A Framework to Enhance Drought Monitoring and Prediction

Submitted to the

Interim National Drought Council

by Phil Pasteris, editor, United States Department of Agriculture (USDA)/Natural Resource Conservation Service (NRCS); Mark Brusberg, USDA/World Agricultural Outlook Board (WAOB); Michael Hayes, University of Nebraska—Lincoln (UNL)/National Drought Mitigation Center (NDMC); Ken Hubbard, UNL/High Plains Regional Climate Center (HPRCC); John Jensen, National Oceanic and Atmospheric Administration (NOAA)/National Climatic Data Center (NCDC); Bob Lefler, NOAA/National Weather Service (NWS); Dave Mason, USDA/NRCS/Soil Survey; Tom McClelland, USDA/Forest Service (FS); Kevin Robbins, Southeast Regional Climate Center (SRCC); Garry Schaefer, USDA/NRCS; and Mark Svoboda, UNL/NDMC.

April 2001

1 Executive Summary

The May 2000 Drought Policy Commission Report made a number of recommendations to meet the country's need to prepare for drought. Five separate, but interrelated, goals were established by the Commission to guide Congress in creating an infrastructure to assess and mitigate the effects of drought in the United States.

The climate community has been tasked to create a framework to meet Goal 2 of the National Drought Policy Commission (NDPC) Report (shown in its entirety in Appendix A.):

> *Goal 2: Improve collaboration among scientists and managers to enhance the effectiveness of observation networks, monitoring, prediction, information delivery, and applied research and to foster public understanding of and preparedness for drought.*

This report outlines the framework's components and establishes a process to ensure that timely and high-quality climate products are available to assess and mitigate the effects of drought. It also highlights examples of ongoing collaborative efforts, including the Drought Monitor product, to assess current drought conditions. Operational and research needs are identified in areas of preparedness, drought outlooks, water conservation strategies, and an information delivery system. The enhancement of a comprehensive drought information gateway is also discussed.

2 Background

The most fundamental component of a comprehensive approach to drought planning and assessment revolves around having an integrated drought monitoring system in place. The ability to better monitor and improve our prediction of drought remains an essential and critical need in this country in order to provide timely recognition of drought to local, state, tribal, and federal officials responsible for implementing drought response and mitigation measures. Enhancement of such a system would better allow for early drought detection, improve response to the event in a proactive way, and help to trigger actions within drought plans at various levels of government. Given the complex characteristics of drought, there is no single "catch-all" indicator used in detecting drought. Instead, a suite of indicators is necessary in tracking drought and its impacts. The recent development of the Drought Monitor is an example of this multiple-indicator approach.

Drought monitoring requires reliable data to create reliable products for the end user. The end users come from many sectors, but, for all of their differences, they have one thing in common: All are affected by drought. In the past, existing networks did not meet the needs of states and other institutions, leading to the establishment of various networks to provide weather and climate data. Often, the mission of the agency operating the network was narrow and the budget insufficient to widen the purpose of the network.

It is at first discomforting to realize that we will be forced to work with many networks because the measurements and practices vary widely. However, although the networks are numerous, we can come to grips with the monitoring issue if we view it from a systems approach. Using recent technologies to nest and link networks makes sense for drought because the impacts that are to be monitored are sector specific. For drought monitoring, users need access to data from the various networks in a timely and straightforward fashion.

In the following pages, this document identifies the needs to accomplish all nine specific recommendations of the NDPC's Goal 2.

3 User Needs Identification

Agriculture
In the agricultural sector, user interests related to drought include the effect of drought on crop yields, the role of drought in determining animal grazing and feed supplies, and the availability of information for use in short-range management and long-range planning decisions to minimize drought effects. The USDA enumerated its operational needs for weather and climate data in a departmental report (USDA 1999).

A group of experts from the North-Central Regional Climate Research Committee (NC94 2000) note the following, "Continued and improved weather monitoring is critical to the future decisions that need to be made to ensure a healthy American agriculture."

Water
All facets of water resource management and use are affected by drought. For example, inland waterways serve as transportation corridors, and drought can reduce river levels to the point that barge traffic is eliminated (nearly 40% of all grain is transported by barge). Management of discharge from reservoirs may extend the barge season, but a reduced shipping season may force shippers to seek additional transport from the railroad and trucking industry, creating an opportunity and at the same time a major challenge associated with redirecting available railroad cars and/or trucks to meet the need.

Up to 80% of the West's water comes from the seasonally variable snowpack that melts in the spring and summer. Competition and demand for this valuable resource--the lifeblood of this semi-arid and arid region--is growing at a dramatic pace along with western populations. These problems are increasing in other parts of the country as well. Water supply information plays a prominent role in processes designed to provide early-season forecasts that facilitate planning among a wide variety of water uses: urban, agricultural, industrial, hydropower, navigation, recreation, tourism, species preservation, and international treaty compliance.

Energy
Lower river flows lead to reduced hydroelectric power generation and in some cases insufficient water for cooling at nuclear power stations. Reservoir management can serve as a tool to maintain river flow, but drought duration and intensity may reduce the storage

below the point where this approach can be used. Summer drought is often accompanied by high temperatures, which lead to greater air conditioning loads that further exacerbate the problem.

Tourism and Recreation
Droughts can also have devastating impacts on tourism and recreation. Some states, and particularly local communities, are highly dependent on this sector and suffer severe economic hardships during drought. Monitoring drought indicators critical to this sector provides opportunities for stakeholders to reduce the drought impacts they face. Stakeholders include skiing, fishing, hunting, camping, rafting, boating, and other related industries.

Environment
Most environmental impacts caused by drought are not very well understood. For example, the relationships between wildfire incidents and drought are not directly related, but certainly fire weather monitoring is an important drought monitoring component. Other environmental issues that need to be addressed involve timber production, salt-water intrusion, estuary and wetland decline, and species populations. It is also important to note that the United States is a recent signatory to the International Convention to Combat Desertification.

4 Assessment of Network Maintenance, Modernization, and Expansion for Observation Networks

4.1 NWS Cooperative (COOP) Network

The Cooperative Observer Network is a nationwide weather and climate monitoring network of volunteer citizens and institutions that observe and report weather information on a scheduled basis. The Coop is an important component of the National Weather Service's (NWS) data collection and is a vital component of the national observing capability for monitoring temperature, precipitation, snowfall, and other weather events across the United States.

The Coop network was established in 1890 to make meteorological observations and establish and record climatic conditions in the United States, primarily for agricultural purposes. In response to recent interest in climate change and variability, the Coop Network has taken on an additional mission, monitoring and detecting climate change. Although not designed for this purpose, it provides invaluable data. Because it has generated consistent, long-term historical climate data, the network has established an invaluable record of the climate in the United States.

The Coop Network is the only nationwide source of data on surface precipitation and the only systematic observations of surface snow, which are critical for long-term forecasts of water resources and research. In recent years Coop data have been used for water management, drought assessment, engineering and architectural design, models of energy consumption, environmental impact assessments, environmental monitoring and prediction.

The Coop Network consists of thousands of volunteer citizens and institutions. Participants are provided with a set of simple weather instruments and observing instructions. Observers provide basic weather data for their locations, usually on a daily basis.

Within the Coop Network there are several types of stations. At the heart of the network are about 5,000 full "climatological stations" that measure daily maximum and minimum temperatures, precipitation, snowfall, and temperature and snow depth at the time of observation. Many observers also provide supplemental information, such as time of day when precipitation fell and other weather conditions, such as fog, thunder, freezing rain, etc. These stations, called "A" stations, are operated predominately by volunteers, either private individuals or employees of cooperating institutions.

Over time, other types of stations have been added to the network. The need for hydrologic data resulted in the establishment of a number of "hydrologic stations" know as "B" stations, many of which report only precipitation and or river stages. A and B stations make up a network of about 11,472 stations. The Coop Network also includes a small number of "C" stations, which serve a variety of special purposes, such as research on, and forecasts of, frost in fruit growing areas and measurement of precipitation in remote areas. The total number of cooperative observer stations managed and maintained by the NWS approximately 11,600.

Major limitations of the Coop Network are the number of measurements (only precipitation and temperature), lack of timeliness, observation time, and siting. Instrumentation, including the use of paper tapes, represents a serious problem in terms of accuracy, completeness, and timeliness of Coop data. Procedural errors and the related problem of "dateshifting" can result in incomplete, incorrect, or misleading observations. When the ending time of the 24-hour-climatological day varies from station to station of over a period of years at a given station, bias is introduced into the calculated temperature, called "timeshifting" The related problem of "dateshifting," is the practice of entering data for a different date than when the observation was made or by combining daily totals. Another problem is dropped of missing observations. Due to observer illness or vacation and they use improperly trained substitutes.

Many Coop sites are located in cities following population shifts from rural to urban centers. The map in Figure 1 shows the location of those stations that measure both temperature and precipitation and report daily. These 1,500 station reports are gathered on a daily basis into data banks maintained by the Regional Climate Centers. The bulk of the remaining 10,000 stations is not useful in near-real time monitoring of drought because it is not summarized and available until observational sheets have been key entered by the National Climatic Data Center. At these sites there is a gap of several weeks to more than a month making it impossible to discern from their record the current status of drought.

For additional information on the NWS Coop Network please visit the following URL: http://www.coop.nws.noaa.gov/.

4.1.1 NWS COOP Maintenance

Costs associated with this activity are under development as part of the Goal 2 process.

4.1.2 NWS COOP Modernization

Current Cooperative Observer Program (CO-OP) instrumentation and methods for precipitation and temperature measurement are antiquated and will begin to fail by FY2002.

Cooperative volunteer observers comprise the backbone of the weather and climate network. Cooperative observers (11,600) donate more than 1 million hours annually to collect weather data. They record rainfall, snowfall and snow depth, river levels, air and soil temperature, and evaporation. The CO-OP network is the world's premier surface climate observing network and has been in operation more than one hundred years. Customers requesting CO-OP data, whose demands range from energy production and consumption planning to water management, are unable to access data quickly. Additionally, modernization is necessary by an exploding demand for higher density, real-time surface data by weather sensitive industries and private and public weather services far in excess of current capabilities.

Attention is directed to preventing failures at existing sites to avoid compromising the nation's climate record. CO-OP "Rescue" provides only $400K of the $2.3M requested in FY 01. These funds will replace the punch paper tape mechanism for precipitation measurements with an electronic data logger at 20 demonstration sites. The NWS proposed an initiative to Congress to modernize the CO-OP. Funds will be directed towards developing a comprehensive plan for improving timeliness and quality of data, improving maintenance activities and continue the replacement of antiquated equipment begun under "CO-OP Rescue". The modernization will be guided by network studies to identify weather and climate requirements of NOAA, its federal partners, and its constituents. The NWS is coordinating interagency support for an FY 02 CO-OP modernization initiative to secure full modernization funding.

In FY00, The National Weather Service proposed an initiative to Congress to modernize the Cooperative Observer Program. The budget initiative will be re-submitted through the NWS to NOAA in April, to the Department of Commerce in June, to Office of Management and Budget during the Summer, 2001 and if approved, will be submitted to Congress in late Summer, 2001.

4.1.3 NWS COOP Expansion

The NWS is responsible for the operation and maintenance of the Coop Network The objective of the expansion is to achieve the optimal mix of station spacing needed to meet

NWS program requirements and the type of hydrometeorological parameters necessary to support the requirements. The NWS has contracted for a study to clearly demonstrate a clear understanding of the future size, distribution, and data composition requirements of the Coop Network. As part of the NWS expansion a subset of these modernized stations (1,000) will be upgraded with sensors identified by the USDA, including soil temperature and evaporation pan sensors.

The proper density and distribution of the Coop Network are being refined by using Geographical Information System (GIS) technology to update the 1953 United States Weather Bureau "Spatial Density" study to incorporate new users and customer requirements. The study is scheduled to be completed by the end of August, 2001 and the results published in October, 2001.

The 1,500 near real-time Coop stations represent one station every 50 miles across the U.S. In relatively simple terrain Hubbard (1994) found that one station every 20 miles is necessary to achieve a "desired" network resolution on temperature, humidity, solar radiation, and ET, i.e. 90% of the variance at any point between stations can be explained by stations on a 20 mile grid. To achieve this criteria on precipitation would require a mush tighter station spacing. We conclude that near-real time Coop stations are not present in sufficient numbers anywhere in the U.S. and especially in the complex terrain of the mountain West and Alaska. Additionally, there are many weather variables, other than precipitation and temperature, to which crops and animals respond.

