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Natural Resources Conservation Service

A Measure of Snow:

Case Studies of the Snow Survey and Water Supply Forecasting Program

NRCS Photo

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SUMMARY

Snow depth and snow water content data have been collected and disseminated throughout the Western United States for over 100 years. Early Snow Survey and Water Supply Forecasting data were gathered through the efforts of university scientists. In 1935, the Soil Conservation Service (SCS) was given $36,000 to establish a formal cooperative Snow Survey and Water Supply Forecasting (SSWSF) Program. The agency was charged with the responsibility for "conducting Snow Survey and Water Supply Forecasts and forecasting of irrigation water supplies." The new program would also develop consistent methods for measuring snow and reliable models for water supply forecasting.

Using a case study approach, this report assesses the various uses of data gathered and published by the SSWSF Program and estimates the value of those data in terms of both the market and non-market values of the information. Additionally, it evaluates the relative merits of maintaining the program as a publicly funded program as opposed to privatizing the program.

This study finds that the SSWSF Program is generating both market and non-market benefits to the U.S. economy and to U.S. society as a whole that are worth significantly more than the cost of the program. Should climate variability increase—as is expected by many of those interviewed in the course of completing this study, and as current climate research strongly suggests—the value of the information provided by the SSWSF Program will increase accordingly.

With adequate time and budget, it would be possible to define the benefits to other users and beneficiaries of the information not included as case studies in this analysis. Also, additional, more thorough modeling could be undertaken in an effort to understand the more complex impacts of changes in agricultural operations and other industry activities that occur in response to SSWSF Program data. Absent those additional analyses, it will suffice to say that, at a minimum, the program more than pays for itself in terms of dollar-valued economic benefits, and the program also generates significant non-market benefits in public safety, recreation, and other non-monotized benefits. Further study would shed more light on these topics as well.

For an Executive Summary of this report, including selected case studies, see a summary report based on this study published by the Natural Resources Conservation Service (NRCS) in November 2008. It is available via the NRCS Web site.

CHAPTER 1. INTRODUCTION

With the pioneering work of University of Nevada scientist Dr. James E. Church in 1906, snow depth and snow water content data have been collected and disseminated throughout the Western United States for over 100 years. Early SSWSF data were gathered through the efforts of university scientists. In 1935, the U.S. Department of Agriculture's (USDA) SCS, now NRCS, was given $36,000 to establish a formal cooperative SSWSF Program. The agency was charged with the responsibility for "conducting Snow Survey and Water Supply Forecasts and forecasting of irrigation water supplies." The new program was also tasked with developing consistent methods for measuring snow and reliable models for water supply forecasting.

The SSWSF Program is designated *cooperative* because it operates with assistance from, and in cooperation with, both public and private entities that have a stake in ensuring that consistent and reliable water forecasts are readily available to cooperators and water managers. These entities fund a portion of the costs for the SSWSF Program activities when they have a specific interest in obtaining snowpack, water content, and soil moisture data about a specific geographic location. Primary among these entities are producers in the agricultural industry, both large and small, whose needs for water supply forecasts constitute the central purpose for the establishment of the SSWSF Program.

The NRCS SSWSF Program has grown into a network of more than 900 manually measured snow courses and over 750 automated Snowpack Telemetry (SNOTEL) weather stations in 12 Western States, including Alaska. The program now issues streamflow forecasts for over 740 locations in the West. The program issues three primary types of data: snow course, SNOTEL, and water supply/streamflow volume. These data, and related reports and forecasts, are made available—mostly in real time—to private industry; Federal, State, and local government entities; and private citizens via extensive Web pages and many other primary and secondary channels of distribution.

This study was conducted in order to achieve two objectives: first, to assess the various uses of data gathered and published by the SSWSF Program and then estimate the value of those data in terms of both the market and non-market values of the information; and second, to evaluate the relative merits of maintaining the program as a publicly funded program as opposed to privatizing it.

With adequate funding and time, it would be possible to establish a reasonably accurate economic value for the program as a whole within the U.S. economy. Absent the availability of those resources, a more limited approach was necessary. Accordingly, the economic analysis was conducted using a "case studies" approach.

