)	Indep. Inflow (1000 AF)	Indep EOM Storage (1000 AF)	Indep Cr blw Indep (1000 AF)
Jan-09	8.0	32.8	6,223.27	0.7	2.3	1.0	3.7	5928.75	0.8	1.3	0.5	1.5	9.9	5703.81	1.5	0.4	15.0	0.1
Feb-09	9.6	41.2	6,223.34	1.1	3.7	1.8	4.1	5929.29	1.4	2.5	0.6	2.0	10.3	5705.10	1.6	0.9	15.1	0.8
Mar-09	43.1	81.3	6,223.67	3.1	8.9	3.8	4.2	5929.41	3.7	6.6	2.4	5.1	10.2	5704.78	5.3	1.2	14.9	1.4
Apr-09	17.1	94.2	**6,223.78**	4.1	12.8	4.9	8.3	5934.37	0.8	4.3	2.1	8.9	13.7	5713.78	5.4	1.6	15.8	0.7
May-09	68.2	158.1	**6,224.30**	4.3	19.7	6.2	9.5	5935.81	5.0	11.3	1.6	13.1	21.0	5728.06	5.7	4.1	17.5	2.4
Jun-09	20.8	173.1	**6,224.43**	5.9	14.2	1.9	9.5	5935.81	1.9	5.3	1.1	7.5	22.4	5730.26	6.2	2.8	17.5	2.8
Jul-09	(26.2)	128.2	**6,224.06**	18.7	20.2	0.2	9.5	5935.8	0.2	0.8	0.9	2.0	20.3	5726.82	4.0	0.6	17.5	0.6
Aug-09	(49.9)	68.6	**6,223.57**	9.7	10.2	(0.0)	9.4	5935.64	0.1	0.3	0.8	0.6	15.8	5718.33	5.1	0.3	17.5	0.3
Sep-09	(45.1)	21.5	**6,223.18**	2.0	2.5	(0.0)	3.7	5928.71	5.7	5.8	0.6	0.5	11.5	5708.37	4.8	0.1	15.6	2.1
Oct-09	(36.5)	(15.1)	**6,222.88**	0.1	0.7	0.0	3.2	5928.08	0.5	0.7	0.6	0.7	9.8	5703.61	2.4	0.1	14.5	1.2
Nov-09	(4.8)	(19.9)	6,222.84	0.0	0.7	0.2	3.2	5928.12	0.2	0.3	0.6	1.0	9.8	5703.61	1.0	0.5	14.5	0.5
Dec-09	16.5	(3.4)	6,222.97	0.0	1.2	0.7	3.4	5928.39	0.5	0.9	0.8	1.8	9.8	5703.61	1.8	0.5	14.5	0.5
TOTAL	**20.9**			**49.8**	**97.1**	**20.7**			**20.8**	**40.0**	**12.6**	**44.7**			**44.8**	**13.2**		**13.4**
Apr-Jul	**79.9**			**33.1**	**66.9**	**13.1**			**7.8**	**21.6**	**5.7**	**31.5**			**21.3**	**9.2**		**6.6**

Apr-Oct: Tahoe elevation RED if below 6225.5 ft (Floriston rates released from Tahoe)