4.2 NWS Automated Surface Observing System (ASOS)

The Automated Surface Observing Systems (ASOS) program is a joint effort of the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DOD). The ASOS systems serves as the nation's primary surface weather observing network. ASOS is designed to support weather forecast activities and aviation operations and, at the same time, support the needs of the meteorological, hydrological, and climatological research communities.

With the largest and most modern complement of weather sensors, ASOS has significantly expanded the information available to forecasters and the aviation community. The ASOS network has more than doubled the number of full-time surface weather observing locations. The ASOS network contains 991 ASOS stations working non-stop, updating observations every minute, 24 hours a day, every day of the year (Figure 2).

Getting more information on the atmosphere, more frequently and from more locations is the key to improving forecasts and warnings. Thus, ASOS information will help the NWS to increase the accuracy and timeliness of its forecasts and warnings--the overriding goal of the recent NWS modernization.

The primary concern of the aviation community is safety, and weather conditions often threaten that safety. A basic strength of ASOS is that critical aviation weather parameters are measured where they are needed most: airport runway touchdown zone(s).

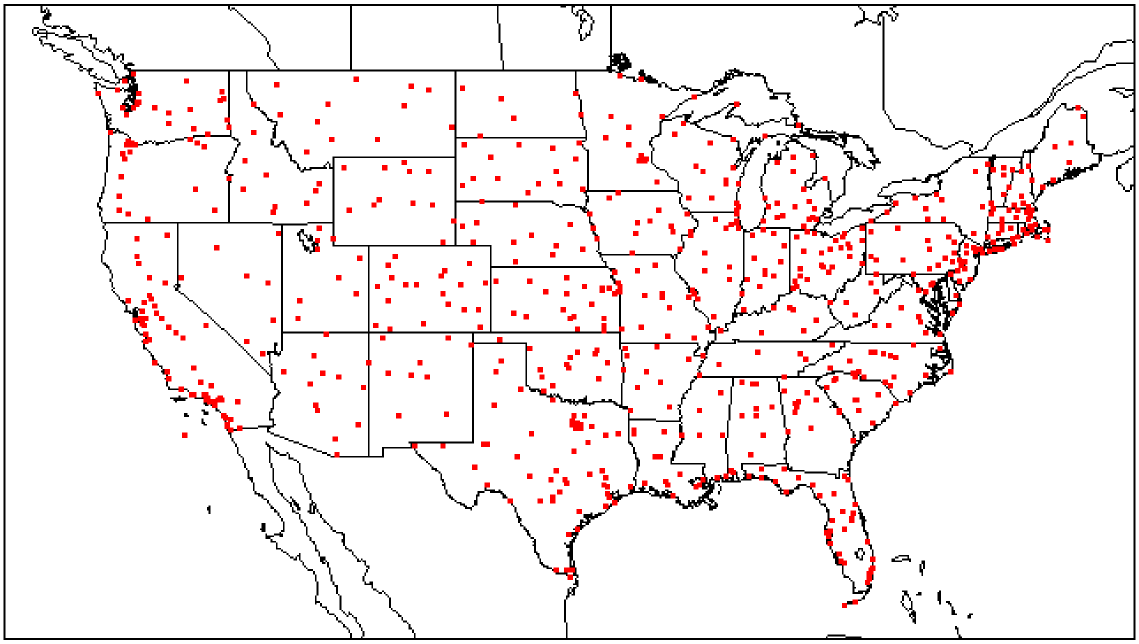

Figure 2. Location of ASOS sites in the U.S.

ASOS detects significant changes, disseminating hourly and special observations via the networks. Additionally, ASOS routinely and automatically provides computer-generated voice observations directly to aircraft in the vicinity of airports, using FAA ground-to-air radio. These messages are also available via a telephone dial-in port. ASOS observes, formats, archives and transmits observations automatically. ASOS transmits a special report when conditions exceed pre-selected weather element thresholds, e.g., the visibility decreases to less than 3 miles.

Reports basic weather elements:

a. Sky condition: cloud height and amount (clear, scattered, broken, overcast) up to 12,000 feet
b. Visibility (to at least 10 statute miles)
c. Basic present weather information: type and intensity for rain, snow, and freezing rain
d. Obstructions to vision: fog, haze
e. Pressure: sea-level pressure, altimeter setting
f. Ambient temperature, dew point temperature
g. Wind: direction, speed and character (gusts, squalls)
h. Precipitation accumulation

i. Selected significant remarks including- variable cloud height, variable visibility, precipitation beginning/ending times, rapid pressure changes, pressure change tendency, wind shift, peak wind.

4.2.1 NWS ASOS Maintenance

The Automated Surface Observation System (ASOS) program is necessary and essential to further the missions of the Federal Aviation Administration (FAA) and the National Weather Service (NWS). To this end the NWS and FAA operate under Interagency Agreement DTFA01–01-X-02002, for operations, maintenance and planned improvement of ASOS. The interagency agreement addresses the ASOS as a joint program in which FAA and NWS share responsibilities for requirements definition, program management, commissioning, operations, maintenance, planned improvement and life cycle support.

Under the interagency agreement the FAA is responsible for aviation safety and operational parameters. The NWS is responsible for requirements for forecasting, generating warnings and collecting weather data for climate research. Quality control of ASOS observa tions includes sensor malfunction and communication system failures, assessment of consistency between elements of the automated observation and operational environment, and assurance of availability and accuracy of data.

The NWS has responsibility for logistics support and performance of site, depot, and facility maintenance for NWS and FAA ASOS. Maintenance policy, and philosophy and responsibilities are jointly approved and documented in NWS Operations Manual Chapter H-54. This document defines maintenance philosophy, restoration requirements, maximum outage times, and the organizational structure required to perform maintenance functions on ASOS.

In order to refresh technology and prolong the system's life, the NWS and FAA have undertaken a planned improvement program. In addition to extending the system's life, this improvement program will enhance the overall capabilities of ASOS. To provide for consistency of data and allow for cost effective maintenance, logistics, and training, it is necessary that all ASOS sites operate using the same hardware/software upgrades and external data sources.

4.2.2 NWS ASOS Modernization

ASOS program efforts are now focused on system enhancements. With widespread use of the system of the system and exposure to many different environments, areas where improvements are needed have been identified. A plan was identified in 1995, which detailed product improvement activities. The NWS began budgeting for new and improved technology and has continued to successfully acquire funds to support development and testing of new sensors and software to enhance the current baseline ASOS.

The ASOS development and test cycle is an interactive one and often must be repeated several times on a given sensor as it is tested under different conditions. The task of exposing to all types of weather is a difficult one. If a sensor does not perform as specified the manufacturer is notified and a fix is derived. Where possible, chambers are used to simulate conditions and test sites from different parts of the country are used when feasible (Gifford 1997, Gifford 1998). Given the lengthy time period required to fully test and integrate a new sensor, many of the enhancements are still years away.

As previously mentioned, the National Weather Service has embarked on an extensive program for ASOS product improvements. These efforts will not only extend the useful life of this network of instrumentation, but will provide more an better data for the research community and the general public. The ASOS Product Improvements Program will continue as new sensors and better processing capabilities are brought on line.

4.2.3 NWS ASOS Expansion

The NWS, FAA, and DoD do not have any plans for the expansion of the ASOS network. The network is fully fielded and the agencies are focused on operational support and sensor improvements. The network's prime mission is support of the aviation community and ASOS site locations are primarily at airports. The location of airports across the country limits the spatial density options for the network. If ASOS were uniformly distributed across the U.S. they would represent a uniform station separation distance of about 70 miles. This is far short of the "desired" criteria for simple terrain, i.e. 20-mile separation.

4.3 SNOTEL and SCAN Networks

The Natural Resources Conservation Service operates two networks, the SNOwpack TELemetry (SNOTEL) and the Soil Climate Analysis Network (SCAN). The SNOTEL

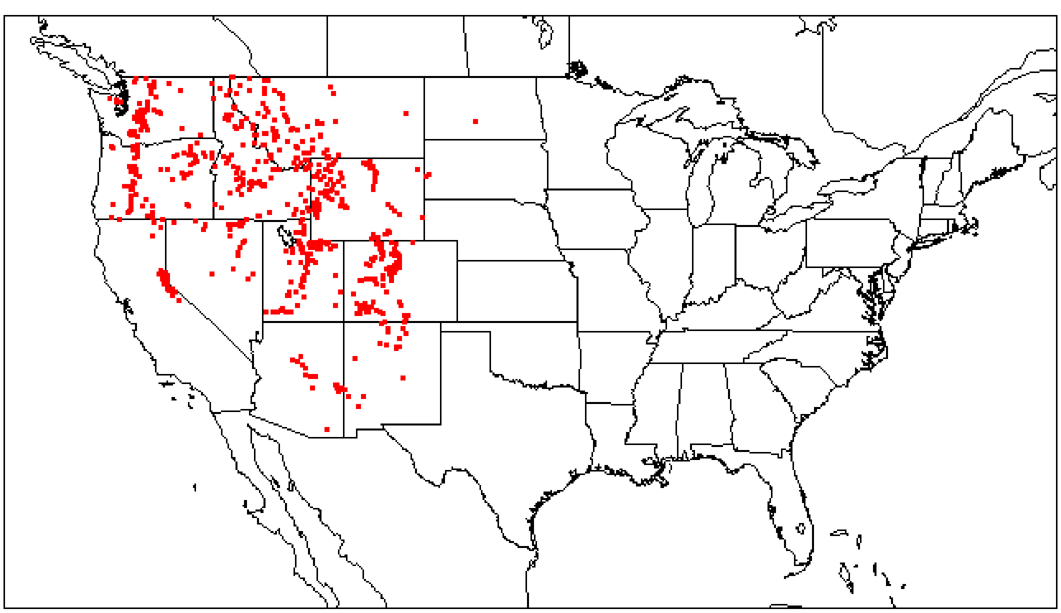

Figure 3. Location of [illegible] SNOTEL stations in the Western U.S.

network has, for more than 20 years, provided high-elevation climate information from the major watersheds in the mountainous West. The network measures precipitation, temperature, and snowpack conditions in near real-time at 662 sites, shown in Figure 3. The data are used for forecasting water supply volumes and are collaterally used in emergency management to mitigate floods, avalanches, and other life- or property-threatening events.

The SCAN Network was developed because of the lack of quality historic and real-time soil-climate information. The SCAN stations measure precipitation, temperature, relative humidity, wind speed and direction, solar radiation, atmospheric pressure, snow water content, snow depth, soil moisture, and soil temperature. Both networks use meteor-burst communications to obtain the data in near real-time. The SCAN sites are shown in Figure 4. There are currently 42 SCAN stations taking data in 37 states.

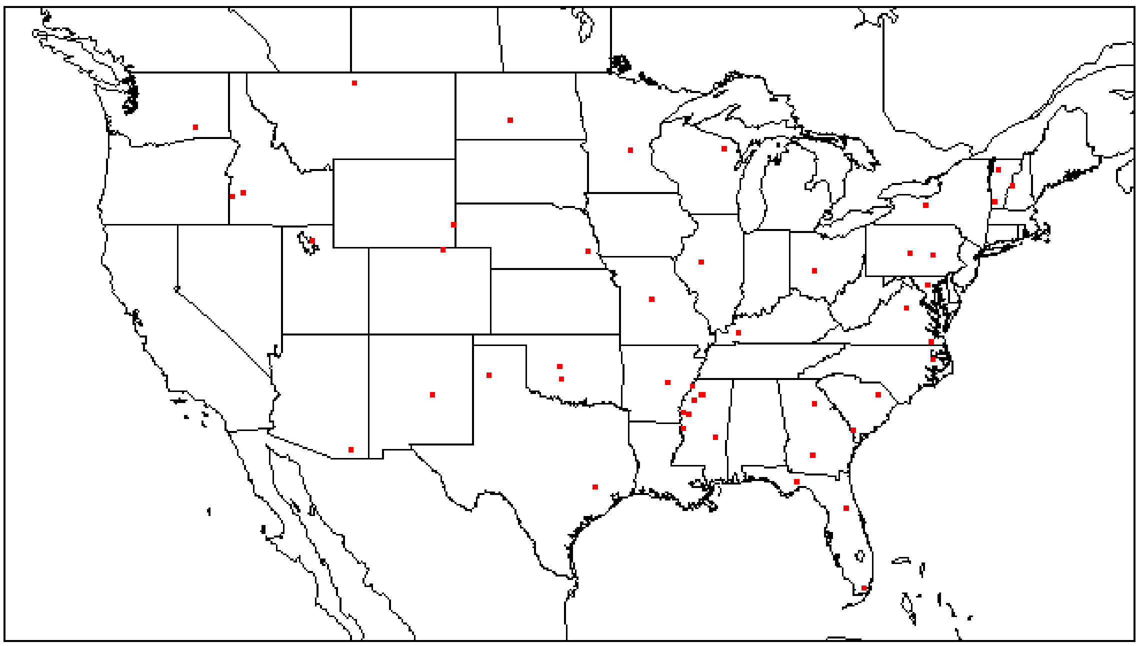

Figure 4. Location of 42 SCAN sites in 42 states.

