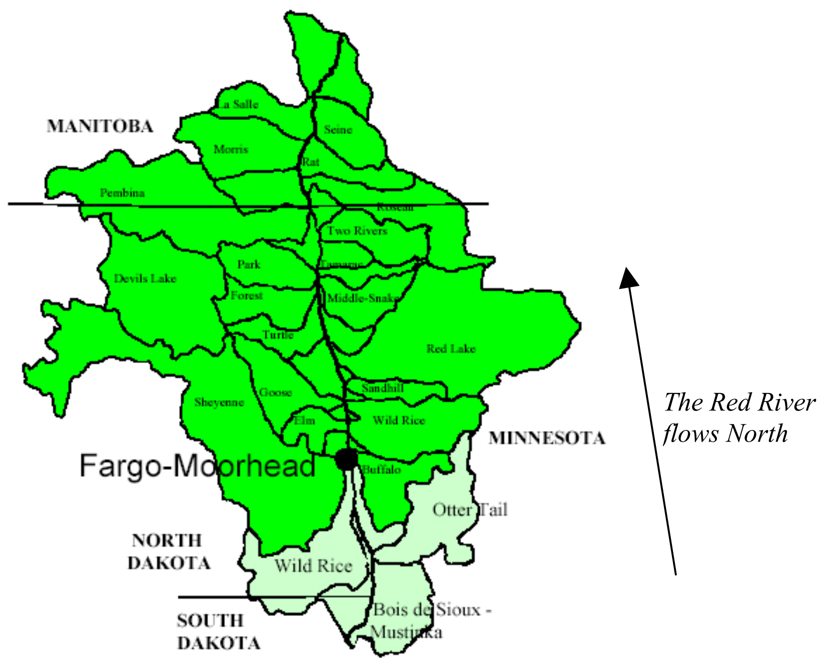
Fargo-Moorhead and Upstream Feasibility Study
Phase 1 Summary
September 9, 2005

I. INTRODUCTION

<u>A. Purpose</u>. This report provides a summary of Phase 1 of the Fargo-Moorhead and Upstream Feasibility study. The study was conducted from August 2004 through June 2005. Comments from meetings on 29-Jun-05 and 8-Sep-05 are incorporated.

<u>B. General Background</u>.

1. The Fargo-Moorhead and Upstream Feasibility Study (FMUS) was recommended in the September 2001 Red River Reconnaissance study and is authorized by a 30-Sep-74 Resolution of the Senate Committee on Public Works. A Feasibility Cost Sharing Agreement was signed on August 20, 2004. The study is looking for ways to reduce flood stages and restore aquatic ecosystems in the Red River Basin upstream (south) of Fargo-Moorhead (see map below). It will evaluate alternatives including a system of multi-purpose surface water storage sites that restore wetland habitat and provide flood damage reduction benefits.



2. The North Dakota State Water Commission and the City of Moorhead are jointly sponsoring the study. Additional cost-sharing partners include Southeast Cass Water Resource District; Richland County Water Resource District; Red River Joint Water Resource District; City of Fargo; Buffalo-Red River Watershed District; Bois de Sioux Watershed District; Minnesota Department of Natural Resources; Minnesota Board of Water and Soil Resources; Minnesota Pollution Control Agency; South Dakota Department of Game, Fish, and Parks; and Red River Basin Commission. The official Sponsors and their partners must provide 50% of all study costs through non-federal cash and in-kind contributions. The US Army Corps of Engineers provides the other 50% of the study funding.

3. The planning objective is to formulate projects that advance both flood damage reduction and natural resource enhancement. The major underlying assumption is that a system of surface water storage sites upstream of Fargo-Moorhead will produce cumulative flood stage reductions and reduce flood damages downstream. We also assume that water storage can be accomplished in ways that restore aquatic ecosystems and increase habitat for wildlife.

4. Phase 1 is the first of three phases planned for the overall Fargo-Moorhead and Upstream Feasibility study. Each phase will be progressively more specific and detailed in order to determine the Federal interest in constructing a project. Phase 1 was intended to test the viability of a "distributed storage concept" and determine whether additional study is warranted. Phase 1 consisted of the following major tasks:

a) Link existing hydraulic models together and use assumed hydrology (with input from others) to determine the potential effects of upstream storage on water levels in F-M.

b) Preliminary urban economic analysis in Fargo and Moorhead to understand potential urban flood damage reduction benefits. Develop depth-damage curves based on a sampling of structures in the flood plain.

c) Begin to identify potential storage sites and assess the total available storage in various basins (using existing planning as much as possible).

d) Consider environmental concerns and opportunities related to the concept of distributed storage. Meet with all environmental stakeholders to identify existing information, plan for additional field studies in Phase 2, and identify concerns that affect the decision to proceed.

e) Discuss plan formulation and justification with Corps of Engineers higher authorities to understand how a multi-site, multi-purpose formulation would be evaluated. (A teleconference was held on May 5, 2005.)

f) Conduct a relatively small public involvement effort to share preliminary study findings. (Public meetings were held on March 28-29, 2005 in Breckenridge, MN and Fargo, ND.)

g) Prepare scope of work for Phase 2 study.

5. Phase 1 was constrained by both time and funding. The study partners desired to focus on the potential for a system of impoundments to produce stage reductions and corresponding flood damage reduction benefits in the Fargo-Moorhead area. While the team recognized that there probably would be significant flood damage reduction benefits to areas between the impoundments and Fargo-Moorhead, no attempt was made in Phase 1 to quantify them. Similarly, preliminary environmental discussions were included in order to identify conceptual opportunities and constraints. Significant environmental assessment was planned to begin in Phase 2.

C. Flood Damage Reduction Issues. The Red River Basin lies in the bed of Glacial Lake Agassiz, and it has a long history of flooding. The cities of Fargo and Moorhead have extensive emergency plans to deal with flooding, and have done so very effectively in the past. Other rural and urban areas within the study area also have recurrent flood damages. Large floods on the Red River typically occur in April during snowmelt, but summer rainfall events can cause significant agricultural damage in the basin. The 1997 flood (which devastated the Grand Forks, ND area further downstream) was approximately a 70-year event in Fargo. (Note: the hydrologic assumptions used throughout this report are different than those used for the FEMA flood insurance mapping.) Floodplain delineations are still being revised to reflect recent significant floods, but it is expected that a large portion of the City of Fargo will be within the new FEMA 100-year flooded outline. The area is extremely flat, so very small reductions in flood elevation would produce large economic benefits. There have been significant investments in flood damage reduction measures for both agricultural and urban areas throughout the study area.

D. Environmental Considerations.

1. The Red River basin lies within the Prairie Pothole Region (PPR), which has been dramatically affected by drainage and tillage predominantly related to this region's urban development and agriculture-based economy (Figure 1).