THE VALUE OF SNOW SURVEY AND WATER SUPPLY FORECASTING DATA

It is crucial to state at the outset that this report does not concern the value of either snow or water *per se*. Rather, it addresses the value of *timely, accurate information about* snow and future water supplies. It is also important to mention that whatever value the program provides to society today will increase over time as climate variability increases. According to researchers from multiple U.S. and international agencies, research centers, and academies, changes in the world's climate have resulted in a loss of predictability in weather, precipitation, and water transport and accumulation patterns (Mille et al., 2008). This loss of predictability means that the mathematical, probabilistic models used in the past—which were based on fairly stable historic patterns and which served as the basis for modern water system design and water management modeling—are in danger of losing their predictive value. Fluctuations in water-cycle patterns are at risk of becoming too unpredictable for current regional-level models to provide a means of reducing risk. Instead, new models must be developed that are based on detailed representations and localized data on existing and dynamic water systems, real surface and groundwater processes, and actual water users. Continuity of data is crucial to establishing new models that can incorporate and respond to a widening range of observations and increasing degree of stochasticity in weather and climate events. The snowpack and water supply data-gathering system of the SSWSF Program has the potential to provide important components of the needed continuity of information. More important, as randomness increases, real-time, localized data will emerge as an absolutely essential element in any water-management decision-making process.

From a fundamental standpoint, the value of the information generated by the SSWSF Program lies in the contribution it makes to the decision-making process. Information produced by the program feeds into four primary types of decisions:

1. Long-term strategic-planning decisions;
2. Logistical, tactical, and operations planning decisions;
3. Short-term planning decisions; and
4. Immediate, reactive decision-making.

Long-term strategic plans drive logistical, tactical, and operations planning, which in turn drive short-term planning and, consequently, routine operations decisions. When situations arise which have not been anticipated either in the long-term or short-term planning process—especially when these situations involve public safety—immediate reactive decision-making must take place. In those cases, the availability and accuracy of data can sometimes be a matter of life and death for members of the benefiting public.

There are two types of water-management scenarios within which the planning and decision-making processes take place. First and foremost is the reservoir-management scenario. The majority of beneficiaries and users of SSWSF data gain their benefits through the ability to manage their public or private water-storage facilities and their associated water-distribution systems. Second is the case where there is no water storage facility involved and the snowpack itself serves as the water storage. In some of these situations, for example the case for an irrigation system with no water storage, the central benefit lies in knowing approximately how far into the irrigation season an adequate water supply will be available. In the case of public safety agencies, the central benefit lies in being able to anticipate the volume and timing of the peak of spring snowmelt and runoff so as to prepare for any necessary flood protection measures.

Another dimension in these decision-making contexts and scenarios is the overall status of the water supply in terms of volume. In common terms, this dimension can be divided into three rough potential circumstances:

1. Below the average amount of water ("short");
2. An average amount of water ("normal"); and
3. Above the average amount of water ("high").

Any specific entity can and often must define for itself what each of these three water supply circumstances actually *is* from its perspective (such as how many seasonal or annual acre-feet of runoff are considered "normal" by a municipal water reservoir system). Generally speaking, in an effective strategic planning process an organization or agency will analyze prospective future conditions and decide ahead of time how they will respond to various circumstances that might be expected to arise in the future. In the case of the SSWSF Program, a data user might make decisions far ahead of time as to how they will respond in the short-term to each of these three water supply circumstances as they arise. These strategic decisions will drive monthly, weekly, and daily operations.

The means by which SSWSF data are accessed, the methods by which the data are incorporated into the decision-making process, and the overall value of the data to users depend on the operational time horizons as well as the purpose and circumstances surrounding the planning and decision-making processes of the various entities that use the data. The more accurate and consistent the data generated by the program, the more useful and beneficial it is in making both short- and long-term decisions. Recent climate data have shown that climate variability is increasing over the recent past, resulting in more extreme temperature changes, more volatile weather patterns, and fewer historically "normal" years in terms of precipitation amounts and snowmelt timing. These factors make it more important than ever to obtain accurate, consistent, and timely snowpack and water supply forecast data.

CONTENT OF SUBSEQUENT CHAPTERS

Chapter 2 presents the basic concepts of public goods analysis and social welfare economics. This chapter includes a comparison between the national SSWSF Program and two existing snowpack data collection systems that use alternate approaches to SSWSF work and data distribution. In comparison with the readily available "public good" approach taken by the NRCS SSWSF Program, these two systems—the New York

City snowpack data system and the California Cooperative Snow Surveys Program, in which NRCS participates as a partner—provide examples of different approaches to funding a SSWSF system and sharing the generated data.