4.3.1 SNOTEL and SCAN Maintenance

Annual maintenance costs for the SNOTEL and SCAN network are $1.1 million and $270,000, respectively.

4.3.2 SNOTEL AND SCAN Modernization

The SNOTEL network is undergoing a modernization that focuses on technology improvements that mimic the SCAN network. These will allow increased observation and transmission frequencies and additional climate sensors. Many SNOTEL sites have been upgraded to measure snow depth. Research is underway to measure snow water equivalent using fluidless sensor technologies.

4.3.3 SNOTEL and SCAN Expansion

A major limitation of the SNOTEL and SCAN networks is station density. Although SNOTEL has taken a major step toward comprehensive high-elevation data, the network is situated in the most complex terrain in the United States, and perhaps the world. Although many of the SCAN sites are located in less complex terrain, the total number of stations has increased only modestly beyond the number planned for the SCAN pilot project.

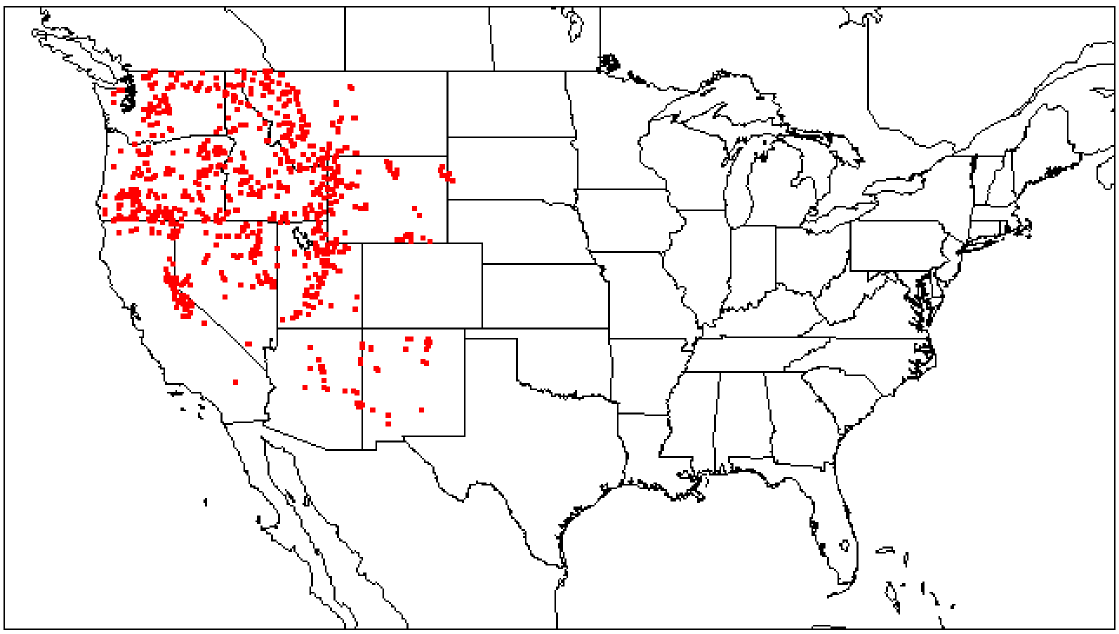

Figure 5. Proposed SNOTEL expansion for the West.

The 662 SNOTEL sites, taken together with the assumption of a uniform distribution over the western United States and Alaska, would result in a separation distance of about 50 miles. This is significantly larger than the optimal 20-mile separation for flat terrain. We have found no station density recommendations in the literature for mountainous terrain, but it would presumably require smaller separation distances to achieve the same network accuracy.

The NRCS Snow Survey and Water Supply Forecasting Program has just completed a multi-state review of the snow survey data collection network, focusing on automating manual snow courses to SNOTEL technology. This will support creation of updated water supply forecasting products, drought/fire weather monitoring, improved data acquisition in data-sparse areas (e.g., tribal nations), improved safety, and improved data delivery. The study indicated an additional 1,246 SNOTEL sites would be required to partially meet these needs, as shown in Figure 5. This would reduce station separation to approximately 17 miles, but the vertical variation of climate in mountainous terrain would require GIS-based spatial analysis to assess the effects of slope, aspect, and exposure to ensure representative data observations.

The fully implemented SCAN network could comprise 1,000 agricultural sites and potentially 1,000 COOP sites. The five-year costs associated with SNOTEL and SCAN expansion are $35 million and $20 million, respectively.

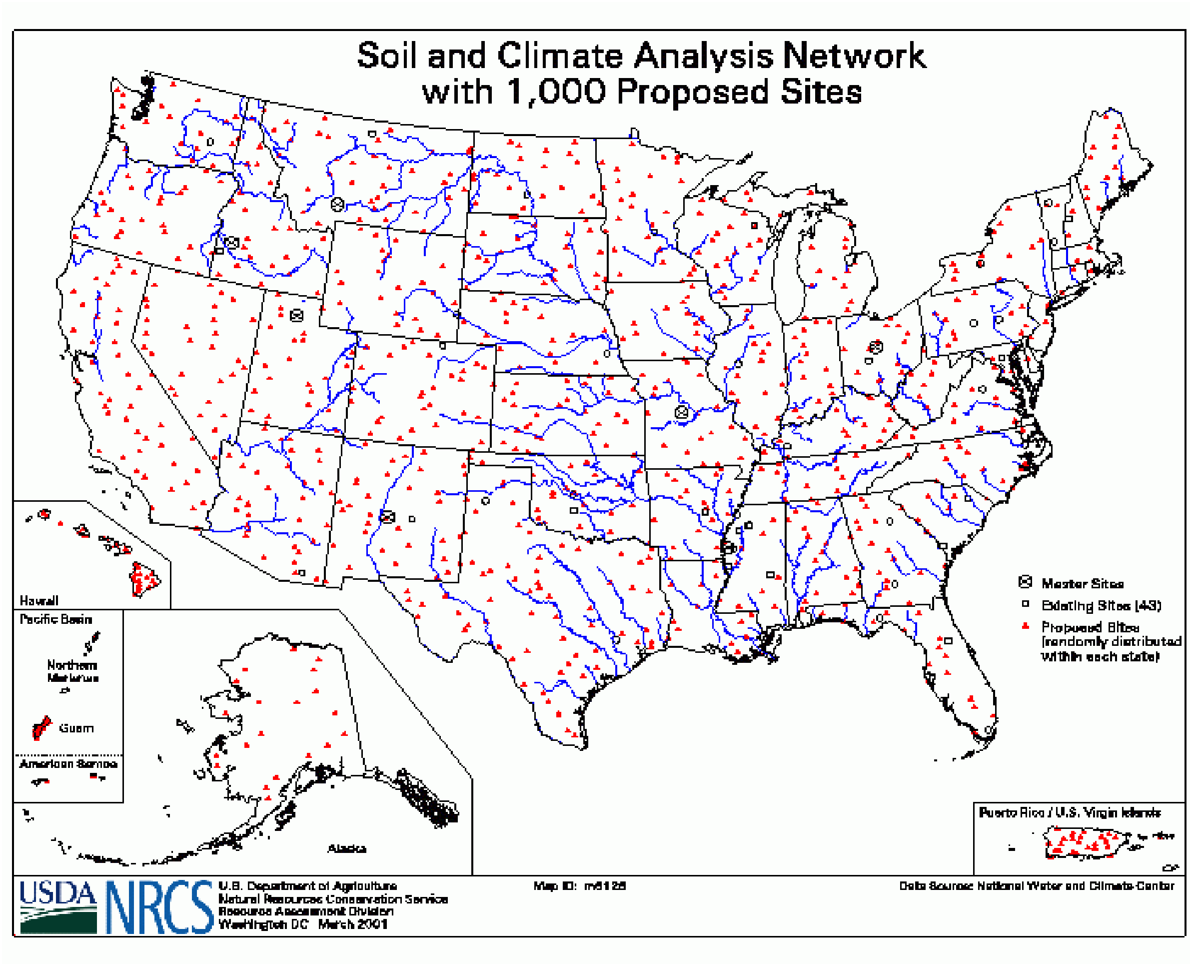

Figure 6. Proposed SCAN 1,000 station expansion for the U.S.

4.4 Remote Automated Weather Station (RAWS)

The United States Forest Service (FS) has collected meteorological data to assist in the prediction and control of forest and range fires and in the management of smoke from prescribed burning. Historically, the Forest Service relied on NWS for fire weather advisories. A national weather program was established to coordinate all FS meteorological activities and to meet the increasing need for diverse weather information. The major objectives of the program are to: 1) improve quality control of weather data, 2) improve the design and operation of data collection from networks, 3) increase data recovery from the weather stations, and 4) upgrade station maintenance. Meteorological data collected from manual weather stations and Remote Automated Weather Stations (RAWS) support research on weather effects on forestry management, forest fires, smoke management, visibility protection in wilderness areas, and atmospheric disposition. A weather information management system and a library to archive all FS weather data are being developed in cooperation with regional climate centers. The FS monitoring network will provide essential data for use in Global Change Research Program (GCRP) work.

The FS currently operates more than 1,200 RAWS and manual stations, many in the western United States, as shown in Figure 6. Air temperature, relative humidity, dew point temperature, wind direction and speed, and precipitation are transmitted via NOAA's Geostationary Operational Environmental Satellite (GOES) telemetry or via radio modem. The satellite-telemetered data are received via a direct-readout ground site in Boise,

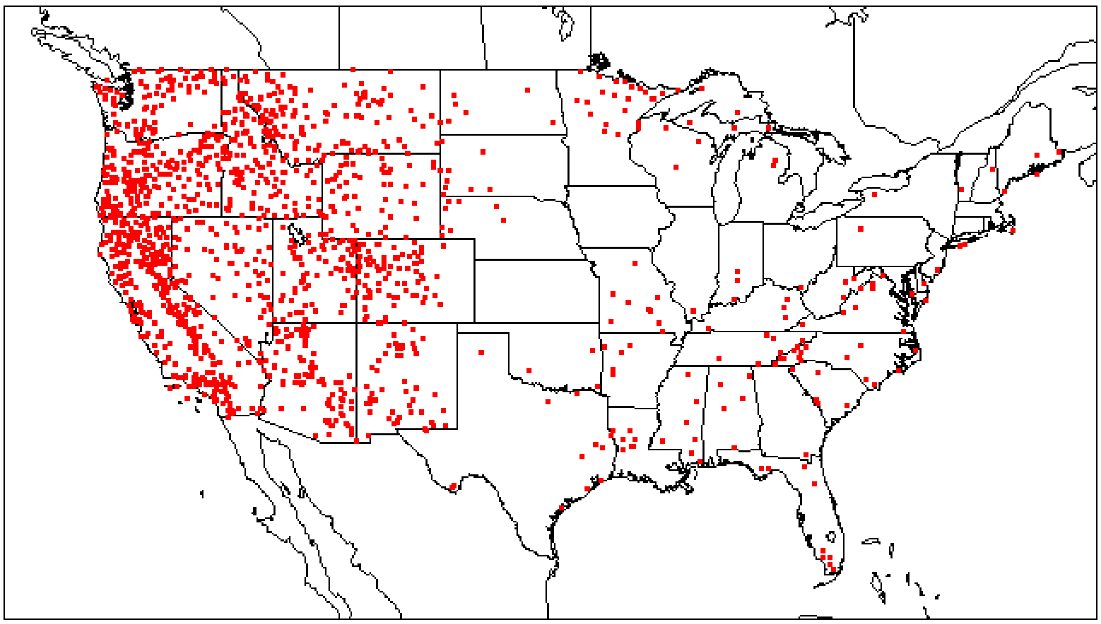

Figure 7. Location of 1,200 FS RAWS sites in the Western U.S.

