Big Blue River Basin

The Big Blue River is located in south-central Nebraska and flows into Kansas where it becomes a tributary of the Kansas River, Figure BB-1. Major tributaries of the Big Blue River in Nebraska include Lincoln Creek, West Fork of the Big Blue River, Turkey Creek, Swan Creek, and Big Indian Creek, Figure BB-2. The total area of the Big Blue River Basin (Basin) in Nebraska is approximately 4,600 square miles and includes all of York County and portions of Adams, Butler, Clay, Fillmore, Gage, Hall, Hamilton, Jefferson, Lancaster, Pawnee, Polk, Saline, and Seward counties. County seats in the Basin include Aurora, Beatrice, David City, Geneva, Hastings, Osceola, Seward, Wilber, and York.

<u>Sources of Water</u>

Precipitation

Annual and growing season (May 1 through September 30) precipitation charts for gage sites in Aurora, Beatrice, Crete, Geneva, Osceola, Seward and York are shown on Figures BB-3 through BB-16. The average annual precipitation ranges from 27.3 inches at Hastings at the western end of the Basin to 30.6 inches at Beatrice in the southeast corner of the Basin. The average growing season precipitation ranges from 18.1 inches at Hastings to 20.3 inches at Beatrice. Locations of the precipitation gages can be seen in Figure BB-17.

Ground Water

Ground water in the study area originates mainly as infiltration from precipitation. Some ground water also flows into the study area from neighboring basins. The location and extent of the supply of economically available ground water is partially determined by the hydrogeology of the Basin. The Basin hydrogeology is complex due to the glacial or glacially influenced origin of the recent sediments. Much of the Basin has been glaciated, Figure BB-18. For purposes of this report, all saturated unconsolidated sediments of Quaternary age above bedrock inclusive of the paleovalley alluvial aquifers where there is a hydrologic connection, the alluvial aquifers, the shallow aquifers and the bedrock Tertiary Ogallala Group are combined into the principal aquifer unit for the Basin. Most of the principal aquifer in the upper part of the Basin is capped by a thick mantle of loess that either does not supply a significant amount of ground water or is not saturated. Bedrock Formations are secondary aquifers in this Basin. Tables BB-1 and BB-2 list all the aquifers by age along with their important hydrogeologic characteristics. The bedrock aquifers range in age from Tertiary to Permian (Figure BB-19) and supply a small amount of water compared to the other aquifers, but are important sources locally (CSD, 2005). In some areas wells drilled in the Dakota Sandstone are known to produce 500 to 800 gallons per minute (gpm) (Ellis, 1981). Generally, the streams in the Basin are not incised into the bedrock aquifers; though in some areas streams are known to be in contact with the Dakota Sandstone (Tabidian, 1987 and Ellis, 1981).

The principal aquifer varies in saturated thickness from 0 to approximately 400 feet, Figure BB-20. Depth to water from the land surface varies from 0 to more than 200 feet, Figure BB-21 (CSD 2005). Transmissivity ranges from less than 20,000 gallons per day per foot (gal/day/ft) to more than 200,000 gal/day/ft. Most areas of the southern and eastern parts of the Basin have a transmissivity value of less than 20,000 gal/day/ft, Figure BB-22. Values of specific yield range from less than 5 to greater than 25 percent, Figure BB-23 (CSD 2005).

There are areas in the Basin where the principal aquifer is absent or very thin due to the glaciated nature of the area. In these areas a hydrologic connection between the principal aquifer and the stream network has not been established (CSD 2005).

In the northwest area of the Basin, most stream reaches have streambed elevations five feet or more above the surrounding water table elevation; therefore, the stream and aquifer in this area are not in hydrologic connection, Figure BB-24 (Bitner, R. J., 2005). An inspection of all current (12/2005) hydrographs available on the U.S. Geological

Survey (USGS) website for the sites located along the West Fork of the Big Blue River within Hamilton and York counties shows that no water levels in that database are within 10 feet of the land surface. There are three sites in Hamilton County that are completed in Platte River alluvium that reflect water levels that are within 10 feet of the land surface. The majority of the Basin beginning in western York, Fillmore, and Polk counties and then extending east to the Basin boundary, lies in an area "where due to the complex hydrogeologic nature of this area the degree of connection between the ground water system and the surface water system is poor and uncertain" (CSD, 2005). The ground water table reflects the complicated nature of this glaciated area, Figure BB-25.

