Red River Valley Water Supply Project

Effects of Alternatives Depleting Water from the Missouri River
on
Missouri River Uses and Resources

by the

Missouri River Water Management Division
Northwestern Division
Corps of Engineers

August 2005

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Executive Summary

Future depletions of water from the Missouri River are going to affect the amount of water that is able to move through the Missouri River Mainstem System (System). The Bureau of Reclamation (Reclamation) initiated a study with the Northwest Division of the U.S. Army Corps of Engineers (Corps) to analyze the potential depletion impact that could be caused by a proposed transfer of water from the Missouri River to the Red River Valley Water Supply (RRVWS) project. This study looks at the effects of select alternatives of the RRVWS Project depleting water from the Missouri River on Missouri River uses and resources.

The Corps conducted this analysis using expertise and tools gained from recent studies and investigations for the *Missouri River Master Water Control Manual Review and Update FEIS (March 2004)* (Master Manual Study) and updated depletion data developed by Reclamation in *A study to determine the historic and present-level streamflow depletions in the Missouri River Basin for the period, 1929 to 2002 (2005.*).

The Corps looked at a range of depletions from two selected alternatives for Missouri River depletion to the Red River Valley, one at Lake Sakakawea and the other on the Missouri River at Bismarck. The Corps' Daily Routing Model (DRM) was run to establish a baseline with updated depletion data and forecasted depletions out to 2050. Next, the alternatives were run adding the corresponding depletions to the two base runs to examine hydrologic and, ultimately economic use and environmental resource differences between each of the alternative runs and their corresponding base DRM run.

The Direct Model results showed very small differences (tenths of a percent change) in economic and environmental resources when alternatives were compared to 2002 depletion conditions. Similar results were found for 2050 depletion conditions with

only tern and plover habitat (less than 3 percent negative change) and wetland habitat (about 0.6 percent negative change) having changes greater than 0.5 percent change.

A Trend Analysis was conducted to look at the impacts data for each use or resource versus the level of depletion for the alternative runs. The slope of the trendline established is the change in the use or resource value per million acre-feet of depletions. This Trendline Analysis found that changes are generally very small (less than 0.5 percent) when the relative changes (percent change) are considered. Therefore, this finding supports the results of direct modeling.

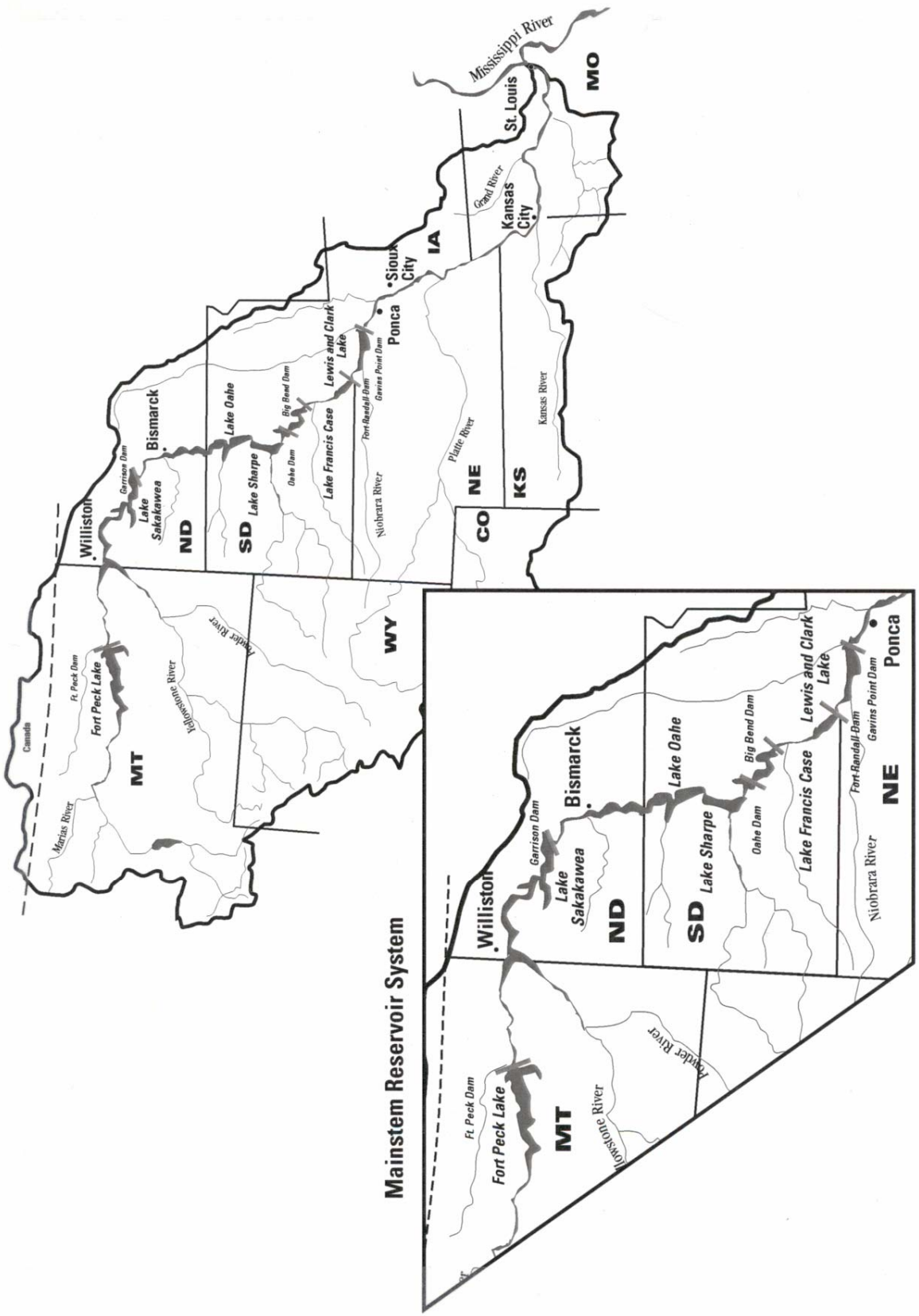
In conclusion, the highest Missouri River depletion proposed for a Red River Valley Water Supply Project alternative is generally small in relationship to total available water supply. In turn, using the analyses developed for the Master Manual Study, the impacts of additional Red River Valley Water Supply Project withdrawals to the Missouri River uses and resources are very small when relative changes are considered.