Idaho, in cooperation with the Bureau of Land Management. The primary use of the data is the calculation of fire danger rating for the FS and cooperating agencies. These data are also used by other resource managers, such as road engineers, wildlife biologists, and hydrologists who monitor precipitation; silviculturalists who are attempting to maximize tree-planting opportunities; and ecologists, soil scientists, and fisheries biologists who monitor the effects of runoff. The main secondary user of RAWS data is the National Weather Service, for fire weather forecasting and flood warnings.

4.4.1 RAWS Maintenance

The FS entered into an interagency agreement with the Bureau of Land Management (BLM) for the maintenance of the FS RAWS . The BLM performs routine regularly scheduled maintenance on FS stations either at the BLM facility in Boise. ID, or at the RAWS site.

4.4.2 RAWS Modernization

An assessment of the FS RAWS network is in progress; the assessment focuses on the efficiency and effectiveness of the current network. Findings of this assessment will be integrated into network planning and modernization of technology for future implementation and coordination of data acquisition and sharing. FS is also implementing new technology to improve efficiency in data sharing to increase the rate of RAWS data transmission through GOES.

4.4.3 RAWS Expansion

Typically RAWS network expansion has occurred on an 'as need' basis at the forest or regional levels. The RAWS assessment will be used to make recommendations to address needs for: long term planning and coordination on a more comprehensive national scale; technology upgrades, data sharing and potential network integration across agencies.

4.5 National Climatic Data Center Climate Reference Network (CRN)

The U.S. Climate Reference Network (CRN) is a new climate-observing network currently being developed as part of the National Oceanic and Atmospheric Administration (NOAA) Climate Observations and Services Initiative. This climate observing network is being established and will be maintained in adherence with the Ten Climate Monitoring Principles recognized by members of the World Meteorological Organization (WMO). It is the first-ever U.S. national observing network with the principal purpose of providing long-term climate records free of time-dependent biases. The CRN Program is being implemented and managed by the National Climatic Data Center (NCDC), located in Asheville, North Carolina.

The primary goal of the CRN is to provide future long-term homogeneous observations of surface air temperature and precipitation that can be coupled to past long-term observations for the detection and attribution of present and future climate change. The CRN fulfills the nation’s need for long-term high-quality climate observations and records with minimal time-dependent biases affecting the interpretation of decadal to centennial climate variability and change.

The CRN will provide the nation with a first-class long-term (50 to 100 years) observing network that will serve as the nation’s benchmark Climate Reference Network and meets the requirements of the Global Climate Observing System (GCOS). When fully implemented, the network will consist of approximately 250 geographic locations (500 paired instrument suites, a primary site and a backup site) strategically selected to capture the representative climate regions of the nation. Data from these CRN sites will be used to provide the best possible information on long-term changes in air temperature and precipitation, including means and extremes.

CRN data will be used in operational climate monitoring activities and for placing current climate anomalies into a historical perspective. These data will be transmitted hourly via the GOES Data Communications System (DCS) and immediately distributed to National Weather Service (NWS) sites via NOAAPort. These observations will also be available on-line and accessible via the WWW at no-cost to users worldwide. Every aspect of the network will be thoroughly documented.

The research community, government agencies, and emerging private businesses have identified significant shortcomings in modeling long-term climate changes over the United States and surrounding regions. These shortcomings are due to the lack of adequate documentation, inadequate overlapping observations when new instruments are installed, and not using well-maintained and calibrated high-quality instruments. These inadequacies increase the level of uncertainty when government and business decision and policy makers are formulating long-range strategic policies. Never before have people been so aware of the impact of the environment and climate variability and change on the quality of life and the economic health of a nation, its citizens, and the population of the world. The CRN Project will serve as a model for establishing similar networks in other countries.

4.5.1 CRN Maintenance

An essential element of the CRN Program is a well-documented life cycle maintenance history of the instruments and sites. There will be regular visits to the instrument sites and annual documentation of the surrounding terrain. There will be regular calibration of the principal sensors (temperature, precipitation gauge, wind speed, and solar radiation). There are several options under consideration for performing maintenance on the instruments and sites.

4.5.2 CRN Modernization

A robust research effort will continually evaluate new sensors and calibration procedures. When it is determined that a new sensor will contribute to improved quality of the observations, there will be at least a one-year continuity overlap of current and new sensors. Replacing sensors before age deteriorates the quality of the data and the reliability of the sensor has been factored into the life cycle health of the network. An integral part of the CRN Program will be routine evaluation of new sensors and periodic replacement of sensors to ensure the best observations available from emerging techniques and technologies. All modernization efforts will be thoroughly documented. Details regarding the CRN Project can be viewed at http://www.ncdc.noaa.gov/crn.html.

4.5.3 CRN Expansion

Additional sensors will be added in the future on a "not to interfere basis" with the CRN principal core observations of air temperature and precipitation. Examples of other sensors under consideration include soil temperature and moisture, humidity, wind speed and direction, evaporation, atmospheric pressure and trace constituents, and solar radiation. These additional observations will be part of collaborative efforts with other agencies dependent on the availability of funding to support these observational enhancements.

4.6 USGS National Streamflow Information Program (NSIP)

Author's Note: USGS personnel will complete this section. WWW references were supplied in this document to make readers aware of this activity.

A decrease in the number of streamgaging stations and a disapportionate loss of streamgaging stations with long-term records, together with an increasing demand for streamflow information, led Congress to request an evaluation of the U.S. Geological Survey's streamgaging network's ability to meet the streamflow information needs of the nation. A November 1998 report to Congress concluded that for five national goals evaluated, the ability of the network to meet the goals had been declining for the last 10 to 20 years: http://water.usgs.gov/wicp/acwi/streams/NSIP.html.

The decline was attributed to the absolute loss in the number of streamgaging stations and the USGS's declining ability to continue operating high-priority stations when partners discontinue funding.

The report also stated that new and changing issues have greatly increased the demand for streamflow information, and that new technologies are needed to support the network to improve the reliability of the data, decrease costs, and decrease uncertainty of the information the network provides.

4.6.1 NSIP Maintenance

To be completed by USGS.

4.6.2 NSIP Modernization

To be completed by USGS.

4.6.3 NSIP Expansion

Major components of the National Streamflow Information Program (NSIP): The National Streamflow Information Program is a vision of the infrastructure that the USGS believes is needed to meet the streamflow information requirements of the nation. This plan proposes methods to increase the quantity and quality of streamflow information, methods to improve the way streamgaging stations are funded and located, and new ways to collect, store, and distribute streamflow information. NSIP consists of five major components:

Enhanced nationwide streamgaging network (Federal-Interest Streamflow Network): There would be a federal-interest network of stations that would be operated by the USGS even in the absence of support of funding partners. It would include about 5,300 stations to meet five critical federal goals, funded entirely by federal appropriation. The fixed costs of the total USGS streamgaging program (about 40% of total network costs) also would be funded by federal appropriation, but the marginal costs for all other streamgaging stations would be funded by partners (including cost sharing under the Cooperative Water program). It is estimated that 2,080 stations are needed to meet the critical federal goals.

Intensive data collection during major floods and droughts: Additional information would be collected to better characterize major floods and droughts. This additional information would include systematic field surveys of precipitation, river stage, and river discharge; the installation of temporary streamgages during events; opportunistic sampling of sediment, nutrients, bacteria, pesticides, and hydrocarbons; and characterization of changes in geomorphology of river channels and reservoir sedimentation.

Streamflow information would be interpreted on regional and national scales: A permanent program of systematic streamflow analysis and interpretation would be established. Regional assessments would be done within physiographic provinces over a period of 10 years. A national assessment would be done every 10 years. The streamflow characteristics analyzed and evaluated would include mean and median flows, flood and low-flow characteristics, seasonal cycles, and evaluations of long-term trends. Information from the assessments would be fed back into network design process. The goal would be to estimate flow characteristics at any site on any stream with a low standard error.

Enhanced streamflow information delivery and products: A new database system would be designed and implemented which provides backup computer and communication mechanisms for reliable data delivery. Stage and discharge information would be available at the time resolution at which it was collected (15-, 30-, or 60-minutes). Data presented also would have uncertainty bounds associated with it. User-specified formats and statistics would be available for unified historical and current data.

Methods development and research: New and emerging technologies for streamflow measurements will be identified, evaluated, and developed as appropriate. This will provide for safer and less-costly data collection in the future. Current needs are for non-contact stage and discharge measurement capabilities, techniques for streamgaging error estimation, dynamic models for continuous streamflow estimation, new methods for flood frequency, trend analysis, and regionalization, and models for real-time inundation mapping of flood risk areas.

4.7 Non-Federal Meso networks

Numerous state, regional, and even private networks serve specific needs not provided by existing networks. Characteristics of these networks were summarized by Meyer and Hubbard (1992). In a later USDA/RCC survey (1999), it was found that about 1,012 mesonet stations are currently operating (see Figure 8). Major functions identified by network managers were public service, public research, and institutional mission. Some specific uses of the data were irrigation management, emergency management, hydrologic modeling, agricultural modeling, and mesoscale modeling.

Management decisions related to wildfire outbreaks and prescribed burning are related to moisture availability and other meteorological parameters such as wind speed and temperature. For example, an Oklahoma fire danger model uses meteorological parameters from Oklahoma's 110-station real-time automated weather network to produce hourly fire and drought indices over the state of Oklahoma. It is used to assist the Oklahoma Department of Agriculture, Forestry Division, in declaring red flag fire alert days and in recommending burn bans to the governor.

Station siting is often in open terrain with good fetch. There is no standard station in this collection of mesonets, but most stations provide at least hourly observations of temperature, precipitation, humidity, solar radiation, and wind speed and direction. Some stations also collect soil temperature, atmospheric pressure, and soil moisture. The resolution attainable with 1,012 stations scattered throughout the United States would equate to a station separation distance of about 60 miles, much larger than the 20-mile optimum for simple terrain. A major limitation of the mesonetworks is the lack of standardization between networks. In some cases there is an issue of restricted access to the data.

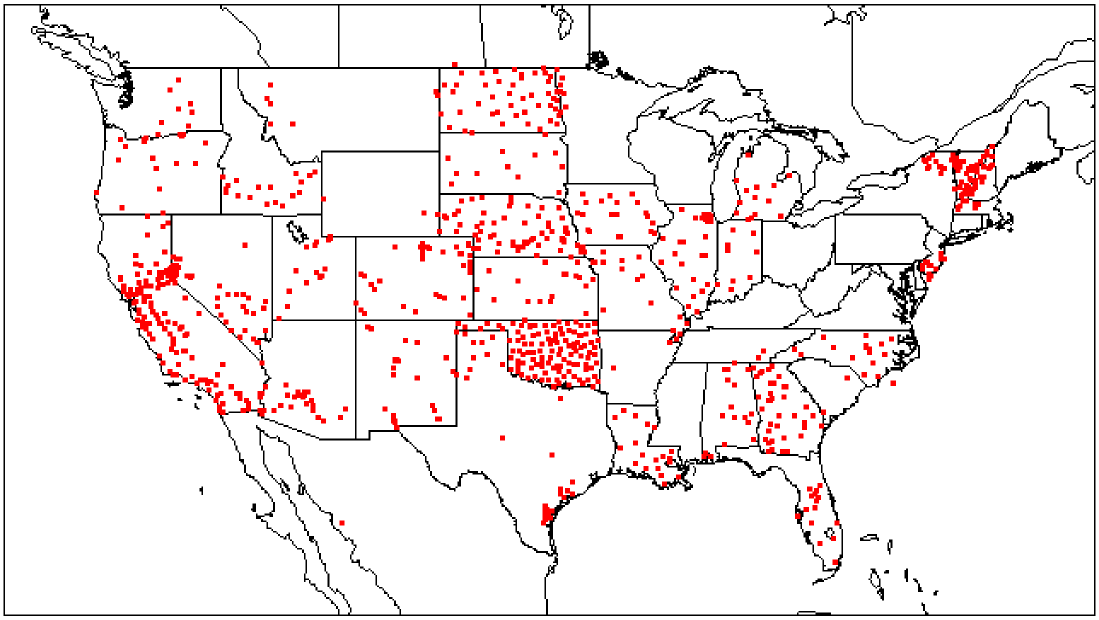

Figure 8. Location of 1,012 Mesonet stations currently operating (1999)

4.8 Gap Analysis

Deficiencies or "gaps" within the drought information collection-to-distribution system exist. These deficiencies result from lack of standardization, disparate spatial monitoring and measurement, and incomplete mechanisms for monitoring drought. The purpose of this section is to highlight interrelated deficiencies in 1) observing systems, 2) information technology, and 3) sector-specific products that can be addressed and overcome under the Collaborative Effort.

