# Creating a Drought Early Warning System for the 21st Century

## The National Integrated Drought Information System


Western Governors' Association • June 2004

The Western Governors' Association wishes to thank Vice Admiral Conrad C. Lautenbacher, Administrator of the National Oceanic and Atmospheric Administration, for his vision and leadership in recognizing the value and importance of the National Integrated Drought Information System. NOAA's partnership with the WGA made this report possible.

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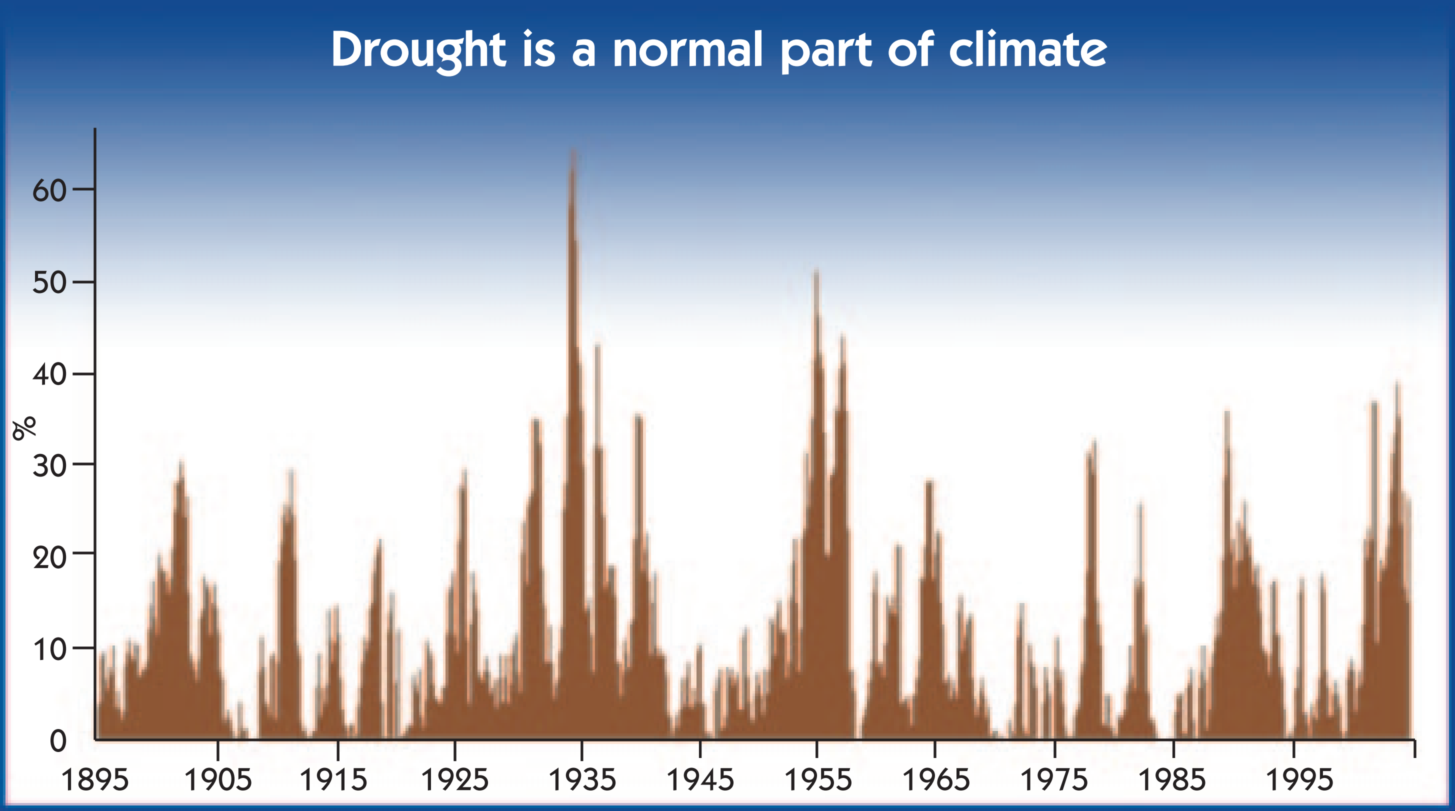
*"With drought causing between $6 billion and $8 billion a year in direct estimated losses to the U.S. economy and devastating impacts on our society, we cannot overlook the need for science to predict, monitor and mitigate this phenomenon. By creating a comprehensive drought information network and setting the state for the first national drought policy, we can provide decision-makers with the best tools to manage our natural resources and ensure an adequate supply of clean water for our nation. Drought monitoring and prediction are key to the earth observation system envisioned by world leaders.*

