

Final Report
Project: Enhancing Soil Moisture



Project Report

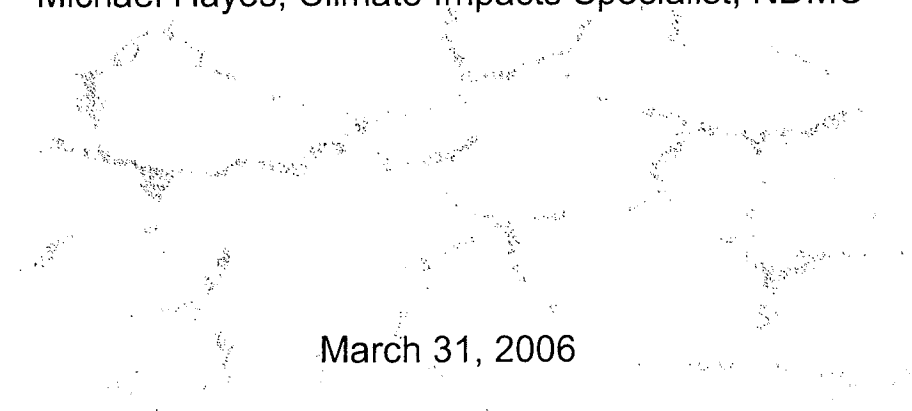
Enhancing Nebraska's State Drought Mitigation Plan and Drought Monitoring Capacity through Improved Soil Moisture Applications

A report prepared by the National Drought Mitigation Center (NDMC)
and the High Plains Regional Climate Center (HPRCC)

For

DOI, Bureau of Reclamation (BOR) and the
Nebraska Department of Natural Resources (DNR)
Lincoln, Nebraska

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Project Overview

Over the past few years, the State of Nebraska has been investing in expanding and enhancing its drought monitoring and assessment capabilities. Through emergency drought funding programs under the authority of the Department of Interior's Bureau of Reclamation, the Nebraska Department of Natural Resources, the National Drought Mitigation Center (NDMC), and the High Plains Regional Climate Center (HPRCC) have collaborated to update and enhance the Automated Weather Data Network (AWDN) that supports the climate and water monitoring activities of Nebraska's State Drought Mitigation Plan.

The National Drought Mitigation Center [<http://drought.unl.edu>] and High Plains Regional Climate Center [<http://www.hprcc.unl.edu>] were contracted to:

- collaborate with the High Plains Regional Climate Center and coordinate efforts to update the Nebraska Drought Mitigation Plan (the Plan);
- include the following updates in the Plan:
 - mitigation programs with soil moisture information as a critical program element;
 - a consideration of how soil moisture information can be used to trigger appropriate mitigation actions;
 - an analysis of near real-time soil moisture data available through the HPRCC's Automated Weather Data Network for all Nebraska locations;
 - a series of web-based maps and graph products depicting the soil moisture status of Nebraska for several time periods in an automated near real-time manner. These include:
 - products that capture a variety of parameters, such as the measurement of water in the soil through a volumetric water content product, which will lead to an aggregate status of the amount of water found in the root zone (down to four feet)
 - the use of a quality control process to analyze and validate the measured data; and
 - a "comparably scaled," second-generation product that is calculated, modeled, and mapped using the AWDN to depict relative wetness/dryness around the state with regard to the wilting point and field capacity of a given location.
- make all products available on the Climate Assessment Response Committee (CARC), High Plains Regional Climate Center (HPRCC), and National Drought Mitigation Center (NDMC) websites for easy access;
- complete all analysis by January 1, 2006; and
- provide a copy of the suggested updates to the Plan to the Nebraska Department of Natural Resources by January 31, 2006.

This report describes the methodologies used, products developed and implemented, and the subsequent project findings and recommendations for updating the State Drought Mitigation Plan.

History

The project started in 1998 with the purchase and installation of Vitel probes at 7 stations. The following year, 7 more Vitels were added. In 2002, Dynamax Theta probes were installed at 9 stations, and in 2004, Theta probes were installed at an additional 28 sites. In 2005, the 14 original Vitel probes were replaced with the more reliable and easier to maintain Thetas. This brings the current number of real-time soil moisture probe sites to 51. They are part of the High Plains Regional Climate Center's Automated Weather Data Network (AWDN).

Nebraska is now positioned at the forefront of soil moisture monitoring capabilities at the national level. Nebraska has the second largest real-time soil moisture monitoring network (among states) in the United States and is in position to use these data in its drought monitoring activities. A comprehensive climate and water supply monitoring network is critical to any drought mitigation plan, providing the foundation for timely assessments for decision support. This investment will allow decision makers to tap into timely and accurate data at critical decision points throughout the year.

