Missouri River Flood Task Force
River Management Working Group
Improving Accuracy of Runoff Forecasts

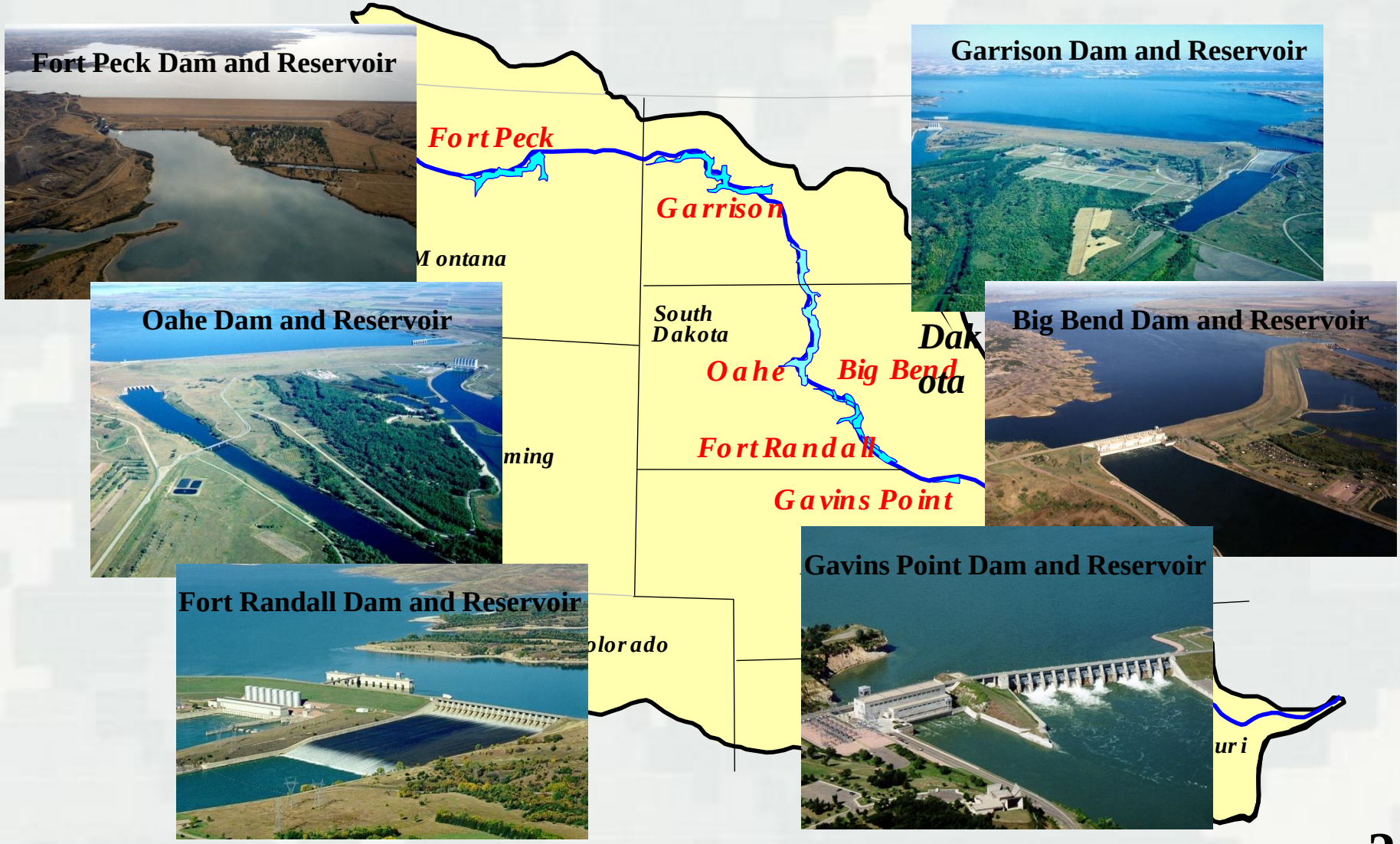
Kevin Grode, P.E.
Reservoir Regulation Team Lead

Missouri River Basin Water Management
Northwestern Division

May 2, 2012

US Army Corps of Engineers
BUILDING STRONG®

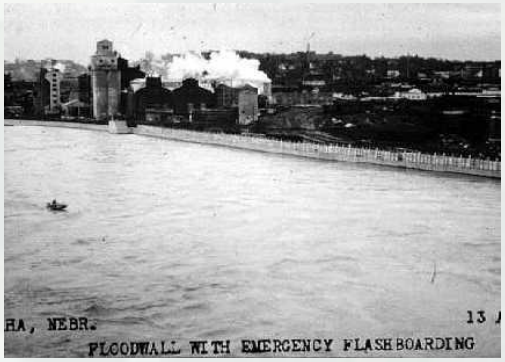
Missouri River Mainstem Reservoir System



Our Mission

Regulate Missouri River Mainstem Reservoirs to Support Congressionally Authorized Purposes

Flood Control



Hydropower

Water Supply

Water Quality Control

Recreation

Navigation

Fish and Wildlife

Including Threatened and Endangered Species

Irrigation

Missouri River Mainstem System Runoff Forecast

- Volumetric forecast in million/thousand acre feet
- Six reservoir/river reaches
- Monthly value for each reach
- Monthly and annual summations above
  - Gavins Point
  - Sioux City
- 72 individual monthly values in the forecast

Missouri River Basin
Calendar Year 2012
Runoff Forecast

1-May-12

	Incremental Runoff in Reaches								
	Fort Peck	Garrison	Oahe	Fort Randall	Gavins Point	Sioux City	Summation above Gavins Point	Summation above Sioux City	End-of-Month Accumulated Runoff above Sioux City
	Values in 1000 Acre Feet								
	(History)								
JAN 2012	334	233	-46	140	100	219	760	980	980
NORMAL	312	261	12	25	100	40	710	750	750
DEPARTURE	22	-28	-58	115	0	179	50	230	230
% OF NORM	107%	89%	-383%	559%	100%	548%	107%	131%	131%
FEB 2012	429	543	183	140	177	174	1,472	1,646	2,625
NORMAL	360	356	90	49	130	92	985	1,077	1,827
DEPARTURE	69	187	93	91	47	82	487	569	798
% OF NORM	119%	153%	203%	286%	136%	189%	149%	153%	144%
MAR 2012	528	881	232	130	157	319	1,927	2,246	4,871
NORMAL	596	1,003	567	209	206	299	2,581	2,880	4,707
DEPARTURE	-68	-123	-335	-79	-49	20	-654	-634	164
% OF NORM	89%	88%	41%	62%	76%	107%	75%	78%	103%
APR 2012	665	593	36	108	198	217	1,600	1,816	6,688
NORMAL	649	1,080	481	144	180	360	2,534	2,894	7,601
DEPARTURE	16	-487	-445	-36	18	-143	-935	-1,078	-914
% OF NORM	102%	55%	7%	75%	110%	60%	63%	63%	88%
	(Forecast)								
MAY 2012	1,046	1,125	140	120	185	220	2,616	2,836	9,524
NORMAL	1,081	1,245	312	147	186	292	2,971	3,263	10,864
DEPARTURE	-35	-120	-172	-27	-1	-72	-355	-427	-1,341
% OF NORM	97%	90%	45%	82%	99%	75%	88%	87%	88%
JUN 2012	1,449	2,030	250	130	160	240	4,019	4,259	13,783
NORMAL	1,612	2,667	423	152	178	286	5,032	5,318	16,182
DEPARTURE	-163	-637	-173	-22	-18	-46	-1,013	-1,059	-2,400
% OF NORM	90%	76%	59%	86%	90%	84%	80%	80%	85%
JUL 2012	724	1,258	150	53	130	216	2,315	2,531	16,314
NORMAL	819	1,776	179	57	137	218	2,968	3,186	19,368
DEPARTURE	-95	-518	-29	-4	-7	-2	-653	-655	-3,055
% OF NORM	88%	71%	84%	93%	95%	99%	78%	79%	84%
AUG 2012	340	600	65	35	110	130	1,150	1,280	17,593
NORMAL	353	604	65	39	115	131	1,176	1,307	20,675
DEPARTURE	-13	-4	-1	-4	-5	-1	-27	-28	-3,082
% OF NORM	96%	99%	99%	90%	96%	99%	98%	98%	85%
SEP 2012	330	445	110	35	110	98	1,030	1,128	18,721
NORMAL	333	452	111	38	111	99	1,045	1,144	21,819
DEPARTURE	-3	-7	-1	-3	-1	-1	-15	-16	-3,098
% OF NORM	99%	99%	99%	92%	99%	99%	99%	99%	86%
OCT 2012	380	520	65	4	115	77	1,084	1,161	19,882
NORMAL	385	523	66	5	120	78	1,099	1,177	22,996
DEPARTURE	-4	-3	-2	-1	-3	0	-13	-13	-3,127
% OF NORM	99%	99%	97%	83%	97%	100%	99%	99%	87%
DEC 2012	325	245	0	10	95	52	675	727	21,646
NORMAL	329	247	0	12	100	52	688	740	24,785
DEPARTURE	-4	-2	0	-2	-5	0	-13	-13	-3,140
% OF NORM	99%	99%	100%	83%	95%	100%	98%	98%	87%
	Calendar Year Totals								
	6,930	8,868	1,249	910	1,651	2,037	19,608	21,646	
NORMAL	7,213	10,612	2,373	883	1,681	2,023	22,762	24,785	
DEPARTURE	-283	-1,744	-1,125	27	-30	14	-3,154	-3,140	
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http://www.nwd-mr.usace.army.mil/rcc/reports/runoff.pdf

