Review of Present-Conditions Stream Reach Flow Gains for the Central Platte River OPSTUDY Model, Platte River EIS

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U.S. Bureau of Reclamation
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The intent of this analysis is to review the adequacy of streamflow gain data developed for the Present-Conditions version of the Central Platte River OPSTUDY model. Input data presently used by the model covers the operational period of 1940 thru 1994. Previous studies performed by the Bureau of Reclamation have analyzed historic streamflow gains. Those studies used statistical procedures to adjust the historic flow gains to represent present-level conditions within the basin. Factors which could be resulting in long term changes to streamflow gains within the basin include irrigation return flows, ground-water depletions or accretions to aquifers which discharge to adjacent streams, changes in the precipitation regime, and an increase or decrease of surface-water diversions with time from the streams.

The last study to define any present-level adjustments to the historic data was performed in 1988 using historic records for 1941-84. Since that time, other agencies have updated the model input data to 1994 by adding on historically recorded data, without analyzing the data to see if more recent changes are occurring to the flow regimes.

Statistical procedures used in previous studies, and in this study, to assess whether there have been significant changes have generally involved using linear regression to correlate reach inflows with adjusted reach outflows. The adjusted reach outflows are defined as flow discharge from the stream reach, plus any recorded diversions from the reach, minus any recorded return flows or tributary flow into the reach. The correlation coefficients produced by the regression analysis are then applied to the reach inflows to develop a predicted adjusted reach outflow. A double-mass diagram was then prepared showing the actual adjusted reach outflows versus the predicted reach outflows. Visual interpretation of the slope of the line in the double-mass diagram was used to determine if any long-term changes in streamflow gains had occurred. If there were no changes, then the line would be straight. Changes or 'breaks' in the slope of the line with time could be interpreted as changes in flow gains. A second graph showing the accumulated difference between the predicted adjusted reach outflow versus the historic adjusted reach outflow can be used to 'magnify' any apparent long-term trend changes. Evaluations also need to take into account any long-term changes in precipitation rates that may have occurred in that stream reach.

When the time periods have been identified from the double-mass diagrams where flow gains have changed, a separate linear-regression analysis is performed for each period to define the equation for that particular line segment. By subtracting the line equation parameters of an earlier period from line equation parameters for the most recent

period, and applying that result to the average inflow for the earlier-period segment, then an adjustment value is derived which is added to the historic flow gain for any earlier period to allow those gains to represent present conditions. Expressed mathematically:

$$Y1 = A1 + M1 \times Inflow1 = \text{equation for recent line segment}$$

$$Y2 = A2 + M2 \times Inflow2 = \text{equation for earlier line segment}$$

where:
M1 = slope of recent line segment
A1 = y-intercept of recent line segment
Inflow1 = reach inflow of recent segment
Y1 = predicted adjusted reach outflow of recent segment

M2 = slope of earlier line segment
A2 = y-intercept of earlier line segment
Inflow2 = reach inflow of earlier segment
Y2 = predicted adjusted reach outflow of earlier segment

The parameters of the two line equations are then subtracted and applied against the average inflow for the earlier period to arrive at a gain adjustment value:

$$GA = (A1 - A2) + (INFLOW_{avg} \times M1) - (INFLOW_{avg} \times M2)$$

where:
GA = gain adjustment (+/-)
$INFLOW_{avg}$ = average inflow for earlier period

For this study, data analyses were made with annual values. Data used to construct historic stream flows were derived from data provided by the state of Nebraska, U.S. Geological WEB page for historical streamflow discharge, and in some cases missing data were taken from input files for an earlier version of Reclamation's Historic Central Platte River OPSTUDY model. Results of analyses for each individual basin are described below.

Birdwood Creek near Hershey, NE.

Previous studies have concluded that the historic flows for 1941-84 were the same as present-level flows. A single mass diagram of historic flow discharge for 1932-94 indicates that there has been no long-term general decline in discharge. The historic discharge record needs no adjustments to represent present-level conditions.

Discharge data for this stream is taken from USGS gaging station records. During calendar years 1991 and 1994, some non-irrigation season data was missing. For those months, the discharge was estimated by using the monthly average discharge

ratio of May thru September of 1993 versus same period of 1994. The ratio used was 1.1.