Real Time Analysis

At the present time, the soil moisture monitoring data resides in the "Nebraska Soil Moisture" section on the HPRCC website (<http://www.hprcc.unl.edu/>). Users can get to this page by clicking on the "Research Projects" entry on the homepage of the HPRCC web site (see Figure 1)

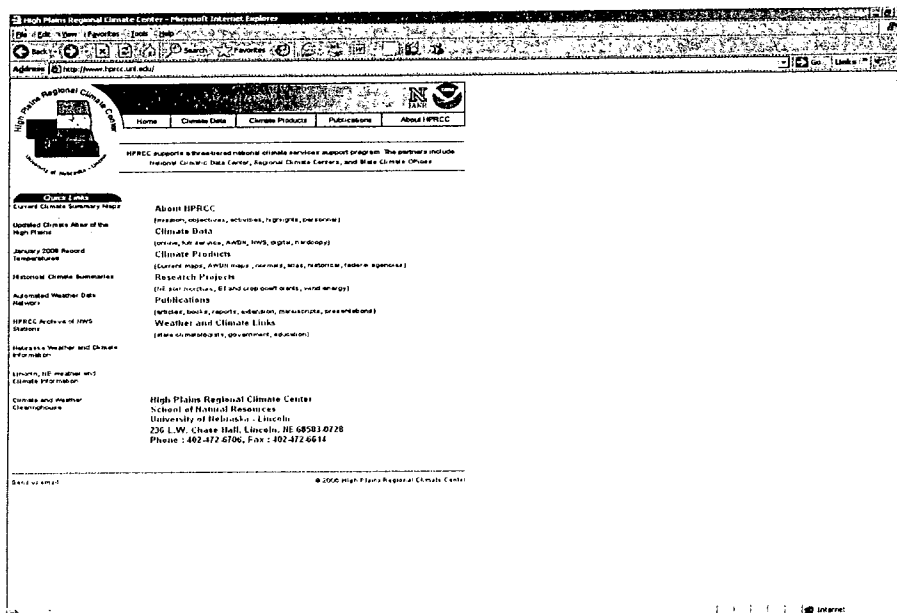


Figure 1. HPRCC web site

The Nebraska Soil Moisture page (see Figure 2) can be found at <http://www.hprcc.unl.edu/soilm/>

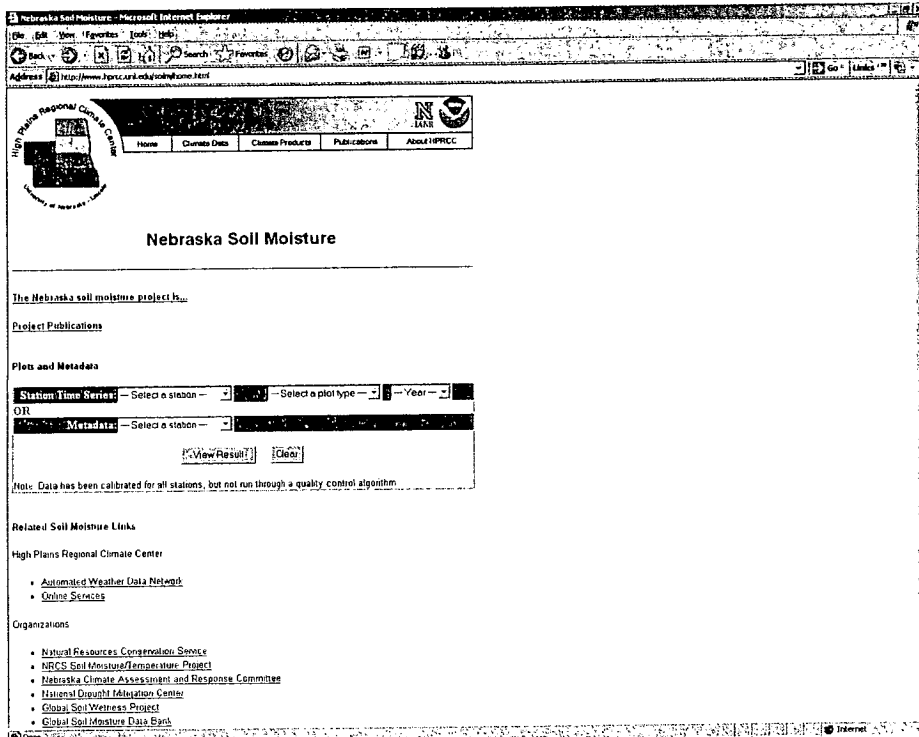


Figure 2. HPRCC Soil Moisture page

A user can click on the red map of Nebraska on the interface (see Fig. 3) to see the locations of the 51 AWDN stations that have near real-time soil moisture monitoring probes:

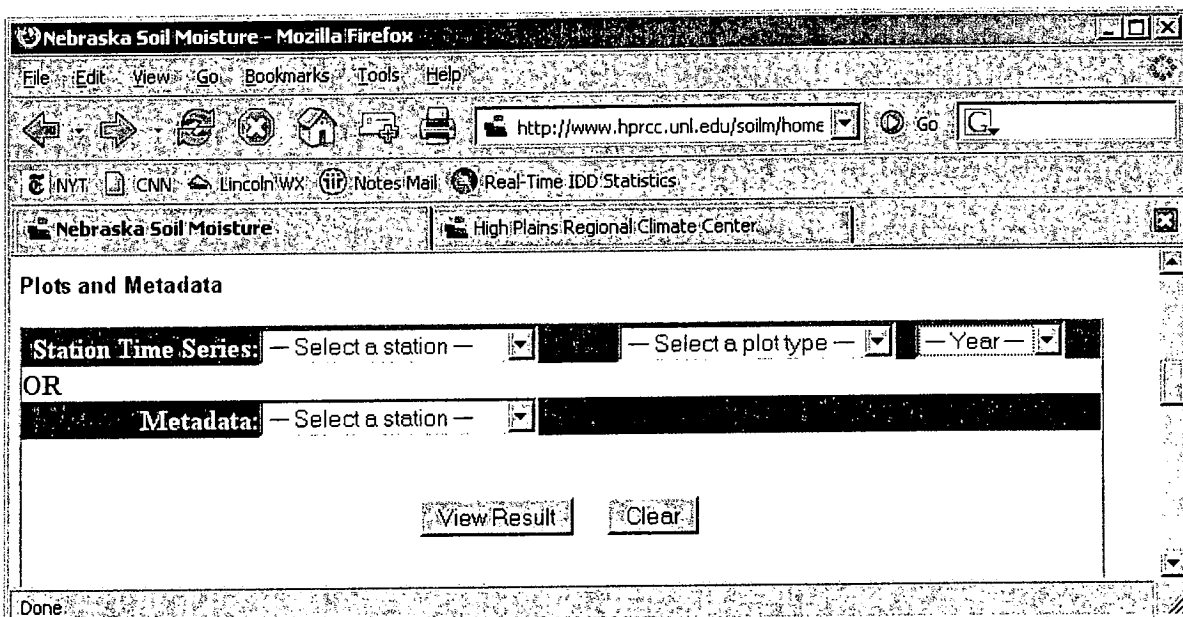


Figure 3. Soil Moisture station selection interface

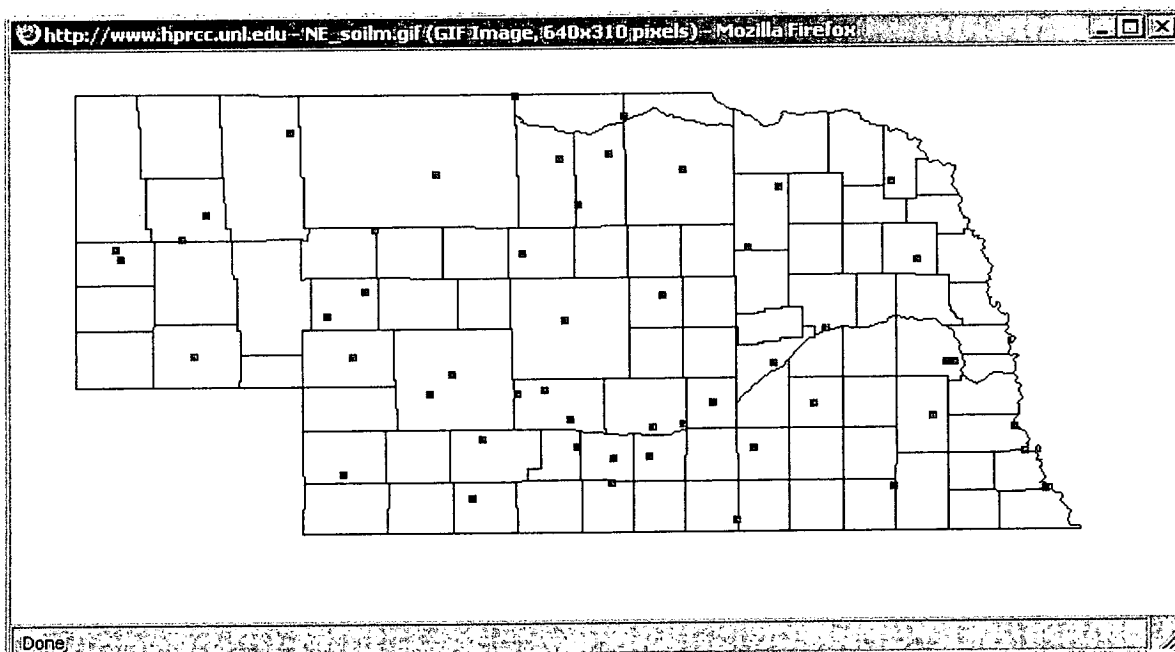


Figure 4. Location of AWDN sites having near-real time soil moisture probes

The map above (Fig. 4) is part of the interactive station selection tool developed to allow users to pick stations for product viewing based on geographic location rather than by name only. When the mouse hovers over a station, the station's name and period of record appear (Fig. 5).

