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RED RIVER VALLEY WATER SUPPLY PROJECT

HYDROLOGY

SPECIFIC PLAN OF STUDY

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INTRODUCTION

The Dakota Water Resources Act (DWRA) directs the Secretary of the Interior to conduct a comprehensive study of the water quality and quantity needs of the Red River Valley in North Dakota and possible options for meeting those needs. The Hydrology Specific Plan of Study (SPOS) identifies analyses and tasks to fully assess the Red River Valley's hydrologic system in relation to satisfying the Red River Valley's water needs.

The Red River Valley Water Supply Project (Red River Project) concentrates on future water needs of Red River Valley~~.~~ in North Dakota. The DWRA identified the water needs of Red River Valley as municipal, rural, and industrial (MR&I), water quality, aquatic environment, recreation, and water conservation measures. The needs will be documented in the Report on Red River Valley Water Needs and Options (Needs and Options Report). As directed by Congress, the Red River Project will include joint preparation of an Environmental Impact Statement (EIS) with the State of North Dakota. Analyses will be developed from previous Red River Valley studies and other on-going regional studies. Coordination between the Bureau of Reclamation (Reclamation) and other federal and state agencies will be incorporated when needed for each aspect of the study.

A general outline for the development of the Red River Project is provided in the RRVWS Master Plan of Study (MPOS). The MPOS provides more detailed study background, authority, scope, purpose, process, and overview of all study activities.

The Red River Project will be developed from previous Red River Valley studies and additional data compilation completed as part of this study. Reclamation's "*Red River Valley Water Needs Assessment*" contains reports that were completed in several stages. Reports from Phase 1, Parts A and B, addressed future MR&I water needs and instream flow needs, respectively. The Phase II report assessed preliminary alternatives to meet projected shortages. These previous studies were completed at an appraisal level. The Red River Project will be a more detailed study of these same issues~~,~~ and will incorporate alternatives and issues not previously addressed.

Objective and Purpose

The purpose of the hydrologic studies is to classify the hydrologic system with sufficient detail to evaluate alternatives and estimate impacts to the system. Specific objectives to be met include:

- Determine the characteristics of surface water supplies in terms of yield, location, water quality, and operations.
- Determine characteristics of existing and future availability of ground-water supplies in terms of yield, location, and water quality.
- Examine water supply conditions to determine any present and potential future water supply shortages.
- Assist in development and evaluation of alternatives for meeting future water needs.
- Determine impacts on the hydrologic system caused by alternatives for meeting future water needs.

Issues to be addressed through hydrologic studies were identified from comments on previous Red River Valley ~~Project~~ studies and recent correspondence. More issues may be identified during the National Environmental Policy Act (NEPA) scoping process. These hydrologic studies will provide information to assess the current and projected conditions of the Red River ~~B~~basin and supply data for use in other study components.

The direction of the hydrologic studies depends ~~highly~~ on the water needs determined in the Needs SPOS~~, as well as public scoping.~~ and issues identified in the EIS process. Most studies described in this SPOS will vary in content depending on which alternatives are chosen for the ~~more detailed~~ feasibility level analyses. Therefore, most tasks are described in general terms, and some tasks may be deemed unnecessary later in the EIS process.

Hydrologic Study Organization

The Hydrology SPOS format is organized into major sections that cover specific tasks. The Hydrology SPOS will address specific hydrology issues raised during previous studies, review existing water resources information, identify data gaps and collect additional data as needed, select water quantity and quality model(s) that will meet the study requirements, analyze the quantity and quality model runs to characterize the water supply of the Red River basin, complete a cumulative effects study on the Sheyenne, Red, and Missouri Rivers, and document study results in a hydrology appendix to the Needs and Options Report.

HYDROLOGY 1 - ADDRESSING HYDROLOGIC ISSUES

Hydrology issues identified in previous Red River Valley studies will be addressed in the Hydrology SPOS. Other points of concern will become evident through the public scoping process associated with the EIS and from these concerns more questions will be added. Identified issues will be used to characterize the geographic area and investigate environmental concerns associated with the Red River Project.

Hydrology 1.1 - Issues And Questions to be Addressed.

Through previous Reclamation Red River Valley studies, many issues have been identified in relation to various aspects of hydrology and the environment. These issues have been grouped by topic and were used to develop a list of questions related to Hydrology. The following questions have been compiled and will be addressed in the Hydrology analyses.

Climate and Droughts:

- What is the severity and extent of the drought analyzed in this study? (Hydrology 4.5)[1]
- How does the ~~1930's~~1930s drought compare to the design drought? (Hydrology 4.5)
- What is the probability of the design drought or a ~~1930's~~1930s type drought occurring within the next 50 years? (Hydrology 4.5)

Streamflow:

- Where are the MR&I points of interest in the Red River Valley? (Hydrology 2.5)
- What is the probability of having shortages at these points of interest, and how severe would the shortages be? (Hydrology 5.3)
- What is the likelihood of experiencing shortages in the Red and Missouri River ~~B~~basins at the same time? (Hydrology 5.3)
- What are the discharge histories (frequency-discharge-duration relationship) of the Sheyenne, Red, and Missouri Rivers? (Hydrology 2.4)
- What effects would the addition of water have on the rivers of the Red River ~~B~~basin in terms of streamflow frequency, duration, and discharge? (Hydrology 5.4)

[1]Question(s) will be addressed generally in the specified Hydrology section, task, or subtask. Specific questions will be addressed in the scope of work for each task.