North Platte River from Keystone to Sutherland, NE.

In previous studies, the historic flow gains for 1941-84 were considered to be the same as present-level flow gains. The data was updated thru 1994, and double-mass curves of adjusted reach outflow versus predicted adjusted reach outflow indicates that there were no significant long-term changes in the reach flow gains. Therefore, the historic flow gains for 1940-94 represent present-level conditions and no adjustments are necessary.

Reach gains are calculated as: N. Platte River near Sutherland minus N. Platte River near Keystone plus Keith-Lincoln Canal diversions plus North Platte Canal diversions plus Paxton_Hershey Canal diversions plus Sheridan_Wilson Canal diversions (including Sarben Slough diversions).

Note that for the station N. Platte River near Sutherland, discharge data for the non-irrigation months during 1993 and 1994 were missing. The missing data were filled in using the average of streamflow at Keystone, and streamflow at North Platte minus Birdwood Creek discharge.

A previous report states that historic negative gains for this reach were eliminated on a monthly basis by averaging with another month of high positive gains within the same year. It could not be determined why these negative gains were eliminated since they represent historically what has happened, assuming the gaged flow data is accurate. Further review should be made to determine if the negative gains should be left as they occur.

North Platte River from Sutherland to North Platte, NE.

No previous adjustments were made to the flow gains in this reach as the historic gains for 1941-84 were considered to be the same as present-level flow gains. In the present analysis, a double-mass plot of adjusted reach outflow versus predicted adjusted reach outflow for the period 1940-94 did not indicate any long-term change in reach gains. No adjustments to the historic record are needed to represent present-level conditions.

Reach gains are calculated as: N. Platte River at N. Platte minus N. Platte River near Sutherland minus Birdwood Cr. plus Cody_Dillon Canal diversions plus Suburban Canal diversions.

A previous report states that historic negative gains for this reach were eliminated on a monthly basis by averaging with another month of high positive gains within the same year. It could not be determined why these negative gains were eliminated since they represent historically what has happened, assuming the gaged flow data is accurate.

Further review should be made to determine if the negative gains should be left as they occur.

South Platte River from Julesburg to Paxton, NE.

Previous studies of the 1941-84 period concluded that the historic reach gains are the same as present-level gains. In this analysis, historic reach flow gains were extended thru 1994 and a linear-regression analysis of reach inflow versus adjusted reach outflow was performed for the period 1940-94. A double-mass plot of adjusted reach outflow versus the predicted adjusted reach outflow indicated no definitive long-term changes in flow gains for the study period. The historic flow gains for 1940-94 represent the present-level flow gains.

Reach gains were calculated as: S. Platte River near Paxton minus S. Platte River near Julesburg plus Western Canal diversions plus Korty Canal diversions.

Flow discharge for S. Platte River near Paxton were taken from USGS gaged data for Jan. 1940 thru April 1970, and from May 1970 to present, discharge was estimated using following equation:

> S. Platte at Julesburg minus Western Canal diversions minus Korty Canal diversions plus 0.623 * (S. Platte at North Platte plus Korty Canal diversions plus Western Canal diversions minus S. Platte at Julesburg) minus 4.39 Kaf.

South Platte River from Paxton to North Platte, NE.

Previous adjustments of the historic gains to present-level for this reach consisted of adding 55.2 Kaf per year for the period 1941 thru 1945. The remaining historic gains for 1946 thru 1984 were considered to be the same as present-level.

In the present analysis of 1940-94 historic gains, a change in gains occurs around 1945, as determined in earlier studies. There was no indication of any significant long-term change from 1984 thru 1994. Therefore, historic gains from 1946 thru 1994 should represent present-level conditions. A review of annual historic precipitation at North Platte, NE did not demonstrate any long-term change in the precipitation regime.

Using regression analyses, the gain adjustment necessary to bring the 1940-45 flow gains to present-level was calculated to be an additional annual volume of 87.1 Kaf rather than the previously used value of 55.2 Kaf. However, it is felt that using the average reach inflow for 1940-45 to determine the 87.1 Kaf adjustment was greatly influenced by the large negative reach gain in 1942. It was decided that using the median flow for the period 1940-45 rather than the average would produce a more reasonable adjustment value. Using the median flow resulted in an annual adjustment value of an additional 63.9 Kaf per year for the period 1940-45.