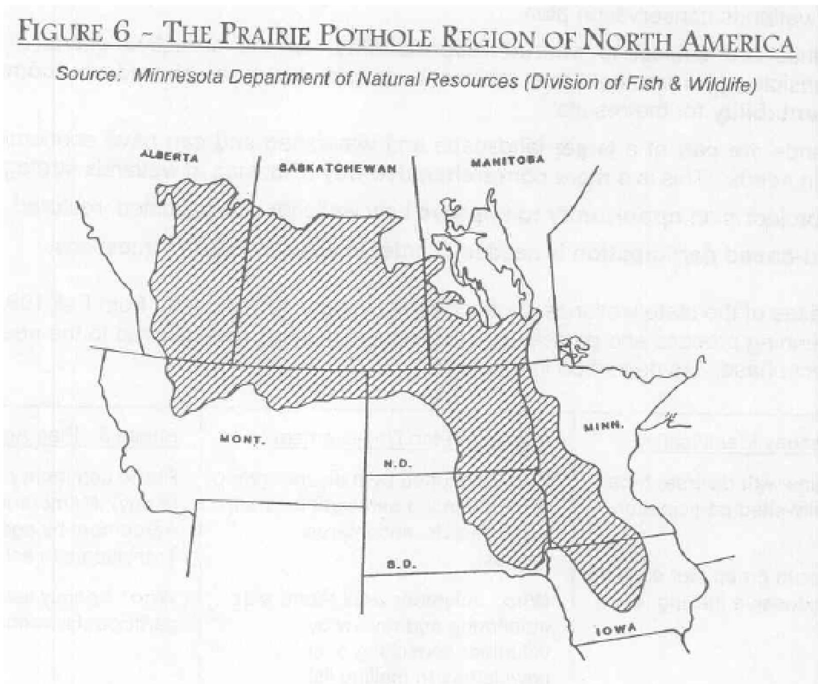


Figure 1-Prairie Pothole Region

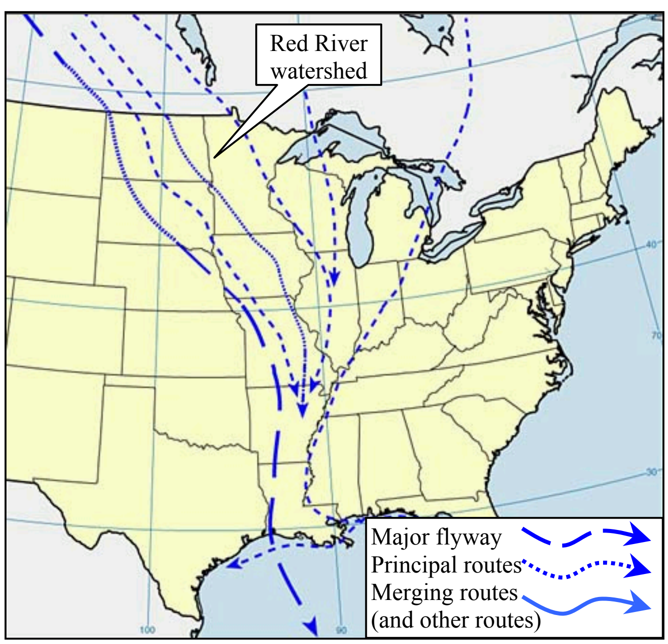


Figure 2 – Mississippi Flyway and study area

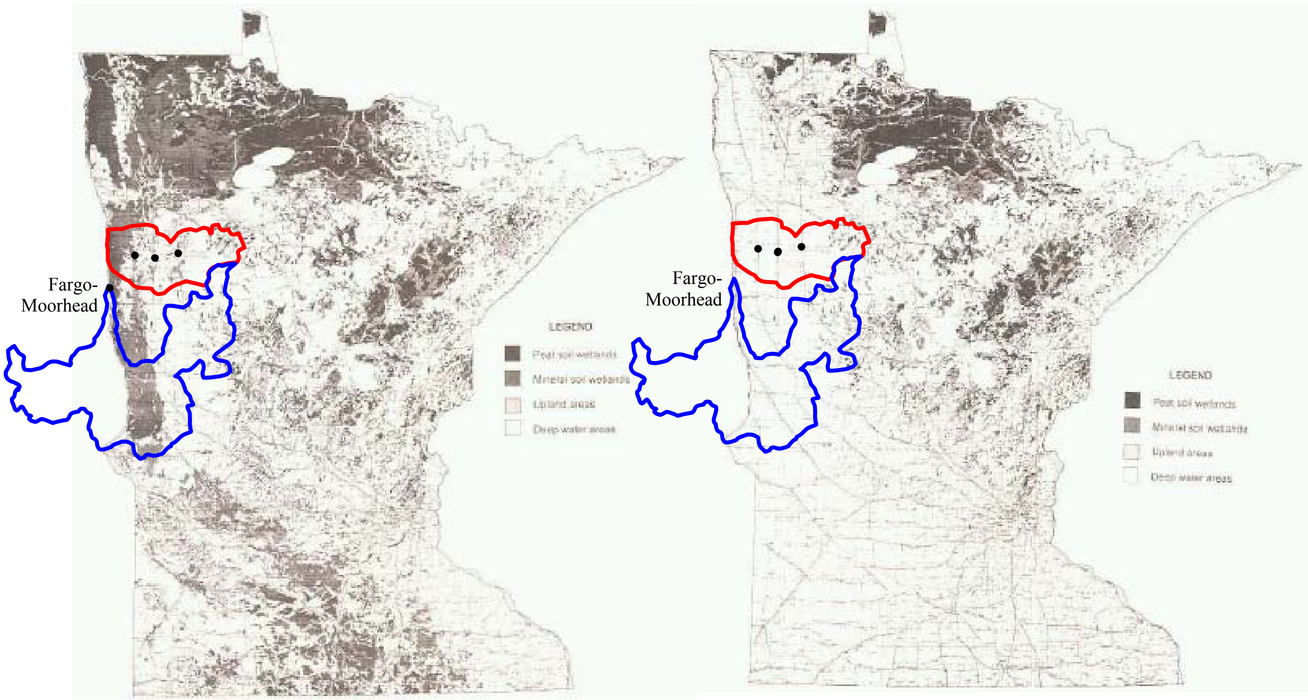


Figure 3 – Estimate of Minnesota Wetlands Circa 1860s and 1981 (FMUS Study area outlined in blue).

2. According to the 1997 Minnesota Wetlands Conservation Plan, over 95 percent of the wetlands in the Minnesota portion of the Fargo-Moorhead and upstream subbasin (blue outline in Figure 3) have been lost. Figure 3 also illustrates the general loss of wetlands in the whole Prairie Pothole Region (PPR). The resulting habitat loss has caused a dramatic decline in wetland-dependent wildlife populations. Because the Red River basin lies within a major waterfowl and shorebird migration route (Figure 2), the loss of permanent and seasonal wetlands has had a measurable adverse impact on migratory success.