The Department has conducted seepage run studies in which streamflow is measured at intervals along a stream during a period in which there is no precipitation to cause surface water runoff. Such studies allow the determination of the extent to which streamflow is enhanced by baseflows from the surrounding ground water aquifer. Based on seepage runs completed in 1978, Soap Creek, Cub Creek, Indian Creek, Bear Creek, Big Indian Creek, Plum Creek, and various reaches of the Big Blue River itself are in some sections of their reaches in hydrologic connection with their surrounding aquifer systems (Ellis, 1981). The Ellis report also states that "All the stratigraphic units that have been described in this report are hydrogeologically interrelated. Conceptually, these deposits can be thought of as forming either a single unconfined aquifer in which there are large lateral and vertical differences in thickness and hydrogeologic properties, or as an unconfined aquifer system composed of hydraulically interconnected aquifers and local confining or semi-confining beds."

Seepage runs completed in 1984 and 1985 showed that streams were also in hydrologic connection to and gaining water from the aquifer for the reach of the Big Blue River between the cities of Dewitt and Beatrice, extending for 3 miles to either side of the river, (Tabidian, 1987). Tabidian states that in some areas the gain in flow was probably from the Dakota Sandstone Formation. Chemical analysis (Emery, 1966) and ground water gradients (Tabidian 1987) also support the fact that there is a hydrologic connection between the Big Blue River and the aquifer.

The information provided by all of the above named studies for seepage runs was insufficient to determine the hydrologic connection for this report.

Ground Water Use

Ground water in the Basin is used for a variety of purposes: domestic, industrial, livestock, irrigation, and others. Irrigation is the largest consumer of ground water, with 16,268 wells registered to irrigate approximately 1,700,000 acres as of October 1, 2005 (Department registered ground water wells database). There are approximately 16,000 registered ground water wells within the Big Blue River Basin as of October 1, 2005 (Department registered ground water wells database). Not all wells are registered in the Department database, especially stock and domestic wells, which if drilled prior to 1993 are not required to be registered. Certain dewatering and other temporary wells are not required to be registered. Figure BB-26 illustrates the location of depletive ground water wells. Depletive wells are those wells that consume water and thus remove water from the ground water system. Depletive wells include uses for: aquaculture, commercial, domestic, irrigation, public water supply, dewatering, stock, and other, except those in the other category noted as sparge, vapor extraction, or another non-consumptive use.

The areal extent of the high capacity wells shown in Figure BB-27 indicates where ground water has been and could be beneficially developed. High capacity wells are depletive wells with registered pumping rates equal to or greater than 50 gpm. This map is also useful in gauging where potential new wells could possibly be developed because future development will likely occur in the same areas. In the east end of the Basin, wells are mostly found in the paleovalleys, narrow alluvial valleys and isolated pockets of sand and gravel in the glacial sediments. In the western end of the Basin wells are mostly completed in the sediments of Pleistocene and Tertiary age. For purposes of this report only high capacity wells (wells capable of pumping more than 50 gallons per minute) have been analyzed for impacts on surface water in both current and future development scenarios. Ground water development analyzed by comparison of completion dates has shown that development of high capacity wells has been steadily increasing with accelerated increases during the years 1967 through 1983 and 1994 to the present, Figures BB-27 to BB-29. Table BB-3 shows the estimated average irrigated acreage by county within the Basin between 1950 and 2003. The increase in the number of other depletive wells seen in Figures BB-28 and BB-29 after 1993 is attributed to revision of the well registration statute in 1993.