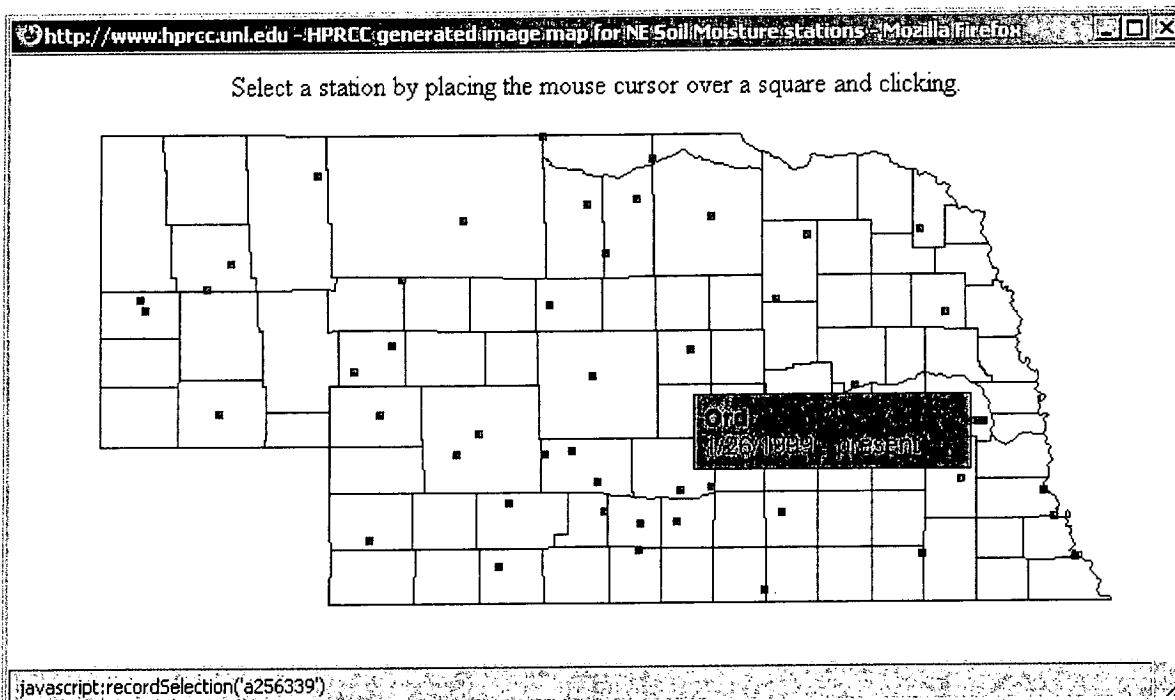


Figure 5. AWDN station interactive metadata

This station selection tool can be used to display both the Metadata and Station Time Series products for that location. The user can simply choose a station from the drop down menu and select the product to view. A mouse click on the station results in that station being selected for the product one is viewing. The Metadata product provides access to a useful suite of metadata parameters for a station. These include station name and location, the soil moisture period of record, the probe type and calibration information, soil types at all levels, and, if the station was once a Vitel site, information relevant to that fact. Figure 6 shows a sample output from the Metadata product.

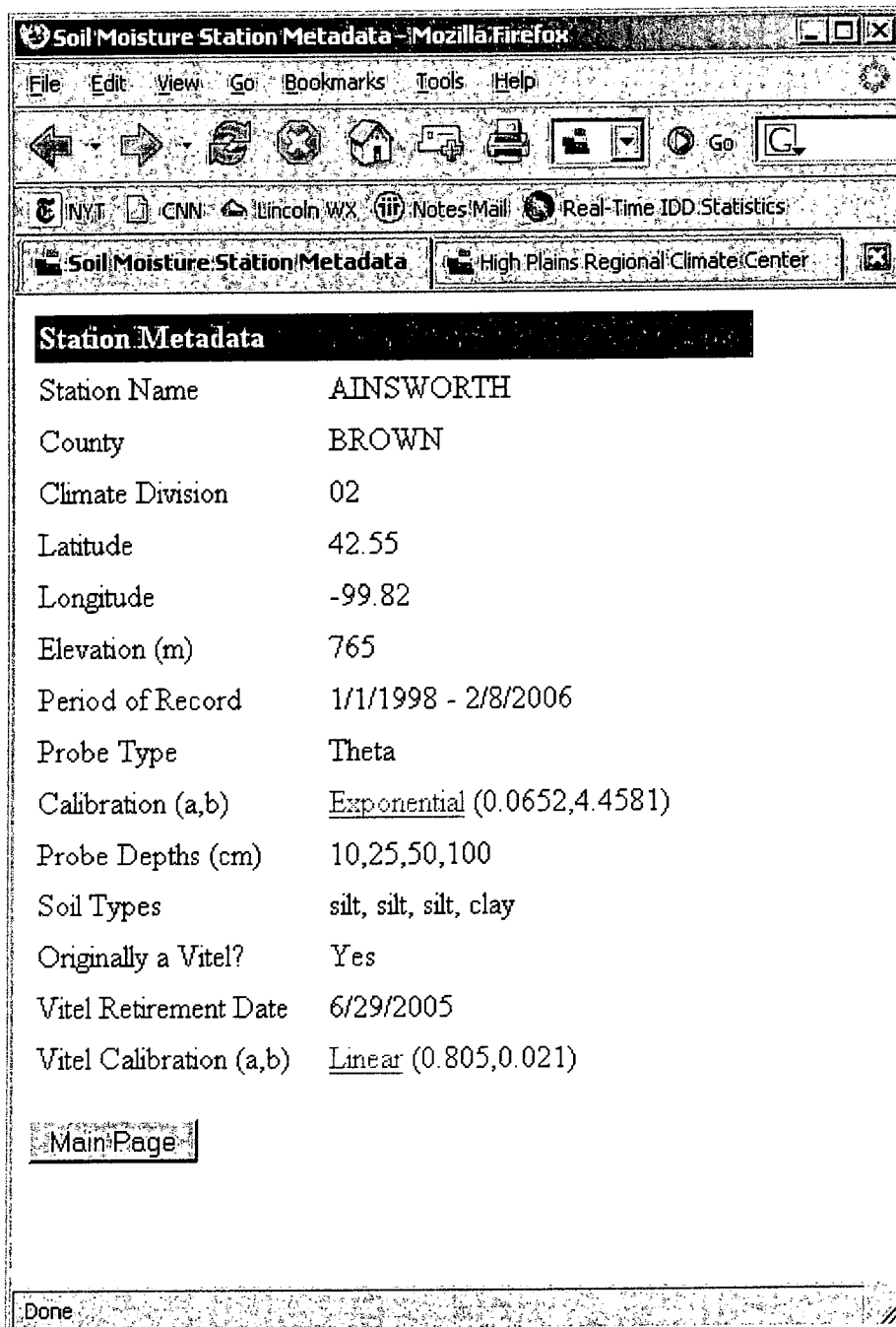


Figure 6. Sample of metadata request for Ainsworth, NE

The Station Time Series Product provides year-to-date, or a complete historical year, time series plots of either observed soil moisture at 4 discrete levels or total root zone water computed from the discrete observations. If a station has more than 3 years of observations, then the root zone plots include curves representing the historical maximum, minimum, and mean root zone water.