Introduction

At the request of the Dakotas Area Office of the U.S. Department of Interior, Bureau of Reclamation (Reclamation), the Northwestern Division (NWD) of the U.S. Army Corps of Engineers (Corps) assisted with conducting a study of the Red River Valley Water Supply Project. Specifically, the Corps was requested to evaluate the effect of select Missouri River water import alternatives for the Red River Valley Water Supply Project on Missouri River economic uses and environmental resources. This report summarizes the data and models used for the hydrologic and impacts analyses, the specific methodology followed using these data and tools, the Missouri River economic uses and environmental resources evaluated, and the impacts of the alternatives on these Missouri River uses and resources under 2002 and 2050 levels of depletions in the Missouri River basin.

This effort was based on a modification of the effort conducted for the Corps' Missouri River Master Water Control Manual Review and Update Study (Master Manual Study), for which a Final Environmental Impact Statement (FEIS) was completed in March 2004. This FEIS evaluated alternatives for the regulation of the Missouri River Mainstem Reservoir System (System) of six dams and reservoirs (see Figure 1). The models used for this evaluation of select alternatives for the Red River Valley Water Supply Project were modified from those used for Master Manual Study FEIS to incorporate updated depletion data for the basin and to address a different period of analysis. Reclamation provided the basic input data on Missouri River depletions with the select alternatives, historic depletions for 2002, and potential other depletions within or from the Missouri River basin between 2002 and 2050. The Missouri River impacts of those select alternatives under current and 2050 conditions were evaluated using the Reclamation data and the Master Manual Study hydrologic and impact evaluation models.

Figure 1. Missouri River Mainstem Reservoir System



Background – Data and Models Used for the Analyses

Daily Routing Model

The first step in conducting this study was to review the Corps' Missouri River Daily Routing Model (DRM). The DRM was developed during the 1990's as part of the Corps' Master Manual Study to simulate and evaluate alternative System regulation for all of the authorized purposes for the System under a widely varying, long-term, hydrologic record. The DRM uses daily input data that provide a level of precision that is necessary to evaluate some the effects of different proposed System regulation alternatives.

The DRM is a water accounting model that consists of 20 nodes, including the six System dams and 14 gaging stations. Output from the model provides data on each of the six System reservoirs. The DRM also provides output at four locations (nodes) along river reaches between System projects: Wolf Point and Culbertson, Montana and Williston and Bismarck, North Dakota; and ten locations along river reaches below the System: Sioux City, Iowa; Omaha, Nebraska City, and Rulo, Nebraska; St. Joseph, Kansas City, Waverly, Boonville, and Hermann, Missouri on the Missouri River and St. Louis, Missouri on the Mississippi River. Besides reservoir level and release data and river flow data, the DRM also provides hydropower generation data and navigation service data for use in subsequent impacts modeling.

The historic data set used for the DRM was developed from the NWD Water Management database, U.S. Geological Survey gaging records, and from the Corps' Long Range Study model (an older Missouri River model with a monthly time step on which the DRM is based) database for reservoir evaporations prior to 1967. Daily records are available for the six System dams since each dam's respective date of closure, and daily flow data are available for the majority of gaging stations since 1930. Prior to 1930, there is general lack of daily records in the basin. Representative daily data were constructed from available monthly data to cover the period from 1898 to 1929 for the Corps' Master Manual Study FEIS to match the beginning of the period of analysis to that for the Long Range Study model. As a result, there were 100 years of data extending from 1898 through 1997 used in evaluating alternatives for the FEIS. The data set has since been extended through 2003. The data are organized in yearly files that contain daily data for each of the dams and gage locations.

The DRM uses two sets of input data and a number of smaller data files. The first set of input data consists of historic reach inflows and streamflow depletions. There is also an option to include forecasted monthly runoff. The second data set contains various constants and variable parameters that define regulation decisions and operational limits for a particular simulation. These include downstream flow targets, reservoir characteristics, regulation levels, regulation guide curves, power generation criteria, navigation guide criteria, and fish and wildlife criteria, including those for endangered and threatened species.

The DRM provides options for creating a number of output files showing various parameters for each node in the model and for the System, using either daily or monthly data for the period of study. At a minimum, certain files are output to provide the required input data files for the impacts models. Other files may also be set up as output to allow additional review of these files to verify that the model simulation for each alternative is reasonable.

2002 and 2050 Level of Depletions without the Project

The next step in this study was to update depletion data. The depletions used in the 100-year data set for the Corps' FEIS were supplied from Reclamation's 1987 study. For the Corps' Red River Valley Water Supply Project analysis, Reclamation updated its depletion data with *A study to determine the historic and present-level streamflow depletions in the Missouri River Basin for the period, 1929 to 2002 (2005.*). For the base run, depletions were adjusted to a 2002 level of development. Reclamation also provided future monthly depletions that were identified as being in place by 2050. These numbers are derived from written plans for future projects that may be reasonably certain to occur within the timeframe of the Red River Valley Water Supply Project, which is 2050. The inclusion of anticipated future depletions allows Reclamation to look at future depletions from a cumulative impacts perspective. These anticipated future depletions to Missouri River flows were forecasted by Reclamation to be about 155,000 acre-feet without implementation of any of the Red River Valley Water Supply Project Missouri River import alternatives.