Groundwater Resources:

- What are the location, volume, recharge rate, transmissibility, specific yield, and quality of aquifers within the Red River ~~B~~basin? (Hydrology 2.3, 2.4)
- Could groundwater sources provide the Red River ~~B~~basin with enough water to satisfy future water needs? (Hydrology 5.3)
- Could aquifers be recharged for storage? (Hydrology 4.2.1)
- What effects would the alternatives have on available groundwater sources? (Hydrology 5.4)

Water quality:

- What is the current water quality of the Sheyenne River, Red River, Bois de Sioux River, Otter Tail River, and Red Lake River (baseline condition)? (Hydrology 2.3)
- What are future water quality issues in the Sheyenne and Red Rivers, such as the potential effects of a Devils Lake outlet? (Hydrology 2.2)
- What is the current water quality of Lake Audubon, McClusky Canal, New Rockford Canal, Lake Ashtabula, Lake Traverse, Orwell Reservoir, and Red Lake? (Hydrology 2.8)
- What is the current water quality of possible surface water sources (baseline condition)? (Hydrology 2.3)
- What water quality changes will result from the reasonable alternatives evaluated in detail? (Hydrology 5.4)

Water Supply:

- What are the existing and projected needs for communities, industry (Hydrology 4.1), and instream flows? (Hydrology 4.3)
- What are the historical water allocations and uses in the Red River ~~B~~basin? (Hydrology 2.4)
- How much water is available from existing water supplies? (Hydrology 2.4)
- Will current water supplies be adequate to meet future water needs? (Hydrology 5.3)
- How much water is projected to be available in the future from the reasonable alternatives evaluated in detail? (Hydrology 5.3)

Surface ~~and Ground~~ Water - Groundwater Interaction:

- Where are the losing reaches of streamflow in the Red and Sheyenne Rivers? (Hydrology 4.3.2)
- Where are the gaining reaches of streamflow in the Red and Sheyenne Rivers? (Hydrology 4.3.2)
- How have these interactions varied over time, and how may these vary in the future? (Hydrology 4.3.2)

- How will low flow in rivers affect surface water and ground-water? (Hydrology 4.3.2)
- How does surface water and ground-water interaction affect water quality in both sources? (Hydrology 4.3.2)
- How do streams and aquifers outside of the Red River ~~B~~basin affect those within the basin? (Hydrology 4.3.2)
- How will artificial recharge affect surface water and ground-water interaction? (Hydrology 4.2.1)
- How would artificial recharge affect streamflows? (Hydrology 4.2.1)

Geomorphology:

- What are current channel geomorphologic characteristics (dimensions, meander geometry, channel stability, and bedload distribution) of the Sheyenne and Red Rivers? (Hydrology 4.3.1)
- How would the possible alternatives affect stream morphology in the Sheyenne and Red Rivers? (Hydrology 5.4)

Basin Hydrology:

- Would basin hydraulics change significantly for the proposed alternatives? (Hydrology 5.4)

Other Downstream Impacts:

- What impacts would alternatives have upon streamflows in the Missouri River or the Red River? (Hydrology 5.4)
- What impacts would alternatives have upon water quality in the Missouri River down to the confluence with the Mississippi River (Hydrology 6.2) or in the Red River in Manitoba? (Hydrology 6.1)
- What are the instream flow needs downstream in the Red and Missouri Rivers, and how would alternatives affect them? (Hydrology 4.3.3)

Devils Lake Outlet:

- How will potential construction of a Devils Lake Outlet be incorporated into this study? (Hydrology 5)

Water Rights:

- How will the differences in water rights be handled between Minnesota (riparian rights) and North Dakota and Canada (priority rights)? (Hydrology 2.7)

Instream Flow Recommendations:

- Will there be instream flow recommendations? (Hydrology 4.3.3)
- If so, what are the instream flow recommendations for the Sheyenne and Red rivers? (Hydrology 4.3.3)

- If so, will sufficient water be available for Instream flow recommendations for the alternatives evaluated? (Hydrology 4.3.3)

Hydrology 1.2 - Determine Methods to Address Issues.
Identified issues will first be addressed using existing documents and reports as found in a literature search. Issues that are not addressed by existing documents will be the basis for studies developed in the Red River Project. Possible methods of analysis include:

- Data collection and analysis
- Modeling - statistical and mathematical
- Other methods yet to be determined

Hydrology 1.3 - Review of Hydrologic Issues.
The issues described in Hydrology 1.1 and 1.2 will be reviewed, changed where appropriate, and resolutions of issues will provide direction for specific tasks. Any additional issues identified through NEPA public scoping will be identified, incorporated, and reviewed by the EIS Interdisciplinary Team as needed (See EIS SPOS).

HYDROLOGY 2 - MODEL EVALUATION AND SELECTION

Once the water quantity and quality issues of concern have been identified and water resource information for the Red River ~~B~~basin has been gathered, the Red River ~~B~~basin can be simulated for present and probable future conditions. Effects on the hydrologic system for each proposed alternative can then be estimated using model simulation. Models will be selected based on model selection criteria and a model evaluation. This model selection process occurs before most data ~~collection~~ compilation efforts, so that only data necessary for each model will be compiled or collected, ~~which will~~in order to minimize the workload.

The model selection process begins with the development of goals and objectives specific to water quantity and quality modeling of the Red River basin. From these goals and objectives, specific model selection criteria will be identified for use in a model evaluation process, in which a model requirement matrix is used to evaluate available model characteristics and limitations. The amount of available data may provide limitations on modeling, so summaries of available water quality and quantity data, if not already available, will be completed for comparison of each models data requirements during the model evaluation. The use of models developed in

previous Red River basin and Reclamation studies will be reviewed when considering minimizing study costs.