4.8.1 Observing System Gaps

In addition to the disparate observing-system practices detailed in Sections 4.1 to 4.7, deficiencies in timeliness, spatial coverage, and observed weather elements permeate a "national" observing system.

Temporal deficiencies occur when data are not observed and redistributed frequently enough to meet user needs. Rapid changes in weather require frequent observations to determine exceedence of ecologically or economically sensitive thresholds. In many cases, data that are observed each day are not immediately submitted to a centralized distribution system. These data may not be published and provided to users until the end of the month. The utility of these data for near-real time drought monitoring and prediction is limited. A good first step to reducing temporal gaps is to provide observers with a means to transmit information as soon as it is observed. For many current applications, data collected once per day is satisfactory. Other applications, such as those involving modeling storm tracks, spray drift, leaf wetness, and insect development, require centralized hourly data collection.

Spatial gaps occur in geographic areas where climatic information is not observed, even though climate affects the area's ecology and economy. Spatial gaps can be a function of insufficient funding for network maintenance, modernization, and expansion (especially nonfederal), designated network purpose (e.g., aviation vs. agricultural), and the inability to implement cost-effective data collection technology (i.e., temporal gaps ? spatial gaps). Land ownership, topography, and population demographics, especially in the West, can play significant roles in the location of climate stations. Spatial gaps can also result from proprietary restrictions that limit the accessibility of climate data and the inability to integrate different observing systems in a meaningful way.

In addition to temperature and precipitation, many new models and techniques for drought monitoring and prediction rely on soil moisture, soil temperature, humidity, solar radiation, and wind information. These climate elements are observed at only a fraction of the stations in existing climate networks. Soil moisture, for example, is observed at fewer than 100 automated weather stations, while precipitation is universally observed at automated weather stations. Thus, spatial gaps for soil moisture are an order of magnitude larger than those for precipitation. Expansion efforts for these elements are discussed in Sections 3.1 to 3.6.

4.8.2 Information Technology Gaps

There is no standard technology to communicate drought conditions to decision makers. This nonstandardization extends to data gathering, quality control, archival, and user access. Much climate information is available in unique formats that require special handling before they can be merged with other datasets. Although the Standard Hydrometeorological Exchange Format was established in the early 1980s, only a fraction of climate data is currently transmitted using this format (Pasteris and Bissell 1985, Pasteris et al. 1982, Bonnin 1984, and Bonnin and Cox 1983). Another critical need is to maintain up-to-date tracking systems for information used to identify, describe, and locate each data source.

A solution to these issues lies in a RCC plan to provide Internet access to U.S. climate information through the Unified Climate Access Network (UCAN), a system that will enable end users to obtain climate information for any region in the United States from a single source. The system--which can be accessed from the World Wide Web--relies on an automated information broker that determines what is needed and where to find it. Thus, information from national, regional, state, and local sources is integrated into a seamless, user-friendly system.

Substantially more climate information would become available to the public if data from the observer or network were transmitted to or broadcasted from centralized systems using standard formats. An Internet gateway for observers to Regional Climate Centers would greatly facilitate this activity.

4.8.3 Sector-specific Product Gaps

Sector-specific drought products can only be generated when timely and spatially relevant climate elements are available. Use of inadequate data to generate climate-based drought monitoring and prediction products can be misleading and costly. For monitoring and predicting drought, topical areas with product gaps are agriculture, hydrology, and forestry. Each topical area has unique data requirements that may transcend common drought monitoring and prediction requirements. This Collaborative Effort promotes standardization while conditionally accounting for all identifiable sector-specific requirements.

Near-surface moisture availability is a very important component of the hydrologic cycle. Water balance approaches, depending solely on temperature and precipitation, have been used to assess relative dryness or wetness. Today, physically based water balance models are essential to the success of crop forecast models. Implementation of reliable water balance models requires accurate estimates of evapotranspiration (ET). ET models, such as Penman-Montieth, in turn, require temperature, humidity, solar radiation, and wind speed. Of course, precipitation represents the other major component in water availability. Soil temperature and soil moisture data can help to frame the growing season and serve as ground truth to validate water balance models. The need for these parameters as input to more reliable models in part explains the rise of nonfederal automated weather networks, SNOTEL, and SCAN.

Agriculture: An interagency committee of the United States Department of Agriculture prepared a report of requirements for weather and climate data, services, and information (USDA 1999). This report, requested by DOC/NOAA, focused on the wide range of data requirements necessary for USDA to meet its objectives. Although USDA's weather data requirements reflect its diverse missions and programs, a prevailing theme of this report was the need for quality assured, near-real time (hourly or daily) data available through electronic media, preferably the Internet. Network gaps, however, were not addressed in this report (USDA 1999).

Hydrology: This topic area is shared by the USGS, NWS, and NRCS. The USGS plan is discussed in Section 3.6 and the NRCS plan is discussed in Section 3.3. The NWS addresses hydrologic network gaps in the National Research Council Report, "Future of the National Weather Service Cooperative Observer Network" (1998).

Forestry: Under construction - USFS

5 The President should appropriately direct and Congress, as necessary, should authorize and fund continuation of the U.S. Drought Monitor and exploration of opportunities for its improvement and expansion.

Until recently, the idea of better monitoring drought and its impacts has received minimal attention, even though drought is the leading hazard in economic losses each year in our country. In the summer of 1999, a new drought classification system, map, and narrative depicting the current status of drought in the United States was developed and placed on a website maintained at the National Drought Mitigation Center (NDMC) (http://drought.unl.edu/) The Drought Monitor (http://drought.unl.edu/dm/) is a synthesis of multiple indices, outlooks, and impacts. The classification system attempts to objectively combine the best of several monitored parameters while tapping into various real-time networks located throughout the country. Access to reliable data (preferably with a long historic record) is essential in assessing the current severity, duration, and spatial extent of drought and its many impacts. Reliable data will also, in turn, improve many of the indicators used in creating the Drought Monitor. The final product incorporates feedback from more than one hundred drought experts around the country using an e-mail list server.

The Drought Monitor (http://drought.unl.edu/dm/) serves as an excellent model of collaboration between federal and academic partners. Currently, the National Drought Mitigation Center, United States Department of Agriculture's Joint Agricultural Weather Facility, and National Weather Service's Climate Prediction Center produce this product completely with in-kind contributions. This will grow to four partners in spring 2001 when the National Climatic Data Center comes on board in helping to produce the Drought Monitor. Produced on a weekly basis, the Drought Monitor has quickly gained acceptance as one of the premiere drought tracking tools in our country. Improvement is needed in the area of forecasting and determining the onset and end of drought in various regions of the United States. Although the Drought Monitor is an assessment rather than a forecast tool, further support in the area of drought forecasting is essential. As a separate effort, the Climate Prediction Center began issuing their monthly Seasonal Drought Outlook forecasts in the spring of 2000.

Additional support and/or resources would assist current efforts to 1) develop and provide access to weekly Standardized Precipitation Index (SPI) values produced from COOP and other local or network data; 2) produce better objective blend maps (maps produced at CPC that combine and weigh various parameters into a final "blend" product used as guidance each week by the Drought Monitor authors on both short- and long-term scales; 3) obtain better soil moisture, reservoir, and groundwater data in a timely fashion; 4) maintain and enhance support of programs such as USDA's Soil Climate Access Network (SCAN), NOAA's Cooperative Network, and the Unified Climate Access Network (UCAN), which are essential to the evolution and viability of the Drought Monitor; and 5) build and improve on the Drought Monitor website by incorporating more links to relevant products at all levels of detail (local to national scales).

6 The President should appropriately direct and Congress, as necessary, should authorize and fund continuation of Drought Predictions/Outlooks and development of techniques to improve their accuracy and frequency.

The Climate Prediction Center began issuing seasonal U.S. drought outlooks in the spring of 2000. These monthly maps schematically combine information on current drought from the weekly U.S. Drought Monitor and future drought from short-, medium-, and long-range forecasts of temperature, precipitation, and soil moisture to arrive at generalized outlooks of drought trends over the following 3.5 months. Both statistical tools and dynamic tools are used, including 1- and 2-week soil moisture forecasts from the Medium-Range Forecast (MRF) models, 1-week forecasts of the Palmer Drought Index based on the MRF model, seasonal forecasts of soil moisture based on multi-year historical analogues (Constructed Analogue Soil model), El Niño/Southern Oscillation (ENSO) historical soil moisture analogues, statistical 3-month Palmer Drought Index probability projections, and temperature and precipitation forecasts for all time periods out to the following 3.5 months. During late winter and spring, seasonal streamflow forecasts are considered. The information is subjectively consolidated to produce maps that indicate if current droughts will persist, intensify, or improve. Development of new droughts can also be indicated if there are strong indications to this effect.

Future advances in seasonal drought forecasting will rely primarily on advances in long-range forecasting, and the greatest potential for improvement in the long-range forecasts will likely come from general circulation models (GCMs), particularly ensemble coupled oceanic-atmospheric models. Improved numerical models will improve the official long-range seasonal forecasts, which incorporate the model output as one of several tools. Additional efforts should go into 1) improving the initial conditions for the model by incorporating better land surface information such as that supplied by the Land Data Assimilation System (LDAS), 2) enabling GCM output of soil moisture and soil moisture anomaly forecasts, and 3) incorporating temperature and precipitation output from the GCM and the CPC long-lead outlooks in the CPC soil model and the Palmer Drought Index to produce seasonal soil moisture forecasts, including soil moisture anomaly probabilities based on GCM probabilities from the ensemble runs.

The Climate Prediction Center should continue to take the lead in developing and improving seasonal drought outlooks, but should work with other entities where appropriate, especially in the use of improved GCM and statistical forecasts. CPC should work with other institutions within and outside of NOAA to explore the role played by annual, decadal, and longer-term climatic fluctuations in drought development, persistence, and cessation, including the impact of ENSO, PDO, NAO, and solar variations.

7 The President should appropriately direct and Congress, as necessary, should authorize and fund a comprehensive information gateway (possibly through expansion of the National Drought Mitigation Center's website or other similar approaches) to provide users with free and open access to observation network data and drought monitoring, prediction, impact, assessment, preparedness, and mitigation measures.

An extensive drought information clearinghouse currently exists on the National Drought Mitigation Center's (NDMC) website. During 2000, this website received more than 4 million hits. There are links to more than 250 drought-related websites worldwide, and more than 1,100 websites link to the NDMC website. In addition, the NDMC has hosted the website for the Western Drought Coordination Council and is currently hosting the Drought Monitor website, a popular weekly drought monitoring tool. It is clear that providing free and open access to information over the World Wide Web, although not the only information dissemination tool, continues to increase in importance. The NDMC website became operational in November 1995. Upgrading this website would emphasize drought monitoring improvements, mitigation strategies, and improved drought climatologies for all regions of the country. Making the website more interactive with users would encourage better information exchange and ensure that all relevant and current information would be continually available on the website. The vision for a comprehensive drought website includes access to reliable climate and observation data networks, drought assessments, and long-lead outlooks, and timely information regarding mitigation, preparedness, and response strategies for decision makers in the public and private sectors. In addition, the NDMC has maintained a substantial drought information library of drought-related materials not available over the web. Enhancing this library, and expanding the capability to provide this information, would serve as another valuable tool and further facilitate the timely exchange of information on drought-related issues.

8 The President should direct the appropriate federal agencies to develop an effective drought information delivery system such as the Unified Climate Access Network (UCAN) to communicate drought conditions and impacts to decision makers at the federal, regional, state, tribal, and local levels and to the private sector and general public.

The basic components of an effective drought information delivery system include 1) climate datasets, 2) climate metadata, 3) climatic products, and 4) a flexible user interface. Individual agencies whose mission areas require acquisition and processing of climate data have historically developed systems tailored to meet their needs; however, the sharing and integration of climate information was not possible until the implementation of the Internet. The Internet allows rapid exchange of climate datasets and metadata and the generation of climate products using standard datasets and standard software analysis tools. The ubiquitous characteristics of the Internet and free browser software permit global access to information at all levels of society.

The Unified Climate Access Network integrates these features with the intent of providing the foundational infrastructure required to provide the climate data and products necessary for monitoring drought conditions, climate change, and their impacts on society.

8.1 UCAN Background

Internet access to a wide variety of climatic information for the United States is nearing reality through the Unified Climate Access Network (UCAN) (Robbins and Perot 1996; Pasteris, Reinhardt, Robbins 1997). The Unified Climate Access Network (UCAN) is a collaborative effort between six Regional Climate Centers (RCC), the National Water and Climate Center (NWCC), and the National Climatic Data Center (NCDC). UCAN is currently undergoing an official "beta test," with an initial release to federal and state cooperators scheduled for March 2001. Phased UCAN access for Tribal Nations, local officials, the public, and the private sector is scheduled for mid-2001.