*Where there is water, there is life. We must deliver the best science and the most well-coordinated program possible to address this challenge. The NIDIS will provide the framework for dealing with the drought conditions that have ravaged our country in recent years. The NIDIS is the early warning system for the 21st century that will improve our existing capabilities in monitoring and forecasting drought."*

Vice Admiral Conrad C. Lautenbacher, Jr., Undersecretary of Commerce for Oceans and Atmosphere; NOAA Administrator




**Percent Area of the United States in Severe and Extreme Drought**
Source: National Climatic Data Center/NOAA

# Creating a Drought Early Warning System for the 21st Century
## The National Integrated Drought Information System

### Executive Summary

> *"Drought is the most obstinate and pernicious of the dramatic events that Nature conjures up. It can last longer and extend across larger areas than hurricanes, tornadoes, floods and earthquakes…causing hundreds of millions of dollars in losses, and dashing hopes and dreams."*
>
> — National Drought Policy Commission Report, May 2000

In 1996, the Western Governors set an aggressive goal to change the way our nation prepares for and responds to droughts. Subsequent efforts by the Western Governors' Association (WGA) led to the Congressional creation of the National Drought Policy Commission (NDPC), which issued its recommendations in May 2000 to establish such a national policy. Among its recommendations, the Commission called for "Improving 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."

The Western Governors agree that improved monitoring and forecasting is fundamental to a proactive national drought policy. Better science will lead to better and more timely decisions, thus reducing or mitigating a drought's impacts. In February 2003, WGA's Lead Governor for Drought, Mike Johanns of Nebraska, met with National Oceanic and Atmospheric Administration (NOAA) Administrator, Vice Admiral Conrad Lautenbacher, to discuss a partnership between NOAA and WGA to develop a vision and recommendations for establishing an improved drought monitoring and forecasting system. The partnership began in April 2003, and this report, *Creating A Drought Early Warning System for the 21st Century: The National Integrated Drought Information System*, is the first product of that partnership.

We highlight two key components of NIDIS described in this report that will be critical to its successful implementation:

1. improve and expand the compilation of reliable data on the various indicators of droughts, from both the physical/hydrological data (such as a national surface observing network) to the socio-economic and environmental impacts data (such as agriculture losses and wildfire impacts); and
2. integrate and interpret that data with easily accessible and understandable tools, which provide timely and useful information to decision-makers and the general public.

For NIDIS to be realized, strong leadership is needed. Western Governors believe NOAA should be designated as the federal lead for NIDIS. NOAA should take the initiative to convene and coordinate all of the relevant entities, including federal and non-federal partners, as well as scientists, water users and policy-makers to implement those aspects of NIDIS that can be accomplished under existing authorities and funding.

While NIDIS will go far in facilitating a proactive approach to drought, the Governors recognize that it is only one component. A comprehensive national drought policy must be established, including improving drought monitoring and forecasting (NIDIS), coordinating and integrating governmental programs, establishing reliable funding for drought preparedness and response activities, and facilitating state-based drought preparedness and mitigation programs, which lead to effective investments in on-the-ground solutions.

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|---|---|---|
| Bill Richardson<br>Governor of New Mexico<br>WGA Co-Lead for Drought | Mike Johanns<br>Governor of Nebraska<br>WGA Co-Lead for Drought | Judy Martz<br>Governor of Montana<br>WGA Co-Lead for Drought |

# NIDIS – A Proactive Approach to Drought

Water users across the board – farmers, ranchers, tribes, land managers, business owners, recreationalists, wildlife managers, and decision-makers at all levels of government – must be able to assess their drought risk in real time and before the onset of drought, in order to make informed decisions.

Droughts are as much a part of the weather and climate extremes as floods, hurricanes and tornadoes. Yet in marked contrast to the myriad federal programs that report, prevent and mitigate the damage of these other extreme events, we passively accept drought's effects as an unavoidable natural hardship.

This passive approach to droughts is manifested in our lack of a comprehensive federal drought policy: we respond to droughts through ad hoc, crisis management, rather than through proactive, coordinated strategies designed to mitigate the impacts. To address other natural disasters — floods, hurricanes, tornadoes, etc. — Congress enacted the Stafford Act, which gives clear roles and responsibilities to the various federal agencies and makes the Federal Emergency Management Agency (FEMA) the federal lead.

A simple explanation for the inferior treatment of droughts, vis a vis other natural disasters, is that droughts are much more difficult to identify. It is hard to miss an oncoming flood, hurricane or tornado — or their immediate aftermath. Droughts, on the other hand, are a creeping phenomenon, which develop slowly over large areas and an extended period of time. This slow nature of drought hinders the recognition of the true impacts, thus diminishing the urgency that would otherwise trigger a timely and comprehensive response.

