RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

"RED RIVER BASIN OVERVIEW"

RED RIVER BASIN COMMISSION

MN & ND GOVERNOR'S TASK TEAM F/M DIVERSION

Fargo, North Dakota

13 November 2017

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RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

EARTH
THE WATER PLANET
nothing like it anywhere

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

FLOODING

FLOOD FACTORS

- Fall Precipitation
- Winter Snowfall
- Spring Temps
- Spring Moisture

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

LAKE WINNIPEG WATERSHED

4 RIVER SYSTEMS 2 MAJOR LAKES

Watershed	953,250 sq/km
Lake Winnipeg	24,387 sq/km
Watershed Population	6.6 million

4 PROVINCES
4 STATES

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS
ASSUMPTIONS
RISKS
RECOMMENDATIONS

LTFS
RETENTION
POTENTIAL

RED RIVER BASIN OF THE NORTH

UNITED STATES & CANADA

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

GLACIAL LAKE AGASSI

FORMED RRB 10,000 YEARS AGO

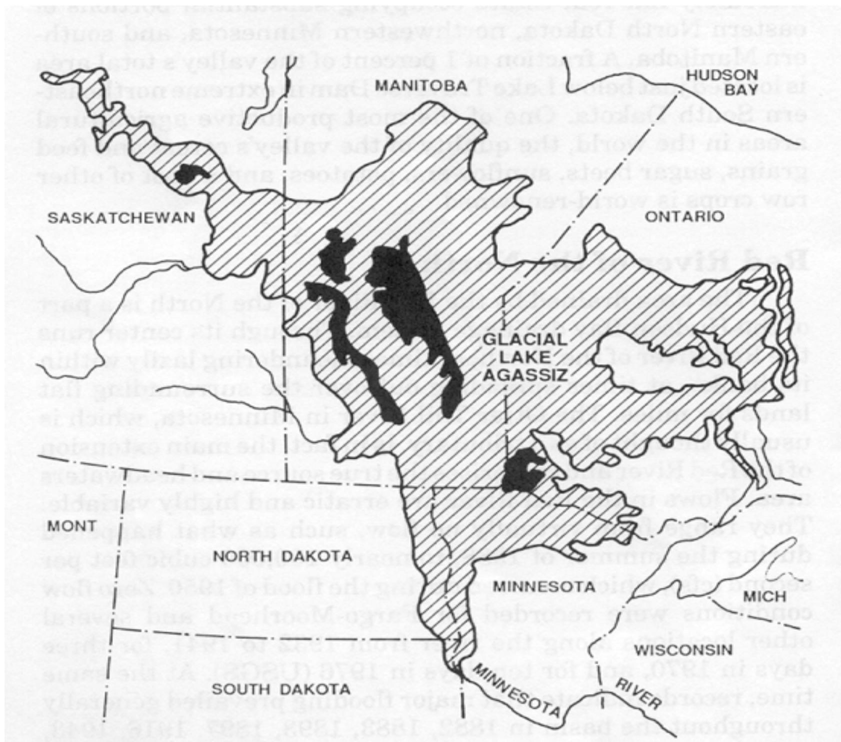


FIGURE 1-1
Glacial Lake Agassiz

- 950,525 sq km (367,000 sq mi) at various times
  - Width: 1127 km (700 mi)
  - Depth: 213 m (700 ft) at Wpg
  - Length: 1127 km (700 mi)
- NOTE: Lake Winnipeg: Today the 10th Largest Lake in the World, by area.
- Lake Agassiz:
  - 300 feet deep in Fargo
  - 500 feet deep in Grand Forks
  - 700 feet deep in Winnipeg

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

RED RIVER BASIN (WATERSHED)

- **869 km (540 mi) long**
- **96 km (60 mi) wide**

- **n/s: .09 m/km (½ ft/mi)**
- **e/w: .38-.57 m/km (2-3 ft/mi)**
- **One of truly flat landscapes in world**

- **People settled in the lowest places. Western settlement stopped at rivers and grew there. N/S river trade on Red River.**

Datasource: RRBC

- 129,500 sq km (50,000 sq. mi) w/o Souris & Assiniboine

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

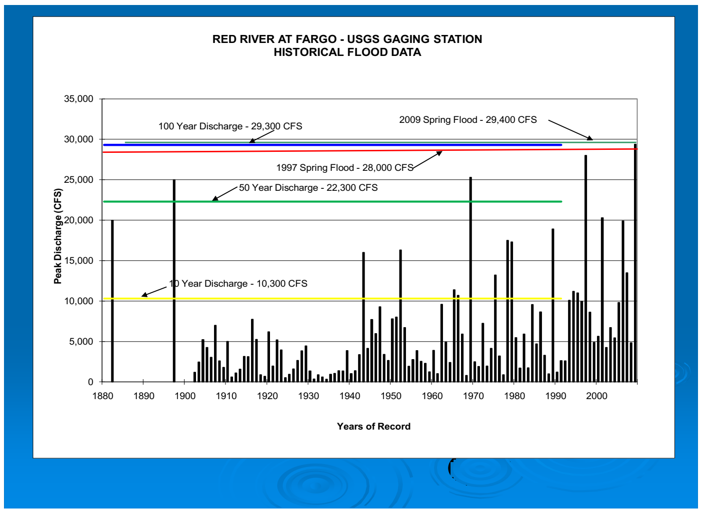
RECOMMENDATIONS

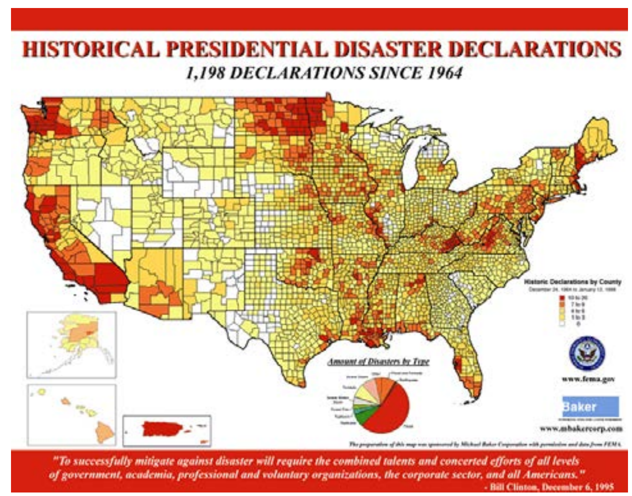
LTFS

RETENTION

POTENTIAL

RED RIVER FLOODING





Fargo-Moorhead area in 1826, 1897, 1969, 1975, 1979, 1984,1989, 1995, 1997, 2001, 2006, 2009, 2010, and 2011.

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

EARLY EFFORTS

- 100 year flood – should occur about 1/100 years
- However: 1979: 10 – 100 year floods in last 25 years
  Mayors: Breckenridge, Wahpeton, Moorhead, Fargo, GF, EGF, Emerson, Morris, Winnipeg, & Selkirk.
- BASIN ORGANIZATIONS:
  1979 GRASSROOTS : TIFC, TIC;
  1996 STATE & PROVINCIAL: RRBB
  2002 COMBINED: RRBC

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS
ASSUMPTIONS
RISKS
RECOMMENDATIONS

LTFS
RETENTION
POTENTIAL

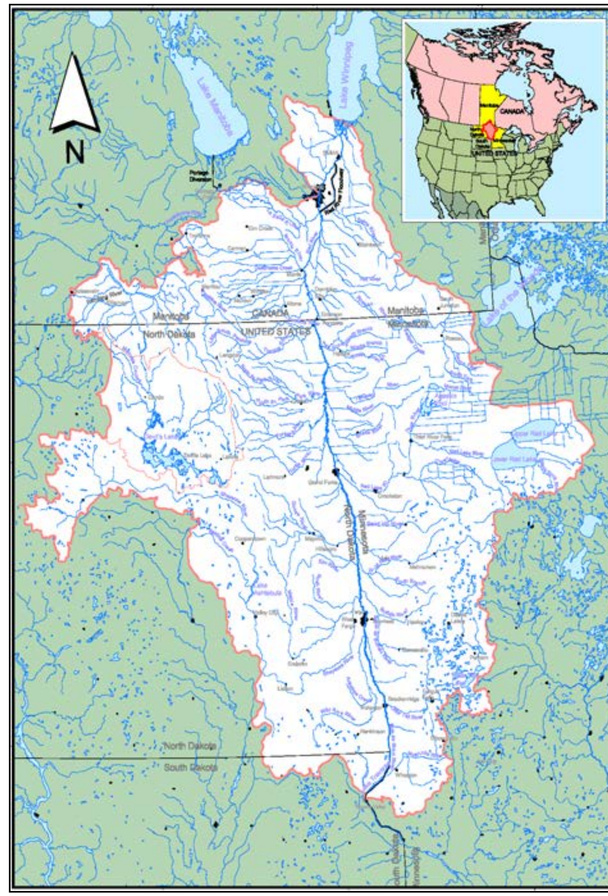
NEED FOR A MAINSTEM MODEL

2005

- **No Mainstem Seamless Model for flow and storage analysis**
- RRBC FDR Working Group
- $ Local/Provincial/State/Other
- RFP - Consultant
- Seamless Mike II Model

➢ Computer based **unsteady flow model** of the Red River and its floodplain from **Lake Traverse to Lake Winnipeg**

➢ Primary purpose is to improve our ability to **predict the effects on the mainstem of upstream tributary flow modifications**



RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

MAINSTEM MODEL

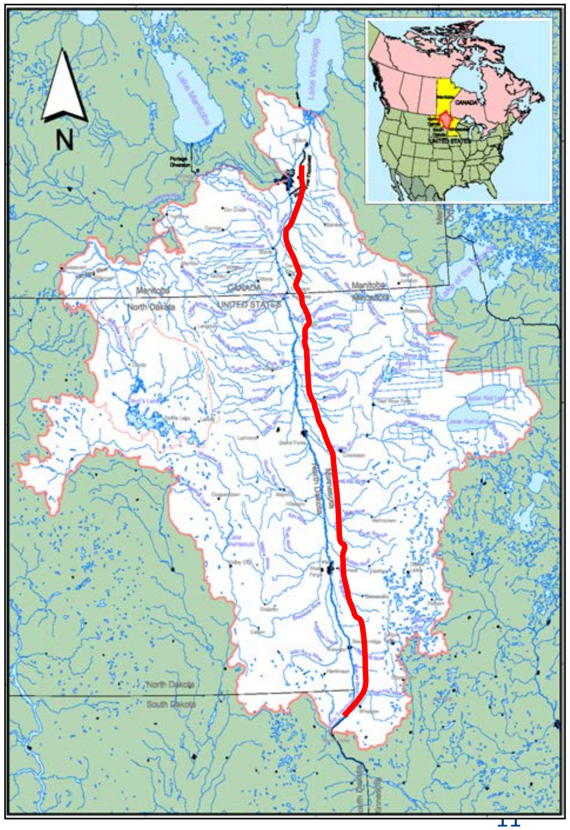
MIKE II THEN LATER HEC/RAS

- Several **Calibrations of the Mike 11** Model RRBC based on 1997 Flood and multiple modeling runs.