Figure 7 shows a sample total root zone water time series product with the period of record max, min, and mean curves.

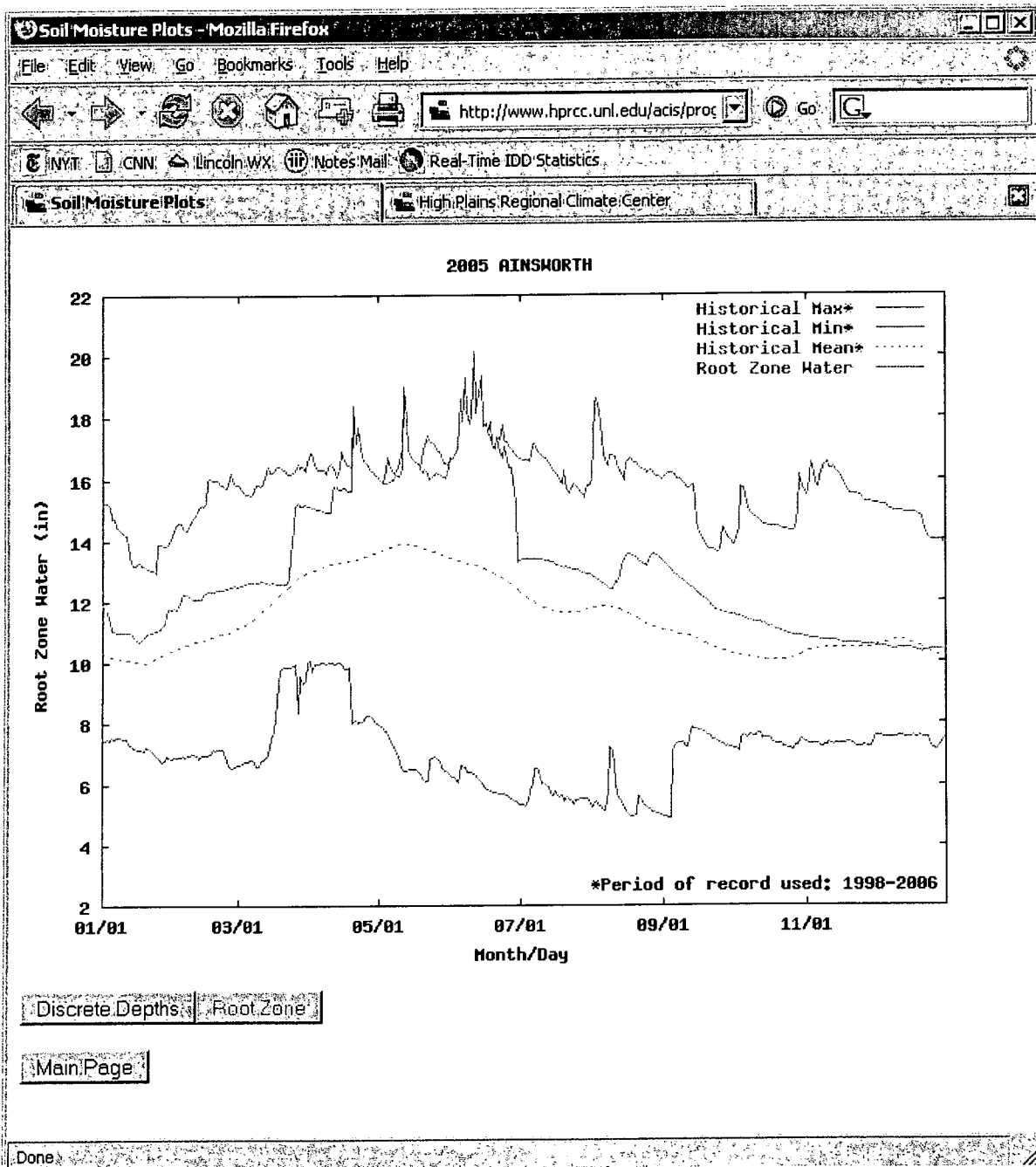


Figure 7. Sample root zone water time series plot for Ainsworth, NE

A sample of the discrete layers time series product is shown in Figure 8.