Recognition of droughts in a timely manner is dependent on our ability to monitor and forecast the diverse physical indicators of drought, as well as relevant economic, social and environmental impacts. Unfortunately, due to the lack of a national drought policy, there has been no development to date of a coordinated, integrated drought monitoring and forecasting system.

Recent trends toward increased climate variability and vulnerability to drought amplify the need for leadership to formulate and implement a more integrated monitoring and forecasting system. Indeed, as the WGA noted in its September 2003 resolution, National Policies Regarding Global Climate Change, "The failure to take appropriate actions to address global climate change risks economic and societal damage." Water users across the board — farmers, ranchers, tribes, land managers, business owners, recreationalists, wildlife managers, and decision-makers at all levels of government — must be able to assess their drought risk in real time and before the onset of drought, in order to make informed decisions.

The U.S. Drought Monitor, created in 1999 to better integrate data on current conditions, is an important new tool in monitoring drought. The U.S. Seasonal Drought Outlook, created in 2000, strives to better forecast drought. However, these two information sources, while very helpful, are initial indicators of the benefits that will be gained from fuller integration of relevant and available data to improve monitoring, provide a better understanding of how and why droughts occur, enhance dissemination of information at the relevant spatial and temporal scales, and, ultimately, improve the forecasting of droughts.

# Vision and Goals

## The National Integrated Drought Information System (NIDIS) Vision

A dynamic and accessible drought information system that provides users with the ability to determine the potential impacts of drought and the associated risks they bring, and the decision support tools needed to better prepare for and mitigate the effects of drought.

## NIDIS Goals

NIDIS is intended to accomplish the following goals:

- Develop the leadership and partnerships to ensure successful implementation of an integrated national drought monitoring and forecasting system;
- Foster, and support, a research environment that focuses on impact mitigation and improved predictive capabilities;
- Create a drought "early warning system" capable of providing accurate, timely and integrated information on drought conditions at the relevant spatial scale to facilitate proactive decisions aimed at minimizing the economic, social and ecosystem losses associated with drought;
- Provide interactive delivery systems, including an Internet portal, of easily comprehensible and standardized products (databases, forecasts, GIS-based products, maps, etc.); and
- Provide a framework for interacting with and educating those affected by drought on how and why droughts occur, and how they impact human and natural systems.

"Since 1989, Congress has appropriated more than $25 billion in agriculture disaster assistance. On average, the federal government spends more than $1.5 billion in response dollars, yet virtually nothing on preparation. Spending a little up front to plan for drought will save states and the federal government billions in the long run. Frankly, in these tough economic times, we cannot afford the alternative."

Rep. Alcee Hastings (Fla.)

# Integrating Observations and Data Systems

### Key Variables for Monitoring Drought

- climate data
- soil moisture
- stream flow
- ground water
- reservoir and lake levels
- short, medium and long range forecasts
- vegetation health/stress and fire danger

## Current Observations and Data Systems

Drought planning and mitigation will be based upon the gathering of high quality information related to a variety of physical, environmental and human conditions. The gathering and integration of data includes making more efficient use of existing data as well as "filling in the holes" in local, state, regional and federal networks. Characterization of drought requires a combination of two types of information:

1. Observations of past and current physical states of the environment and their context within the relevant historical record.
2. Documented impacts on human and natural systems that are a consequence of the physical conditions.

## The Importance of a Drought Early Warning System

- allows for early drought detection
- allows for proactive (mitigation) and reactive (emergency) responses
- “triggers” actions within a drought plan
- bottom line – provides information for decision support

*SNOTEL Monitoring Station*

It will require a network of scientists to maintain the physical observing system, collect and analyze the data, and to collect and synthesize the information on drought impacts. These and related observations must meet data quality standards for siting, performance and maintenance.

The necessary physical information includes observations of precipitation, soil moisture, snow water content and snow depth, soil and air temperatures, humidity, wind speed and direction, and solar radiation. Currently, the placement of soil temperature and soil moisture measurements is too sparse, and nonexistent in many areas, for effective use.

Drought revolves around the supply of and the demand for water. Integrating data on stream flow, lake and reservoir levels, and ground water status also is required for NIDIS. With our increasing dependence on ground water, a cooperative system of ground water monitoring wells is essential.

The greatest current data shortfalls are on the local (city/county) and state levels. Physical information and drought impact information at these levels is almost impossible to obtain in a uniform manner across the nation. The National Weather Service (NWS) has proposed in its modernization of the Cooperative Observer Network a minimum spatial density of one observing site for each 400 square miles across the country, or in other words, sites would be about 15 to 20 miles apart. Other placement strategies, such as using hydrologic units, may need to be employed to optimize spatial coverage.

Drought information needs also differ greatly by region. In the West, for example, mountain snow pack is a critical component of water supply. It is thus essential to generate and distribute the best estimates possible of the water content of snow on the ground, snowmelt, and snow-to-vapor sublimation.