Depletions for Select Missouri River Alternatives

Reclamation's Bismarck Office provided monthly depletions for select alternatives for the Red River Valley Water Supply Project that would withdraw water from either Garrison reservoir (Lake Sakakawea) or the Missouri River downstream from Bismarck. The alternatives selected by Reclamation for this analysis include the Missouri River to Red River Valley Import Alternative (Missouri River below Bismarck) and the Garrison Diversion Unit Water Supply Replacement Pipeline Alternative (Lake Sakakawea). Because of the uncertainty in making future demand projections out to 2050, Reclamation decided to use a range of demand scenarios for each alternative. So for each alternative, two depletion scenarios were evaluated.

These depletions are presented in Table 1. The annual depletions (Table 1) range from 22 percent of the forecasted (2002-2050) amount of depletions to as high as 48 percent. In other words, the highest Missouri River depletion alternative, Scenario 2 for the Garrison Diversion Unit Water Supply Replacement Pipeline Alternative (withdrawal from Lake Sakakawea), could about double forecasted depletions over the next approximately 50 years if it were the alternative selected for implementation and forecasted depletions were realized. However, to put this in perspective the volume of water of the highest Missouri River depletion alternative plus the forecasted future depletion (total of about 298,000 acre-feet) is only about 1.8 percent

of the 16,690,000 acre-feet of average yearly inflow into Lake Sakakawea for the 1967 through 2004 period. From another perspective, the 298,000 acre-feet is about 1.6 percent of the average annual storage in Lake Sakakawea of about 18,215,000 acre-feet for the 1967 through 2002 period. Furthermore, the highest proposed depletion alternative for a 2050 demand of 143,097 acre-feet is only about 2.0 percent of the current depletion for all project withdrawals on the lower Missouri River below Gavins Point Dam from since 1898 (7,300,000 acre-feet).

Table 1
Red River Valley Water Supply Project
Maximum Monthly Depletions From Missouri River
All values are shown in acre-feet

GDU Replacement (Lake Sakakawea)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Scenario 1	7,805	7,335	8,393	8,578	9,937	11,955	13,214	11,080	9,760	8,915	8,602	8,130	113,702
Scenario 2	10,025	9,364	10,647	10,873	12,529	14,851	16,297	13,825	12,193	11,210	10,877	10,405	143,097
Missouri River to Red River Valley Import (Missouri River at Bismarck)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Scenario 1	2,583	2,333	2,583	2,499	2,583	2,499	2,583	2,583	2,499	2,583	2,499	2,583	30,410
Scenario 2	3,689	3,332	3,689	3,570	3,689	3,570	3,689	3,689	3,570	3,689	3,570	3,689	43,435

Increased Level of Depletion

Next, to provide a check on impacts, an extra depletion level greater than the alternative runs was completed for this analysis. For this extra run, the depletions for GDU Replacement Scenario 1 and for Missouri River to Red River Valley Import Scenario 1 were extrapolated to a total annual depletion of 800,000 acre-feet. These extra runs were used to incorporate additional data into an impacts trend analysis that could be used to support (or a second set of data if it did not support) the data results of the direct modeling of the alternatives.

Missouri River Impacts Models

Several impacts models were developed for the Corps' Master Manual Study that used the hydrologic, hydropower generation, and navigation data from the DRM to compute Missouri River economic use and environmental resource impacts that were subsequently used to prepare the FEIS for the Master Manual Study. These same models were used to identify potential impacts of diverting water from the Missouri River to the Red River Valley under the Water Control Plan implemented in 2004 for the first time based on a revised Master Manual. This new water control plan is commonly referred to as the new Water Control Plan (NWCP) by the Missouri River

Water Management staff in the Corps' NWD due to its recent implementation following 44 years of operation under the previous Water Control Plan.

Table 2 lists the Missouri River economic uses and environmental resources for which impacts were computed for the Red River Valley Water Supply Project. This table also includes the units for each of the uses or resources. A brief description of each use and resource follows.

Table 2. Missouri River economic uses and environmental resources evaluated for the Red River Valley Supply Project.

Use/Resource Category	Abbreviation	Unit
Flood Control	FC	$ million
Missouri River Navigation	NAV	$ million
Hydropower	HYD	$ million
Water Supply	WS	$ million
Recreation	REC	$ million
Total Economics	TOT	$ million
Reservoir Coldwater Habitat	CS	million acre-feet
Riverine Coldwater Habitat	CR	miles
Riverine Warmwater Habitat	WR	miles
Reservoir Young Fish Production	YOY	index
Riverine Fish Physical Habitat	PH	index
Riverine Tern and Plover Habitat	TP	acres
Wetland Habitat	WT	1000 acres
Riparian Habitat	RP	1000 acres
Historic Properties	HS	index

Flood control (FC) National Economic Development (NED) benefits are those that would be prevented by the construction and operation of the six dams on the Missouri River. The benefits computed represent the difference between the damages that would have occurred had the dams and reservoirs not been constructed and those with these projects in place.

Missouri River navigation NED (NAV) benefits represent the cost savings provided by navigation on the Missouri River from Sioux City, Iowa to the mouth versus movement of those commodities by the next least costly mode of transportation, which is this case is generally rail or truck transport to St. Louis where Mississippi River navigation is used to transport the commodity to the ultimate destination for down bound movements and vice versa for up bound movements.

Hydropower NED (HYD) benefits are computed for the capacity provided and the energy generated by the hydropower units at the six Missouri River dams. The benefits represent the cost savings provided by generating the electricity at the dams versus building additional generating facilities in the basin. These additional facilities would be a mix of base load and peaking powerplants, and the cost for the power from them would be more costly than the hydropower.

