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Appendix D

PRELIMINARY ESTIMATE OF HISTORICAL STREAM FLOW REDUCTIONS IN THE OVERAPPROPRIATED PORTION OF THE PLATTE RIVER IN NEBRASKA

Preliminary Estimate of Historical Stream Flow Reductions in the Overappropriated Portion of the Platte River in Nebraska.

Prepared at the Request of the Basin-Wide Stakeholder Group

by

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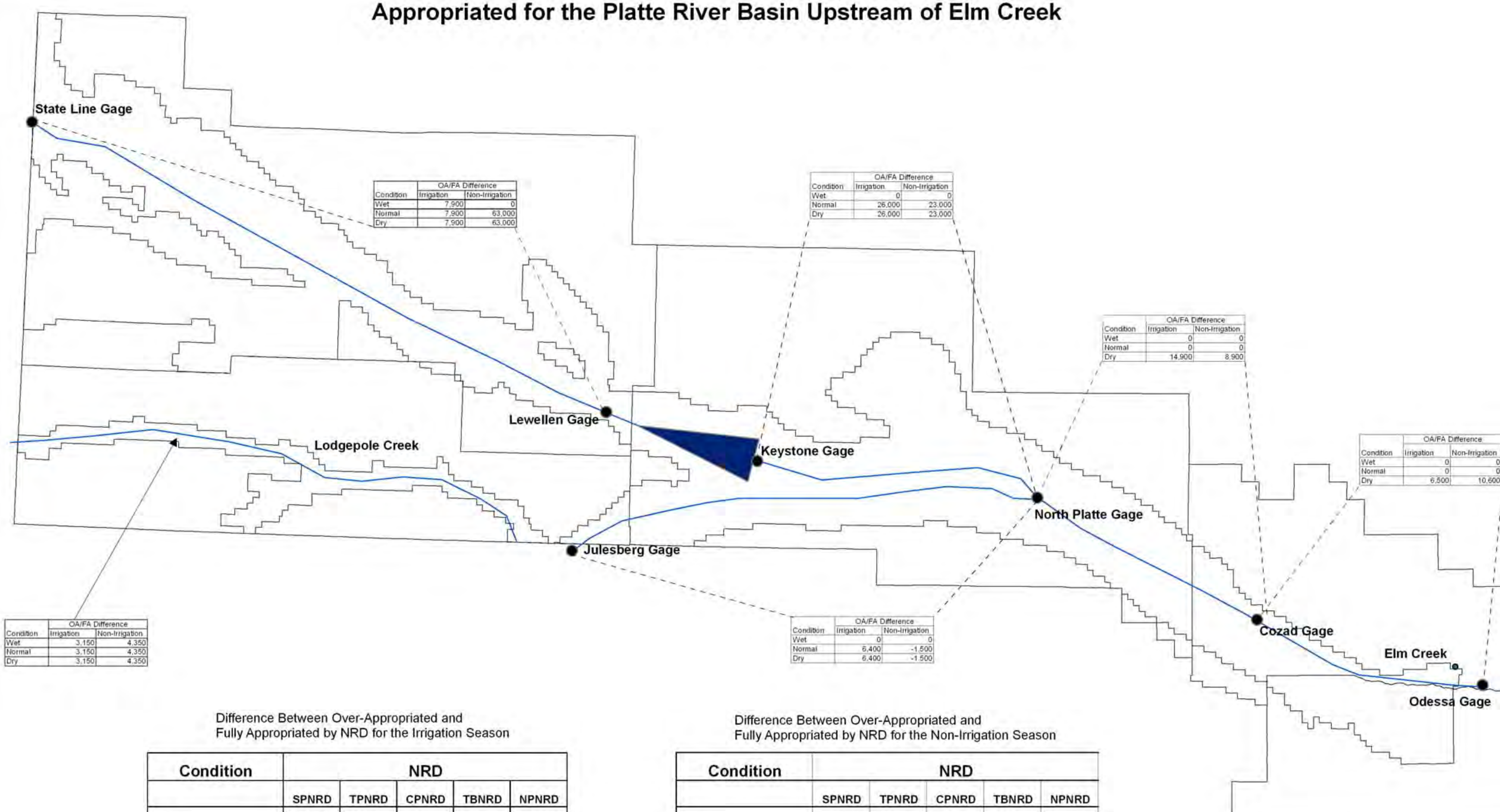
1.0 EXECUTIVE SUMMARY

The objective of this study was to identify the overall difference between overapproriated and fully appropriated for the Platte River Basin upstream of Elm Creek. This study focused on analyzing the impacts to the gains in surface water flows for specific reaches of the Platte River. The gains were used to represent the natural flow conditions that are available to surface water appropriations. The reaches identified for purposes of this study were based on long-term gage locations and the demands of surface water appropriations. The five reaches evaluated in this study include: 1) Cozad to Odessa; 2) North Platte to Cozad; 3) Keystone to North Platte; 4) state line to Lewellen; and 5) Julesburg to North Platte on the South Platte River. In addition to these five reaches, Lodgepole Creek was also evaluated.

The process used to evaluate each reach consists of three steps. Step one was to identify reach gain changes that have occurred within the reach. Reach gain reductions were identified by distinguishing significant changes in historical gains due to factors other than precipitation. Step two was to identify the unmet demands for each reach, which sometimes included unmet demands occurring downstream. Unmet demands were identified for surface water appropriations used for irrigation, hydropower, instream flows, and aquifer storage, as well as for groundwater users reliant on surface water flows for aquifer recharge. Unmet demands were based on specific users' historical need for water under varying hydrologic conditions. Three hydrologic conditions were considered in the evaluation: wet, normal, and dry. These conditions were necessary since stream reach gain reductions and unmet demands can be closely linked to the hydrologic conditions of the basin. Step three was to identify the overall difference between overappropriated and fully appropriated. This difference was determined by comparing the stream reach gain reductions within a reach to the cumulative unmet demands for that reach. The lesser of the two values was used to represent the difference, with certain exceptions that are specifically noted in the report. The lesser value was used because when reach gain reductions are less than unmet demands, it would not be expected that unmet demands be fully met, only that reach gain reductions not further erode the supply available for those demands. Conversely, when reach gain reductions are greater than unmet demands, reach gain reductions would not be expected to be made up in the absence of demands for the supply. Figure 1-1 summarizes the overall difference between overappropriated and fully appropriated for each reach and for Lodgepole Creek.

Overall Difference Between Overappropriated and Fully Appropriated for the Platte River Basin Upstream of Elm Creek



Difference Between Over-Appropriated and Fully Appropriated by NRD for the Irrigation Season

Condition	NRD				
	SPNRD	TPNRD	CPNRD	TBNRD	NPNRD
Wet	3,200	0	0	0	7,850
Normal	3,850	31,750	0	0	7,850
Dry	3,850	40,450	9,200	3,500	7,850

Difference Between Over-Appropriated and Fully Appropriated by NRD for the Non-Irrigation Season

Condition	NRD				
	SPNRD	TPNRD	CPNRD	TBNRD	NPNRD
Wet	4,350	0	0	0	0
Normal	4,625	21,650	0	0	62,575
Dry	4,625	26,850	8,550	5,750	62,575

Figure 1-1

Figure 1-1. Summary of the stream reach gain reductions, unmet demands, and overall difference between overappropriated and fully appropriated.

2.0 PROCESS OVERVIEW

2.1 Selection of Reaches

Within the overappropriated basin, precipitation generally increases and irrigation requirements generally decrease from west to east. Additionally, the further upstream a stream reach gain reduction occurs, the greater the number of downstream uses that can potentially be impacted. To address issues resulting from the spatial variation of precipitation supplies and demands, the overappropriated area was divided into six sub-areas or reaches.

Reaches were selected based upon a combination of key river gage locations and key points of diversion or use. The number and size of the reaches balance the analytical need to differentiate between various locations (generally easier with more numerous and shorter reaches) and the analytical need to discern differences in the data (generally easier with less numerous and lengthier reaches). Stream inflows and outflows for each reach are measured by key gages, diversions, and returns located at or near the ends of the reaches. The following reaches were used in the analyses:

- North Platte River –state line to Lewellen
- Lodgepole Creek – Wyoming state line to Colorado state line
- South Platte River and North Platte River below McConaughy, subdivided as
    - North Platte River – Keystone to North Platte; and
    - South Platte River – Julesburg to North Platte
- Platte River – North Platte to Cozad
- Platte River – Cozad to Odessa

Note that the above listing of reaches excludes the stretch of North Platte River from Lewellen to Keystone, which is basically the stretch of river containing Lake McConaughy and Lake Ogallala. Streamflow reductions through this reach, and their consequent potential impact to uses and contribution to the overappropriated condition were not evaluated due to the ungaged nature of tributaries within the reach. The potential for Lake McConaughy storage to satisfy unmet downstream demands was not evaluated since the analysis focused on nature flows (e.g., reach gains). Additionally, the demand for storage water losses (e.g., evaporation and seepage) was considered but not included as part of the unmet demands, as will be discussed.

2.2 Hydrologic Variability in the Analysis

Consideration was given to the potential for temporal hydrologic variation in the analyses of the overall difference between overappropriated and fully appropriated conditions. Generally, stream reach gain reductions are less likely to have an adverse impact on downstream demands under wetter hydrologic conditions than under drier hydrologic conditions. Moreover, some streamflow demands, such as irrigation diversions, are seasonal in nature. The irrigation requirement for crops can increase and decrease with annual variations in effective precipitation.

In these analyses, the difference between overappropriated and fully appropriated was evaluated for the irrigation season and non-irrigation season, and for a range of hydrologic conditions (wet, normal, and dry). The duration of the irrigation season and non-irrigation season was kept constant for all reaches: the irrigation season encompassed May through September, and the non-irrigation season encompassed October through April. The hydrologic periods representing wet, normal, and dry conditions were determined on a reach-by-reach basis. The reaches downstream of Lake McConaughy all appeared to be subject to the same periods of wet, normal, and dry conditions, whereas the reach from the state line to Lewellen had a different set of periods (table 2-1).

Table 2-1. Representative periods for wet, normal, and dry conditions in the six reaches used in the analysis.

Reach	**Wet**	**Normal**	**Dry**
State line to Lewellen	1971-1973 and 1995-1999	1962-1967	1954-1961 and 2002-2006
Lodgepole Creek	Specific period not identified	Specific period not identified	Specific period not identified
Julesburg to North Platte	1983-1986 and 1995-1999	1974-1979 and 1988-1994	1953-1956 and 2002-2006
Keystone to North Platte	1983-1986 and 1995-1999	1974-1979 and 1988-1994	1953-1956 and 2002-2006
North Platte to Cozad	1983-1986 and 1995-1999	1974-1979 and 1988-1994	1953-1956 and 2002-2006
Cozad to Odessa	1983-1986 and 1995-1999	1974-1979 and 1988-1994	1953-1956 and 2002-2006

For areas downstream of Lake McConaughy, wet conditions were defined as periods when all uses were able to satisfy their full beneficial use and reservoir levels in Lake McConaughy were sustained at a full pool. Dry conditions were defined as periods of near-historic low streamflows and precipitation and an inability to satisfy the beneficial uses of all demands. The periods used to assess normal conditions were difficult to determine, but they were predominantly periods of near-average streamflows and precipitation but inadequate surface water storage supplies to satisfy all beneficial uses of the demands.

For areas upstream of Lake McConaughy, wet conditions were defined as periods when all downstream uses were able to satisfy their full beneficial use and reservoir levels in Lake McConaughy were sustained at a full pool. Dry conditions were defined as periods of historic low streamflows and precipitation and an inability to satisfy the beneficial uses of all demands. The periods used to assess normal conditions were difficult to determine, but they were predominantly periods of near-average streamflows, state line inflows, near-average precipitation, and inadequate surface water storage supplies to satisfy all downstream beneficial uses of the demands.

Although the method of analysis recognized the potential for temporal variation by season and hydrologic condition, it was also recognized that this might not always be the case. In some cases, a temporal distribution in streamflow impact or unmet demand simply might not exist. In other cases, the method of analysis may not have been sufficient to identify a temporal variation that may have been present in the dataset. Where a streamflow impact or unmet demand was identified with no observable temporal distribution, a single value was used for all conditions.

2.3 Stream Reach Gain Reductions

The assessment of stream reach gain reductions focused on the gains in the Platte River between specified gages or on specific tributaries (e.g., Lodgepole Creek) when necessary. This type of analysis was used as a means to assess total impacts to surface water flows within the overappropriated basin. For the purposes of this report, stream reach gain reductions are defined as ***any long-term reduction in the gain within a specific reach or tributary*** (the reaches are described in section 2.1). Long-term reduction would include only those periods of five or more years in which the trend was consistent.

The gain within a reach is measured as the increased streamflow at a downstream gage when compared to an upstream gage, taking into account the activities occurring within that reach. Figure 2-1 illustrates a typical reach of the Platte River and the data used to calculate the reach gain.

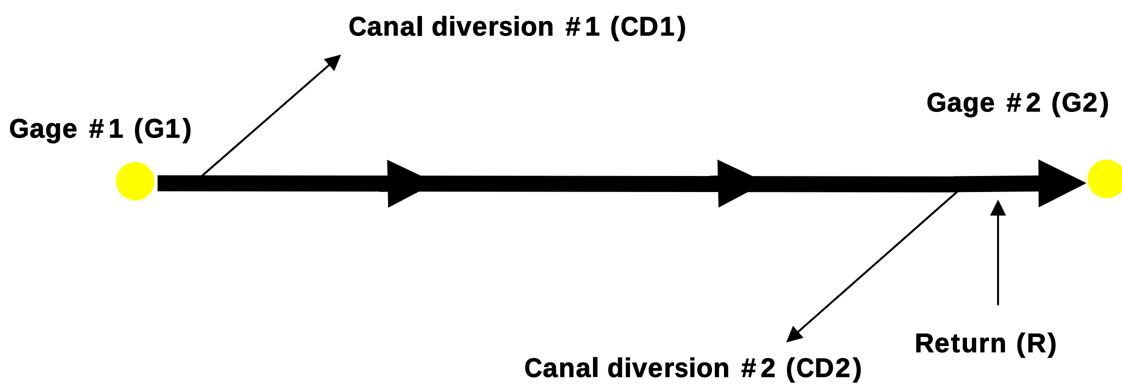


Figure 2-1. Representation of typical reach gain segment.

This type of reach analysis is useful for removing the impacts of anthropogenic activities (e.g., reservoir releases, diversions, etc.) and focusing on changes within the reach. Reach gain is computed by adding all canal diversions to the downstream gage and subtracting the return flows and flows at the upstream gage, as follows (using the abbreviation from figure 2-1).

Reach Gain = G2 + CD1 + CD2 – R –G1

Reach gains were calculated on an irrigation season (May – September) and a non-irrigation season basis (October – April). Any reduction in the reach gains would indicate a reduction in the natural flow available within the reach.

Stream reach gain reductions calculated using this methodology could include impacts from: reduced runoff, reduced surface water return flows (relative to diversions), reduced groundwater inflow, and reduced tributary inflows.

2.3.1 Assessment of Changes in Streamflow

The first step in analyzing the calculated reach gains was an assessment of the long-term trends in streamflow relative to natural variability (e.g., precipitation cycles) and anthropogenic changes (e.g., increased diversions). Double-mass curves were developed for each reach or tributary investigated in this study to understand better the points in time related to and the potential causes of long-term changes in streamflow. A double-mass curve is the plot of the cumulative amount of one variable relative to the cumulative amount of a second variable. These are useful for identifying points in time at which the relationship between these two values changes (termed “break points”).

The double-mass curve was used in this study to analyze the temporal variability (if any) in the relationship between reach gains and other factors (e.g., precipitation) that could influence those reach gains. The resulting plot will form a straight line if the variability in reach gain can be attributed only to the corresponding variable (e.g. precipitation) against which gain is plotted. If the reach gains are influenced by other factors (figure 2-2), then break points in the double-mass curve will be apparent. These break points may be due to a single cause or some combination of several of the potential causes discussed below.

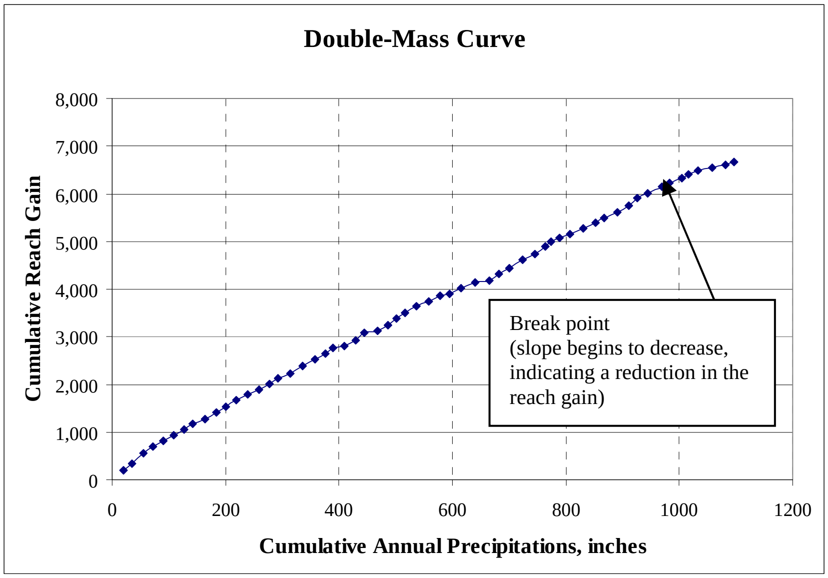


Figure 2-2. Example of a double-mass curve of cumulative reach gain and cumulative precipitation.

2.3.2 Quantification of Stream Reach Gain Reductions

Once stream reach gain reductions had been identified, the next step was to quantify the magnitude of the change. This was done by calculating the precipitation-corrected slopes for the “representative period” prior to a break point in the double-mass curve and the precipitation-corrected slope for the “recent period” following the break point (figure 2-3). Each slope was then multiplied by the average precipitation for both time periods and the result for the recent period was subtracted from the result for the representative period.

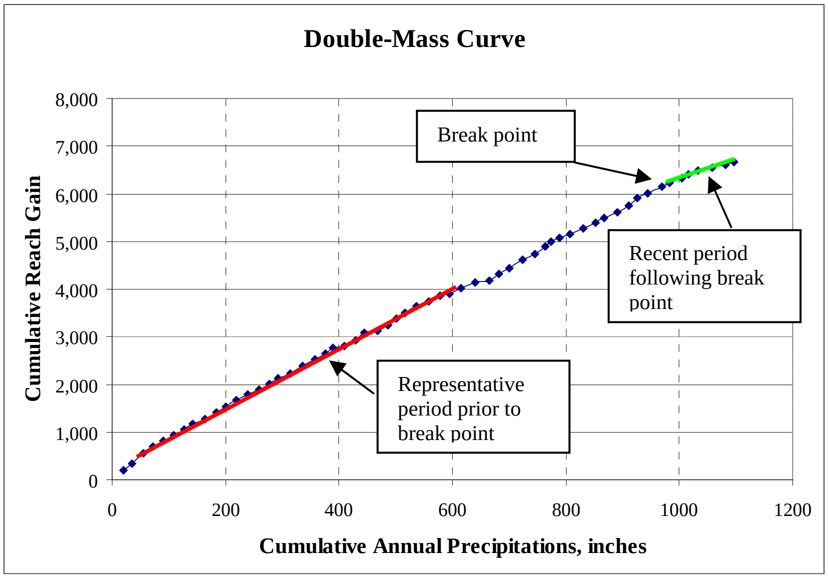


Figure 2-3. Example of using the double-mass curve to determine a representative-period slope and the more recent-period slope.

For example if:

Representative period average reach gain prior to break point 1952-1980

Recent period average reach gain following the break point 1999-2006

Calculating the average reach gains:

Representative period average reach gain = (y_2-y_1/ x_2-x_1) * average precipitation (1952-1980 and 1999-2006)

Recent period average reach gain = (y_4-y_3/x_4-x_3) * average precipitation (1952-1980 and 1999-2006)

where

x_1 = cumulative precipitation at the beginning of the representative period (1952)

x_2 = cumulative precipitation at the end of the representative period (1980)

x_3 = cumulative precipitation at the beginning of the recent period (1999)

x_4 = cumulative precipitation at the end of the recent period (2006)

y_1= cumulative reach gain at the beginning of the representative period (1952)

y_2= cumulative reach gain at the end of the representative period (1980)

y_3= cumulative reach gain at the beginning of the recent period (1999)

y_4= cumulative reach gain at the end of the recent period (2006)

Calculate stream reach gain reduction:

Stream reach gain reduction = (Representative period average reach gain – Recent period average reach gain)

2.3.3 Assessment of Potential Causes

Break points identified in the double-mass curves were further investigated by analyzing the relationship between the reach gain and five potentially related datasets: 1) baseflow (e.g., groundwater inflow to the reach); 2) surface water inflows; 3) surface water diversions; 4) groundwater development; and 5) surface water development. The source of data and potential significance of any relationship between the reach gains and that data type is explained in the following sections. The authors recognize that this list may not be comprehensive and that further assessment of potential causes of reach gain reductions may be warranted.

2.3.3.1 Baseflow Changes

Baseflow is a term often used to describe the groundwater component of flow into a stream. Baseflow can be determined using various hydrograph separation techniques; the goal of each technique is to determine the consistent component of flow within the hydrograph or the baseflow. A digital filtering technique was used in this report to calculate baseflow for each reach. Baseflows were compared to reach gains or tributary flows to determine whether changes in the reach gains were associated with changes in the baseflow component. Reductions in the baseflow component could represent a reduction of groundwater inflow within that reach, thereby identifying the portion of the reach gain reduction due to decreased groundwater inflow.

2.3.3.2 Inflow Changes

Inflows as described here represent flows that occur at the upstream end of a reach that could influence the gains within the reach being evaluated. Inflows were evaluated due to the fact that many reaches receive returns from canal deliveries that have significant influence on the potential gain within the reach.

2.3.3.3 Diversion Changes

Diversions are the surface water deliveries used by the major canals within each reach, and are added to the downstream gaged flows when determining the reach gains. Diversions within a reach can be a significant component in the amount of gain within that reach. Therefore, this study evaluated the consistency of diversions occurring within each reach. If diversions were determined to have decreased in volume within a reach, this could be a potential cause for a portion of any reduced reach gains due to reductions in seepage from those diversions back to the reach. To account for this, a correction was applied to the stream reach gain reductions to account for the seepage change between the representative period and the recent period.

2.3.3.4 Groundwater Development Changes

Groundwater irrigated acres were assessed to determine if any general increase of groundwater irrigated acres is related to any reduction in reach gains. New groundwater irrigated acres were computed in annual quantities based on completion dates within the Nebraska Department of Natural Resources (NDNR) water well registration database. These annual new groundwater irrigated acres were plotted cumulatively to determine trends in development. The cumulated groundwater irrigated acres extracted from the NDNR water well registration database were compared to the estimates of groundwater irrigated acres developed by COHYST for the years 1997 to 2005 to validate recent acre estimates.

2.3.3.5 Surface Water Development Changes

Acres approved to be irrigated under surface water appropriations were assessed to determine if an increase in surface water irrigated acres is related to any reduction in reach gains. Surface water irrigated acres were extracted from the NDNR surface water appropriation database to determine the annual newly appropriated acres. The annual acres associated with new appropriations were accumulated to determine trends in surface water development.

2.4 Unmet Demand

A streamflow reach gain reduction alone does not necessarily result in an adverse impact to an appropriation, to recharge needed for existing wells, or to the State's ability to comply with an interstate agreement. For a streamflow reach gain reduction to result in such an adverse impact, the reach gain reduction would have to be sufficient to reduce the supply that would be available to and needed by one of the abovementioned uses. Therefore, in order to determine when and how often streamflow reach gain reductions might have an adverse impact, it is necessary to determine when and how often shortages to appropriations, to streamflow needed for recharge, or to streamflow needed for compliance with interstate agreements occur. These shortages to uses are referred to in these analyses as "unmet demands."

In assessing unmet demands, it is recognized that some demands, and therefore unmet demands, can or do make use of the same water supply. For example, streamflow in the non-irrigation season may be used for power production and then returned to the river, and it may then flow downstream to become part of the water supply for instream flow appropriations. Other examples include water diverted for irrigation that also is used in power production, water that is used for power production in multiple locations, and water in the river that is used for both instream flow appropriations and recharge for wells. Thus it is important to recognize that unmet demands are not always cumulative, and efforts were made in the analyses where appropriate to avoid double-counting the impacts from streamflow reach gain reductions.

2.4.1 Instream Flow Appropriations Unmet Demands

Both the Central Platte Natural Resources District (CPNRD) and the Nebraska Game and Parks Commission (NGPC) hold natural flow appropriations for instream flows within and below the lower reaches of the study area. For purposes of estimating the unmet demand, the instream flow appropriations as measured at Odessa were compared against the historic daily streamflow record. If the streamflows were greater than the instream flow appropriation, there was no unmet demand. If the streamflows were less than the instream flow appropriation, then the difference between the instream flow appropriation and recorded streamflow was determined to be a daily unmet demand. The daily values were then totaled for the irrigation and non-irrigation seasons to determine the average seasonal unmet demands.

2.4.2 Irrigation Appropriations Unmet Demands

Appropriations for irrigation exist throughout the study area. The unmet demands for these appropriations were considered for the irrigation season only; it is assumed that no unmet irrigation appropriation demand exists during the non-irrigation season. Because not all irrigation appropriations have storage water available as an additional source of supply, two methods were employed to determine the unmet demand. For those appropriations with a storage supply, it was assumed that historic storage use could be used as an estimate of unmet demand, provided that the storage quantity available was not otherwise reduced (allocated) to below-normal amounts. For those appropriations for which storage water is not available to supplement natural flow for irrigation, the historical diversion record was compared against the consistent historical use (i.e., total diversion at times when natural flow availability was not a limiting factor in the amount diverted) as a way to estimate unmet demand.

2.4.3 Power Appropriations Unmet Demands

Appropriations for power production in the study area include water used in hydropower plants and water used as cooling water in thermal generation plants.

Hydropower generation in the study area represents a large non-consumptive demand in both the irrigation season and the non-irrigation season. Because hydropower generation is non-consumptive, the water used to meet a hydropower demand is often the same water used to meet other demands as well, including other hydropower generation, irrigation, and instream flows. The historical diversion record was compared against the consistent peak historical use (i.e., total diversion at times when natural flow availability was not a limiting factor in the amount diverted) to estimate unmet demand. Unmet demand for hydropower that would also coincide with other unmet demands identified elsewhere was not double-counted.

Cooling water uses in the study area were typically designed to take advantage of other already existing uses. For the purposes of these analyses, any unmet cooling water demand was assumed to coexist with some other unmet demand and therefore did not need to be counted separately.

2.4.4 Storage Reservoir Appropriation Unmet Demands

Appropriations exist in the study area for the purpose of storing water in reservoirs, with the intent that the storage water would then be put to some later use. These storage appropriations are primarily located in Lake McConaughy (including Lake McConaughy appropriations allowed to be stored in Elwood Reservoir) and in the Sutherland system (some of which are also allowed to be stored in Lake McConaughy). The demand for storage includes both the water needed to be stored for some future use and the water needed to satisfy evaporation and seepage losses from the reservoir.

Because the uses to which storage water would be applied have their own estimates of unmet demand (e.g. irrigation and hydropower generation), no additional unmet demand was estimated for storage for these purposes. In addition, because the reservoir evaporation and seepage demands are uncontrolled and have historically been met, no unmet demand was assumed to exist for this storage demand. Consequently, total demand for water from storage will likely be underestimated, as storage often occurs at times when all other demands are already met. Nevertheless, these analyses assumed that omitting these additional unmet storage demands does not substantially affect the estimate of the overall difference between overappropriated and fully appropriated.

2.4.5 Groundwater Recharge Demands

Water flowing in a river or stream can provide recharge to the underlying or surrounding aquifer, particularly where the river or stream is a losing (as opposed to gaining) reach. For purposes of these analyses, an unmet demand for recharge was assumed to exist where river or stream reaches that were historically continuously flowing with baseflow are now dry. In many or all cases, the water needed in the river or stream to keep a stream flowing is the same water needed to meet some other use. Consequently, the unmet demand for recharge would coincide with some other unmet demand and did not need to be quantified separately.

2.4.6 Interstate Agreement Unmet Demands

The only interstate agreement operative within the study area is the Platte River Recovery and Implementation Program (PRRIP). Under PRRIP, additional unmet demands could be those post-1997 reach gain reductions that impact United States Fish and Wildlife Service (USFWS) target flows or PRRIP water supply projects. Although instream flows do not always equal or exceed USFWS target flows, the authors assumed that the requirement to get to a fully appropriated condition for these appropriations alone will probably provide benefits equal to or in excess of those required to meet Nebraska’s obligations under PRRIP in terms of water quantity. Thus, no separate unmet demand for purposes of compliance with interstate agreements was estimated. These analyses do not estimate the amount of time that will be needed to achieve the fully appropriated condition, however, and PRRIP compliance issues with respect to timing of water obligations have not been addressed in this report.

2.5 Accumulating Unmet Demands

Reach gain reductions within a given reach can have impacts on both the demands within the reach and the demands downstream of that reach. The total unmet demands for each reach were calculated by adding the unmet demands in that reach to the accumulated unmet demands from the reach downstream. The cumulating process is not always strictly additive; water can be used multiple times by non-consumptive users (e.g. instream flow and hydropower uses). Careful consideration was given to those reaches in which non-consumptive uses were a portion of the unmet demand to ensure that unmet demands were not overestimated.

2.6 Overall Difference between Overappropriated and Fully Appropriated

The overall difference between overappropriated and fully appropriated was determined by comparing each reach's accumulated unmet demands with each reach's stream reach gain reductions. When reach gain reductions are less than unmet demands, unmet demands would not be expected to be fully met but reach gain reductions would not further erode the supply available for those demands. When reach gain reductions are greater than unmet demands, reach gain reductions would not be expected to be made up in the absence of demands for the supply. Therefore, the lesser of the two values was used to determine the total difference between overappropriated and fully appropriated for each reach.

For example, if unmet demands in a given reach equal 50,000 acre-feet, but if the stream reach gain reduction is only 100 acre-feet, then 100 acre-feet would be the value used because that value represents the magnitude of the impact to the available supply. If the results indicate that the total reach gain reduction is greater than accumulated unmet demand, then the sponsors will be responsible for negotiating how much stream reach gain reduction must be replaced in the system within each reach.

3.0 CALCULATION OF STREAM REACH GAIN REDUCTIONS, UNMET DEMANDS, ACCUMULATED UNMET DEMANDS, AND THE OVERALL DIFFERENCE BETWEEN OVERAPPROPRIATED AND FULLY APPROPRIATED

3.1 Section Overview

This section details the double-mass curves used to determine irrigation season and non-irrigation season stream reach gain reductions and provides supporting data as to potential causes of the stream reach gain reductions, unmet demands within each reach, and the accumulated unmet demands assigned to each reach. Further refinement of these estimates will likely be completed in the future and those future refinements may more specifically identify causes of the stream reach gain reductions and the timing of unmet demands.

3.2 Platte River – Cozad to Odessa Reach

The Cozad to Odessa reach is the contributing surface water basin between the stream gages located on the Platte River at Cozad and at Odessa. This reach includes inflows from the Johnson Return and small ungaged tributaries and outflows to the Kearney Canal.