## Transmitting Climate Data

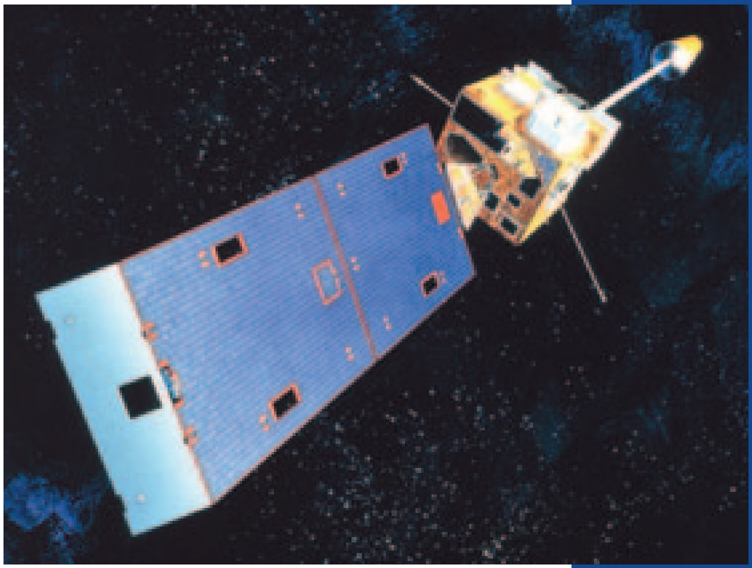
Weather and climate observations have limited value if they cannot become part of a larger drought risk mosaic. A wide variety of data networks currently exist throughout the U.S. Many of these networks transmit their observations with telecommunications that balance frequency and reliability with operation and maintenance costs. A large number of hydroclimatic observations, including the USGS streamflow network, are transmitted in near real-time by satellites (GOES). In the mountainous West, where data transmissions are often blocked by mountains, the meteor-burst technology used by the NRCS SNOTEL (SNOw TELemetry) network provides a reliable and cost-effective real-time data transmission method.

In areas where terrain is not a constraint to data transmission, innovative partnerships have been established to “piggy-back” climate data over existing data networks.

In Oklahoma, the Oklahoma Climatological Survey (OCS) has a partnership with the Oklahoma Law Enforcement Telecommunications System (OLETS) allowing the transmission of its Mesonet data through police, fire and emergency management offices throughout the state. This high quality, land-line network eliminates the need for OCS to deploy and maintain an independent communications network solely for Mesonet data. The bandwidth required to transmit all Mesonet observations and communications represents only a very small fraction of the total OLETS capacity. The cooperative arrangement represents a savings of over one million dollars annually for Mesonet operations. This model could be replicated in other states, working with the National Enforcement Telecommunications System (NLETS).

## The Role of Remote Sensing

The use of an individual type or sources of data involves inherent tradeoffs and shortcomings, so data must be integrated to enhance meaning and value. Complementary data from remote sensing, satellites, radar, aircraft and other technologies must be explored, encouraged and incorporated to fill important data gaps.



## Working with the Private Sector

While governmental agencies have shown great innovation in collection of drought data and development of new tools, an important role exists for the private sector. Opportunities may exist in which government can set priorities and provide direction, and then allow for a competitive and innovative private sector to meet the needs. During the course of public-private interaction, the NIDIS Leadership Team will need to be sensitive to such issues as proprietary information, quality control of data, consistent methodologies, and standardization of the data.

## Building a Baseline of Social, Environmental and Economic Observations

No systematic collection and analysis of social, environmental and economic data focused on the impacts of drought within the United States exists today. Examples of data that could be collected include drought-related relief payments; mental health visits in drought-stricken areas; losses of revenue due to low water, ranging from river rafting guide revenues to barge tonnage; reduced hydropower production; increased ground water pumping costs for agriculture and municipal purposes; revenues from fish camp and canoe outposts; golf course revenue; agricultural yield losses not eligible for relief payments (e.g., nurseries); skier days and snow-related tourism revenue; and ecological impacts data such as water quality, and impacts from wildland fires; etc. Because such data either are not centralized or not collected, officials often underestimate economic and social costs related to drought.

NIDIS should fill that gap by developing methodologies to collect and assess the social, environmental and economic impacts of drought across the United States. These methodologies also should develop assessments from sectors not always at the forefront, such as the livestock, timber, wildlife, energy, recreation and tourism sectors.

Understanding these impacts of drought will empower users and expand the comprehension of the full magnitude of drought losses. By so doing, it will encourage local, state and federal officials to increase efforts in drought planning, preparation, and mitigation. Comprehensive baseline data on drought impacts also will help to verify the relative cost effectiveness of "risk" versus "crisis-management" approaches to drought management.