Changes in Ground Water Table Elevation

Figure BB-30 is a map made from a compilation of all ground water levels reported to the Conservation and Survey Division of the University of Nebraska-Lincoln in cooperation with the USGS and the Natural Resources Districts (NRDs). It shows an area in southeast Butler County with a decline of up to 30 feet in ground water table elevations from predevelopment through the spring of 2005. A decline between 5 and 10 feet covers much of the western portion of the Basin, with an area of decline in the range of 20 to 30 feet in Fillmore County and an area of 10 to 20 feet of decline in Clay County. Figure BB-31 is the location map for selected ground water hydrographs across the Basin. Figures BB-32 through BB-37 are hydrographs (USGS 2005) which give a representative change in ground water table elevations for the particular area. Where possible a graph of a continuous recorder site is used. There are two very small areas of ground water table elevation increase in the Basin, one in Gage County and one in Polk County; both are very small in areal extent.

Ground Water Management

On December 9, 1977, the Upper Big Blue Natural Resources District (UBBNRD) instituted a ground water quantity management area. Permits have been required to construct certain wells since January 8, 1978. Currently, newly permitted wells are subject to 1,000 foot well spacing requirements. Large capacity well developers, such as industrial users exceeding 500 acre-feet per year, are required to submit ground water studies to show the expected impacts of their proposed well development. The UBBNRD Board considers permits for these wells on a case-by-case basis. Ground water allocations will be implemented by the UBBNRD if the weighted average district ground water level drops below the 1978 level, Figure BB-38. If allocations are implemented, ground water users will be required to certify to the UBBNRD how many acres of land they irrigate and install a meter to measure ground water use.

The Lower Big Blue Natural Resources District (LBBNRD) has established a ground water management area (GWMA) for quality purposes. As part of the GWMA requirements in the LBBNRD, permits are required prior to the construction of wells pumping greater than 50 gallons per minute (gpm).

Surface Water

Hydrographs from eight surface water gages in the Basin are included in this report, Figures BB-39 through BB-46. They are Lincoln Creek near Seward, West Fork of the Big Blue River near Dorchester, Turkey Creek near Wilber, Big Blue River at Surprise, Big Blue River near Seward, Big Blue River near Crete, Big Blue River at Beatrice and Big Blue River at Barneston, Figure BB-47. Streamflow in the Basin is driven primarily by precipitation and generally follows the annual variation in precipitation.

Surface Water Use

As of October 1, 2005, there are approximately 1,500 surface water appropriations in the Basin for a variety of uses. The majority of the surface water appropriations are for irrigation use and tend to be located on the major streams. There are no instream flow appropriations in the Basin. The first surface water appropriations in the Basin have a priority date of 1868 and development has continued through present day. The largest period of development occurred between 1967 and 1975, Figure BB-48 and Figure BB-49. The approximate locations of the surface water irrigated acres are shown in Figure BB-50. Information on specific appropriations is available in the Department's biennial report. Information on categories of use can be found in Appendix H.

Surface Water Compact

The State of Nebraska is a signatory member of the Kansas – Nebraska Big Blue River Compact (Compact). The purposes of the Compact are: To promote interstate comity, to achieve an equitable apportionment of the waters of the Big Blue River Basin, to encourage continuation of the active pollution-abatement programs in each of the two states, and to seek further reduction in pollution of the waters of the Big Blue River Basin.

The Compact sets state line flow targets from May 1 through September 30. The targets for the Big Blue River are shown in Table BB-4 and are measured at the Big Blue River gage at Barneston. If the targets are not met the State of Nebraska is required to:

1. Limit surface water diversions by natural flow appropriators to their decreed appropriations,
2. Close natural flow appropriators with priority dates junior to November 1, 1968 in accordance with the doctrine of priority,
3. Ensure that no illegal surface water diversions are taking place, and
4. Regulate wells installed after November 1, 1968, within the alluvium and valley side terrace deposits downstream of Turkey Creek, unless it is determined by the Compact Administration that such regulation would not yield any measurable increase in flows at the state line gage.

At the present time the Compact Administration has found that the regulation of those wells will not yield measurable increases in flow at the state line. Administration for the Compact occurred in 2002 and 2003 on the Big Blue River in Nebraska.