Missouri River Mainstem Runoff Forecast

Missouri River Basin
Calendar Year 2012
Runoff Forecast

1-May-12

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JUL 2012	724	1,[illegible]	[illegible]	53	[illegible]	[illegible]	2,315	2,531	16,314
NORMAL	819	1,[illegible]	[illegible]	57	[illegible]	[illegible]	2,968	3,186	19,368
DEPARTURE	-95	-518	-29	-4	-7	-2	-653	-655	-3,055
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NORMAL	385	523	66	5	120	78	1,099	1,177	22,996
DEPARTURE	-5	-3	-1	-1	-5	-1	-15	-16	-3,114
% OF NORM	99%	99%	98%	80%	96%	99%	99%	99%	86%
NOV 2012	380	395	65	5	115	76	960	1,036	20,918
NORMAL	384	398	67	6	118	76	1,049	1,125	24,045
DEPARTURE	-4	-3	-2	-1	-3	0	-89	-89	-3,127
% OF NORM	99%	99%	97%	83%	97%	100%	99%	99%	87%
DEC 2012	325	245	0	10	95	52	675	727	21,646
NORMAL	329	247	0	12	100	52	688	740	24,785
DEPARTURE	-4	-2	0	-2	-5	0	-13	-13	-3,140
% OF NORM	99%	99%	100%	83%	95%	100%	98%	98%	87%
	Calendar Year Totals								
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DEPARTURE	-283	-1,744	-1,125	27	-30	14	-3,154	-3,140	
% OF NORM	96%	84%	53%	103%	98%	101%	86%	87%	

Jan-Apr: actual

May-Dec: forecasted

21.6 MAF

Missouri River Mainstem Reservoir Forecast

Basic = 21.6 MAF

MAY 1, 2012 / BASIC CONDITION / 21.6 MAF / BALANCED
FULL SERV / FULL NAV SEAS / NO PULSE
Date of Study: May 1, 2012

	30-Apr-12	31-May	30-Jun 2012	31-Jul	31-Aug	30-Sep	31-Oct	30-Nov	31-Dec	31-Jan 2013	28-Feb
FORT PECK											
ELEV FTMSL	2235.8	2236.3	2237.4	2236.2	2234.1	2232.8	2232.0	2231.6	2230.6	2229.4	2228.5
DISCH KCFS	6.9	10.0	11.5	11.5	11.5	9.4	8.0	8.0	10.0	11.5	11.5
GARRISON											
ELEV FTMSL	1835.8	1835.8	1836.0	1836.7	1835.6	1835.3	1835.4	1835.9	1835.0	1833.7	1832.9
DISCH KCFS	26.6	26.0	24.5	23.5	23.5	18.9	15.0	15.0	19.0	23.0	23.0
OAHE											
ELEV FTMSL	1606.3	1606.6	1606.7	1605.2	1602.9	1600.7	1599.5	1598.7	1599.7	1601.1	1602.8
DISCH KCFS	24.8	25.[illegible]	25.8	29.9	32.3	29.2	20.5	18.5	12.9	16.2	15.3
BIG BEND											
ELEV FTMSL	1420.8	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0
DISCH KCFS	23.0	26.3	25.8	29.8	32.0	28.8	20.1	18.1	12.8	16.2	15.3
FORT RANDALL											
ELEV FTMSL	1354.[illegible]	1355.2	1355.2	1355.2	1355.2	1353.5	1345.0	1337.5	1339.3	1344.8	1350.0
DISCH KCFS	23.[illegible]	27.2	27.7	30.2	31.9	31.2	30.3	25.7	11.1	10.9	9.4
GAVINS POINT											
ELEV FTMSL	1206.6	1206.0	1206.0	1206.0	1206.5	1207.5	1207.5	1207.5	1207.5	1207.5	1206.0
DISCH KCFS	26.2	30.0	30.0	31.6	33.2	32.6	32.0	27.8	12.5	12.5	12.5
SYSTEM											
STORAGE 1000 AF	56722	56938	57591	56774	55308	54205	53094	52445	52373	[illegible]	[illegible]
ENERGY GWh	7805	920	894	986	1026	886	742	647	534	[illegible]	[illegible]
PEAK POWER MW		2308	2314	2304	2287	2278	2261	2224	2234	2261	2275

52.9 MAF

Lower Basic = 17.6 MAF

MAY 1, 2012 / LOWER BASIC / 17.6 MAF / BALANCED
FULL SERV 1ST HALF / 1.6 BLW 2ND HALF / FULL NAV SEAS / NO PULSE

	30-Apr-12	31-May	30-Jun 2012	31-Jul	31-Aug	30-Sep	31-Oct	30-Nov	31-Dec	31-Jan 2013	28-Feb
FORT PECK											
ELEV FTMSL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2220.9
DISCH KCFS	[illegible]	10.0	11.[illegible]	11.5	11.5	9.0	7.0	7.1	10.0	11.0	11.0
GARRISON											
ELEV FTMSL	1835.8	1833.5	1832.8	1831.3	1829.9	1829.5	1829.5	1830.0	1828.7	1827.4	1826.5
DISCH KCFS	26.6	29.0	23.0	21.0	21.0	16.4	12.0	12.0	19.0	21.0	21.0
OAHE											
ELEV FTMSL	1606.3	1606.6	1605.5	1602.8	1599.8	1596.8	1594.7	1593.2	1594.1	1595.1	1596.3
DISCH KCFS	24.8	27.6	28.7	32.2	32.1	29.3	20.6	17.6	13.4	16.6	16.0
BIG BEND											
ELEV FTMSL	1420.8	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0
DISCH KCFS	23.0	28.4	28.7	32.1	31.7	28.8	20.2	17.2	13.2	16.6	16.0
FORT RANDALL											
ELEV FTMSL	1354.5	1355.2	1355.2	1355.2	1355.2	1353.5	1345.0	1337.4	1339.3	1344.8	1350.0
DISCH KCFS	23.4	28.4	29.8	32.2	31.5	30.9	30.2	24.6	11.4	11.2	9.9
GAVINS POINT											
ELEV FTMSL	1206.6	1206.0	1206.0	1206.0	1206.5	1207.5	1207.5	1207.5	1207.5	1207.5	1206.0
DISCH KCFS	26.2	30.0	31.0	32.7	32.4	31.9	31.5	26.4	12.5	12.5	12.5
SYSTEM											
STORAGE 1000 AF	56722	55969	55268	53571	51765	50376	48982	48122	47804	[illegible]	[illegible]
ENERGY GWh	7643	979	923	993	978	847	694	584	530	[illegible]	[illegible]
PEAK POWER MW		2299	2290	2269	2246	2233	2211	2171	2178	[illegible]	2211