UCAN's goal is to provide seamless web-based access to distributed archives of national and regional climatic data and information. Most of the data warehoused at these centers consists of national climate archives comprising more than 25,000 daily and 2,500 hourly observation sites, with numerous sites composed of observations dating back into the 1800s.

UCAN design requirements can be encapsulated within several distinct functional components. These include: 1) climate datasets, 2) climate metadata, 3) climatic products, and 4) a flexible user interface. There are certainly other factors that determine the system design, such as synchronicity of distributed data resources, legal requirements for data integrity, best data values versus official data values, timeliness of near real-time data incorporation into the distributable data archive, administrative rules for participation in the distribution system (including definition of data suppliers versus data users), system security and accounting, and a host of other factors. In the following sections we will discuss the major functional components of UCAN.

A complete summary of the UCAN project and on-line demonstration can be found at the following URL: http://www.srcc.lsu.edu/ucan.net/UCAN.html.

8.2 UCAN Climate Data

The climate data archived at the RCCs, NRCS, and NCDC form a unique set of climatic information for the entire United States. For the most part, these data can be described as time-series observations of climatic elements collected at spatially distinct locations. The basic observational elements include, but are not limited to, air temperature, dew point, relative humidity, wind speed, wind direction, horizontal visibility, occurrence of weather, cloud height and coverage, precipitation amount, snow depth, soil temperature, evaporation, and solar radiation. The actual elements contained within a dataset depend on the observational network to which a station belongs. Some of these time-series observational records began in the late 1800s and are still operational.

Datasets are usually categorized by observational networks and administering organizations. They are also categorized by the time resolution (hourly, daily, monthly, annual, etc.) over which an observed or derived data element is applicable. National-scale datasets are collected by national agencies such as the National Weather Service, U.S. Forest Service, U.S. Geological Service, U.S. Corps of Engineers, and Bureau of Land Management. Regional and state-level datasets are operated by state and federal agencies, universities, municipalities, private corporations, and even individuals. Most of the national datasets are maintained and archived at the NCDC but others at the national level are maintained, solely, by the managing agency. Regional and state-level datasets are maintained, almost exclusively, by the managing agencies. The RCCs, and to a lesser extent the NRCS, are accepting the role of collecting national, regional, state, and local datasets and organizing them for use in end-user applications.

The datasets archived at the NCDC are stored in formatted ASCII files that are grouped by station and sorted by time. Although this format is acceptable as a long-term, stable format that maintains compatibility with historical data archives and processing routines, it is not acceptable as an operational data storage format. Extraction of a single observation for a single station contained within a monolithic, non-indexed ASCII file is an expensive operation. Operational data storage for the UCAN system at the RCCs and the NRCS utilizes either a netCDF (Network Common Data Form) file, a RDBMS (Relational Database Management System), or proprietary systems that employ indexed binary files. Since different systems are employed to store similar datasets, UCAN is designed to operate using any underlying data storage structure. Low-level data access within the UCAN system is defined as a local implementation consideration. This is a design decision that allows for incorporation of legacy datasets as well as new data centers with proprietary data storage systems.

Most UCAN data centers use netCDF as their basic dataset storage methodology. The netCDF software was developed at the Unidata Program Center (UPC) in Boulder, Colorado, and consists of a library interface and machine-independent binary file format for array-oriented access to scientific data. It is perfectly suited for the storage of time-series climate data. The netCDF interface has been enhanced for the UCAN project by the addition of libraries that provide dynamic file compression and a high-level PYTHON language interface. The dynamic compression algorithm is unique. Although it utilizes standard Lempel-Ziv coding libraries, compression is coupled closely to the netCDF file structure and allows for incremental compression and decompression. Utilizing fixed-block data compression and an uncompressed file index header, it is possible to add compressed blocks to the netCDF files as new data are added and to extract selected compressed blocks that contain indexed data. Selective decompression actually improves data extraction performance in some cases and adds minimal performance degradation in most others. The nature of climatic observations offers storage compression ratios that range from 6:1 to as much as 50:1. Data storage costs are cut immensely without degrading data access performance.

As mentioned previously, all datasets belong to a distributed data archive. As a primary organizational method, each RCC archives data for its own region of responsibility. Specialized datasets, such as the NRCS SNOwpack TELemetry (SNOTEL) network, are maintained by the managing agency and may cross regional boundaries. However, this strategy of single-source data management is not conducive to a stable archive system. Hardware or software failures could cause a data center or network link to fail, resulting in loss of an entire portion of the data archive. Therefore, data storage redundancy is implemented such that each dataset is duplicated, at least once, at different data centers. Thus, barring a network-wide communication failure, data accessibility should be high.

8.3 UCAN Metadata Management

Over the span of a station's history, a site may experience relocation or instrument redefinition that requires documentation of station location, instrumentation changes, and observational activity or inactivity. Relocation alone accounts for more than 100,000 station descriptions for the national station archive. The RCCs also warehouse extensive climatic information for local, state, and federal climate networks that do not appear in the national archive, further increasing the magnitude of inventory information. Management of these data inventories is made possible using distributed relational database management systems (RDBMS) synchronized to a master RDBMS.

The climate data resources archived in the UCAN system consist of thousands of individual "stations" (data collection sites) with different instrumentation, data collection frequencies, reporting intervals, and management agencies. Many of these stations have changed fundamental characteristics during a history spanning more than 100 years. These stations form the basis of a long-term climate data record used to design large-scale engineered systems, establish insurance rates for weather-related natural disasters, and assess the magnitude of global climate change. It should not be surprising that metadata is essential for proper interpretation of the climate information obtained from these stations. Furthermore, metadata is at the heart of the UCAN strategy for locating climate data to satisfy user requests for specific climate information and data products.

8.4 UCAN Products

A product, as defined in UCAN, is any organized collection of climatic information returned to a user to satisfy a specific request or query. A product could be a tabular listing of raw observations, an analysis of recurrence intervals for flood-producing rainfall within a hydrologic region, a graphical depiction of daily average temperature for a specific location, or a single number that represents the maximum observed wind gust in Washington, D.C. Thus, products vary in complexity and may involve single or multiple datasets or simple or complex climatic analysis tools; they may even require interaction between multiple data centers.

Critical design considerations for all UCAN products include accuracy, consistency, and the ability to satisfy user information needs. Accuracy includes factors such as adherence to accepted practices for scientific analysis and correct parsing and interpretation of user inputs so that returned results reflect user-intended results. Consistency refers to the ability to accurately regenerate stored elements derived from observed elements, one-to-one mapping of a returned product to a unique user request, and exact correlation of results obtained from different data centers when given identical input requests. Finally, products must be designed with sufficient analysis and formatting options to satisfy user needs for climatic information.

These design requirements are met by defining UCAN Standard Products that are installed at each data center. The analysis routines that operate on the data archives must be the same at all centers to ensure consistency of results. The calculation modules (statistics, data quality rules, sorting, etc.) must also be consistent between products at a single data center to ensure consistency of inter-product results. Thus, a modular design philosophy using object-oriented programming (OOP) was adopted with tightly defined modularity and a software design philosophy that is centered on data elements.

8.5 UCAN User Interface

The system is designed to support any Internet browser or system-level software to seek climate information or run an application. Specifically, the user interface to the UCAN system is designed as three separate entities: a forms-based HTML document, a custom graphical user interface (GUI), and an embedded programmatic interface. The GUI and programmatic interface have received less development attention, so far. A prototype GUI was built which allowed for selection of station groups and returned data into a JAVA mapping application. The programmatic interface has been specified but not implemented. It is intended to make network calls to distributed metadata and data resources from applications such as simulation and decision models. The general access method that most users will experience is the forms-based interface. We have chosen this as our primary interface because it is a recognizable metaphor for most users, it is a well-tested methodology embedded in a graphical browser, and it is cost-effective.

A form-based interface offers other practical design advantages. They are easy to modify and can be enhanced with JAVA applets to increase functionality. Ease of configuration also makes it possible to customize the UCAN interface to meet the agency-specific needs for climate data access. For instance, an agency can define an interface that restricts access to a subset of UCAN information that satisfies specific agency needs. A simpler interface could be designed to reduce complex options, perform input error checking, restrict output formats to agency-wide standards, and reduce the overall costs associated with obtaining climate data. Since the interface is implemented on an Internet browser, it can be implemented and maintained by the local agency and linked to UCAN brokers (we'll mention these later) to complete the request.

Information passed from the form, GUI, or programmatic interface is formatted as name-value pairs. Names represent registered entities associated with climate data or UCAN product metadata. These name-value pairs are parsed by the UCAN broker and passed to appropriate routines for processing. Adherence to a standard name-value interface construction simplifies the implementation of the CORBA brokers.

8.6 UCAN Functional Component Integration

The UCAN system is designed as an object-oriented system. Every element in UCAN is a separate entity with a well-defined external interface and an internal state that depends on the particular object modeled. Implementing UCAN as a collection of distinct objects provides several benefits, including modularity, scalability, portability, and maintainability.

Modularity is enabled by a coherent object interface. The object interface ensures that the implementation of each object can be performed by different programming groups, independently. The data and metadata accessed by any object is encapsulated and any object implementation or database specific code is isolated from the rest of the system. Application programs (products) can be written to the general interface and access any data or metadata object in the UCAN system.

Scalability is provided by the provision of internal state maintenance for each object and special data routine. System-wide data structures are not used, as they can cause performance or administrative barriers to growth. As increased system usage places greater demand on system resources, object implementation can migrate from a single computer to multiple computers with no change to the supporting code. Local data domains will provide a hierarchy of data and metadata servers and keep a local directory of available objects.

8.7 Unified Climate Access Network Cost

The annual costs for UCAN implementation are $1.5 million for a 24/7 climate information system.

9 The President should direct appropriate federal agencies to expand technology transfer of water conservation strategies and innovative water supply techniques as part of drought preparedness programs.

9.1 The Snow Survey and Water Supply Program

In 1935, Congress authorized the USDA's Snow Survey and Water Supply Forecast Program (SS/WSF) through Public Law 46. The program provides agricultural water users and other water management groups in the western states area with water supply forecasts to enable them to plan for efficient water management. The program also provides the public and the scientific community with a database that can be used to accurately determine the extent of the snow resource. The western states area comprises Alaska, Arizona, California (east side of the Sierra Nevada mountain range only), Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

A congressional allocation to the Natural Resources Conservation Service (NRCS) provides funds to collect and interpret data as a service and an aid to agricultural interests, particularly those served by, or affiliated with, soil, water, and other conservation districts. Information collected by the NRCS for these agricultural users is also made available to other federal, state, and private agencies and to the general public without charge. Cooperator financial contribution is usually required for special measurements or interpretations as part of the regular program.

The Program has been a critical component in the economic development of the western United States for 60 years. Approximately 80% of the West's water comes from the seasonally variable snowpack that melts in the spring and summer. Competition and demand for this valuable resource--the lifeblood of this semi-arid and arid region--is growing at a dramatic pace along with western populations. In addition, recent climate variations, in the form of droughts and floods, have had a devastating impact on the western economy and rapidly developing population centers. Water supply information generated by the SS/WSF Program plays a prominent role in processes designed to provide early-season forecasts that facilitate planning among a wide variety of water uses--urban, agricultural, industrial, hydropower, navigation, recreational, species preservation, and international treaty compliance.

9.2 Expanded Use of a Surface Water Supply Index (SWSI) to Assess Western Drought

Indices of various kinds are widely used as tools to monitor drought, water supplies, and climate trends, yet no tool exists that integrates all the hydroclimatic elements (snowpack, precipitation, streamflow, and reservoir storage) associated with drought or water supply availability. Existing indices include the well-known Palmer Drought Index (PDI), the Surface Water Supply Index (SWSI, developed by the NRCS), and the Standardized Precipitation Index (SPI, developed by the Colorado Climate Center). Because of some weaknesses, the PDI is not very relevant in the irrigated areas of the West, and this was the motivation for the NRCS to develop the SWSI, beginning in the early 1980s. SWSI was intended to be a probabilistic multivariate index and include four variables relevant to surface water supply--precipitation, snowpack, streamflow, and reservoir storage.

Its original formulation, however, had some fundamental statistical flaws, which led to its reformulation in the early 1990s. This reformulation was based on using seasonal streamflow volume forecasts as a way to combine the variables into one and hence to overcome the statistical difficulties of dealing with a multivariate probability distribution.