3. The Prairie Pothole Region Joint Venture is one of six original joint venture regions under the North American Waterfowl Management Plan (NAWMP). The joint venture was established to conserve and enhance wetland habitat throughout the region. Wetlands in the PPR are among the continent's most biologically productive systems, providing habitat for waterfowl, shorebirds, wading birds, amphibians, and a variety of other wildlife. These wetlands are important for maintaining and recharging groundwater supplies and improving water quality, storing floodwaters, and trapping sediments. The PPR wetland complexes and their associated grasslands are an integral component of the prairie landscape, providing a wide array of ecological, social, and economic benefits.

4. The FMUS study is evaluating projects that would restore many different types of wetland habitat. Smaller scale impoundments and "pothole" restorations would contribute toward the NAWMP's acreage goals. Wetland restoration projects within the study area would provide waterfowl breeding habitat, and shorebird migration habitat in areas where it is currently limited or nonexistent, especially during late summer and fall. Restored wetlands could also provide other wetland functions, including low flow augmentation, improved fish habitat, improved water quality, and aquifer recharge. Given the extent of wetland drainage in the basin, there is a high potential for wetland restoration to provide significant habitat benefits.

II. HYDROLOGY AND HYDRAULICS

A. Description of distributed storage concept.

1. A range of storage potential was estimated by reviewing preliminary watershed district plans for basin storage. The storage potential for two preliminary plans was averaged over the drainage area of the corresponding basin. The estimate for the low end of the range of storage potential was 40 acre-feet per square mile for a total of 200,000 acre-feet of storage upstream of the Fargo gage. The estimate for the upper end of the range of storage potential was 80 acre-feet per square mile for a total of 400,000 acre-feet of storage upstream of the Fargo gage. Figures 4 and 5 show the low and high estimates of potential storage for various watersheds. A 31,000 acre-foot and a 60,000 acre-foot reservoir downstream of White Rock Dam were also modeled in combination with the 200,000 acre-feet of storage resulting in scenarios of 231,000 acre-feet and 260,000 acre-feet of storage for Scenarios L3 and L2, respectively.

2. The storage for the scenarios analyzed is distributed throughout the basin in small impoundments ranging in size from 2,000 acre-feet to 20,000 acre-feet. This type of storage would affect the tributary hydrograph throughout the flood event. Without knowing the specific size and location of the storage impoundments and without using a detailed hydrologic model, it is difficult to compute the change in the tributary hydrographs. For this analysis under scenarios L1, L2, L3 and H1 as discussed in the following paragraphs, it is assumed that the storage effect would be proportionate to the original flood hydrograph for a 30-day period from 15 March to 15 April. For scenario H5, the storage is taken off the tributary hydrographs by eliminating flow above a constant discharge that provides the estimated storage potential. Scenario H5 has less impact on the tributary hydrographs in comparison to Scenarios L1, L2, L3 and H1 since the storage was divided by a factor of 5 to reflect transferring the impacts to the upstream boundary for the HECRAS unsteady flow model.

B. Methodology for modeling.

1. A Hydraulics and Hydrology Technical Team was established in accordance with the Fargo Moorhead and Upstream Feasibility Study Project Management Plan dated November 18, 2004. The Hydraulics and Hydrology Technical Team is as follows:

Hydraulics and Hydrology Technical Team

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Meetings with the Hydraulics and Hydrology Technical Team were held on November 19, 2004 and June 22, 2004 at the Red River Basin Commission Office in Fargo, North Dakota. Additional coordination with various members of the team was accomplished on as needed basis. Extensive coordination with the EERC, the NDSWC and others took place. The Hydrology used for 1997 Flood Event HECRAS unsteady flow simulation in this study is from the EERC and required close coordination so that the SWAT simulated hydrographs could be incorporated into the HECRAS unsteady flow model simulation for the 1997. This applies to the Red River of the North Main Stem unsteady flow modeling and the unsteady flow modeling of the lower Maple and Sheyenne Rivers. In addition, the unsteady flow modeling of the Maple and Sheyenne Rivers was coordinated closely with the participants of a subcommittee for the Red River Basin Commission.

2. The hydraulic evaluation uses both steady flow HECRAS models and unsteady flow HECRAS models. The steady flow HECRAS models developed for the January 2003 *Regional Red River Flood Assessment Report for Wahpeton, North Dakota/Breckenridge, Minnesota to Emerson, Manitoba* prepared by the U.S. Army Corps of Engineers, St. Paul District and the Federal Emergency Management Agency, Region V and Region VII were used for developing the existing conditions water surface profiles. The only change from the January 2003 profiles is that different hydrology is used, reflecting the required hydrology for evaluating Corps of Engineer projects. A HECRAS unsteady flow model was utilized for evaluating the project impacts on discharge hydrographs for the different scenarios. The impacts on the flow frequency curve at Fargo were then used to determine the impacts on the elevation frequency relationships.

3. The Scenarios evaluated are described below and summarized on Table 1:

a) Scenario H5- This scenario consists of taking storage off the upstream boundary condition hydrographs for the tributaries by eliminating flow above a certain discharge. The High Storage Potential value for the upstream boundary condition was divided by 5 to represent the storage at the upstream boundary of the HECRAS model.

b) Scenario L1 - This scenario is for a low estimate of storage as shown on Figure 4 with the storage distributed over a one month time period.

c) Scenario L2 - Same as L1 except that additional storage for State Line Dam was taken out of the White Rock Dam Outflow hydrograph after the distributed storage upstream of White Rock Dam was taken into account. This scenario does not impact the peak stage and discharge at Fargo but does lower the recession hydrograph. Essentially, what happens is that after a certain date for the 1997 simulation flood which is roughly April 15th, any further reduction in flow does not impact the peak stage at Fargo. The benefits of Scenario L2 are the same as L1.

d) Scenario L3 - Similar to L1 except that about 31,000 acre-feet storage was taken out of the flow from the tributary area of Big Slough located immediately downstream of White Rock Dam. This simulates the potential flood storage before April 15th that would be provided by the State Line Dam alternative.

e) Scenario H1- This scenario is for a high estimate of storage as shown on Figure 5 with the storage distributed over a one month time period.

4. For this study, uncertainty is addressed in the Economic Analysis. Uncertainty in the stage and discharge is taken into account as part of the Flood Damage Assessment risk analysis. Other considerations that contribute to uncertainty are:

a) In this evaluation, the specific size and location of the storage impoundments are not known making it difficult to determine the change in the tributary hydrographs for the upstream boundary conditions for the HECRAS unsteady flow model. Different assumptions were made resulting in the different scenarios analyzed. As can be seen from the results, the stage reductions vary. During the next phase of study, additional work is needed to refine this part of the analysis.

b) The analysis for this evaluation only looked at the 1997 historical flood event. For the frequency analysis, the impacts for events less than the 1997 flood are taken from the hydrographs simulated for this event. For events greater than the 1997 flood, it is assumed that the reduction in discharge would be the same as the 1997 event. Other flood events may not react similar to the 1997 event.