47.9 MAF

MAY 1, 2012 / UPPER BASIC / 27.4 MAF / BALANCED
FULL SERV / FULL NAV SEAS 10-DAY EXT / NO PULSE

	30-Apr-12	31-May	30-Jun 2012	31-Jul	31-Aug	30-Sep	31-Oct	30-Nov	31-Dec	31-Jan 2013	28-Feb
FORT PECK											
ELEV FTMSL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2234.0
DISCH KCFS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13.0
GARRISON											
ELEV FTMSL	1835.8	1837.6	1842.2	1843.0	1842.3	1841.6	1840.5	1840.0	1839.3	1838.2	1837.5
DISCH KCFS	26.6	26.0	27.0	26.0	26.0	25.2	24.5	24.2	21.5	25.5	25.5
OAHE											
ELEV FTMSL	1606.3	1607.2	1608.8	1608.3	1606.8	1605.8	1606.3	1606.3	1606.2	1606.6	1607.5
DISCH KCFS	24.8	23.5	22.8	28.7	31.7	30.4	22.4	24.8	21.2	23.1	22.2
BIG BEND											
ELEV FTMSL	1420.8	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0	1420.0
DISCH KCFS	23.0	24.3	22.8	28.6	31.4	30.1	22.1	24.7	21.1	23.1	22.2
FORT RANDALL											
ELEV FTMSL	1354.5	1355.2	1355.2	1355.2	1355.2	1353.5	1345.0	1337.5	1339.3	1344.8	1350.0
DISCH KCFS	23.4	25.9	26.1	29.4	31.6	32.8	32.4	32.4	19.5	17.9	16.5
GAVINS POINT											
ELEV FTMSL	1206.6	1206.0	1206.0	1206.0	1206.5	1207.5	1207.5	1207.5	1207.5	1207.5	1206.0
DISCH KCFS	26.2	30.0	30.0	31.6	33.2	34.5	34.5	34.5	21.5	20.0	20.0
SYSTEM											
STORAGE 1000 AF	56722	58085	60927	61015	59909	59002	58011	57254	56815	[illegible]	[illegible]
ENERGY GWh	8949	888	885	1009	1062	1004	905	893	767	[illegible]	[illegible]
PEAK POWER MW		2319	2352	2358	2340	2332	2320	2284	2288	[illegible]	[illegible]

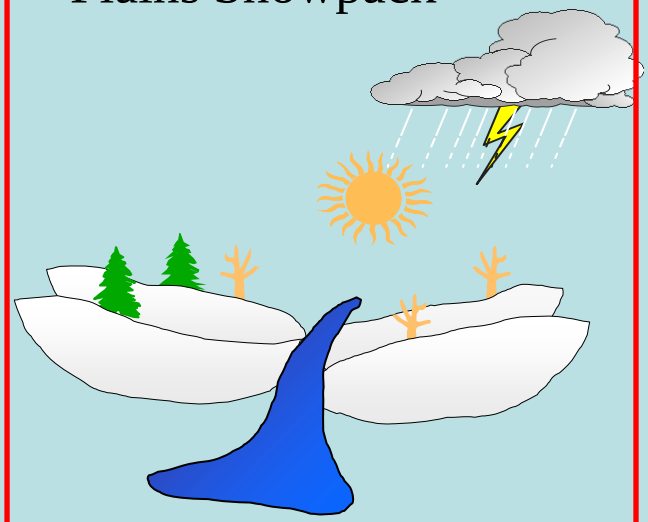
56.8 MAF

5

http://www.nwd-mr.usace.army.mil/rcc/reports/resfcast.pdf

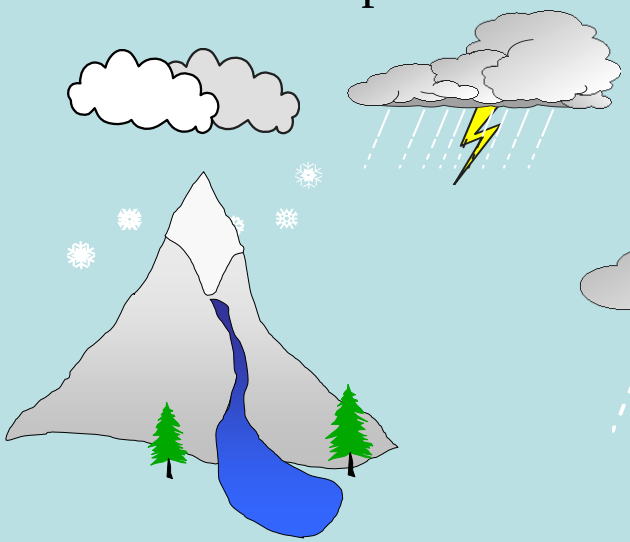
Runoff Components

Plains Snowpack



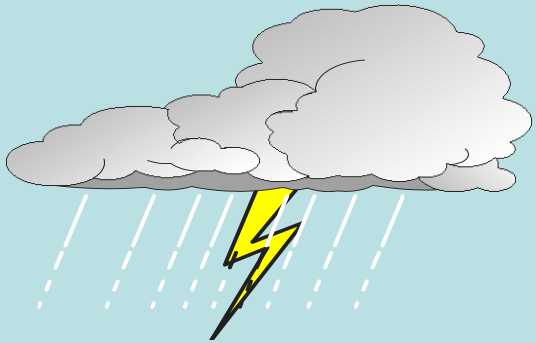
March and April

Mountain Snowpack



May, June and July

Rainfall



March through October

2012 Forecast* = 21.6 MAF

*May 1 Forecast

Runoff During May-July

- Long established and reliable mountain snowpack monitoring network (NRCS)
- Correlation regarding mountain snowpack and May-July runoff much stronger than plains snowpack and March-April runoff.
- Mountain snowpack runoff **and** May-July precipitation **and** basin /soil conditions

Runoff During August-February

- August – February precipitation **and** basin/soil conditions **and** temperature

Importance of Forecasting March/April Runoff

1. Runoff season begins on or about March 1

2. 16.3 MAF of annual flood control and multiple use zone
   a. Store runoff for 5 months to serve purposes 12 months
   b. March-July (store)
   c. August-February (evacuate)

Year	Plains Snowpack	Mar/Apr Runoff
2009	Heavy	9.7 MAF
2010	Heavy to Very Heavy	9.4 MAF
2011	Heavy to Very Heavy	13.2 MAF
2012	Light	4.1 MAF

Understanding March/April Runoff

1. Runoff during March/April is from:
    a. Melt from Plains Snow **and** Precipitation
    b. Not Lost to Soil Infiltration/Evapotranspiration

2. Factors Involved in (1a.) and (1b.):
    a. Plains Snowpack (liquid content or SWE)
    b. Basin/Soil Conditions (soil moisture and frost depth)
    c. Observed / Forecasted Temperature
    d. Observed / Forecasted Precipitation

Proposal for a Missouri River Basin Interagency Expanded Plains Snow and Basin Condition Network

Independent Expert Review Panel (IEPR) report (Recommendation #5):

Studies to enhance data collection, forecasting, and resulting runoff from plains snow. Suggested activities include establishment of additional permanent plains snow measurement stations (using already established snow measurement standards), focused on the development of improved historical record at permanent stations; and research on the effects of prairie soils, geomorphology, and hydrology on snowmelt runoff. Also, the Corps should work to improve collaboration with other groups that collect and analyze snow data, for example, the Community Collaborative Rain, Hail and Snow (CoCoRaHS) network.

March 2012:

"An expanded Plains snowpack monitoring system needs to be set up while memories of the floods are fresh and everyone is willing to spend the money, **Daugaard** told top officials of the U.S. Army Corps of Engineers,"

"**McMahon** said the corps is working with other agencies to determine how to create and fund an expanded plains snowpack monitoring system, one of the recommendations made by an expert panel that studied last summer's flooding. A more extensive system is already in place for monitoring the snowpack in the northern Rocky Mountains, he said."

Proposal for a Missouri River Basin Interagency Expanded Plains Snow and Basin Condition Network

Purpose:

The goal of this proposal is to present a framework for the establishment of an interagency, usable and sustainable network that will enhance the forecasting of runoff during the plains snowmelt period. This proposal is not intended to be a final plan, rather a launching point for additional discussion to include appropriate subject matter experts into developing the final plan.