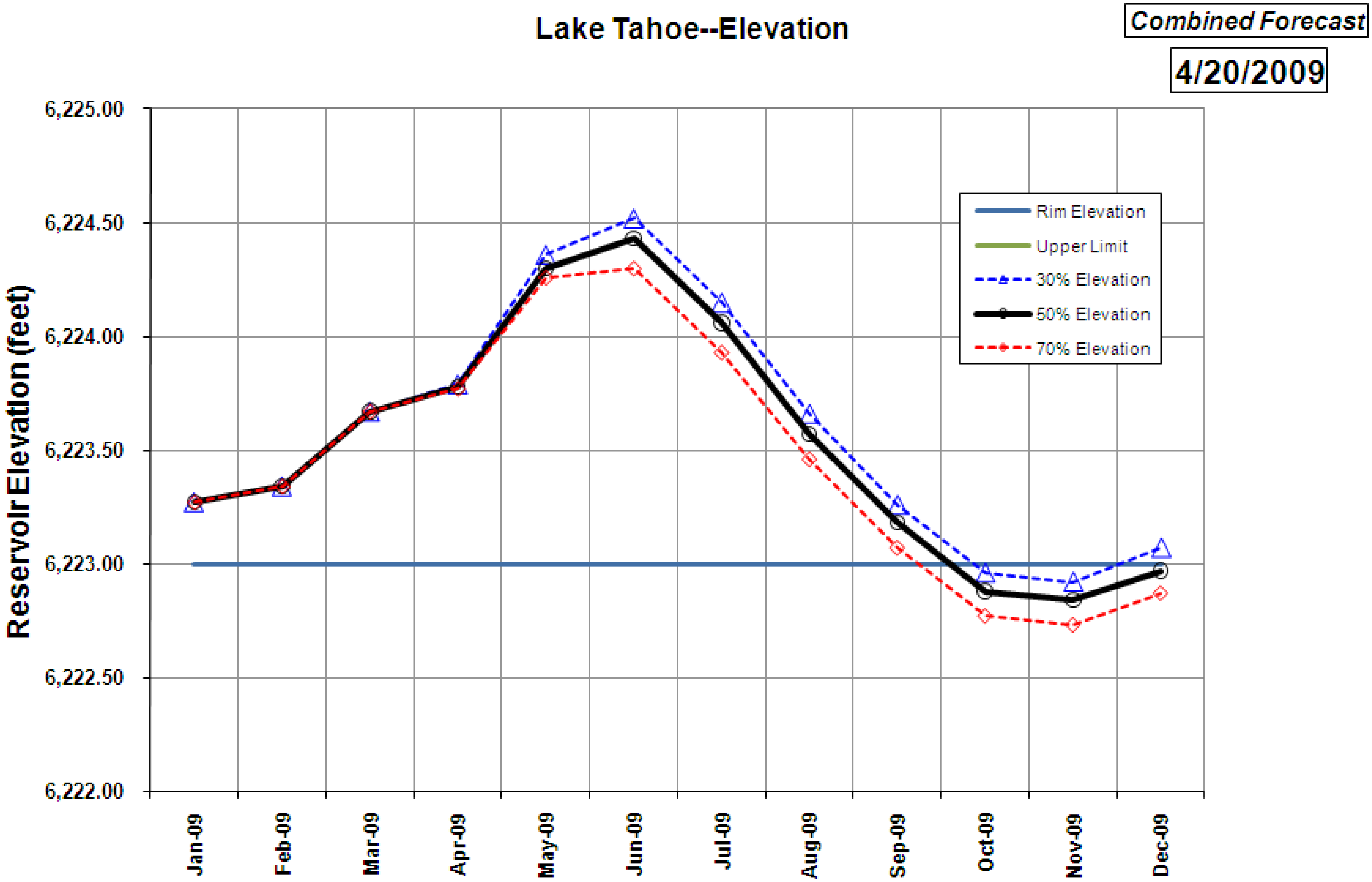
Apr-Oct: Tahoe elevation BLACK if above 6225.5 ft (Floriston Rates released from Boca)