Gains for this reach were calculated as: S. Platte River at North Platte minus S. Platte River near Paxton.

Platte River from North Platte to Brady, NE.

Previous corrections to present-levels involved adding 22.8 Kaf per year to reach gains during the period 1941-63, with the period 1964-84 using historic gains. Updating the reach gain data to 1994 resulted in another apparent break in the long term trend occurring about 1983, in addition to the previously defined break occurring about 1963.

An evaluation of average precipitation for stations at North Platte and Gothenburg indicated that there was no significant long-term change in total annual precipitation.

A linear-regression analysis of reach inflows and outflows resulted in the following annual adjustments to bring historic gains to present levels:

For the period 1940-63, an additional 51.300 Kaf per year.
For the period 1964-82, an additional 28.100 Kaf per year.
For the period 1983-94, use historical gains.

Reach gains calculated as: Platte River at Brady minus flow past Central District Diversion Dam. Flow past Central District Diversion Dam estimated to equal the sum of the S. Platte River at North Platte plus N. Platte River at North Platte plus N. Platte Hydro return minus Central District Canal diversion. If the sum was less than zero, then it was set to zero.

Platte River from Brady to Cozad, NE.

Previous analyses indicated that the present level reach gains are the same as the historic reach gains for 1941 thru 1984. A double-mass plot of historic adjusted reach outflow versus predicted reach outflow based on a linear regression analysis of 1940-94 data did not show any long-term change in flow gains. The 1940-94 historic flow gains represent present-level conditions, and no adjustments are necessary.

Flow gains for this reach are calculated as: Platte River at Cozad minus Platte River at Brady plus Gothenburg Canal diversions plus Thirty Mile Canal diversions plus Six Mile Canal diversions plus Orchard_Alfalfa Canal diversions plus Dawson County Canal diversions plus Cozad Canal diversions minus Gothenburg Hydro returns minus Jeffy Hydro returns.

Platte River from Cozad to Overton, NE.

Previous corrections for this reach involved adding 74.4 Kaf per year to the flow gains for 1941 thru 1946. For 1947 thru 1984, the historic flow gains were assumed to represent present level.

For this analysis, a double-mass plot of adjusted reach outflow vs. predicted adjusted reach outflow resulted in an apparent change in trends occurring around 1970. There was no clear change in flow gain trends occurring around 1946 as established in previous studies. There was no discernable change in flow trends from 1984 thru 1994.

A review of average annual precipitation for Gothenburg and Kearney did not indicate any long term changes in the precipitation regime that would be responsible for changes in the flow regime around 1970.

Linear regression analyses for the two periods of 1940-69 and 1970-94 resulted in 98.58 Kaf needed to be added to the annual flow gains for the period 1940-69 to bring them to present conditions. The historic flow gains for 1970 thru 1994 are considered to represent present conditions.

Reach gains calculated as: Platte River at Overton minus Platte River at Cozad minus Johnson Hydro returns.

Platte River from Overton to Odessa, NE.

Previous studies concluded that the present-level gains for this reach were the same as the historic gains. The historic data was updated from 1940 thru 1994 and a linear regression analysis resulted no long-term change in flow-gain trend over the entire period.

Reach gains calculated as Platte River at Odessa minus Platte River at Overton plus Elm Creek Canal diversions plus Kearney Canal diversions.

Platte River from Odessa to Grand Island, NE.

Previous studies concluded that the present-level gains for this reach were the same as the historic gains. Updating the data through 1994 indicated no significant long-term change in flow gains since 1984. However, a double-mass plot of adjusted reach outflow versus predicted adjusted reach outflow indicates that there were generally less flow gains before about 1957 than there were after. From 1940 thru 1956, all annual gains were negative, whereas from 1957 on, there is a mixture of positive and negative flow gains.

A single mass diagram of average precipitation for Kearney and Grand Island did not demonstrate any long-term change in precipitation rates on an annual basis that could be responsible for the general increase in flow gains occurring after 1956.