Chapter 3 consists of an outline and explanation of the basic categories of beneficiaries and users of SSWSF data. These include private industry, government agencies and other government entities, public utilities, educational and research institutions, private citizens, and entities that fit into multiple user-group categories. The same chapter provides an overview of the primary ways in which these beneficiaries use information generated by the SSWSF Program.

The following six chapters present a variety of case studies showing how specific businesses, organizations, agencies, and individuals use and benefit from SSWSF data. Within these case studies, specific dollar values of benefits to particular data users are calculated where possible and meaningful, and these specific values are then used to extrapolate outward and estimate total potential dollar benefits to the applicable category of beneficiaries. These benefits are evaluated within a risk and uncertainty framework, taking into consideration probability distributions and accuracy ranges for SSWSF data. In addition, non-market, non-dollar qualitative benefits are identified for each case study, as appropriate.

Chapter 10 presents a range of alternative formats—public, private, or cooperative—in which snow survey programs in general might be funded and operated. This chapter compares eight alternative formats with the current, cooperative format of the SSWSF Program and addresses many of the related implications and issues. Factors discussed include quality, reliability, and accessibility of data, potential biases in privately funded data gathering and reporting, strategic release and/or sharing of data, the continuity of the national snowpack and water supply record, issues related to the profit imperative of private firms and the provision of long-term data (such as vulnerability to cost-cutting in the case of short-term market fluctuations), and the probability of long-term tenure of SSWSF personnel.

Chapter 11 of the report summarizes the results obtained in the economic analysis and provides an estimate of the economic benefits generated by the program compared with its cost in budget dollars.[1] The final chapter also presents an estimate of several "worst-case" scenarios as a means of estimating a potential upper bound to the economic benefits provided by the existing program.

Unless otherwise noted, all reported dollar values are nominal values.

[1] This summary is not to be construed as providing a total and encyclopedic economic value for the program. To develop an accurate estimate of the total economic value of the SSWSF Program would require a budget and quantity of staff hours that exceed those available for completion of this study.

CHAPTER 2. PUBLIC GOODS AND SNOW SURVEY AND WATER SUPPLY FORECASTING

PUBLIC GOODS THEORY

Economists divide goods and services into four main categories:

1. Private goods;
2. Natural monopolies;
3. Open-access goods; and
4. Public goods.

The defining differences among these four categories are based on whether or not they are rival in nature, and whether or not people can be excluded from enjoying their use. A good or service is rival if one person's use of that good diminishes or completely eliminates the ability of another to also use it. For example, if one consumer eats a particular apple, that apple is no longer available for another consumer to enjoy. A good or service is excludable if it is possible to prevent individuals from consuming it or enjoying its benefits. An example of a good that is excludable is a shirt on a rack at a retail store. Unless a given consumer pays for the shirt, the store has a right—as well as the physical ability, for the most part—to prevent that consumer from taking and wearing the shirt.

Private goods are both rival and excludable. Most consumer goods and services, such as food, automobiles, doctor visits, and so on, fall into this category. Natural monopolies arise when a good or service is not rival but is excludable. Cable television service falls into this category. If a new customer ties into a cable hook-up, the signal to other cable customers is not diminished. (Another definition of natural monopolies relates to the lower cost of having one seller provide the good or service in comparison with having multiple sellers provide it.) Open-access goods are rival but not excludable. An example of this is a crowded, free public road. As additional cars squeeze onto the road, the ability of all drivers to enjoy the benefits of the road is diminished. But no law, physical barriers, or tolls exists that could exclude the additional cars from turning onto that road. Public goods are neither rival nor excludable. An example of a true public good is a street light. If a street light is installed and maintained by one individual, he or she has no way of preventing others from using it. Absent government intervention, the providing individual also has no way of requiring others to pay for the use of the light generated by the lamp. Once the street light is installed and turned on, the light it generates is available for use by all who happen to pass by. One person's use of the light does not affect other consumers' ability to enjoy the benefits provided by the light. And if the lamp is available for use by even one member of the community, no other member of the community can be prevented from enjoying its use. In other words, once a public good is made available for one person's use, it is available for all too freely use and enjoy. Generally speaking, the individual who cares the most about the provision of a particular public good will be the one who ends up providing that good for all affected individuals, assuming that no government or other entity is providing the good. Once the good is provided for one beneficiary, there is no incentive for any others to contribute to the effort or expenses associated with the provision of the good.