C. Results. Table 1 summarizes the estimated flood elevations and stage reductions in Fargo-Moorhead for the 100-year flood event under each scenario. The expected flow and stage reductions in the Fargo-Moorhead reach of the Red River of the North are shown in Figures 6, 7 and 8. Figure 6 shows the observed 1997 discharge hydrograph, the simulated 1997 discharge hydrograph and discharge hydrographs for simulations of the scenarios analyzed. Figure 7 shows the discharge frequency relationship for existing conditions and the different scenarios analyzed. Figure 8 shows the elevation frequency relationship for existing conditions and the different scenarios analyzed.

Table 1: Hydrologic and Hydraulic Scenarios and estimated stage reductions in Fargo-Moorhead

Scenario	Stored Volume (acre-feet)	Description	1% Flood Elevation (feet)*	Stage Reduction (feet)
Existing Conditions			902.4	
H5	400,000	Total volume divided by 5, peak-shaving method	902.1	0.3
L1	200,000	Total volume distributed over 30 days.	901.3	1.1
L2	260,000	L1 + 60,000 AC-FT Stored after April 15	901.3	1.1
L3	231,000	L1 + 30,000 AC-FT Stored before April 15	901.0	1.4
H1	400,000	Total volume distributed over 30 days.	900.8	1.6

* Note: the hydrologic assumptions used throughout this report are different than those used for the FEMA flood insurance mapping.

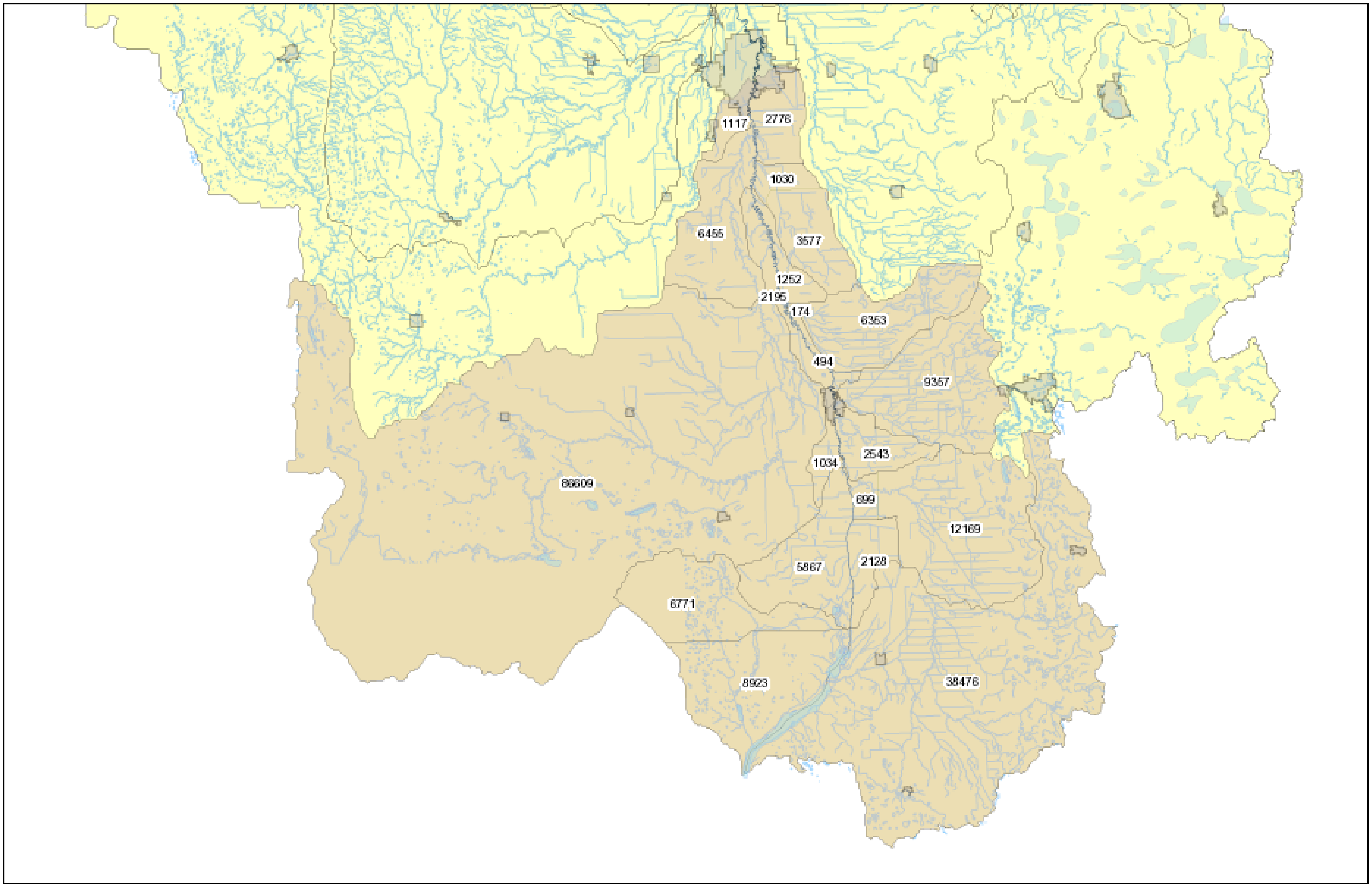

Figure 4. Low estimate of potential storage for the various watersheds upstream of the communities of Fargo, North Dakota and Moorhead, Minnesota.