Water supply NED (WS) benefits are computed based on costs for water supply facilities that depend on the Missouri River and the six reservoirs as a direct source of water. Typically, the costs increase during extended droughts when the reservoir levels drop and the river flows are reduced. Increased costs occur when the users must increase efforts to ensure that the water intakes continue to function as the water surface drops toward the top of intakes during the droughts. In some cases, the intakes must be modified to ensure that the user has continued access to the water throughout the drought. In the case of powerplants that rely on once-through cooling, the cost for intake modifications are compared to the costs associated with meeting discharge requirements for the waste heat as it is returned to the Missouri River in the form of warmer water. Both the intake limitation and the discharge limitation generally result in reduced power generation. To meet the greater limitation of the two in any given month, replacement energy would need to be purchased from the power grid, which means that additional generating capability must be constructed to provide the capacity needed in the region during power shortfalls. The cost of providing this additional capacity was included in the water supply benefits for the powerplants in the reach downstream from Garrison Dam in North Dakota and along the Lower Missouri River from Gavins Point Dam, the lower most of the six dams, and the mouth of the river.

Recreation NED (REC) benefits are based on the value of the various forms of recreation provided on the Missouri River and its six reservoirs. This value is generally based on the amount of money the users are willing to spend to travel to the recreation facilities. Reductions in benefits are computed to reflect increased costs during abnormally high and low reservoir levels. Benefits, therefore, fluctuate as the visitation varies and the costs increase during extreme events such as extended droughts and very wet years in the upper Missouri River basin.

Total NED (TOT) benefits are just a summation of the benefits for the five economic uses described above. All of these economic benefits are computed in millions of dollars.

Reservoir coldwater fish habitat (cold storage, or CS) is the volume of habitat in millions of acre-feet (MAF) that meets the temperature and oxygen requirements of the coldwater species in the four larger Missouri River reservoirs (behind Fort Peck, Garrison, Oahe, and Fort Randall Dams). The requirements for these two parameters vary from month to month, and the month with the least amount of habitat meeting the requirements for each year is the value selected for presentation. A value is computed for each year of the period of analysis, and this value normally diminishes during droughts.

Riverine coldwater habitat (CR) is the number of river miles meeting specified temperature and dissolved oxygen requirements extending downstream from Fort Peck and Garrison Dams. As the coldwater habitat in the upstream reservoirs

diminishes during droughts, the number of river miles of coldwater habitat generally diminishes.

At some point downstream from Fort Peck and Garrison Dams the water in the Missouri River warms up enough to meet the temperature and oxygen requirements for warmwater fish species. The number of river miles from that point downstream to the next reservoir is computed for each month, and the month with the lowest number of miles has the value that is used for each year for warmwater fish habitat (WR). This resource value generally increases during droughts.

Another measure of appropriateness of habitat for reservoir fish is the success of young-of-year production (YOY). Data on young of year were obtained for each of the six reservoirs from the corresponding State game and fish agency. Various hydrologic parameters and combinations of parameters were then used to develop regression equations with these parameters as variables. Multiple regressions were used to determine the combination of these variables that best predicted young-of-year catch in a reservoir. Various species were selected for each reservoir on which to conduct the analyses. The species selected were generally a combination of game and forage fish. The net output from this model is an index for each reservoir, and the individual indices are combined to come up with a total index for each year that is an indicator of relative fish production for that year. The higher the value is, the greater the likelihood for successful young fish production.

The success of native riverine fish to produce and recruit was measured as a comparing the cross-section depth or velocity in a given river reach under current conditions for each year to the habitat that was available in a given reach prior to the construction of the six dams and reservoirs. The basic assumption is that the closer the existing habitat correlates to this historical habitat, the greater the likelihood for the native species to survive. The end product of this model is an index for each reach. The closer this index value is to 1.0, the closer the existing habitat in that year corresponds to the historical habitat. The index values for the nine reaches are summed to provide a total physical habitat (PH) value for each year.

Terns and plovers use relatively bare sand habitat on islands in the river reaches for nesting and rearing of the young to the point of fledging. A model was developed to compute changes in this type of habitat on the four river reaches downstream from Fort Peck, Garrison, Fort Randall, and Gavins Point Dams. The amount of tern and plover habitat (TP) is affected by the elevation of the water on the sandbars and islands and the amount of erosion of vegetation resulting during high river flows. A third factor, rebuilding and erosion of sandbars and islands, could not be modeled; however, this model provides some insight on how flows affect the amount of habitat. The number of acres that is available in June, July, and August is computed, and the month with the lesser amount of habitat when June and July, July and August, and then the minimum from these two periods are compared. The larger of these two becomes the amount of habitat selected for each year for each reach. The annual total value is the sum of the four reach values.

Wetland and riparian habitats are representative of the range of vegetation that grows in areas identified as wetlands along the river reaches and the deltas of each reservoir. Forty-two sites were selected for inclusion in this model. The model tracks the changes between the more woody-type vegetation (riparian vegetation) and the more pulpy-type vegetation (wetland vegetation) as the water surface in the site varies from year to year. These sites were fixed in size and included bare sand and open water areas within the sites. In some years when water levels were higher, the sand, water, and riparian habitat portions of the site could convert to the wetland type. Conversely, drier years could lead to a shift to riparian habitat in a given site. Overall, the models provided acreage values for both habitat types for each site that were summed to provide a value for each reach. The total yearly wetland habitat (WT) and riparian habitat (RP) values were a summation of the reach values.

Finally, the effect of reservoir levels on the known historic, cultural, and prehistoric sites around each of the upper three reservoirs was computed based on the potential for erosion of each site. If the water surface was within a specified distance above to some distance below, the potential accompanying wave action could be eroding the site. Each month was checked to determine if the site was experiencing erosive forces. The number of "hits" was summed (maximum of 12 per year) for each site for each year. All known sites (from surveys) had annual values that were summed to arrive at an annual value for each of the upper three, larger reservoirs. The final total historic, cultural, and prehistoric sites annual value (HS) is computed based on an inverse relationship of the total number of hits each year. This inverse relationship was used to provide a final number that would increase if the number if hits decreased. An increase in the final number is, therefore, good for the known sites. Unfortunately, this analysis cannot account for the effects to unknown sites.