Because of the non-excludable nature of public goods, they tend to be provided in quantities lower than those that would optimize social well-being. If the community does not provide a public good by means of social or governmental action, the good will be provided only if one or more members of the community with the financial ability and the motivation to provide it do so in spite of the fact that others will then "free-ride" by using the good free of charge. In the case of a true public good—a good that possesses the characteristics of being non-rival and non-excludable—if it is provided to one person, it is automatically available for all to use regardless of whether or not they pay for it. In addition, economists recognize that attempts to provide public goods by private means will result in provision of lower quantities of those goods than would be socially optimal. In other words, if a good has the characteristics of a public good, the private sector will not provide as much of the good as society in general would desire in comparison with other goods. Cooperative or government provision of the good would result in a greater amount of the good being made available, to the benefit of all.

Basic research and the information generated are acknowledged within formal economic theory as having the nature of public goods. Information is difficult to protect from being re-distributed by initial users and so is subject to externality effects, meaning that benefits can accrue to people who have not contributed any financial resources to the process of data development. Once the data are gathered, they can be freely used by anyone who has access to them. Unlike the "natural monopoly" of goods produced and sold by regulated utilities, such as power and natural gas, information—by its very nature—can be used by limitless numbers of individuals at any given time without loss of usefulness. This ability for a good to be used by multiple individuals at the same time without any compromise in its usefulness is termed "non-rival" in nature. Once the good is provided for one individual, it can be made available for all others at a marginal cost that is equal to only the cost of distribution. Although there are indisputable private benefits that can be obtained through the *use* of the data once they are generated, the data themselves can be used over and over, endlessly, without any loss of value to others who may use them. In some cases, private providers of specific types of information form subscription services through which they obtain compensation for developing and distributing the information. Members of the subscription service are under strict contractual obligation to refrain from sharing data with others, sometimes under threat of legal action should they fail to keep those provisions of the contract. Maintaining such a contract requires willingness on the part of the information provider to vigorously and publicly pursue legal action against any who "defect" from his or her contract. While this is, in theory and reality, a feasible option, given today's information technologies, it is, in practice, very difficult to protect data from universal distribution once they are created and released to any given entity.

There are some goods which are somewhat public in nature but which can be transformed into private or quasi-private goods by means of exclusion techniques. Research is one example of this. Results from basic research can be openly and publicly shared, or they can be hidden or withheld from public use by means of patent protection, through subscription service charges, or by other methods of concealment or restriction of use. When these types of goods are limited in their availability to the public, usually for the purpose of maximizing profits for the entities that generate them, total public welfare is sometimes diminished in comparison with what it would have been had the good been made freely available to all members of the public.

ALTERNATIVE MODELS FOR SNOW SURVEY AND WATER SUPPLY FORECASTING SYSTEMS

The collection and distribution of snowpack and water supply and streamflow data has been treated as a public good within the 12 Western States participating in the SSWSF Program. Data generated by the program have been made readily available to all users via a wide variety of means of distribution. NRCS is not the only entity that produces snow level and water supply data as a public good. For example, the Northeast Regional Climate Center at Cornell University, in cooperation with the National Oceanic and Atmospheric Administration, operates a cooperative snow survey program that produces information that is treated as a public good in much the same way as the NRCS program. The State of Maine, as well, produces snow survey data based on a public goods model of information collection and distribution.

The public good model, however, is not the only way in which snowpack and water supply data can be gathered, distributed, and used. The State of California operates a cooperative snow survey program that is organized and operated on a model that differs slightly from that applied in the USDA-based SSWSF Program, as will be described below. New York City also operates a separate snow survey program that gathers and distributes snow depth, water content, and precipitation data. This program supplies its data to the public via surface mail and through the Northeast Regional Climate Center. The operating methodology of the New York City snow survey program differs somewhat from that of the NRCS SSWSF Program both in terms of the data-gathering technology used and in that the data are not available to the public in real time. It is anticipated that at some point in the near future, New York City’s snow survey program will create an Internet interface through which the public will be able to access the program’s data.

In the early 1900s, in the State of California, natural resource professionals and leaders in agriculture and other industries, as well as government officials, realized the value of snowpack and water supply data. Acting on this realization, California commenced operating its own cooperative snow survey program in 1930, five years before the national, federally led SSWSF Program was formally launched. Because California already had its own system in place, California and the partners in its system chose not to participate in the new Federal system. In addition to California’s own cooperative snow survey program, the NRCS SSWSF Program operates within California boundaries in much the same way as in other States. The difference lies in that the SSWSF Program in