3.2.1 Assessment of Reach Gain Reductions

The double-mass curve of cumulative reach gains and cumulative precipitation during the period of 1949-2006 for the irrigation season and non-irrigation season, respectively, are illustrated in figures 3-1 and 3-2. The cumulative precipitation for this reach was developed based on the weighted precipitation from the following gages:

Gage	Weight of Gage (based on Thiessen polygons)
Elwood	0.218
Gothenburg	0.456
Holdrege	0.179
Kearney	0.063
North Platte	0.069
Stockville	0.015

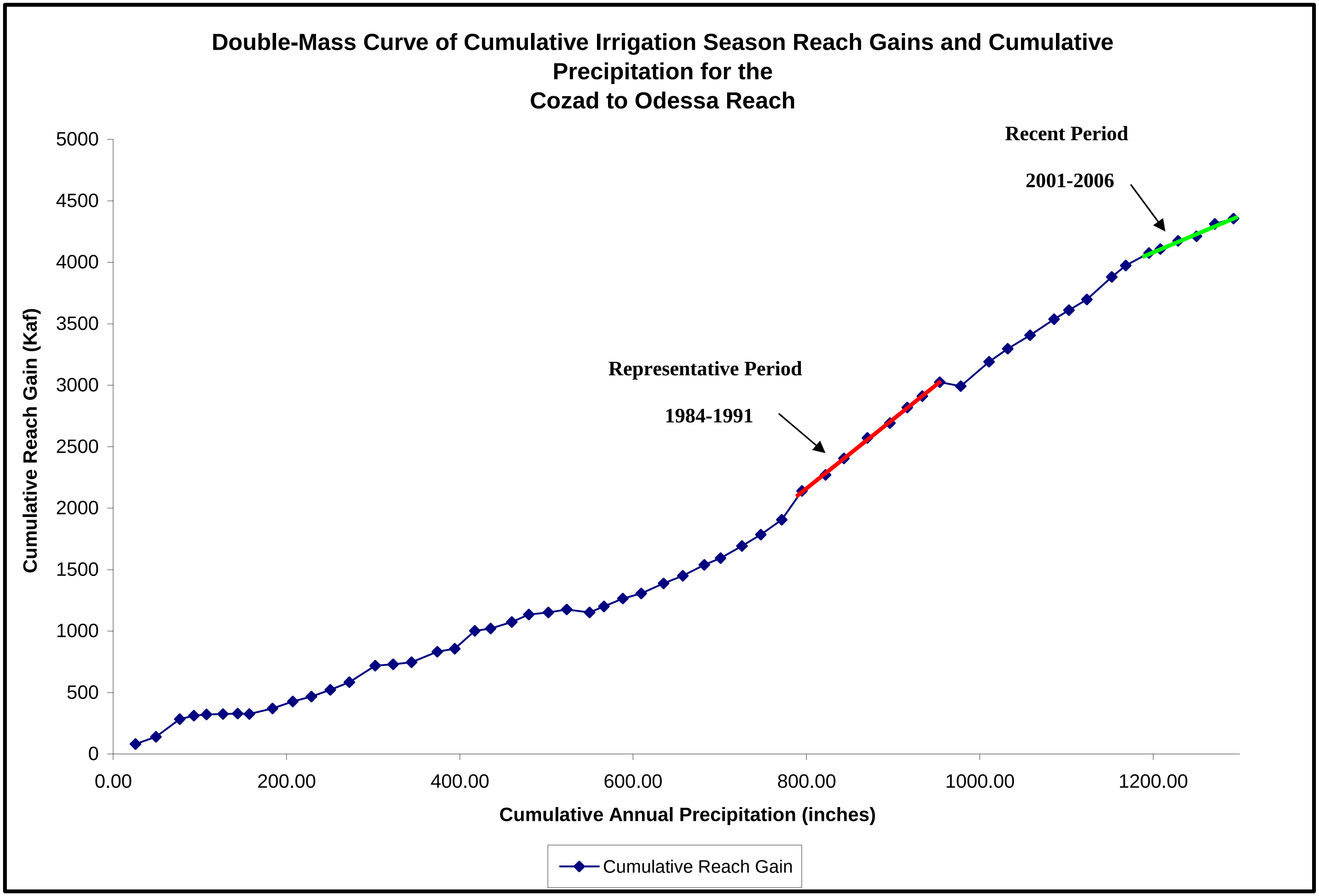


Figure 3-1. Double-mass curve of the cumulative irrigation season reach gain and cumulative annual precipitation.

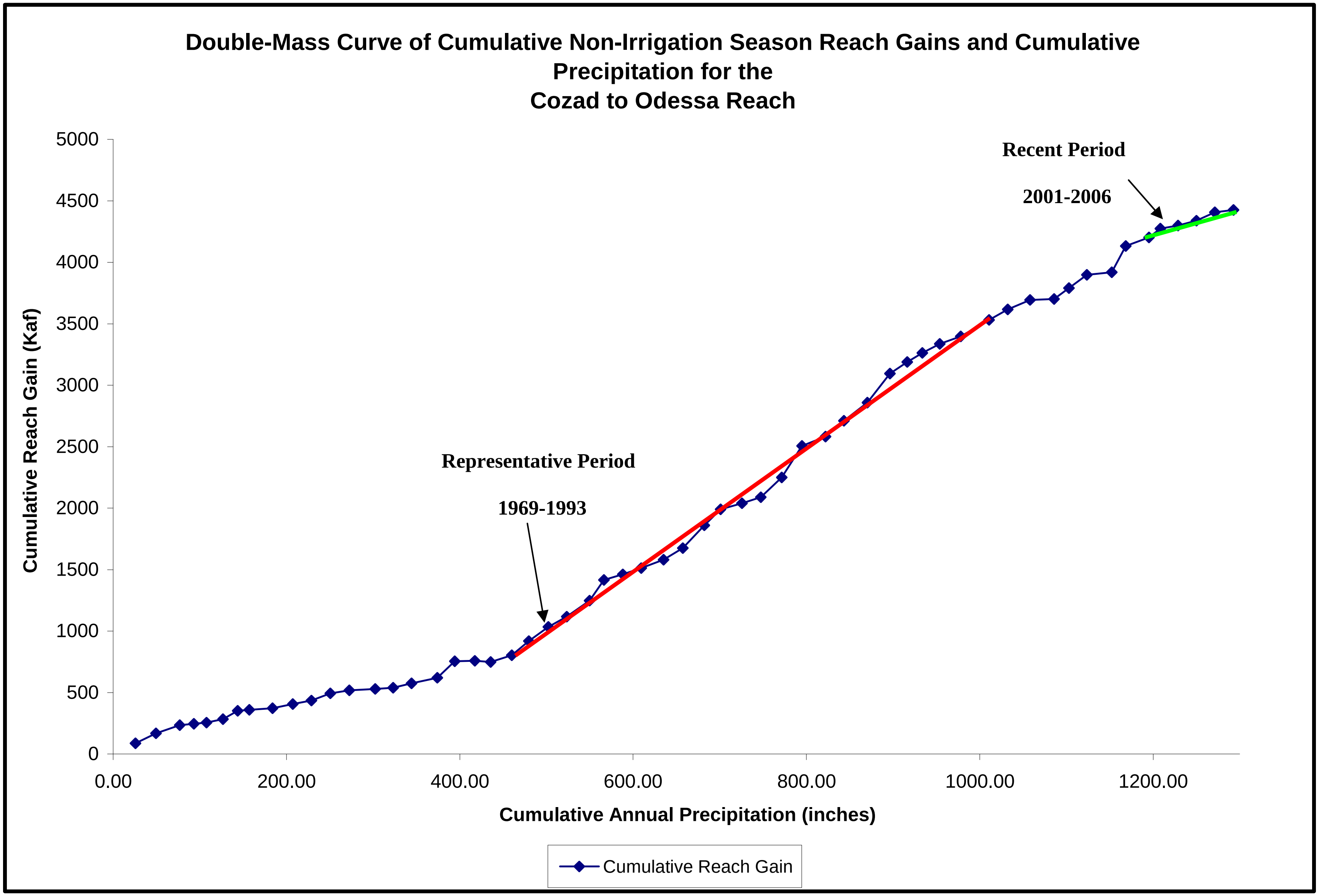


Figure 3-2. Double-mass curve of the cumulative non-irrigation season reach gain and cumulative annual precipitation.

In evaluating potential stream reach gain reductions, the 1969-1993 period was used as the representative period for the non-irrigation season and the 1984-1991 period was used as the representative period for the irrigation season. The period 2001-2006 was used to represent the recent periods for both the irrigation season and the non-irrigation season. The authors acknowledge that the 2001-2006 period represents a dry condition, thus any stream reach gain reductions identified for this reach were thought to represent only dry conditions. An earlier breakpoint in the double mass curve for the irrigation season was indicated, but a corresponding point in the non-irrigation season was not evident, and therefore further work should be completed to determine the cause of this inconsistency between the irrigation season and non-irrigation season double mass curves.

The calculated stream reach gain reductions for this reach are summarized in table 3-1. The stream reach gain reductions within this reach are very sensitive to the representative period used. The representative value used for this reach was selected by the authors because it appeared to represent conditions in which seepage from canals within the reach reached equilibrium. Increased gains within this reach from 1960 to 1990 may be due to a variety of factors, however, and further investigation is necessary.

Table 3-1. Summary of stream reach gain reductions for the Cozad to Odessa reach.

Cozad to Odessa Reach Gain Reduction		
Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	0	0
Normal	0	0
Dry	59,300	60,300

3.2.2 Potential Causes for Reach Gain Reductions

The potential causes for stream reach gain reductions within this reach were investigated by evaluating reach gain baseflows, diversions (seepage returns to the reach), groundwater development, and surface water development. Figures 3-3 and 3-4 illustrate how baseflow within the reach has changed over this period. The baseflows appear to have increased through the 1965-1990 period with a rapid decrease in the more recent period. This decrease in baseflow could indicate that a portion of the recent period stream reach gain reduction is due to reduced groundwater inflow in the reach.

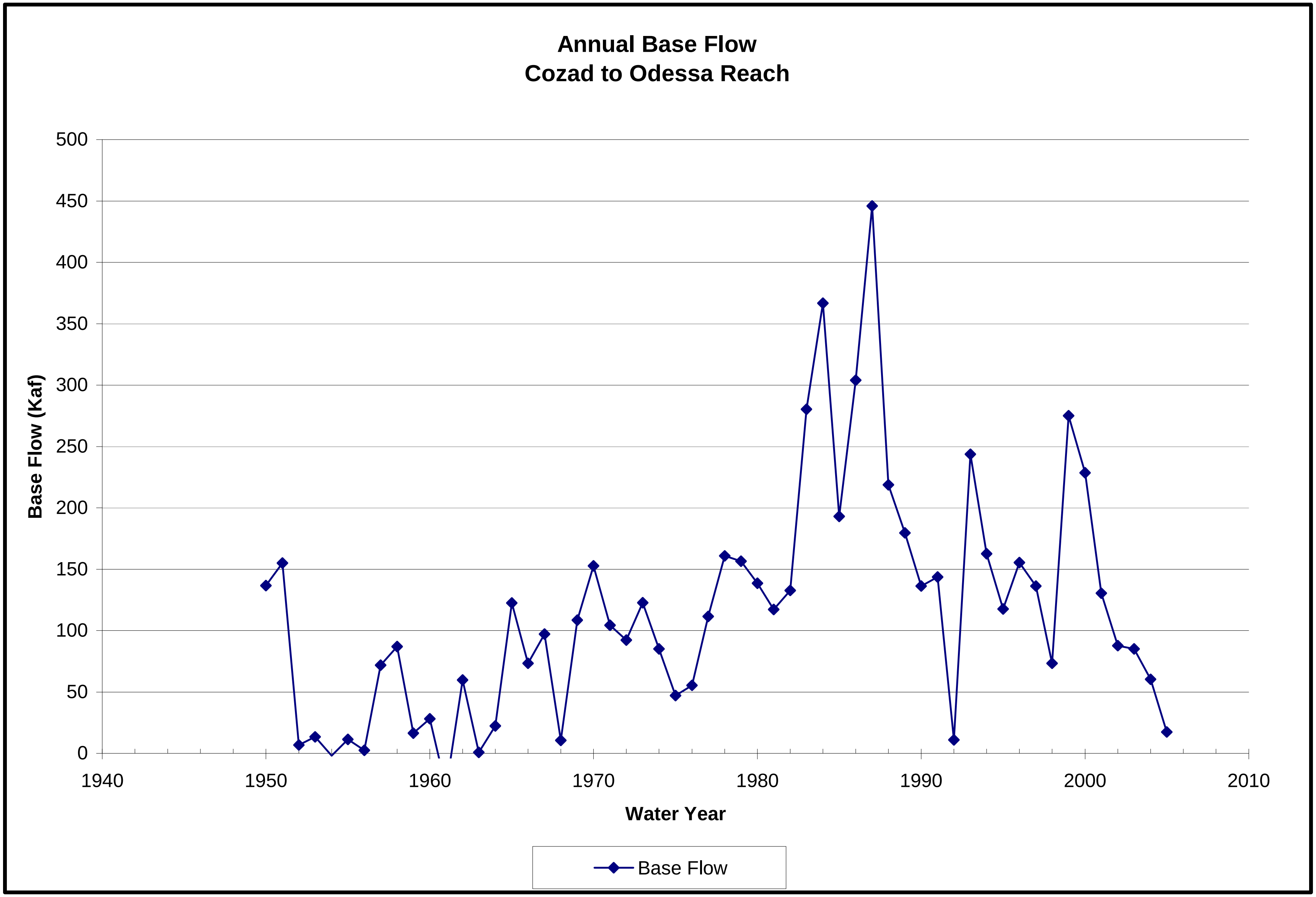


Figure 3-3. Cozad to Odessa reach annual baseflow gain.

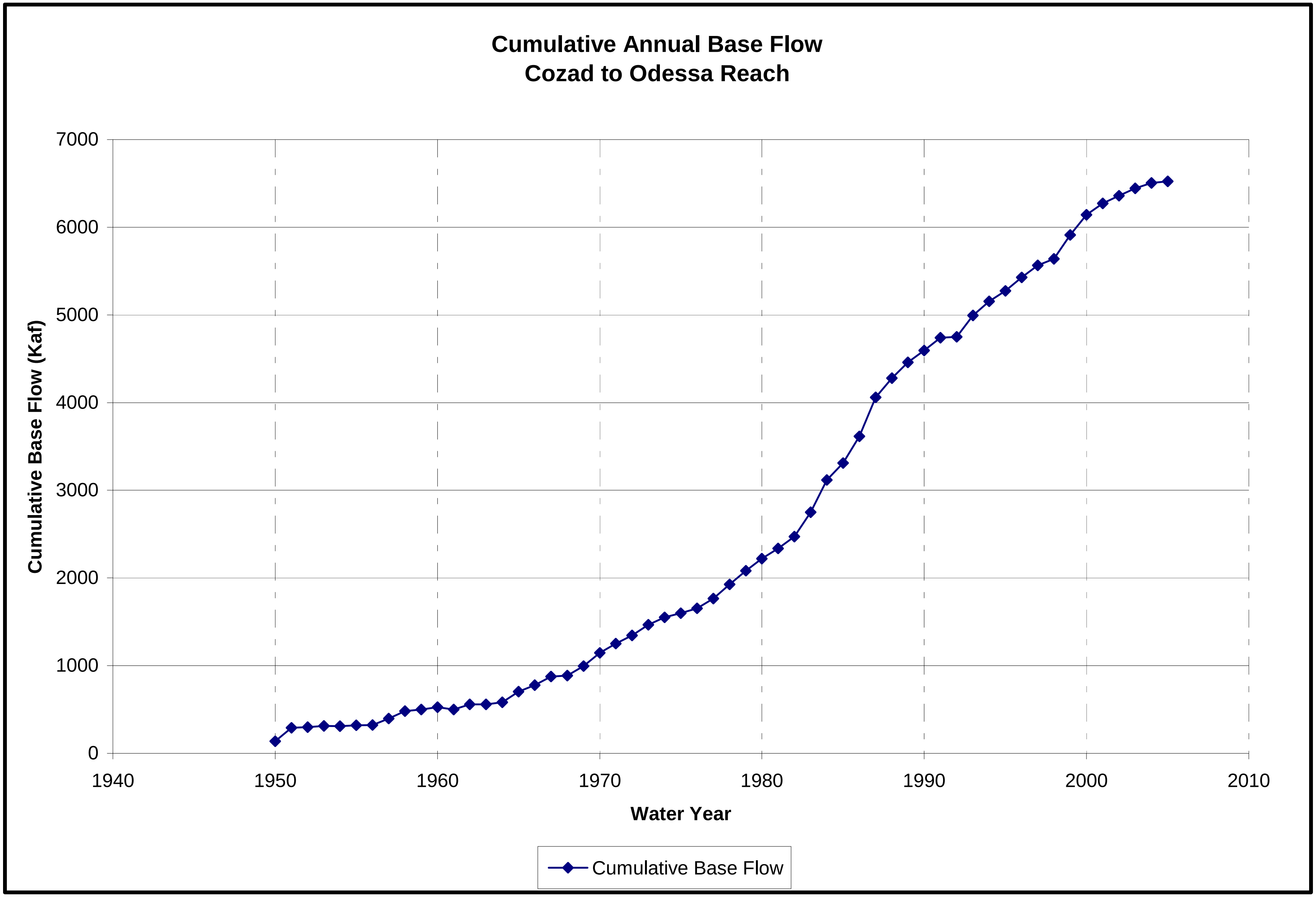


Figure 3-4. Cozad to Odessa cumulative annual baseflow.

Surface water diversions within the reach were evaluated to determine if reduced surface water diversions, and, therefore, reduced returns from those diversions, could be a potential cause of stream reach gain reductions. Figures 3-5 and 3-6 illustrate historical diversions for irrigation and hydropower demands for Kearney Canal and the Tri-County Canal.

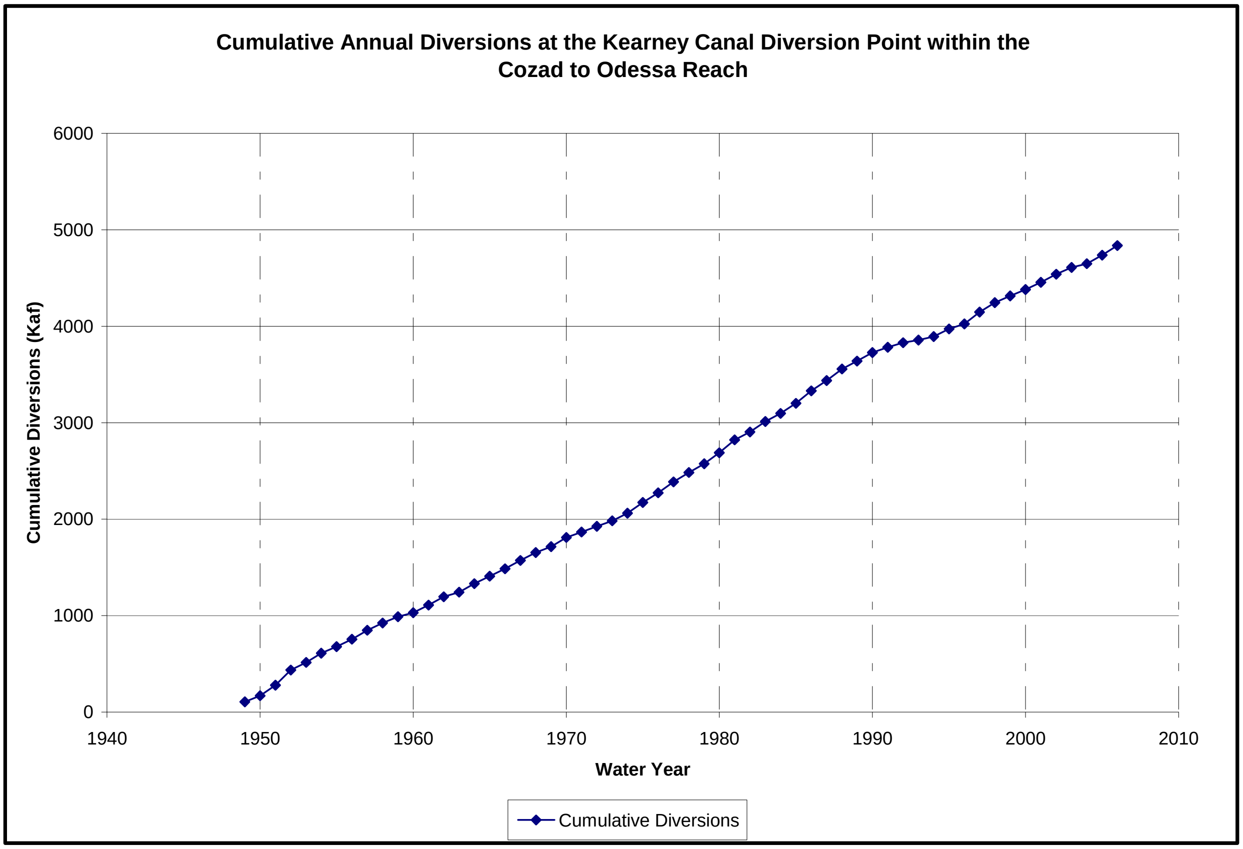


Figure 3-5. Cumulative surface water diversions for Kearney Canal.

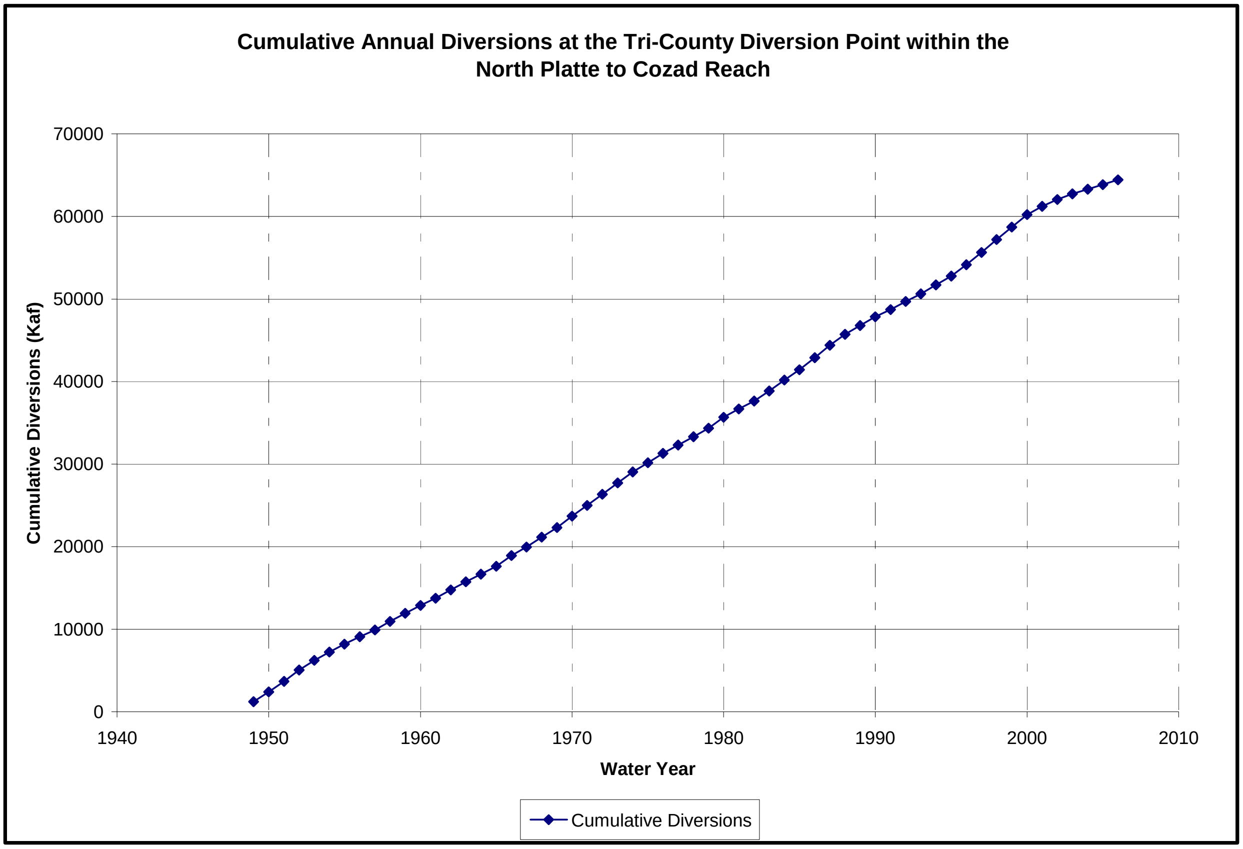


Figure 3-6. Cumulative surface water diversions for the Tri-County Canal.

Evaluation of the diversion records indicated that estimated annual seepage from diversions affecting this reach decreased significantly from the representative period to the recent period (2001-2006). Annual seepage decreased by an estimated 33,200 acre-feet per year (ac-ft/yr) in the irrigation season and 17,800 ac-ft/yr in the non-irrigation season when comparing the representative period to the later recent period. Since any reach gain would include gains from these seepage losses, the seepage changes were subtracted from the calculated reach gain reductions to derive the final reach gain reductions shown in table 3.2.

Table 3-2. Summary of stream reach gain reductions for the Cozad to Odessa reach adjusted for reduced seepage from diversions.

Cozad to Odessa Reach Reach Gain Reduction		
Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	0	0
Normal	0	0
Dry	26,100	42,500

The level of groundwater development within the reach was evaluated and is illustrated in figures 3-7 and 3-8. The results indicate that approximately 210,000 additional groundwater irrigated acres were developed through the period analyzed (1949-2006). The increase in groundwater irrigated acres may be potential cause of reductions in the reach gain.

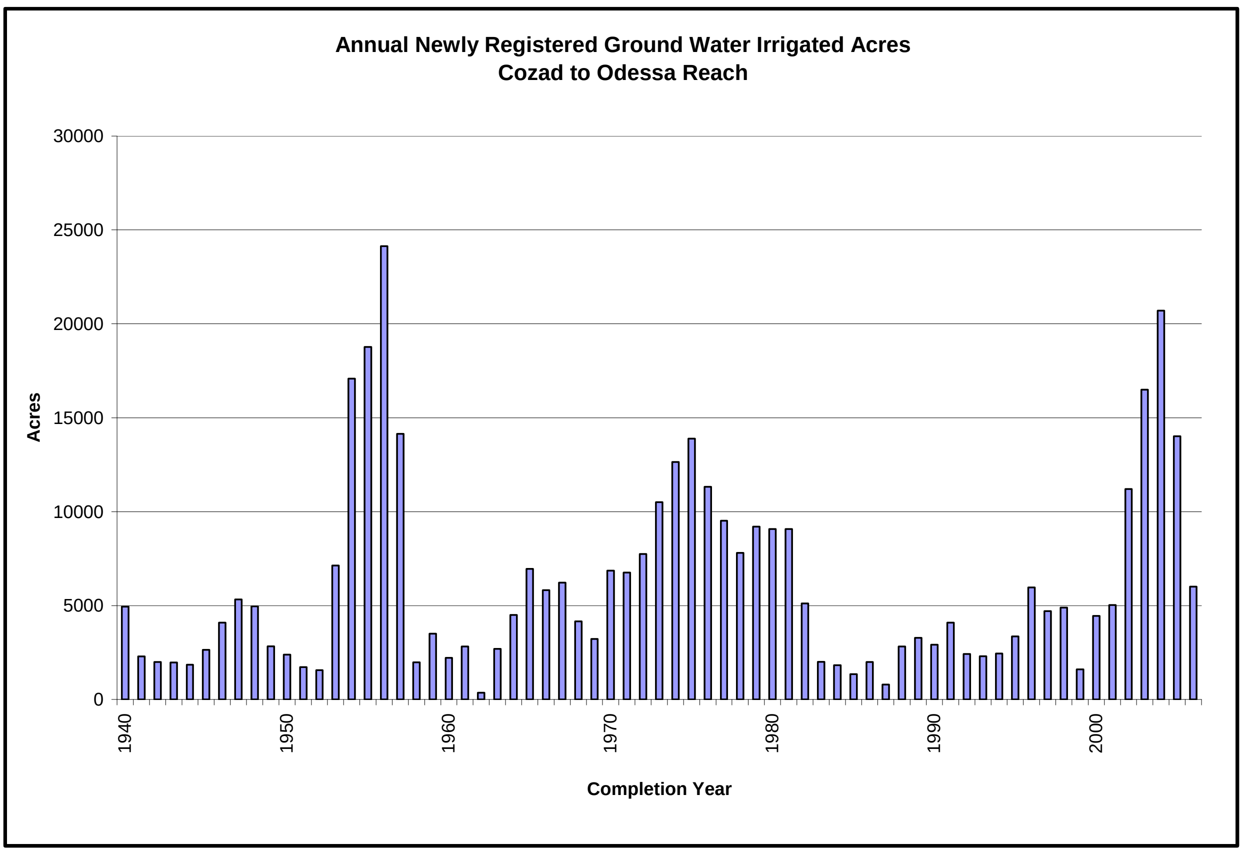


Figure 3-7. Annual newly registered groundwater irrigated acres.

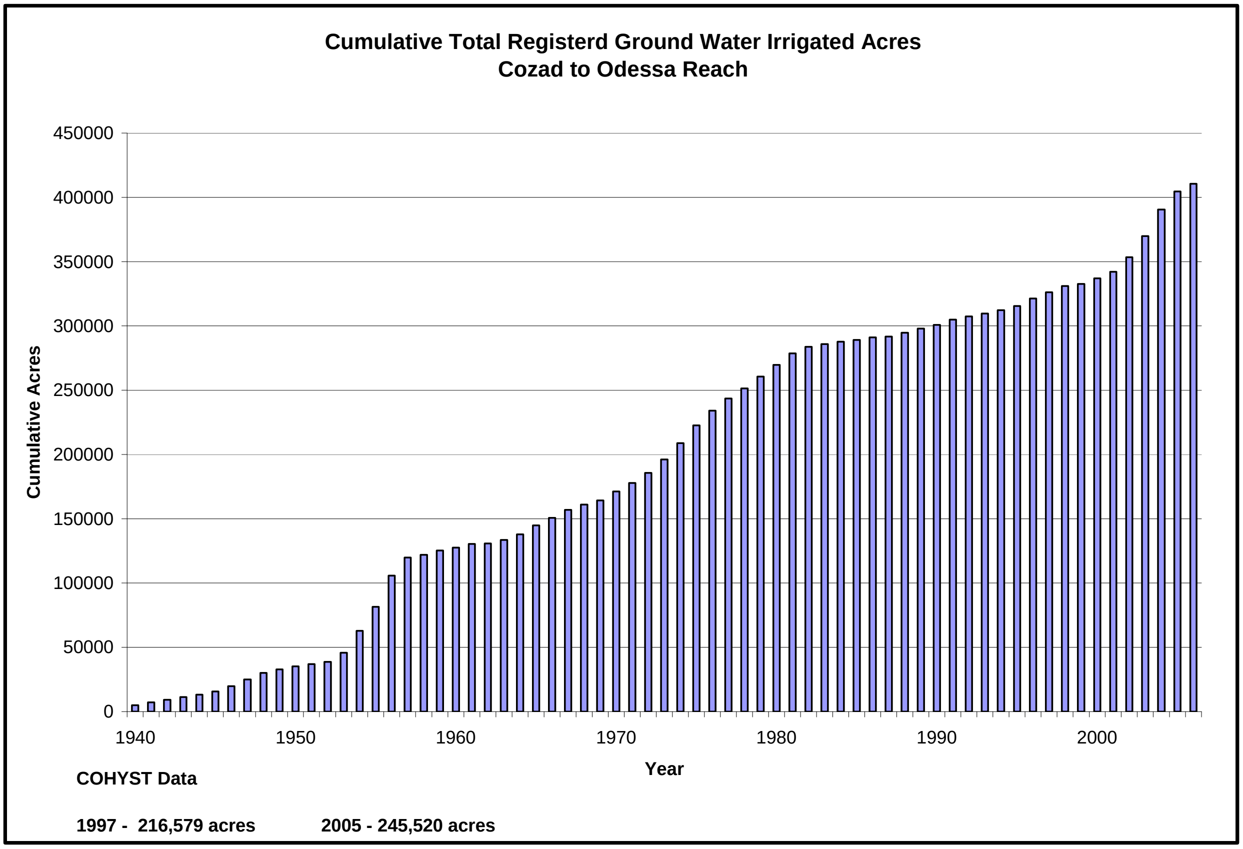


Figure 3-8. Cumulative groundwater irrigated acres.

The level of surface water development within the reach was evaluated and is illustrated in figures 3-9 and 3-10. The results indicate that approximately 7,500 additional acres were approved for surface water irrigation through the period analyzed (1949-2006). These new appropriations may have an impact on reductions in the reach gain. These reductions may be minimal during dry periods, however, when senior appropriations can call for administration on the river.

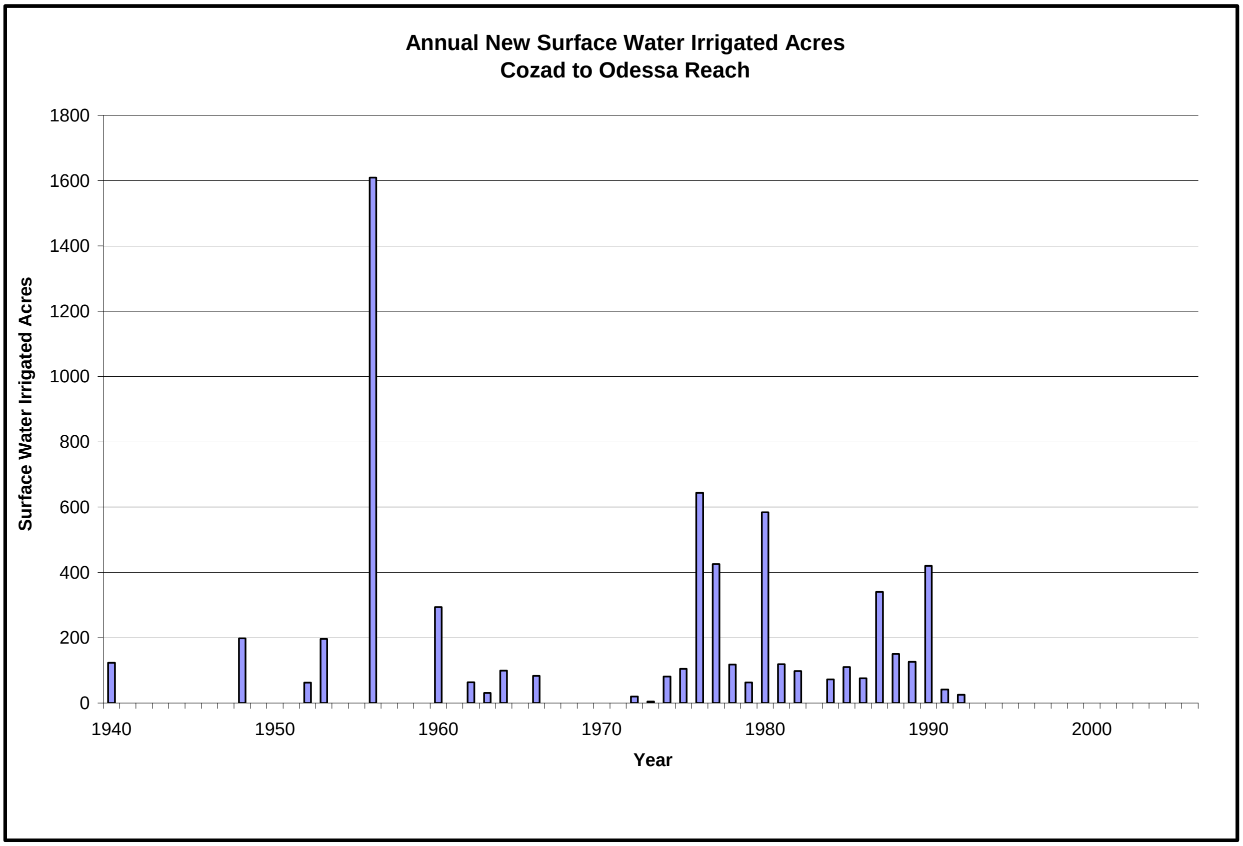


Figure 3-9. Annual new surface water irrigated acres.