TRUCKEE RIVER OPERATION STUDY ***30% EXCEEDENCE FORECAST***

	Tahoe Inflow (1000 AF)	Tahoe EOM Storage (1000 AF)	Tahoe EOM Elevation (feet)	Truckee River at Tahoe City (1000 AF)	Truckee River nr Truckee (1000 AF)	Donner Inflow (1000 AF)	Donner EOM Storage (1000 AF)	Donner EOM Elevation (feet)	Don Cr at Donner (1000 AF)	Don Cr at Hwy 89 (1000 AF)	Martis Cr blw Martis (1000 AF)	Prosser Inflow (1000 AF)	Prosser EOM Storage (1000 AF)	Prosser EOM Elevation (feet)	Pross Cr blw Prosser (1000 AF)	Indep. Inflow (1000 AF)	Indep EOM Storage (1000 AF)	Indep Cr blw Indep (1000 AF)
Jan-09	8.0	32.8	6,223.27	0.7	2.3	1.0	3.7	5928.75	0.8	1.3	0.5	1.5	9.9	5703.81	1.5	0.4	15.0	0.1
Feb-09	9.6	41.2	6,223.34	1.1	3.7	1.8	4.1	5929.29	1.4	2.5	0.6	2.0	10.3	5705.10	1.6	0.9	15.1	0.8
Mar-09	43.1	81.3	6,223.67	3.1	8.9	3.8	4.2	5929.41	3.7	6.6	2.4	5.1	10.2	5704.78	5.3	1.2	14.9	1.4
Apr-09	18.8	95.9	**6,223.79**	4.1	13.1	5.0	8.4	5934.55	0.8	4.4	2.1	9.2	14.5	5715.63	4.9	1.7	15.9	0.7
May-09	73.5	165.1	**6,224.36**	4.3	21.3	6.8	9.5	5935.81	5.8	12.7	1.8	14.5	24.8	5734.05	4.2	4.5	17.5	2.9
Jun-09	24.1	184.1	**6,224.52**	5.2	14.4	2.1	9.5	5935.81	2.1	5.9	1.2	8.3	27.7	5738.23	5.5	3.1	17.5	3.1
Jul-09	(27.9)	136.8	**6,224.15**	19.4	21.0	0.2	9.5	5935.8	0.2	0.9	1.0	2.2	27.6	5738.18	2.3	0.7	17.5	0.7
Aug-09	(51.6)	74.2	**6,223.66**	11.1	11.6	(0.0)	9.4	5935.64	0.1	0.3	0.8	0.6	20.6	5727.32	7.6	0.3	17.5	0.3
Sep-09	(46.8)	25.0	**6,223.26**	2.4	2.9	(0.0)	3.7	5928.71	5.7	5.8	0.6	0.5	14.4	5715.25	6.8	0.1	15.6	2.1
Oct-09	(38.2)	(13.4)	**6,222.96**	0.2	0.8	0.0	3.2	5928.08	0.5	0.7	0.6	0.7	9.8	5703.61	5.2	0.1	14.5	1.2
Nov-09	(6.5)	(19.8)	6,222.92	0.0	0.7	0.2	3.2	5928.12	0.2	0.3	0.6	1.0	9.8	5703.61	1.0	0.5	14.5	0.5
Dec-09	14.7	(5.1)	6,223.07	0.0	1.2	0.7	3.4	5928.39	0.5	0.9	0.8	1.8	9.8	5703.61	1.8	0.5	14.5	0.5
TOTAL	**20.9**			**51.5**	**101.8**	**21.7**			**21.8**	**42.2**	**13.0**	**47.4**			**47.6**	**14.1**		**14.3**
Apr-Jul	**88.5**			**33.0**	**69.8**	**14.1**			**8.9**	**23.8**	**6.1**	**34.2**			**16.8**	**10.1**		**7.4**

Apr-Oct: Tahoe elevation RED if below 6225.5 ft (Floriston rates released from Tahoe)

Apr-Oct: Tahoe elevation BLACK if above 6225.5 ft (Floriston Rates released from Boca)



Lake Tahoe--Elevation
Combined Forecast
4/20/2009
Reservoir Elevation (feet)
6,225.00
6,224.50
6,224.00
6,223.50
6,223.00
6,222.50
6,222.00
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
Nov-09
Dec-09
Rim Elevation
Upper Limit
30% Elevation
50% Elevation
70% Elevation

Appendix B. List of Participants

Name	Organization	Phone	E-Mail
Kevin Werner	NOAA - CBRFC	801-524-5130	Kevin.Werner@noaa.gov
Leo House	USGS-National Research Program	303-36-5023	Lbhouse@usgs.gov
Chris Lynch	Reclamation(PN-CCAO-YGO)	509-697-5646 x252	clynch@pn.usbr.gov
David Bowles, Ph.D.	Utah State University	435-770-8709	David.Bowles@usu.edu
Steven Bowser	Reclamation (UC-Albuquerque)	505-462-3592	sbowser@usbr.gov
Katrina Grantz	Reclamation (UC)	801-524-3635	kgrantz@usbr.gov
Jose D. Sales	Colorado State University	970-491-6057	jsalas@engr.colostate.edu
Chris Holmquist-Johnson	USGS Fort Collins Science Center	970-226-9382	H-JohnsonC@usgs.gov
Brad Udall	CU-NOAA Western Water Assessment	303-497-4573	bradley.udall@colorado.edu
Bill Hasencamp	Metropolitan Water District	323-496-3648	whasencamp@mwdh2o.com
Rolf Olsen	U.S. Army Corps of Engineers	703-428-6314	j.rolf.olsen@usace.army.mil
Tom Scott	Reclamation (MP-LBAO)	775-884-8357	tscott@mp.usbr.gov
Michael Beus	Reclamation (PN-SRAO)	208-678-0461x27	mbeus@usbr.gov
Edward Kandl	Reclamation (UC-Albuquerque)	505-462-3586	ekandl@usbr.gov
Pat Fritchel	Reclamation (MP-LBAO)	775-884-8358	pfritchel@mp.usbr.gov
Pat McGrane	Reclamation (PN)	208-378-5215	pmcgrane@usbr.gov
Mike Gillespie	USDA-Natural Resources Conservation Service	720-544-2852	mike.gillespie@co.usda.gov
John Gierard	Western Area Power Administration	970-461-7445	gierard@wapa.gov
Betty Dinneen	Reclamation (Denver)	303-45-3029	edinneen@usbr.gov
Dave Kanzer	Colorado River District	970-945-8522	dkanzer@crwcd.org
Warren Sharp	Reclamation (Albuquerque)	505-462-3637	wsharp@usbr.gov
Bill Fiedler	Reclamation (Denver)	303-445-3248	wfiedler@usbr.gov
Heather Patno	Reclamation (UC)	801-524-3883	hpatno@usbr.gov
Beth Faber	USACE Hydrological Engineering Center	530-756-1104x335	beth.faber@usace.army.mil
Scott Guenthner	Reclamation (GP)	406-247-7736	rguenthner@usbr.gov
Michael Tansey	Reclamation (MP)	916-978-5197	mtansey@usbr.gov
David Raff	Reclamation (Denver)	303-445-2461	draff@usbr.gov