Water availability in the Red River basin has been estimated through previous modeling. As part of Reclamation's past water quantity modeling efforts, a modeling committee was established as described in a North Dakota State Water Commission (SWC) memorandum dated February 11, 1997. This memorandum includes a list of objectives, limitations, required capabilities, and desired capabilities that were developed by this modeling committee for a Red River Valley water quantity modeling effort. Many agencies were members of this committee including Reclamation, Garrison Diversion Conservancy District, NDSWC, U.S. Geological Survey (USGS), North Dakota Department of Health (ND Department of Health), and the U.S. Army Corps of Engineers (COE). Based on this information, Reclamation selected the Hydrologic River Operation Study System (HYDROSS) model for use in Reclamation's Red River Valley Water Needs Assessment, Phase II; *Appraisal of Alternatives to Meet Projected Shortages* (January 2000). The recommendations of this committee will serve as a starting point for developing model selection criteria, and HYDROSS will be compared to other available models through the model evaluation process.

Some water quality modeling of the Red River basin has already been undertaken. The COE is presently using their HEC-5Q model for the analysis of water quality of flows in the Sheyenne and Red Rivers from a proposed Devils Lake outlet. Previous Reclamation studies in North Dakota have utilized Reclamation's Canals, Rivers, and Reservoirs Salinity Accounting Procedure (CRRSAP) for water quality modeling, but no water quality model was used in the Phase II study. This model was used in the USGS Water-Resources Investigation Report 93-4200 Simulated Effects of the Proposed Garrison Diversion Unit on Streamflow and Dissolved Solids in the Sheyenne River and the Red River of the North, North Dakota and Minnesota, 1993. A water quality model was not used for the Bureau of Reclamation Red River Valley Water Needs Assessment, Phase II; *Appraisal of Alternatives to Meet Projected Shortages* (January 2000). These models will be compared, along with other water quality models.

Hydrology 2.1 - Model Selection Criteria.

The selected model(s) must be capable of meeting well-defined goals and specific technical objectives of the Red River Project. From these goals and objectives, model selection criteria will be developed specific to the ~~problems~~ water supply issues within the Red River ~~Valley~~ basin. ~~These~~ Separate goals, objectives, and criteria will be developed for evaluating available water quality and water quantity models for use in the Red River Project. ~~selection purposes.~~

Draft lists of water quality and quantity model selection criterion have been initiated and will be developed fully by Reclamation and members of other agencies through participation in the Red River Project Needs and Options Report's Technical Team (Technical Team). ~~Reclamation will also evaluate available models using the established model criteria.~~

~~Previous to this study a modeling committee was established as described in a North Dakota State Water Commission (SWC) memorandum dated February 11, 1997. This memorandum includes a list of objectives, limitations, required capabilities, and desired capabilities that were developed by this modeling committee for a Red River Valley modeling effort. Many agencies were members of this committee including Reclamation, Garrison Diversion Conservancy District, NDSWC, U.S. Geological Survey (USGS), North Dakota Department of Health (ND Department of Health), and the U.S. Army Corps of Engineers (COE). Based on this information, Reclamation selected the Hydrologic River Operation Study System (HYDROSS) model for use in Reclamation's Red River Valley Water Needs Assessment, Phase II; *Appraisal of Alternatives to Meet Projected Shortages* (January 2000). Previous Reclamation studies in North Dakota have utilized Reclamation's Canals, Rivers, and Reservoirs Salinity Accounting Procedure (CRRSAP) for water quality modeling, but no water quality model was used in the Phase II study.~~

Hydrology 2.1.1 - Water Quantity Model Criteria.

Previous water quantity modeling studies will be reviewed to develop goals and objectives, required capabilities, and desired capabilities of a water quantity model for the Red River Project. ~~The use of models developed in previous Red River Valley and Reclamation studies will be reviewed when considering minimizing study costs. From the goals and objectives selected, a process for evaluating water quantity models will be developed in which a model requirement matrix is used to evaluate available model characteristics and limitations.~~ Four types of model criteria will be investigated, which are functionality, operational, water rights, and information technology (IT) requirements. The following are examples of model requirements: administrative requirements (Graphical User Interface, user support, etc.), capabilities for simulating location and magnitude of water shortages, river reach gains and losses, and main-stem and off-stream reservoir operations.

Hydrology 2.1.2 - Water Quality Model Criteria.

Previous water quality modeling studies will be reviewed to develop goals and objectives, required capabilities, and desired capabilities of a water quality model for the Red River Project. ~~Models used in previous Red River Valley and Reclamation studies will be reviewed.~~ Four types

of model criteria will be investigated, which are functionality, operational, water rights, and information technology (IT) requirements. ~~From the goals and objectives selected, a process for evaluating water qualtity models will be developed in which a model requirement matrix is used to evaluate available model characteristics and limitations. A draft model evaluation matrix has been initiated and will be developed fully by members of the Technical Team.~~

Hydrology 2.2 - Model Evaluation (Water Quantity and Quality).

Two hydrologic models will most likely be needed for the Red River Project, one for water quantity and another for water quality. The water quality model ~~must~~ needs to be compatible with the water quantity model, as the flows computed from the quantity model will be necessary to run the quality model. The model evaluation will examine available, conceptual models by rating them against the model selection criteria through the use of a matrix. Draft water quality and quantity model evaluation matrices have been initiated and will be developed fully by Reclamation and members of other agencies through participation in the Technical Team.