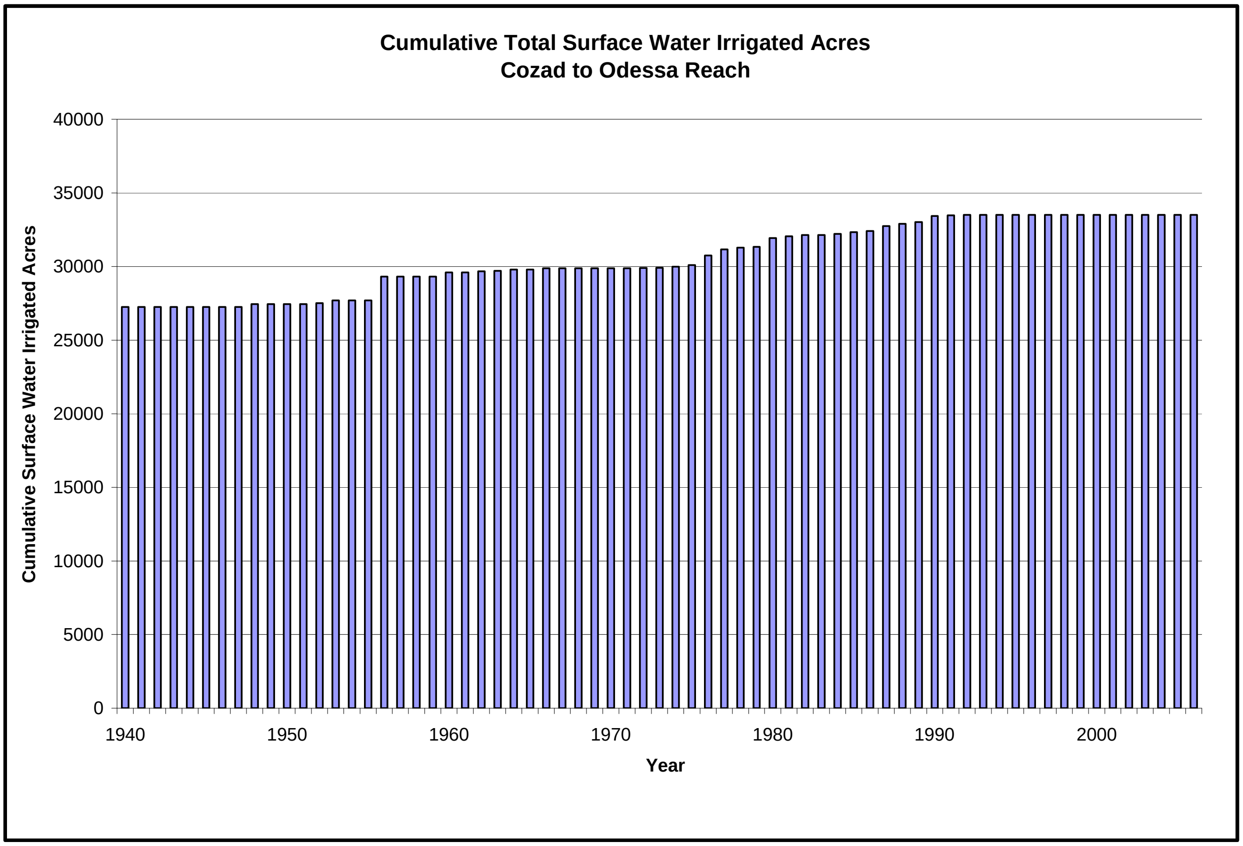


Figure 3-10. Cumulative total surface water irrigated acres.

3.2.3 Unmet Demands

The following demands were considered for the Cozad to Odessa reach:

- Instream flow appropriations
- Platte River recharge for wells
- Kearney Canal irrigation
- Kearney Canal hydropower generation

Both the CPNRD and the NGPC hold instream flow appropriations in the Platte River. The instream flow appropriations of the NGPC are additive to those of the CPNRD. Unmet demand in the normal and dry periods (as defined in table 2-1) was determined by comparing the combined CPNRD and NGPC appropriations against the historic river flow at the Odessa gage. Unmet demand for instream flows in wet periods was assumed to be zero. This was assumed because in the later process of accumulating, the unmet demands for instream flows are overridden by hydropower demands or irrigation operations such that instream flow demands are no longer factored into the calculations for reaches upstream of North Platte.

The need for recharge from the Platte River for the maintenance of existing wells was also considered. Although no actual shortage of water for wells in or below this reach has been demonstrated, some water quality issues with the Grand Island municipal wellfield have been measured when the river goes completely dry. Because the amount of streamflow that would be necessary to keep the river from going completely dry is believed to be substantially less than the flow required for the instream flow appropriations, and because the same water in the stream can serve both purposes, the unmet demand for recharge for wells was assumed to be zero.

The Kearney Canal's primary appropriations for both irrigation and power generation are some of the most senior appropriations on the Platte River, and as such, the demand for water on Kearney Canal is almost always met by natural flow alone. In some instances natural flow in the Platte River has been insufficient to satisfy Kearney Canal's demand (typically during dry periods), however, these instances are infrequent and for the purposes of these analyses, the unmet demand for Kearney Canal for both irrigation and hydropower is assumed to be zero. Thus the only unmet demand that was quantified for this reach was the instream flow demand during normal and dry conditions (table 3-3).

Table 3-3. Cozad to Odessa reach unmet demands.

Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	0	0
Normal	38,000	44,000
Dry	101,000	128,000

3.2.4 Accumulated Unmet Demands

This reach is at the furthest downstream end of the reaches analyzed and therefore nothing accumulates to this reach's unmet demands from downstream. The unmet demands from the reach (instream flows, hydropower, and irrigation) are passed entirely upstream to the North Platte to Cozad reach (table 3-4).

Table 3-4. Unmet Demands passed upstream to the North Platte to Cozad reach.

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	0	0
Normal	38,000	44,000
Dry	101,000	128,000

3.2.5 Overall Difference between Overappropriated and Fully Appropriated

The overall difference between overappropriated and fully appropriated (termed the "OA/FA difference", table 3-7) was reduced from the total reach gain reduction (table 3-5) to account for the junior priority status of the instream flows and the level of development that was established within the basin. The magnitude of this adjustment was determined by assessing the level of groundwater development prior to 1990 (the approximate priority date of the instream flow appropriations) and the 2005 level of groundwater development. The assessment showed that only twenty-five percent of groundwater development occurred subsequent to the priority of the instream flow appropriations; the stream reach gain reduction values were correspondingly reduced by seventy-five percent. This methodology should be scrutinized in future reports to assess its validity.

Table 3-5. Stream reach gain reduction for the Cozad to Odessa reach.

Condition	Stream Reach Gain Reduction	
	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	0	0
Normal	0	0
Dry	26,100	42,500

Table 3-6. Unmet demands for the Cozad to Odessa reach.

Condition	Unmet Demands	
	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	0	0
Normal	38,000	44,000
Dry	101,000	128,000

Table 3-7. Overall difference between overappropriated and fully appropriated for the Cozad to Odessa reach.

Condition	OA/FA Difference	
	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	0	0
Normal	0	0
Dry	6,500	10,600

3.3 Platte River – North Platte to Cozad Reach Gain Reductions

The North Platte to Cozad reach is the contributing surface water basin between the stream gages located on the North Platte River at North Platte and the Platte River at Cozad. This reach includes inflows from the South Platte River, Sutherland Return, Jeffrey Return, Gothenberg Return (1949-1973), and small ungaged tributaries and outflows to the Tri-County Canal, Gothenberg Canal, Thirty-Mile Canal, Orchard-Alfalfa Canal, Six-Mile Canal, Cozad Canal, and Dawson County Canal.

3.3.1 Assessment of Reach Gain Reductions

The double-mass curves of cumulative reach gains and cumulative precipitation during the period of 1949-2006 for the irrigation season and non-irrigation season, respectively, are illustrated in figures 3-11 and 3-12. The cumulative precipitation for this reach was developed based on the weighted precipitation from the following gages:

Gage	Weight of Gage (based on Thiessen polygons)
Arthur	0.005
Gothenburg	0.310
Stapleton	0.309
North Platte	0.376

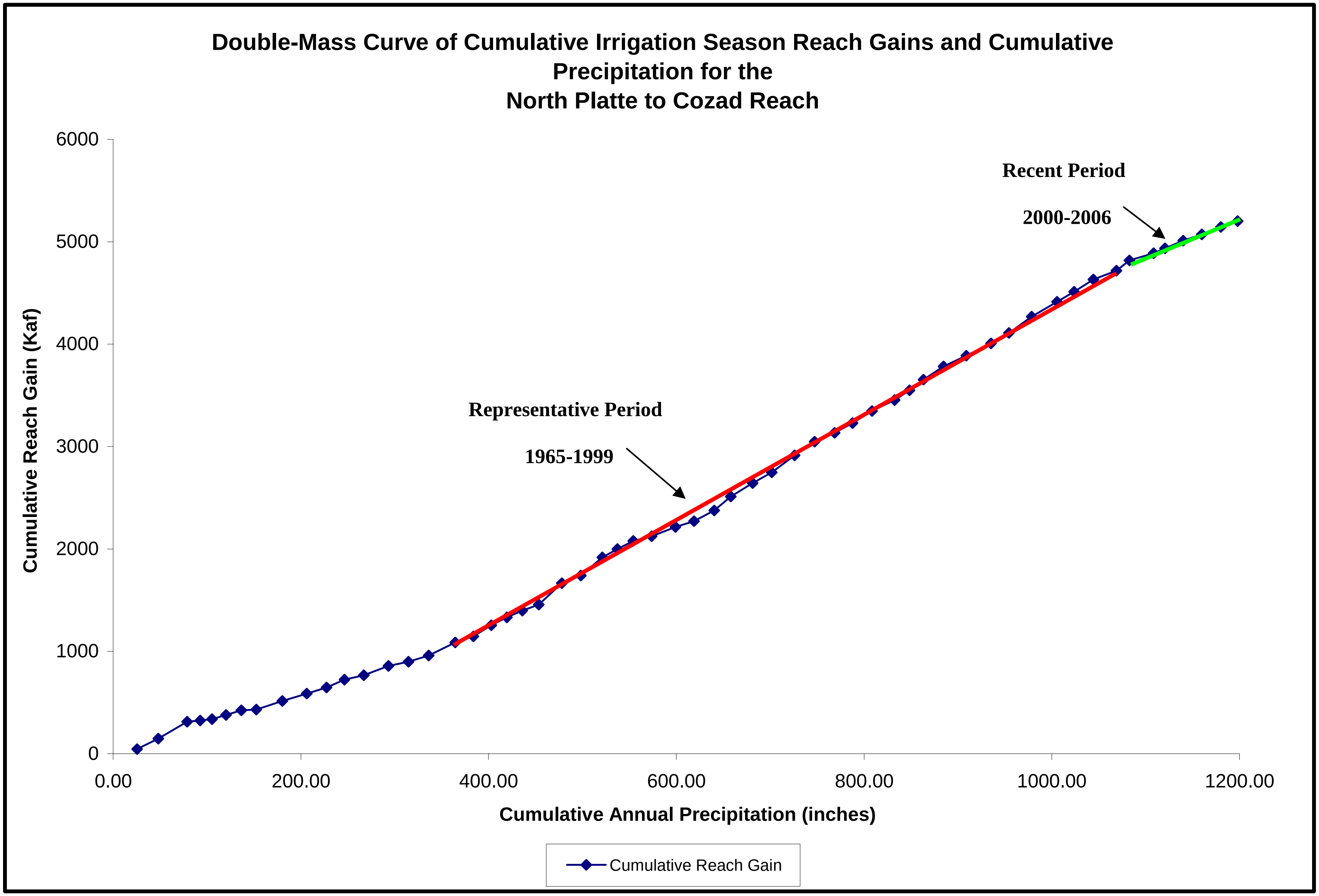


Figure 3-11. Double-mass curve of the cumulative irrigation season reach gain and cumulative annual precipitation.

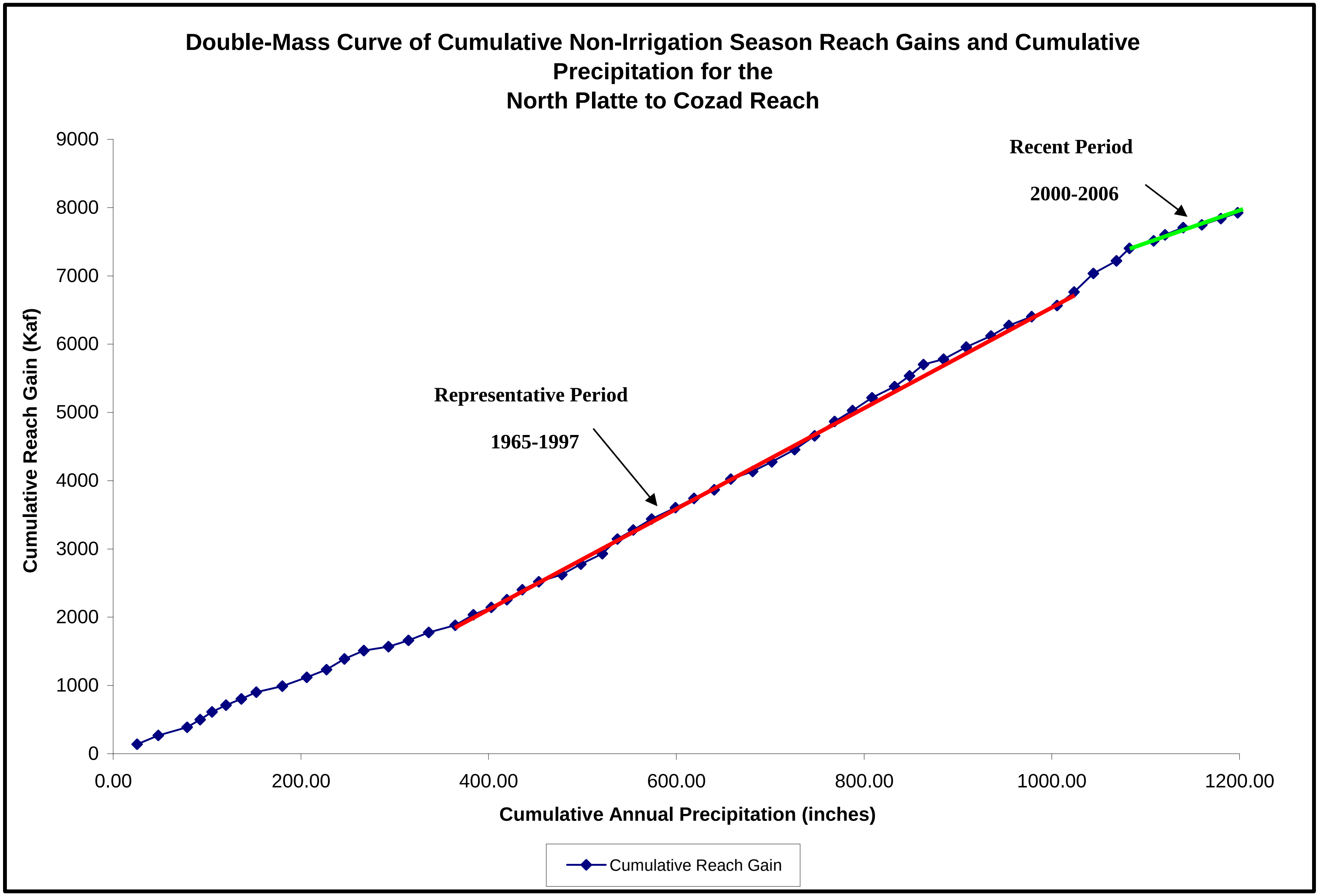


Figure 3-12. Double-mass curve of the cumulative non-irrigation season reach gain and cumulative annual precipitation.

In evaluating potential stream reach gain reductions, the 1965-1999 period was used as the representative period for the irrigation season and the 1965-1997 period was used as the representative period for the non-irrigation season. The period 2000-2006 was used to represent the recent periods for both the irrigation season and the non-irrigation season. The authors acknowledge that the 2000-2006 period represents a dry condition, thus any stream reach gain reductions identified for this reach were only with dry conditions. The calculated stream reach gain reductions for this reach are summarized in table 3-8.

Table 3-8. Summary of stream reach gain reductions for the North Platte to Cozad reach.

North Platte to Cozad Reach Gain Reduction		
Condition	Irrigatation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	0	0
Normal	0	0
Dry	37,300	59,000

3.3.2 Potential Causes for Reach Gain Reductions

The potential causes for stream reach gain reductions within this reach were investigated by evaluating reach gain baseflows, diversions (seepage returns to the reach), groundwater development, and surface water development. Figures 3-13 and 3-14 illustrate how baseflow within the reach has changed over this period. The baseflows appear to have increased through the 1965-1990 period with a rapid decrease in the more recent period. This decrease in baseflow could indicate that a portion of the recent period stream reach gain reduction is due to reduced groundwater inflow in the reach.

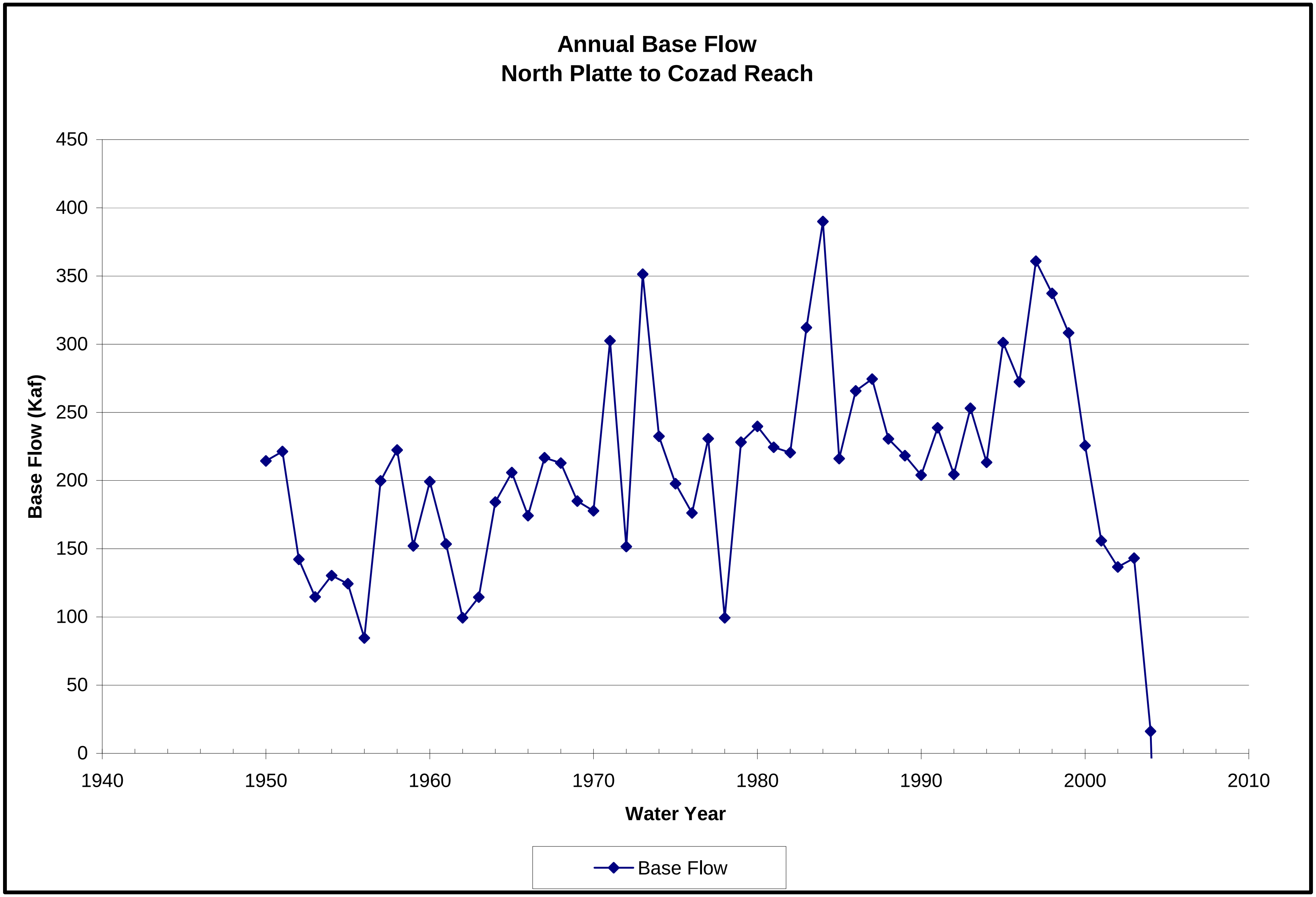


Figure 3-13. North Platte to Cozad reach annual baseflow gain.

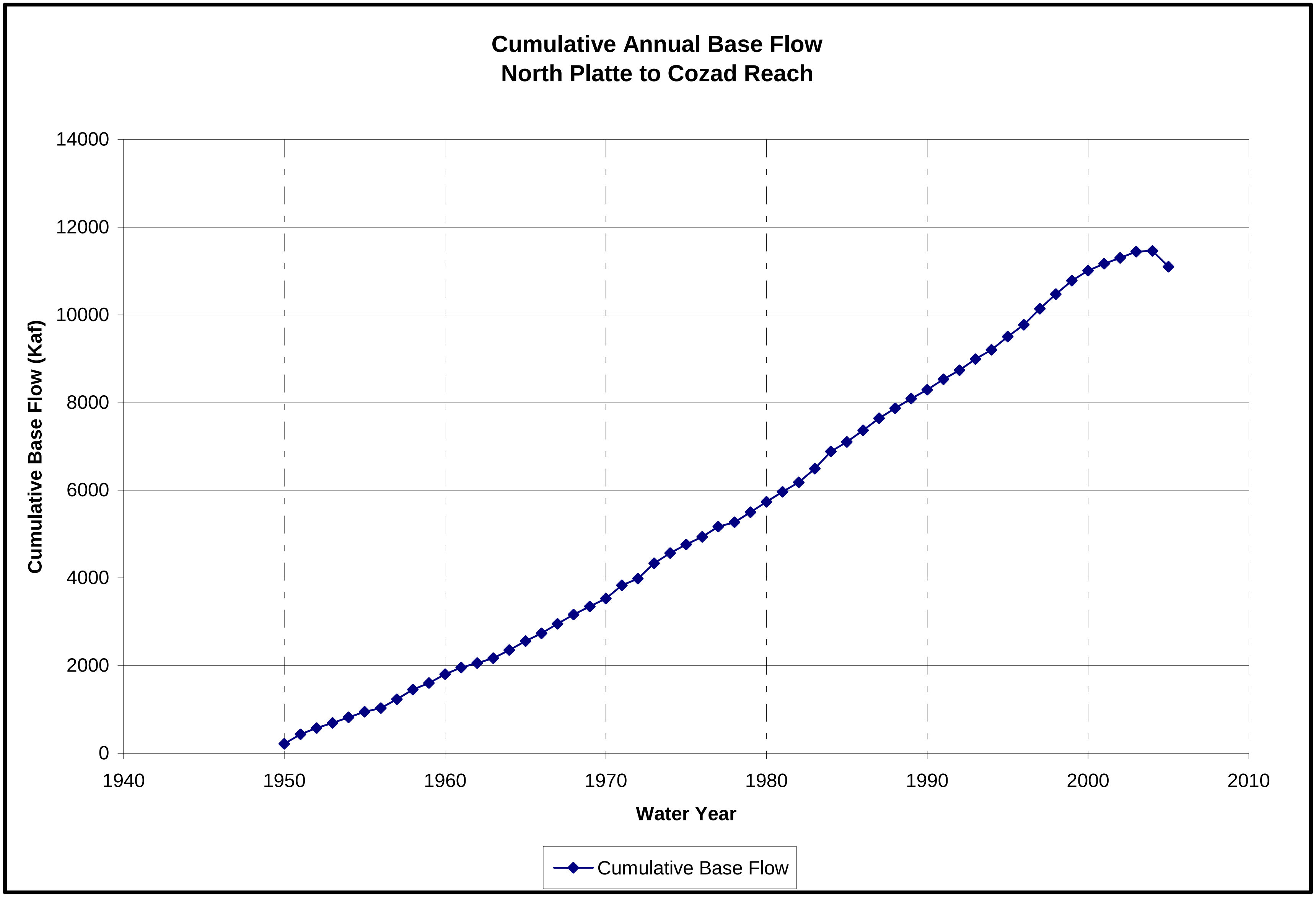


Figure 3-14. North Platte to Cozad cumulative annual baseflow.

Surface water diversions within the reach were evaluated to determine if reduced surface water diversions and therefore reduced returns from those diversions could be a potential cause of stream reach gain reductions. Figures 3-15 and 3-16 illustrate historical diversions for irrigation within this reach and historical diversions for the Tri-County Canal.

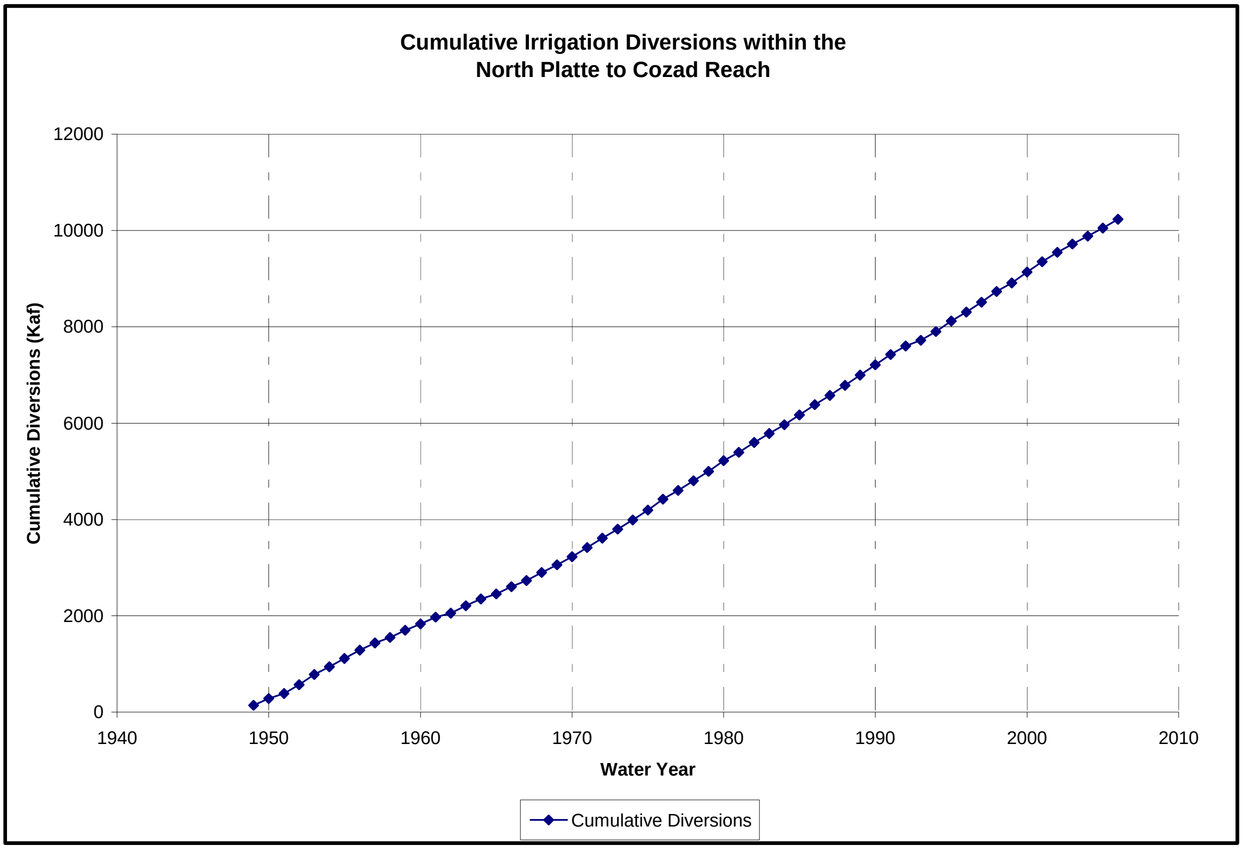


Figure 3-15. Cumulative surface water diversions for irrigation within the North Platte to Cozad reach.

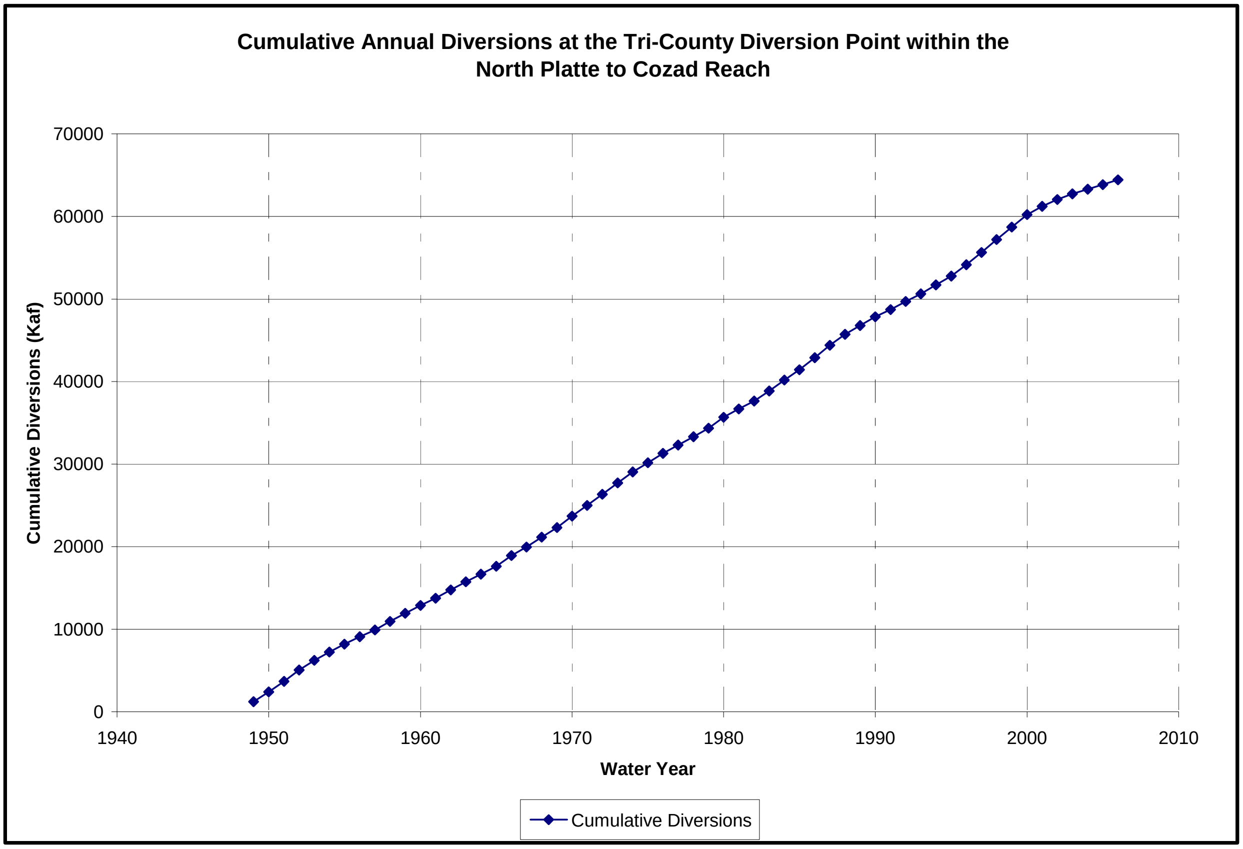


Figure 3-16. Cumulative surface water diversions of the Tri-County Supply Canal.

Evaluation of the diversion records indicated that estimated annual seepage from diversions affecting this reach decreased significantly from the representative period to the recent period (22,400 ac-ft/yr in the irrigation season and 29,500 ac-ft/yr in the non-irrigation season). Since any reach gain would include gains from these seepage losses these seepage changes were subtracted from the reach gain reduction to derive the final reach gain reductions shown in table 3-9.

Table 3-9. Summary of stream reach gain reductions for the North Platte to Cozad reach adjusted for reduced seepage from diversions.