Approach:

This proposal involved consultation with subject matter experts from various agencies. Establishment of the plains snow network in the same manner as the mountain snow network could be established over a period of time. Initially, use of near real-time, on-the-ground snow depth and snow water equivalent (SWE) measurements made manually at regular intervals would provide necessary information in the short-term and also be extremely useful in determining long-term, possibly automated, network needs.

Proposal for a Missouri River Basin Interagency Expanded Plains Snow and Basin Condition Network

March/April Runoff Components

The components used to forecast March and April runoff in the upper Missouri River basin are:

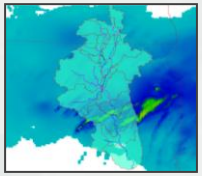
1. Assessment of plains snow liquid content or snow water equivalency (SWE).
2. Assessment of basin soil conditions, specifically soil moisture and frost depth.
3. March and April temperature and precipitation forecasts.
4. Modeling tools to predict runoff that incorporate components #1 through #3.

Increasing Accuracy of March/April Runoff Forecast

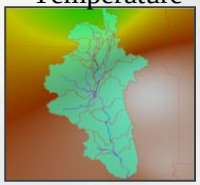
Logically, the accuracy of the modeling (output) is a direct correlation of the accuracy of the information that is fed into the models (input). Simply put, if the accuracy of components #1 through #3 (plains snow, basin conditions, temperature/precipitation forecasts) is increased, the accuracy of #4 (forecasted runoff) will also increase.

4. USACE Spring Snowmelt/Rainfall Runoff Modeling

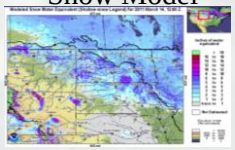
NWS MBRFC Precipitation



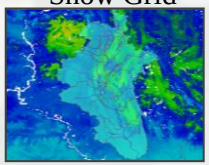
NWS/USACE Temperature



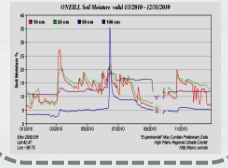
NWS NOHRSC Snow Model



USACE CRREL Snow Grid



NWS/NRCS/ State/USACE Soil Moisture



Observed Precipitation

Forecast Precipitation

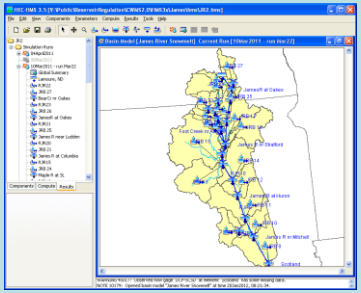
Observed Temperature

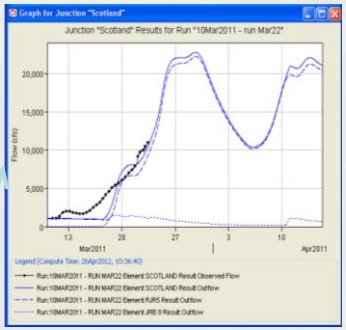
Forecast Temperature

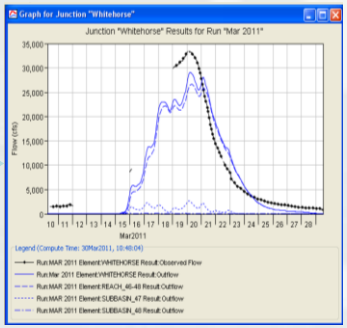
Current Snow Water Equivalent

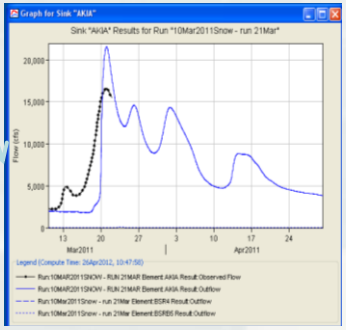
Current Soil Moisture

USACE HEC-HMS Snowmelt Runoff Models

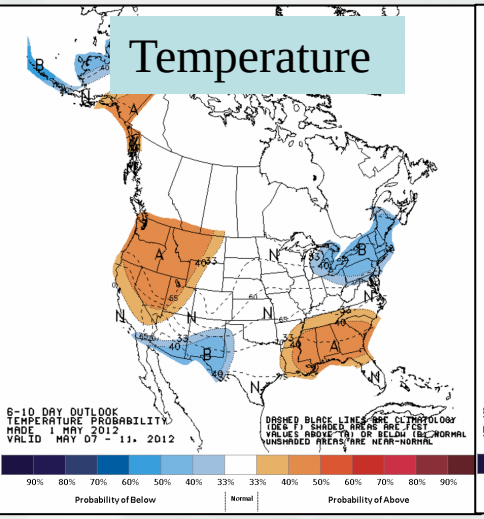




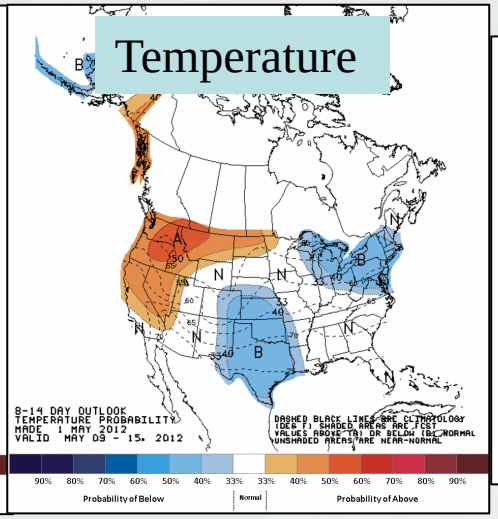




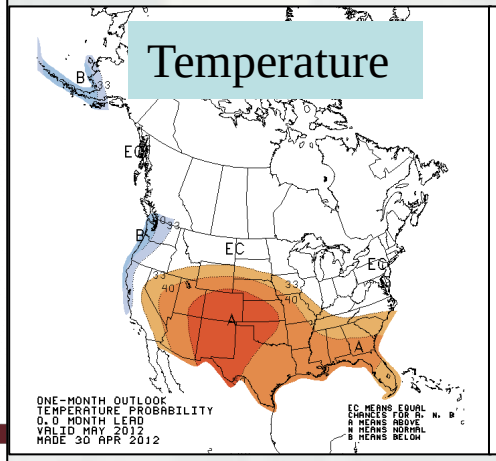
3. NOAA Climate Prediction Center (CPC) Temperature and Precipitation Outlooks