~~In previous Red River Valley Studies by Reclamation, the HYDROSS model was used for water quantity modeling. In terms of water quality, the COE is presently using their HEC-5Q model for the analysis of water quality of flows in the Sheyenne and Red Rivers from a proposed Devils Lake outlet. Previous to this study, the CRRSAP model was used in the USGS Water-Resources Investigation Report 93-4200 Simulated Effects of the Proposed Garrison Diversion Unit on Streamflow and Dissolved Solids in the Sheyenne River and the Red River of the North, North Dakota and Minnesota, 1993. A water quality model was not used for the Bureau of Reclamation Red River Valley Water Needs Assessment, Phase II; *Appraisal of Alternatives to Meet Projected Shortages* (January 2000).~~

Hydrology 2.2.1 - Water Quantity Model Evaluation.

Models will be evaluated based on the process determined in Hydrology 2.1. Water quantity models to be investigated include Reclamation's ~~Hydrologic River Operation Study System (~~HYDROSS~~)~~, Reclamation's RiverWare, COE's Simulation of Flood Control and Conservation Systems (HEC-5), River ~~Basin~~basin Network Simulation Model (MODSIM), Environmental Protection Agency's (EPA) Hydrologic Simulation Program-Fortran (HSPF), and Surface Water Modeling System (SMS).

Hydrology 2.2.2 - Water Quality Model Evaluation.

The model evaluation process developed in Hydrology 2.1 will be used to compare water quality modeling programs on their capabilities and methodologies to model various water quality parameters. Models that have been used by Reclamation and other organizations and agencies will be evaluated, including Reclamation's CRRSAP, ~~Corps'~~ COE's Simulation of Flood Control and Conservation Systems including Water Quality Analysis (HEC-5Q), River Water Quality Model (RIVWQ), Better Assessment Science Integrating Point and Nonpoint Sources (BASINS), Water Quality Analysis Simulation Program (WASP), River Simulation System (RSS), Enhanced Stream Water Quality Model (QUAL2E), and COE's Hydrodynamic and Water Quality Model for rivers, estuaries, lakes, and reservoirs (CE-QUAL-W2).

Hydrology 2.3 - Review Model Evaluation and Make Recommendations.

Members of the Technical Team will review the model evaluation process completed in Hydrology 2.2. From this review, preferred models will be identified, and Technical Team will recommend ~~a~~ preferred water quantity and quality models and/or methods.

Hydrology 2.4 - Select Water Quality and Quantity Models.

Reclamation will review the recommended models from Hydrology 2.3 and select the water quantity and quality models for use in Hydrology 5, the Hydrologic Modeling Studies.

HYDROLOGY 3 -COMPILE AND ANALYZE EXISTING WATER RESOURCES INFORMATION

Historic water quality and quantity data of the Red River Valley have been collected by many federal and state agencies, including the USGS, Reclamation, COE, Minnesota Department of Natural Resources (~~MNDNR~~MDNR), Minnesota Pollution Control Agency (~~MNPCA~~MPCA), EPA, ~~North Dakota State Health Department (~~ND ~~Health~~ Department of Health~~)~~, Minnesota Department of Health ~~Department~~ (MN ~~Health~~ Department of Health), and SWC. Data will be gathered from these agencies for use in the Red River Project.

Hydrology 3.1 - Water Quality Constituent Selection.

Water quality data analysis poses a significant challenge, as data are limited and not consistent at each site. Each area of analysis, or SPOS, may require different constituents to be analyzed, e.g. the EIS SPOS may require investigation into relationships between water quality and aquatic life, while the Engineering SPOS will focus on water treatment and associated costs. Different levels

of analysis can be performed on various constituents including modeling, trend analysis, and a statistical summary. Potential water quality constituents to be modeled, analyzed for trends, or statistically summarized will be identified based on whether sufficient data exists for each type of analysis. Current water quality issues ~~in the Red River Basin will be~~ , developed Total Maximum Daily Loads (TMDLs), and the identified ~~and may~~ water quality impaired rivers in the Red River basin will aid in the constituent selection. A final set of water quality constituents will be chosen for each type of analysis based on requirements of each SPOS or area of analysis.

Hydrology 3.2 - Water Quality Data Compilation.

Historical water quality data will be assembled for constituents of interest to analyze changes in the Red River ~~B~~basin and for use in water quality modeling. Initially, water quality data will be gathered from the USGS due to data consistency and ease of use. The available data will be reviewed, and efforts may be made to fill existing data gaps by estimation methods or by requesting data from other sources mentioned at the beginning of this section. The specific data needed for input into the water quality model will be determined after a model is chosen in Hydrology 2.4 (Select Water Quality and Quantity Models). This compilation of water quality data has been broken into Surface Water Quality (Hydrology 3.2.1) and ~~Ground Water~~Groundwater Quality (Hydrology 3.2.2).

Hydrology 3.2.1 - Surface Water Quality Data Compilation.

From the surface water information gathered, ~~T~~the following sub-tasks have been developed to compile the different types of surface water quality data needed for use in these studies.

Hydrology 3.2.1a - In-basin Streamflow.

Reclamation has contracted with the USGS to prepare a report on water quality constituents for selected sites in the Red River ~~B~~basin including North Dakota, South Dakota, and Minnesota sites. This report is an update of *Methods for Estimating Monthly Mean Concentrations of Selected Water-Quality Constituents for Stream Sites in the Red River of the North Basin, North Dakota and Minnesota, Water-Resources Investigation Report 91-4086* (Guenther 1991)~~,~~ and will include statistical summaries of available water quality constituents as well as relationships of concentration to streamflow for several specific parameters. These relationships will be necessary to complete water quality modeling.