- **Initial Targeted Goal**
  - **20% peak flow reduction**
  - **GF in 1997 - 20% too Much**

- Develop the necessary models
  - **Hydraulic: Mainstem**
  - **Hydrologic: Sub-Watershed**

- Quantify the **flow reduction** required from **each watershed**



RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

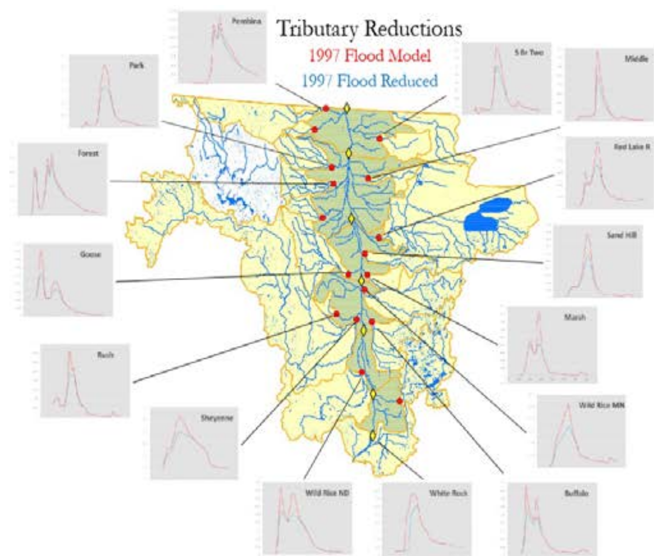
POTENTIAL

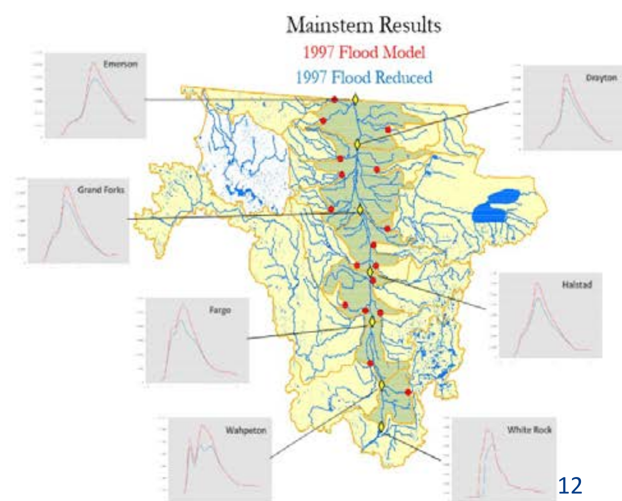
BASIN WIDE FLOW REDUCTION STRATEGY RRBC LTFS

Established flow reduction goals for the Red River based on 1997 flood modeling using MIKE 11 hydraulic modeling software

20% Goal for the Red River

Various flow reduction assumptions were applied to tributaries to achieve the 20% goal for the Red River





RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

BASIN WIDE FLOW REDUCTION STRATEGY
RRBC LTFS

Phase I -- Mike 11 Calibration

Phase II – Mike 11 Calibration

Run # 1 – IJC Scenario Modeling - With/without each tributary

10-20% scalar reduction

Run # 2 – 20% Flow Reduction

Calibration III – Mike 11, HEC/RAS, RR north of border

Calibration IV – RR south of border to GF

Pembina Modeling: Mike II & Telmac

New LiDAR Data

New HEC/RAS Models in US & Expand to Manitoba

F/M and Upstream Study

New HEC/HMS Models in US (Sub-Watershed Models MN, ND)

Halstad Upstream Retetion

Hydrology Studies and Site Identification in Tributary Sub-Basins

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

IMPETUS FOR LONG TERM FLOOD SOLUTIONS (LTFS)

- Spring 2009 basin wide flood: MN & ND Governors visit ask "why do we keep having these floods?
- We "React" to latest crises and built to just above it, We aren't "Proactive" to reduce risk as much as possible.
- Response by local Legislator's "We lack a comprehensive basin wide plan of action" to address, mitigate, and respond to flooding and related water quality and land conservation issues
- Funding of $500,000 each – ND & MN provided to RRBC to produce such a report.

ASSUMPTIONS (LTFS)

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

- **Agriculture** will continue to be the dominant land use throughout the basin. Adequate surface drainage has been and will continue to be integral to maintaining productivity of cropland. Sub-surface drainage is likely to become increasingly popular.
- **Current development and infrastructure** trends will continue into the foreseeable future. The major urban centers and communities will continue in their present locations. The major metropolitan areas will continue to grow. Future development will occur in compliance with floodplain management regulations.
- **Floods** will continue into the future. Floods larger than historically experienced can be expected to occur.
- **Flood damage reduction** will need to be implemented in the basin based primarily on the identified needs of the basin residents and their willingness to provide or seek the funding necessary to implement the measures which they believe are appropriate, effective, and justified. State and federal agencies will facilitate the implementation of the various measures based on their policies, regulations and availability of funding.
- **Flood damage reduction is just one issue** that affects the sustainability of the region. Other key resource issues need to be considered as this plan is developed and implemented, including droughts, water supply, water quality, and other natural resource areas.

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

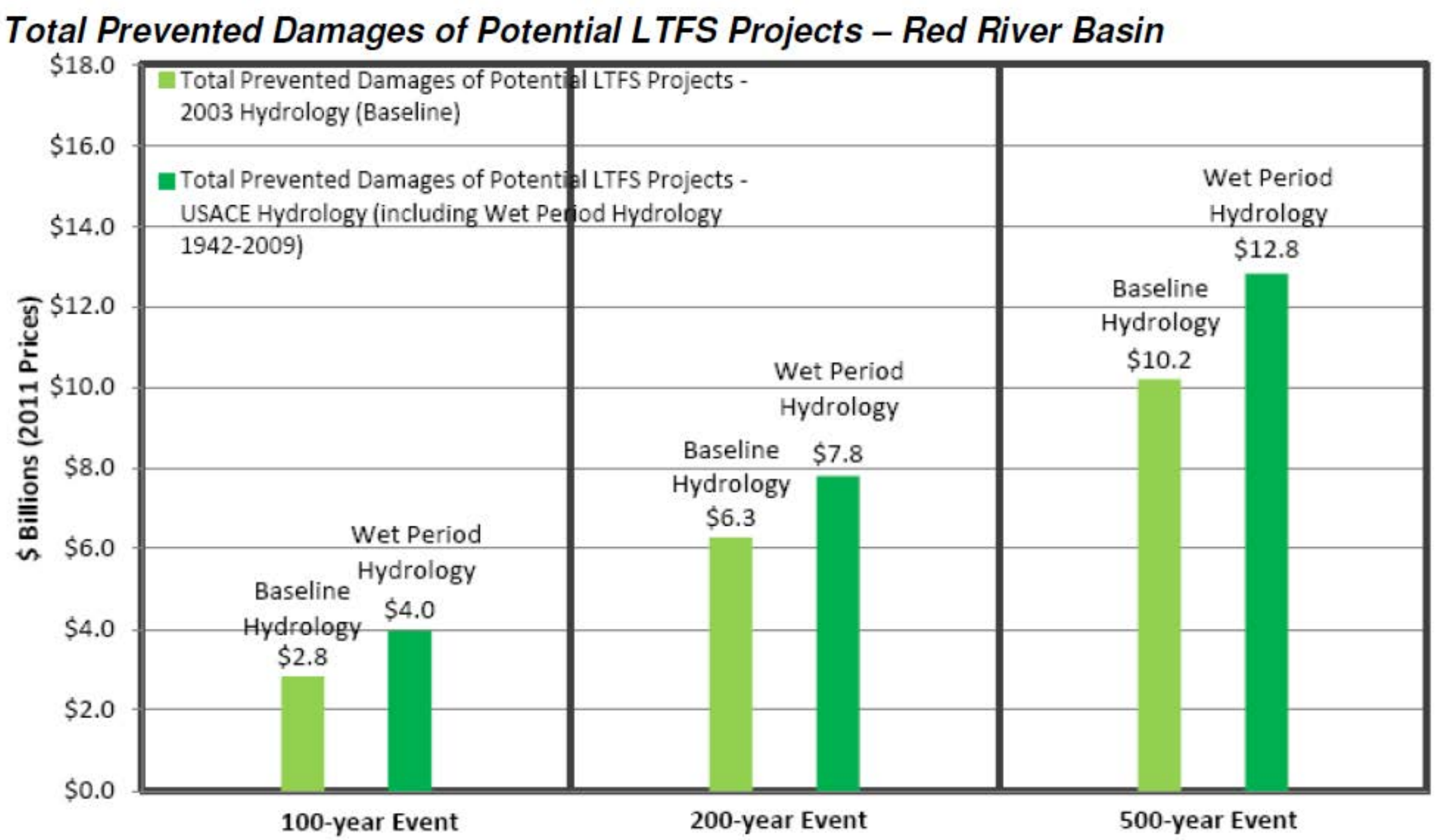
RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

DAMAGE POTENTIAL RISK (LTFS)



RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

CATASTROPHIC EFFECTS WHEN RISKS ARE REALIZED

- **Grand Forks/East Grand Forks: 1997** - 100 year and temporary Levees overtopped – leads to 250 year levee system
- **Rochester: 1978** – intense rainstorm floods Rochester – leads to 100 year channel improvements and upstream storage
- **Souris/Mouse: Minot area** – 1969 flood leads to channel improvements, levees and upstream storage at 100 year level; then 2011 flood overwhelms previous system leading to increasing levee systems to handle 2011 flood (approaching 500 year level)
- **New Orleans: Katrina 2005** – Levee system not designed for overtopping; leads to reevaluation of system and new criteria and upgraded 100 year level of protection that is designed to not fail if overtopped.