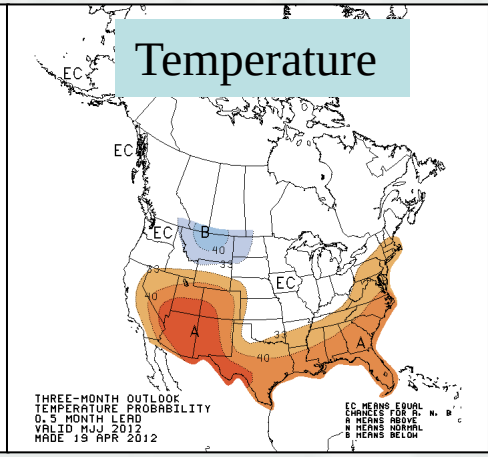
6 – 10 Day



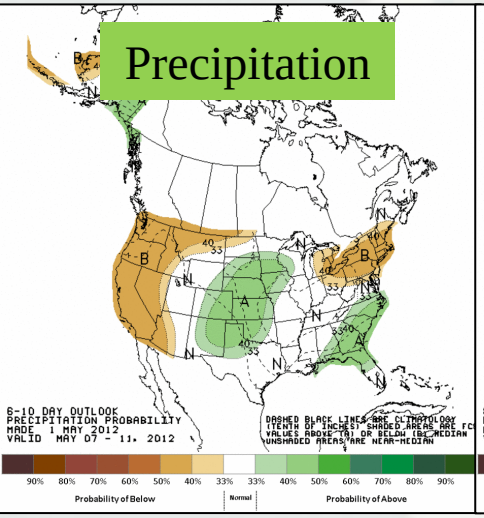
8 – 14 Day

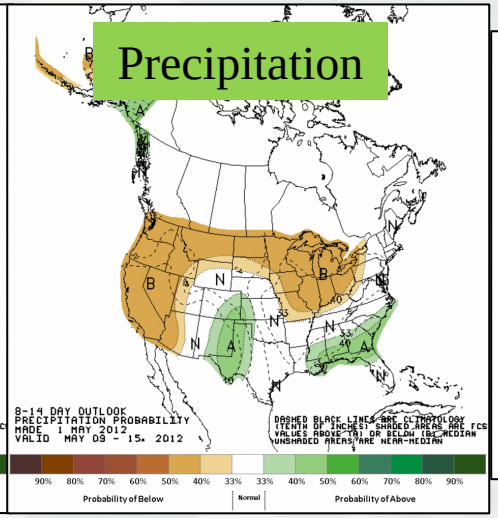


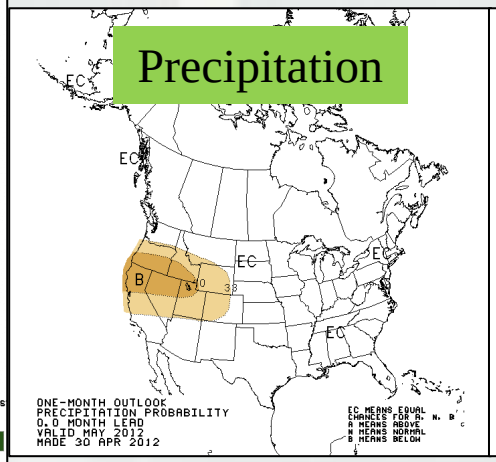
1 Month

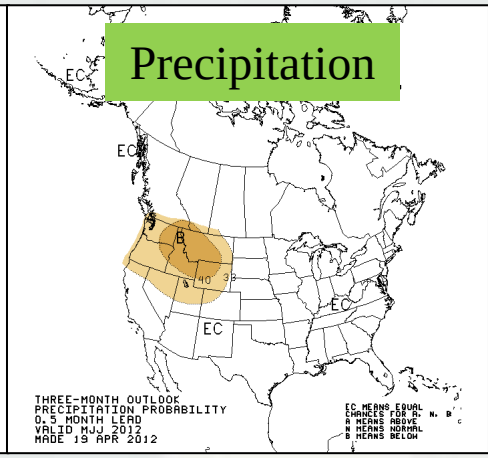


3 Months

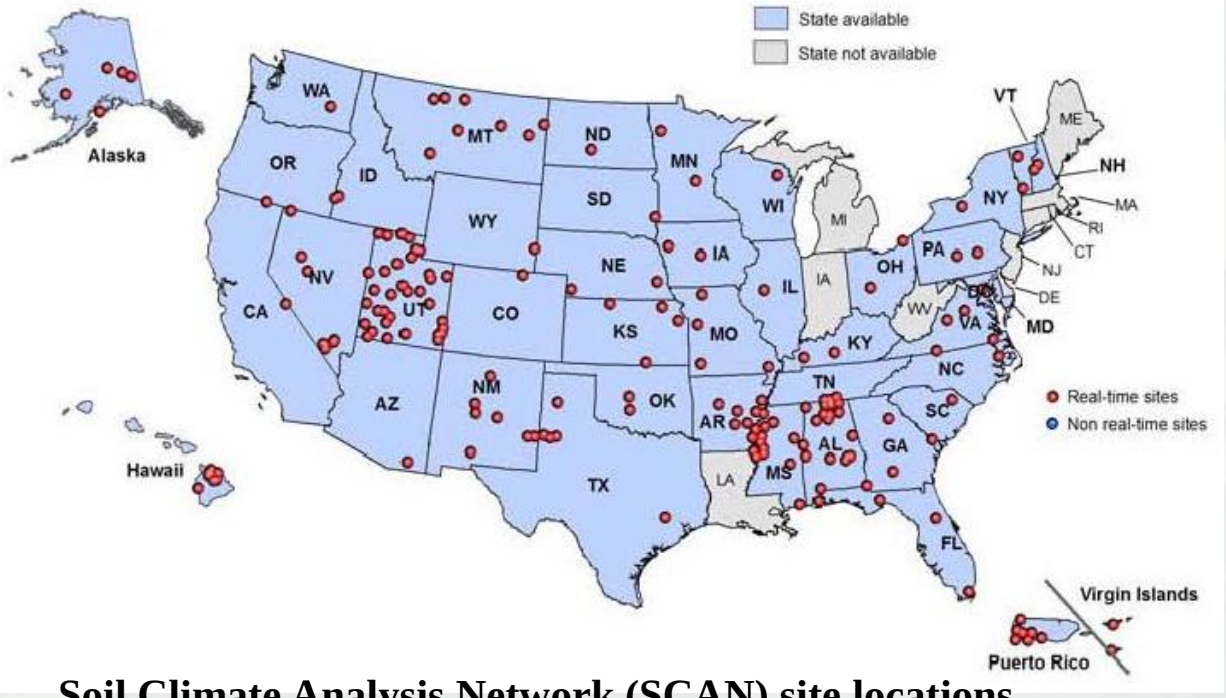








2. Basin Conditions



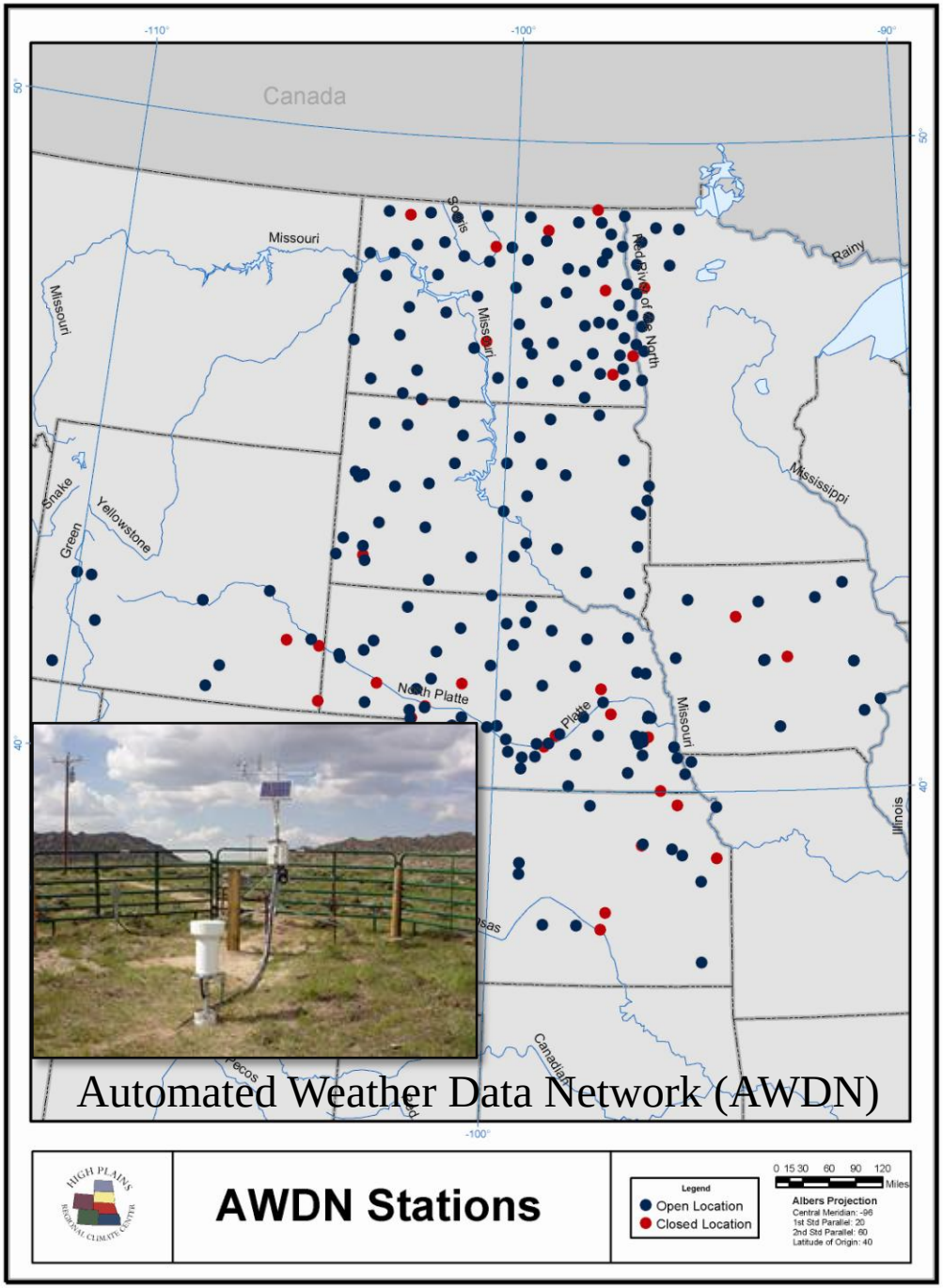
Soil Climate Analysis Network (SCAN) site locations