**No systematic collection and analysis of social, environmental and economic data focused on the impacts of drought within the United States exists today.... Because such data either are not centralized or not collected, officials often underestimate economic and social costs related to drought.**

*Photo left: Lake Mead - photo courtesy of Dr. Ken Dewey, High Plains Regional Climate Center*

NIDIS will bring together a variety of observations, analysis techniques and forecasting methods in an integrated system that will support drought assessment and decision-making at the lowest geopolitical level possible.

U.S. Drought Monitor maps on these pages show the intensity of drought for mid May over the past six years. The Monitor is a joint effort by the USDA, National Drought Mitigation Center, Climate Prediction Center (NOAA), and National Climate Data Center (NOAA)

# Developing New Tools

## Current Tools and Needs

Current efforts at drought management are scattered throughout numerous federal, state, regional and local agencies. The Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) manages snow pack information, the Army Corps of Engineers (COE) and Bureau of Reclamation (BOR) manage reservoir storage data, NOAA manages hydroclimatic data, Interior's Geological Survey (USGS) has ground water and stream flow information, and the Environmental Protection Agency (EPA) manages various water quality programs in concert with the states and tribes.  Regional and state entities also provide considerable data and information services used for drought analysis in real time.  These programs have generally evolved independently, require separate appropriations and, until recently, have not been available to users at a central location due to their complexity and the absence of tools to accomplish data integration.

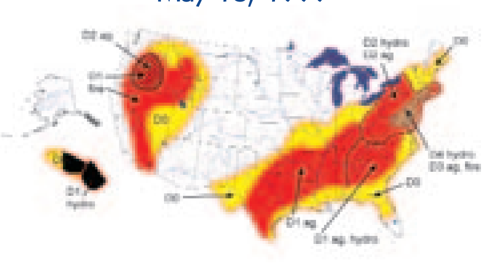
NIDIS will bring together a variety of observations, analysis techniques and forecasting methods in an integrated system that will support drought assessment and decision-making at the lowest geopolitical level possible. The tools will allow users to access, transform and display basic data and forecasts across a range of spatial and temporal scales most suited to their individual needs. There are four basic types of drought information tools:

1. Data access tools facilitate the retrieval of data from the different agencies that collect and archive it.
2. Analysis tools add value to the raw data through computer data transformation, modeling and statistical analysis.
3. Data display tools enable visual display of raw and analyzed data in ways to enhance its value to users. Geographic Information System (GIS) software enables the examination of geo-referenced information.
4. Forecast tools are a specialized analysis combining statistical properties of available observations and models of future developments to make forecasts.

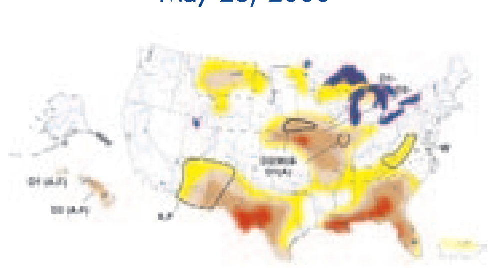
## Future Tools

An infrastructure to develop, integrate and maintain a suite of drought decision support and simulation tools is fundamental for the success of NIDIS. It will be built on existing institutions with complementary expertise at local, state, regional and national levels.

May 18, 1999



May 23, 2000



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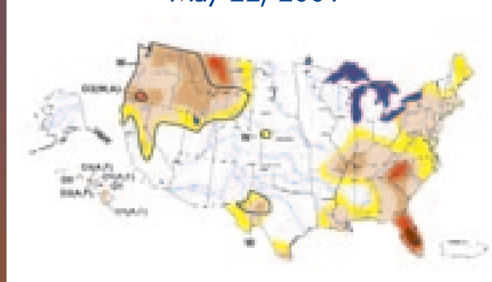


The NIDIS infrastructure will be developed in stages, and is dependent on adequate and sustained funding. Some drought tools focused on environmental variables (e.g., precipitation and temperature) are currently available but not integrated with user needs to comprise a complete product suite. Drought impact assessment tools and databases do not exist and will need to be developed.

### Benefits of New Tools

The Internet will allow quick, convenient, frequent, and low-cost assessments of drought risk by users. Access to immediate drought information will be of continuing benefit, since drought impacts vary by time of year. On-demand risk analysis will provide the lead time needed to implement appropriate economic strategies to reduce drought impacts.