Table BB-4. Stateline flow targets for the Big Blue River.

Month	Target Flow
May	45 cfs
June	45 cfs
July	80 cfs
August	90 cfs
September	65 cfs

Analyses for the Fully Appropriated Determination

Surface Water Administration

In the 137-year period since the first surface water appropriation was perfected in the Basin, there have only been a few recorded instances of surface water administration in the administrative record, with the first occurring in 1954. A summary of water administration that occurred between 1985 and 2004 can be found in Table BB-5. The junior surface water appropriations in the Basin above Lincoln Creek had an average of 57 days in which surface water was available for diversion from July 1 through August 31 and 148 days in which surface water was available for diversion from May 1 through September 30. The junior surface water appropriations below Lincoln Creek on average had 61 days in which surface water was available for diversion from July 1 through August 31 and 152 days in which surface water was available for diversion from May 1 through September 30.

Table BB-5. Water Administration in the Big Blue River Basin between 1985 and 2004.

Year	Water Body	Days	Closing Date	Opening Date
2000	Turkey Creek	3	Jun 9	Jun 12
2000	Big Blue River above Lincoln Creek	2	Aug 15	Aug 17
2001	Big Blue River above Lincoln Creek	1	Aug 14	Aug 15
2002	Big Blue River above Lincoln Creek	11	Jul 11	Jul 22
2002	Big Blue River above Lincoln Creek	14	Jul 30	Aug 13
2002	Big Blue River	8	Aug 5	Aug 13
2002	North Fork Big Blue River	1	Aug 14	Aug 15
2003	Big Blue River above Lincoln Creek	49	Jul 16	Sep 3
2003	Big Blue River	11	Jul 17	Jul 28
2003	Big Blue River	8	Aug 11	Aug 19
2004	Big Blue River above Lincoln Creek	16	Aug 3	Aug 19

The senior surface water appropriations that caused administration in the Basin have priority date years prior to 1985 (1937, 1966, and 1968 are some of the known dates from the administration record), therefore it is not necessary to reconstruct the water administration table.

Determination of Hydrologically Connected Area

a) Big Blue River 10/50 area

There are four ground water models covering all or portions of the Basin. Some of these models are outdated and all are mentioned here for historical perspective of the modeling effort. In 1965, the USGS created an electric analog model of the Big and Little Blue River Basins to determine the effect of ground water withdrawals on the flow of the Big and Little Blue Rivers at or near the Nebraska-Kansas state line. This model is outdated and could not be used today to determine the 10/50 area or the impacts of current well development. The 1987 computer model developed by Mohamad Ali Tabidian is not useful for the purposes of this report because the model only covers a limited area of the Basin. The 2005 Cooperative Hydrology Study (COHYST) model also is limited in aerial extent and is therefore not useful for determining the 10/50 areas for the Basin. It is, however, useful in determining to the 10/50 area for the Platte River and is discussed in section b found below. Another model based on the COHYST model and further developed by the UBBNRD is also useful in determining to the 10/50 area for the Platte River and is discussed in section b found below. It does not cover enough of the Basin to be used to determine the 10/50 area connected to the Big Blue River and its tributaries.

For those areas of the Basin without a suitable numeric model, the Jenkins method is the selected tool for this report. However, the Jenkins method cannot be used because the restrictive and complex nature of the hydrogeology of the glaciated portions of the Basin violates the Jenkins methodology assumption that the aquifer consists of homogeneous, isotropic materials. The geology of the western area of the Basin is less complex; however, in most areas the principal aquifer is not in hydrologic connection with the streams because the water table is lower than the streambed elevation. Figure BB-25 shows that in the upper Big Blue drainage only a few small areas are in connection with the stream (Bitner, R. J., 2005). Because of the Jenkins assumptions violations and the limited area of stream/aquifer connection, much of the Basin cannot be analyzed using the Jenkins method. At the present time the Department cannot determine the 10/50 area for the Big Blue River and its tributaries.