Name	Organization	Phone	E-Mail
W. Paul Miller	Reclamation (LC)	702-293-8381	wmiller@usbr.gov
Veva Deheza	Colorado Water Conservation Board	303-866-3441x3226	veva.deheza@state.co.us
Andrea Ray, Ph.D.	NOAA - ESRL	303-497-6434	andrea.ray@noaa.gov
Peter Dickerson	USACE Portland District	503-808-4964	peter.d.dickerson@usace.army.mil
Jim Prairie	Reclamation (UC)	303-492-8572	jprairie@usbr.gov
Tom Perkins	USDA-NRCS-NWCC	503-414-3059	tom.perkins@por.usda.gov
Rod Wittler	Reclamation (MP)	530-262-3670	rjwittler@usbr.gov
Kristen Averyt	Western Water Assessment	303-497-4344	kristen.averyt@noaa.gov
Margaret Matter	Colorado State University	970-491-7620	Margaret.Matter@Colostate.edu
Thomas Maher	Southern Nevada Water Authority	702-862-3702	tom.maher@snwa.com
John Lhotak	NOAA - NWS - CBRFC	801-524-5130x341	john.lhotak@noaa.gov
Carly Jerla	Reclamation (LC)	303-735-1729	cjerla@usbr.gov
David J. Williams, Ph.D.	U.S. Army Corps of Engineers	918-669-7091	david.j.williams@usace.army.mil
Mike Reddy	USGS-WRD-NRP	303-236-5021	mmreddy@usgs,gov
Chuck Hennig	Reclamation (Denver)	303-445-2134	chennig@usbr,gov
Bret Bruce	USGS	303-236-4902	bbruce@usgs.gov
Ted Day	Reclamation (PN)	208-378-5273	tday@usbr.gov
Karen Weghorst	Reclamation (Denver)	303-445-2548	kweghorst@usbr.gov
Don Campbell	USGS	303-236-4882x298	dhcampbe@usgs.gov
Mary Mellema	Reclamation (PN)	208-378-5118	mmellema@usbr.gov
Rick Koehler	NOAA - NWS	303-497-8369	Richard.koehler@noaa.gov
Edith Zagona	University of Colorado (CADSWES)	303-492-2189	zagona@colorado.edu
Joseph Barsugli	NOAA	303-497-6042	joseph.barsugli@noaa.gov
Kieran Bhatia	NOAA	301-221-9638	kieran.bhatia@noaa.gov

Appendix C: List of Presentations with Brief Descriptions

Presentations are available online at http://www.esrl.noaa.gov/psd/workshops/ccawwg/2009/

Day 1 – Tuesday, June 16

BOR Pacific Northwest Region
Mary Mellema will present how reservoir operators assess risk in real-time for the Boise system. Reclamation manages three major reservoirs on the Boise River with total capacity of approximately 1 MAF, which is fifty percent of the basin's average runoff. These reservoirs provide irrigation water for approximately 325,000 acres and provide millions of dollars of flood control protection annually for the city of Boise. This presentation will show techniques used by the reservoir operators to assess the risk of flooding and providing water for irrigation and other uses in the Boise basin.