North Platte to Cozad Reach Gain Reduction		
Condition	Irrigatation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	0	0
Normal	0	0
Dry	14,900	29,500

The level of groundwater development within the reach was evaluated and is illustrated in figures 3-17 and 3-18. The results indicate that approximately 135,000 acres of additional groundwater irrigated acres were developed through the period analyzed (1949-2006). The increase in groundwater irrigated acres may be a potential cause of reductions in the reach gain.

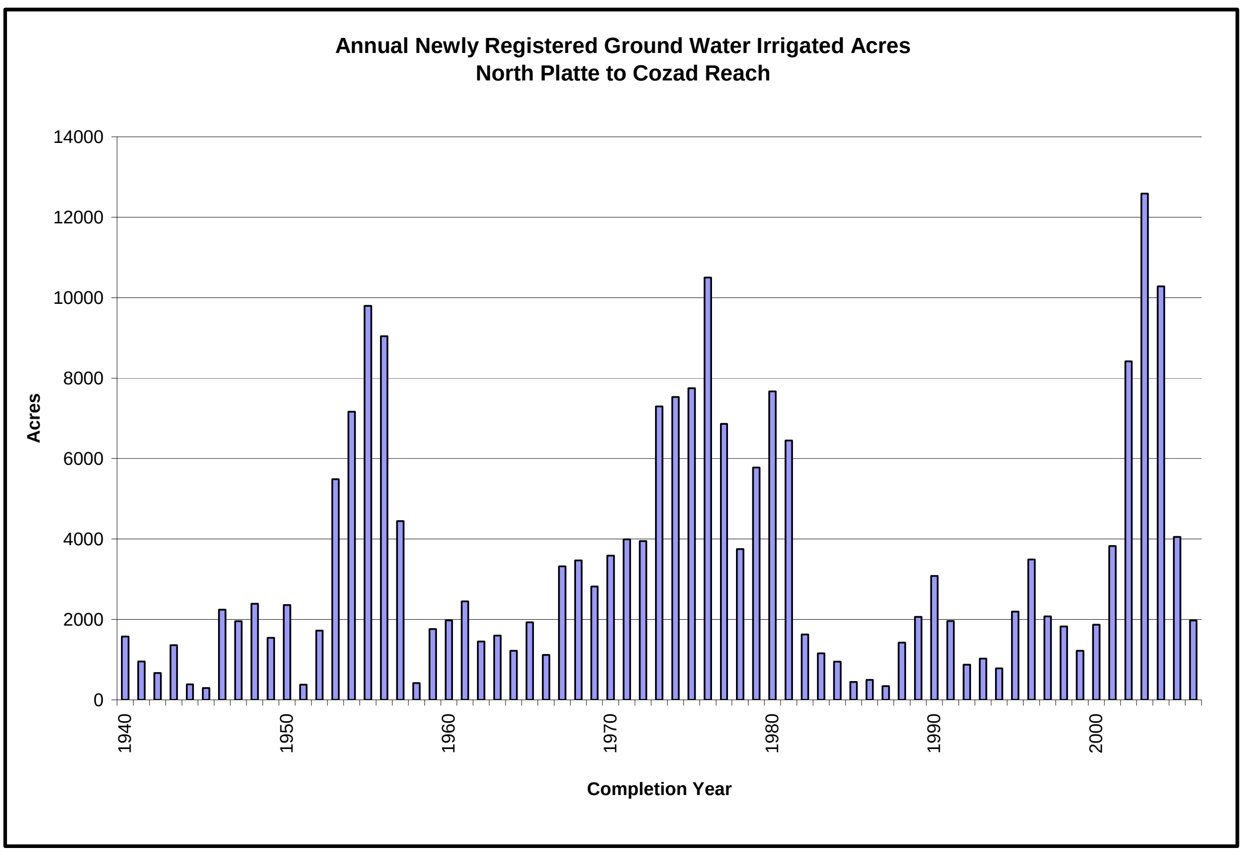


Figure 3-17. Annual newly registered groundwater irrigated acres.

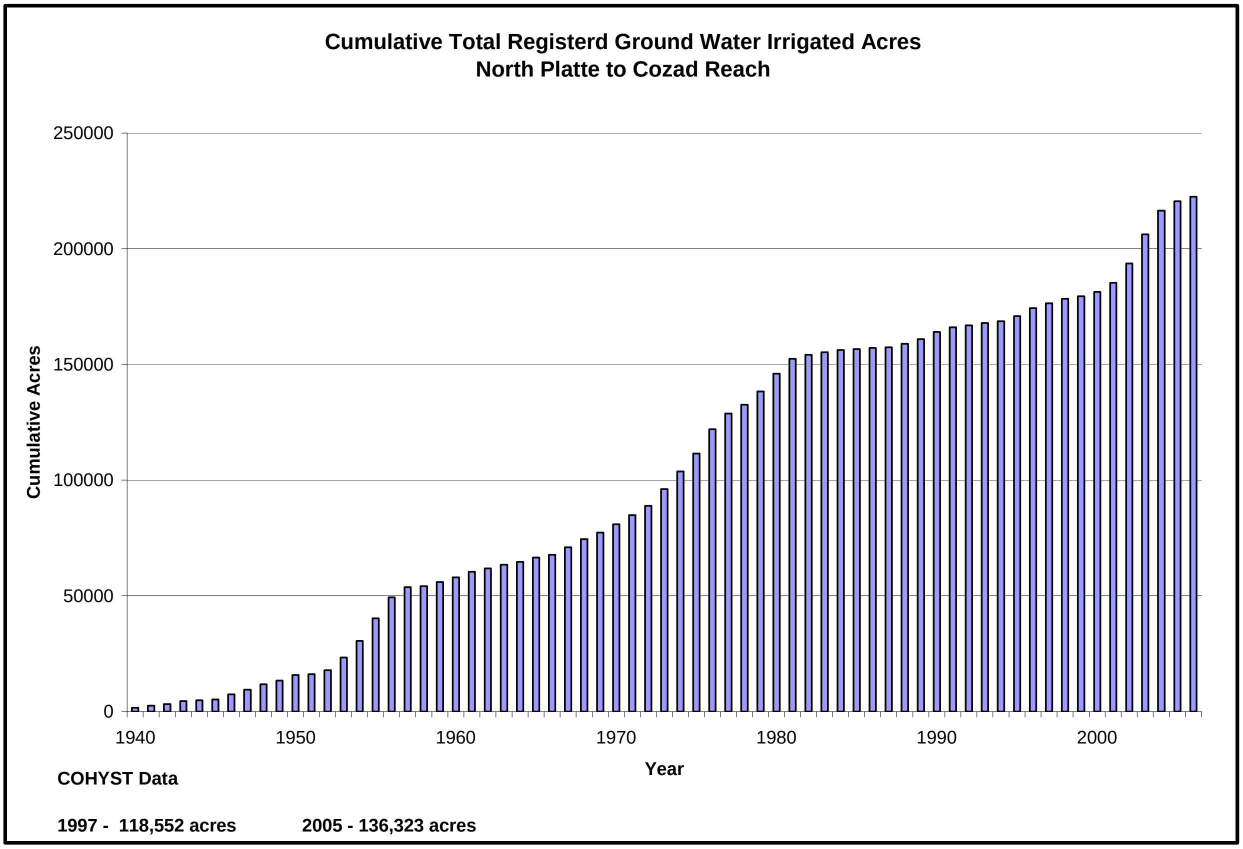


Figure 3-18. Cumulative groundwater irrigated acres.

The level of surface water development within the reach was evaluated and is illustrated in figures 3-19 and 3-20. The results indicate that approximately 45,000 additional acres were approved for irrigation under surface water appropriations through the period analyzed (1949-2006). These new acres may have an impact on reductions in the reach gain; these reductions may be minimal during dry periods, however, when senior appropriations can call for administration on the river.

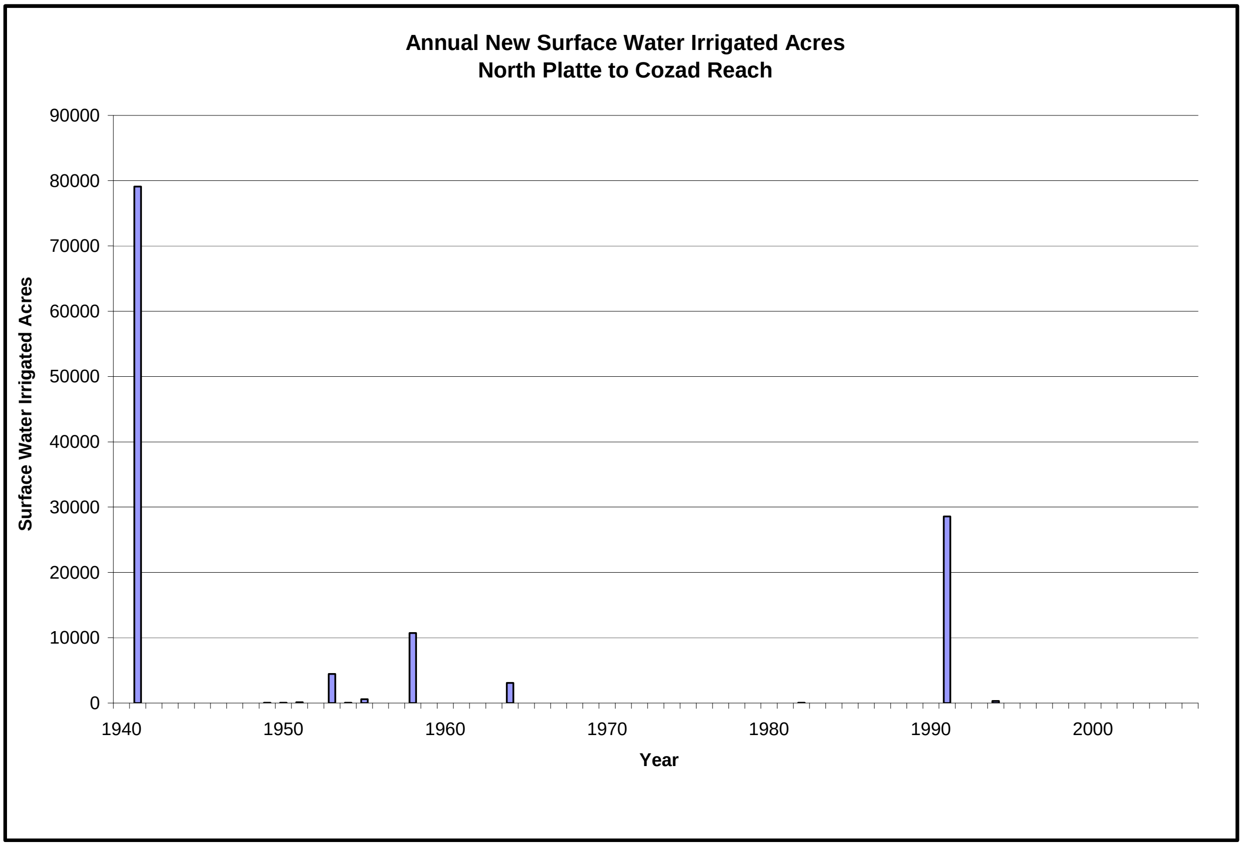


Figure 3-19. Annual new surface water irrigated acres.

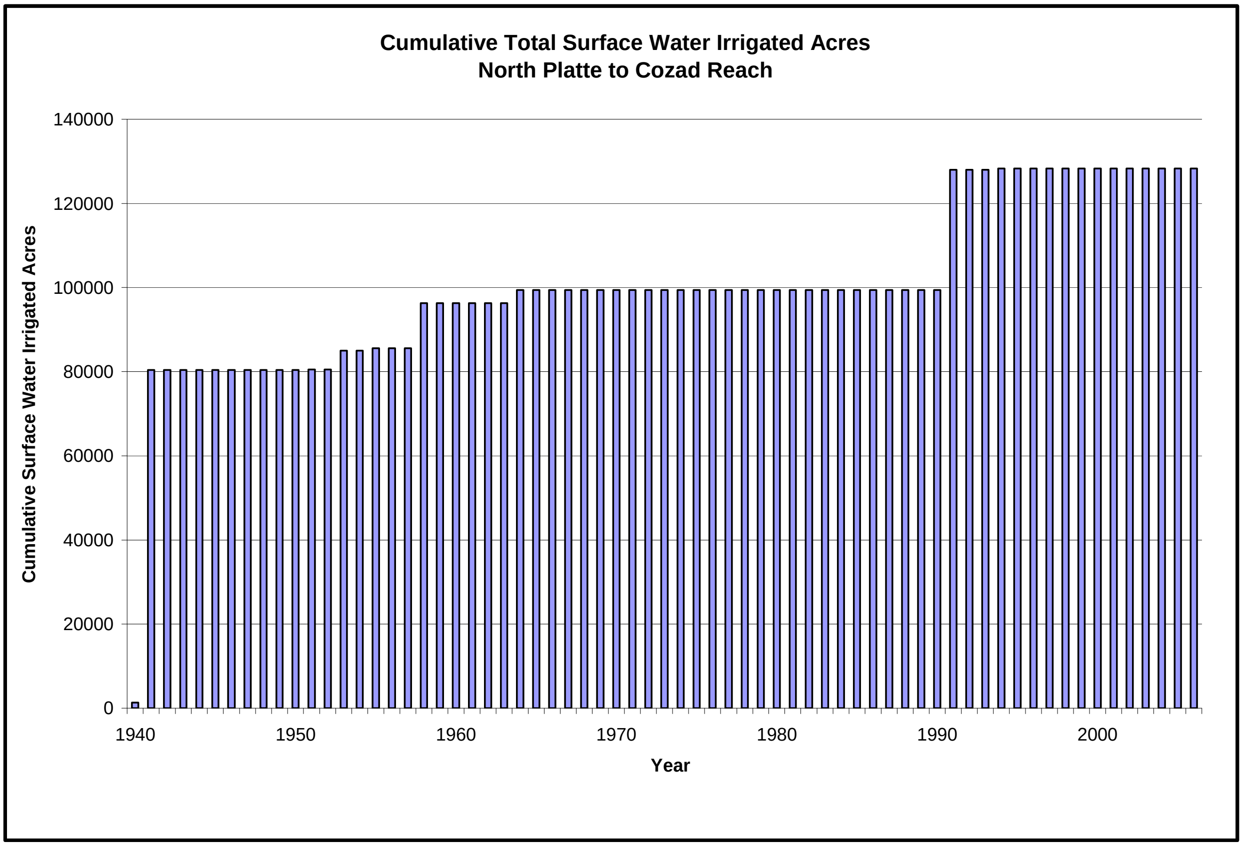


Figure 3-20 Cumulative total surface water irrigated acres.

3.3.3 Unmet Demands

The following demands were considered for the North Platte to Cozad reach:

- Irrigation from six Platte River canals

Surface water irrigation demand in the North Platte to Cozad reach occurs primarily from six irrigation canals: Gothenburg Canal, Thirty Mile Canal, Cozad Canal, Orchard-Alfalfa Canal, Six-Mile Canal, and Dawson County Canal. These canals represent a demand in the irrigation season only. All of these canals have access to storage water from Lake McConaughy and the Sutherland Reservoir as a supplemental source of water when natural flow alone is insufficient to meet irrigation demands. For the purposes of these analyses, storage water diversions by these canals were assumed to represent unmet demand for natural flow for irrigation. Unmet demand for irrigation for this reach was estimated by evaluating the annual cumulative storage diversions for these canals for representative wet, normal, and dry periods (figure 3-21).

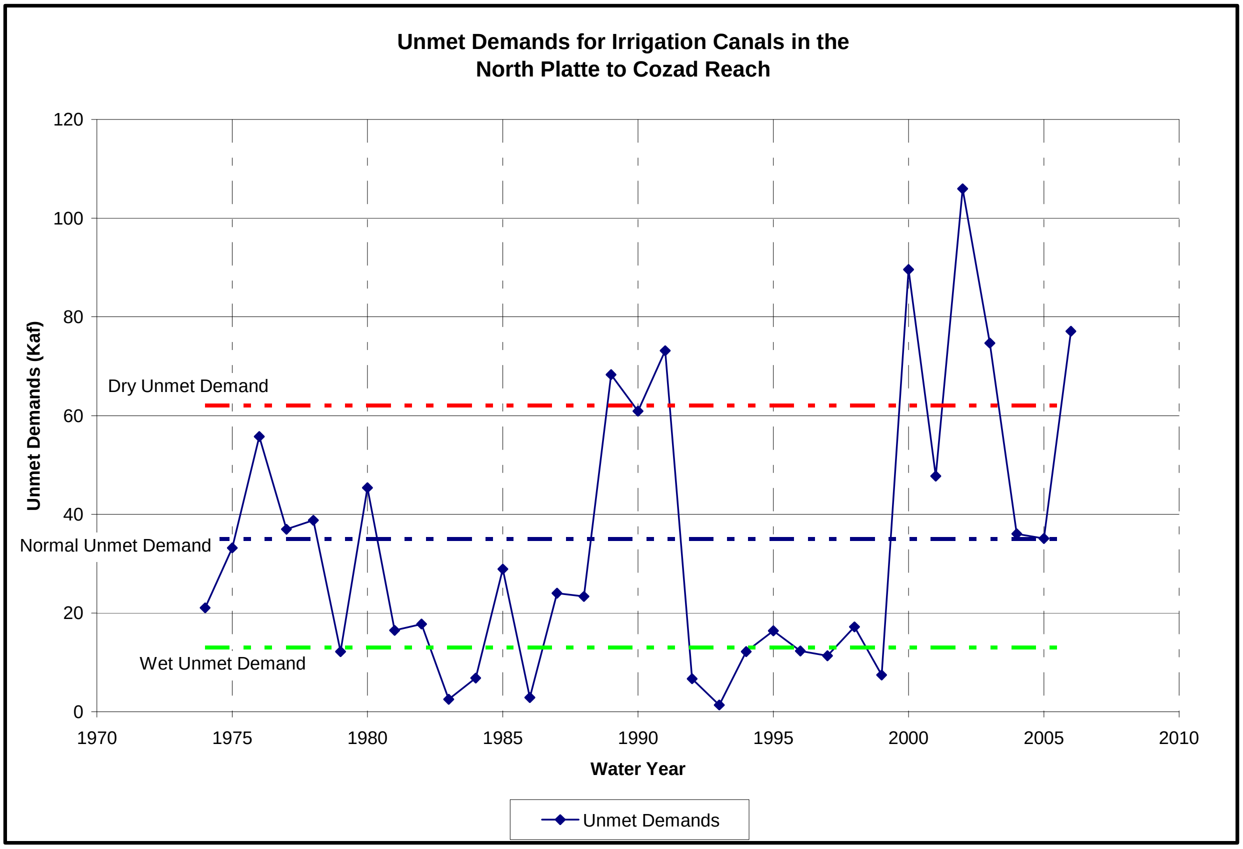


Figure 3-21. Annual storage demands for the six irrigation canals in the North Platte to Cozad reach.

For this reach, demand, and therefore unmet demand, was assumed to be zero in the non-irrigation season. The unmet demand for the North Platte to Cozad reach is summarized in table 3-10.

Table 3-10. North Platte to Cozad reach unmet demands.

Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	13,000	0
Normal	35,000	0
Dry	62,000	0

3.3.4 Accumulated Unmet Demands

The unmet demands from the reach below (Cozad to Odessa) are passed into this reach and added to the unmet demands in this reach to determine the accumulated unmet demands within the reach (tables 3-11 through 3-13)

Table 3-11. Unmet demands passed upstream from the Cozad to Odessa reach.

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	0	0
Normal	38,000	44,000
Dry	101,000	128,000

Table 3-12. Unmet demands in the North Platte to Cozad reach.

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	13,000	0
Normal	35,000	0
Dry	62,000	0

Table 3-13. Cumulative unmet demands in the North Platte to Cozad reach.

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	13,000	0
Normal	73,000	44,000
Dry	163,000	128,000

Not all of the cumulative unmet demands for this reach were passed upstream to the next reach. The upstream reaches include large, non-consumptive, hydropower demands which are larger that those associated with the instream flow. Consequently, only the consumptive portion (i.e., irrigation) of the cumulative unmet demands is passed upstream.

Table 3-14. Unmet demands passed upstream to the South Platte and to the North Platte below McConaughy reaches.

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	13,000	0
Normal	35,000	0
Dry	62,000	0

3.3.5 Overall Difference between Overappropriated and Fully Appropriated

The OA/FA difference (table 3-17) was reduced from the total reach gain reduction (table 3-15) to account for the junior priority status of the instream flows and for the level of development in the basin. The magnitude of this adjustment was determined by assessing the level of groundwater development prior to 1990 (the approximate priority date of the instream flow appropriations) and the 2005 level of groundwater development. The assessment showed that only thirty percent of groundwater development occurred subsequent to the priority of the instream flow appropriations. Thus, the stream reach gain reduction values for the non-irrigation season were correspondingly reduced by seventy percent. However, the irrigation-season reach gain reductions were not reduced, as both instream flow and irrigation appropriation demands occur in the irrigation season, and the unmet irrigation demands exceed the level of stream reach gain reduction. This methodology should be scrutinized in future reports to assess its validity.

Table 3-15. Stream reach gain reduction for the North Platte to Cozad reach.

Condition	**Stream Reach Gain Reduction**	
	Irrigation Season (ac-ft)	**Non-Irrigation Season (ac-ft)**
Wet	0	0
Normal	0	0
Dry	14,900	29,500

Table 3-16. Unmet demands for the North Platte to Cozad reach.

Condition	**Unmet Demands**	
	Irrigation Season (ac-ft)	**Non-Irrigation Season (ac-ft)**
Wet	13,000	0
Normal	73,000	44,000
Dry	163,000	128,000

Table 3-17. Overall difference between overappropriated and fully appropriated for the North Platte to Cozad reach.

Condition	OA/FA Difference	
	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	0	0
Normal	0	0
Dry	14,900	8,900

3.4 North Platte River – Keystone to North Platte

The Keystone to North Platte reach is the contributing surface water basin between the stream gages located on the North Platte River at Keystone and the North Platte River at North Platte. This reach includes inflows from Birdwood Creek and small ungaged tributaries and outflows to the North Platte Canal, Keith-Lincoln Canal, Suburban Canal, Paxton-Hershey Canal, Cody-Dillon Canal, and historic outflows for Sheridan-Wilson Canal (through 1964).

3.4.1 Assessment of Reach Gain Reductions

The double-mass curves of cumulative reach gains and cumulative precipitation during the period 1949-2006 for the irrigation season and non-irrigation season, respectively, are illustrated in figures 3-22 and 3-23. The cumulative precipitation for this reach was developed based on the weighted precipitation from the following gages:

Gage	Weight of Gage (based on Thiessen polygons)
Arthur	0.566
Ogallala	0.182
Stapleton	0.096
North Platte	0.132
Wallace	0.024

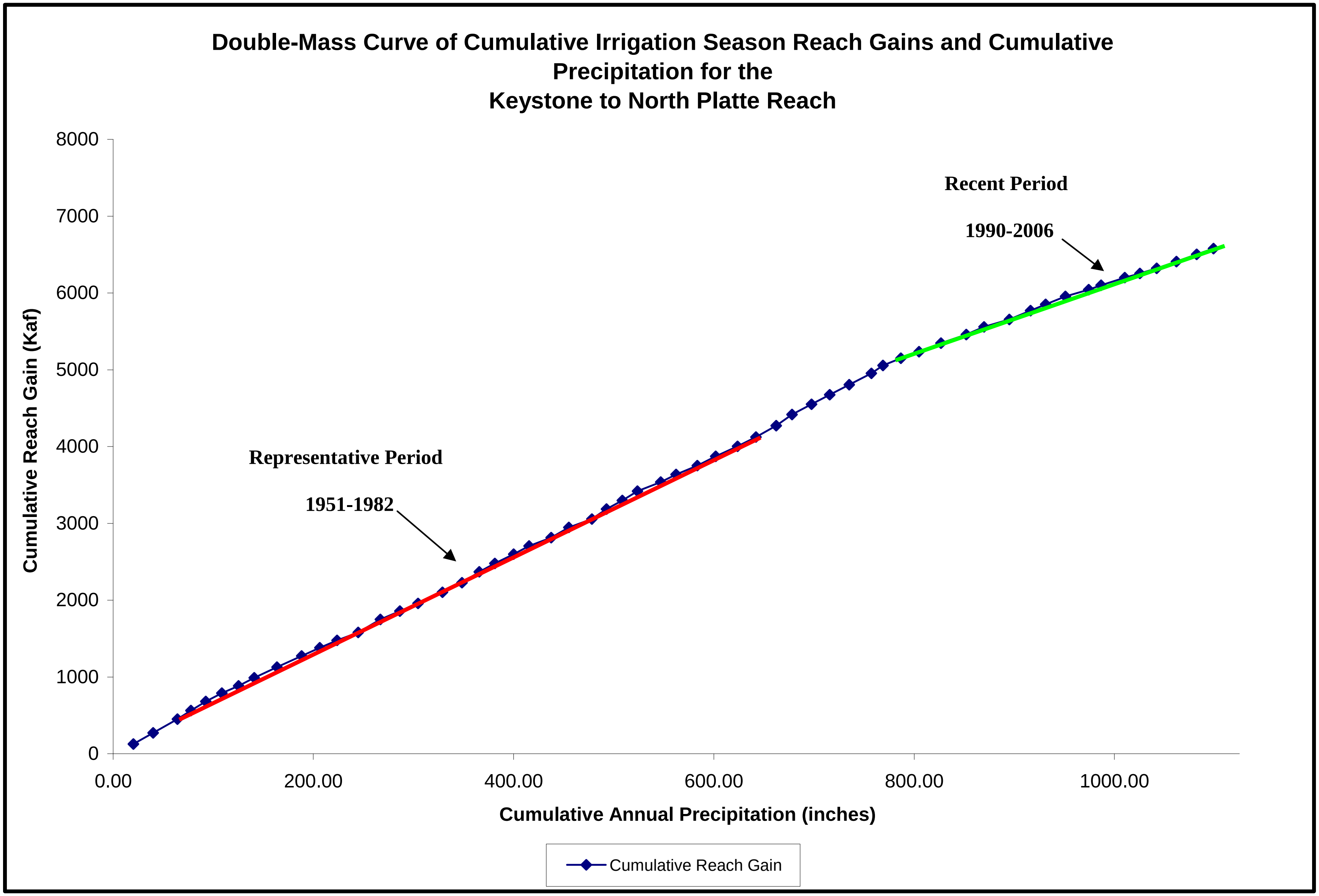


Figure 3-22. Double-mass curve of the cumulative irrigation season reach gain and cumulative annual precipitation.

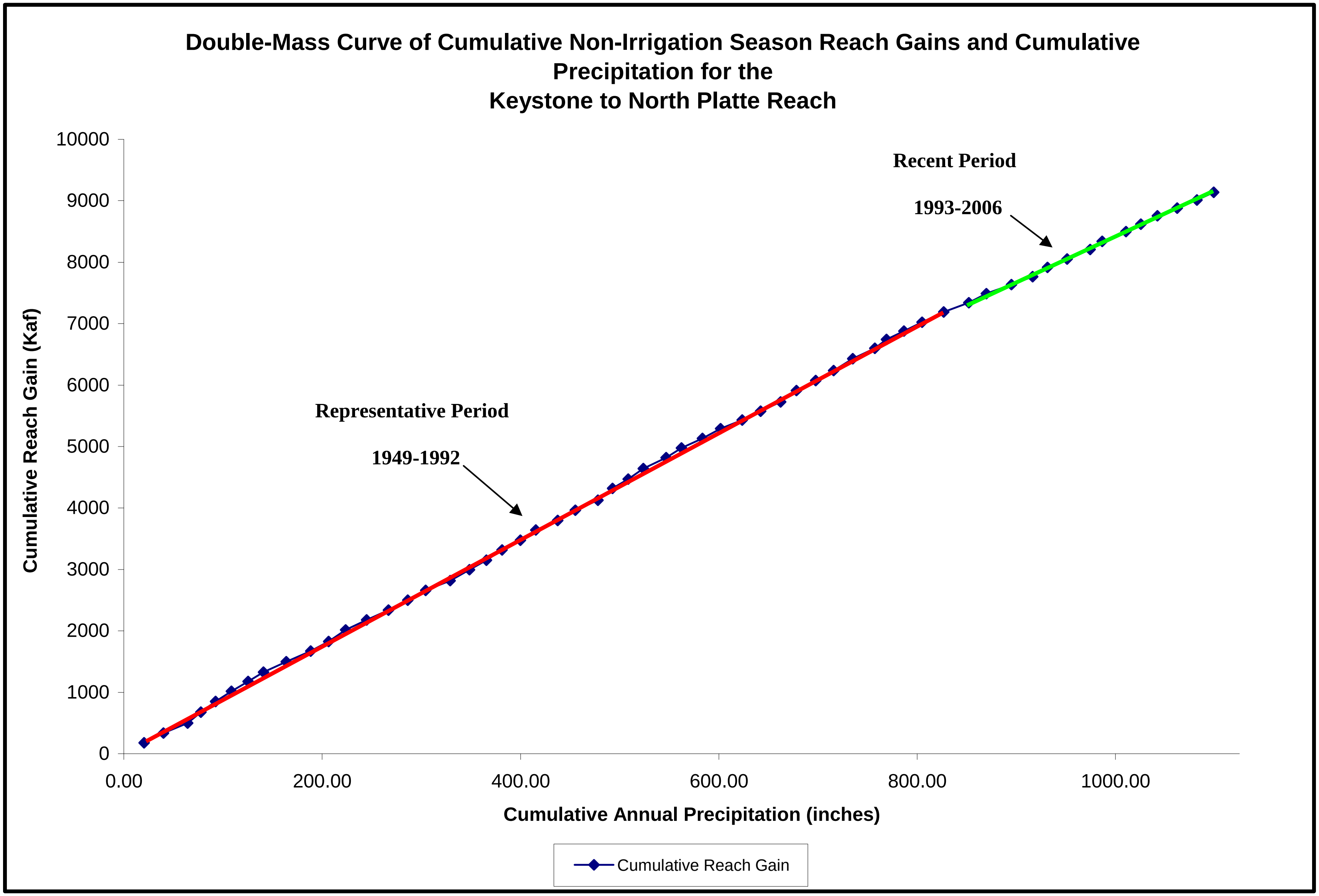


Figure 3-23. Double-mass curve of the cumulative non-irrigation season reach gain and cumulative annual precipitation.

In evaluating to determine potential stream reach gain reductions, the 1951-1982 period was used as the representative period for the irrigation season and the 1949-1992 period was used as the representative period for the non-irrigation season. The intervals used to represent the recent periods were 1990-2006 for the irrigation season and 1993-2006 for the non-irrigation season. Since the break point on the curves falls prior to the dry conditions of 2000-2006 that were identified in the downstream reaches, this break point seems to represent reach gain reductions that have occurred under wet, normal, and dry hydrologic conditions. The calculated stream reach gain reductions for this reach are summarized in table 3-18.

Table 3-18. Summary of stream reach gain reductions for the Keystone to North Platte reach.

Keystone to North Platte Reach Gain Reduction		
Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	33,900	26,700
Normal	33,900	26,700
Dry	33,900	26,700

3.4.2 Potential Causes for Reach Gain Reductions

The potential causes for stream reach gain reductions within this reach were investigated by evaluating reach gain baseflows, diversions (seepage return to the reach), groundwater development, and surface water development. Figures 3-24 and 3-25 illustrate how baseflow within the reach has changed over this period. The baseflows appear to have remained fairly constant through the 1949-1992 period with sharp increases during the wet periods. The more recent period (2000-2005) saw a rapid decrease in baseflow. This decrease in baseflow could indicate that a portion of the recent period stream reach gain reduction is due to reduced groundwater inflow in the reach.