The alluvial aquifer is known to be in hydrologic connection with the streams in many areas of the middle and lower Basin. However, the hydrogeology of the alluvial area violates the Jenkins assumptions that the aquifer is isotropic, homogenous and semi-infinite in aerial extent. In particular, the Dakota Sandstone is known to be in contact with certain stream reaches which could cause calculated depletions to be greater than actual depletions and the presence of boundary conditions within a few miles or less of the stream could lead to an underestimate of actual stream depletions. Given this limitation, any Jenkins method calculation of stream depletions could deviate significantly from actual depletions. Datasets are not available to modify the Jenkins method to incorporate the effects of image well theory into the analysis which would improve the depletions calculations. Additionally, no data exists that defines the extent of the alluvial areas of the Basin.

There is no determination of the 10/50 area due to the hydrogeologic complexities of the Basin and lack of sufficient data. As better and more data become available it may be possible to determine areas of the principal aquifer that meet the criteria for determining the 10/50 area.

b) Platte River 10/50 Area

The 10/50 area of the Basin, as relating to the Platte River, was determined using the Upper Big Blue ground water model developed by the UBBNRD. It is based on the COHYST model. Figure BB-51 shows the 10/50 area along the Platte River.

Lag Impacts

a) Current Well Development

Due to the lack of sufficient hydrogeologic data, no lag impacts were calculated for the Basin. The lack of a lag impact calculation is the result of the same factors that limited the use of the Jenkins method as described above in the subsection on “Determination of Hydrologically Connected Area.”

Even if lag impacts could be calculated, other information suggests that the current well development has a minimal effect on the long term streamflow. Many high capacity ground water wells have been completed in the Basin in the last 40 years, but there are no large areas of severe ground water decline (more than 10 feet) except for Butler, Clay, and Fillmore counties or observed decreases in streamflow that are not primarily due to cyclical climatic conditions. Most high capacity wells have been developed in the principal aquifer, outside of the alluvial valleys.

b) Future Well Development

The lag impact calculation of projected future ground water uses was not carried out for the same reasons as stated above. Estimates of the number of high capacity wells that would be completed over the next 25 years if no new legal constraints were imposed were calculated based on extrapolating the present day rate of increase in well development into the future, Figure BB-52. For the past 20 years, the rate of increase in high capacity wells is nearly linear at a rate of 158 wells per year.

Future Surface Water Development and Uses

The number of surface water appropriations in the Basin has grown steadily over the past 30 years and it appears reasonable to project that that trend will continue into the future,

Figure BB-48. The number of acres permitted for surface water irrigation also has grown steadily for the past 30 years, Figure BB-49.

Ability to Satisfy Net Corn Crop Irrigation Requirement

Figure BB-53 shows the net corn crop irrigation requirement for the Basin. The map shows the net corn crop irrigation requirement to range just over 9 inches in the northwestern portion of the Basin to less than 7 inches at the southeast corner of the Basin. Assuming a surface water diversion rate equal to 1 cubic foot per second per 70 acres and a downtime value of 10 percent (see Appendix D); depending on the location in the Basin, it takes between 18.6 and 23.9 days annually to divert 65% of the net corn crop irrigation requirement from July 1 through August 31 and 24.3 to 31.3 days to divert 85% of the net corn crop irrigation requirement from May 1 through September 30 in the Basin.

The surface water administration analysis showed an average of at least 57 days in which surface water was available for diversion from July 1 through August 31 and an average of at least 148 days in which surface water was available for diversion from May 1 through September 30.

Sufficiency of Surface Water Supply [Nebraska Revised Statutes Section 46-713(3)(a) (Reissue 2004)]

The average number of days in which surface water was available for diversion in both the July 1 through August 31 and the May 1 through September 30 time frames required by Department rule 457 Nebraska Administrative Code (NAC) 24.001.01 exceeds the number of days surface water is required to be available pursuant to the rule during those same periods. Because the average annual number of days in which surface water was available for diversion far exceed the number of days required (57 available versus 23.9 needed and 148 available versus 31.3 needed) it is unlikely that the existing level of well development will cause flows in the Big Blue River or its tributaries to decrease to the point where they may become fully appropriated without the initiation of additional uses. Table BB-6 summarizes the results of comparisons between the number of days surface water must be available to meet the 65% and 85% net corn crop irrigation requirements and the number of days in which surface water was available for diversion to the junior surface water appropriations.