Chris Lynch will present a method used by the Yakima Field Office to determine winter minimum flows. The YFO has developed an empirical decision support tool known as the "storage and precipitation threshold method" that indicates if winter target flows should be held constant or should be reduced in December and/or early January. The method is intended to increase the beneficial use of the water supply for fisheries without a detrimental impact to existing irrigation obligations.

U.S. Army Corps of Engineers (USACE)
Reservoir operations and operating rules are developed based on streamflow information of various types, from historical to annual outlooks to short-term forecasts. Each type of information reduces uncertainty in what's to come that year and allows less hedging in operation.

Beth Faber and Rolf Olsen will review how each type of information is used. Additionally, now we recognize that uncertainty does not just span the historical variability but also climate change, and how the future might differ from the past. One recommendation for adapting USACE water management to climate change is to revise water control plans so adaptive management can be used and there is more flexibility to account for new information.

BOR Great Plains Region
Scott Guenthner will present monthly and annual reservoir operating plans that describe three possible operating alternatives. These alternatives incorporate a range of possible reservoir inflows, water supply demands, and foreseen facility operation and maintenance needs for a 12-month look ahead period. This information is shared with stakeholders by direct mail, electronically, and during public meetings with a variety of stakeholders.

BOR Upper Colorado Region
Katrina Grantz will present mid-term operations and planning for the major reservoirs in the Upper Colorado River. The UC office uses a monthly timestep operations model that

incorporates forecasted most probable inflows and expected operations to project future Colorado River reservoir volumes and releases for the next 24-month period. The deterministic model is run near the beginning of each month and projections are updated using the previous month's reservoir volumes and the latest inflow forecasts and water use forecasts. In January and April the model is run using the minimum, maximum, and most probable (10, 90 and 50th percentile) forecasts to better assess the risk and uncertainty and the potential range of operations. The updated results of the 24-Month Study model run are published in the 24-Month Study report which is issued to stakeholders and the public monthly.

Steve Bowser will present on the Albuquerque Area Office Annual Operating Plan (AOP) process, and discuss their particular set of uncertainties and risks. He will conclude with a description of a recent event that suffered from uncertainty and a lack of process/policy on risk/risk management.

Chasing Certainty in Uncertain Times; Managing Water Supplies in the Colorado River Basin of Western Colorado

Dave Kanzer, P.E. - Managing water supplies in Western Colorado today is more art than science. Current practices employed by operators and stakeholders in the Colorado River District to manage water resources depend primarily upon traditional and conventional approaches. These water users are typically risk-averse and rely on long-term averages and practices to dictate operations. Recently, competing demands (endangered fish needs, related seasonal flow targets, recreation, agriculture and growing municipalities) combined with earlier runoff and climate variability have forced these users to consider new operating principles that rely upon different forecasting products and increased risk.

Without reliable and accurate forecasts and operational outlooks, limited water supplies are put at risk, subjecting water users to unnecessary uncertainty. With better forecast and accurate outlooks everyone wins. It's a gamble that water users do not take lightly.

Western Area Power Administration

John Gierard will present Western's legislated obligations and the risk presented to Western by operational uncertainty. John will explain how Western uses Reclamation's operational outlooks in planning wholesale energy purchases and sales in addition to meeting reserve obligations for power system reliability. He will finish with suggested improvements for the one to twenty four month operation outlook process.

BOR Lower Colorado Region

Paul Miller will present risk and uncertainty as it relates to the 24-Month study. The presentation will focus on uncertainty related to side inflow projections, Colorado River user water demands, energy demands and how they impact releases from Hoover Dam, and how operators look at weather and climate conditions that may impact the 24-Month study. Paul will also present on how Reclamation programs (such as ICS and ICUA) have added some uncertainty to water use in the Lower Basin. He intends to conclude with a discussion of the impacts of excess flows to Mexico.

Metropolitan Water District (MWD)
Bill Hasencamp will present how data provided by Reclamation is used by MWD and why knowing risk and uncertainty associated with the data is important to them. Bill will also cover how MWD makes decisions to maintain a reliable water supply to their customers while minimizing costs. He will cover the data they use from both the Colorado River and Sacramento River systems. Specifically, on the Colorado River MWD used data within the year (water use forecasts of the higher priorities within California) and also forecasts of Lake Mead storage levels for the upcoming year, which determine the triggers for surplus and shortages. On the Sacramento River, MWD use forecasts of runoff into the Sacramento Delta to determine their annual water supplies and the ability to move water transferred from the Central Valley Project to MWD. All of the information is then used to manage their storage reserves and to determine if MWD needs to purchase additional supplies or, in the extreme, ration water to their customers.