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

SOURIS (MOUSE) RIVER – MINOT, ND 2011 FLOOD

- **Federal Flood Control Project in Place Prior to 2011 Flood:**
  - Design Flood – 100 year (**5,000** cfs) -- Federal
  - 3 Large Upstream Dams – 500,000 acre-ft of flood storage
  - Levees & Channel Enlargements

- **2011 Flood**:
  - 4-5 inches of water content in snow pack
  - Snowmelt plus concurrent rainfall of over 6 inches filled all flood storage to capacity (resulting flows at Minot up to **8,000** cfs contained with flood fight)
  - Large rainfall event after flood storage filled of over 5 inches resulted in peak flows at Minot of **27,000** cfs, overwhelming permanent and emergency flood fight levees (State-City and maybe Federal)
  - Flood damages $700+ million to over 4,700 structures

- **Post 2011 Flood Situation**:
  - Flood frequency re-evaluated with new flood records – 100 year flow now at **10,000** cfs Levee system being developed to protect from recurrence of 2011 flood (greater than 500 year)

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

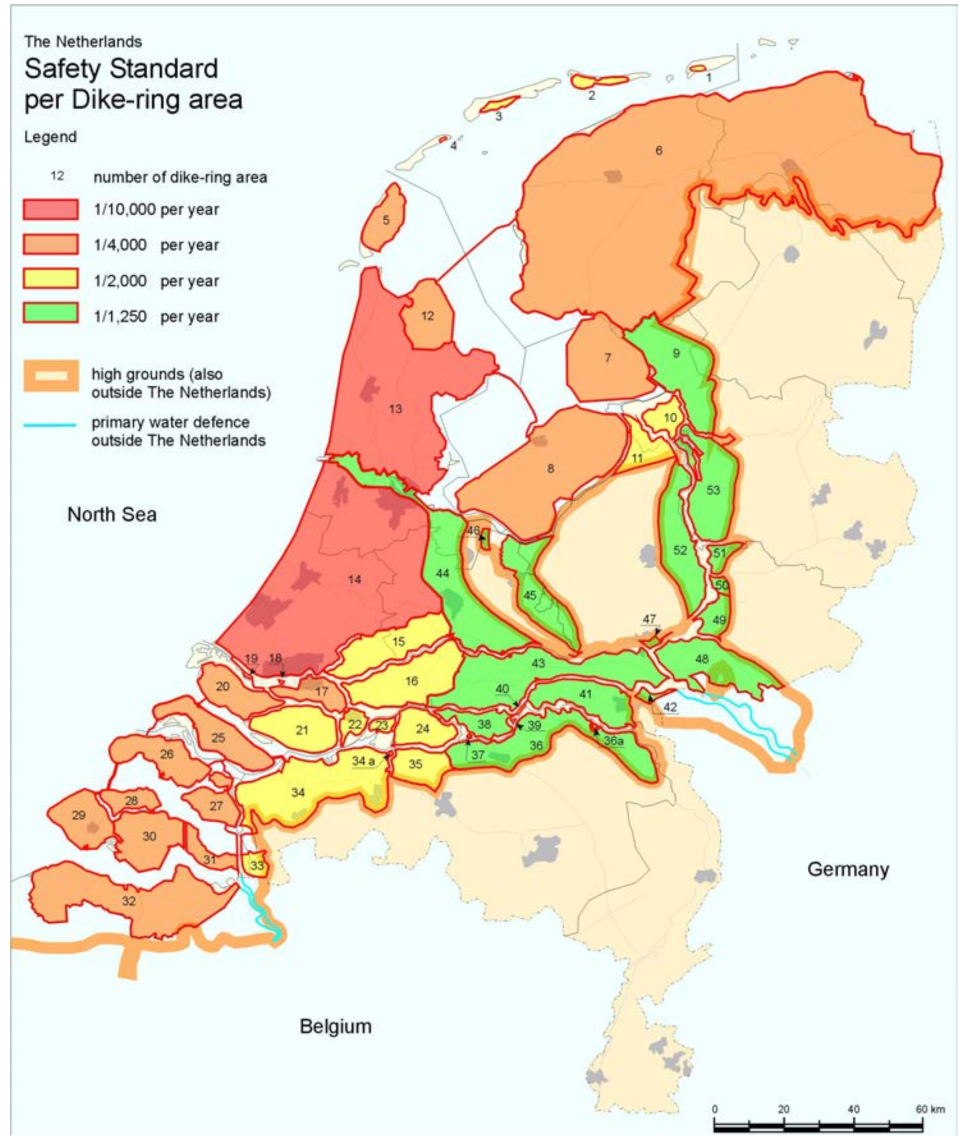
LTFS

RETENTION

POTENTIAL

LEVELS OF PROTECTION NETHERLANDS

- 10,000 year North Sea
- 4,000 year inland and North Sea
- 1,250, 2,000, & 4,000 along rivers and inland



RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

LEVEL OF PROTECTION GOALS (LTFS)

Level of Flood Protection Goals for the Red River Basin

Area Protected	Estimated Recurrence Interval
Major urban/metropolitan areas (1) (2) (4)	500 year or greater
Critical infrastructure (1) (2)	500 year or greater
Cities/municipalities (1) (2)	200 year or greater
Rural residences & farmsteads (1) (2)	100 year or greater
Agricultural cropland: Summer flood	10 year or greater
Transportation (2) (3) Critical transportation system and emergency service links	200 year or greater

Notes

(1) Protection for urban areas, critical infrastructure, cities, rural residences, and farmsteads should all have appropriate freeboard (i.e., contingency or risk and uncertainty allowance) with any projects designed to provide the specified level of protection.

(2) If a flood of record has occurred which exceeds the specified level of protection goal, the flood of record should be used in place of the specified level of protection goal.

(3) The critical transportation systems should be maintained passable during a flood of the described level of protection to assure safe and reliable transportation and provision of emergency services. The transportation system should not increase flooding problems either upstream or downstream.

(4) Includes Fargo-Moorhead, Grand Forks-East Grand Forks, and Winnipeg.

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

WHY 500 LEVEL OF PROTECTION FOR MAJOR URBAN AREAS

- **Effects of Flooding extend beyond the flooded urban area**; adverse effects extend to region and potentially to multi-state area and internationally
  - Hospitals
  - Transportation (airport, major rail and highway routes)
  - Water supply and waste treatment
  - Businesses that supply goods and services to larger area
- **Evacuation of large urban areas during a major flood event** can be very complicated, disruptive and hazardous
- **Recovery from major flood** event for a large urban area can be extremely expensive, take a very long time and affect the viability of the urban area and the region

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

CONSIDERATIONS FOR LEVEL OF PROTECTION AND RISK REDUCTION

- Winnipeg: 700 year Diversion Channel & levees
- Manitoba: Use 200 year or greater
- Minot: 500 year+ levee system under development
- Red River Basin Commission LTFS Recommendation:
  - 500 year or greater for major urban areas
  - 200 year or greater for communities
  - 100 year or greater for developments, individual homes and rural farmsteads
- Netherlands: Greater than 1,000 year (1,250-2,000-4,000)
- Protect for the Risk: like: Fire/Car Insurance
- b/c ration looks at rate of return short term

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

RECOMMENDED LEVELS OF PROTECTION STATUS

ON RED RIVER

First Green: Meet RRBC Recommended Guidelines Under Current Conditions. (**Halstad/Oslo**)

Second Green: Meet RRBC Recommended Guidelines with Current Planned Upgrades. (Same)

Third Green: Meet RRBC Recommended Guidelines with Current Planned Upgrades & Upstream Storage (20%).

Fourth Green: 9 still need additional measures (W-B, F-M, Nielsville, Climax, Drayton, Pembina, Noyes)

Level of Protection at Cities along the Red River

City/Location	Level of Protection: RRBC Recommended Guideline	Current Conditions	Meets RRBC Recommended Guideline?	Future Conditions including Planned Upgrades	Meets RRBC Recommended Guideline?	Future Conditions including Planned Upgrades plus Proposed Upstream Flood Storage	Meets RRBC Recommended Guideline?	Additional Measures Needed to Meet RRBC Recommended Guideline?
Red River Main Stem								
Wahpeton, ND	200 yr	100-125 yr	No	100-125 yr	No	< 200 yr	No	Yes
Breckenridge, MN	200 yr	100-125 yr	No	100-125 yr	No	< 200 yr	No	Yes
Fargo, ND	500 yr	< 100 yr	No	> 200 yr	No	> 200 yr	No	Yes
Moorhead, MN	500 yr	< 100 yr	No	> 200 yr	No	> 200 yr	No	Yes
Georgetown, MN	200 yr	< 100 yr	No	100 yr	No	> 200 yr	Yes	No
Perley, MN	200 yr	< 100 yr	No	100 yr	No	> 200 yr	Yes	No
Hendrum, MN	200 yr	< 100 yr	No	100 yr	No	> 200 yr	Yes	No
Halstad, MN	200 yr	250 yr	Yes	250 yr	Yes	> 250 yr	Yes	No
Shelly, MN	200 yr	< 100 yr	No	100 yr	No	> 200 yr	Yes	No
Nielsville, MN	200 yr	no permanent protection	No	100 yr	No	> 100 yr	No	Yes
Climax, MN	200 yr	no permanent protection	No	100 yr	No	> 100 yr	No	Yes
Grand Forks, ND	500 yr	250 yr	No	250 yr	No	> 500 yr	Yes	No
East Grand Forks, MN	500 yr	250 yr	No	250 yr	No	> 500 yr	Yes	No
Oslo, MN	200 yr	> 200 yr	Yes	> 200 yr	Yes	> 200 yr	Yes	No
Drayton, ND	200 yr	< 100 yr	No	< 100 yr	No	< 100 yr	No	Yes
Pembina, ND	200 yr	100 yr	No	100 yr	No	> 100 yr	No	Yes
St. Vincent, MN	200 yr	< 100 yr	No	>100 yr	No	200 yr	Yes	No
Noyes, MN	200 yr	100 yr	No	100 yr	No	> 100 yr	No	Yes