## Coordinating Research and Science

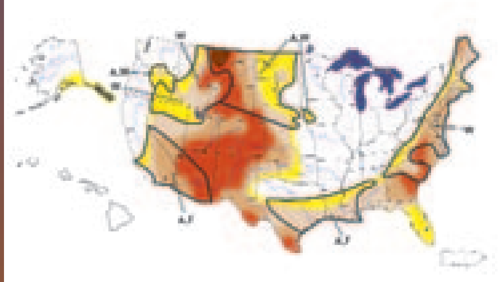
Drought-related research is critical in the production of innovations and technology that lead to improved drought preparedness.  Currently a coordinated and integrated drought research program does not exist at the national level, despite the enormous impact of droughts every year on the nation's economy, society and the environment. This fact sets drought apart from other major natural disasters, which have sustained federal research programs and significant interagency coordination. One example is the continuing research on hurricanes or severe storms and their impact.  Currently, drought research is scattered across many agencies, universities, and other research institutions, without formal coordination or planning to maximize the value of the research dollars spent and without effort to ensure that the priority needs of the public and decision-makers are being addressed. The simple act of coordinating drought research within and between levels of government, as well as with private entities and universities, will help accelerate the development and provision of scientifically-based information products, thereby, enabling users to better prepare for, manage and respond to the impacts of drought.

The most effective drought research efforts must include sustained interactions between the research community and the customers of the information, such as decision-makers, agriculture producers, water users, and other future NIDIS users. This collaboration would ensure that research stays focused on the highest priority needs for drought information.

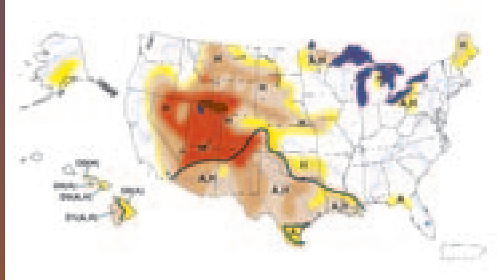
**Intensity**

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

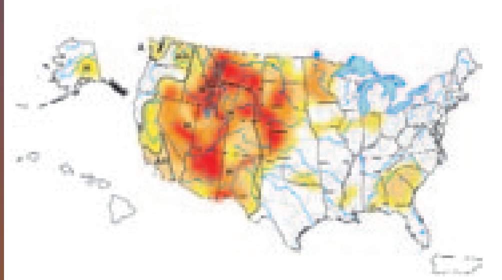
May 14, 2002



May 20, 2003



May 11, 2004



The most effective drought research efforts must include sustained interactions between the research community and the customers of the information, such as decision-makers, agriculture producers, water users, and other future NIDIS users.

Significant research efforts should focus on the development of improved drought monitoring and forecasting at the regional and local levels where decisions are made. Research to better understand drought decision processes and the opportunities for the use of drought information in new applications also should be undertaken. Every improvement in the ability to predict drought frequency, duration and severity will result in increased effectiveness in planning and preparation to minimize its impacts, including planning for new or expanded water storage facilities. The drought indices and program triggers should be subject to refinement and revision in response to the needs of decision-makers and to advances in scientific understanding.

Drought tools and products must always be presented in a way that highlights the inherent uncertainties they contain. The value of coupling physically based drought models to impact or adaptive management models also should be investigated. Better documentation of all parameters of past droughts can improve history's usefulness in developing plausible "If, then..." scenarios. Parameters include the relationships among the extent, severity and longevity of droughts on humans and the environment, plus impacts.

## Information Dissemination and Feedback

Many people are aware of the need for water conservation and other measures during drought. But once drought is over, old habits tend to dominate. The benefits of sustained public awareness will be realized through NIDIS.

NIDIS will allow active user interaction in identifying and resolving problems with the use of scientific information. Documentation and outreach is essential to inform the user community while also building confidence in the system's integrity. User feedback on system functionality and ease of use will be an essential part of an adaptive management approach to system maintenance and improvement.

The drought monitoring and prediction information produced by federal and nonfederal partners currently poses a problem for many users. The information is often technical, complex and typically is not presented in a standardized format. Many potential users do not even know some drought resources exist. NIDIS will provide drought information through the Internet in an interactive environment. NIDIS on the Internet also will provide access to related research that is not always disseminated in a timely way or through easily accessible modes. Opportunities should be utilized to integrate NIDIS with existing systems (e.g., state flood warning systems) used by decision-makers responding to other natural disasters.

Gaining and keeping the trust and confidence of users is essential for the proposed system to have credibility and long-term support. Achieving this goal will require a continual focus on education, outreach, product development, verification and refinement. Panels for initial testing of the system should be created that include users representing a wide range of education levels and sectors of the economy, as well as federal, state and local government entities. Their input will help guide fine-tuning of the system.