Hydrology 3.2.1b - Garrison Diversion Unit Principal Supply Works.

In considering the use of Garrison Diversion Unit principal supply works for future water supply, as required by DWRA, water quality data will be needed for Lake Sakakawea and Lake

Audubon, as well as the McClusky and New Rockford Canals. This compilation may mirror the streamflow water quality data compilation, with development of statistical summaries of available water quality parameters and relationships to flow.

Hydrology 3.2.1c - In-basin Reservoirs.

Water quality data for reservoirs are needed for modeling purposes, specifically from Lake Ashtabula, Orwell Reservoir, Lake Traverse, and the Red Lakes. These data will also be used to evaluate effects on water quality if Baldhill Dam were to be raised, as proposed in alternatives developed in the Phase II report. It has not yet been determined if additional reservoir water quality data will be needed for other areas of analysis.

Hydrology 3.2.2 - ~~Ground Water~~Groundwater Quality Data Compilation.

Ground-water data provided by the SWC for previous Red River Valley studies will be reviewed and updated ~~with newly available information~~. The SWC will document characteristics of North Dakota aquifers within the Red River Valley based on their historical findings and ND Department of Health ~~Department~~ findings. Similar data will be developed for Minnesota aquifers through data collected by the ~~MNDNR~~MDNR.

Hydrology 3.3 - Water Quantity Data Compilation (Ground and Surface Water).

To accurately characterize the basin, surface water and ground-water volumes and flows must be summarized. Existing databases will be updated and expanded to include new information. These data will be used in hydrologic modeling of the Red River ~~B~~basin. This compilation of water quantity data has been broken into Surface Water Quantity (Hydrology 3.3.1) and ~~Ground Water~~Groundwater Quantity (Hydrology 3.3.2).

Hydrology 3.3.1 - Surface Water Quantity Data Compilation.

For surface water, historical streamflow records will be gathered for sites along major rivers in the Red River ~~B~~basin. The data will include discharge history and reservoir inflow, outflow, evaporation, and storage values. Reported water withdrawals and return flows are also needed to model the effects of any water additions or depletions. The USGS, COE, SWC, and ~~MNDNR~~MDNR are potential data sources. Using surface water data, the USGS will complete an updated and revised version of their report entitled, *Gaged and Estimated Monthly Streamflow for Selected Sites in the Red River Basin of the North in North Dakota and Minnesota, Water-Resources Investigation Report 90-4167* (Guenther et al. 1990). This report will provide the naturalized flow database necessary for hydrologic modeling of the ~~B~~basin. This database will extend far enough up Red River tributaries to estimate water availability for all current surface

water users. Daily or weekly streamflow data may also be compiled for a recent drought period of 1988-1992, in order to estimate probable daily or weekly water availability in specific areas of the Red River basin.

Hydrology 3.3.2 - ~~Ground Water~~ Groundwater Quantity Data Compilation.

Groundwater information is necessary to assess the Red River ~~B~~basin's aquifer resources. Aquifer locations, volume, appropriated volume (or rate), and estimated recharge rate, transmissibility, and specific yield will be required to effectively assess aquifer capacity available as a source of raw water or to analyze the potential to pump water into aquifers for storage and recovery. Other ground-water analyses will be developed as needed. The majority of the ground-water data will be collected from the SWC for North Dakota aquifers and data for Minnesota aquifers will be compiled from ~~MNDNR~~MDNR.

Hydrology 3.4 - Existing Water Supply Demands.

For the hydrologic modeling, information on existing municipal and rural water supply demands will be received from Needs 3.3. The volume, frequency, water quality, and location of facilities' intakes will be used in the hydrologic studies. The future water demands of cities using Red River ~~B~~basin water not included in this study may also be developed to evaluate depletions in the Red River ~~B~~basin. This information will be developed in Needs 6.3 and 6.4. Other water supply facilities analyses will be covered in Needs 4, including each system's capacity, treatment abilities and efficiency.

Hydrology 3.5 - Return Flow Data.

Return flows from MR&I, existing irrigation, fish, wildlife, and recreation activities will be required for the hydrologic modeling. Return flow estimates are usually difficult to assess and in some cases little or no data exist. In these instances assumptions must be derived from regional estimates or studies in the general vicinity. Assumptions used in previous Red River Valley studies will be reviewed for accuracy, and methods to estimate return flows will be developed if deemed necessary. This data will be developed in Eng 1.3(Compile Wastewater Quantity and Quality Data).

Hydrology 3.6 - Water Right Information.

The Red River ~~B~~basin covers portions of North Dakota, South Dakota, and Minnesota in the United States, as well as the province of Manitoba in Canada. The basis for establishing a water right varies across these states and province. Minnesota's water rights are based upon riparian water rights, whereas North Dakota, South Dakota and Canada use priority water rights. A

compilation of specific water rights will be fundamental for hydrologic modeling of the basin, especially permitted water rights within the United States.

Hydrology 3.7 - Reservoir Net Evaporation.
Evaporation losses on reservoirs can affect the amount of water in a hydrology system. The monthly net evaporation loss at each reservoir will be estimated by using monthly evaporation and precipitation data at local climatological stations or from the COE reservoir data.

Hydrology 3.8 - Crop Irrigation Requirements for Existing Irrigation.
The amount of water needed for existing crop irrigation, including irrigation for city parks and golf courses, will be examined to ensure existing irrigation water rights are being sufficiently estimated in the hydrologic modeling. Crop irrigation requirements will be estimated for each acre based on the modified Blaney-Criddle computational method. This method utilizes precipitation, evaporation, temperature, and frost data to determine monthly crop water needs.