RELATED TO DISTRIBUTED STORAGE

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

- The flow reduction shown is what could be achieved by strategically placed and operated, gate controlled, long term storage with no release during the entire flood period. Most storage facilities would not be that high quality.
- Storage constructed to achieve the modeled results would likely be greater than the modeled 885,000 acre-feet of flow reduction upstream from Emerson.
  - Ungated storage will likely be part of the mix but is less effective depending on the duration of storage.
  - Selection of storage sites will likely be influenced by the need to provide local, as well as mainstem, flood control. Properly operated, this storage will be beneficial on the mainstem but may be somewhat less efficient.
- Tributary peak flow reductions ranged from 0 to 50%. Peak flow reduction on strategic tributaries was about 35%
- Volume flow reduction on all tributaries upstream from Emerson ~13% of the total 1997 flood volume
- **THIS IS IF STORAGE IS PEAK FLOW TIMED FOR THE BORDER**
- If not the storage needed to obtain 20% flow reduction at border based on the 1997 Flood and Mike 11 Model identified in the LTFS is around 1.5 million ac/ft

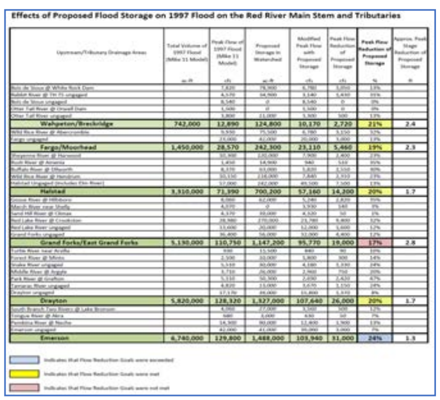
LTFS GRAPHS RELATED TO DISTRIBUTED STORAGE

Summary of Mainstem Flow Reductions 1997 Spring Flood	Upstream Contributing??? Drainage Area	Peak Flow Reduction	Peak Flow Reduction	Upstream Tributary Volume	Upstream Tributary Volume Reduction	Upstream Tributary Volume Reduction
Mainstem Locations	sqmi	cfs	%	acft	acft	%
Wahpeton	4010	2723	21%	801206	106075	13%
Fargo	6210	5459	19%	1425717	160209	11%
Halstad	15430	14236	20%	3307686	426566	13%
Grand Forks	21690	18911	17%	5149686	776752	15%
Drayton		25155	20%	5912194	890303	15%
Emerson		30539	24%	6915848	988094	14%

Less than allocation or goal

Meets allocation or goal

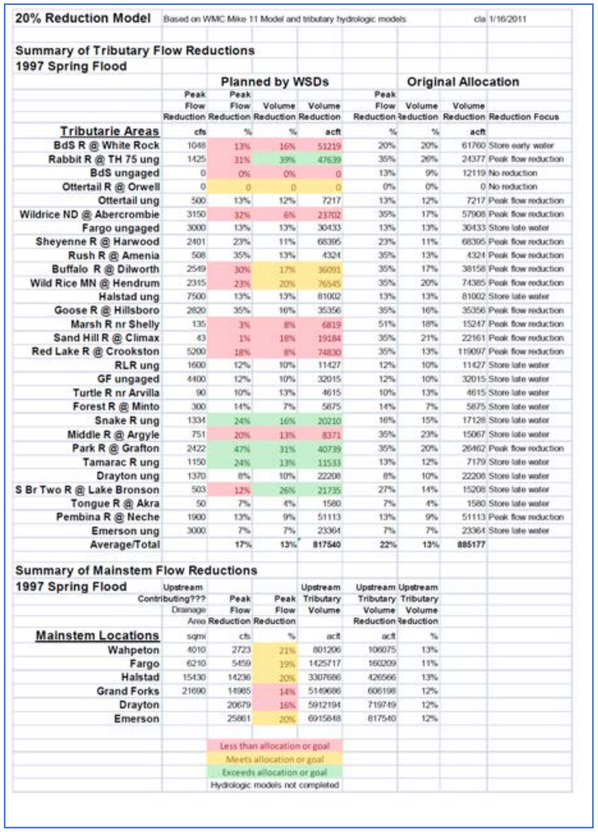
Exceeds allocation or goal



Effects of Proposed Flood Storage on 1997 Flood on the Red River Main Stem and Tributaries

Upstream/Tributary Drainage Areas	Total Volume of 1997 Flood (Mike 11 Model)	Peak Flow of 1997 Flood (Mike 11 Model)	Proposed Storage in Watershed	Modified Peak Flow with Proposed Storage	Peak Flow Reduction of Proposed Storage	Peak Flow Reduction of Proposed Storage	Approx. Peak Stage Reduction of Proposed Storage
Wahpeton/Breckridge	742,000	12,890	124,800	10,170	2,720	21%	2.4
Fargo/Moorhead	1,450,000	28,570	242,300	23,110	5,460	19%	2.3
Halstad	3,310,000	71,390	700,200	57,160	14,200	20%	1.7
Grand Forks/East Grand Forks	5,150,000	110,750	1,147,200	95,770	19,000	17%	2.8
Drayton	5,820,000	128,320	1,327,000	107,640	26,000	20%	1.7
Emerson	6,740,000	129,800	1,488,000	103,940	31,000	24%	1.3

	Peak Flow Reduction	Peak Flow Reduction	Volume Reduction	Volume Reduction	Reduction Focus
	%	cfs	%	acft	
BdS R @ White Rock	20%	1542	20%	61760	Store early water
Rabbit R @ TH 75 ung	35%	2108	26%	24377	Peak flow reduction
Ottertail R @ Orwell	0	0	0	0	No reduction
Buffalo R @ Dilworth	35%	2930	17%	38158	Peak flow reduction
Wild Rice MN @ Hendrum	35%	3610	20%	74385	Peak flow reduction
Marsh R nr Shelly	51%	2100	18%	15247	Peak flow reduction
Sand Hill R @ Climax	35%	1510	21%	22161	Peak flow reduction
Red Lake R @ Crookston	35%	9600	13%	119097	Peak flow reduction
Snake R ung	16%	1367	15%	17128	Store late water
Middle R @ Argyle	35%	1330	23%	15067	Store late water
Tamarac R ung	13%	563	12%	7179	Store late water
S Br Two R @ Lake Bronson	27%	1100	14%	15208	Store late water



20% Reduction Model Based on WMC Mike 11 Model and tributary hydrologic models cla 1/16/2011

Summary of Tributary Flow Reductions
1997 Spring Flood

	Planned by WSDs				Original Allocation			
	Peak Flow Reduction	Peak Flow Reduction	Volume Reduction	Volume Reduction	Peak Flow Reduction	Volume Reduction	Volume Reduction	Reduction Focus
Tributarie Areas	cfs	%	%	acft	%	%	acft	
BdS R @ White Rock	1048	13%	16%	51219	20%	20%	61760	Store early water
Rabbit R @ TH 75 ung	1425	31%	39%	47639	35%	26%	24377	Peak flow reduction
BdS ungaged	0	0%	0%	0	13%	9%	12119	No reduction
Ottertail R @ Orwell	0	0	0	0	0%	0%	0	No reduction
Ottertail ung	500	13%	12%	7217	13%	12%	7217	Peak flow reduction
Wildrice ND @ Abercrombie	3150	32%	6%	23702	35%	17%	57908	Peak flow reduction
Fargo ungaged	3000	13%	13%	30433	13%	13%	30433	Store late water
Sheyenne R @ Harwood	2401	23%	11%	68395	23%	11%	68395	Peak flow reduction
Rush R @ Amenia	508	35%	13%	4324	35%	13%	4324	Peak flow reduction
Buffalo R @ Dilworth	2549	30%	17%	36091	35%	17%	38158	Peak flow reduction
Wild Rice MN @ Hendrum	2315	23%	20%	76545	35%	20%	74385	Peak flow reduction
Halstad ung	7500	13%	13%	81002	13%	13%	81002	Store late water
Goose R @ Hillsboro	2820	35%	16%	35356	35%	16%	35356	Peak flow reduction
Marsh R nr Shelly	135	3%	8%	6819	51%	18%	15247	Peak flow reduction
Sand Hill R @ Climax	43	1%	18%	19184	35%	21%	22161	Peak flow reduction
Red Lake R @ Crookston	5200	18%	8%	74830	35%	13%	119097	Peak flow reduction
RLR ung	1600	12%	10%	11427	12%	10%	11427	Store late water
GF ungaged	4400	12%	10%	32015	12%	10%	32015	Store late water
Turtle R nr Arvilla	90	10%	13%	4615	10%	13%	4615	Store late water
Forest R @ Minto	300	14%	7%	5875	14%	7%	5875	Store late water
Snake R ung	1334	24%	16%	20210	16%	15%	17128	Store late water
Middle R @ Argyle	751	20%	13%	8371	35%	23%	15067	Store late water
Park R @ Grafton	2422	47%	31%	40739	35%	20%	26462	Peak flow reduction
Tamarac R ung	1150	24%	13%	11533	13%	12%	7179	Store late water
Drayton ung	1370	8%	10%	22208	8%	10%	22208	Store late water
S Br Two R @ Lake Bronson	503	12%	26%	21735	27%	14%	15208	Store late water
Tongue R @ Akra	50	7%	4%	1580	7%	4%	1580	Store late water
Pembina R @ Neche	1900	13%	9%	51113	13%	9%	51113	Peak flow reduction
Emerson ung	3000	7%	7%	23364	7%	7%	23364	Store late water
Average/Total		17%	13%	817540	22%	13%	885177	