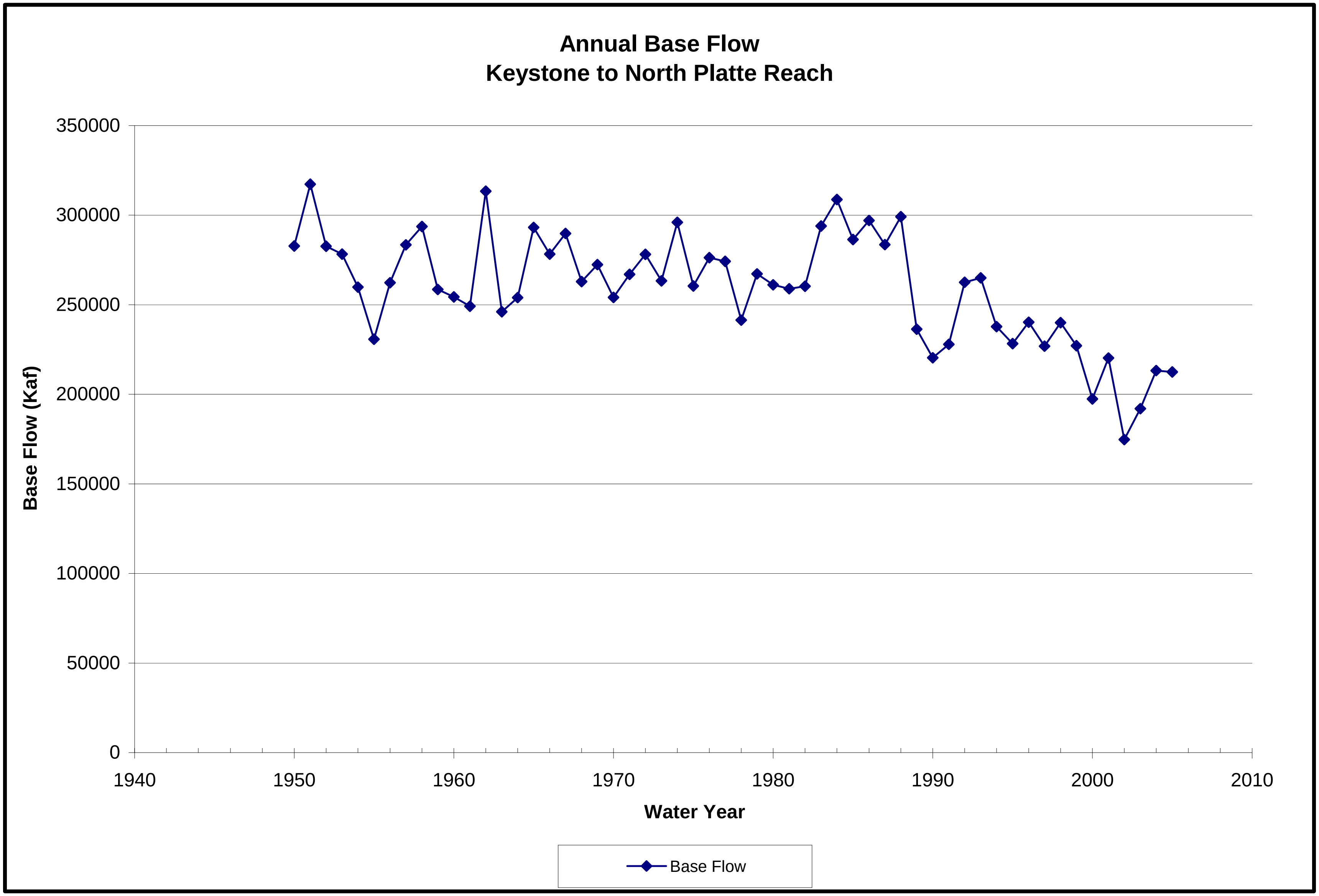


Figure 3-24. Keystone to North Platte reach annual baseflow gain (reach baseflow includes contribution from Birdwood Creek).

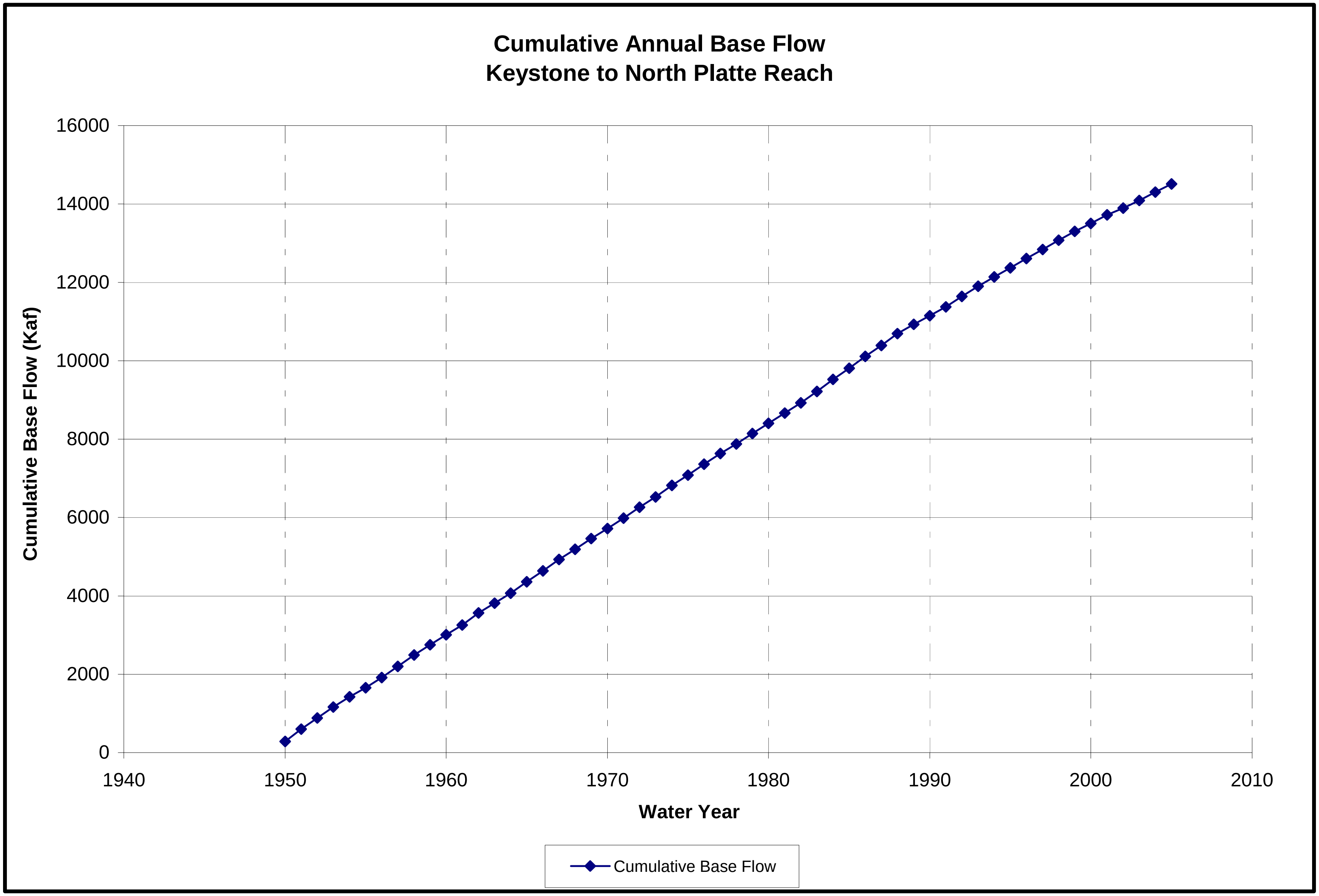


Figure 3-25. Keystone to North Platte cumulative annual baseflow (reach baseflow includes contribution from Birdwood Creek).

Surface water diversions within the reach were evaluated to determine if reduced surface water diversions and therefore reduced returns from those diversions could be a potential cause of stream reach gain reductions. Evaluation of the diversion records indicated that estimated annual seepage from diversions affecting this reach decreased significantly from the representative period to the recent period (7,900 ac-ft/yr in the irrigation season and 3,800 ac-ft/yr in the non-irrigation season). Since any reach gain would include gains from these seepage losses, these changes were subtracted from the reach gain reduction to derive the final reach gain reductions (table 3.19).

Table 3-19. Summary of stream reach gain reductions for the Keystone to North Platte reach adjusted for reduced seepage from diversions.

Keystone to North Platte Reach Gain Reduction		
Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	26,000	22,900
Normal	26,000	22,900
Dry	26,000	22,900

The level of groundwater development within the reach was evaluated and is illustrated in figures 3-26 and 3-27. The results indicate that approximately 27,000 additional groundwater irrigated acres were developed through the period analyzed (1949-2006). The increase in groundwater irrigated acres may be a potential cause of reductions in the reach gain.

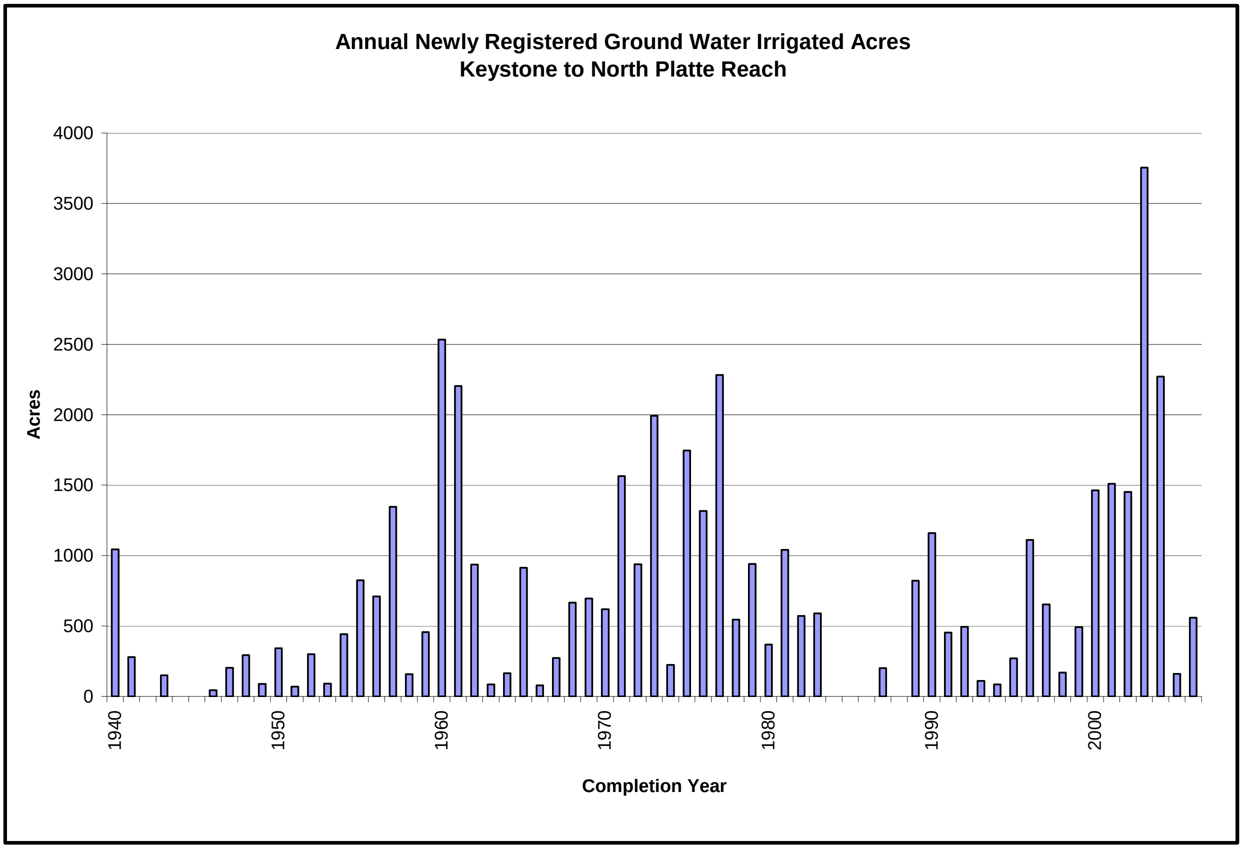


Figure 3-26. Annual newly registered groundwater irrigated acres.

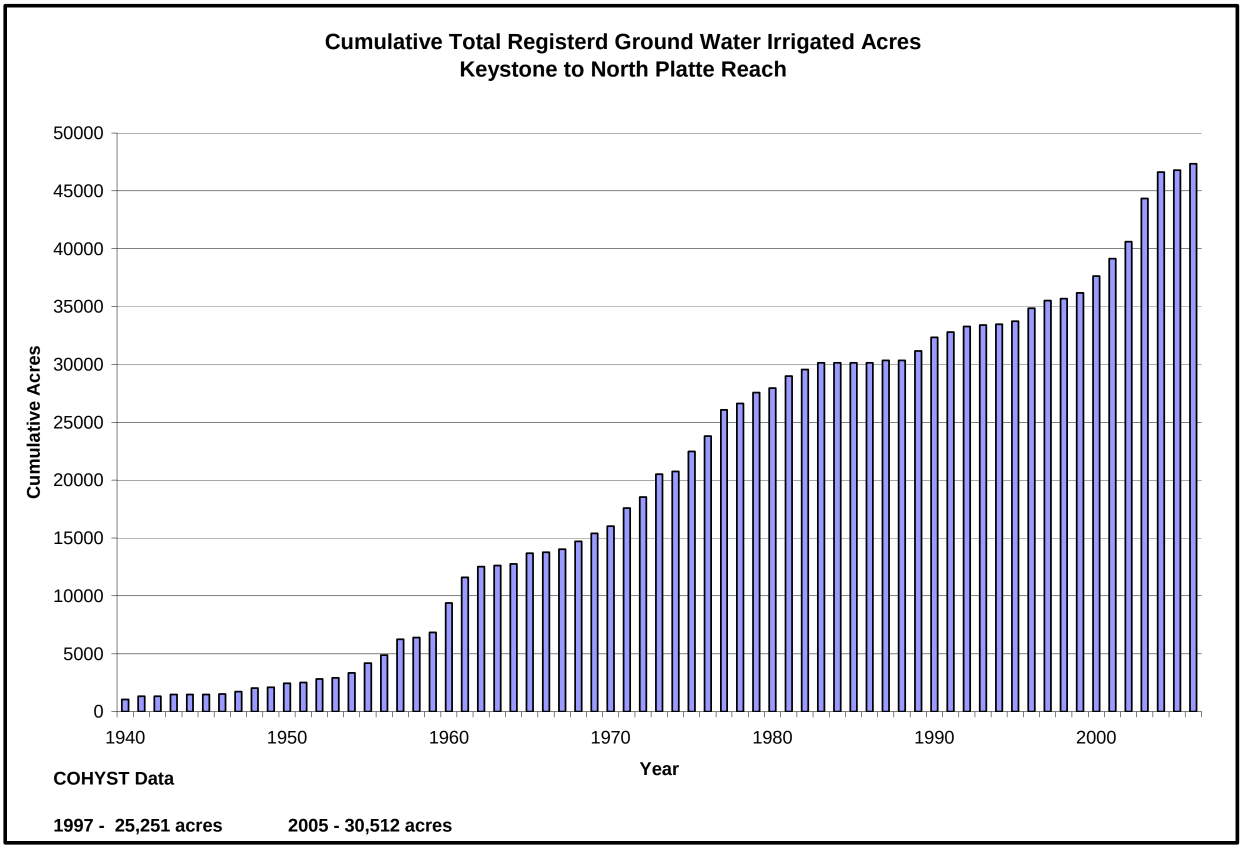


Figure 3-27. Cumulative groundwater irrigated acres.

The level of surface water development within the reach was evaluated and is illustrated in figures 3-28 and 3-29. The results indicate that approximately 30,000 additional acres were approved for irrigation under surface water appropriations through the period analyzed (1949-2006). The majority of these new acres were added early in the representative period (prior to 1955). Thus any impacts from the additional surface water acres on the reach gains would be expected to be minimal.

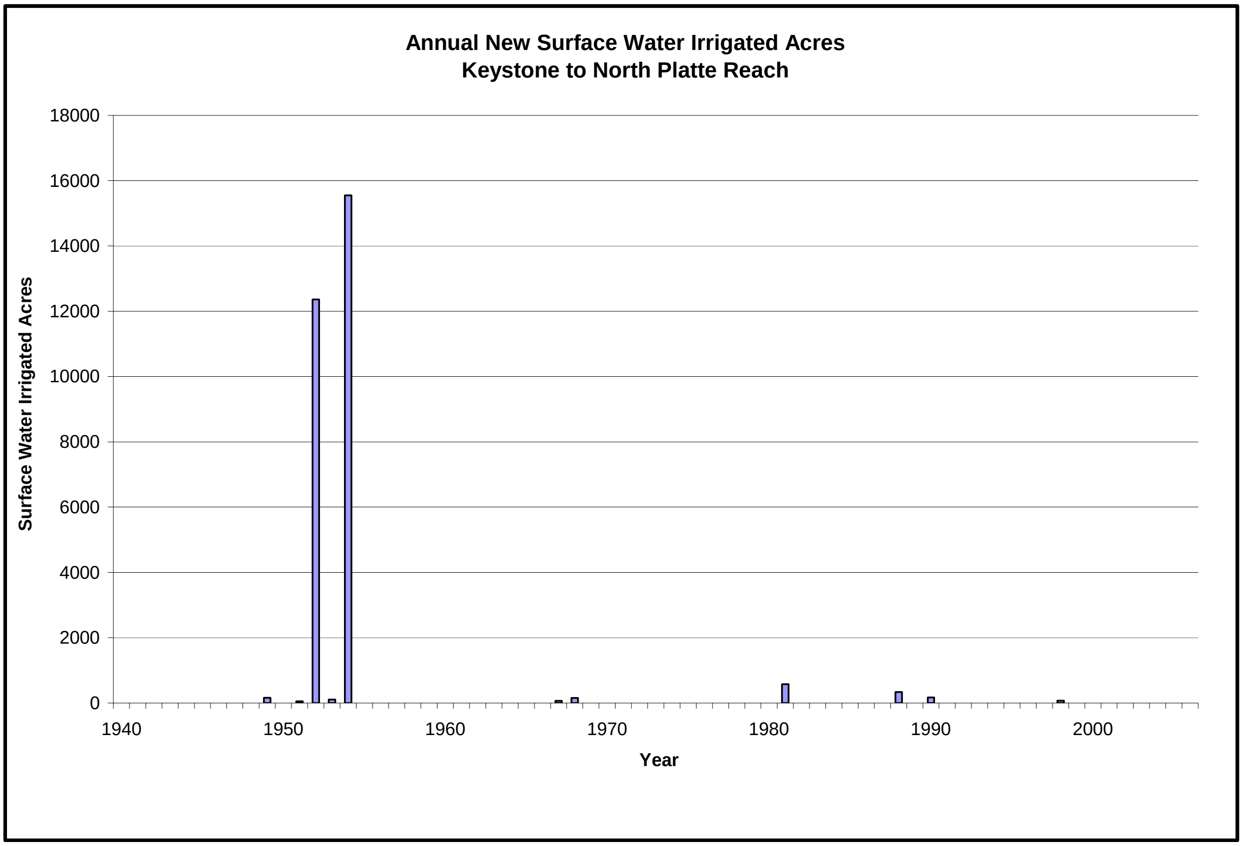


Figure 3-28. Annual new surface water irrigated acres.

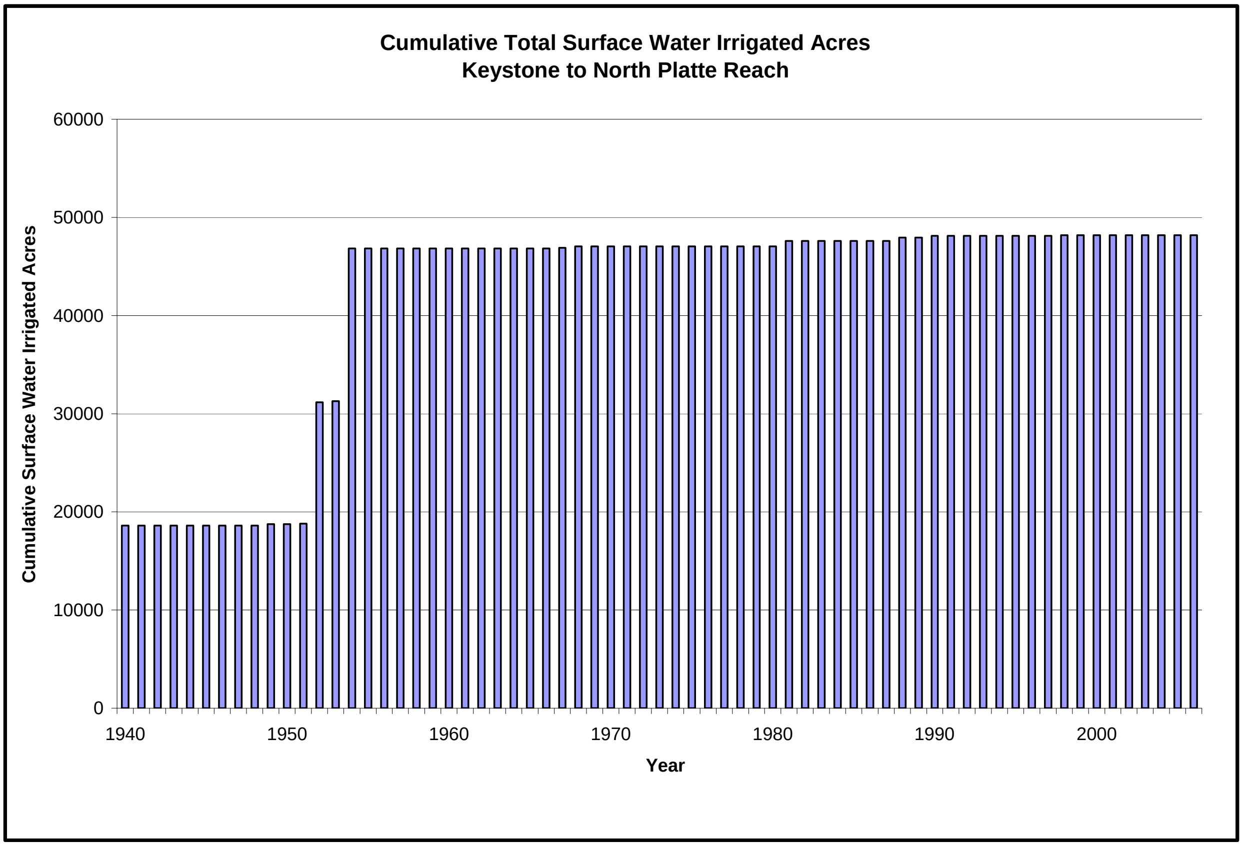


Figure 3-29. Cumulative total surface water irrigated acres.

3.4.3 Unmet Demands

The following demands were considered for the Keystone to North Platte reach:

- CNPPID irrigation
- CNPPID Supply Canal hydropower generation
- Canaday Steam Plant cooling
- Irrigation from five North Platte River canals

The Central Nebraska Public Power and Irrigation District (CNPPID) irrigation, CNPPID Supply Canal hydropower generation, and Canaday Steam Plant cooling demands all receive Platte River water through the Tri-County Canal diversion near North Platte. Because the Tri-County diversion point is located at the confluence of the North Platte River and South Platte River, these uses represent demands (and therefore potentially unmet demands) for both the North Platte River-Keystone to North Platte reach and the South Platte River-Julesburg to North Platte reach.

CNPPID irrigation is assumed to be a demand in the irrigation season only. CNPPID irrigation typically has access to storage water from Lake McConaughy as a supplemental source of water when natural flow alone is insufficient to meet irrigation demand. For the purposes of these analyses, storage water diversions by these canals were assumed to represent unmet demand for natural flow for irrigation, except for those years in which the irrigation use is allocated to a less-than-normal supply because of a limited supply of storage water in Lake McConaughy. Unmet demand for irrigation for this reach was estimated by evaluating the annual cumulative storage diversions for the Tri-County Canal for representative wet, normal, and dry periods. The years 2005 to present were excluded, as irrigation deliveries were limited in duration and quantity to less than a normal supply due to limited storage supplies in Lake McConaughy. Unmet demand for CNPPID irrigation is summarized in table 3-20.

Table 3-20. Unmet demand for CNPPID irrigation.

Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	200,000	0
Normal	235,000	0
Dry	290,000	0

Hydropower generation on the CNPIPD Supply Canal represents a year-round non-consumptive demand for Platte River water. Water diverted for CNPPID hydropower generation that is not also used for CNPPID irrigation is returned to the Platte River at the J-2 Return near Lexington or, to a lesser extent, the Jeffrey Return near Brady. Like irrigation, CNPPID hydropower generation has access to storage water from Lake McConaughy. Unlike for irrigation, however, storage water will not always be released for hydropower generation to cover an unmet demand. Instead, the priority is to preserve the storage water for future unmet demand for irrigation. Thus, storage water use is not a good indicator of unmet demand for hydropower generation. Instead, it is assumed that Tri-County Canal total diversions in the most recent wet period of the late 1990s were assumed to be representative of a fully-met hydropower demand. Unmet demand for CNPPID Supply Canal hydropower generation was thus estimated by comparing historic total diversions for representative periods against the total diversion amount from the late 1990s. Because storage water for irrigation is a part of this total diversion, the unmet irrigation demand will not be double-counted as a part of the unmet hydropower demand; in other words, the unmet demand for hydropower is above and beyond the unmet demand for irrigation. Unmet demand for CNPPID Supply Canal hydropower generation is summarized in table 3-21.

Table 3-21. Unmet demand for CNPPID hydropower generation.

Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	0	0
Normal	152,000	240,000
Dry	220,000	440,000

Canaday Steam Plant draws cooling water year-round from the CNPPID Supply Canal just upstream from the J-2 Return. Cooling for Canaday Steam Plant is mostly non-consumptive and was designed to take advantage of water that is already in the CNPPID Canal for other purposes. Demand for Canaday Steam Plant cooling was assumed to be met if other CNPPID hydropower and irrigation demands are met, and the additional unmet demand for Canaday Steam Plant cooling is therefore assumed to be zero.

Surface water irrigation demand in the Keystone to North Platte reach occurs primarily from five irrigation canals: North Platte Canal, Paxton-Hershey Canal, Suburban Canal, Keith-Lincoln Canal, and Cody-Dillon Canal. These canals represent a demand in the irrigation season only. These canals often have contractual access, under certain condtions, to storage water from Lake McConaughy (including some storage water from Glendo Reservoir in Wyoming that is sent to McConaughy) as a supplemental source of water when natural flow alone is insufficient to meet irrigation demand. For the purposes of these analyses, storage water diversions by these canals at the times that their contracts allow them access to such storage water were assumed to represent unmet demand for natural flow for irrigation. Unmet demand for irrigation for this reach was estimated by evaluating the annual cumulative storage diversions for these canals for representative wet, normal, and dry periods (figure 3-30 and table 3-22).

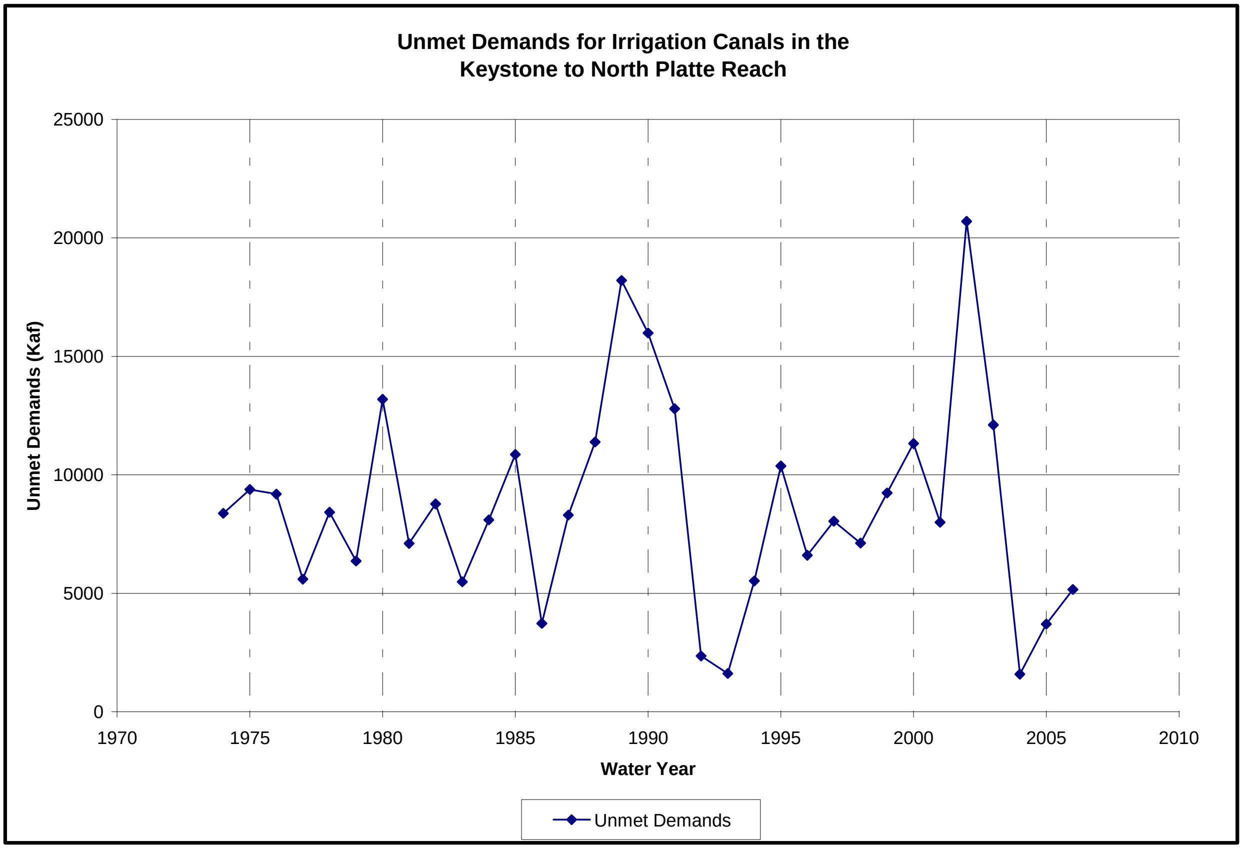


Figure 3-30. Storage demands for the irrigation canals located in the Keystone to North Platte reach.

Table 3-22. Unmet demands for the irrigation canals located in the Keystone to North Platte reach.

Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	7,500	0
Normal	7,500	0
Dry	15,000	0

The total unmet demands for the Keystone to North Platte reach were calculated by adding the unmet demands for CNPPID's irrigation and hydropower needs to the unmet demands for the five irrigation canals within the reach (table 3-23).

Table 3-23. Total unmet demands for the Keystone to North Platte reach.

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	207,500	0
Normal	394,500	240,000
Dry	525,000	440,000

3.4.4 Accumulated Unmet Demands

The unmet demands from the downstream reaches are passed into this reach and added to the unmet demands in this reach to determine the cumulative unmet demands within the reach (tables 3-24 through 3-26).

Table 3-24. Unmet demands passed upstream from the Cozad to Odessa and North Platte to Cozad reaches.

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	13,000	0
Normal	35,000	0
Dry	62,000	0

Table 3-25. Unmet demands in the Keystone to North Platte reach.

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	207,500	0
Normal	394,500	240,000
Dry	525,000	440,000

Table 3-26. Cumulative unmet demands in the Keystone to North Platte reach.

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	220,500	0
Normal	429,500	240,000
Dry	587,000	440,000

All of the cumulative unmet demands for this reach were passed upstream to the state line to Lewellen reach (table 3-27). None of the cumulative unmet demands for this reach were passed upstream to the Lodgepole Creek reach. An analysis was completed that showed that if stream reach gain reductions were replaced in Lodgepole Creek reach, almost all of the water would go to users in Colorado and not benefit the unmet demands downstream of the Colorado-Nebraska state line.

Table 3-27. Unmet demands passed upstream to the state line to Lewellen reach.

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	220,500	0
Normal	429,500	240,000
Dry	587,000	440,000

3.4.5 Overall Difference between Overappropriated and Fully Appropriated

The overall difference between overappropriated and fully appropriated was set to zero under wet conditions. This was considered a reasonable adjustment because no unmet demands appear to be present under wet conditions. Future work should evaluate these conclusions.

Table 3-28. Stream reach gain reduction for the Keystone to North Platte reach.

Condition	Stream Reach Gain Reduction	
	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	26,000	22,900
Normal	26,000	22,900
Dry	26,000	22,900

Table 3-29. Unmet demands for the Keystone to North Platte reach.

Condition	Unmet Demands	
	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	220,500	0
Normal	429,500	240,000
Dry	587,000	440,000

Table 3-30. Overall difference between overappropriated and fully appropriated for the Keystone to North Platte reach.

Condition	OA/FA Difference	
	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	0	0
Normal	26,000	22,900
Dry	26,000	22,900

3.5 South Platte River – Julesburg to North Platte

The Julesburg to North Platte reach is the contributing surface water basin between the stream gages located on the South Platte River at Julesburg and the South Platte River at North Platte. This reach includes inflows from some small ungaged tributaries and outflows to Western Canal and Korty Canal.