USDA – NRCS

Measure various climate and soil data:

- Air temperature
- Barometric pressure
- Dew point temperature
- Ground surface temperature
- Solar radiation
- Vapor pressure
- Soil moisture percent
- Wind direction, movement and speed
- MT – 7; 1 each in ND, SD and WY

2. Basin Conditions



Automated Weather Data Network (AWDN)

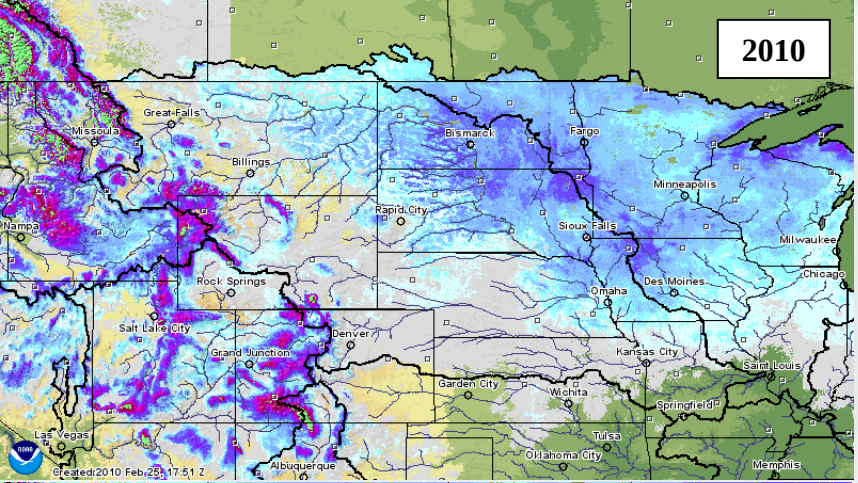
NOAA – High Plains Regional Climate Center

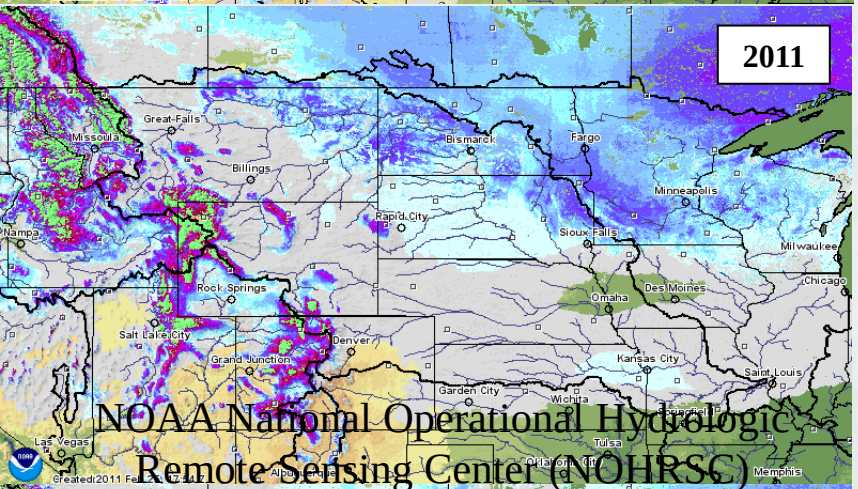
Measure various climate and soil data:

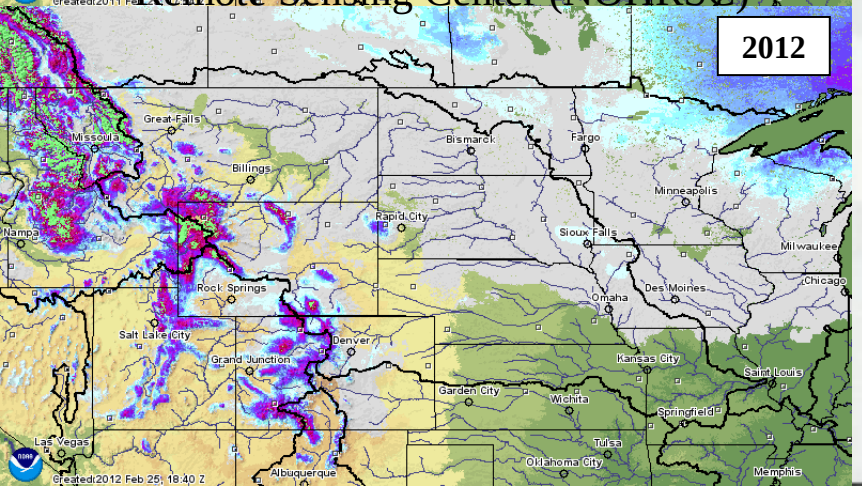
- Air temperature
- Precipitation
- Soil Temperature
- Soil Moisture (see below)
- Relative Humidity
- Solar Radiation
- Wind Speed

- Soil moisture collected in about 20 locations in SD; none in ND; almost all in NE