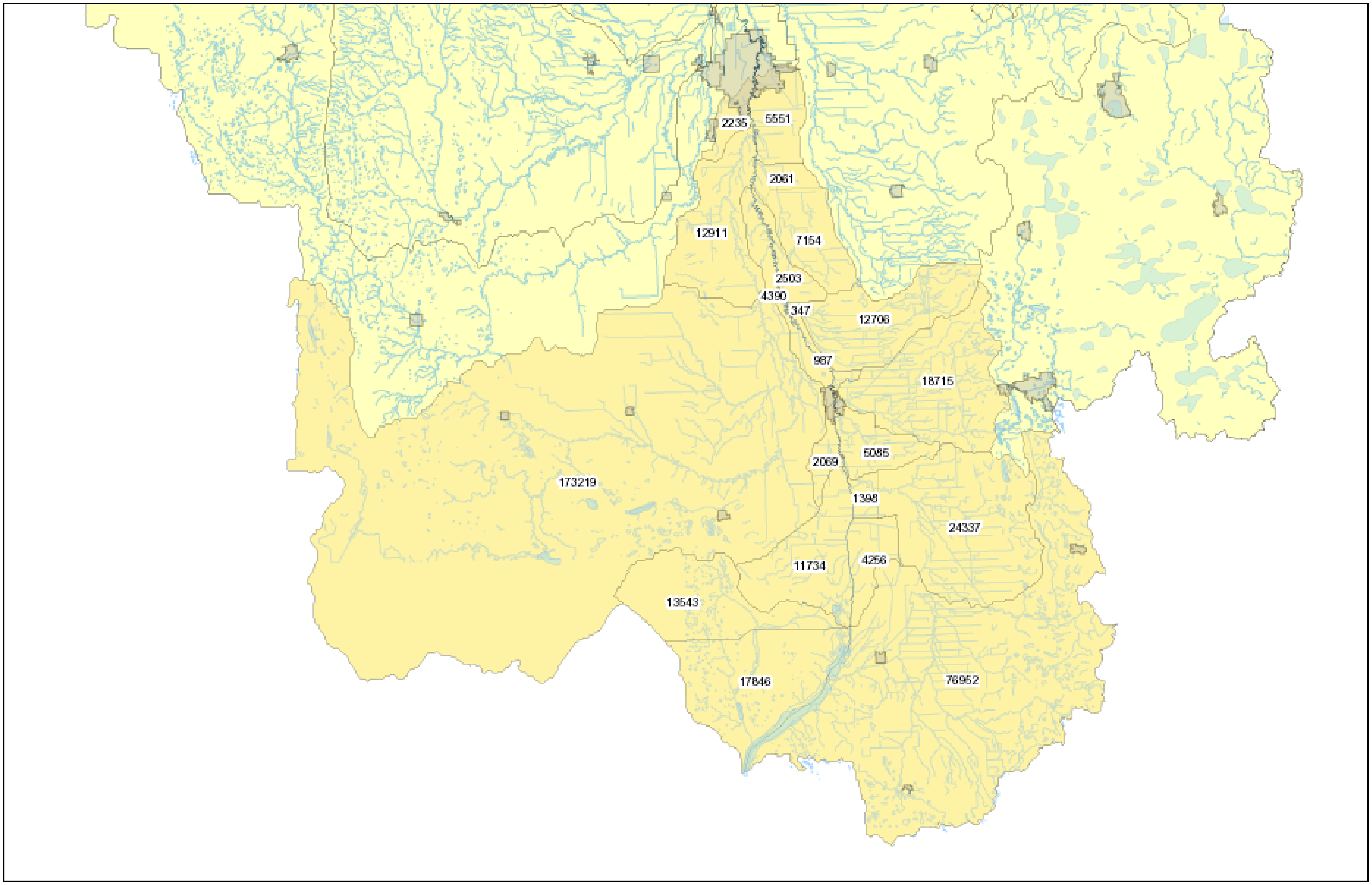

Figure 5. High estimate of potential storage for the various watersheds upstream of the communities of Fargo, North Dakota and Moorhead, Minnesota.

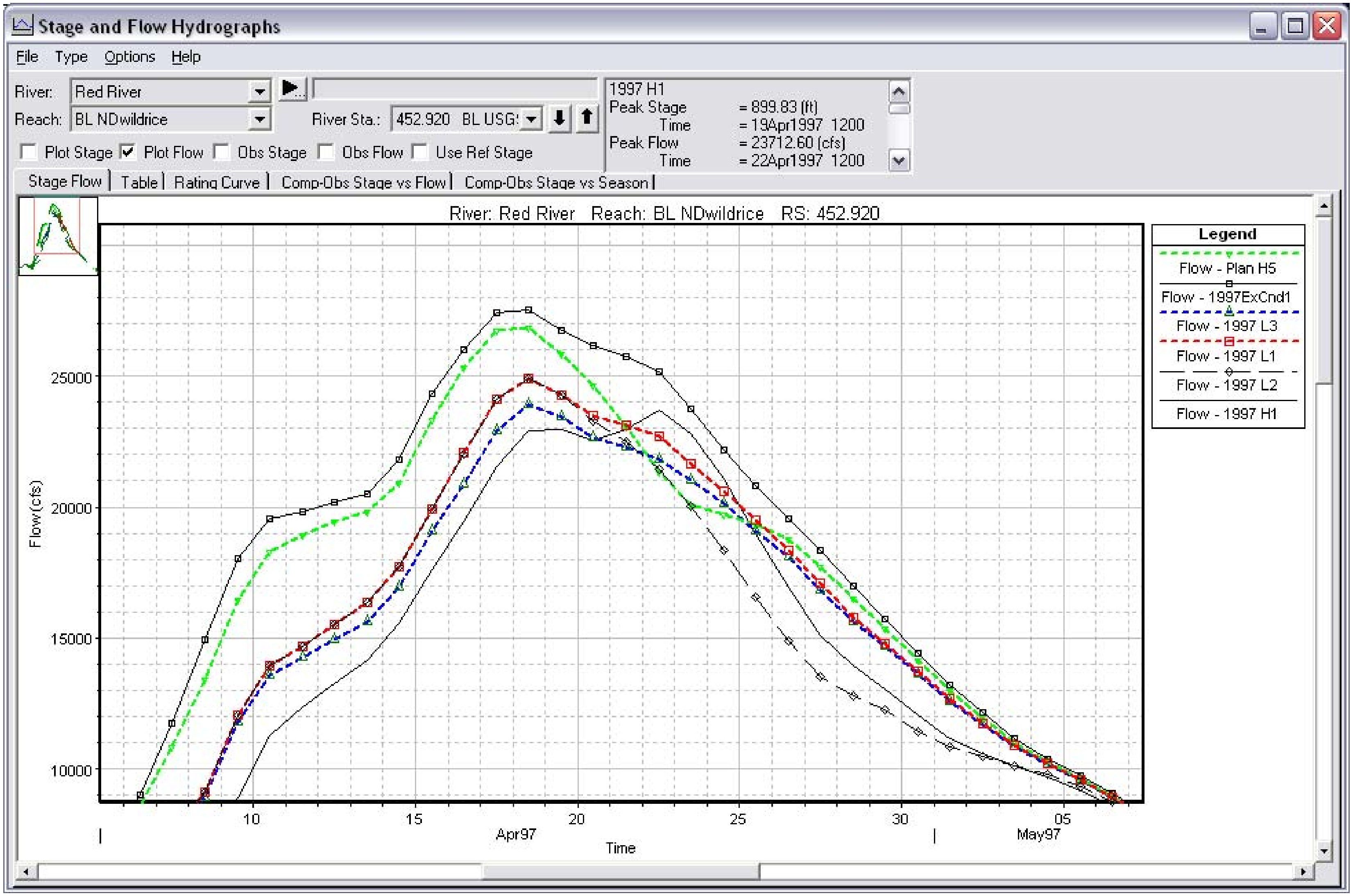

Figure 6. The HECRAS unsteady flow simulation results are shown for various scenarios in addition to the observed 1997 flood event discharge hydrograph for the location of the USGS Gage for the Red River of the North at Fargo, North Dakota.