In contrast, the SPI avoided the multivariate issue by focusing on only one variable--precipitation.

The forecast-based SWSI has a very specific interpretation, but can be adapted for use during the portion of the year when water supply forecasts are not made. This would provide a tool that can be used for a quick, yet comprehensive, assessment of the water situation and a comparison among river basins.

The result will be a more generally applicable index than the SPI and one that is also relevant in the West. This SWSI will find immediate applications in drought monitoring, particularly in states that already have drought plans that make use of the existing indices.

9.3 Implementation of Provisional Sub-Monthly Water Supply Forecasts

In response to NWS/NRCS Technical Working Group discussions during the fall of 1999, the NRCS began issuing provisional, sub-monthly water supply forecasts during Water Year 2000 for selected river basins in Montana, Wyoming, Colorado, Arizona, and New Mexico.

Production of sub-monthly water supply forecasts is driven by customer requests for more frequent assessments of water supply availability using data collected by the SNOTEL network. The Montana NRCS home page located at http://www.mt.nrcs.usda.gov/swcs/forecast/forecast.html contains links to both a text-based product and a graphical version of this product.

One of the primary goals for establishing the SNOTEL network was to support creation of water supply forecasts throughout the month. With nearly 20 years of observed data, SNOTEL information now plays a significant role in creation of the standard monthly and sub-monthly water supply forecasts.

Another goal of this project is to identify non-SNOTEL (e.g., COOP) climate stations necessary to create sub-monthly WSF, with the intent to either automate the climate station or recalibrate WSF procedures to use only automated data. The automation of COOP stations is an important component of NOAA's strategy to monitor climate in near real-time. Other climate activities, such as the National Drought Policy Commission's focus on drought monitoring and preparedness, play a key role in developing new water supply forecast products.

With these basic goals in place, our basic strategy is to qualitatively and quantitatively assess the value of these new forecast tools this year. The qualitative methods involve direct user feedback from web pages that contain the provisional forecasts. Qualitative methods involve the journalization of sub-monthly WSF issued and comparison to both monthly water supply forecasts and observed streamflow at the end of the water year.

A longer-term strategy involves integration of long-lead climate forecasts and water supply forecasting technology. It should be noted, however, that SNOTEL data were not used during the long-lead climate calibration process. SNOTEL data could provide a valuable data source in predicting climate at middle and higher elevations characteristic of the West.

Provisional sub-monthly WSF are filling an immediate need for assessing water resources in the West. Automation of existing climate stations and expansion of the SNOTEL network are key components of providing users with the water supply information needed to assess water supplies in the West.

An efficient and relevant presentation of water supply information is the final step to meet user needs for information. The "static water supply graphics" web page environment must migrate to a dynamic system that invites the user to view water supply products in a meaningful way. A dynamic web page would minimize the time required to understand what is happening and allow managers to fully participate in any decision process. This will require a design and implementation strategy that supports 24/7 product availability via the Internet.

9.4 Implementation of a Spatially Distributed Hydrologic Model

A fully GIS-based hydrologic model is fundamental to NRCS goals in snowmelt and streamflow prediction, and assessing the effects of land use and climate change. Some existing models make use of GIS to develop input data, but the basic structure and hydrologic process descriptions within these models remain largely unchanged from when they were first developed 20 or 30 years ago. The spatially distributed soils, vegetation, elevation, and climate data, along with the powerful GIS software and computers available today, allow major improvements in the fundamental descriptions of hydrologic processes. This can be achieved by conceptualizing models to take advantage of all of this additional capability, and therefore more accurate predictions of water quantity and quality can be achieved.

Over the past four years, the NWCC has been working with two primary partners to develop and apply a new spatially distributed hydrologic model. One partner (ARS Boise) has supplied a snowmelt model, and the other (Ruhr University Bochum, Germany) has supplied much of the model code for a soil moisture and streamflow simulation model. The NWCC has helped in the development of these models and is actively working to test the two and integrate them into a complete hydrologic simulation package.

9.5 Water Supply Technology Implementation Budget

The 5-year estimated cost to implement a more robust and responsive innovative water supply toolkit, as part of drought preparedness programs is $1.47 million.

Activity	Enhanced Water Supply Forecasts/ GIS	Surface Water Supply Index	Spatial Hydrology Model	5-Year Total
Salary/Travel	$148,000	$149,400	$230,870	$528,270
Services/Printing	$202,500	$183,000	$183,000	$568,500
Supplies/Equipment	$105,000	$102,750	$160,613	$368,363
TOTAL	**$455,500**	**$435,150**	**$574,483**	**$1,465,133**

10 The President should direct and Congress should continue to adequately fund existing and future drought-related research. Existing competitive research grant programs should give high priority to drought.

Current formalized research is insufficient to address needs or opportunities for optimizing drought preparedness and response efforts. Research and technology development are needed to help the various sectors affected by drought maximize water-use efficiency before the onset of drought and to decrease the cost/benefit ratio of drought response actions.

Drought mitigation and response planners need a wide variety of historical records. They also need analyses of weather, hydrology, climate, demographic, economic, agricultural practices and soils, and social data directly related to the assessment of drought risks. Finally they need to review the development, adoption, and use of specific triggers for planned drought response and mitigative practices over the geographic area of interest (local, state, tribal, regional, and/or federal) in order to evaluate the costs, benefits, and risks of proposed responses. Examples of these triggers include an assessment of soil moisture in a region compared to the historical record, a base indicator level of water in a reservoir, municipal and industrial water demand, or a certain number of inches of rain during required critical stages of the growing season.

Drought assessment and risk models need to be perfected and transferred to the decision makers as a “ready to implement” tool for local assessment and interpretation. Water users, institutional authorities, and the media will not be uniformly familiar with tools such as the Drought Monitor and drought indices to be able to develop useful information about drought. Information is often limited to analyses of climate, hydrology, and other physical data without integration of the societal impacts of the physical event so that the understanding of local, regional, or national conditions is incomplete. Also, the meaning, accuracy, and limitations of weather and climate forecasts are not clearly understood by users of the information. Different stakeholders (e.g., the agricultural community, government agencies at different levels, industries, environmental managers, etc.) will require different types of indices and context information to be able to make rational decisions regarding mitigation or response activities. Research should be conducted to improve ways of relating the scientific information to the decision processes.

Putting an index value of a current or projected drought into historical context enables a user to interpret the severity and likelihood of the event. For example, water suppliers or crop insurers probably would find recent precipitation records, soil moisture measurements, or other quantitative but simple indices alone inadequate as “assessments” on which to base decisions. Although the quantitative indices are a starting point for communications concerning drought, their use as triggers in planning or decision making is minimal without historical and geographical perspective. Historical data sets are a valuable tool in helping us understand the temporal and spatial extents of past droughts. Research is needed to characterize and define our experience with historical drought phenomena.

Coincident with the research need to improve the understanding by the decision makers is the need to improve the basic information. Deficiencies in drought monitoring, assessment, and prediction products can be improved with more research into and technology development of new types of products, new and improved instrumentation, and new methods of analysis. Users with specific needs, from agricultural producers to navigation interests, should be included as partners in researching and developing meaningful, sector-related products. Remote sensing should be explored as a viable means of monitoring drought. Analyses are needed to quantify drought characteristics that can be used to trigger user actions over time scales ranging from a few days to years or decades and over spatial scales ranging from a local water supply to a large region. Analyses of the errors inherent in the measurement, assessment, and application of these triggers also need to be quantified so that users will be able to determine the risks of taking or not taking an action.

Improved, timely forecasts are needed to give users the best available information at the earliest possible time so that mitigative decision making and policy implementation can take place. There is a need for more accurate quantitative forecasts of precipitation to better forecast runoff and streamflow, for longer-range forecasts to be issued more frequently, for verification scores for all forecasts to be made readily available, for a forecast of the number of hours temperatures will remain above or below freezing (to help in forecasting snowpack and runoff), and for forecasts giving the probabilities of recording various precipitation totals. Some progress has been made on the prediction of rainfall on daily time scales using numerical weather prediction methods, and also on multi-seasonal time scales related to the impact of El Niño. However, research efforts are needed to understand the basic drought meteorology. A better understanding of drought will yield a meaningful suite of prediction products pertaining to water supply that span the time continuum from days to decades.

11 The President should direct and Congress should fund completion of the soil survey on all lands, with special and immediate emphasis on tribal lands. As the Western Drought Coordination Council advised the Commission, basic weather, water, soil moisture, mountain snow amount, and climate observations are the foundation of the monitoring and assessment activity that alerts the nation to impending drought.

1. Lead Agency/Person and Backup: Lead - USDA-Natural Resources Conservation Service, Conservation Operations Division, Dave Mason 202-7201873 dave.mason@usda.gov **Backup--USDA-Natural Resources Conservation Service, Soil Survey Division, Horace Smith, Director, Washington, D.C. 202-720-1820; horace.smith@usda.gov**

- Actions and Products Required to Implement Recommendation:

Submit the following proposals for budget initiatives in Soil Survey to the USDA-NRCS through the Secretary of Agriculture:
SOIL SURVEY NATIONAL DROUGHT POLICY COMMISSION BUDGET PROPOSAL

The first initiative is to increase the soil survey activities in the western states with an emphasis on Native American lands.
- The workload on Native American lands and remaining private land is estimated at about 94,000,000 acres.
- That would take 2,350 staff years over a period of about 9 years.
- This initiative will place additional staff in states with a large acreage of Native American lands and accelerate that work. This same staff would then be available to work on the remaining 128,000,000 acres of federal lands that occur intermingled with the largest acreage of remaining unmapped private lands occurring in the western states.
- In FY 2001 the Division would continue to earmark funds specifically to accelerate mapping on Native American lands.
- An increase of 50 staff years in 2002 would map an additional 2,000,000 acres each year and significantly accelerate mapping of Native American lands. An additional 50 staff years in 2003, working cooperatively on private and federal lands, would accelerate that effort by an additional 2,000,000 acres per year.
- Increases requested in base funding of $5 million in FY 2002 and an additional $5 million in 2003 will be added to the funding provided to states. That amount of funding will support a total of 100 field staff and will produce an additional 4,000,000 acres of soil survey each year.

The second proposal is to provide information on drought-prone soils that can be used in GIS applications or prediction models.
- Provide data on drought-prone soils
- In FY 2001 the Agency would accelerate the digitizing of soil surveys by continuing to honor the eight-year 1998 Congressional earmark for implementing the USDA Service

Center GIS Strategy for digital data production, and provide $10,000,000 for the SSURGO initiative.

- In FY 2002 a $10,000,000 increase to the soil survey base funding would double the digitizing initiative, making national digital soil survey coverage available more rapidly.
- Drought predictions depend on reliable soil data. The National Soil Information System (NASIS) contains data fields for available water capacity, soil moisture, and water tables. There are about 392,000 data map units in NASIS. Only about 10% of the data map units are populated with information that could be used to predict soil moisture deficits. Additional resources would fill the data gaps and enable landscape models in conjunction with Geographic Information Systems to make accurate, detailed maps of soil moisture conditions. This soil moisture and temperature data would be collected through the proposed SCAN project. The monitoring of soil moisture and temperature requires special equipment that must be calibrated to specific soils. This expertise is best maintained in our National Soil Survey Laboratory.
- Develop drought susceptibility or probability maps based on STATSGO and soil temperature and moisture data and models.
- The ability of the NRCS to provide these technical soil services has been stressed to the limits since about 1985 because of the mandates of FSA and other more recently enacted programs such as EQUIP, CRP, WRP, WQA, CWA, EMAP, and now drought prediction. At the same time, NRCS is mandated to lead the National Cooperative Soil Survey Program and to publish the resulting reports. Soil survey and publication schedules are being negatively impacted and NRCS cannot afford to redirect additional financial resources away from the soil survey program to fund this new essential initiative of providing technical expertise and assistance in the use, augmentation, and management of soil survey information.
- NRCS will need an additional 100 specialists to collect the additional data needed by drought models, WEPP, WEPS, HEL, and wetland determinations, and other soil data needed both to meet the requirements of laws such as the Food Security Act and to provide direct assistance to farmers. Funds are needed for the additional staff and equipment required to collect the new data, enter it into the NASIS database, and provide assistance in its use.

The third proposal is to develop a methodology to tailor conservation systems for sustaining the soil resource, helping enhance the soil's ability to withstand drought, and maintain productivity.