*The cross-section is from a ponderosa pine stump, collected at Sheep Pen Canyon in far southeast Colorado, between Trinidad and Springfield. The pith (innermost) ring is AD 1514, and the outermost ring is 1768. All of the bark and sapwood have eroded away, indicating that the death of the tree occurred >100 years after the outer date, so in the late 1800s or early 1900s, which is consistent with the tree being cut by an early settler of the area. The trees at this site are very drought-sensitive, and the site ring-width chronology that includes this cross-section was used to reconstruct summer PDSI (Palmer Drought Severity Index) in eastern Colorado from 1550 to 1995.*

*Image courtesy of Jeff Lukas, INSTAAR Dendrochronology Lab,University of Colorado.*

# Recommendations

Through implementation of the recommendations below, we believe the goals for a National Integrated Drought Information System will be achieved. If so, we can successfully establish a dynamic and accessible drought information system to provide users with the decision-support tools needed in preparing for and mitigating the impacts of drought.

The recommendations outlined in this report will require the commitment of essential personnel, funding and cooperation for NIDIS to be successfully accomplished.

1. **Establishing NIDIS:** The successful launch of the NIDIS will require effective leadership to oversee the development, coordination and implementation of its various components and programs.

   **Recommendation 1a:** NIDIS should be formally established.

   **Recommendation 1b:** The National Oceanic and Atmospheric Administration (NOAA) should be the lead federal agency for coordinating implementation of NIDIS.

   **Recommendation 1c:** In anticipation of Congressional authorization of NIDIS, NOAA should immediately establish a broad-based Implementation Team to carry out those aspects of NIDIS that can be accomplished through existing authorities and resources.

   **Recommendation 1d:** The drought infrastructure at the federal level should not be centralized in Washington, D.C. States and regional groups should be allowed to play a key role in the successful design and implementation of NIDIS, and should have a designated and adequately supported, drought contact. These contacts should be identified and incorporated in the NIDIS development process, and should be provided the resources necessary for information exchange, research, and tool development that is regionally or locally specific.

2. **Data Needs and Integration Tools:** In order to make informed decisions, water users and resource managers need credible and readily accessible drought information describing current and forecasted drought conditions and impacts.

   **Recommendation 2a:** The NIDIS framework must integrate data from the wide variety of existing networks, and determine related gaps, both spatially and temporally. The networks should be stable, modernized and expanded to provide the hydroclimatic data needed to assess drought risk. These data need to be real-time, be of appropriately fine focus to serve local areas, and have sufficient long-term continuity and quality assurance to meet NIDIS requirements.

   1. NOAA's multi-use National Mesonet, made up of a modernized Cooperative Observer Network at its core, should be created and integrated with other federal and nonfederal networks.

"We must be vigilant and prepare ourselves for quick action when the next drought cycle begins. Better planning on our part could limit some of the damage felt by drought. I propose that this bill is the exact tool needed for facilitating better planning."

Sen. Pete Domenici, New Mexico, upon introducing The National Drought Preparedness Act of 2003

2. Additional federal and nonfederal networks also are vital to the success of NIDIS. These include those operated by NASA, EPA, USGS, USDA/NRCS, USDA/Forest Service, DOI's Bureau of Land Management, Bureau of Reclamation, state and regional mesonets, state flood warning systems, etc. The necessary resources to maintain and strengthen their monitoring capabilities and integrate them with NIDIS are critical.

3. Using the Oklahoma Mesonet as a model, the NIDIS Leadership Team should explore partnership opportunities with the National Law Enforcement Telecommunications System (NLETS) and the various state law enforcement telecommunication systems in each state to transmit real time weather and climate monitoring data

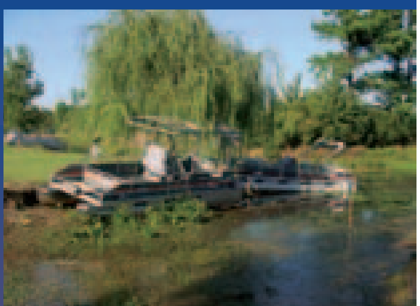
**Recommendation 2b:** The NIDIS Leadership Team should identify and evaluate current and historical data sources on climate, water supply and storage capabilities, and drought indices for their utility and applicability. NIDIS will be built on the integration of these existing databases, and expanded to fill information gaps. Tools and programs to fill the current gaps in drought monitoring may include the following:

1. Integrating meteorological, climatological, hydrological and agricultural/vegetation drought assessment tools within the NIDIS infrastructure, thereby deriving useful information beyond that contained in the separately maintained databases.

2. Developing new drought assessment tools that provide access to environmental data and analyses at the appropriate scale (e.g., state, watershed, county) in a GIS modeling framework.

3. Creating new water resources assessment tools to improve the understanding of hydrological drought.

4. Producing tools capable of generating credible short- and long-term drought forecasts in forms specific to user needs and locations.