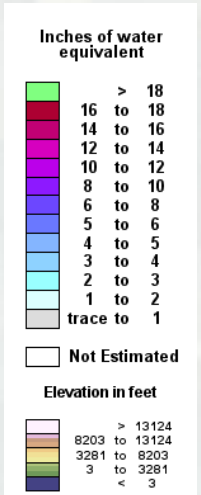
1. Plains Snow / Precipitation

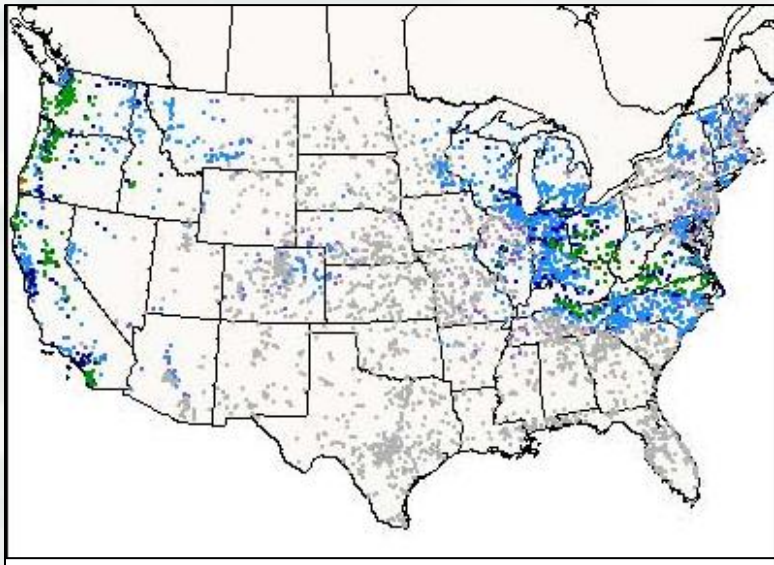


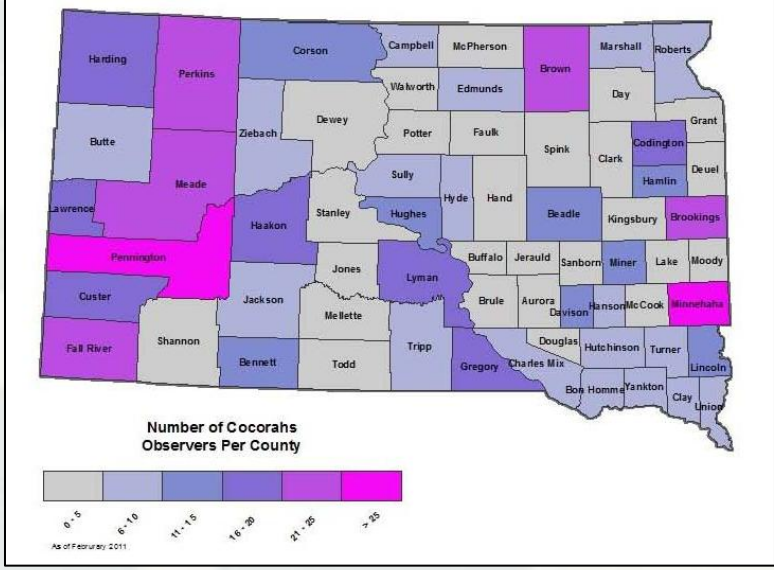




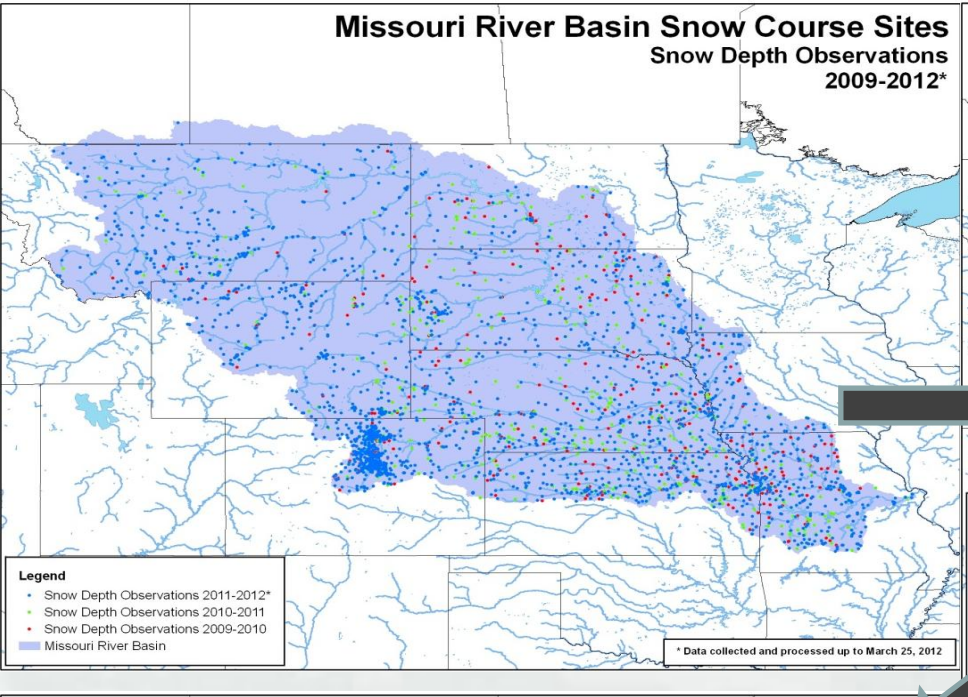
NOAA National Operational Hydrologic Remote Sensing Center (NOHRSC)