Hydrology 3.9 - Appraisal-level Modeling and Analysis.
All previously modeled alternatives from Reclamation's Red River Valley Phase II study will be remodeled using the same water quantity model, HYDROSS, using newly compiled water quantity data. Shortages will also be estimated by modeling modified versions of the Phase II alternatives that are now considered to be more feasible that the original alternatives. Any ~~entirely~~ new alternatives that are considered reasonable by Reclamation will also be modeled.

Hydrology 3.10 - Summarize Existing Water Resources Information.
Existing water resources information will be summarized prior to being used in analyses or studies and will be presented in the Red River Project Hydrology Appendices to the Needs and Options Report.

HYDROLOGY 4 - ADDITIONAL DATA COLLECTION AND SPECIFIC STUDIES

Public scoping and model requirements will determine if additional studies are required. Development of additional databases for modeling purposes will occur after a model is chosen. Namely, if the selected model(s) needs additional input to run, then data gathering would immediately proceed to fill data gaps and would be completed in this section. Necessary specific studies are also developed in this section, which generally focus on analyses not related to modeling.

Hydrology 4.1 - Additional Data Collection.

Efforts will be made to fill existing data gaps at this point in the study. Model selection may also lead to the collection of other necessary data.

Hydrology 4.2 - Groundwater Studies.

Groundwater sources will be investigated for their potential to supply and store raw water in the future. Information will first be compiled through a literature search, which will be reviewed for adequacy. Data gaps will be identified and filled as necessary for use in these ground-water studies. Various sources of groundwater data include, but are not limited to, county groundwater studies, SWC well inventory database, various city groundwater studies, SWC *Water Resources Characteristics of the West Fargo Aquifer System* (Ripley, 2000), and *Phase II Hydrology Appendix, Attachment B - Groundwater Supporting Material* (Reclamation, 2000).

Hydrology 4.2.1 - Potential for Aquifer Storage and Recovery.

Many alternatives investigated previously included storage of water for future use. The potential to mechanically pump or create artificial recharge of water into existing aquifers will be analyzed for feasibility and effectiveness. Impacts to surface water and ground-water interaction and streamflows will be estimated. Specific areas to be examined are within the Red River ~~B~~basin, mainly within eastern North Dakota, but may extend into Minnesota.

Hydrology 4.2.2 - Potential for Additional Groundwater Use from Existing Aquifers.

Existing North Dakota groundwater sources will be evaluated for the potential to withdraw more water as needs increase in the future. Reclamation's 2000 *Phase II Hydrology Appendix, Attachment B - Groundwater Supporting Material* has information on major aquifers in the Red River Valley in North Dakota. The Minnesota aquifers in the Red River Valley may also be studied for potential future use for water supply in cooperation with ~~MNDNR~~MDNR.

Hydrology 4.3 - Specific River Studies.

When considering alternatives that may affect streamflow in the major rivers of the Red River ~~B~~basin, specific rivers and surrounding areas ~~initially~~ should be characterized. Once baseline conditions are documented, effects of water additions and depletions can be estimated. Several specific studies have been identified to assess geomorphology, channel losses, and instream flow recommendations and will most likely be completed on the Sheyenne, Red Lake, and Red Rivers. These hydrologic studies will be completed in coordination with the EIS SPOS. The

Sheyenne River is currently being analyzed by other Federal agencies, such as the COE for the Devils Lake Outlet EIS.

Hydrology 4.3.1 - River Geomorphology.

The type of terrain, amount of streamflow in a river, and distribution of the streambed sediment greatly affects a river's size and shape. Also, the stability of a river is highly dependant on riparian vegetation and channel capacity. These factors are part of a river's geomorphology. An inventory of major geomorphological factors for specific rivers or sections of rivers will be conducted as described in *Applied River Morphology* (Rosgen 1996). Maximum streamflow recommendations can be developed from such an inventory for maintaining stream morphology or increasing bank stability. This work will be completed in Needs 9.1.5, the Geomorphology Component of Aquatic Environmental Needs ~~(Needs 9)~~.

Hydrology 4.3.2 - Surface ~~and Ground~~ Water - Groundwater Interaction.

Gains and losses in hydrologic systems affect the amount of streamflow in a river. Surface ~~and ground~~ water - groundwater interactions can vary with changes in streamflow, groundwater levels, or climate. Channel gains and losses, as well as operational losses of water supply works, will be estimated for historical, current, and for possible future conditions. The effects of these interactions on surface water and ground-water supply and quality will be evaluated.

Hydrology 4.3.3 - Instream Flow Recommendations.

The amount of streamflow in a river affects its channel stability, water quality, and aquatic life, which can be maintained using instream flow recommendations. Previous Reclamation studies on the Sheyenne and Red River provide some instream flow analysis. All instream flow analyses will be completed in coordination with the EIS and Needs SPOSs to identify instream flow recommendations for the Red and Sheyenne Rivers. Any existing downstream flow requirements will be identified. Each potential alternative will be evaluated for the availability of water to meet instream flow recommendations.

Hydrology 4.4 - Water Quality Trend Analysis.