Summary of Mainstem Flow Reductions 1997 Spring Flood	Upstream Contributing??? Drainage Area	Peak Flow Reduction	Peak Flow Reduction	Upstream Tributary Volume	Upstream Tributary Volume Reduction	Upstream Tributary Volume Reduction
Mainstem Locations	sqmi	cfs	%	acft	acft	%
Wahpeton	4010	2723	21%	801206	106075	13%
Fargo	6210	5459	19%	1425717	160209	11%
Halstad	15430	14236	20%	3307686	426566	13%
Grand Forks	21690	14985	14%	5149686	606198	12%
Drayton		20679	16%	5912194	719749	12%
Emerson		25861	20%	6915848	817540	12%

Less than allocation or goal

Meets allocation or goal

Exceeds allocation or goal

Hydrologic models not completed

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

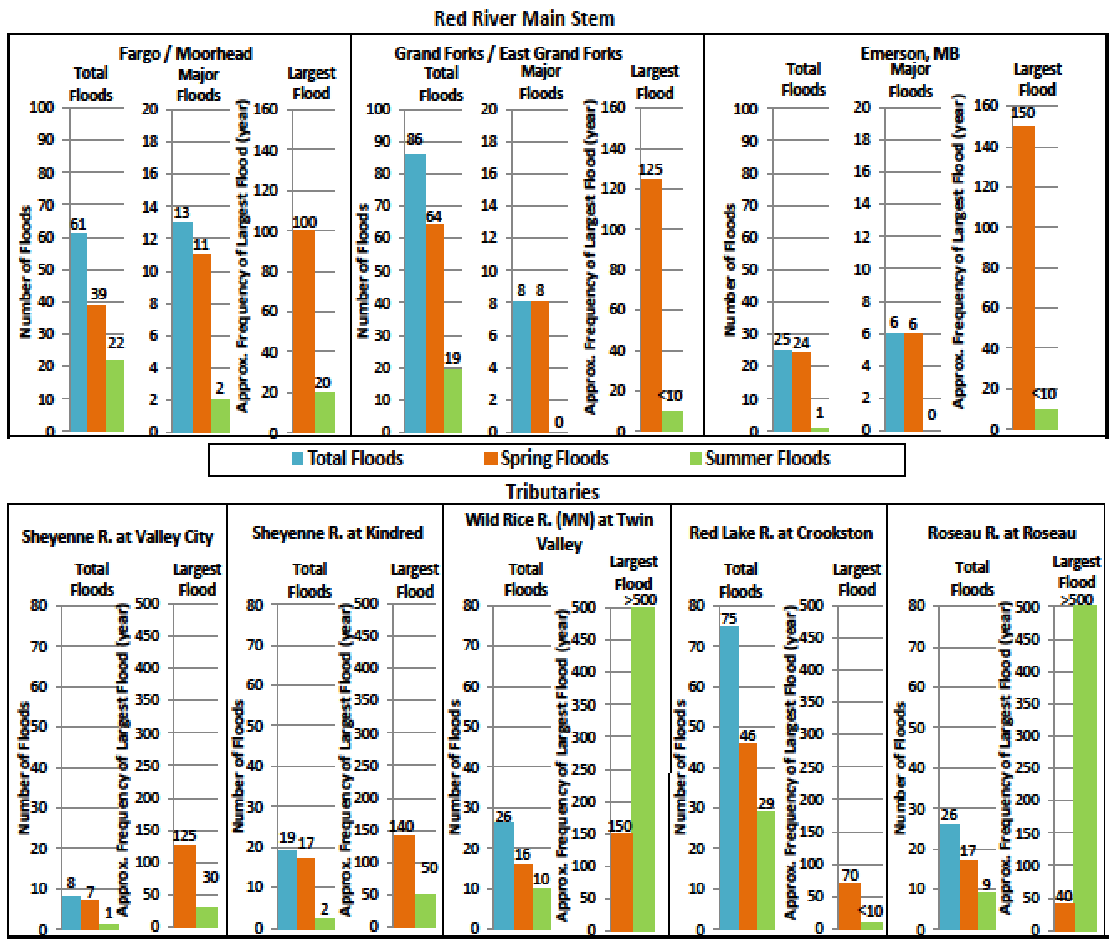
LTFS RETENTION POTENTIAL

FLOODS

TOTAL SPRING SUMMER

- Largest **Spring Floods** along the **Mainstem.**
- Largest **Summer Floods** in the **Tributaries**

Figure B-8 Comparison of Spring Snowmelt and Summer Rainfall Floods - Red River Basin



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9/13/2011

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

FLOODS

VARY BY LOCATION IN THE BASIN

Using the upcoming FEMA adopted guidelines at F-M this graph shows that floods vary by location.

Using the agreed to Task Force 33,000 cfs flows, the 2009 flood is less than 100-year flood at 29,500 cfs (peak discharge).

Summary of Relative Magnitude of Select Historic Floods in the Red River Basin

Year	Red River @ Pembina/ Emerson	Red River @ Grand Forks/East Grand Forks	Red River @ Fargo/ Moorhead	Sheyenne River @ Valley City	Maple River @ Mapleton	Wild Rice River @ Twin Valley	Roseau River @ Roseau	Pembina River @ Neche	Park River @ Grafton
1882	< 10	> 10	> 10	> 50	n.r.	n.r.	n.r.	n.r.	< 10
1897	> 10	> 10	> 10	> 10	n.r.	n.r.	n.r.	n.r.	< 10
1948	< 10	< 10	< 10	> 10	< 10	< 10	< 10	> 10	> 50
1950	> 10	< 10	< 10	> 10	< 10	> 10	< 10	> 50	> 50
1969	< 10	< 10	> 10	> 10	> 10	> 10	> 10	> 10	< 10
1975	< 10	< 10	< 10	> 10	> 50	< 10	< 10	< 10	< 10
1979	> 10	> 10	> 10	> 10	> 10	> 10	> 10	> 10	> 10
1996	> 10	> 10	< 10	> 50	< 10	< 10	> 10	> 10	< 10
1997	> 100	> 100	> 10	> 10	> 10	> 100	< 10	> 100	< 10
2002	< 10	< 10	< 10	< 10	< 10	> 500	> 500	< 10	< 10
2006	> 10	> 10	> 10	< 10	> 10	> 10	< 10	> 10	< 10
2009	> 10	> 10	> 50	> 100	> 10	> 10	< 10	> 100	< 10
2010	> 10	> 10	> 10	> 10	> 10	< 10	< 10	< 10	< 10
2011	> 10	> 10	> 10	> 100	> 10	< 10	< 10	> 50	< 10
2013	< 10	< 10	< 10	> 10	< 10	> 10	< 10	> 100	> 10

Legend:

> 500	Greater than 500 year event
> 100	From 100 year to 500 year event
> 50	From 50 year to 100 year event
> 10	From 10 year to 50 year event
< 10	Less than 10 year event

n.r. = no records available

MAJOR FLOODS IMPACT MAINSTEM LOCATIONS DIFFERENTLY

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

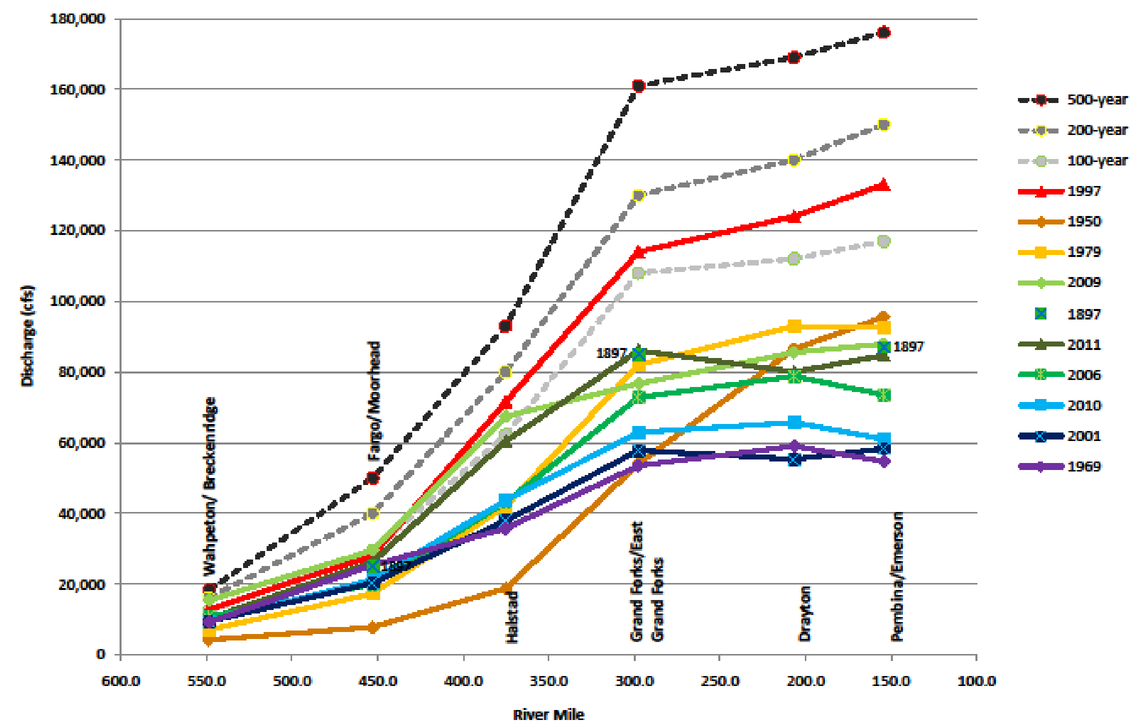
LTFS

RETENTION

POTENTIAL

- Gray: 100 Year Flood have been experienced in Halstad, GF/EGF, Drayton and Pembina/Emerson
- 200 Year and 500 Year Floods: Not Yet

Figure B-6 Comparison of Discharge along Main Stem of Red River of the North for Select Historical Floods and Design Flood Events