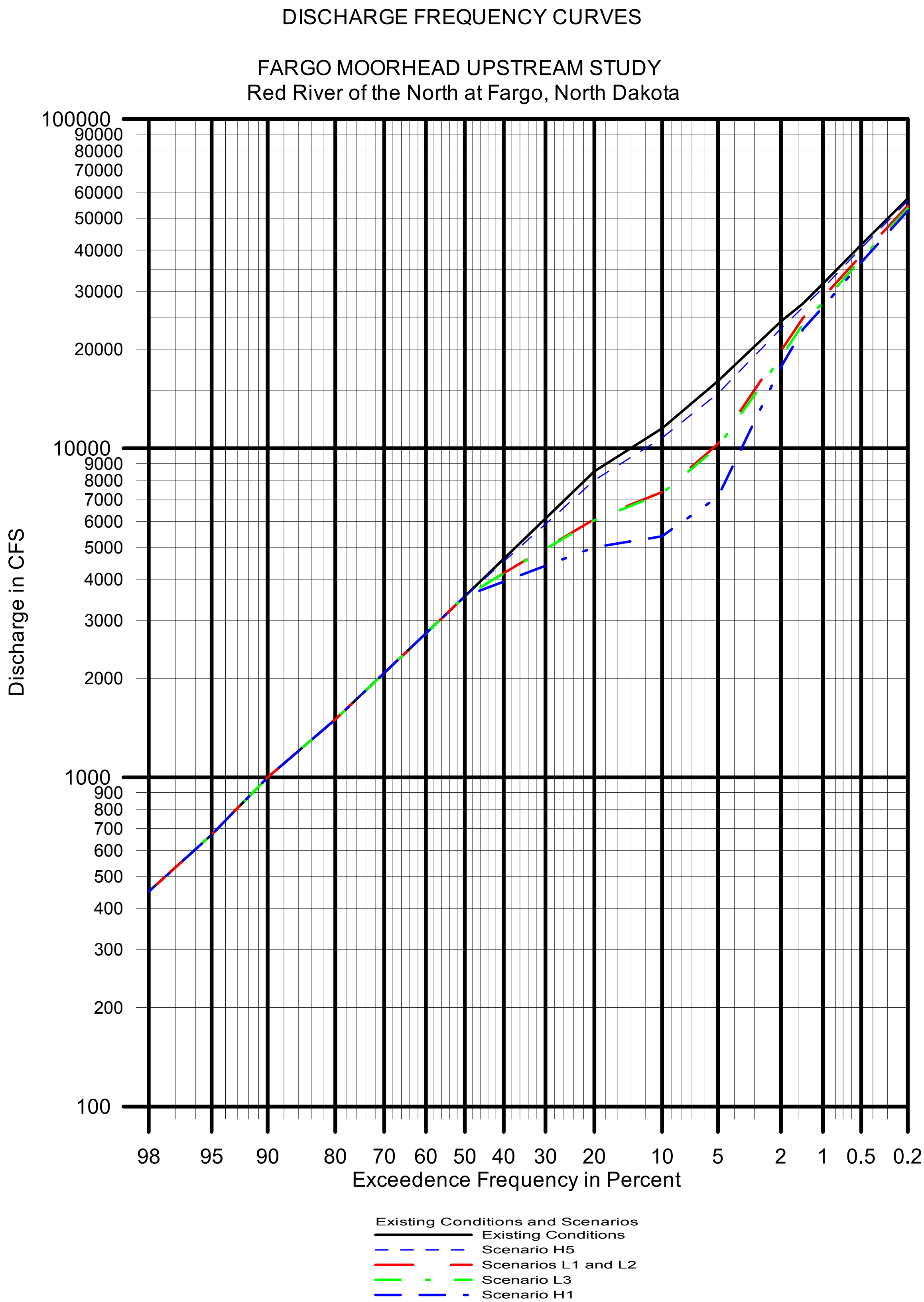

Figure 7. Discharge frequency curve for existing conditions and various scenarios for the Red River of the North at the location of the USGS gage for the Red River of the North at Fargo, North Dakota.