The future of water quality in the Red River ~~B~~basin as a whole can be difficult to determine. Water quality modeling can be done fairly easily for conservative constituents by finding direct correlations to streamflow at specific study points using regression equations and projecting water quality values downstream. Non-conservative constituents, such as nitrates and phosphates, have poor correlations to streamflow. Modeling of such parameters is highly

technical, since many factors must be considered, and is usually done on small stretches of stream to insure accuracy. The COE has been investigating modeling of non-conservative water quality constituents for the Sheyenne and Red Rivers, and their efforts may aid in the Red River Project water quality modeling. More directly, trend analyses can demonstrate what has happened to such constituents in the past, and from these analyses, predictions can be made for the future. The Red River ~~B~~basin will be analyzed within North Dakota and Minnesota for water quality trends using historical data from at least the last 10 years. Such an analysis can be highly effective for short-term predictions.

Hydrology 4.5 - Climatological Study.

To account for probable future conditions of the Red River Valley, climatological cycles and probabilities can be estimated by studying historical climatic data, temperature, precipitation, streamflow, etc. This analysis will specifically explore the probability of a severe and extensive drought occurring within the next 50 years, as well as how this drought, the design drought, compares to the ~~1930's~~1930s drought. This study will estimate the effects the design drought might have on the Sheyenne and Red Rivers. A literature search of available climatological studies will be completed. Available and relevant drought contingency plans and proxy records will be examined to determine the probability of risk regarding the occurrence of severe and extensive droughts. A comparison of the 1930s drought with the 1988 drought will be attempted to evaluate the severity of the design drought and the ~~1930's~~1930s drought. ~~An evaluation of~~ Review of tree-ring analyses and early settler's personal opinions of the weather, from their diaries, may also be considered when evaluating the possibility that a severe and extensive flood could occur. The climatic effects on groundwater may also be ~~completed~~evaluated.

Hydrology 4.6 - Summarize Specific Studies.

The studies described in Hydrology 4 will be summarized prior to being used in other studies or analyses.

Hydrology 4.7 - Review Hydrology 3 and 4.

The specific studies completed under Hydrology 4 and the water resource information compilations and analyses completed under Hydrology 3 will be reviewed. Changes will be incorporated where appropriate, and the final conclusions will be provided for use in other Hydrology tasks.

HYDROLOGY 5 - HYDROLOGIC MODELING STUDIES

Future water quantity and quality will be modeled for the Red River basin.~~Basin, as well as for part of the Missouri River Basinbasin.~~ Once ~~a model has~~models have been selected and some public scoping for the EIS has been completed, more information will be provided about the modeling. The effects of possibly taking water from the Missouri River will be analyzed in the hydrologic cumulative effects analysis in Hydrology 6.

Due to high water levels in Devils Lake, the St. Paul District of the COE is considering the construction of an emergency outlet. A temporary outlet is also being studied by the State of North Dakota. The proposed COE outlet could convey between 300 and 480 cfs of water into the Sheyenne River above Lake Ashtabula. The State's proposed temporary outlet is considering releases of 300 cfs. The water quality of this additional water varies depending on the proposed point of release from Devils Lake. Water quality and quantity modeling of the Sheyenne and Red Rivers will consider the potential effects of a Devils Lake emergency outlet(s) in cooperation with the COE and SWC.

Hydrology 5.1 - Water Quantity Modeling.

Once a model is selected it will be calibrated to match historic streamflow conditions of the Red River ~~B~~basin. Historic surface water quantity will be modeled to analyze the water supply of the basin. From these values, present level of development and future demands on streamflows can be estimated, and analyses of existing and possible future water supplies can be completed. Both ground and surface water supplies will be incorporated in water quantity modeling.

A separate modeling effort will be done for the Missouri River ~~B~~basin in cooperation with the Omaha District of the COE. It is anticipated that the existing COE water quantity model can be used to analyze Red River Valley proposed withdrawals from the Missouri River. From this model, potential impacts of these withdrawals can be characterized. Additional model development may still be needed, but the COE model will initially be investigated for use in our study.

Hydrology 5.2 - Water Quality Modeling.

Water quality modeling will be completed to quantify the effects each reasonable alternative will have on water quality of the Red River ~~B~~basin. Once a water quality model is selected it will be calibrated to match historic water quality conditions. This modeling will be completed, as

needed, on the major rivers and lakes of the Red River ~~B~~basin. Water quality constituents modeled will include, but are not limited to:

- Total Dissolved Solids (TDS)
- Carbonate Hardness
- Sodium
- Sulfates
- Chloride

Some water quality parameters may be directly related to flow; therefore, information from the updated USGS 1991 report will be used, as appropriate, to provide such relationships between water quality parameters and streamflow.

Hydrology 5.3 - Analysis of Model Output.

Output from water quantity and quality modeling scenarios will be analyzed to compare the amount and quality of water available from each feature and reasonable alternative. Surface water and ground-water sources will be assessed for the ability to supply the present and future needs of the Red River ~~B~~basin, assuming probable operational scenarios for reservoirs and historical streamflows. The output will also be used to address the hydrologic issues and answer questions posed in public scoping. The amount of water projected to be available from each alternative will be addressed specifically. If any shortages exist, the probabilities and severities of these raw water shortages will be estimated and the percent of needs satisfied by each alternative will be quantified. The availability of sufficient water volumes to meet ecosystem requirements and other current requirements will also be addressed. The effects of meeting current and future water demands will be analyzed in Hydrology 5.4, the Analysis of Current and Future Conditions. Conclusions from the model analyses will be compiled into the Hydrology Appendix.

Hydrology 5.4 - Analysis of Current and Future Conditions.