3.5.1 Assessment of Reach Gain Reductions

The double-mass curve of cumulative reach gains and cumulative precipitation during the period 1949-2006 for the irrigation season and non-irrigation season, respectively, are illustrated in figures 3-31 and 3-32. The cumulative precipitation for this reach was developed based on the weighted precipitation from the following gages:

Gage	Weight of Gage (based on Thiessen polygons)
Big Springs	0.320
Ogallala	0.309
Sidney	0.007
North Platte	0.069
Wallace	0.211
Oshkosh	0.084

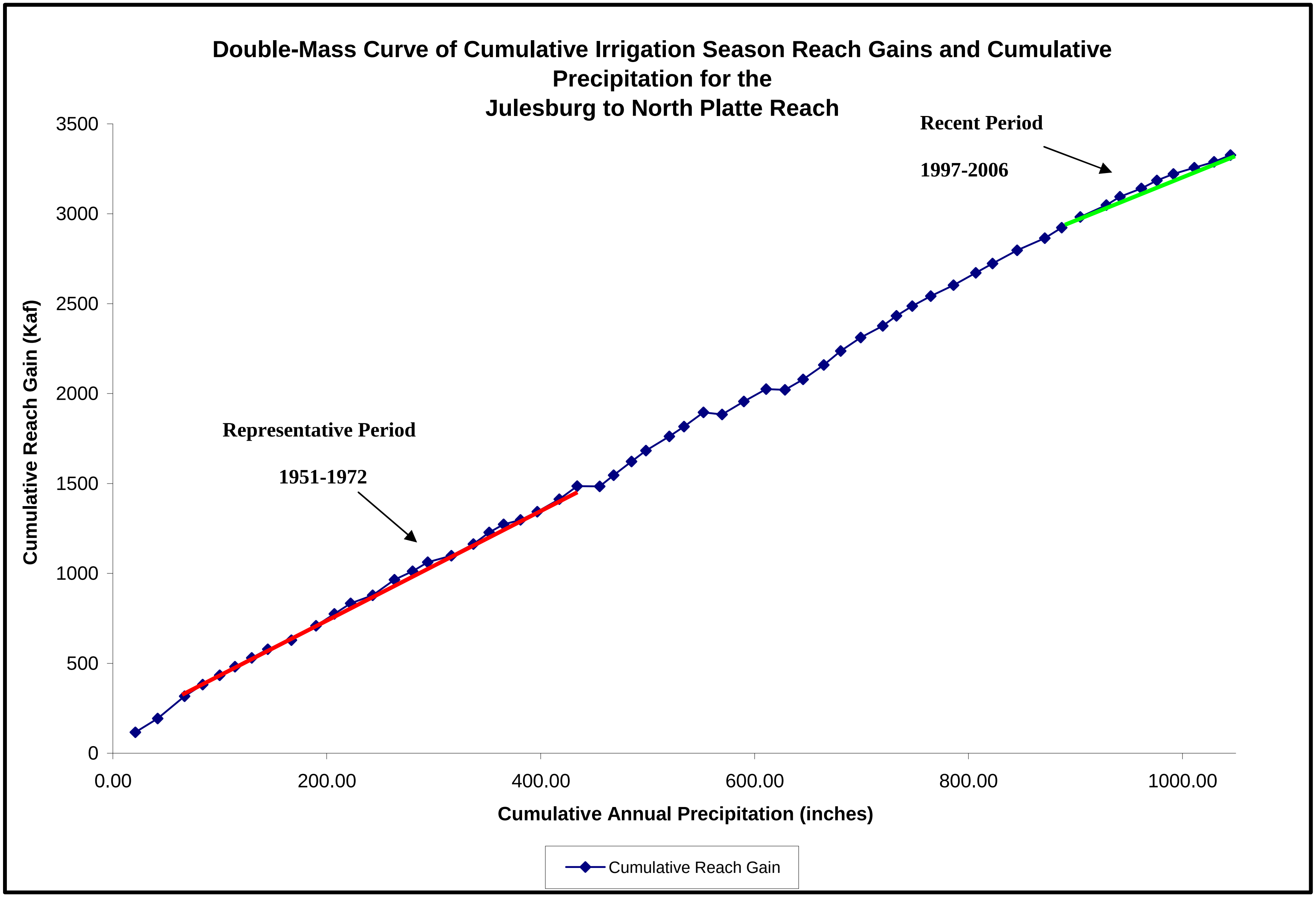


Figure 3-31. Double-mass curve of the cumulative irrigation season reach gain and cumulative annual precipitation.

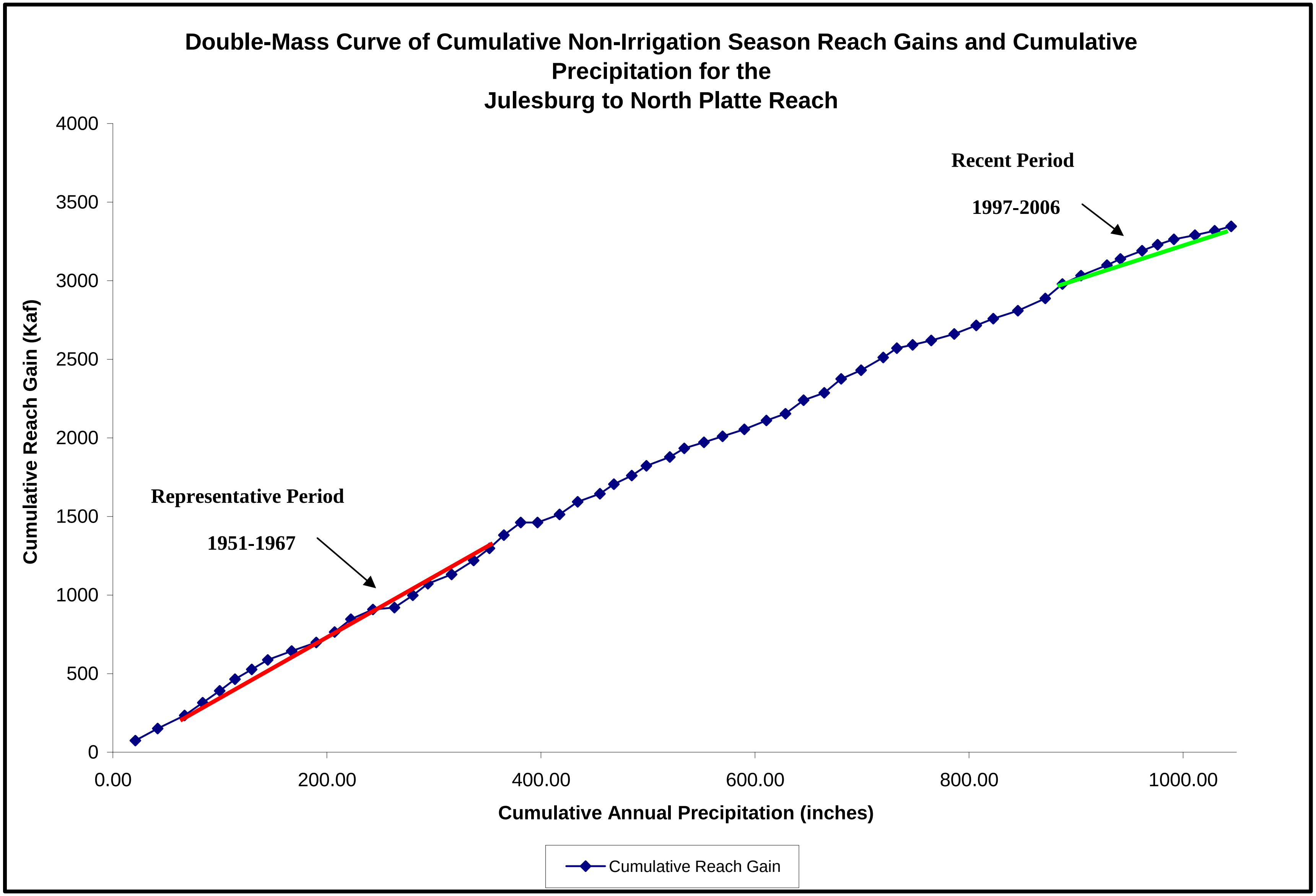


Figure 3-32. Double-mass curve of the cumulative non-irrigation season reach gain and cumulative annual precipitation.

In evaluating potential stream reach gain reductions, the 1951-1972 period was used as the representative period for the irrigation season and the 1951-1967 period was used as the representative period for the non-irrigation season. The period 1997-2006 was used to represent the recent period for both the irrigation season and the non-irrigation season. Since the break point on the curves falls prior to the dry conditions of 2000-2006 that were identified in the downstream reaches, this break point seems to represent reach gain reductions that have occurred under wet, normal, and dry hydrologic conditions. The calculated stream reach gain reductions for this reach are summarized in table 3-31.

Table 3-31. Summary of stream reach gain reductions for the Julesburg to North Platte reach.

Julesburg to North Platte Reach Gain Reduction		
Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	25,300	11,000
Normal	25,300	11,000
Dry	25,300	11,000

3.5.2 Potential Causes for Reach Gain Reductions

The potential causes for stream reach gain reductions within this reach were investigated by evaluating reach gain baseflows, diversions (seepage returns to the reach), groundwater development, and surface water development. Figures 3-33 and 3-34 illustrate how baseflow within the reach has changed over this period. The baseflows appear to have remained consistent through the 1949-2000 period with a decrease in the period subsequent to 2000. This decrease in baseflow could indicate that a portion of the recent period stream reach gain reduction is due to reduced groundwater inflow in the reach.

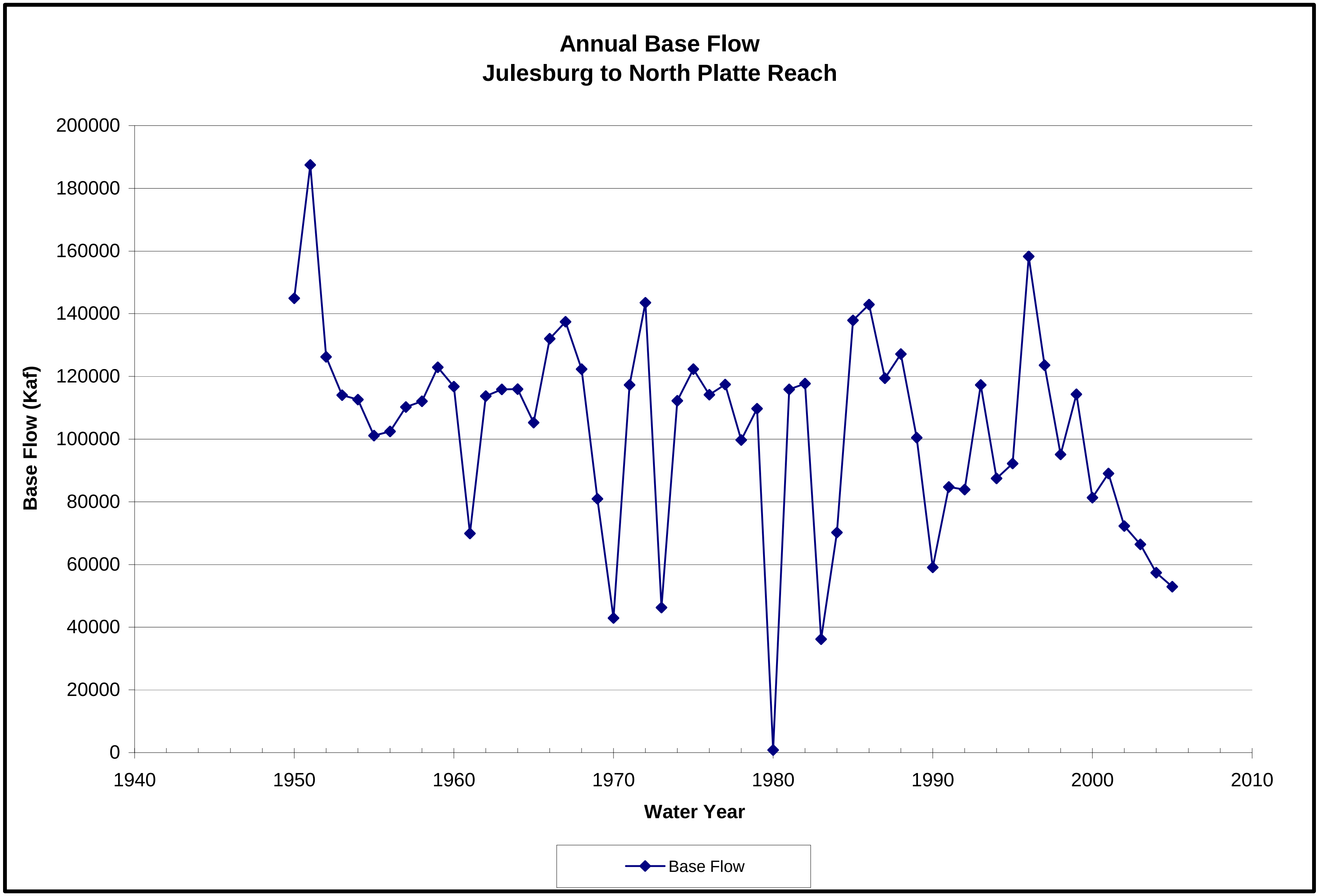


Figure 3-33. Julesburg to North Platte reach annual baseflow gain.

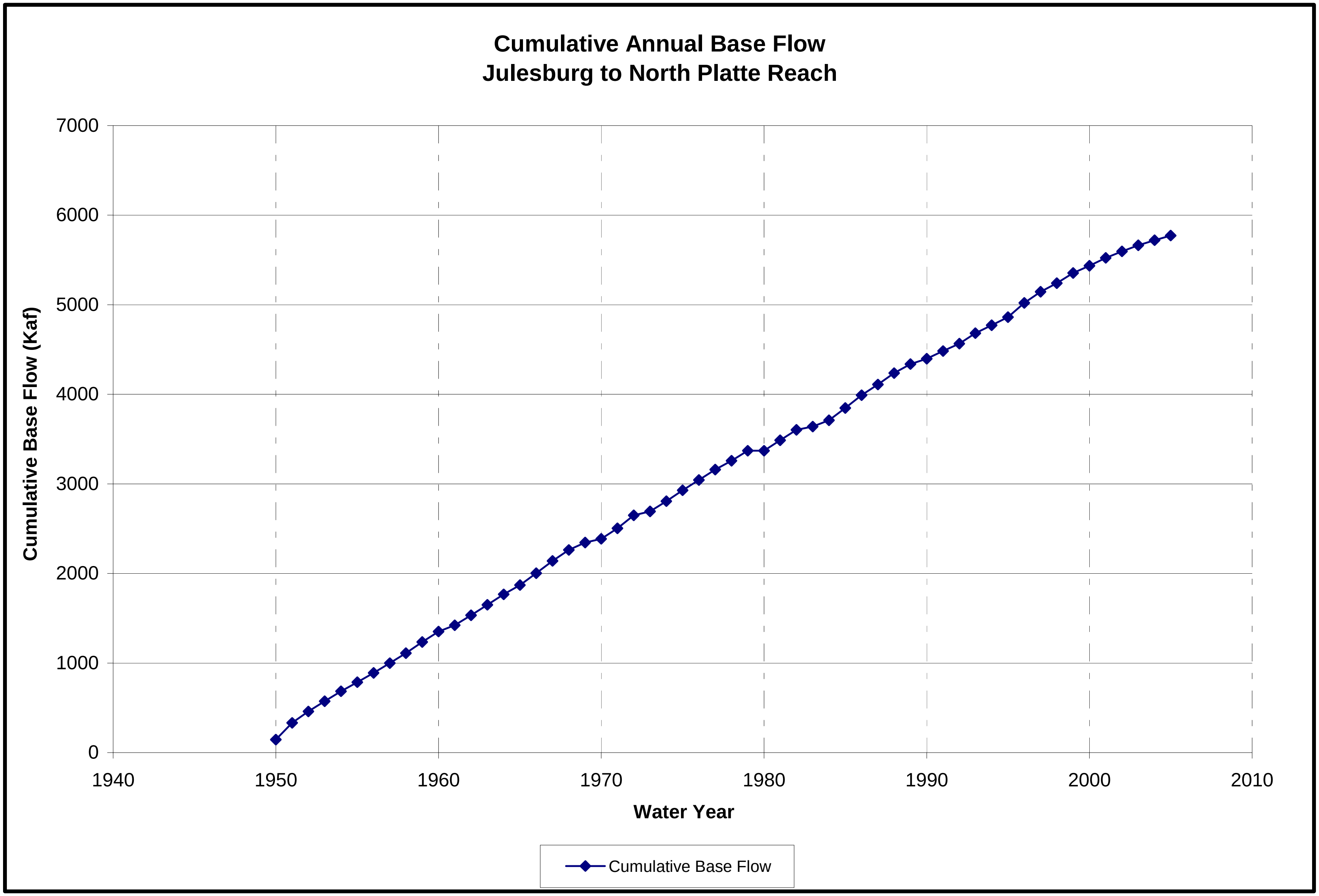


Figure 3-34. Julesburg to North Platte cumulative annual baseflow.

Surface water diversions within the reach were evaluated to determine if reduced surface water diversions and therefore reduced returns from those diversions could be a potential cause of stream reach gain reductions. Figures 3-35 and 3-36 illustrate historical diversions for irrigation within this reach and historical diversions for the Korty Canal.

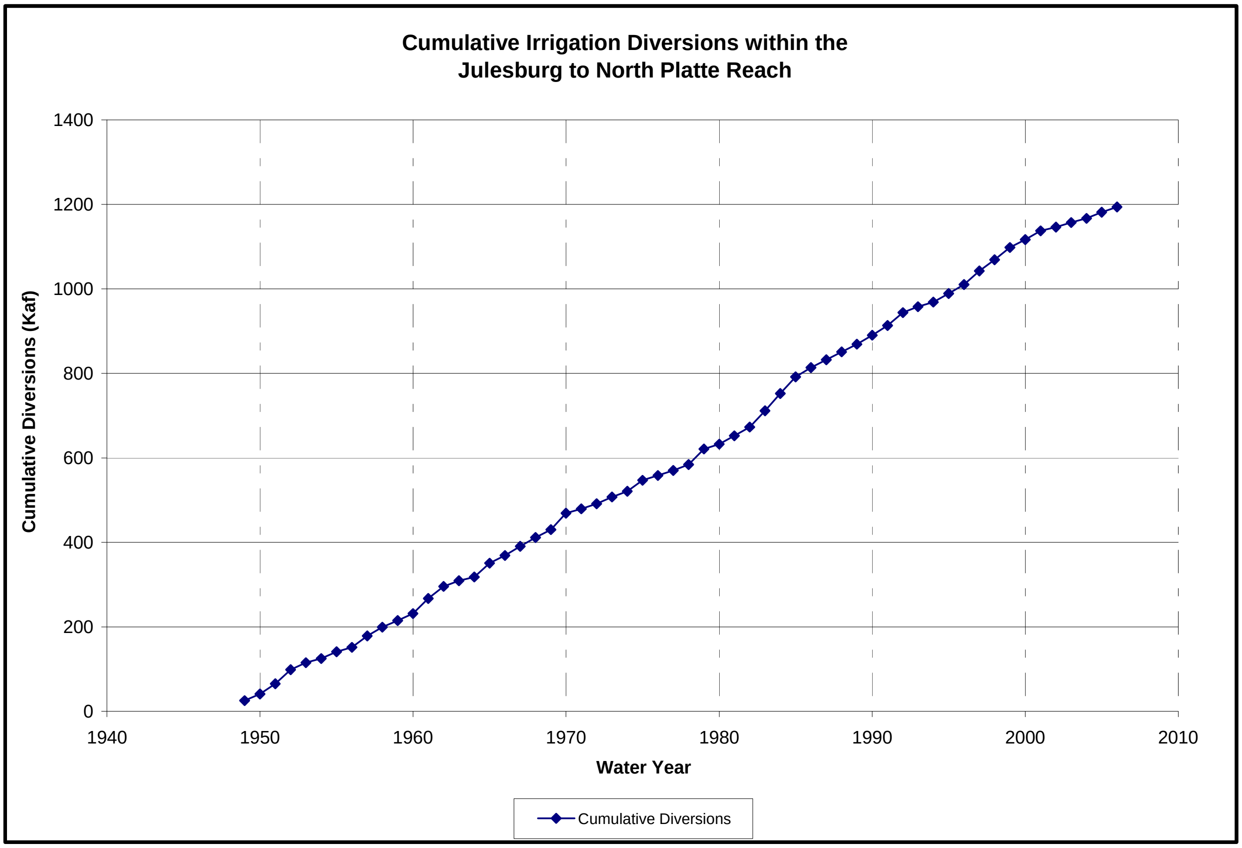


Figure 3-35. Cumulative surface water diversions for irrigation within the Julesburg to North Platte reach.

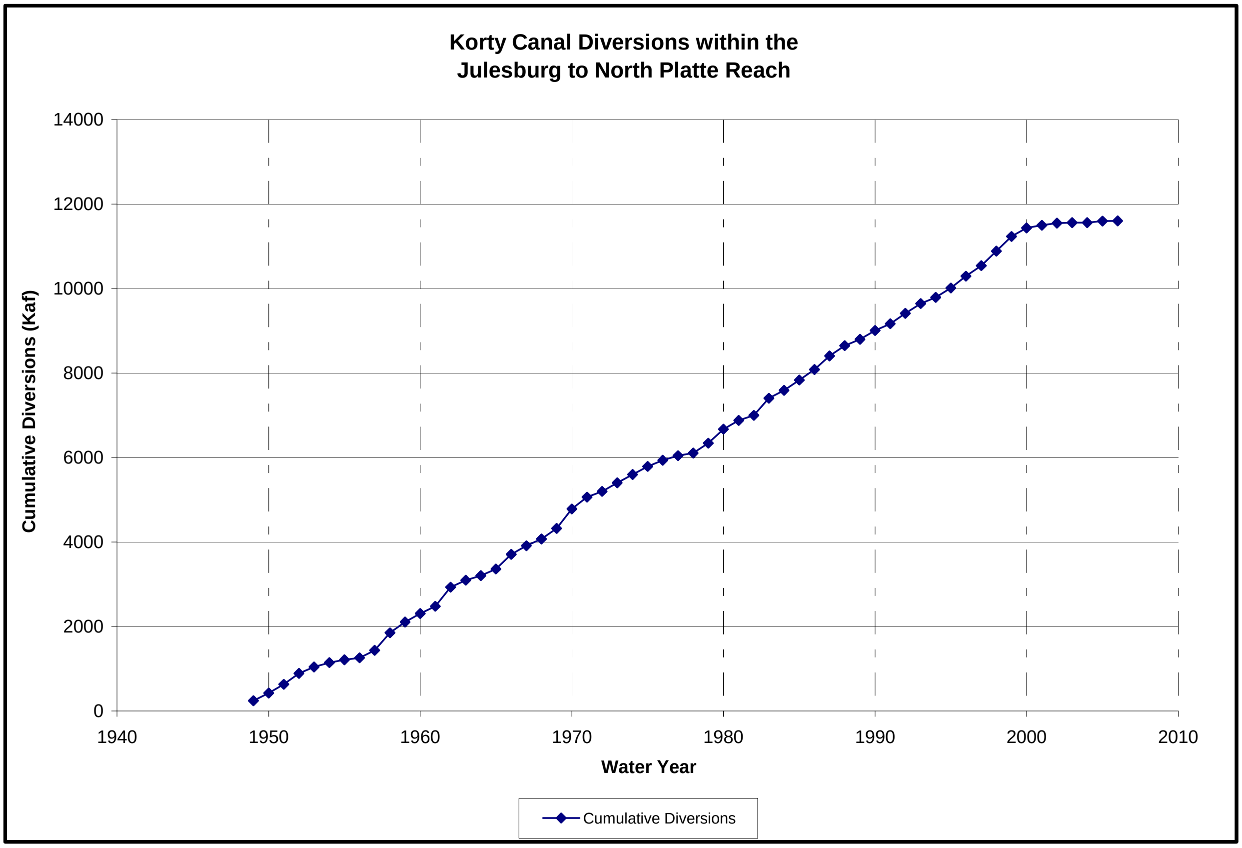


Figure 3-36. Cumulative annual surface water diversions of Korty Canal.

Evaluation of the diversion records indicated that estimated annual seepage from diversions affecting this reach decreased significantly from the representative period to the recent period (4,600 ac-ft/yr in the irrigation season and 26,800 ac-ft/yr in the non-irrigation season). Since any reach gain would include gains from these seepage losses, these seepage changes were subtracted from the reach gain reduction to derive the final reach gain reductions shown in table 3-32.

Table 3-32. Summary of stream reach gain reductions for the Julesburg to North Platte reach adjusted for reduced seepage returns.

Julesburg to North Platte Reach Gain Reduction		
Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	6,400	-1,500
Normal	6,400	-1,500
Dry	6,400	-1,500

The level of groundwater development within the reach was evaluated and is illustrated in figures 3-34 and 3-35. The results indicate that approximately 140,000 acres of additional groundwater irrigated acres were developed through the period analyzed (1949-2006). The increase in groundwater irrigated acres may be a potential cause of reductions in the reach gain.

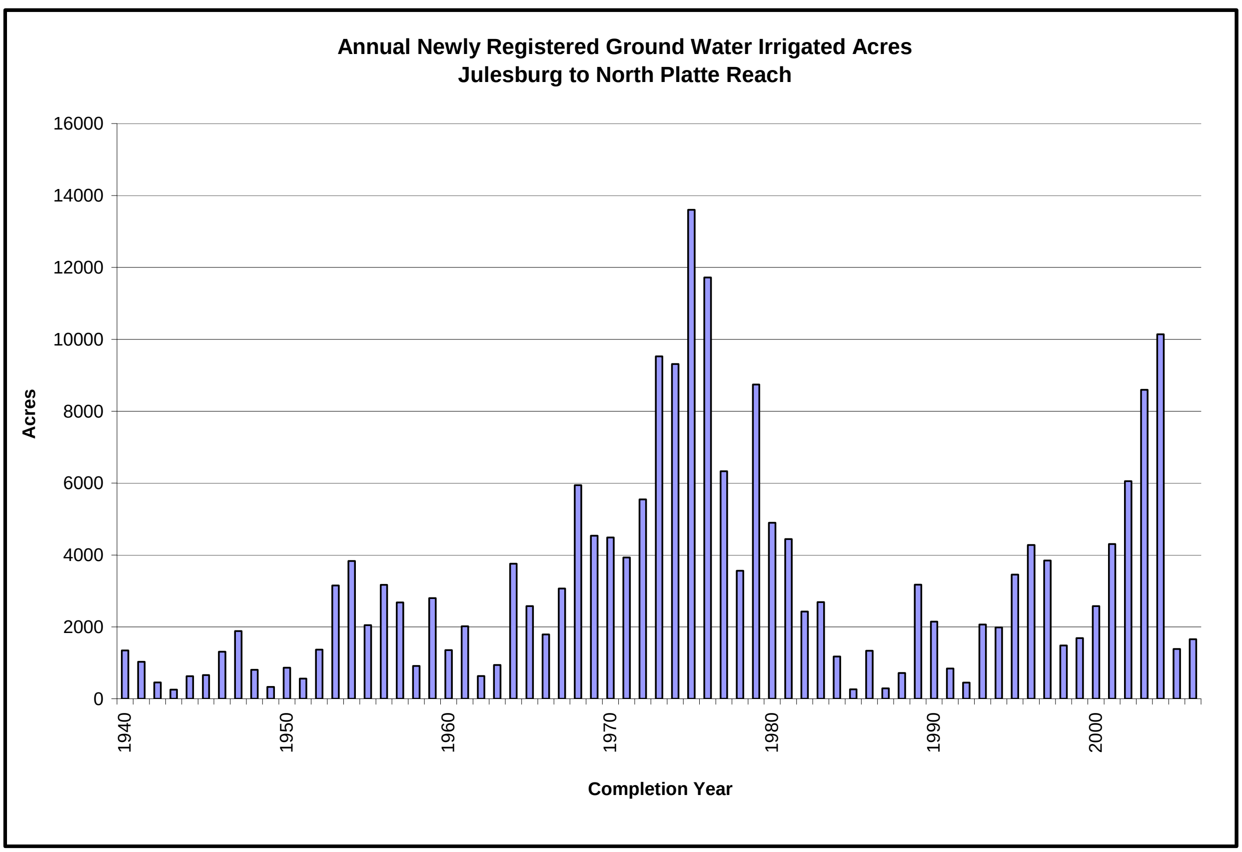


Figure 3-37. Annual newly registered groundwater irrigated acres.

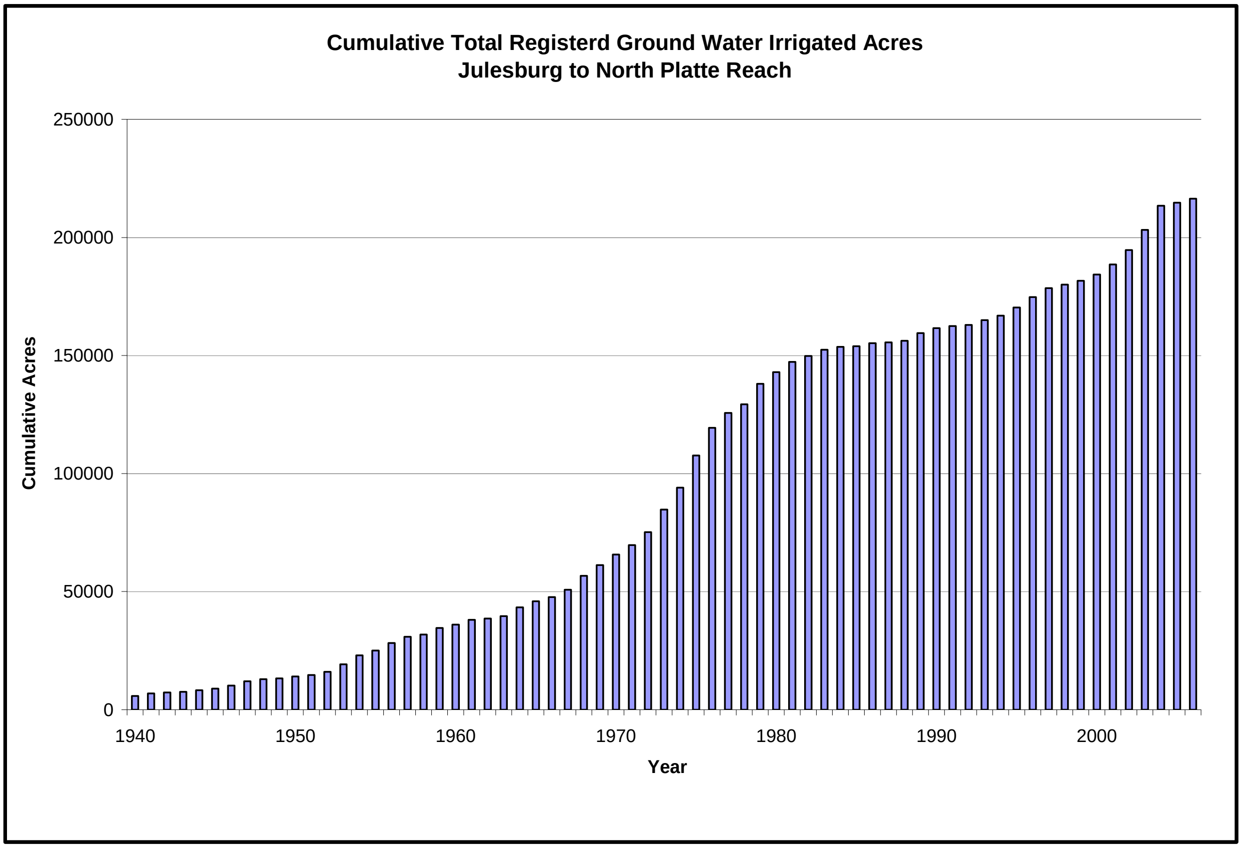


Figure 3-38. Cumulative groundwater irrigated acres.

The level of surface water development within the reach was evaluated and is illustrated in figures 3-39 and 3-40. The results indicate that approximately 1,700 additional acres were approved for irrigation under surface water appropriation through the period analyzed (1949-2006). These new acres may have an impact on reductions in the reach gain; these reductions may be minimal during dry periods, however, when senior appropriations can call for administration on the river.

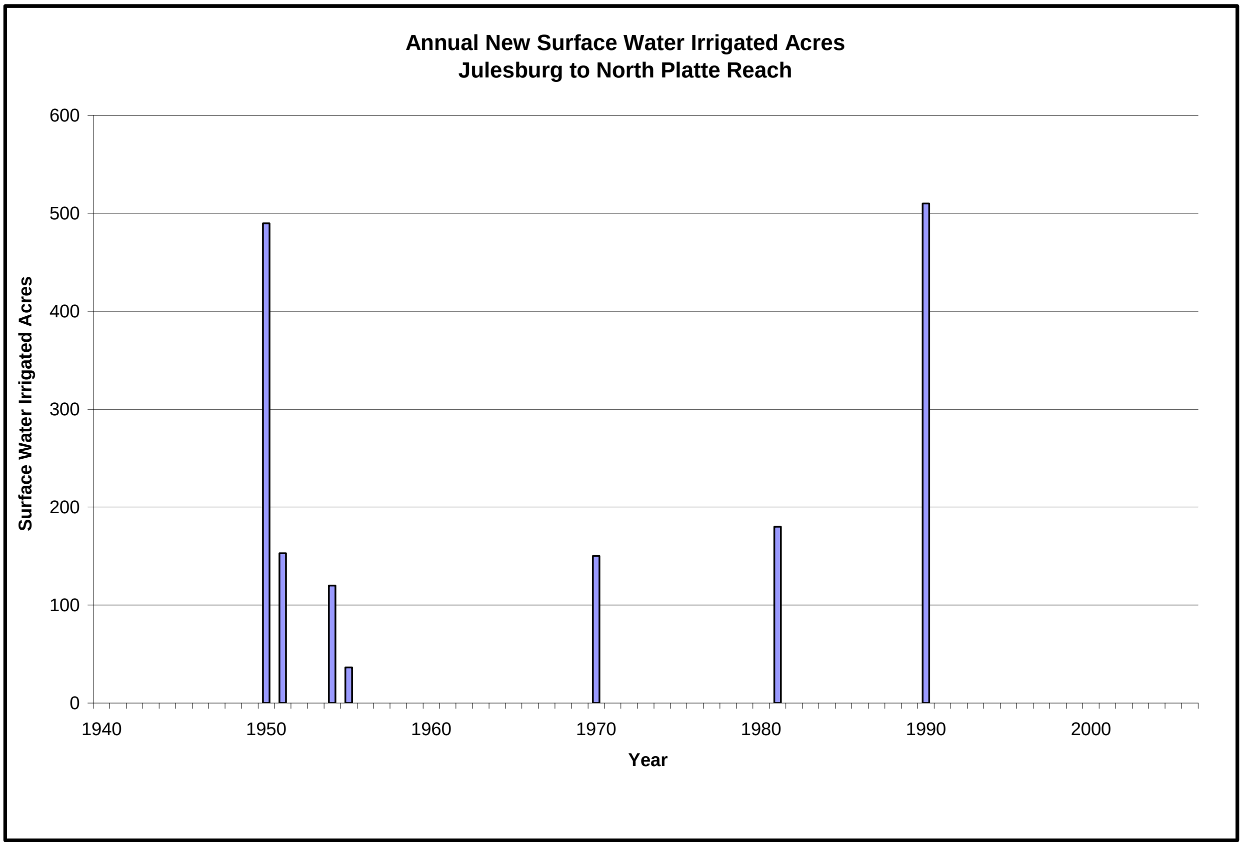


Figure 3-39. Annual new surface water irrigated acres.