Table BB-6. Summary of Comparison Between Net Corn Crop Irrigation Requirement and Number of Days Surface Water is Available for Diversion.

	Number of Days Necessary to Meet the 65% and 85% of Net Corn Crop Irrigation Requirement	Average Annual Number of Days Available to the Junior Surface Water Appropriations (1985-2004)	Average Annual Number of Days Available in 2030 with no Additional Well Development	Average Annual Number of Days Available in 2030 with Additional Well Development
July 1 – August 31	23.9	57 (34.1 days above the requirement)	Not Calculated*	Not Calculated*
May 1- September 30	31.3	148 (116.7 days above the requirement)	Not Calculated*	Not Calculated*

* This number was not calculated. Because the number of days in which surface water was available for diversion far exceed the number of days necessary to meet the net corn crop irrigation requirement, the final conclusion would not change even with the addition of lag impacts from additional wells.

Sufficiency of Streamflow for Ground Water Supply [Nebraska Revised Statutes Section 46-713(3)(b) (Reissue 2004)]

Since the criteria for Nebraska Revised Statutes Section 46-713(3)(a) were satisfied, the conclusion for this section is the same for reasons explained in the report introduction.

Sufficiency of Surface Water Supply for Compliance with Compacts or State Laws [Nebraska Revised Statutes Section 46-713(3)(c) (Reissue 2004)]

As discussed previously, Section 46-713(3) requires the Department to make a determination that a basin is fully appropriated if current use of hydrologically connected surface water and ground water will create a reduction in the flow of a river sufficient to cause Nebraska to be out of compliance with an interstate compact. The requirements for compliance with the Kansas – Nebraska Big Blue River Compact are stated in the Surface Water Compact Section of this Basin chapter. As long as Nebraska administers surface and ground water in compliance with the Compact, decreased streamflow, in and of itself, will not cause Nebraska to be in noncompliance; therefore, any depletion would not cause Nebraska to be in noncompliance. However, decreased streamflows could increase the number of times the state would have to administer to remain in compliance.

The future usable water supply in the Basin may actually improve in the future if water can be made available to augment state line flows to meet Compact targets. A cooperative study between the Department, the U.S. Bureau of Reclamation, and the Basin NRDs is tentatively planned to examine the value of augmentation water and to develop potential criteria for locating reservoirs to store and release augmentation water.

Future Development of Surface and Ground Water [Nebraska Revised Statutes Section 42-713(1)(b) (Reissue 2004)]

Given the rate of registered ground water well and surface water appropriation development, the conclusion that the Basin is not fully appropriated would not change even if no additional legal constraints were placed on development and a reasonable projection of a continuation of the current trend of well development of the last 20 years is used.

Conclusions

There is no evidence that current ground water depletions to streamflow in the Basin are affecting surface water users sufficiently to meet the criteria for being fully appropriated as found in Department rule 457 NAC 24.001.01 when compared to the amount of surface water available at the present time.

There is not sufficient data available at this time to determine the lag impact over the next 25 years; however, due to the fact that the number of days in which surface water was available for diversion far exceeds the number of days required to meet the net corn crop irrigation requirements, it is unlikely that any lag impact could sufficiently affect the streamflow to lower the number of days in which surface water was available for diversion below the criteria for being fully appropriated as found in Department rule 457 NAC 24.001.01.

Based upon available information and its evaluation, the Department has reached a determination that the Basin is not fully appropriated except for those areas where the ground water is hydrologically connected to the Platte River (See Upper Platte River Basin Chapter). The Department has also determined that even if no additional legal constraints are imposed on future development of hydrologically connected surface water and ground water and reasonable projections are made about the extent and location of future development, this conclusion would not change.

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