The analysis of model output will be used to characterize and compare the effects of obtaining water from each proposed source and reasonable alternative. Information from the hydrologic studies and modeling will be incorporated to assess the hydrologic system of the Red River ~~B~~basin. The basin will first be hydrologically characterized, so that effects of meeting current and future water demands on the basin can be estimated. Once the final future scenarios have been refined through modeling, changes in basin hydraulics will be estimated.

Similar effects analyses on the Red River ~~B~~basin were completed in previous studies; however, more detailed information needs to be incorporated in this study. The present uses and operation

plans for Minnesota and Manitoba were not included when previously assessing the Red River. Present management goals and objectives for fisheries, rivers, watersheds, and ecosystems were also not integrated in previous studies.

The hydrologic system of the Red River ~~B~~basin can be altered in numerous ways depending on each alternative. The effects of withdrawing or adding water to the Sheyenne and Red Rivers on streamflow will be examined for each reasonable alternative evaluated in detail. The Sheyenne and Red Rivers will be investigated for effects on frequency, magnitude, duration and timing of streamflows. Alteration of streamflows will also affect the geomorphology of rivers, e.g. bank stability, which also will be evaluated. The impacts on water quantity and quality of surface water and groundwater supplies will be examined for each reasonable alternative evaluated in detail.

Hydrology 5.5 - Summarize Hydrology Modeling Studies.
Modeling studies described in Hydrology 5 will be summarized prior to being used for tasks outlined on other SPOSs. These results will be handed off to the Engineering SPOS as Water Supply Source Characteristics (Eng 3.2).

Hydrology 5.6 - Review Hydrology Modeling Studies.
The modeling study analysis will be reviewed ~~by study staff~~ and~~/or teams,~~ changes will be incorporated where appropriate. The final modeling study analysis will be provided for use in Hydrology 6, Hydrologic Cumulative Effects Analysis, and other SPOSs.

HYDROLOGY 6 - HYDROLOGIC CUMULATIVE EFFECTS ANALYSIS

Cumulative impacts to potentially affected hydrologic systems, including lakes, rivers, streams, wetlands, and aquifers, will be evaluated for each alternative investigated as part of the EIS. This analysis will examine how impacts associated with each alternative contribute to the overall impact that would result from that alternative in combination with other existing and reasonably foreseeable future actions.

Cumulative impacts will be evaluated for the Red, Sheyenne, and Missouri Rivers. Other water bodies may also be evaluated, depending on the alternatives evaluated in detail in the EIS.

Hydrology 6.1 - Cumulative Effects on Red and Sheyenne Rivers.
Direct and indirect cumulative effects on the Sheyenne and Red Rivers will be estimated for each alternative. Specifically, a carrying capacity analysis may be completed on the Red River and possibly on the Sheyenne River, depending on the alternatives studied in detail.

Hydrology 6.2 - Cumulative Effects on Missouri River.
Direct and indirect cumulative effects on the Missouri River will be estimated for each alternative. Any withdrawals identified in the detailed alternative study will be analyzed for effects on the Missouri River, most likely through use of a cumulative effects model developed for the Missouri River by the Omaha District of the COE. Cumulative effects will be estimated on the Missouri River from Montana to the confluence with the Mississippi River.

Hydrology 6.3 - Cumulative Effects on Other Water Sources.
Direct and indirect cumulative effects on the other water sources will be estimated for each alternative. Other cause-and-effect relationships between actions and resources, ecosystem, or human communities will be addressed in other study component SPOSs.

Hydrology 6.4 - Summarize Cumulative Effects.
The direct and indirect cumulative effects of each alternative described in Hydrology 6 will be summarized prior to being used in other studies or analyses.

Hydrology 6.5 - Review Cumulative Effects.
The cumulative effects will be reviewed, changes will be incorporated where appropriate, and the final cumulative effects will be provided for use in other SPOS tasks.

HYDROLOGY 7 - HYDROLOGY APPENDIX

Hydrology study tasks will be analyzed and the results will be used to characterize the Red River ~~B~~basin and part of the Missouri River ~~B~~basin. The present and probable future conditions of these areas will be described using results from all hydrologic analyses completed specifically for the Red River Project or in conjunction with other agencies. Documentation of the study results will be presented in a Hydrology Appendix.

Hydrology 7.1 - Summarize Hydrology Studies Results.
Study results will be summarized in a draft Hydrology Appendix. This Appendix will include all references, methodologies, results and conclusions of each hydrologic study. Specific portions may be compiled into a separate more detailed report if deemed necessary.

Hydrology 7.2 - Review Hydrology Studies Results.
The study results will be reviewed by peers, changes will be incorporated where appropriate, and the final study results will be provided to other study components.

Hydrology 7.3 - Complete Hydrology Appendix.
Reclamation will prepare the final ~~draft of the~~ Hydrology Appendix for the Needs and Options Report.

REFERENCES

Bureau of Reclamation, 2000, Phase II Hydrology Appendix, Attachment B - Groundwater Supporting Material.

Guenther, R. Scott et al., 1990, Gaged and Estimated Monthly Streamflow During 1931-84 for Selected Sites in the Red River Basin of the North in North Dakota and Minnesota, Water-Resources Investigation Report 90-4167, Bismarck, North Dakota.

Guenther, R. Scott, 1991, Methods for Estimating Monthly Mean Concentrations of Selected Water-Quality Constituents for Stream Sites in the Red River of the North Basin, North Dakota and Minnesota, Water-Resources Investigation Report 91-4086, Bismarck, North Dakota.

Ripley, Dave, 2000, Water Resources Characteristics of the West Fargo Aquifer System, Bismarck, North Dakota.

Rosgen, Dave, 1996, Applied River Morphology, Wildland Hydrology.