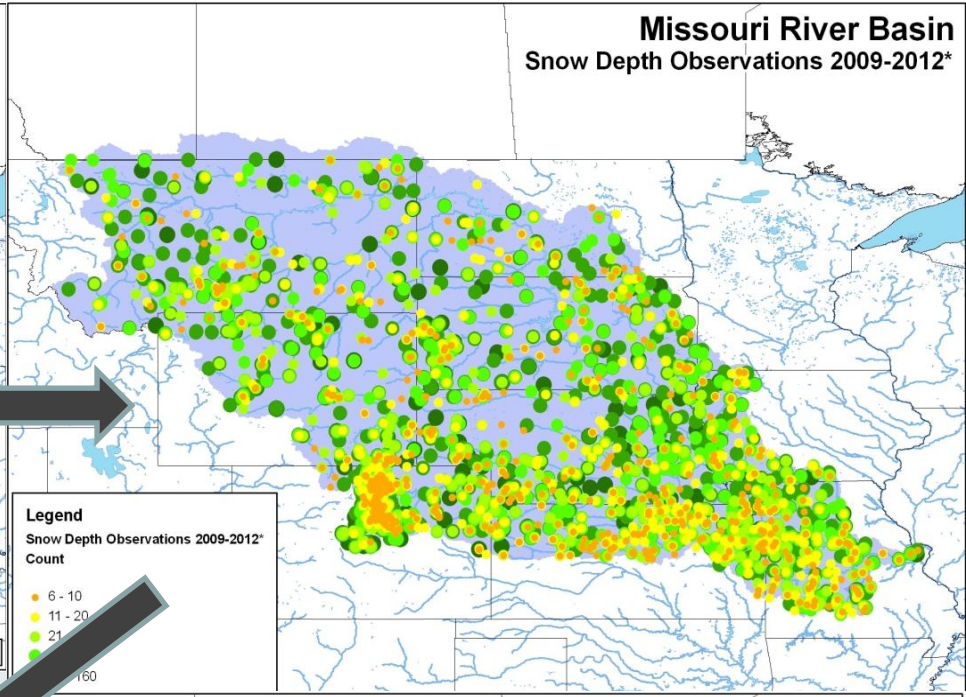


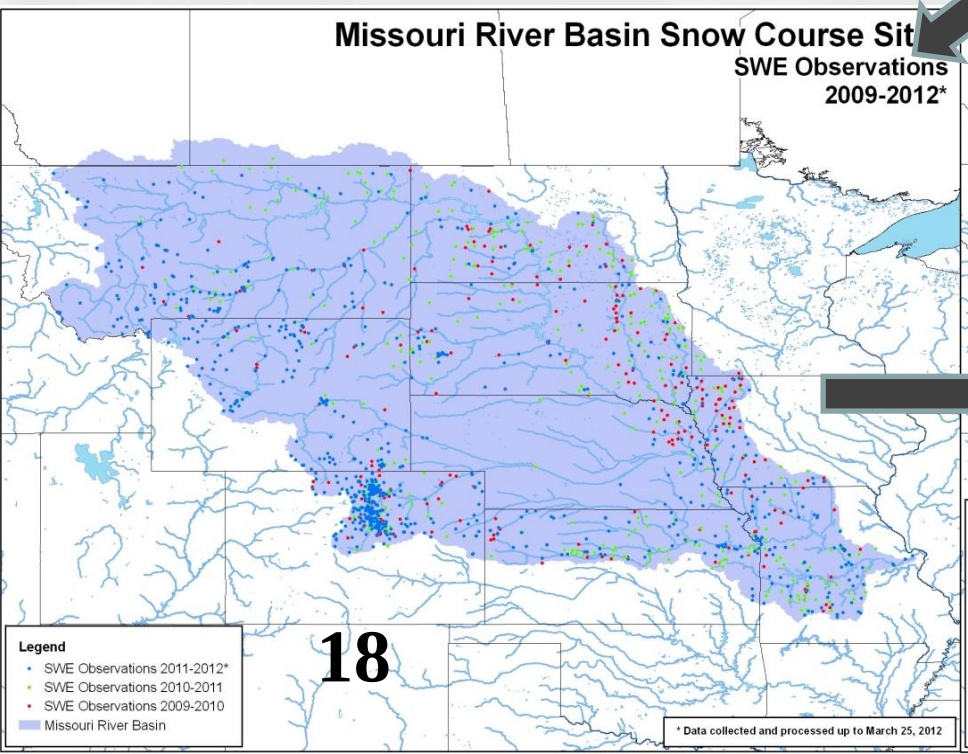


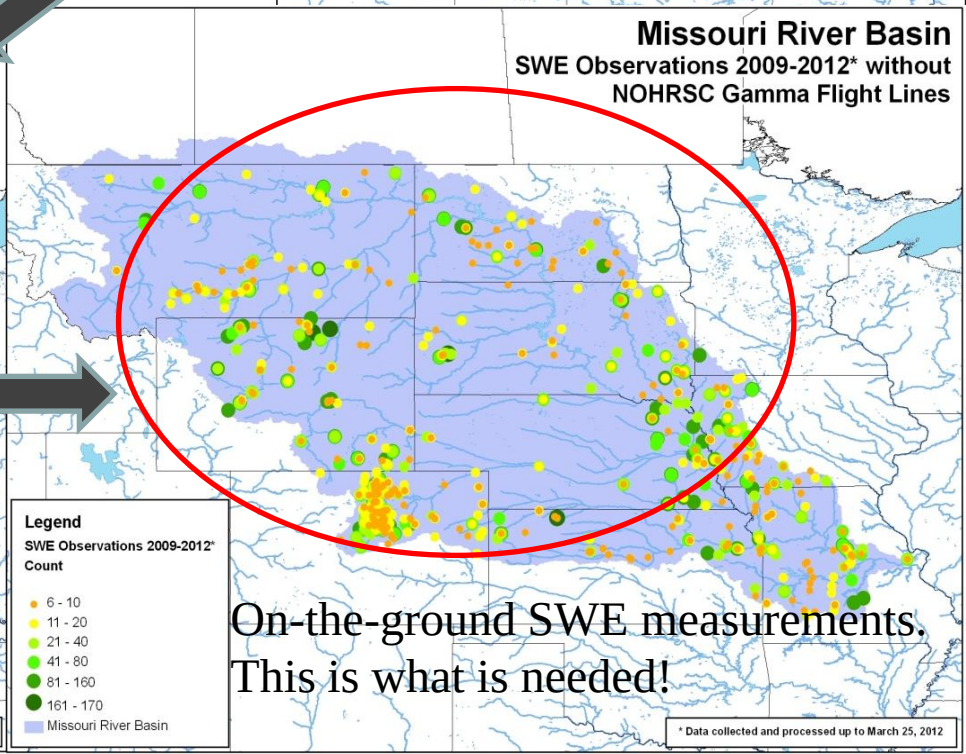


Community Collaborative Rain, Hail & Snow Network (CoCoRaHS) observer locations



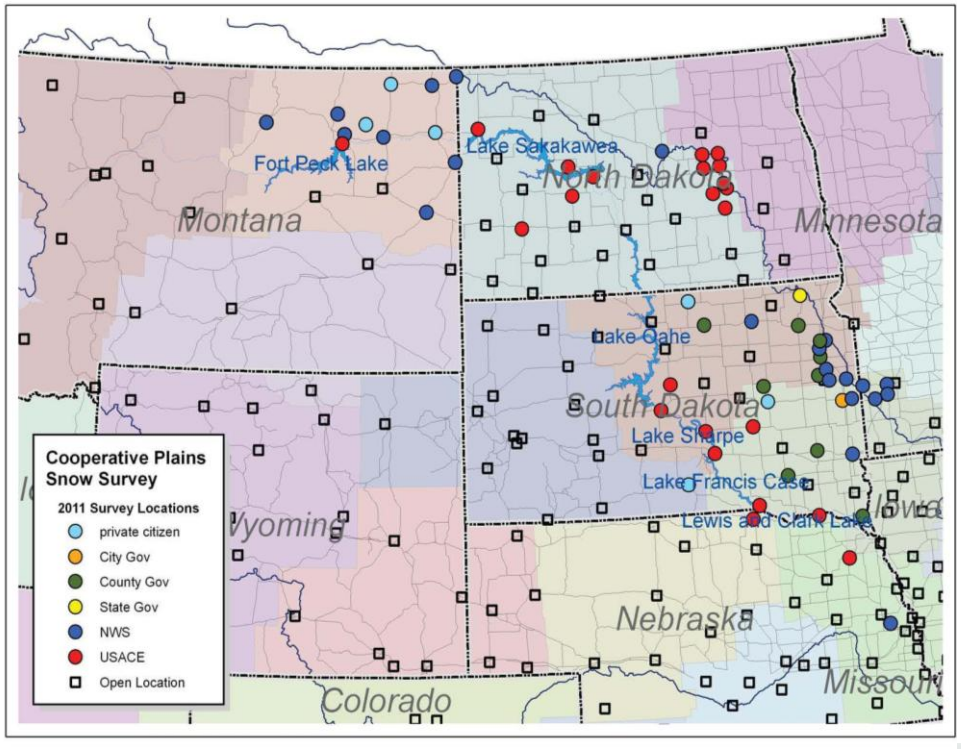


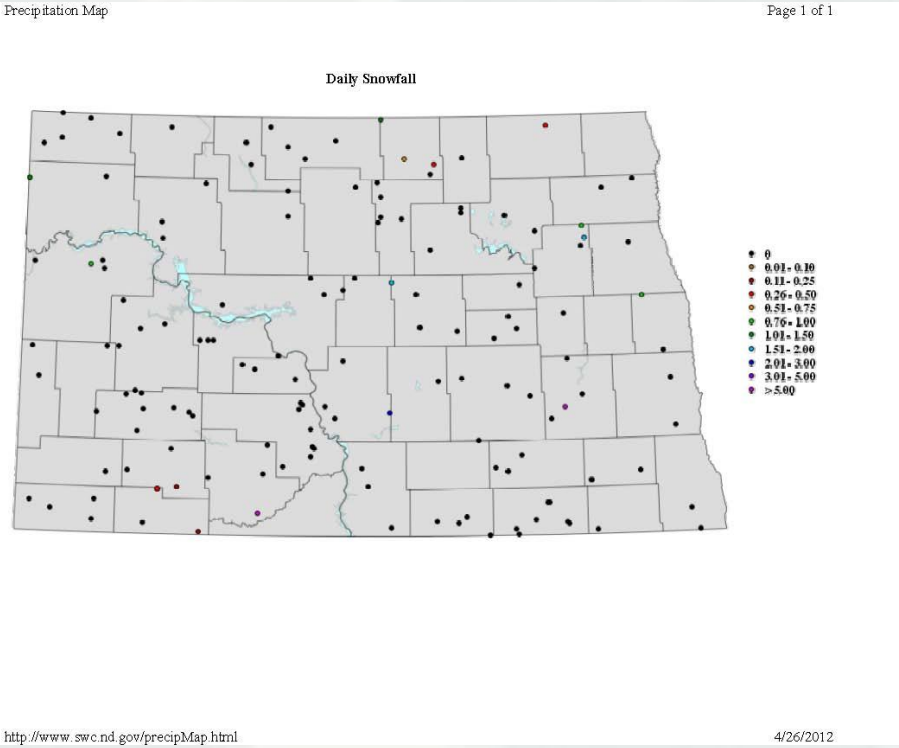




On-the-ground SWE measurements.
This is what is needed!

1. Plains SWE On-the-Ground Measurements





USACE

State of ND

Improving March-April Runoff Forecast

Summary

1. On-the-Ground plains SWE measurements - established at pre-defined locations for year-to-year comparisons and taken at regular intervals (e.g. every 2 weeks from January through March.
2. Expand existing SCAN and AWDN networks to include soil moisture and frost depth conditions.
3. NOAA provide USACE with daily forecasted temperature and precipitation data through end of April.
4. USACE continue to develop basin-wide runoff models to incorporate #1 - #3 and present basin stakeholders with 3 improved runoff scenarios … expected, wetter-than-expected and drier-than-expected.

Improving Runoff Forecast

Summary

- This presentation focused mostly on March-April timeframe.
- Accurate assessment of SWE (plains and mountains) essential.
- Assessment of basin/soil conditions applicable year-round extremely helpful.
- Accuracy of temperature and precipitation forecasts applicable year-round necessary.
- Everyone in basin – federal, tribes, states, counties, local, private citizens affected by runoff.
- ***Increasing the accuracy in forecasting the amount of runoff that will occur in the upper Missouri River basin, especially during the early part of the runoff season (March and April) will allow everyone more time to prepare for the rest of the runoff season. This applies to all runoff conditions – wet, dry or normal.***

Questions?

Planning for Future …

- After Action Review (AAR)
- Transition Plan
- May 24 – MRFTF (Omaha)