9/15/2011

MAJOR DAMS IN RED RIVER BASIN

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

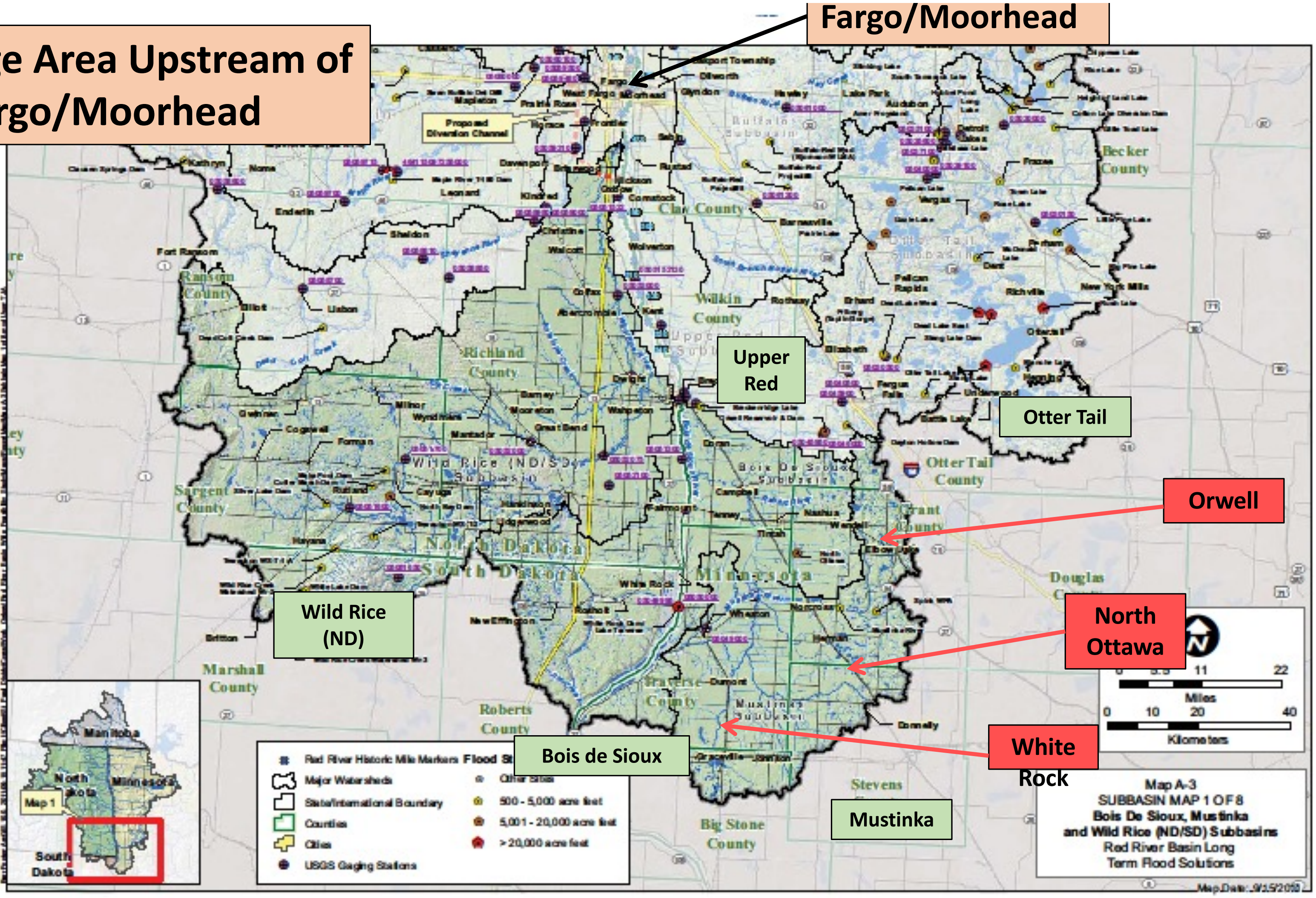
LTFS

RETENTION

POTENTIAL

- **Fargo/Moorhead** have Bois de Sioux/Mustinka, Ottertail & Wild Rice (ND) Rivers upstream
- White Rock, Orwell, and North Ottawa dams have significant flood storage to potentially reduce flood flows at Fargo/Moorhead
- Effects of each dam varies with specific flood
- ND Other Rivers and Dams: Baldhill and Maple River enter downstream of F/M.

Drainage Area Upstream of Fargo/Moorhead



RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

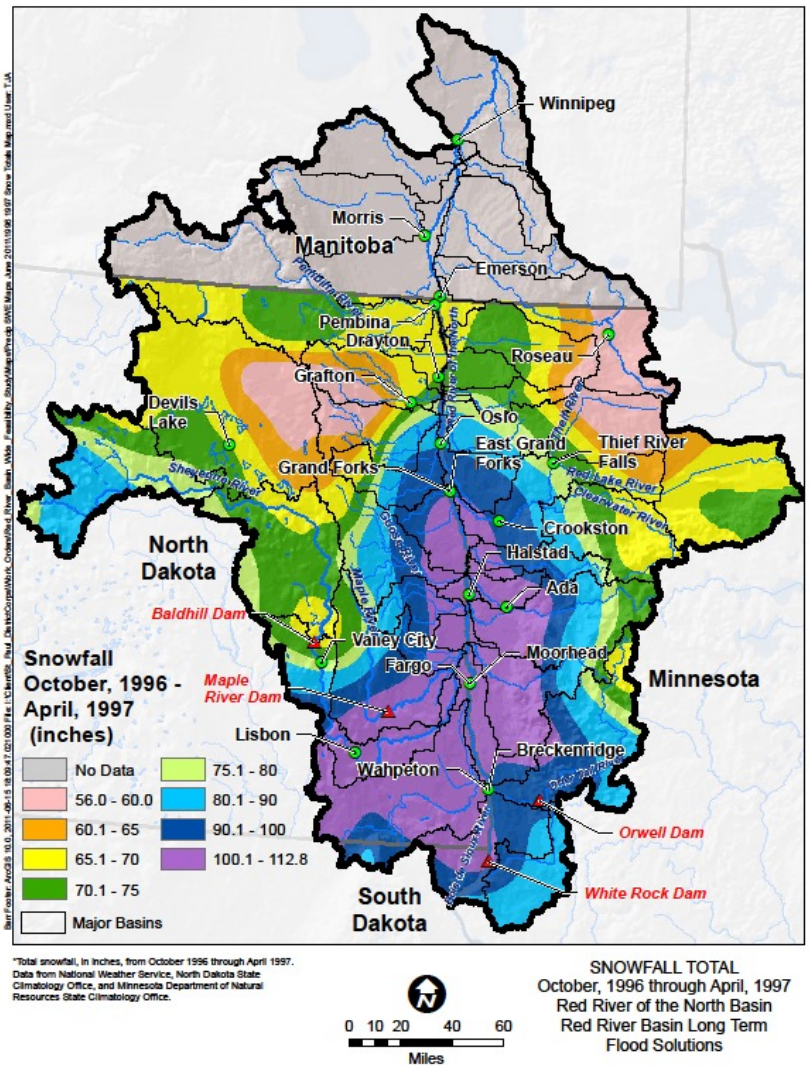
RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL



TOTAL SNOWFALL

PRIOR TO 1997 FLOOD

- Very large part of the drainage area upstream of Grand Forks and East Grand Forks had over 100 inches of total snowfall (potentially greater than 10 inches of water content)
- 10 inches snow = approx. 1 inch water
- Predictions can be off due to: 1) snow & water content in deep river ravines, 2) dryness of soil to absorb water, 3) and melt conditions.

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

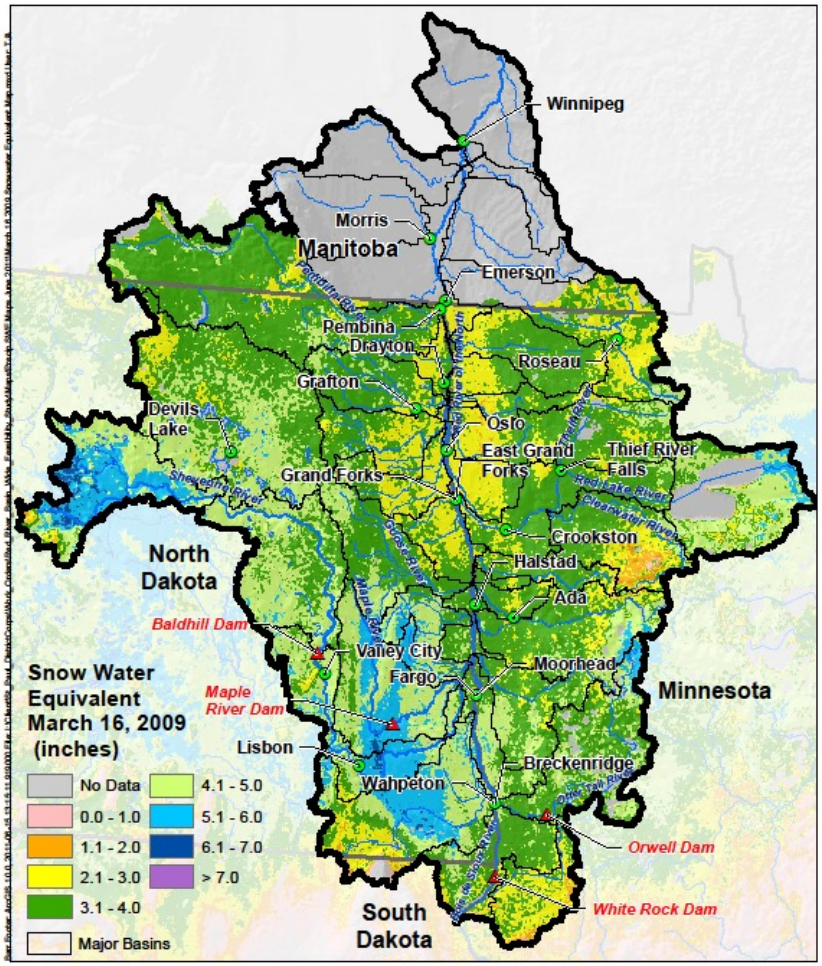
RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL



MODELED SNOW WATER EQUIVALENT ESTIMATE
March 16, 2009 (NOAA)
Red River of the North Basin
Red River Basin Long Term Flood Solutions

SNOW WATER
CONTENT ESTIMATE 2009
MAY 16, 2009

- Most of drainage area upstream of Fargo/Moorhead had over 4 inches of water content
- Portions of the Sheyenne River and Wild Rice River (ND) watersheds had over 5 inches of water content
- Amount of water ready to run off upstream of F/M most on ND side.