Methodology Used to Compute Impacts

Two separate impacts analyses were conducted to determine the impacts for each alternative and to provide a comparative set of results. The first used the direct results from the impacts models, and the second used these data to develop trend plots for a trends-based analysis. Because the depletions were relatively small for each alternative, the trends analysis provided the opportunity to look at higher depletions and to provide some assurance that the impacts that are identified have the right mathematical sign (positive or negative) on them.

DRM Hydrologic Model

The first step in conducting the impact analysis of this study for the select Red River Valley Water Supply Project alternatives was to complete base DRM runs without the depletions for the alternatives in 2002 and 2050. Next, the select alternatives were run adding the corresponding depletions to the two base runs to examine hydrologic

and, ultimately, economic use and environmental resource differences between each of the alternative runs and their corresponding base DRM run.

Base DRM Runs for 2002 and 2050 Depletion Levels. Reclamation provided updated monthly depletions from 1929 to 2002 at a 2002 level of Missouri River basin development. The Corps distributed these depletion data as daily values so that they could be reinserted into the DRM yearly, daily-time-step input files. This data set was then used with each of the alternatives. The Corps' NWCP was used to produce output files for the base run. Since daily data were available generally starting in 1930 and the model readily begins calculations in that year, it was decided to produce output starting in 1930 rather than 1929. Simulations for all of the alternatives produced data through 2002. The base DRM run was labeled NWC300 for data management purposes.

Future depletions are handled separately in the DRM. Rather than inserting daily values into the yearly files, monthly values are entered into a corresponding future depletions input file that was used to evaluate potential depletions for the Master Manual Study FEIS. The forecasted depletions provided by Reclamation were used and, again, the base set of data was used with the forecasted depletions through 20~~0~~50 added to the select alternative depletions. This DRM run was labeled NW300F.

DRM runs for the Select Alternatives. The select Red River Valley Water Supply Project alternative runs, including scenarios 1 and 2, were done in two sets. The first set used the base DRM run (NWC300) along with the four depletion data files, as defined by Reclamation. The second set used the same select alternatives, including scenarios 1 and 2, with the addition of the future depletions (based on DRM run NW300F). The eight runs for the select alternatives are listed in Table 3.

Table 3. DRM simulation runs for the four Red River Valley Water Supply Project alternatives using water from the Missouri River.

	With Base Run NWC300	With Future Depletions Run NW300F
Replacement Scenario 1	NWC3R1	NW3R1F
Replacement Scenario 2	NWC3R2	NW3R2F
Import Scenario 1	NWC3I1	NW3I1F
Import Scenario 2	NWC3I2	NW3I2F

Economic and Environmental Impacts Models

Three models were used to compute the impacts to the economic uses and environmental resources that rely on the Missouri River. These three models are the flood control benefits, economic impact, and environmental impact models. The flood control benefits model, a daily-time-step model, was developed to replace the monthly-time-step flood control component of the economic impacts model. Of these

three models, only the flood control benefits model had to be modified to use for the Corps' support to the Red River Valley Water Supply Project.

All three models were applied to each of the ten simulation runs listed in Table 3. The output files were the average annual impacts over the 73 years of the 1930 to 2002 period of analysis. Differences between the corresponding base run (NWC300 for the 2002 runs and NW300F for the 2050 runs) and each of the four alternatives were computed, and the percentage change from the corresponding base run was computed.

Discussion of the Impacts

Direct Model Results

Table 4 presents the impacts data for the ten simulation runs. The Corps developed the impacts models to provide absolute numbers for comparison with the focus of the final analyses to be on the relative change in values. Based on this recommendation by the Corps, the focus of the review of Table 4 should be on the percent changes from the two base runs. These values are all very small (tenths of a percent change) with only the recreation, cold storage, warmwater fish habitat, young-of-year fish production, tern and plover habitat, wetland habitat, and historic properties having percent changes greater than 0.5 percent when compared to the base run representing 2002 depletion conditions in the Missouri River basin. Only tern and plover habitat and wetland habitat have a percent change greater than 0.5 percent when 2050 depletion conditions are modeled when compared to the impacts of the future depletions run without either alternative.

Trends Analysis Results

A second impacts analysis was conducted using the raw data from the direct modeling results. Each on of the alternatives had a level of depletion that varied from that of the 2002 base run and the eleventh and twelfth "high" depletion runs (NWC308 and NW3082) with 800,000 acre-feet of depletions from Lake Sakakawea and downstream from Bismarck, respectively. For example, the NWC3I1 alternative had a depletion level of 30,400 acre-feet, and the NW3I1F alternative had a depletion level of 30,400 plus 155,000 acre-feet (depletions forecasted from other projects in the basin between 2002 and 2050), or 185,400 acre-feet. The impacts data for each use or resource were plotted versus the level of depletion for the alternative run. Figure 2 is an example of one of these plots. The Microsoft Excel software program has a feature in which a trendline can be included in the plot, as shown. The program also computes the equation of the line and provides the R^2 value (correlation coefficient) for the fit of the trendline to the data. The closer the R^2 value is to 1.00, the better the data points align with the trendline.. The slope of the trendline (coefficient before the dependent variable, or "x" in this case) is the change in the use