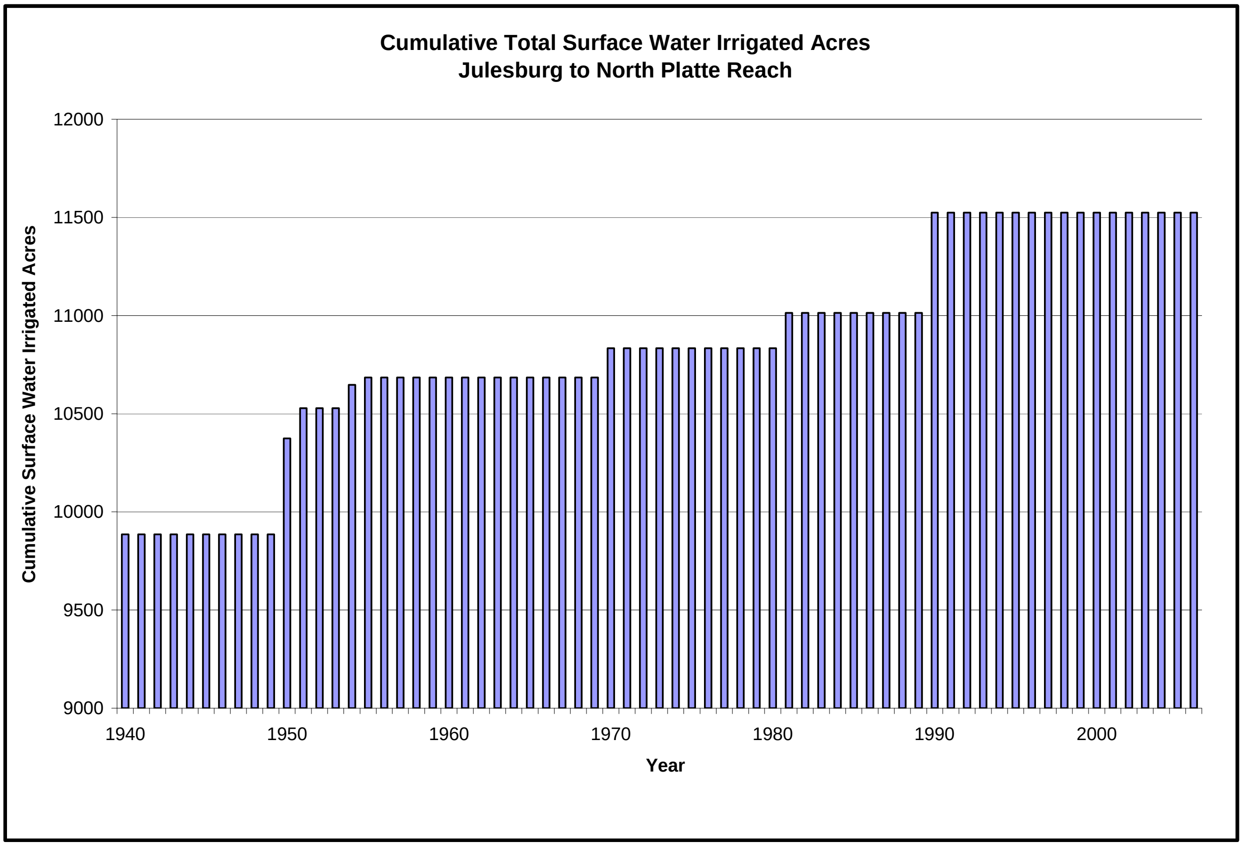


Figure 3-40. Cumulative total surface water irrigated acres.

3.5.3 Unmet Demands

The following demands were considered for the Julesburg to North Platte reach:

- CNPPID irrigation
- CNPPID Supply Canal hydropower generation
- Canaday Steam Plant cooling
- North Platte Hydro (via Korty Canal diversion)
- Gerald Gentleman Station cooling (via Korty Canal diversion)

Because the Tri-County diversion point is located at the confluence of the North Platte River and South Platte River, the unmet demands for CNPPID Irrigation, CNPPID Supply Canal hydropower generation, and Canaday Steam Plant cooling for the South Platte-River Julesburg to North Platte reach are the same as those for the North Platte River-Keystone to North Platte reach.

One source for the North Platte Hydro use is the Korty Canal diversion on the South Platte River in the Julesburg to North Platte reach; the other source is the Keystone Canal diversion on the North Platte River just below Lake McConaughy). Hydropower generation for North Platte Hydro represents a year-round non-consumptive demand for Platte River water. The water passed through the North Platte Hydro is returned to the South Platte River just upstream of the Tri-County diversion. Thus, the demand for North Platte Hydro was assumed to be met if the demands associated with the Tri-County diversion were met. Therefore, to avoid double-counting of unmet demand, additional unmet demand for North Platte Hydro was assumed to be zero.

Like North Platte Hydro, Gerald Gentleman Station cooling represents a year-round demand for the Korty Canal diversion in this reach as well as for the Keystone Canal diversion in another reach. In addition, Gerald Gentleman Station cooling water takes advantage of other water moving through the Sutherland system that is returned to the river just upstream of the Tri-County diversion. Therefore, additional unmet demand for Gerald Gentleman Station cooling was assumed to be zero. Thus, the unmet demand for the Julesburg to North Platte reach is the same as the Keystone to North Platte reach, except for irrigation season demands resulting from the five irrigation canals located in the Keystone to North Platte reach (table 3-33).

Table 3-33. Unmet demands for the Julesburg to North Platte reach.

Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	200,000	0
Normal	387,000	240,000
Dry	510,000	440,000

3.5.4 Accumulated Unmet Demands

The unmet demands from the downstream reaches are passed into this reach and added to the unmet demands in this reach to determine the cumulative unmet demands within the reach (tables 3-34 through 3-36).

Table 3-34. Unmet demands passed upstream from the Cozad to Odessa and North Platte to Cozad reaches.

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	13,000	0
Normal	35,000	0
Dry	62,000	0

Table 3-35. Unmet demands in the Julesburg to North Platte reach.

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	200,000	0
Normal	387,000	240,000
Dry	510,000	440,000

Table 3-36. Cumulative unmet demands in the Julesburg to North Platte reach.

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	213,000	0
Normal	422,000	240,000
Dry	572,000	440,000

All of the cumulative unmet demands for this reach were passed upstream to the state line to Lewellen reach (table 3-37). None of the cumulative unmet demands for this reach were passed upstream to the Lodgepole Creek reach. An analysis showed that if stream reach gain reductions were replaced in Lodgepole Creek reach, almost all of the water would go to users in Colorado and not benefit the unmet demands downstream of the Colorado-Nebraska state line.

Table 3-37. Unmet demands passed upstream to the state line to Lewellen Reach (refer to table 3-27 in section 3.4.4).

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	220,500	0
Normal	429,500	240,000
Dry	587,000	440,000

3.5.5 Overall Difference between Overappropriated and Fully Appropriated

The overall difference between overappropriated and fully appropriated was set to zero under wet conditions. This was considered a reasonable adjustment because no unmet demands appear to be present under wet conditions. Future work should evaluate the authors' conclusions more carefully.

Table 3-38. Stream reach gain reduction for the Julesburg to North Platte reach.

Condition	Stream Reach Gain Reduction	
	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	6,400	-1,500
Normal	6,400	-1,500
Dry	6,400	-1,500

Table 3-39. Unmet demands for the Julesburg to North Platte reach.

Condition	Unmet Demands	
	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	213,000	0
Normal	422,000	240,000
Dry	572,000	440,000

Table 3-40. Overall Difference between overappropriated and fully appropriated for the Julesburg to North Platte reach.

Condition	OA/FA Difference	
	Irrigation	**Non-Irrigation**
Wet	0	0
Normal	6,400	-1,500
Dry	6,400	-1,500

3.6 State Line to Lewellen Reach

The state line to Lewellen reach is the contributing surface water basin between the stream gages located on the Wyoming-Nebraska state line at North Platte and the North Platte River at Lewellen. This reach includes inflows from Wyoming, Horse Creek, Interstate Canal, Mitchell-Gering Canal, Fort Laramie Canal and many tributary drains and outflows for numerous canals including: Tri-State Canal, Winters Creek Canal, Empire Canal, Central Canal, Enterprise Canal, Minatare Canal, Chimney Rock Canal, Beerline Canal, Browns Creek Canal, Lisco Canal, Midland-Overland Canal, Belmont Canal, Castle Rock Canal, Short Line Canal, Nine Mile Canal, along with other canals located on the tributaries.

3.6.1 Assessment of Reach Gain Reductions

The double-mass curves of cumulative reach gains and cumulative precipitation during the period 1949-2006 for the irrigation season and non-irrigation season, respectively, are illustrated in figures 3-41 and 3-42. The cumulative precipitation for this reach was developed based on the weighted precipitation from the following gages:

Gage	Weight of Gage (based on Thiessen polygons)
Big Springs	0.003
Agate	0.042
Alliance	0.097
Bridgeport	0.227
Harrisburg	0.107
Oshkosh	0.223

Scottsbluff	0.192
Sidney	0.061
Kimball	0.048

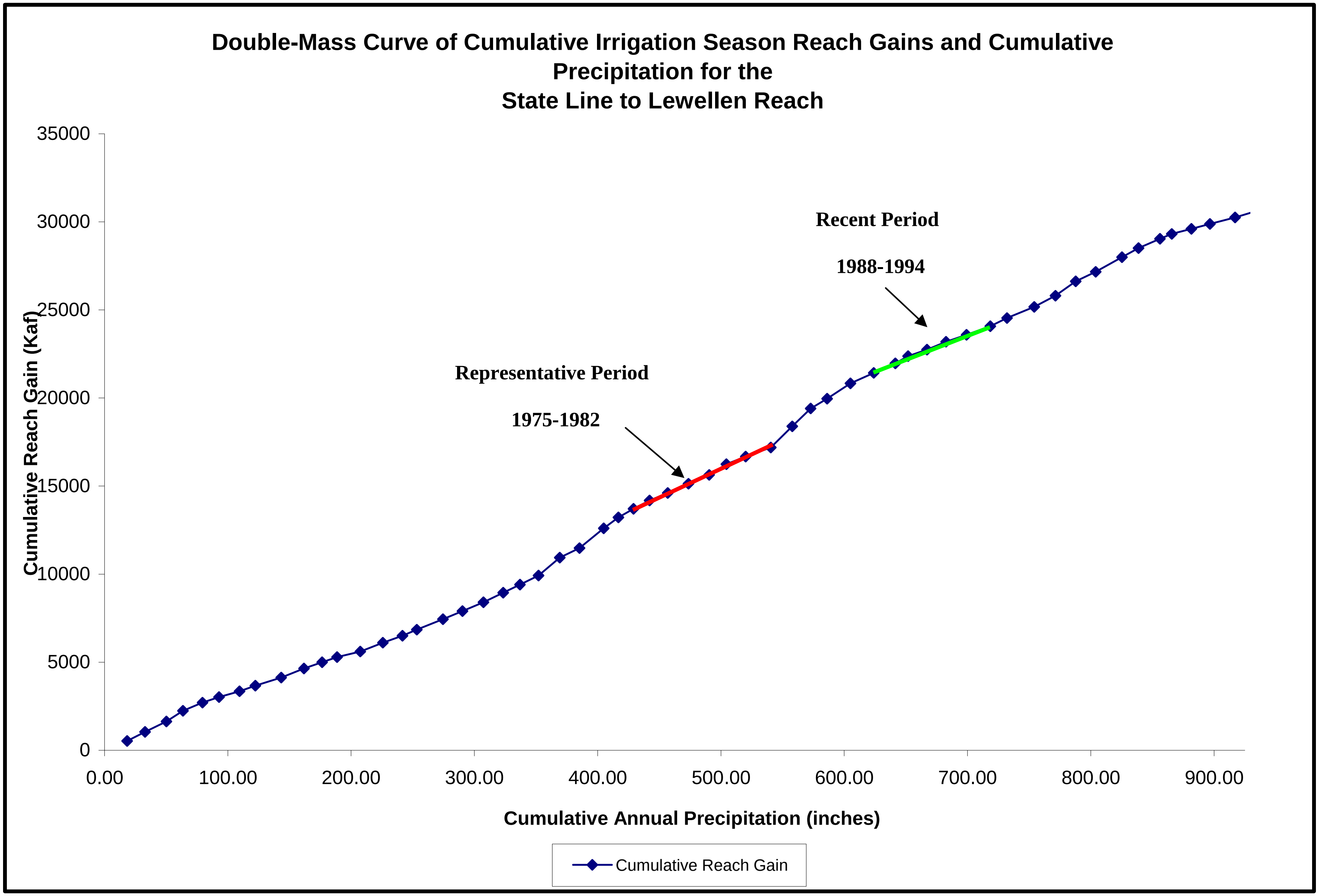


Figure 3-41. Double-mass curve of the cumulative irrigation season reach gain and cumulative annual precipitation.

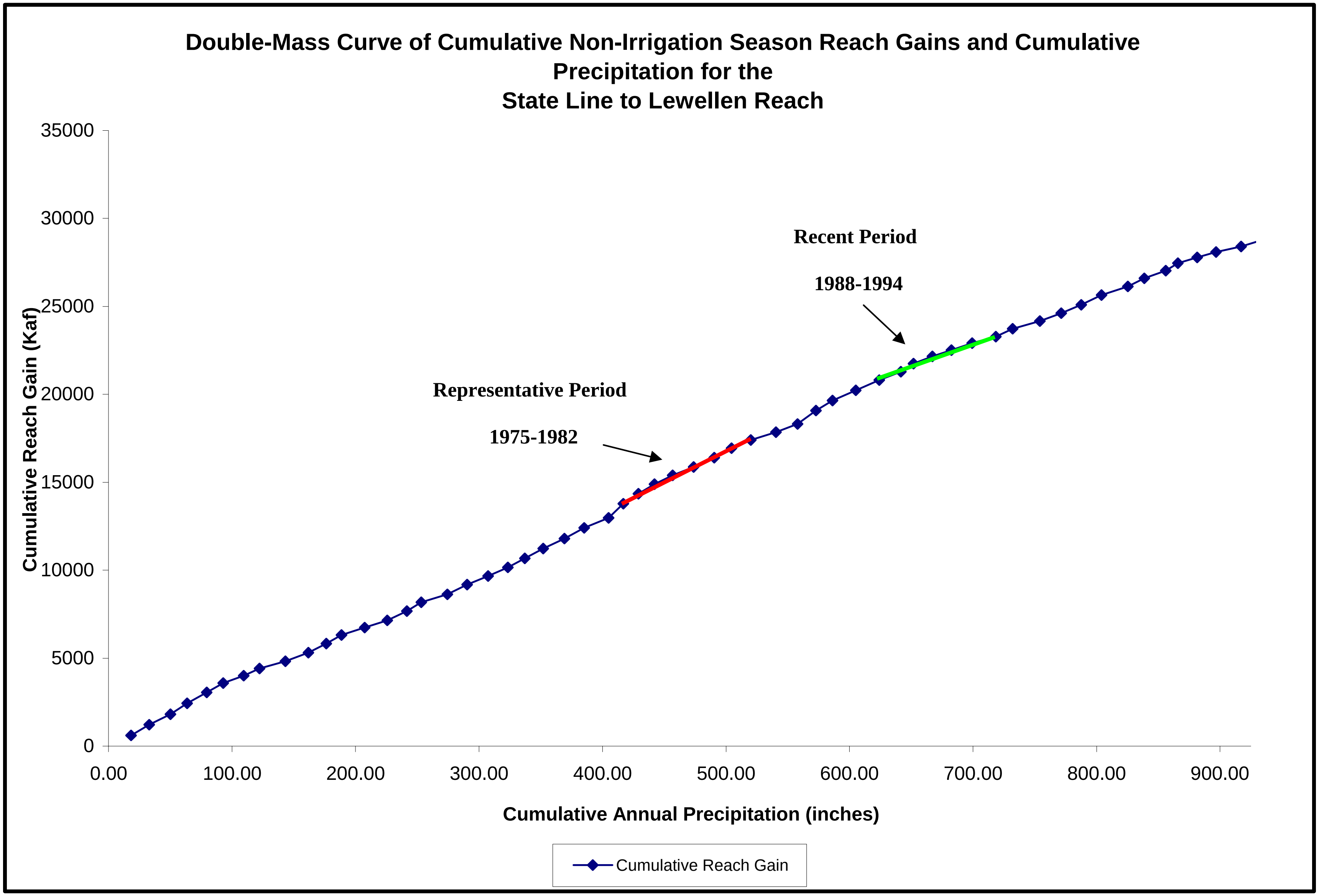


Figure 3-42. Double-mass curve of the cumulative non-irrigation season reach gain and cumulative annual precipitation.

In evaluating potential stream reach gain reductions, the 1975-1982 period was used as the representative period for both the irrigation season and the non-irrigation season. The period 1988-1994 was used to represent the recent period for both the irrigation season and the non-irrigation season. Since the break point on the curves falls prior to the dry conditions identified subsequent to 2000, this break point seems to represent reach gain reductions that have occurred under wet, normal, and dry hydrologic conditions. The calculated stream reach gain reductions for this reach are summarized in table 3-41.

Table 3-41. Summary of stream reach gain reductions for the state line to Lewellen reach.

State Line to Lewellen Reach Gain Reduction		
Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	44,900	68,500
Normal	44,900	68,500
Dry	44,900	68,500

3.6.2 Potential Causes for Reach Gain Reductions

The potential causes for stream reach gain reductions within this reach were investigated by evaluating state line canal inflows, diversions (seepage returns to the reach), groundwater development, and surface water development. Figure 3-43 illustrates state line inflows from canals that originate in Wyoming (Interstate Canal, Mitchell-Gering Canal, and Fort Laramie Canal). Surface water diversions within the reach were evaluated to determine if reduced surface water diversions and therefore reduced returns from those diversions could be a potential cause of stream reach gain reductions.

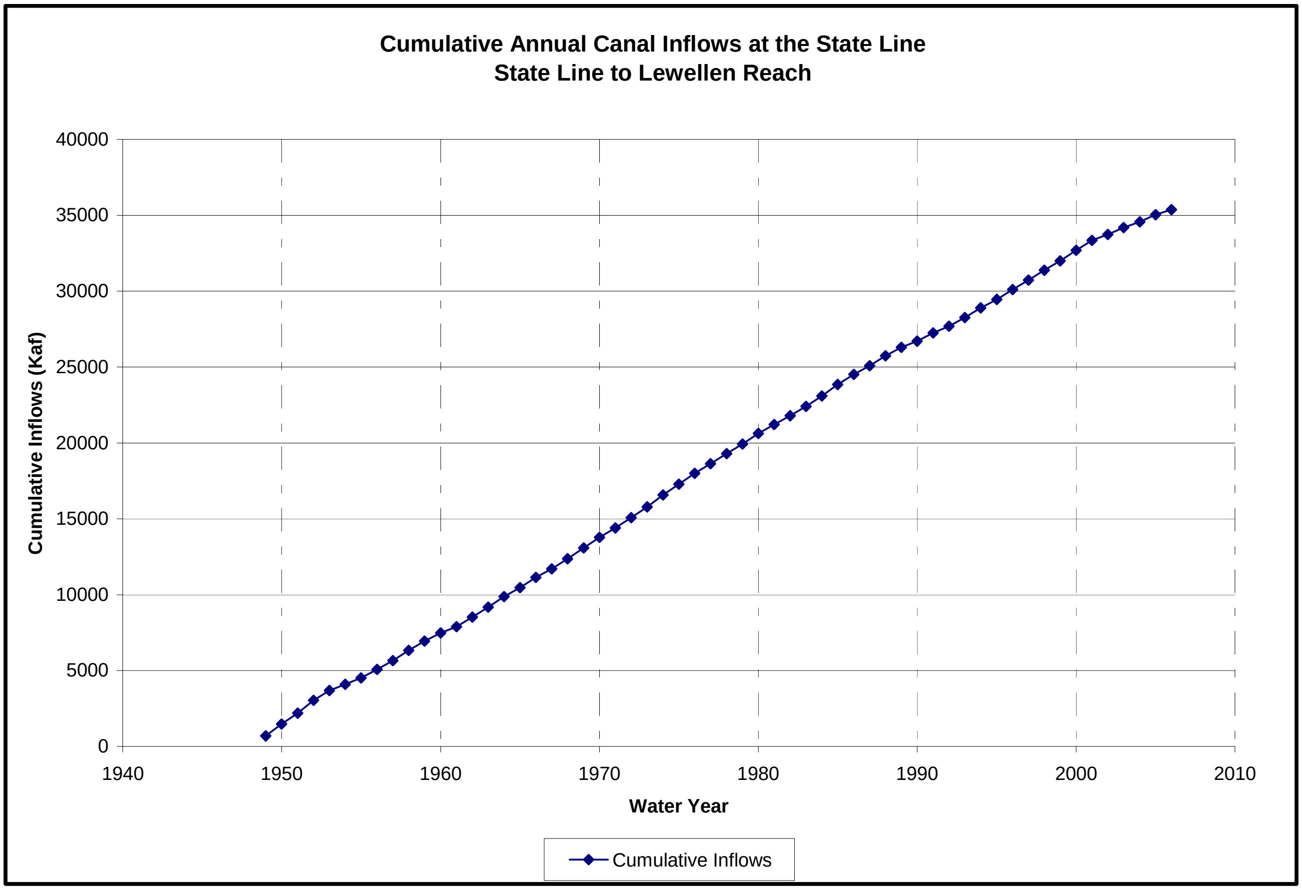


Figure 3-43. Cumulative annual state line canal inflows.

Evaluation of the diversion records indicated that estimated annual seepage from diversions affecting this reach decreased significantly from the representative period to the recent period (37,000 ac-ft/yr in the irrigation season and 5,500 ac-ft/yr in the non-irrigation season). Since any reach gain would include gains from these seepage losses, these seepage changes were subtracted from the reach gain reduction to derive the final reach gain reductions shown in table 3-42.

Table 3-42. Summary of stream reach gain reductions for the state line to Lewellen reach adjusted for reduced seepage from canal diversions.

State Line to Lewellen Reach Gain Reduction		
Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	7,900	63,000
Normal	7,900	63,000
Dry	7,900	63,000

The level of groundwater development within the reach was evaluated and is illustrated in figures 3-44 and 3-45. The results indicate that approximately 120,000 additional groundwater irrigated acres were developed through the period analyzed (1949-2006). The increase in groundwater irrigated acres may be a potential cause of reductions in the reach gain.

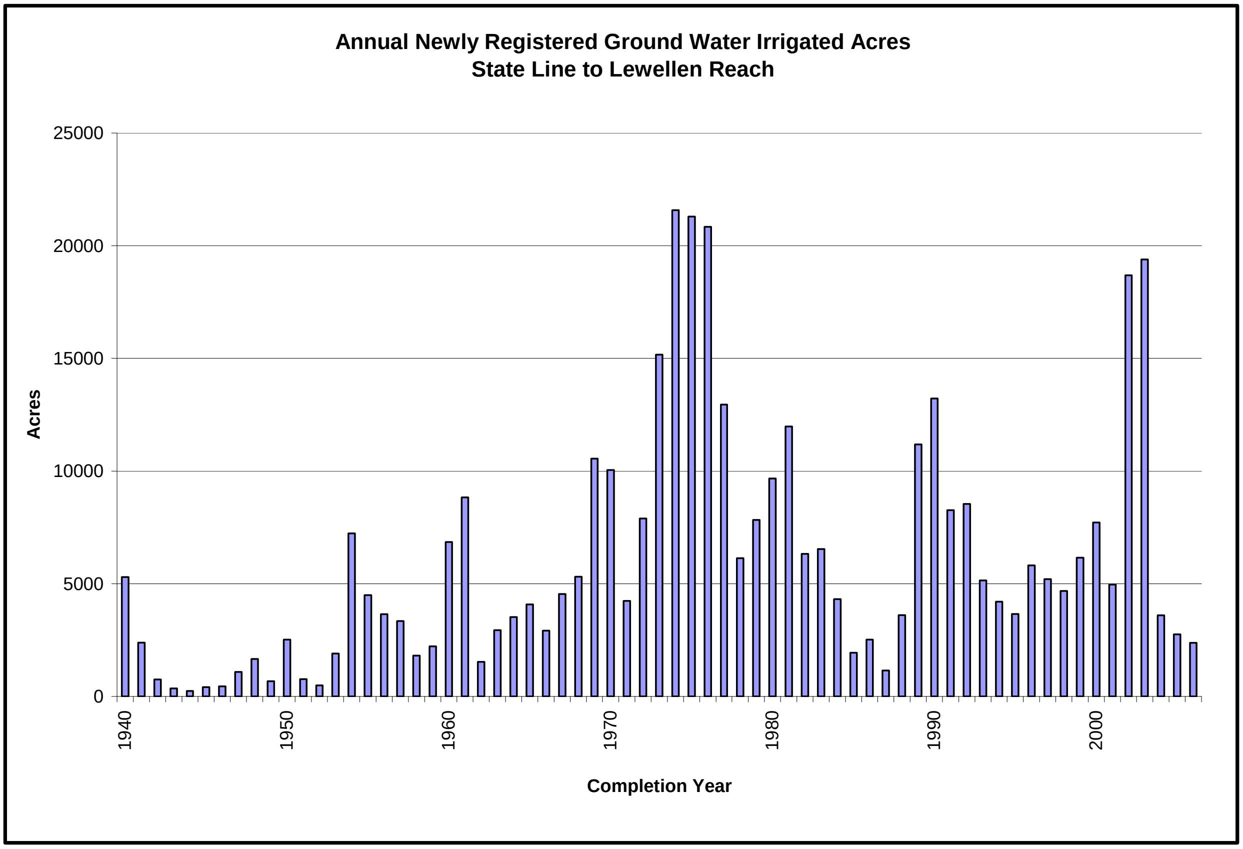


Figure 3-44. Annual newly registered groundwater irrigated acres.

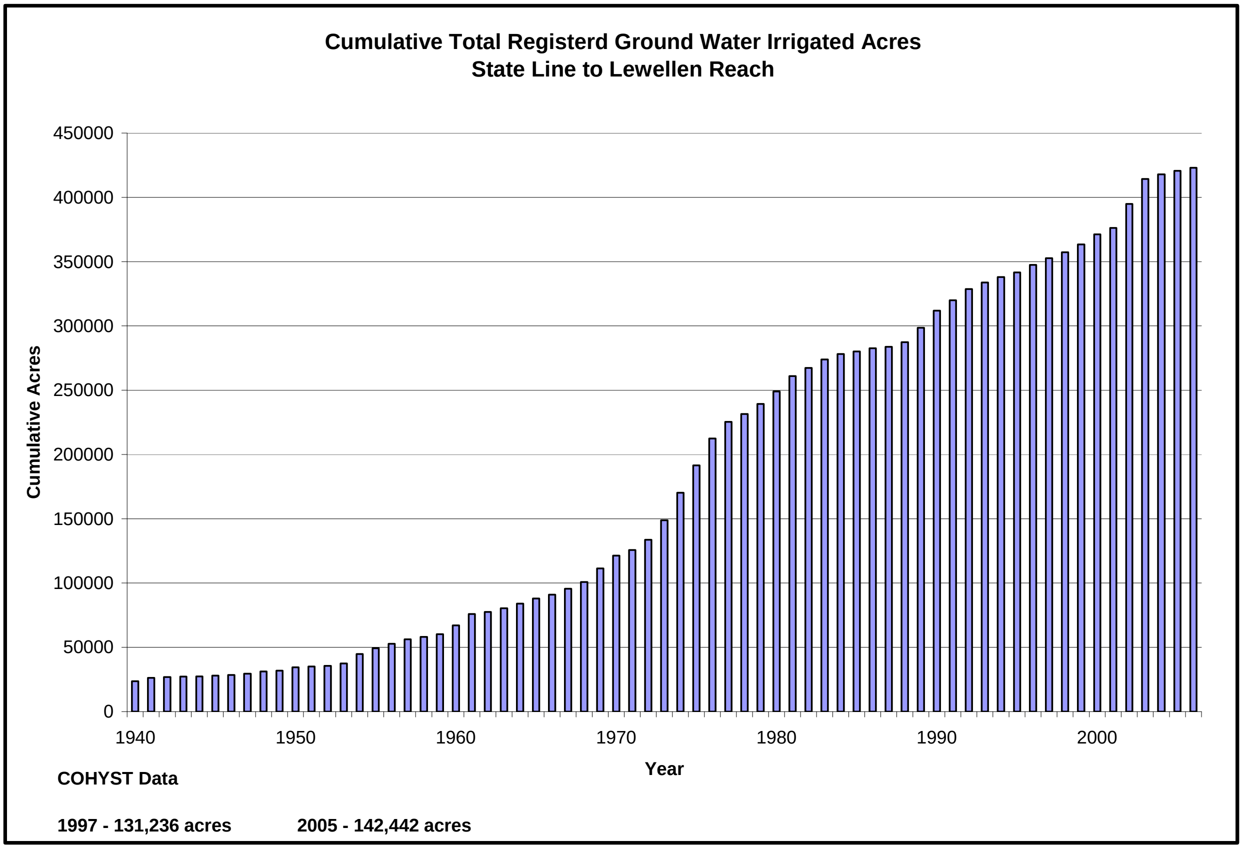


Figure 3-45. Cumulative groundwater irrigated acres.

The level of surface water development within the reach was evaluated and is illustrated in figures 3-46 and 3-47. The results indicate that approximately 45,000 additional acres were approved for irrigation under surface water appropriations through the period analyzed (1949-2006). These new acres may have an impact on reductions in the reach gain; these reductions may be minimal during dry periods, however, when senior appropriations can call for administration on the river.

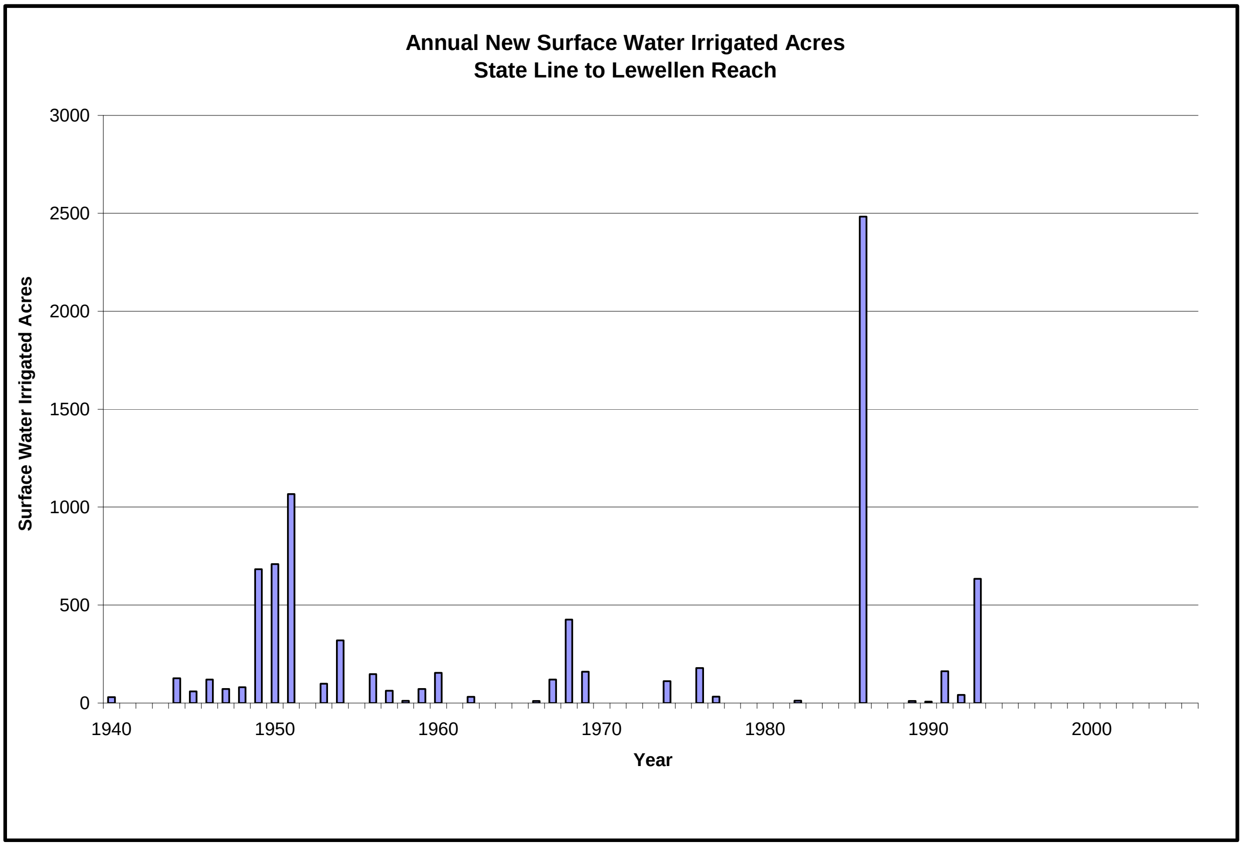


Figure 3-46. Annual new surface water irrigated acres.