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

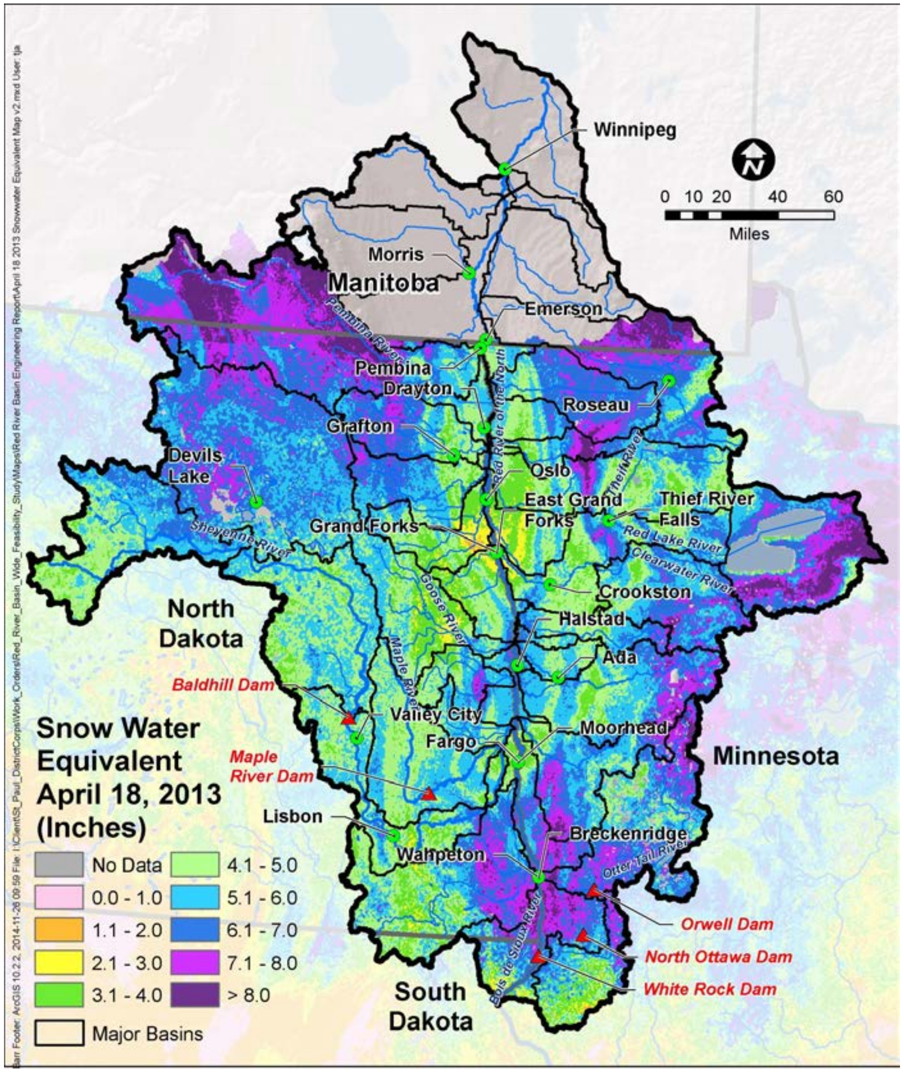
LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS RETENTION POTENTIAL



SNOW WATER

CONTENT ESTIMATE 2013 APRIL 18, 2013

- Major flood predicted at Fargo/Moorhead based on upstream water content just prior to melt and potential melt/runoff conditions
- Greater than 7 inches of water content upstream of Fargo/Moorhead, but downstream of flood storage dams
- Ideal melt and runoff conditions resulted in only minor flood event
- Heavy water content on ground all downstream of reservoirs, upstream of F/M, no flood due to ideal melt no rain. Typical spring F/M would have flooded—was forecast.

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

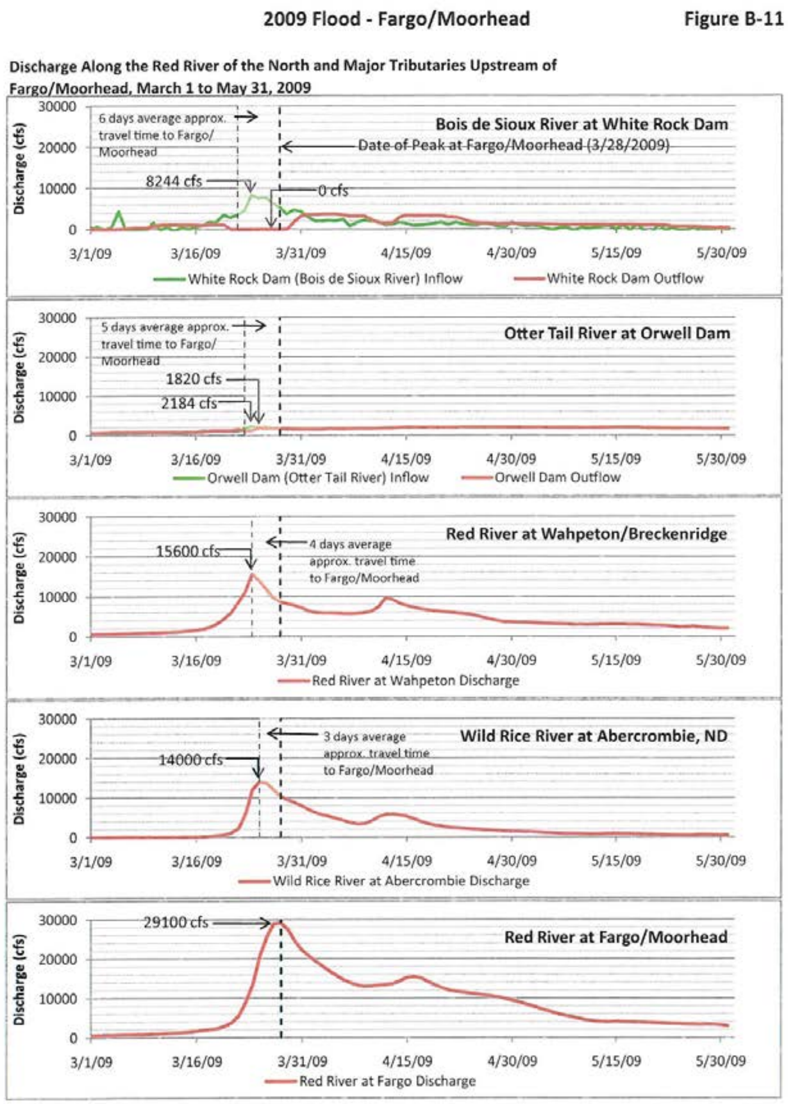
RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL



2009 FLOOD
RED RIVER@ FARGO

- White Rock Dam effectively controlled flood inflows so that outflows had no contribution to F/M peak flow
- Ottertail River & Orwell Dam had little effect on flood
- Peak flows from Red River @ Wahpeton/ Breckenridge and Wild Rice (ND) contributed directly to Fargo peak

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

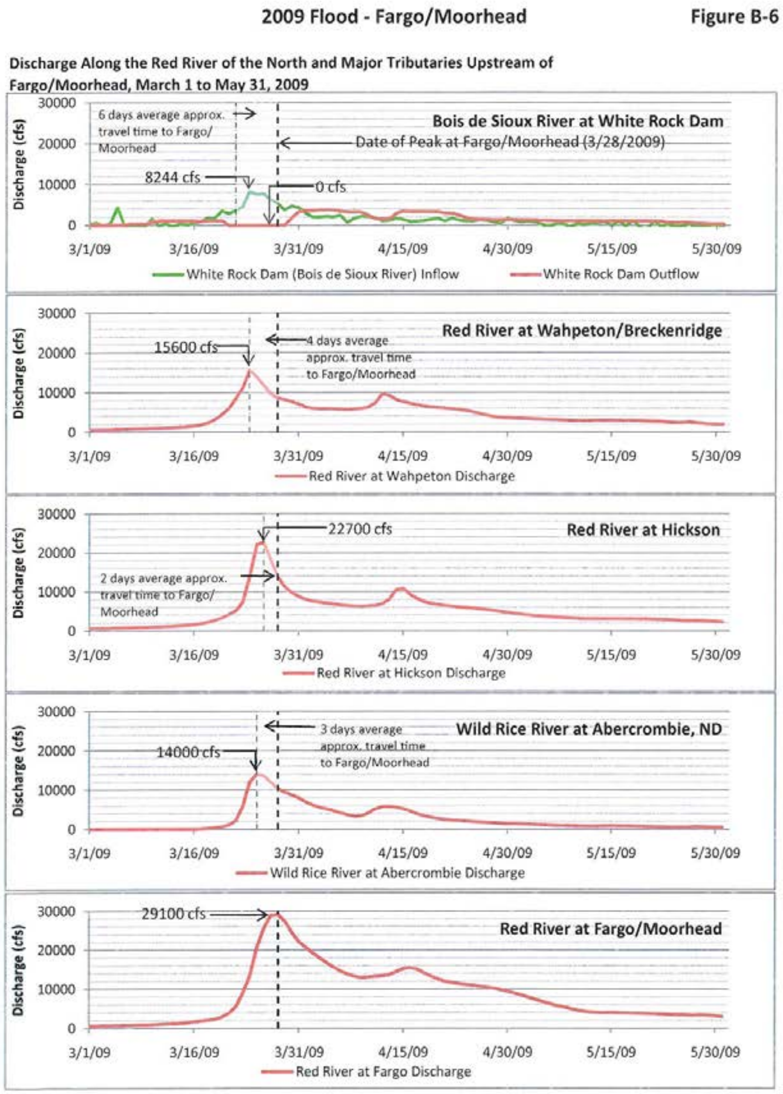
RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL



2009 FLOOD RED RIVER@ FARGO

- Peak flows on Red River increased between Wahpeton/ Breckenridge and Hickson
- Significant runoff from drainage area to Red River between Wahpeton/ Breckenridge and Hickson contributed directly to peak flows at Fargo (The difference between the two comes mostly from the Upper Red area. 2009 but not 1997)

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

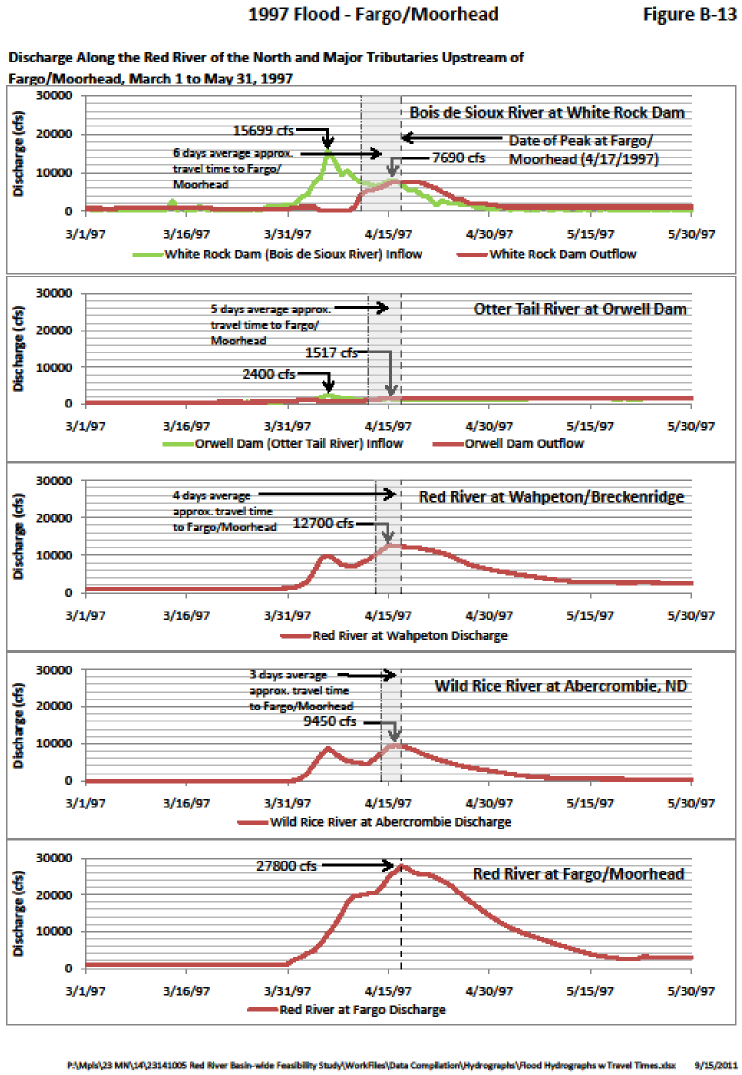
RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL



1997 FLOOD RED RIVER@ FARGO

- White Rock Dam significantly reduced flood flows on Bois de Sioux River, however outflows did contribute to F/M flood peak
- Orwell Dam and Otter Tail River had little effect on flood peak at F/M area
- Drainage areas from Bois de Sioux and Wild Rice Rivers were primary contributors to F/M flood peak

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

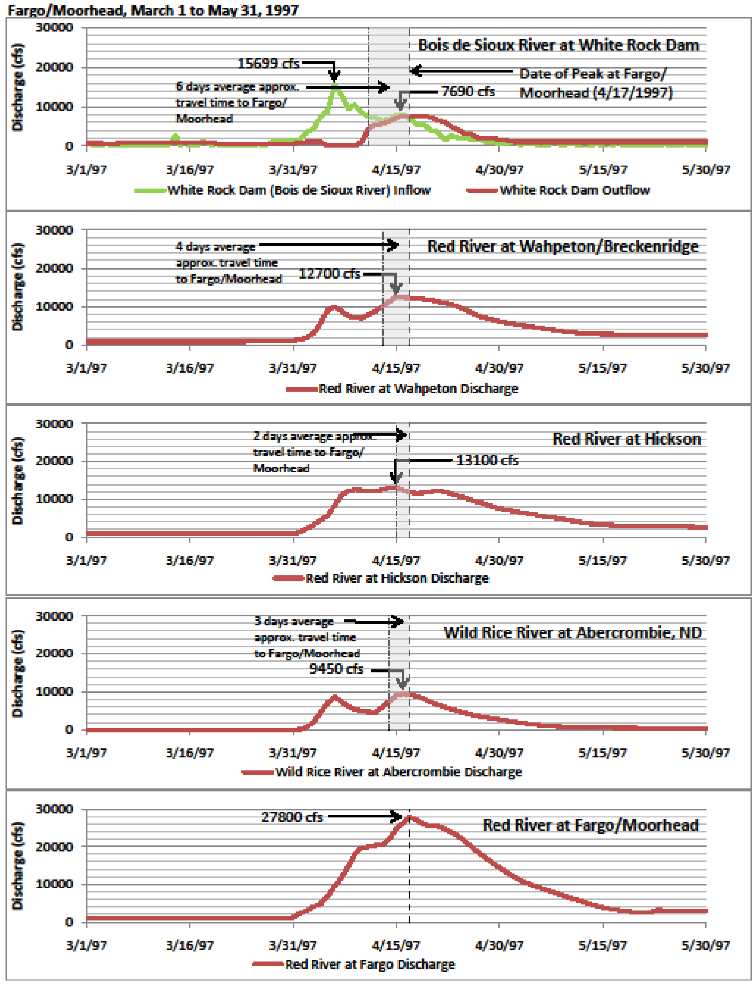
RISKS

RECOMMENDATIONS

LTFS RETENTION POTENTIAL

1997 Flood - Fargo/Moorhead **Figure B-14**

Discharge Along the Red River of the North and Major Tributaries Upstream of Fargo/Moorhead, March 1 to May 31, 1997



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1997 FLOOD RED RIVER@ FARGO

- Drainage area along Red River between <u>Wahpeton/ Breckenridge and Hickson did contribute</u> some to F/M flood peak flows

RED RIVER BASIN

EARLY FLOOD ORGANIZATIONAL HISTORY

MAINSTEM MODELING

LTFS

ASSUMPTIONS

RISKS

RECOMMENDATIONS

LTFS

RETENTION

POTENTIAL

RELATED TO DISTRIBUTED STORAGE

- LTFS distributed storage goal is to reduce future flood damages by reducing flows.
- Accomplished primarily by detaining/retaining water upstream.
- 20% Flow Reductions for the Red River Basin at the International Boundary and as each tributary enters the Red River.
- <u>Are there enough locations to achieve this?</u>

- The Basin Commission next encouraged each water district to identify storage it could build to meet its flow reduction allocation.
- Existing hydrologic models (where available) were used by local water management engineers to prepare revised tributary hydrographs to the Red River that would result from the planned storage.
- Requires construction of multiple storage facilities (impoundments) distributed throughout the basin.
- <u>How can distributed storage change our floods</u>?
  - Set a goal high enough to significantly reduce flood damages
  - Set it low enough to be considered doable and reasonably foreseeable

WRAP-UP: LTFS GUIDING THE FUTURE

1. Updates annually by RRBC (annual conference)
2. **Working Toward Flood Damage Reduction** (mostly dikes, diversions)
3. **Reducing Losses Biggest Risks**
   - Fargo-Moorhead (in progress) & Devils Lakes (done)
5. **Level of Protection Goal Recommendations** (Oslo & Halstad only)
6. Floodplain Management (some progress, new maps)
7. Retention (planning but little construction since 2013-LTFS)
8. Administration, Policy, Coordination, Research, Data (some data and decision tools progress, more needed in all areas)
9. Basin Funding Strategy (going backwards at water district level-states)

WRAP-UP: LTFS FUNDING NEEDS

Based on 2011-2013 Numbers

Flood Damage Risk Reduction: Will cost $4.6 billion for the U.S. portion of the basin. (see graph in LTFS report)

- **Greatest Risk #1: Fargo-Moorhead**
  - *Includes $1.77 billion for a proposed* diversion channel to *protect Fargo-Moorhead*

- **Greatest Risk #2: Devils Lake**
  - Over a billion dollars has been invested and since 2013 the emergency armoring is complete.

- **Distributed Storage:**
  - It will take years, decades to fully implement.
  - 1.5 million acre-feet of storage on the U.S. side of the border to ensure a 20 percent reduction in peak flows.
  - Cost at $1,000 ac/ft is $1.5 billion.

- **Community projects, rural ring dikes, Buy-Outs:** the remaining costs**.**

If implemented, the comprehensive plan would prevent significant damage from flooding: $10.2 billion and $12.8 billion for the basin with most of the damages in the F/M area, for a single 500-year flood.

WRAP-UP: IMMEDIATE CRITICAL NEEDS/CRITICAL RISKS FARGO-MOORHEAD

➢ Recommendation for Action 1.1

- The flood protection trajectory that has increased protection in F/M metro area since 2009 flood should continue. State and federal funds, with local government cost share, should continue supporting ongoing dike construction, property acquisitions, flowage easements, and flood infrastructure project to be able to fight at least a 100-year flood, and upwards of a 500-year flood in the long term.

➢ Recommendation for Action 1.2

- Progress towards the proposed $1.77 billion diversion should be continued utilizing local, state, and federal funds so that, combined with current flood protection strategies, this community will have the capacity within 10 years to wage a successful flood fight equal to or greater than the LTFS 500-year flood.

WRAP-UP: IMMEDIATE CRITICAL NEEDS/CRITICAL RISKS FARGO-MOORHEAD

➢ Recommendation for Action 1.3

- Retention upstream of the Hickson and Abercrombie stream gage for a flow reduction of 20% (minimum) should be advanced with shared funding by the F-M flood Diversion Authority working with local and joint water boards, using city, local, state and federal funds.

➢ Recommendation for Action 1.4

- Leader in state government in ND and MN, along with key local government officials and with input from the Diversion Authority and federal agencies, should convene by early 2012 to determine the non-federal cost share formula for the Locally Preferred Plan ($1.77 billion) diversion, and related #3.5 million operational estimates.