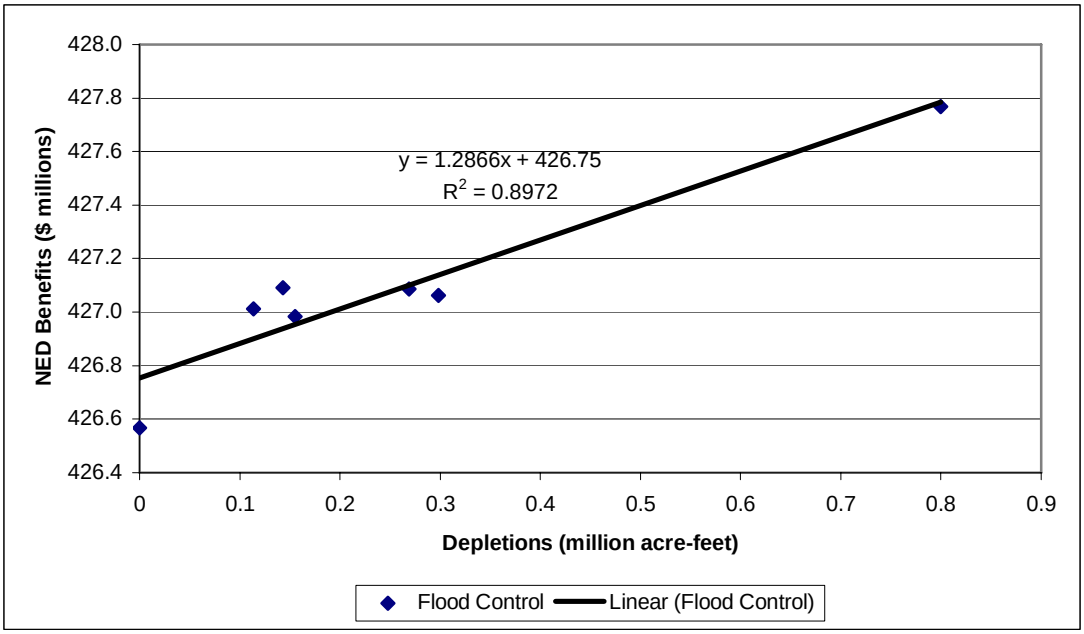
or resource value per million acre-feet of depletions, in this case from the Lake Sakakawea reach.

Tables 5 and 6 present the slopes and R^2 values for the uses and resources modeled for the Replacement Alternative (Lake Sakakawea diversion) and the Import Alternative (downstream from Bismarck diversion). Each table also shows the depletion levels for the current and 2050 runs for each alternative and the 2050 base run. The computed changes in use and resource values from the 2002 base run using the trendline slopes are presented in each table followed by the percent change from the 2002 base run values. Of interest are the R^2 values, which are generally very good. The only exceptions are the R^2 values for recreation, tern and plover habitat, and wetland habitat. Review of the percent changes for all of the uses or resources shows that these changes are generally less than 0.5 percent. None has a change greater than 0.5 percent for the either of the two alternatives at the 2002 level of depletions.

For the Replacement Alternative, the 2050 level of depletion impacts show percent changes greater than 0.5 percent for young reservoir fish production, reservoir coldwater fish habitat, tern and plover habitat, and historic properties, all of which the percent changes are about 2 percent or less. Only three resource categories have changes greater than 0.5 percent for the Import Alternative. These three resources are reservoir fish coldwater habitat, tern and plover habitat, and historic properties. Comparing the changes for the Replacement alternative to the 2050 base run shows that only reservoir coldwater fish habitat and tern and plover habitat have a percent change greater than 0.5. Only one resource, tern and plover habitat, has a change greater than 0.5 percent for the Import Alternative. In other words, the trends analysis found that the changes are generally very small (less than 0.5 percent) when the relative changes (percent change) are considered. This finding supports the results of the direct modeling.

Conclusion

The highest Missouri River depletion proposed for a Red River Valley Water Supply Project alternative is generally small in relationship to total available water supply. In turn, using the analyses developed for the Master Manual Study, the impacts of additional Red River Valley Water Supply Project withdrawals to the Missouri River uses and resources are very small when relative changes are considered.



Absolute Values for Average Annual Benefits

Model Run	Depletion (MAF)	Flood Control ($ million)
NWC300	0	426.57
NWC3R1	0.114	427.01
NWC3R2	0.143	427.09
NW300F	0.155	426.98
NW3R1F	0.269	427.09
NW3R2F	0.298	427.06
NWC308	0.8	427.77

Figure 2. Trend plot for Missouri River flood control NED benefits for the GDU Replacement Alternative with the values included in the plot presented below the plot.

Table 4. Impacts of the select alternatives based on the direct model results.

2002 Depletions Runs

	FC	NAV	HYD	WS	REC	TOT	CS	CR	WR	YO	PH	TP	WT	RP	HS
Absolute Values for Average Annuals															
NWC300	426.57	8.60	659.22	613.06	87.46	1794.92	9.728	183.61	50.15	2.094	81.11	332.68	150.65	116.67	5092
NWC3R1	427.01	8.58	657.12	612.98	86.92	1792.61	9.633	183.16	50.58	2.083	81.09	356.70	150.27	116.80	5137
NWC3R2	427.09	8.58	656.64	612.93	87.09	1792.34	9.622	183.29	50.54	2.084	81.10	362.25	150.81	116.83	5138
NWC3I1	426.74	8.60	658.74	613.04	87.35	1794.47	9.712	183.22	50.56	2.096	81.11	334.15	151.59	116.43	5101
NWC3I2	426.87	8.58	658.53	613.03	87.33	1794.34	9.697	183.42	50.14	2.090	81.09	373.09	150.59	116.65	5105
NWC308	427.77	8.47	646.66	610.79	86.98	1780.66	9.40	181.59	50.84	2.06	81.24	327.30	151.50	117.58	5234
NW3082	427.81	8.51	646.58	611.39	86.54	1780.82	9.36	181.69	50.66	2.05	81.34	274.64	151.37	118.10	5264
Absolute Change from NWC300															
NWC3R1	0.44	-0.02	-2.10	-0.08	-0.54	-2.31	-0.09	-0.45	0.42	-0.01	-0.02	24.02	-0.38	0.13	45
NWC3R2	0.52	-0.02	-2.58	-0.13	-0.37	-2.58	-0.11	-0.32	0.38	-0.01	-0.01	29.58	0.15	0.16	47
NWC3I1	0.17	-0.01	-0.49	-0.02	-0.11	-0.45	-0.02	-0.39	0.41	0.00	-0.01	1.47	0.94	-0.24	9
NWC3I2	0.30	-0.02	-0.69	-0.03	-0.13	-0.58	-0.03	-0.19	-0.01	0.00	-0.03	40.41	-0.07	-0.01	13
Percentage Change from NWC300															
NWC3R1	0.10	-0.26	-0.32	-0.01	-0.62	-0.13	-0.97	-0.24	0.84	-0.53	-0.03	7.22	-0.25	0.11	0.88
NWC3R2	0.12	-0.21	-0.39	-0.02	-0.42	-0.14	-1.09	-0.17	0.76	-0.50	-0.01	8.89	0.10	0.14	0.91
NWC3I1	0.04	-0.07	-0.07	0.00	-0.13	-0.03	-0.16	-0.21	0.81	0.11	-0.01	0.44	0.62	-0.20	0.19
NWC3I2	0.07	-0.26	-0.11	-0.01	-0.15	-0.03	-0.31	-0.11	-0.03	-0.21	-0.03	12.15	-0.04	-0.01	0.26