Linear regression analyses of reach inflows and outflows for the two periods of 1940-56 and 1957-94 indicated that 77.1 Kaf per year should be added to the 1940-56 period to bring the flow gains to present level. However, this appears to be in error as it creates

more flow gains for the 1940-56 period than there should be. The error appears to be due to the way the linear regression analysis calculated the straight-line trend through the 1957-94 data which was scattered much more than the earlier period data. It is estimated that an additional gain of 40.0 Kaf per year for the period 1940-56 would bring the gains in line with more recent flow gains.

Reach gains calculated as: Platte River at Grand Island minus Platte River at Odessa minus Kearney Hydro returns.

Platte River from Grand Island to Duncan, NE.

Previous studies concluded that present level gains for this reach were the same as the historical reach gains. In this study, there is an apparent general increase in annual flow gains beginning about 1983. However, the data in inconclusive as to whether this increase is truly long-term through the present period. Gain data for 1994 thru 1996 suggests that gains may be returning to pre-1983 trends.

An analysis of average annual precipitation for Grand Island and Columbus, NE. suggests that there was a general increase in precipitation from 1982 thru 1987. This appears to coincide with the general increase in reach gains. However, double-mass diagrams of precipitation expressed as a 3-year moving average versus the annual reach gains does not definitively show that precipitation is totally responsible for the general increase in flow gains after 1982. Correlations between the annual precipitation and 3-year moving average precipitation versus annual reach gains resulted in poor correlation coefficients. This could be due to a non-linear relationship between precipitation, surface runoff, and ground-water contributions influenced by precipitation in previous years.

Linear regression analyses of annual reach inflow and reach adjusted outflow were performed for the two periods of 1940 - 1982 and 1983 - 1996. Subtracting the resultant line equations for the two periods indicated that 156.0 Kaf per year should be added to the reach gains for the period 1940 - 1982 to bring them up to present level. This would be assuming that the general increase in flow gains since 1983 is a long-term change. However, since the data is somewhat inconclusive as to whether this is a long term change due to return flows or precipitation events, then it would be better to treat the historic record as representing present conditions and make no adjustments to the gains.

Reach gains calculated as: Platte River near Duncan minus Platte River near Grand Island.

Summarization of Gain Adjustments

Reach	Updated Annual Gain Adjustments	Previous Adjustments
Birdwood Creek	1940 - 1994 = No Adjustment	1941 - 1984 = No Adjustment
N. Platte from Keystone to Sutherland	1940 - 1994 = No Adjustment Check elimination of negative gains	1941 - 1984 = No Adjustment
N. Platte from Sutherland to North Platte	1940 - 1994 = No Adjustment Check elimination of negative gains	1941 - 1984 = No Adjustment
S. Platte from Julesburg to Paxton	1940 - 1994 = No Adjustment	1941 - 1984 = No Adjustment
S. Platte from Paxton to North Platte	1940 - 1945 = +63.9 Kaf 1946 - 1994 = No Adjustment	1941 - 1945 = +55.2 Kaf 1946 - 1984 = No Adjustment
Platte R. from North Platte to Brady	1940 - 1963 = +51.3 Kaf 1964 - 1982 = +28.1 Kaf 1983 - 1994 = No Adjustment	1941 - 1963 = +22.8 Kaf 1964 - 1984 = No Adjustment
Platte R. from Brady to Cozad	1940 - 1994 = No Adjustment	1941 - 1984 = No Adjustment
Platte R. from Cozad to Overton	1940 - 1969 = +98.6 Kaf 1970 - 1994 = No Adjustment	1941 - 1946 = +74.4 Kaf 1947 - 1984 = No Adjustment
Platte R. from Overton to Odessa	1940 - 1994 = No Adjustment	1941 - 1984 = No Adjustment
Platte R. from Odessa to Grand Island	1940 - 1956 = +40.0 Kaf ? 1957 - 1994 = No Adjustment	1941 - 1984 = No Adjustment
Platte R. from Grand Island to Duncan	1940 - 1994 = No Adjustment	1941 - 1984 = No Adjustment