BOR Mid Pacific Region
Michael Tansey will present methods to forecast agricultural water demands in the San Joaquin Valley. The Mid Pacific Region's primary objective is to develop a method that provides improved forecasts of demands than can be obtained using the current allocation approach. Their goal is not to replace the existing tools but rather to supplement them with improved estimates of demand by forecasting potential evapotranspiration (PET) out to 90 days in the future. To accomplish this goal, Reclamation is partnering with NCAR to develop forecasts of PET across California's Central Valley at 14 and 90 day lead times.

The forecasted values of PET are then used as inputs to the Land Atmosphere Water Simulator (LAWS) model that determines monthly demand. The resulting time series can be used as an input to the Central Valley Project (CVP) operations model and together both models can be used as tools for discussions with CVP water users to develop alternatives strategies to adapt to a forecasted imbalance between supply and demand. Such strategies might involve additional groundwater pumping, imported water, changes in crops types or acreages, deficit irrigation, land fallowing and others.

Pat Fritchel will present a brief review of the methodologies the Lahontan Basin Area Office utilizes in calculating risk and uncertainty in the forecasting of water supply (e.g., similar years and Monte Carlo). This will be followed by a presentation of the communication tools used in conveying the water forecast information to stakeholder groups.

NOAA-Climate Prediction Center
Ed O'Lenic will present the scientific basis, production methods, skill and user-focus of CPC's operational ISI forecasts, with an emphasis on forecasts on seasonal time scales. The probabilistic nature and limitation to two parameters, temperature and precipitation, of these forecasts pose challenges to users related to understanding and applying forecasts to their unique needs. The paper discusses CPC's activity to implement and expand the capability of dynamic, interactive web tools, such as the Forecast Evaluation Tool, developed at CLIMAS, as one possible way to address these user issues. His group also solicits participation with CPC to decide what other measures they should take, including new forecast variables, to improve service to their communities.

NOAA-River Forecast Centers
Kevin Werner will describe (1) current methodologies including how CPC climate forecasts can be applied to the streamflow forecasts, (2) new and ongoing research and development to improve Ensemble Streamflow Predication (ESP), and (3) current uses of ESP. NOAA River Forecast Centers (RFCs) developed ESP capabilities for their simulation models in the 1970s. Since that time, RFCs have increasingly used ESP as a basis for seasonal water supply forecasts in the western United States as well as forecast uncertainty information for the Advanced Hydrologic Prediction Service nation wide. Improving ESP to better leverage weather and climate forecasts and to reduce forecast uncertainty is an important area with significant ongoing activity. Applying ESP to decision making is also an important area.

Natural Resources Conservation Service
The Natural Resources Conservation Service (NRCS), in cooperation with the National Weather Service (NWS) and other federal and private agencies, produces water supply forecasts for hundreds of basins in the western U.S.

To address the water user community's requests for more information on the volume and timing of water availability, and to improve forecast accuracy and timing, the NRCS is researching and developing several technologies at the National Water & Climate Center (NWCC) in Portland, Oregon.

Tom Perkins will describe several new technologies that NRCS are in the process of implementing to achieve the goals stated above. These include (1) daily water supply trend forecasts, utilizing snow telemetry (SNOTEL) snow water equivalent (swe) and precipitation data, (2) a newly developed visual forecast environment (VIPER) to improve our regression-based water supply forecasting products, (3) integration of soil moisture point data into our regression models, (4) developing the capability to use distributed-parameter, physical process models to provide hydrograph products, based on ensemble streamflow prediction (esp) methodology, (5) use of peak swe data values to increase seasonal forecast accuracy, (6) developing ArcGIS spatial techniques to aid in locating new SNOTEL sites in areas where additional climate and watershed parameter data could lead to greater forecast accuracy.

Day 2 – Wednesday, June 17

Risk, Uncertainty and Decision Concepts for Water Resources Systems Operation - David S. Bowles, Utah State University and RAC Engineers & Economists

Prof. Bowles will define and distinguish present concepts of risk and uncertainty. Some common approaches to characterizing and communicating risk and uncertainty will be reviewed. Several levels of complexity in uncertainty analysis will be defined to provide a framework for discussion of estimating uncertainty. Some basics of decision analysis will be discussed with examples of decision criteria to emphasize the importance of carefully selecting the appropriate basis for considering risk and uncertainty in decision making.