2050 Depletions Runs

	FC	NAV	HYD	WS	REC	TOT	CS	CR	WR	YO	PH	TP	WT	RP	HS
Absolute Values for Average Annuals															
NW300F	426.98	8.59	656.62	612.90	87.22	1792.31	9.637	182.89	50.57	2.084	81.14	332.53	152.03	116.68	5131
NW3R1F	427.09	8.61	655.29	612.22	87.50	1790.70	9.647	182.98	50.64	2.080	81.10	356.29	151.37	116.61	5131
NW3R2F	427.06	8.60	654.75	612.17	87.60	1790.18	9.620	182.40	50.80	2.079	81.11	326.23	151.82	116.69	5128
NW3I1F	426.95	8.59	656.21	612.87	87.20	1791.83	9.633	183.10	50.44	2.085	81.17	322.45	151.09	116.67	5136
NW3I2F	427.03	8.58	656.07	612.83	87.25	1791.76	9.616	183.02	50.43	2.084	81.18	331.23	151.40	116.69	5141
Absolute Change from NW300F															
NW3R1F	0.10	0.02	-1.32	-0.69	0.28	-1.61	0.01	0.10	0.07	0.00	-0.04	23.76	-0.66	-0.07	1
NW3R2F	0.08	0.01	-1.86	-0.74	0.37	-2.14	-0.02	-0.49	0.23	-0.01	-0.03	-6.30	-0.21	0.01	-2
NW3I1F	-0.03	0.01	-0.41	-0.03	-0.02	-0.48	0.00	0.22	-0.13	0.00	0.03	-10.08	-0.94	0.00	5
NW3I2F	0.05	-0.01	-0.55	-0.08	0.03	-0.55	-0.02	0.14	-0.14	0.00	0.04	-1.31	-0.63	0.02	10
Percentage Change from NW300F															
NW3R1F	0.02	0.25	-0.20	-0.11	0.32	-0.09	0.10	0.05	0.13	-0.23	-0.05	7.14	-0.43	-0.06	0.02
NW3R2F	0.02	0.15	-0.28	-0.12	0.43	-0.12	-0.18	-0.27	0.45	-0.24	-0.04	-1.89	-0.14	0.01	-0.05
NW3I1F	-0.01	0.08	-0.06	-0.01	-0.02	-0.03	-0.04	0.12	-0.26	0.04	0.04	-3.03	-0.62	0.00	0.10
NW3I2F	0.01	-0.12	-0.08	-0.01	0.04	-0.03	-0.21	0.07	-0.27	-0.04	0.05	-0.39	-0.42	0.01	0.20

Table 5. Impacts of the GDU Replacement Pipeline Alternative Model Runs based on the trendline computations from the linear regressions.