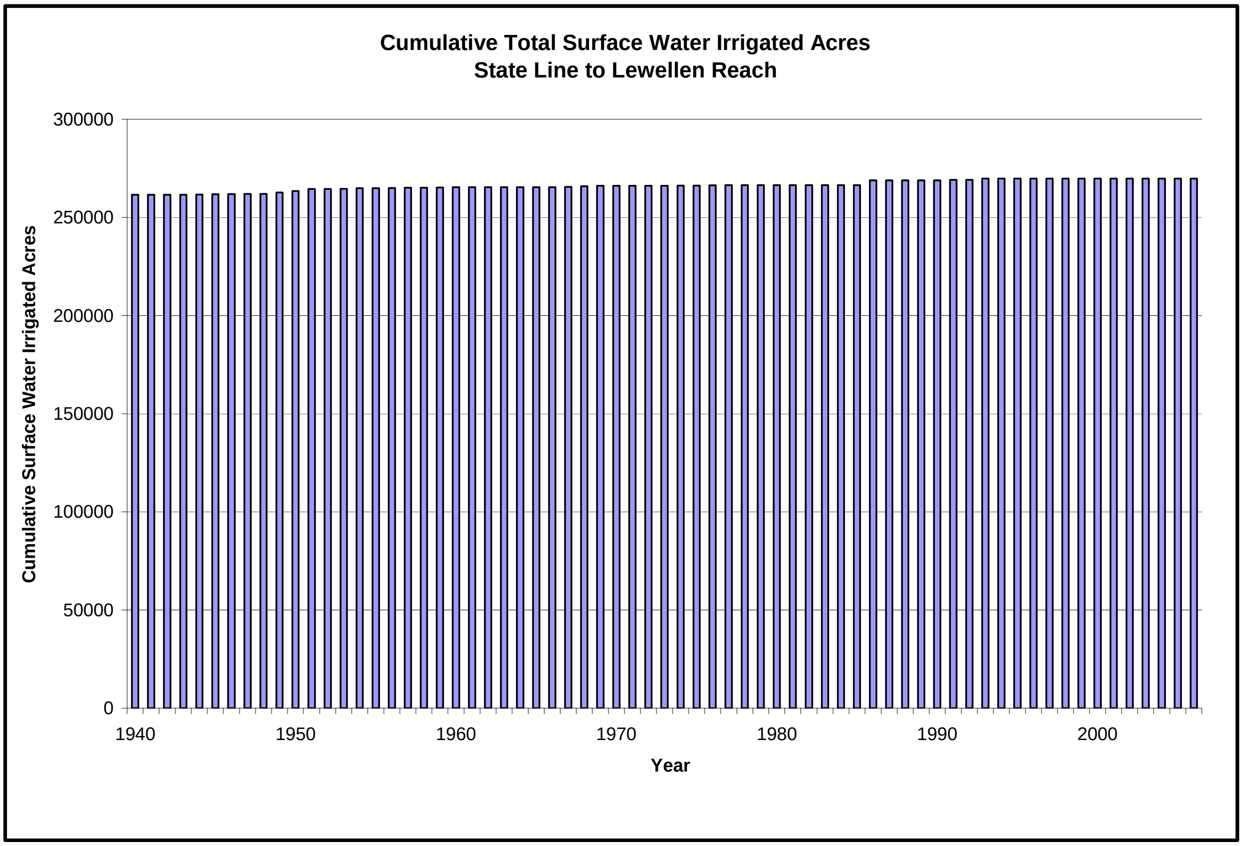


Figure 3-47. Cumulative total surface water irrigated acres.

3.6.3 Unmet Demands

The following demands were considered for the Wyoming state line to Lewellen reach:

- Kingsley Hydropower generation
- Environmental Account
- Lake McConaughy storage
- North Platte Hydro (via Keystone Canal diversion)
- Gerald Gentleman Station cooling (via Keystone Canal diversion)
- Sutherland storage (via Keystone Canal diversion)
- Panhandle Irrigation canals with storage water
- Panhandle Tributary Irrigation canals without storage water

The Kingsley Hydropower Plant is located within Kingsley Dam and serves as the primary outlet works for Lake McConaughy. Kingsley Hydro primarily generates as storage water is released from Lake McConaughy or natural flow is passed through Kingsley Dam for some other purpose. Though exceptions may occur, these analyses assumed that if all other demands that rely on Lake McConaughy for supplemental storage are met, then Kingsley Hydro demand is met as well. Therefore, additional unmet demand associated with Kingsley Hydropower Plant generation was assumed to be zero.

The Environmental Account is a storage-use appropriation that provides storage water from Lake McConaughy for instream use for fish and wildlife. Though the end use is intended for downstream reaches, the amount of water available for use is calculated based upon storable inflows to Lake McConaughy at Lewellen. The "demand" for the Environmental Account is an amount derived through a complex set of calculations. Because it is anticipated that all new uses that post-date the Environmental Account will have to be offset as a result of the PRRIP requirement to offset for post-1997 reach gain reductions (the Environmental Account has a 1998 priority date), the unmet demand for the Environmental Account was assumed to be zero.

The total demand for water to be stored in Lake McConaughy includes the amount needed to supplement downstream demands, as well as the amount needed to maintain evaporation and seepage losses from the reservoir. Because the unmet demands for the downstream uses that rely on Lake McConaughy as a supplemental source have already been calculated, additional unmet demand for storage for those purposes was assumed to be zero. Additionally, because seepage and evaporation losses from the reservoir are uncontrolled and have historically been "met" under all conditions, additional unmet demand for storage for those purposes was also assumed to be zero.

The Keystone Canal diversion point is physically located immediately downstream from Lake McConaughy. As noted above, because Lake McConaughy basically bears all losses between Lewellen and Keystone on the North Platte River, the demands associated with the Keystone Canal diversion are treated as reach demands for the state line to Lewellen reach. As was the case for the Korty Canal diversion on the South Platte River, the additional unmet demands for the Keystone Canal diversion for both the North Platte Hydro and Gerald Gentleman Station were assumed to be zero.

Storage appropriations for Sutherland Reservoir specify the North Platte River, at the Keystone Canal diversion, as the source of supply. As was the case with Lake McConaughy storage, however, because unmet demands have already been calculated for those uses that rely on Sutherland Reservoir storage, and because seepage and evaporation losses have historically been “met,” the additional unmet demand for Sutherland Reservoir storage was assumed to be zero.

Several irrigation canals are located within the reach: Enterprise Canal, Central Canal, Chimney Rock Canal, Bridgeport Canal, Browns Creek Canal, Beerline Canal, and Lisco Canal. These canals all utilize storage to satisfy their demands fully. The unmet demand for these canals was determined based on the estimated storage used by these canals during varying hydrologic conditions.

In addition to determining the demands for the abovementioned canals, the demands for the canals that divert from the tributaries of Pumpkin Creek and Blue Creek were also determined. Figure 3-48 illustrates the demands for the irrigation canals on Pumpkin Creek. The historic demand was estimated at 7,700 acre-feet but current supply allows for 350 acre-feet of diversion. Thus the unmet demand was determined to be 7,350 acre-feet for the canals diverting from Pumpkin Creek.

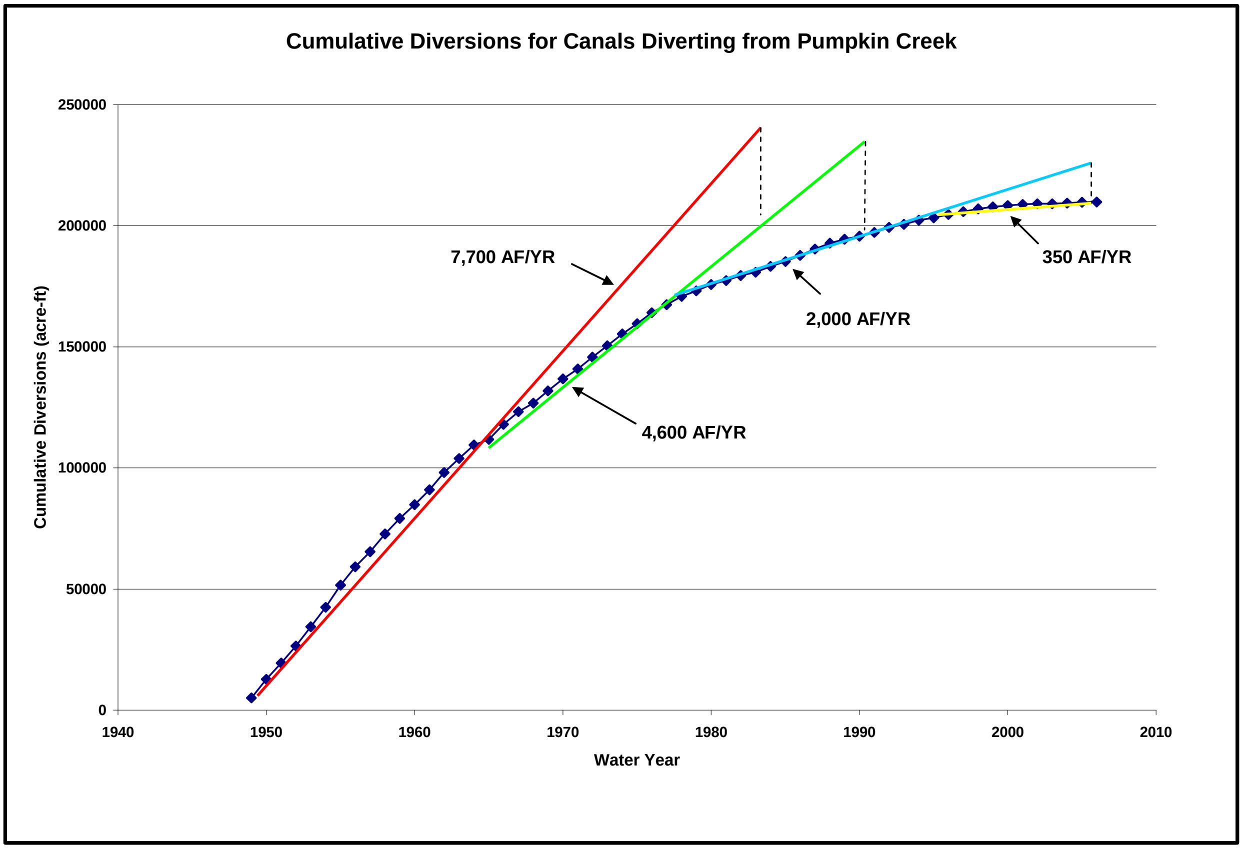


Figure 3-48. Cumulative diversions for canals diverting from Pumpkin Creek.

The canals that divert from Blue Creek were evaluated to determine if historic canal diversions have changed through time. The evaluation indicated no significant changes in current diversions from historic diversions. Therefore, no unmet demand was assumed to exist for those users. Table 3-43 summarizes the unmet demands for the irrigation canals evaluated in this reach.

Table 3-43. Unmet demands for irrigation canals in the state line to Lewellen reach.

Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	9,350	0
Normal	10,550	0
Dry	15,350	0

3.6.4 Accumulated Unmet Demands

The unmet demands from the downstream reaches are passed into this reach and added to the unmet demands in this reach to determine the cumulative unmet demands within the reach (tables 3-44 through 3-46).

Table 3-44. Unmet demands passed upstream from the Cozad to Odessa, North Platte to Cozad, South Platte, and North Platte below McConaughy reaches.

Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	220,500	0
Normal	429,500	240,000
Dry	587,000	440,000

Table 3-45. Unmet demands in the state line to Lewellen reach.

Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	9,350	0
Normal	10,550	0
Dry	15,350	0

Table 3-46. Cumulative unmet demands in the state line to Lewellen reach.

	Irrigation Season Ac-ft	Non-Irrigation Season Ac-ft
Wet	229,850	0
Normal	440,050	240,000
Dry	602,350	440,000

3.6.5 Overall Difference between Overappropriated and Fully Appropriated

The overall difference between overappropriated and fully appropriated is the intersection of the stream reach gain reduction (table 3-47) and the unmet demands for the state line to Lewellen reach (table 3-48). Although the difference between overappropriated and fully appropriated (table 3-49) was set to zero under wet conditions for other reaches downstream (i.e., Keystone to North Platte and Julesberg to North Platte), the difference was not set to zero for this reach since unmet demands for irrigation within the reach were identified for canals that do not have access to supplemental storage water. The unmet demands for these canals should be reassessed in the future.

Table 3-47. Stream reach gain reduction for the state line to Lewellen reach.

Condition	Stream Reach Gain Reduction	
	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	7,900	63,000
Normal	7,900	63,000
Dry	7,900	63,000

Table 3-48. Unmet demands for the state line to Lewellen reach.

Condition	Unmet Demands	
	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	229,850	0
Normal	440,050	240,000
Dry	602,350	440,000

Table 3-49. Overall difference between overappropriated and fully appropriated for the state line to Lewellen reach.

Condition	OA/FA Difference	
	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	7,900	0
Normal	7,900	63,000
Dry	7,900	63,000

3.7 Lodgepole Creek

The Lodgepole Creek reach includes its entire contributing surface water basin upstream from the Nebraska–Colorado state line to the Nebraska–Wyoming state line. Available long-term records are very limited in the basin, so only a small portion of the basin (Bushnell to Ralton) was analyzed. Data used in the reach gain calculations included inflows from Lodgepole Creek at Bushnell and outflows to the eleven irrigation canals in the reach, as well as changes in storage to Oliver Reservoir, and Lodgepole Creek at Ralton. Because of the relatively short period of available data for the abovementioned gages (1955-1971), previously described analyses were not used for evaluating the changes in gains for Lodgepole Creek.

3.7.1 Assessment of Reach Gain Reductions

The streamflow reach gain reduction estimation was simplified by using our knowledge of the existing flows in the creek and assuming the present period gains to be zero. This assumption can be justified by comparing the Bushnell and Ralton annual streamflows for the period 2003 to 2006 (table 3-50).

Table 3-50. Recent streamflows at Bushnell and Ralton for Lodgepole Creek.

Year	Lodgepole Creek at Bushnell Annual Flows, (ac-ft)	Lodgepole Creek at Ralton Annual Flows, (ac-ft)
2003	350	0
2004	190	0
2005	80	No data published
2006	16	0

The historical gains for 1955-1971 were calculated using the gaged data available for the period. The gains range from 700 acre-feet in 1964 to over 14,000 acre-feet in 1959 as shown in table 3-51. The average gain for the analysis period is 7,500 acre-feet and the median gain is 6,900 acre-feet. For this analysis, the annual stream reach gain reduction was estimated at 7,500 acre-feet since this represented the average historical gain; as stated above, recent gains are assumed to be zero.

Table 3-51. Lodgepole Creek historical reach gains for the Bushnell to Ralton reach.

Year	Stream Gain (ac-ft)
1955	9,800
1956	4,100
1957	3,200
1958	13,700
1959	14,400
1960	5,700
1961	5,600
1962	7,600
1963	8,600
1964	700
1965	11,300
1966	8,800
1967	5,500
1968	12,300
1969	6,900
1970	4,800
1971	5,000

If the annual gain is assumed to occur at an equal rate through the year, 42% will occur during the irrigation season and 58% will occur during the non-irrigation season. By proportionally dividing the annual figure, 7,500 acre-feet into the respective seasons, the resulting reach gain reduction for the irrigation season is 3,150 acre-feet and the non-irrigation season reduction is 4,350 acre-feet.

3.7.2 Unmet Demands

Detailed records do not exist to allow the unmet demand for surface water irrigation to be calcualted in this reach for surface water irrigation using previously described methods. The 1955-1971 diversion records and gain calculations do show that the reach gain and the diversions are nearly equal in magnitude. Therefore, for this analysis, the reach gain was assumed to be equal to the unmet demand (table 3-52).

Table 3-52. Unmet demands for irrigation canals in the Lodgepole Creek reach.

Condition	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	3,150	4,350
Normal	3,150	4,350
Dry	3,150	4,350

3.7.3 Accumulated Unmet Demands

Further analysis is warranted to assess the fate of flows that cross the state line into Colorado. In the absence of such an analysis, no unmet demand was assumed to be passed upstream into the Lodgepole Creek reach. Additionally, this reach is at the upstream end of the analysis, so no demand is passed upstream.

3.7.4 Overall Difference between Overappropriated and Fully Appropriated

Table 3-53. Stream reach gain reduction for Lodgepole Creek.

Condition	Stream Reach Gain Reduction	
	Irrigation Season (ac-ft)	Non-Irrigation Season (ac-ft)
Wet	3,150	4,350
Normal	3,150	4,350
Dry	3,150	4,350

Table 3-54. Unmet demands for Lodgepole Creek.

Condition	Unmet Demands	
	Irrigation Season (ac-ft)	**Non-Irrigation Season (ac-ft)**
Wet	3,150	4,350
Normal	3,150	4,350
Dry	3,150	4,350

Table 3-55. Overall difference between overappropriated and fully appropriated for Lodgepole Creek.

Condition	OA/FA Difference	
	Irrigation Season (ac-ft)	**Non-Irrigation Season (ac-ft)**
Wet	3,150	4,350
Normal	3,150	4,350
Dry	3,150	4,350

Based on current understanding and methodology, the Lodgepole Creek reach is not thought to have any impacts on downstream reaches. Consequently, the overall difference between overappropriated and fully appropriated may largely depend on the assessment of current unmet demands within the Lodgepole Creek reach.

4.0 ASSIGNMENT OF IMPACTS TO INDIVIDUAL NRDS

4.1 Methodology

The assessment of the difference between overappropriated and fully appropriated was completed on each of the reaches discussed in this report. Since the contributing surface water basins for the reaches used for the analysis do not coincide with the boundaries of the NRDs, through which the reaches pass, the overall OA/FA difference needed to be apportioned to each individual NRD. This apportionment was completed using the 2005 COHYST groundwater irrigated acres in each reach by NRD within the defined overappropriated basin. Table 4-1 illustrates the percentage of impacts that were assigned to each NRD.

Table 4-1. Percentage of reach impacts to be assigned to each NRD based on 2005 COHYST groundwater irrigated acres within the overappropriated basin.

Reach	SPNRD	TPNRD	CPNRD	TBNRD	NPNRD
Stateline - Lewellen	0.7%	0.0%	0%	0%	99.3%
Julesburg - North Platte	10.4%	89.6%	0%	0%	0%
Keystone - North Platte	0%	100%	0%	0.0%	0%
North Platte - Cozad	0%	58.5%	41.5%	0.0%	0%
Cozad - Odessa	0%	0%	45.9%	54.1%	0%
Lodgepole Creek	100%	0%	0%	0%	0%

4.2 North Platte NRD

The North Platte NRD (NPNRD) was assigned reach impacts only in the state line to Lewellen reach. The total difference between overappropriated and fully appropriated for this reach is listed in table 4-2.

Table 4-2. Overall difference between overappropriated and fully appropriated for the state line to Lewellen reach.

State Line to Lewellen Reach		
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	7,900	0
Normal	7,900	63,000
Dry	7,900	63,000

NPNRD was assigned 99.3 percent of the total impacts, based on acres within the overappropriated basin. Table 4-3 summarizes the results from the analysis of the overall difference between overappropriated and fully appropriated for the NPNRD during the irrigation season, non-irrigation season, and annually.

Table 4-3. Overall difference between overappropriated and fully appropriated for the NPNRD for the irrigation season, the non-irrigation season, and annually.

NPNRD			
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**	**Total Annual (ac-ft)**
Wet	7,850	0	7,850
Normal	7,850	62,575	70,425
Dry	7,850	62,575	70,425

4.3 South Platte NRD

For the purposes of this analysis, the South Platte NRD (SPNRD) was assigned reach impacts in the state line to Lewellen reach, Julesburg to North Platte reach, and Lodgepole Creek. The total difference between overappropriated and fully appropriated for these two reaches and Lodgepole Creek is listed in tables 4-4, 4-5, and 4-6.

Table 4-4. Overall difference between overappropriated and fully appropriated for the state line to Lewellen reach.

State Line to Lewellen Reach		
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	7,900	0
Normal	7,900	63,000
Dry	7,900	63,000

Table 4-5. Overall difference between overappropriated and fully appropriated for the Julesburg to North Platte reach.

Julesburg to North Platte Reach		
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	0	0
Normal	6,400	-1,500
Dry	6,400	-1,500

Table 4-6. Overall difference between overappropriated and fully appropriated for Lodgepole Creek.

Lodgepole Creek		
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	3,150	4,350
Normal	3,150	4,350
Dry	3,150	4,350

SPNRD was assigned 0.7 percent of the total impacts in the state line to Lewellen reach based on acres within the overappropriated basin. SPNRD was assigned 10.4 percent of the total impacts in the Julesburg to North Platte reach and 100 percent of the difference between overappropriated and fully appropriated for Lodgepole Creek. Tables 4-7 through 4-9 list the results from the analysis of the overall difference between overappropriated and fully appropriated for the South Platte NRD during the irrigation season, the non-irrigation season, and annually for the three reaches for which impacts were assigned to SPNRD.

Table 4-7. Overall difference between overappropriated and fully appropriated for the SPNRD for the irrigation season, the non-irrigation season, and annually for the state line to Lewellen reach.

SPNRD			
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**	**Total Annual (ac-ft)**
Wet	50	0	50
Normal	50	425	475
Dry	50	425	475

Table 4-8. Overall difference between overappropriated and fully appropriated for the SPNRD for the irrigation season, the non-irrigation season, and annually for the Julesburg to North Platte reach.

SPNRD			
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**	**Total Annual (ac-ft)**
Wet	0	0	0
Normal	650	-150	500
Dry	650	-150	500

Table 4-9. Overall difference between overappropriated and fully appropriated for the SPNRD for the irrigation season, the non-irrigation season, and annually for Lodgepole Creek.

SPNRD			
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**	**Total Annual (ac-ft)**
Wet	3,150	4,350	7,500
Normal	3,150	4,350	7,500
Dry	3,150	4,350	7,500

4.4 Twin Platte NRD

For purposes of this analysis, the Twin Platte NRD (TPNRD) was assigned reach impacts in the Keystone to North Platte reach, the Julesburg to North Platte reach, and the North Platte to

Cozad reach. The total difference between overappropriated and fully appropriated for these three reaches is listed in tables 4-10 through 4-12.

Table 4-10. Overall difference between overappropriated and fully appropriated for the Keystone to North Platte reach.

Keystone to North Platte Reach		
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	0	0
Normal	26,000	23,000
Dry	26,000	23,000

Table 4-11. Overall difference between overappropriated and fully appropriated for the Julesburg to North Platte reach.

Julesburg to North Platte Reach		
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	0	0
Normal	6,400	-1,500
Dry	6,400	-1,500

Table 4-12. Overall difference between overappropriated and fully appropriated for the North Platte to Cozad reach.

North Platte to Cozad Reach		
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation (ac-ft)**
Wet	0	0
Normal	0	0
Dry	14,900	8,900

TPNRD was assigned 100 percent of the total impacts in the Keystone to North Platte reach, 89.6 percent of the total impacts in the Julesburg to North Platte reach, and 58.5 percent of the total impacts in the North Platte to Cozad reach. Tables 4-13 through 4-15 list the results from the analysis of the overall difference between overappropriated and fully appropriated for the Twin Platte NRD during the irrigation season, non-irrigation season, and annually for the three reaches for which impacts were assigned to TPNRD.

Table 4-13. Overall difference between overappropriated and fully appropriated for the TPNRD for the irrigation season, the non-irrigation season, and annually for the Keystone to North Platte reach.

TPNRD			
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**	**Total Annual (ac-ft)**
Wet	0	0	0
Normal	26,000	23,000	49,000
Dry	26,000	23,000	49,000

Table 4-14. Overall difference between overappropriated and fully appropriated for the TPNRD for the irrigation season, the non-irrigation season, and annually for the Julesburg to North Platte reach.

TPNRD			
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**	**Total Annual (ac-ft)**
Wet	0	0	0
Normal	5,750	-1,350	4,400
Dry	5,750	-1,350	4,400

Table 4-15. Overall difference between overappropriated and fully appropriated for the TPNRD for the irrigation season, the non-irrigation season, and annually for the North Platte to Cozad reach.

TPNRD			
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**	**Total Annual (ac-ft)**
Wet	0	0	0
Normal	0	0	0
Dry	8,700	5,200	13,900

4.5 Central Platte NRD

For purposes of this analysis, the Central Platte NRD (CPNRD) was assigned reach impacts in the North Platte to Cozad reach and the Cozad to Odessa reach. The total difference between overappropriated and fully appropriated for these two reaches is listed in tables 4-16 and 4-17.

Table 4-16. Overall difference between overappropriated and fully appropriated for the North Platte to Cozad reach.

North Platte to Cozad Reach		
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	0	0
Normal	0	0
Dry	14,900	8,900

Table 4-17. Overall difference between overappropriated and fully appropriated for the Cozad to Odessa reach.

Cozad to Odessa Reach		
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**
Wet	0	0
Normal	0	0
Dry	6,500	10,600

The CPNRD was assigned 41.5 percent of the total impacts in the North Platte to Cozad reach and 45.9 percent of the total impacts in the Cozad to Odessa reach. Tables 4-18 and 4-19 list the results from the analysis of the overall difference between overappropriated and fully appropriated for the Central Platte NRD during the irrigation season, non-irrigation season, and annually for the two reaches for which impacts were assigned to CPNRD.

Table 4-18. Overall difference between overappropriated and fully appropriated for the CPNRD for the irrigation season, the non-irrigation season, and annually for the North Platte to Cozad reach.

CPNRD			
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**	**Total Annual (ac-ft)**
Wet	0	0	0
Normal	0	0	0
Dry	6,200	3,700	9,900

Table 4-19. Overall difference between overappropriated and fully appropriated for the CPNRD for the irrigation season, the non-irrigation season, and annually for the Cozad to Odessa reach.

CPNRD			
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**	**Total Annual (ac-ft)**
Wet	0	0	0
Normal	0	0	0
Dry	3,000	4,850	7,850

4.6 Tri-Basin NRD

For purposes of this analysis, the Tri-Basin NRD (TBNRD) was assigned impacts only included in the Cozad to Odessa reach. The total difference between overappropriated and fully appropriated for this reach is listed in table 4-20.

Table 4-20. Overall difference between overappropriated and fully appropriated for the Cozad to Odessa reach.

Cozad to Odessa Reach		
Condition	**Irrigated Season (ac-ft)**	**Non-Irrigated Season (ac-ft)**
Wet	0	0
Normal	0	0
Dry	6,500	10,600

TBNRD was assigned 54.1 percent of the total impacts for the Cozad to Odessa reach. Table 4-21 lists the results from the analysis of the overall difference between overappropriated and fully appropriated for the TBNRD during the irrigation season, the non-irrigation season, and annually.

Table 4-21. Overall difference between overappropriated and fully appropriated for the TBNRD for the irrigation season, the non-irrigation season, and annually.

TBNRD			
Condition	**Irrigation Season (ac-ft)**	**Non-Irrigation Season (ac-ft)**	**Total Annual (ac-ft)**
Wet	0	0	0
Normal	0	0	0
Dry	3,500	5,750	9,250

5.0 LIMITATIONS AND FUTURE WORK

5.1 Limitations and Assumptions

The methodology used is this report focused on identification of overall changes in reach gains for the five reaches and Lodgepole Creek. With the exception of corrections for reduced canal deliveries, this methodology did not seek to specifically identify the causes for the reduction in reach gains. This limitation will need to be addressed when more refined estimates are calculated in the future. The method also attempted to indentify when changes in reach gains would have a potential impact on existing users dependent on those gains to meet their natural flow appropriations or to provide recharge for existing wells. These potential impacts were indentified under three hydrologic conditions (i.e., wet, normal, and dry). A more rigorous analysis should be conducted in the future to further refine hydrologic conditions and the estimates related to potential shortages.

Reach selection was driven in part by the need to be able to discern differences in data within a river reach, which tends to require that reaches be larger in size. Many of these reaches are composed of separate subreaches or tributary streams for which the actual flow changes may vary greatly from one to the other. As a consequence, it is possible that changes in one subreach or tributary are being masked by other changes in another subreach or tributary of the same overall reach. It is also possible that impacts on individual tributaries would be more easily determined if tributaries were analyzed separately. The ability to more easily discern changes in the smaller flows of the tributary are not adequately captured by the river reach analysis because the changes in tributary flow, though real, are simply not discernable within the total mainstem flow. Additional work or alternative methodologies may be needed to discern changes at smaller scales and different locations than those used in this analysis.

Several assumptions were utilized for simplicity when identifying potential shortages to surface water appropriations. Due to the non-consumptive nature of the Tri-County Canal power diversions, the unmet demands associated with the Tri-County Canal were used to represent the potential shortage of the Sutherland System, including the North Platte Hydro (non-consumptive), and Gerald Gentlemen Station, instream flows upstream of the Tri-County County diversion (non-consumptive), and storage water shortages in Lake McConaughy. Additionally, these analyses assumed that if all other demands that rely on Lake McConaughy for supplemental storage are met, then Kingsley Hydro demand is met as well.

Shortages to surface water appropriations for irrigation were assessed through evaluation of historical Platte Water Accounting Program (PWAP) data maintained by NDNR. Shortages were estimated by averaging the storage water usage through the various hydrologic conditions for those districts to which storage water was available. The canals that divert from Blue Creek were evaluated to determine if historic canal diversions have changed through time. The evaluation indicated no significant changes in current diversions from historic diversions. Therefore, no unmet demand was assumed to exist for those users.

The instream flow appropriations were evaluated for shortage through evaluation of daily shortages to the appropriation located at Overton. It is not clear at the time of publication of this report if the instream flow appropriations should be evaluated based on daily shortages (as done for this report) or through evaluation of the frequency at which flows occur. Additionally, instream flows are much more junior than other appropriations evaluated in this report and interpretation of statutes may be required to further assess what, if any, shortages exist for these appropriations. If shortages are not determined to exist for the instream flow appropriations then the assumption that the Kearney Canal appropriation is satisfied may need to be further evaluated.

The Environmental Account is a storage-use appropriation that provides storage water from Lake McConaughy for instream use for fish and wildlife. Though the end use is intended for downstream reaches, the amount of water available for use is calculated based upon storable inflows to Lake McConaughy at Lewellen. The "demand" for the Environmental Account is an amount derived through a complex set of calculations. It is assumed for purposes of this report that no unmet demand exists for the Environmental Account since depletions resulting from development subsequent to 1997 will be offset through the integrated management planning process.

The total demand for water to be stored in Lake McConaughy includes the amount needed to supplement downstream demands, as well as the amount needed to maintain evaporation and seepage losses from the reservoir. Because the unmet demands for the downstream uses that rely on Lake McConaughy as a supplemental source have already been calculated, additional unmet demand for storage for those purposes was assumed to be zero. Additionally, because seepage and evaporation losses from the reservoir are uncontrolled and have historically been “met” under all conditions, additional unmet demand for storage for those purposes was also assumed to be zero.

Gerald Gentleman Station cooling water takes advantage of other water moving through the Sutherland system that is returned to the river just upstream of the Tri-County diversion. Therefore, additional unmet demand for Gerald Gentleman Station cooling was assumed to be zero.

Canaday Steam Plant draws cooling water year-round from the CNPPID Supply Canal just upstream from the J-2 Return. Cooling for Canaday Steam Plant is mostly non-consumptive and was designed to take advantage of water that is already in the CNPPID Canal for other purposes. Demand for Canaday Steam Plant cooling was assumed to be met if other CNPPID hydropower and irrigation demands are met, and the additional unmet demand for Canaday Steam Plant cooling is therefore assumed to be zero.

The need for recharge from the Platte River for the maintenance of existing wells was also considered. Although no actual shortage of water for wells has been demonstrated, some water quality issues with the Grand Island municipal wellfield have been measured when the river goes completely dry. Because the amount of streamflow that would be necessary to keep the river from going completely dry is believed to be substantially less than the flow required for the instream flow appropriations, and because the same water in the stream can serve both purposes, the unmet demand for recharge for wells was assumed to be zero.

5.2 Future Work

As discussed in section 5.1 (above), future work will need to focus on identification of causes for reduction in reach gains. This future work should include: 1) evaluation of historical groundwater well depletions; 2) evaluation of the impact of conservation practices; 3) evaluation of changes in historical diversions and the potential reduction in return flows; 4) evaluation of the impacts of riparian vegetation; and 5) improvements to or replacements of the methodologies used to estimate changes in flow, unmet demands, or the intersection of changes with unmet demands, including refinements in reaches and locations for analysis, greater consideration of consequences of variable hydrologic conditions, and use of other analytical tools or numerical models as appropriate.

In addition to the technical limitations and future work described above, there are certain policy/statute-related issues that need to be considered. These issues include: 1) when shortages are identified, how these shortages should be distributed (i.e., only within the natural resources district where the appropriation is located, all natural resources districts upstream of the appropriation, etc.); 2) how should instream flow appropriations be evaluated; 3) what is the acceptable level of depletion to streamflow from groundwater uses permitted prior to July 1, 1997; 4) evaluation of the socioeconomic implications of shortages to existing permit or appropriation holders; and 5) what is the role of PRRIP projects or retirements.