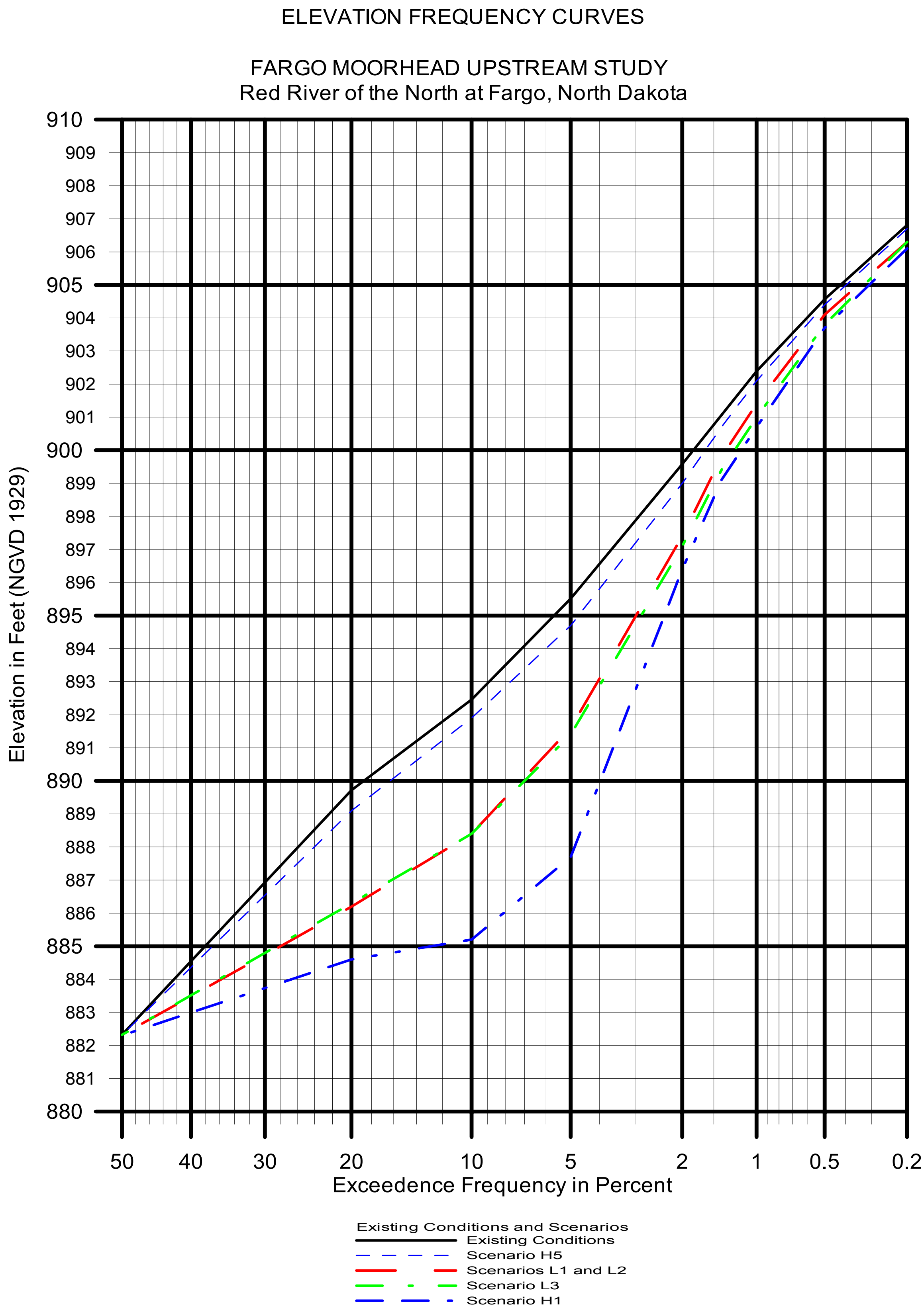

Figure 8. Elevation frequency curve for existing conditions and various scenarios for the Red River of the North at the location of the USGS gage for the Red River of the North at Fargo, North Dakota.

III. ECONOMIC ANALYSIS

A. Methodology.

1. The economic analysis for Phase 1 of the Fargo-Moorhead and Upstream Feasibility Study (FMUS) focused on potential benefits at Fargo-Moorhead. This is where most of the Federal (National Economic Development) flood damage reduction benefits for an upstream storage plan will likely occur and hence, this is where initial efforts were focused to help decide whether or not to proceed with Phase 2 of the study. The project features would create economic benefits to agricultural and urban areas upstream of Fargo-Moorhead, but no attempt was made in Phase 1 to quantify those benefits.

2. The Corps' Flood Damage Assessment computer model (FDA) was used to evaluate flood damages for existing conditions and for conditions with various storage plans in place. The reduction in flood damage resulting from a storage plan is the project benefit (referred to, in Corps vernacular, as National Economic Development, or NED, benefits). Among the input required by the model is data on structures in the flood plain including structure type, value, and ground and first floor elevations. This data was obtained from the respective cities and formatted for use in the model. Additional input required for the model is a set of eight water surface profiles ranging from the 2-year event up to the 500-year event. For this evaluation, existing conditions water surface profiles were developed for the eight events as indicated in Table 2. Separate profiles were not developed for the different scenarios. Instead, the new flood event probabilities for each were developed by using the revised discharge hydrographs for each scenario and the elevation discharge rating curve at the location of the USGS Gage for the Red River of the North at Fargo, North Dakota. Table 1 below presents the flood probabilities for the eight profiles under the existing condition and for four different with-storage scenarios. A description of the scenarios can be found in the H&H section of this report.

Table 2 – Flood Event Probabilities by Scenario (% Chance of Occurrence)*

Flood Profile #	Existing Condition	With-Storage Scenarios H5	L1 & L2	L3	H1
1	0.20	0.19	0.17	0.16	0.15
2	0.50	0.47	0.40	0.39	0.37
3	1.00	0.92	0.78	0.72	0.66
4	2.00	1.77	1.42	1.38	1.30
5	5.00	4.30	2.80	2.60	2.20
6	10.00	8.90	4.50	4.20	3.10
7	20.00	17.50	7.70	7.00	4.10
8	50.00	50.00	50.00	50.00	50.00

* Note: the hydrologic assumptions used throughout this report are different than those used for the FEMA flood insurance mapping.

3. Due to the preliminary nature of the Phase 1 economic analysis, some critical assumptions were made. One assumption deals with the level of flood protection provided by the existing system of levees and floodwalls. The system is not continuous throughout the Fargo-Moorhead flood plain. Gaps in the line of protection are filled by temporary levees during flood emergency situations. The existing levees provide as much as 100-year protection or more. But the level of protection assumed in the areas where the gaps exist is uncertain. For the purpose of this analysis, it was assumed that the existing flood protection is at the 100-year level.

4. Other significant assumptions dealt with the magnitude of potential storage volume that could be expected with a project in place and the effectiveness of this storage in reducing the flood threat downstream. At this time there is a high degree of uncertainty regarding this issue. The wide range in flood frequency reductions (Table 2) and the resultant benefits (Table 3 below) reflects this uncertainty.

B. Results.

1. As Table 2 indicates, upstream storage reduces the frequency of a flood event, the magnitude of which depends on volume and location of the storage impoundments. Reducing the probability of a flood event directly reduces the average annual damage, essentially a measure of the flood threat over a range of flood events. The amount of damages reduced equates to the benefit for the scenario under consideration. Table 3 displays the average annual damages and benefits associated with the storage scenarios evaluated. Table 3 also shows the present value equivalent of the average annual benefits. This figure is typically viewed as the amount of project costs that can be supported by the benefits and still maintain a benefit-cost ratio of 1.0.

Table 3 - Average Annual Damages and Benefits and PV Equivalent of Benefits ($000)

Scenario	Avg Annual Damages	/ Interest & Amort Factor *	PV of Avg Ann Benefits
Existing Conditions	$ 22,357		
Scenario H5	20,691		
Avg Ann Benefits	1,666	0.058	$ 28,724
Scenario L1 & L2	19,789		
Avg Ann Benefits	2,568	0.058	44,276
Scenario L3	19,119		
Avg Ann Benefits	3,238	0.058	55,828
Scenario H1	17,563		
Avg Ann Benefits	4,794	0.058	82,655

* At 5-3/8% interest over 50-year life

2. As mentioned above, one of the assumptions made for this analysis pertains to the level of protection provided by existing levees, floodwalls, and flood emergency efforts. A sensitivity analysis was performed to determine the effect of the assumed existing level of protection on flood damages and project benefits. This analysis showed that, while damages are sensitive to the assumed level of existing protection, more importantly, the incremental damages between the existing and with-project scenario (i.e., flood damage reduction benefits) are not particularly sensitive. The level of benefits remains fairly consistent regardless of the level of existing protection assumed in place.

IV. ENVIRONMENTAL AND WATER QUALITY CONSIDERATIONS

1. The EWQ Technical Team met in Moorhead on 19 January and 8 February 2005 with representatives of Minnesota Pollution Control Agency, North Dakota Department of Health, Minnesota Department of Natural Resources, Minnesota Board of Water and Soil Resources, Red River Basin Commission, South Dakota Game Fish and Parks and Corps of Engineers attending one, or both, meetings.