*Lake Moultrie in South Carolina in September .*

5. Assembling tools to assimilate both remotely sensed (e.g., satellite, radar) and in situ instrument-based observations, with emphasis on techniques to analyze and model the status of drought by integrating both types of observations.

6. Having the National Drought Mitigation Center, at the University of Nebraska in Lincoln, be a principal clearinghouse for tools designed to address the needs of the drought community.

**Recommendation 2c:** NIDIS must provide a methodology to accurately and comprehensively quantify the reporting of drought impacts across all relevant sectors and scales, through the following actions:

1. Developing a Web-based reporting system to collect quantitative and qualitative drought impact information for all sectors into a national database within an interactive GIS modeling framework.

2. Developing tools capable of integrating drought impacts and environmental data into forms useful for mitigation and adaptive management.

3. Having the NIDIS Implementation Team identify opportunities to use existing agency collection programs to gather additional data relevant to drought impacts. For example, the USDA's National Agricultural Statistical Service (NASS) annual acreage and production survey could be modified to request information on crops, acreages and livestock numbers affected by drought. NASS also could be used to establish impact reports for other drought issues, (i.e., economic and social) as needed.

**3. Research Needs.** Agricultural producers, resource managers, municipalities, industries and other water users are obliged to make risk management and investment decisions that rely on current and anticipated climatic conditions. Research is needed to improve the forecasting of short- and long-term drought conditions, to make the forecasts more useful and timely, and to establish priorities based on the potential to reduce drought impacts.

**Recommendation 3a:** NIDIS must facilitate the coordination and program delivery across interagency, intergovernmental and private sector science and research programs by establishing an integrated federal drought research program:

1. Improving capabilities to monitor, understand and forecast droughts.
2. Developing methodologies to integrate data on climate, hydrology, water available in storage, and socioeconomic and ecosystem conditions, in order to better understand and quantify the linkages between the physical characteristics of drought, the impacts that result from droughts, and the triggers used by decision-makers who respond to drought.
3. Identifying regional differences in drought impacts and related information needs and delivery systems, and developing regionally specific drought monitoring and forecasts.
4. Developing new decision support tools, such as drought "scenarios" (e.g., "if, then."), that would give decision-makers (such as agricultural producers) a better range of risks and options to consider.
5. Improving the scientific basis for understanding ground water and surface water relationships and developing triggers and thresholds for critical surface water flows and ground water levels.
6. Encouraging all relevant federal agencies, in cooperation with the NIDIS Implementation Team, to expand their drought research portfolios by undertaking an analysis of existing research and identifying gaps. The findings of this gap analysis should guide funding and priorities for future drought research.
7. The federal agencies participating in the coordinated research program under NIDIS should commit a percentage (no less than five percent) of their research budgets to drought issues.

*Cornfield affected by drought and grasshoppers (2002 National Drought Mitigation Center)*

*Joshua Tree National Park, Arizona, in 2003. Photo courtesy of Kelly Redmond of the Western Regional Climate Center.*

4. **Facilitating Drought Preparedness Programs.** NIDIS will provide a sound, scientific basis on which to develop effective drought mitigation and response plans, by describing the nature and magnitude of the historical drought threat and providing information on the likelihood and severity of drought. Additionally, federal drought programs need better coordinated triggers to facilitate timely assistance to areas where drought is emerging.

   **Recommendation 4a:** NIDIS should facilitate drought planning by providing information to aid in development of science-based triggers in preparedness plans that will result in timely actions to minimize impacts and reduce risks. The National Drought Mitigation Center, which has established expertise, should help in this effort.

   **Recommendation 4b:** The NIDIS Leadership Team should work in partnership with federal agencies responsible for drought assistance programs to analyze program triggers and make recommendations for improving program delivery.

5. **Interaction and Education:** Building on existing programs, NIDIS must provide a framework for education of water users, resource managers and the public, and for interaction among users of the system.

   **Recommendation 5a:** To address the information needs of the various users of the NIDIS and assure continuing feedback from them on how to improve its design, NOAA, private entities, and the NIDIS Implementation Team should perform ongoing evaluation of the usefulness, usability and timeliness of NIDIS products. To accomplish this task, NIDIS should create user panels to test initial phases of the system and to conduct ongoing quality assurance/quality control assessment.

   **Recommendation 5b:** NIDIS should support drought outreach efforts by providing guidance and assistance to education programs and outreach training on ways to plan for, mitigate, anticipate and respond to droughts.

*Almost empty Platte River near Mahoney State Park (9/3/03). Photo courtesy of Ken Dewey of the High Plains Regional Climate Center*

*This foundation rests about a half-mile southeast of the main townsite. This is in the lake bed, about 100 yards from the lake's eastern dike, which comes into view about halfway up the right side of this photo. The establishment of many grasses indicates that this area has been exposed for quite a while.*

# Acknowledgements

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