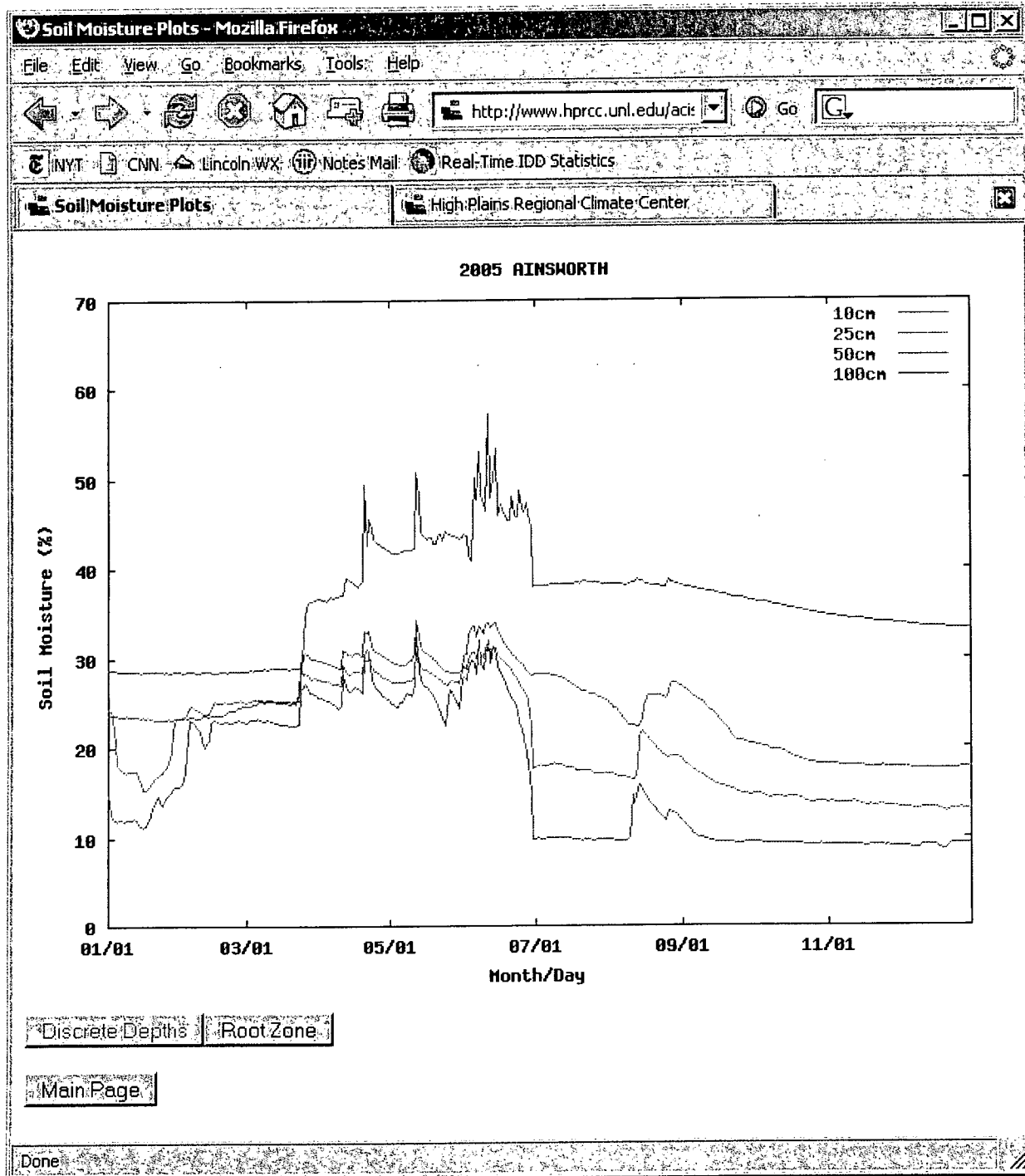


Figure 8. Soil moisture levels by depth for Ainsworth, NE

The spatial product Percent of Maximum Available Water (PMAW) (see Figure 9) provides a Nebraska-wide picture of the current soil water conditions. Meaningful spatial comparisons of soil moisture observations were made possible by using physical soil properties to normalize soil moisture observations. The computation used is:

$$(SW - WP) / (FC - WP) * 100$$

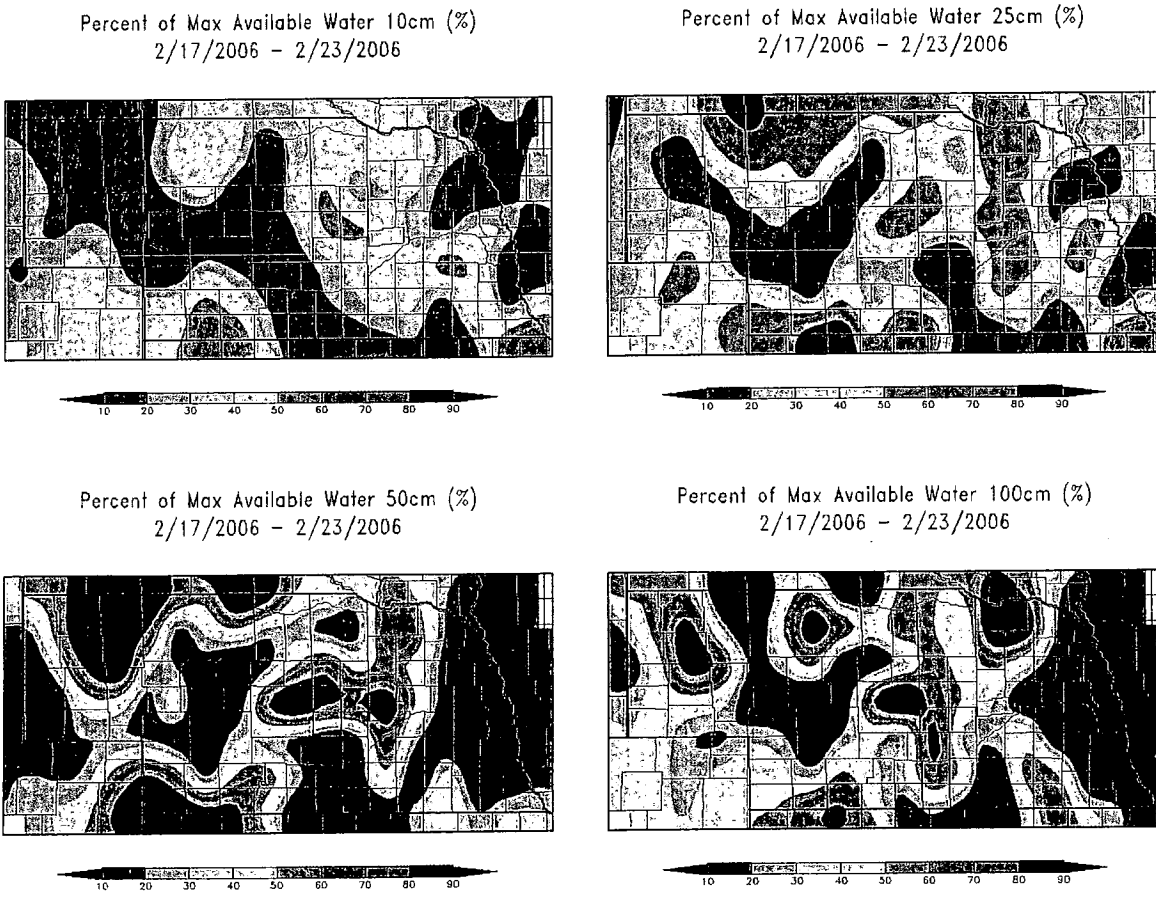
Where:

SW= Observed Soil Water

WP=Wilting Point

FC = Field Capacity

A 7-day average SW is used, and in the future the product will be expanded to other time periods. The result is multiplied by 100 to provide a more user- and contour-friendly number. The product is available in contour and color-coded dot map format (see Figure 10), with maps for all four levels provided in one image.

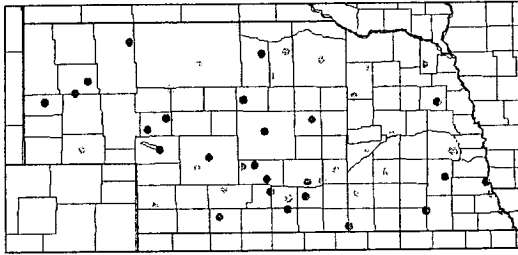


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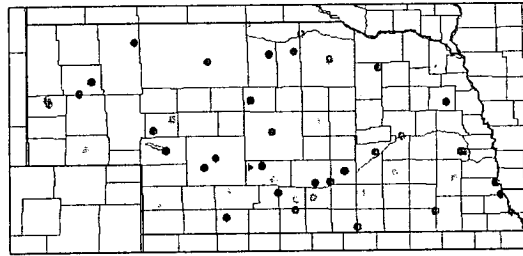
NOAA Regional Climate Centers

Figure 9. Sample output of PMAW for Nebraska

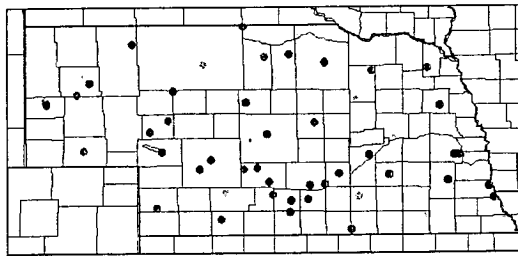
Percent of Max Available Water 10cm (%)
2/17/2006 - 2/23/2006



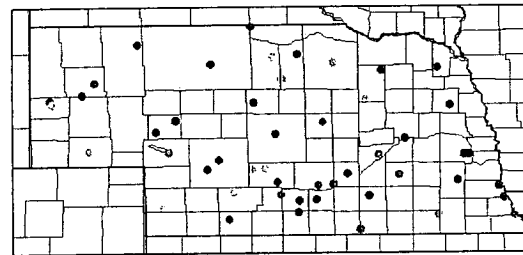
Percent of Max Available Water 25cm (%)
2/17/2006 - 2/23/2006



Percent of Max Available Water 50cm (%)
2/17/2006 - 2/23/2006



Percent of Max Available Water 100cm (%)
2/17/2006 - 2/23/2006



Generated 2/24/2006 by HPRCC

NDA Regional Climate Centers

Figure 10. PMAW dot map product

Quality Control of Soil Moisture Data

An effective Quality Control (QC) system is an essential component of any climate data collection, archival, and dissemination system. A QC system is designed to ensure a high-quality climate dataset by actively monitoring data quality, serving as an early warning system for instrument failure and site disruption, and providing the best possible estimates for missing and bad values.

The relatively immature science of soil moisture monitoring and the methods used to observe soil moisture make it imperative that a proper QC process exists before data can be used for research and decision making. Potential sources of bad or missing soil moisture data include, but are not limited to, instrument failure, lightning, heavy rainfall, direct (chewing of wires) and indirect (burrowing near sensor) animal influence, required maintenance, and human error.

Extensive testing and analysis was conducted to determine the most effective QC algorithm for a soil moisture dataset. Early results led to the conclusion that standard QC tests for climate data would not be sufficient, so efforts to design QC tests unique to soil moisture were undertaken. This process resulted in five useable tests. Four of the tests are based on the properties of soil moisture, the statistical characteristics of the

measurements, the soil properties, and precipitation measurements at the site. These tests were found to be effective in catching errors caused by instrumental failures, and they were an asset in the soil type categorization process. The fifth, and most promising test, is a more complex test based on the HPRCC's soil water balance model and a spatial regression test. The test is able to identify a sudden rise of water content and it generates reasonable estimates. The soil moisture QC system continues to undergo tests to ensure stable and reliable operation.