			Compared to NWC300 Impacts					Compared to NW300F Impacts	
			NWC3R1	NWC3R2	NW300F	NW3R1F	NW3R2F	NW3R1F	NW3R2F
			Relative Depletion in million acre-feet						
	Trend	R^2	0.114	0.143	0.155	0.269	0.298	0.114	0.143
	Slope	Value	Absolute Values Using the Trend Slopes from Linear Regressions						
FC	1.29	0.90	0.15	0.18	0.20	0.35	0.38	0.15	0.18
NAV	-0.17	0.77	-0.02	-0.02	-0.03	-0.05	-0.05	-0.02	-0.02
HYD	-15.43	1.00	-1.76	-2.21	-2.39	-4.15	-4.60	-1.76	-2.21
WS	-3.07	0.97	-0.35	-0.44	-0.48	-0.83	-0.91	-0.35	-0.44
REC	-0.29	0.07	-0.03	-0.04	-0.04	-0.08	-0.09	-0.03	-0.04
TOT	-17.67	1.00	-2.01	-2.53	-2.74	-4.75	-5.27	-2.01	-2.53
CS	-0.38	0.92	-0.04	-0.05	-0.06	-0.10	-0.11	-0.04	-0.05
CR	-2.46	0.91	-0.28	-0.35	-0.38	-0.66	-0.73	-0.28	-0.35
WR	0.65	0.58	0.07	0.09	0.10	0.17	0.19	0.07	0.09
YO	-0.04	0.95	0.00	-0.01	-0.01	-0.01	-0.01	0.00	-0.01
PH	0.17	0.76	0.02	0.02	0.03	0.05	0.05	0.02	0.02
TP	-23.38	0.15	-2.67	-3.34	-3.62	-6.29	-6.97	-2.67	-3.34
WT	1.04	0.18	0.12	0.15	0.16	0.28	0.31	0.12	0.15
RP	1.13	0.77	0.13	0.16	0.18	0.30	0.34	0.13	0.16
HS	159.5	0.89	18.18	22.81	24.72	42.91	47.53	18.18	22.81
	NWC300	NW300F							
	Abs. Value	Abs. Value	Percent Change from the Corresponding Base Run						
FC	426.57	426.98	0.03	0.04	0.05	0.08	0.09	0.03	0.04
NAV	8.6	8.59	-0.23	-0.28	-0.31	-0.53	-0.59	-0.23	-0.28
HYD	659.22	656.62	-0.27	-0.33	-0.36	-0.63	-0.70	-0.27	-0.34
WS	613.06	612.90	-0.06	-0.07	-0.08	-0.13	-0.15	-0.06	-0.07
REC	87.46	87.22	-0.04	-0.05	-0.05	-0.09	-0.10	-0.04	-0.05
TOT	1794.92	1792.31	-0.11	-0.14	-0.15	-0.26	-0.29	-0.11	-0.14
CS	9.73	9.64	-0.45	-0.56	-0.61	-1.05	-1.16	-0.45	-0.56
CR	183.61	182.89	-0.15	-0.19	-0.21	-0.36	-0.40	-0.15	-0.19
WR	50.15	50.57	0.15	0.19	0.20	0.35	0.39	0.15	0.18
YO	2.09	2.08	-0.22	-0.27	-0.30	-0.51	-0.57	-0.22	-0.27
PH	81.11	81.14	0.02	0.03	0.03	0.06	0.06	0.02	0.03
TP	332.68	332.53	-0.80	-1.00	-1.09	-1.89	-2.09	-0.80	-1.01
WT	150.65	152.03	0.08	0.10	0.11	0.19	0.21	0.08	0.10
RP	116.67	116.68	0.11	0.14	0.15	0.26	0.29	0.11	0.14
HS	5092	5131	0.36	0.45	0.49	0.84	0.93	0.35	0.44

Table 6. Impacts of the Red River Valley Import Alternative Model Runs based on the trendline computations from the linear regressions.

			Compared to NWC300 Impacts					Compared to NW300F Impacts	
			NWC3I1	NWC3I2	NW300F	NW3I1F	NW3I2F	NW3I1F	NW3I2F
			Relative Depletion in million acre-feet						
	Trend	R^2	0.03	0.043	0.155	0.185	0.198	0.03	0.043
	Slope	Value	Absolute Values Using the Trend Slopes from Linear Regressions						
FC	1.40	0.96	0.04	0.06	0.22	0.26	0.28	0.04	0.06
NAV	-0.11	0.92	0.00	0.00	-0.02	-0.02	-0.02	0.00	0.00
HYD	-15.78	1.00	-0.47	-0.68	-2.45	-2.92	-3.12	-0.47	-0.68
WS	-2.16	0.98	-0.06	-0.09	-0.33	-0.40	-0.43	-0.06	-0.09
REC	-1.09	0.98	-0.03	-0.05	-0.17	-0.20	-0.22	-0.03	-0.05
TOT	-17.74	1.00	-0.53	-0.76	-2.75	-3.28	-3.51	-0.53	-0.76
CS	-0.45	1.00	-0.01	-0.02	-0.07	-0.08	-0.09	-0.01	-0.02
CR	-2.21	0.95	-0.07	-0.10	-0.34	-0.41	-0.44	-0.07	-0.10
WR	0.46	0.38	0.01	0.02	0.07	0.09	0.09	0.01	0.02
YO	-0.05	0.98	0.00	0.00	-0.01	-0.01	-0.01	0.00	0.00
PH	0.30	0.96	0.01	0.01	0.05	0.06	0.06	0.01	0.01
TP	-90.42	0.74	-2.71	-3.89	-14.02	-16.73	-17.90	-2.71	-3.89
WT	0.44	0.06	0.01	0.02	0.07	0.08	0.09	0.01	0.02
RP	1.98	0.94	0.06	0.09	0.31	0.37	0.39	0.06	0.09
HS	212.5	1.00	6.38	9.14	32.94	39.31	42.08	6.38	9.14
	NWC300	NW300F							
	Abs. Value	Abs. Value	Percent Change from the Corresponding Base Run						
FC	426.57	426.98	0.01	0.01	0.05	0.06	0.06	0.01	0.01
NAV	8.6	8.59	-0.04	-0.06	-0.20	-0.24	-0.25	-0.04	-0.06
HYD	659.22	656.62	-0.07	-0.10	-0.37	-0.44	-0.47	-0.07	-0.10
WS	613.06	612.90	-0.01	-0.02	-0.05	-0.07	-0.07	-0.01	-0.02
REC	87.46	87.22	-0.04	-0.05	-0.19	-0.23	-0.25	-0.04	-0.05
TOT	1794.92	1792.31	-0.03	-0.04	-0.15	-0.18	-0.20	-0.03	-0.04
CS	9.73	9.64	-0.14	-0.20	-0.72	-0.86	-0.92	-0.14	-0.20
CR	183.61	182.89	-0.04	-0.05	-0.19	-0.22	-0.24	-0.04	-0.05
WR	50.15	50.57	0.03	0.04	0.14	0.17	0.18	0.03	0.04
YO	2.09	2.08	-0.07	-0.10	-0.37	-0.44	-0.47	-0.07	-0.10
PH	81.11	81.14	0.01	0.02	0.06	0.07	0.07	0.01	0.02
TP	332.68	332.53	-0.82	-1.17	-4.21	-5.03	-5.38	-0.82	-1.17
WT	150.65	152.03	0.01	0.01	0.05	0.05	0.06	0.01	0.01
RP	116.67	116.68	0.05	0.07	0.26	0.31	0.34	0.05	0.07
HS	5092	5131	0.13	0.18	0.65	0.77	0.83	0.12	0.18