2. It was suggested that this team should assume an unbounded perspective in identifying environmental restoration needs and remediation options and not focus only on features that also provide storage for flood damage reduction. Others agreed but recognizing that we should limit the assessment to the aquatic environment.

3. One suggestion was that base flow could be improved in some stream reaches where local storage structures could improve groundwater recharge. The subject of "ecological connectivity" came up with recognition

that ecological degradation is often the result of interrupted ecological pathways. One of the tasks of this group, then, would be to identify significant restorable linkages especially those affected by past hydrologic modification.

4. The group agreed that we should gather and review planning documents from the various jurisdictions and develop a matrix containing previously identified resource management proposals, and relevant functional attributes to aid in identifying structures or management activities that could be implemented with federal cost-sharing by virtue of meeting both flood damage reduction and environmental restoration objectives. The ensuing discussion on how to proceed with scoring the matrix led to the observation that objective scoring of generic structure types (such as on or off channel gated or ungated wet or dry impoundments) is difficult when considered outside their physical and operational contexts. Team members agreed that some of these structure types could score favorably for natural resource (NR) values but only if *done right*; that is to assume that the structures would be placed and operated in ways that restore or protect channels, wetlands, and marginal grasslands, etc. and allow or promote hydrologic regimes consistent with self-sustaining and diverse ecosystem structure and function. The group agreed that the ideal approach to provide maximum environmental benefits would be to restore drained wetlands, particularly in southwest Minnesota, where most of the land is in row crop agriculture with drain tile and a system of drainage ditches. This type of wetland restoration would greatly contribute toward the goals of the Prairie Pothole Joint Venture under the North American Waterfowl Management Plan by providing spring pair water and some summer brood water for nesting waterfowl. Ideally, small wetland restoration would be coupled with some grassland nesting cover creation, either through CRP or grassland easements. Additionally, the group agreed that restoring sinuosity to channeled creeks and rivers, such as the Bois de Sioux River, would contribute to flood reduction and provide maximum ecological benefits.

5. Applying the NR *done right* assumption to the scoring matrix of generic structure types automatically scores it with all +'s. The scoring matrix may be more appropriately used to evaluate existing and proposed structures with known design and operational parameters. The EWQ Technical Team needs to develop a more complete narrative statement defining the NR *done right* assumption and to compare it with a corresponding flood damage reduction *done right* assumption, which may or may not indicate compatibility.

6. The next step for the EWQ Team would be to populate the scoring matrix with actual structures with known physical and design parameters, scope and perform environmental monitoring and analysis, and then score it. In the Phase 2 report we would expect to be able to show many more +'s than -'s on the score sheet for both NR and FDR values.

V. COST CONSIDERATIONS

NOTE: The following discussion of costs is considered very preliminary and should not be used outside of this study. It is presented for general context only. Significantly more detailed work is needed to quantify the costs of projects once specific sites have been identified and conceptual design has been completed.

1. Red River Watershed Districts in Minnesota have been developing plans for small scale flood damage reduction projects that are consistent with the goals of this study. Cost estimates for two projects in the Red Lake Watershed District were developed by HDR. The Euclid East Impoundment provides gated storage of 1,878 acre-feet and an additional ungated storage of 565 acre-feet for a total of 2,443 acre-feet of flood storage. The estimated cost for the East Euclid site is $2.51 million. The average cost per acre-foot of storage is $1000. The Brandt Impoundment provides gated storage of 3,126 acre-feet and an additional ungated storage of 786 acre-feet for a total of 3912 acre-feet of flood storage. The estimated cost for the Brandt site is $2.63 million. The average cost per acre-foot of storage is $840.

2. The Red River Watershed Management Board provided information about 23 projects that have been proposed and/or constructed in the Red River Basin in Minnesota. These projects ranged in total storage from 280 acre-feet to 33,650 acre-feet. Costs per acre-foot ranged from $105 to $1,453, but the average for the 23 projects was $607. It is clear that costs for storage in small impoundments will vary depending on local land acquisitions costs, depth of the impoundment, and other site-specific considerations.

3. Assuming a cost of $800 per acre-foot of storage and an estimate of 200,000 acre-feet constructed, the cost of providing storage would be $160 million. Assuming a cost of $1000 per acre-foot and 400,000 acre-feet of

storage, the cost would be $400 million. Corps of Engineers flood damage reduction and ecosystem restoration projects are typically cost-shared between the Federal government and non-Federal sponsors. Feasibility study costs are shared 50/50. Implementation costs (plans and specifications and construction) are usually shared 65% Federal and 35% non-Federal. Non-Federal sponsors must provide all lands, easements, rights-of-way and relocations as part of the non-Federal share.

4. The Corps of Engineers has authority to build ecosystem restoration projects based on ecosystem benefits. Ecosystem benefits are not quantified in dollars but are evaluated qualitatively. The determination of justification is based on significance of the habitat benefits provided and the reasonableness of the cost to achieve the benefits. Costs for recent Corps projects around the Nation have averaged about $20,000 per acre of restored habitat.

5. It is difficult to estimate the footprint of the proposed system of impoundments without having specific sites identified. Assuming an average flood storage depth of 6 feet and a total of 200,000 acre-feet of storage, the footprint would be 33,000 acres.

6. Assuming a cost of $1000 per acre-ft and an average 6 foot depth of storage, a 200,000 acre-foot project would create 33,000 acres of habitat at a cost of $6,060 per acre. This is well within the range of what has been considered reasonable on past Corps projects.

VI. CONCLUSIONS

1. The following conclusions are intended to summarize the key findings of Phase 1 of the study:

- A system of multi-purpose impoundments has the potential to reduce the 100-year flood elevations in Fargo-Moorhead by as much as 1.6 feet.
- A system of multi-purpose impoundments would provide the greatest stage reductions for floods of the 10-year to 20-year magnitude.
- From a Federal justification perspective, flood damage reduction benefits in the Fargo-Moorhead area alone would probably justify 20-25% of the costs of constructing a system of impoundments.
- Agricultural flood damage reduction benefits and urban benefits outside of Fargo-Moorhead have not been quantified but would probably be significant.
- <u>With careful design</u>, it is likely that a system of multi-purpose impoundments could be justified largely by ecosystem restoration benefits.

2. Discussion with the Corps Mississippi Valley Division and HQ staff indicated that the conceptual plan described in this report is sound. Significantly more work will be needed to quantify both economic (flood damage reduction) and ecosystem benefits in order to justify Federal involvement. Phase 2 must address significant ecosystem issues early in order to identify and describe ecosystem needs and to be sure that the flood damage reduction and ecosystem restoration features are compatible.

3. The project management plan for the study calls for a decision between the completion of Phase 1 analysis and the beginning of Phase 2 work. This report is intended to provide the information necessary to make an informed decision.