Use of Soil Moisture in Monitoring/Triggers

Since we cannot predict when and where the next drought will occur, we need to place even more emphasis on monitoring and early warning. Having established this network, Nebraska is in a position to detect the onset and decay of droughts across the state. The use of the network's soil moisture data by CARC, agricultural producers, natural resource managers, policy makers, UNL Extension, and others will prove invaluable as an aid in decision and management issues. This near-real time network will allow for better ground truthing of crop and soil models, irrigation scheduling, and satellite remote sensing products. Management strategies involving crop type or hybrids, cultivation, fertilization, and other key decisions could be enhanced with access to this timely data. In addition, the information could be used to help determine triggers for certain actions within the NE Drought Mitigation Plan as well as by the Water Availability and Outlook Committee (WAOC) and CARC itself in setting up meetings and assessing the current situation. Having this information during the growing season, off-season recharge period, and pre-planting will enable better drought assessments to be made. The soil moisture data can also be used to better determine saturation levels for flash flood potential and could be useful to the National Weather Service in their soil moisture model and in day-to-day forecasting as well.

Opportunities for State Plan Updates

A key objective of this project was to develop a new series of decision-support products for users that would provide soil moisture products (i.e., graphs and maps) in near-real time. The ultimate goal is to make this information available to members of the WAOC and CARC with the expressed purpose of providing these committees with new information that could be used to trigger actions on the part of both of these committees and the mitigation working groups. At the CARC meeting on February 27, 2006, the results of this project and the related products were presented to CARC members and the WAOC committee. The discussion that followed was supportive of the value of this information for CARC and other users. It was recommended that the WAOC examine these products in greater detail and provide feedback to the NDMC and HPRCC on any further modifications as soon as possible. The products developed to date are scheduled to become operational on the HPRCC web site on April 1, 2006.

At the next CARC meeting (likely in April or May 2006), recommendations from the WAOC to CARC members should be available to evaluate proposed updates the Nebraska Drought Mitigation Plan. At the February 27 meeting, it was suggested by CARC member Dr. Wilhite, NDMC Director, that the committee considers other possible

updates or revisions of the drought plan simultaneously. Jamie Karl, CARC Chair, suggested that each of the working groups meet before the next CARC meeting to recommend other changes that could be incorporated in the drought plan, including the application of the new soil moisture products to the specific objectives of each working group. Following the receipt of these recommendations, it would be the responsibility of CARC members to appoint a small subcommittee to draft changes in the Plan for approval by the full committee at a subsequent meeting.

Conclusion

A comprehensive climate and water supply monitoring network is critical to any drought mitigation plan, providing the foundation for timely assessments and decision support. There is a glaring need for this type of network nationally. Nebraska, however, is in a good position when compared to other states with the second-largest (51 locations) near-real time soil moisture monitoring network in the United States, embedded within the High Plains Regional Climate Center's Automated Weather Data Network (AWDN). Every new year adds value to the baseline data set we are building. Derivative products are now the focus so that we can capitalize on this network and use it to better assess drought conditions. Perhaps most importantly, the information from this network will increase Nebraska's ability to be proactive in mitigating the impacts of drought across the state. Data and products from this network will be helpful to agricultural producers and other decision makers, and will have the potential to be used in triggering actions by various entities within the Nebraska Drought Mitigation Plan, CARC, and WAOC.

Assistance from the Bureau of Reclamation and Nebraska Department of Natural Resources has been critical to the success in building this premier network. This investment has built the foundation that will now allow decision makers to tap into timely and accurate data at critical decision points throughout the year. The value of this is immeasurable.

Several products have been enhanced or developed as a result of this project:

- 1) implementation of a quality control procedure to ensure high-quality data and derivative products from the near-real time soil moisture monitoring network
- 2) enhancement and simplification of access to the soil moisture data through the HPRCC's web site, including identification and metadata for the AWDN sites that have automated soil moisture probes in place (currently at 51 locations across the state). This will also be made available through the CARC website
- 3) development of new time series graphics and content to display information by depth or for the root zone
- 4) development of new statewide Percent of Maximum Available Water (PMAW) product that is available for individual sites or as a statewide map. This provides a snapshot of current soil water conditions across the state at 10, 25, 50, and 100cm and is updated daily using a 7-day average value

- 5) Initiation of the implementation of these products into the WAOC and CARC decision-making (triggering) process and eventually into updating and revising the mitigation actions and programs within the Nebraska Drought Mitigation Plan.

In order to maintain and improve this network and its derivative products, we strongly recommend that the State of Nebraska continue to find ways to help support the expansion of the HPRCC's Automated Weather Data Network and the near-real time soil moisture capacity that it has through future funding opportunities with the Bureau of Reclamation or other venues.

Primary Document and Website Sources

National Drought Mitigation Center
[<http://drought.unl.edu/>]

High Plains Regional Climate Center
[<http://www.hprcc.unl.edu/>]

High Plains Regional Climate Center Soil Moisture Project
[<http://www.hprcc.unl.edu/soilm/home.html>]

State of Nebraska Climate Assessment and Response Committee (CARC)
[<http://carc.dnr.state.ne.us>]

Bureau of Reclamation, Great Plains Regional Office
[<http://www.usbr.gov/gp/>]

State of Nebraska: Department of Natural Resources
[<http://www.dnr.state.ne.us/>]