1. For drought-prone soils, develop threshold limits beyond which the soil resource is degrading.
2. Identify conservation practices such as conservation tillage, crop rotation systems, cover crops, etc. that help reduce soil dispersion and susceptibility to compaction; improve aeration, infiltration and permeability; reduce soil erosion; and increase available water. Using these practices, develop conservation systems that help keep the soil resource below the degradation threshold during short-term drought and reduce the level of degradation during sustained drought.
3. Provide demonstration areas for marketing these concepts and systems.
4. Participate in developing programs that provide incentives to those land managers instituting drought mitigating conservation systems.

Total Additional Resource Requirements in CO-02 Soil Survey for NRCS:

	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
Funding Impact: ($000)	1,000	21,000	31,000	31,000	31,000
FTE Impact	10	110	210	210	210

Funding and staffing levels would need to be maintained from 2005 through 2009 to achieve completion of initial acre mapping on private lands.

- **Timeline:** 2,350 staff years over a period of about 9 years

- **Level of Decision-making to Accomplish Recommendations:** Secretary of Agriculture and Congress to sufficiently supply funding and resources to accomplish job

- **Team Recommendation:**
  The Secretary of Agriculture should submit to the President for consideration in the 2002 through 2009 budgets funding initiatives to supplement soil survey mapping, database, and research activities in the remaining private lands that have not been inventoried for soils. Startup activities in 2001 would be funded through a re-prioritization of funds within the Department of Agriculture. Drought-related research to facilitate real time monitoring of soil moisture conditions and conservation planning practices for drought mitigation should be included in these initiatives.

- **Discussion:**
  Drought mitigation planning and monitoring for prediction on a local level uses soil survey information as the basis for decisions. Without soil survey information at the county level, mitigation planning tools and models for drought prediction and monitoring are impaired. With the workload on Native American lands and remaining private land estimated at about 94,000,000 acres, significant acreage is left vulnerable with no resources to mitigate risk.

- **Resource Implementations:**

2. Budgetary: Funding levels would need to be maintained from 2005 through 2009 to achieve completion of initial acre mapping on private lands.

Increase the soil survey activities in the western states with an emphasis on Native American lands

Resource Requirements:

	FY 01	FY 02	FY 03	FY 04	FY 05
Funding Impact ($000s)	5,000	10,000	10,000	10,000	10,000

Provide information on drought-prone soils that can be used in GIS applications or prediction models

Resource Requirements:

	FY 01	FY 02	FY 03	FY 04	FY 05
Funding Impact ($000s)	15,000	20,000	20,000	20,000	20,000

Develop a methodology to tailor conservation systems for sustaining the soil resource, helping enhance the soil's ability to withstand drought, and maintain productivity.

Resource Requirements:

	FY 01	FY 02	FY 03	FY 04	FY 05
Funding Impact ($000s)	1,000	1,000	1,000	1,000	1,000

3. **Staff:** Staffing levels would need to be maintained from 2005 through 2009 to achieve completion of initial acre mapping on private lands

Increase the soil survey activities in the western states with an emphasis on Native American lands

Resource Requirements:

	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
FTE Impact	50	100	100	100	100

Provide information on drought-prone soils that can be used in GIS applications or prediction models

Resource Requirements:

	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
FTE Impact	50	100	100	100	100

Develop a methodology to tailor conservation systems for sustaining the soil resource, helping enhance the soil's ability to withstand drought, and maintain productivity.

Resource Requirements:

	FY 2001	FY2002	FY 2003	FY 2004	FY 2005
FTE Impact	10	10	10	10	10

- **Policy Issues:** No policy issues at agency or departmental levels affect this proposal

- **Cross-Cutting Recommendations:**

Specific recommendations from the Final Report of the National Drought Policy Commission that directly relate to the Soil Survey Program

Recommendation 1.1

Congress should adequately fund existing drought preparedness programs such as the U.S. Department of Agriculture's Conservation Technical Assistance Program (Public Law 46) and

Environmental Quality Incentive Program (16 U.S.C. 3839) and Bureau of Reclamation's drought planning program (Public Law 102-250, Title II)

Recommendation 2.1
The President should appropriately direct and Congress, as necessary, should authorize and fund a viable plan to maintain, modernize, expand, and coordinate a system of observation networks that meets the needs of the public at large. Priority should be placed on filling the gaps on tribal lands and in rural America.

Recommendation 2.2
The President should authorize and fund continuation of the U.S. Drought Monitor and exploration of opportunities for its improvement and expansion.

Recommendation 2.3
The President should appropriately direct and Congress, as necessary, should authorize and fund continuation of Drought Predictions/Outlooks and development of techniques to improve accuracy and frequency.

Recommendation 2.4
Federal agencies providing drought planning assistance should encourage state, local, regional, and tribal planners to use or adapt existing planning materials and resources. These include materials developed by the National Drought Mitigation Center, the Army Corps of Engineers, the U.S. Department of Agriculture, the Western Drought Coordination Council, the states, and urban and rural water districts.

Recommendation 4.4
We recommend that emergency assistance acknowledge, encourage, and reward natural resource stewardship and self-help without discriminating against those truly in need.

12 Budget Summary

The follow table summarizes a proposed 5-year budget to implement the Goal 2 recommendations of the National Drought Policy Commission report. The "TBD" placeholder denotes "to be determined" and that progress is underway to provide an estimated cost.

Agency/Network	Maintenance Of Existing Networks Annual / (5-year Total)	Modernization of Existing Networks (Multi-year)	Expansion & Maintenance of Networks to Meet User Needs (5-Year)	Combined Costs Maintenance (5-year) Modernization (multi-year) Expansion (5-year)
Goal 2.1 Observation Networks				
NWS/COOP	$8.00 mil / ($40 mil)	$160.00 mil	0	$200.00 mil
NWS/ASOS	$5,7 mil NWS 315 Stns ($28.5 mil) $9.2 mil FAA + others 600 Stns ($46.0 mil)	$52.0 mil NWS $0 FAA	0	$126.5 mil
NRCS/SNOTEL	$1.10 mil / ($5.5 mil)	$4.70 mil	$44.90 mil	$55.10 mil
NRCS/SCAN	$0.05 mil / ($0.25 mil)	$0.50 mil	$55.60 mil	$56.35 mil
USFS/RAWS	$0.38 mil / ($1.90 mil)	$0.20 mil	$.80 mil	TBD
USGS/NSIP	$78.00 mil / ($390 mil)	$64.00 mil	$5.00 mil	$459.00 mil
Reg. Networks	TBD	TBD	TBD	TBD
State Networks	$1.52 mil / ($7.60 mil)	TBD	TBD	TBD
Totals (Provisional)	**$89.05 mil / ($519.75)**	**$281.40 mil**	**$105.50 mil**	**$896.95 mil**

Table 1. Composite Goal 2.1 Budget Estimates

Program/Activity	Current Operational Program Costs Personnel and Services (Annual Est.)	New Products/ Services (Annual)	Additional Funds for New Services (5-year)	Combined Operational Costs and New Products and Services (5-Year)
Goal 2.2 Drought Monitor Improve / Expand	$0.2 mil	$0.2 mil	$1.0 mil	$2.0 mil
Goal 2.3 Drought Predictions/ Outlooks	$0.1 mil	$0.1 mil	$0.5 mil	$1.0 mil
Goal 2.4 Drought Information Gateway	$0.1 mil	$0.2 mil	$1.0 mil	$1.5 mil
Goal 2.5 Information (UCAN) Delivery System	$1.5 mil	$1.5 mil	$7.5 mil	$15.0 mil
Goal 2.6 Water Supply Technology	$1.1 mil	$1.5 mil	$7.5 mil	$13.0 mil
Goal 2.7 Drought Research	TBD	$0.5 mil	$2.5 mil	$2.5 mil
Goal 2.8 Complete Soil Survey	TBD	$145 mil	$145 mil	$145 mil
Totals (Provisional)	**$3.0 mil**	**$149.0 mil**	**$165.0 mil**	**$180.00 mil**

Table 2. Composite Goal 2.2 to Goal 2.8 Budget Estimates

13 Courses of Action

This section is currently under development. It will be the result of input supplied by of agency and cooperators to the Goal 2 framework.

14 Appendix A.

Goal 2 Recommendations from the Report of the National Drought Policy Commission

Improve collaboration among scientists and managers to enhance the effectiveness of observation networks, monitoring, prediction, information delivery, and applied research and to foster public understanding of and preparedness for drought.

Our findings and conclusions point out the value of observation networks, monitoring, prediction, information gateways and delivery, and research to drought preparedness.

Specific Recommendations

2.1 The President should appropriately direct and Congress, as necessary, should authorize and fund a viable plan to maintain, modernize, expand, and coordinate a system of observation networks that meets the needs of the public at large. Priority should be placed on filling the gaps on tribal lands and in rural America. Examples of critical observation networks include:

- Department of Commerce, National Weather Service, Cooperative Observer (COOP) Program Hydrometeorological Network
- U.S. Department of Agriculture, Soil Climate Analysis (SCAN) and Snowpack Telemetry (SNOTEL) networks
- U.S. Forest Service, Remote Automated Weather Station (RAWS) Network
- U.S. Geological Survey, Streamgaging and Groundwater Network
- Other regional observation networks

2.2 The President should appropriately direct and Congress, as necessary, should authorize and fund continuation of the U.S. Drought Monitor and exploration of opportunities for its improvement and expansion.

2.3 The President should appropriately direct and Congress, as necessary, should authorize and fund continuation of Drought Predictions/Outlooks and development of techniques to improve their accuracy and frequency.

2.4 The President should appropriately direct and Congress, as necessary, should authorize and fund a comprehensive information gateway (possibly through expansion of the National Drought Mitigation Center's website or other similar approaches) to provide users with free and open access to observation network data and drought monitoring, prediction, impact, assessment, preparedness, and mitigation measures.

2.5 The President should direct the appropriate federal agencies to develop an effective drought information delivery system such as the Unified Climate Access Network (UCAN) to communicate drought conditions and impacts to decision makers at the federal, regional, state, tribal, and local levels and to the private sector and general public.

2.6 The President should direct appropriate federal agencies to expand technology transfer of water conservation strategies and innovative water supply techniques as part of drought preparedness programs.

2.7 The President should direct and Congress should continue to adequately fund existing and future drought-related research. Existing competitive research grant programs should give high priority to drought.

2.8 The President should direct and Congress should fund completion of the soil survey on all lands, with special and immediate emphasis on tribal lands. As the Western Drought Coordination Council advised the Commission, basic weather, water, soil moisture, mountain snow amount, and climate observations are the foundation of the monitoring and assessment activity that alerts the nation to impending drought.

15 References

Bonnin, G.M. August 1984. The Standard SHEF Decoder Version 1.1. NOAA Tech. Memo NWS CR-72, NWS Central Region, Kansas City, Missouri.

Bonnin, G.M. and R.S. Cox. April 1983. An Explanation of the Standard Hydrologic Exchange Format (SHEF) and Its Implementation in the Central Region. NOAA Technical Memorandum NWS CR-67.

Hubbard, K.G. 1994. Spatial variability of daily weather variables in the high plains of the USA. Agric. and Forest Meteorol. 68:29-41.

Meyer, S.J. and K.G. Hubbard. 1992. Nonfederal automated weather stations and networks in the United States and Canada: A preliminary study. Bull. Amer. Meteorol. Soc. 73(4):449-457.

NC94. 2000. United States Agricultural Meteorology/Climatology Program Vision. NC94 Regional Research Committee Vision Statement. 2 pp.

NRC. 1998. Future of the National Weather Service Cooperative Observer Network. National Research Council. National Academy Press. Washington, D.C. 65 pp.

Pasteris, P.A. and V.C. Bissell. 1985. SHEF and Its Application in the Pacific Northwest. International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology, American Meteorological Society, pp. 9-13.

Pasteris, P.A., V.C. Bissell, and D.G. Bennett. 1982. Standard Hydrologic Exchange Format (SHEF) Version 1.0., NOAA Technical Memorandum NWS WR-180.

Pasteris, Reinhardt, Robbins, Perot, "UCAN-Climate Information Now for the Next Century," 1st Symposium on Integrated Observing Systems, AMS, Long Beach, CA, February 1997.

Robbins, K., Perot, C., "Unified Climate Access Network (UCAN), "Sixth International Conference on Computers in Agriculture, Cancun, Mexico, June 1996. pp. 1135-1142

USDA. 1999. Operational Meteorological Data Requirements. United States Department of Agriculture. An Interagency Committee Report. Washington, D.C. 33 pp.