Model Representation of River Gains and Losses in the Heise/Ashton to Milner Reaches of the Snake River

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Eastern Snake Plain Aquifer Model Enhancement Project
Scenario Document Number DDW-017

DESIGN DOCUMENT OVERVIEW

Design documents are a series of technical papers addressing specific design topics on the Eastern Snake Plain Aquifer Model Enhancement. Each design document will contain the following information: topic of the design document, how that topic fits into the whole project, which design alternatives were considered and which design alternative is proposed. In draft form, design documents are used to present proposed designs to reviewers. Reviewers are encouraged to submit suggested alternatives and comments to the design document. Reviewers include all members of the Eastern Snake Hydrologic Modeling (ESHM) Committee as well as selected experts outside of the committee. The design document author will consider all suggestions from reviewers, update the draft design document, and submit the design document to the SRPAM Model Upgrade Program Manager. The Program Manager will make a final decision regarding the technical design of the described component. The author will modify the design document and publish the document in its final form in .pdf format on the SRPAM Model Upgrade web site.

The goal of a draft design document is to allow all of the technical groups that are interested in the design of the SRPAM Model Upgrade to voice opinions on the upgrade design. The final design document serves the purpose of documenting the final design decision. Once the final design document has been published for a specific topic, that topic will no longer be open for reviewer comment. Many of the topics addressed in design documents are subjective in nature. It is acknowledged that some design decisions will be controversial. The goal of the Program Manager and the modeling team is to deliver a well-documented, defensible model that is as technically representative of the physical system as possible, given the practical constraints of time, funding and manpower. Through the mechanism of design documents, complicated design decisions will be finalized and documented.

Final model documentation will include all of the design documents, edited to ensure that the "as-built" condition is appropriately represented.

INTRODUCTION

Understanding gains and losses of the Snake River is an important aspect of conjunctive management of the water resources of southern Idaho. Quantifying the surface and ground water exchange is fundamental to management and to the development of technical tools such as the Snake River Plain aquifer model. The exchange of water between the Snake River Plain aquifer and the Snake River is a primary target in the calibration of the model. The model will ultimately be used to guide aquifer and river management.

The purpose of this document is to describe the gains and losses of the upper reaches of the Snake River within the bounds of the Snake River Plain aquifer. This document is also intended to give readers a sufficient understanding of the uncertainties in the methods so that they may infer a level of confidence in the results. The presented analyses are described for all river reaches defined by gaging stations for reaches above Milner on the Snake River continuously or nearly continuously operational during the 1980 through 2002 period (Figure 1). Some adjacent reaches may later be aggregated as determined to be appropriate during aquifer model calibration. This period was selected to match the calibration period of the Snake River Plain aquifer model. The gains and losses described in this document are intended to represent the calibration targets for the aquifer model. The description of the analysis in each reach is intended to assist in assignment of a confidence in that target.

This document describes the estimation of Snake River gains and losses from Near Heise (station 13037500) on the Snake River and Near Ashton on the Henrys Fork (station 13046000, water years 1980 and 1993-on; station 13046023, water years 1981 to 1992) to the At Milner gage (station 13088000) on the Snake River. A related document, DDM-018, describes the calculation of Snake River gains from the At Milner gage to the gage at King Hill (station 13154500). In DDM-017, gains and losses of the individual reaches are determined as the residual of a water budget that includes all measured values of inflow and outflow to a reach. This analysis is using output from the IDWR Reach Gain and Loss Program, which will be documented in DDM-004. In DDM-018, reach gains from Milner to King Hill are determined using a regression equation developed by Kjelstrom (1995a).

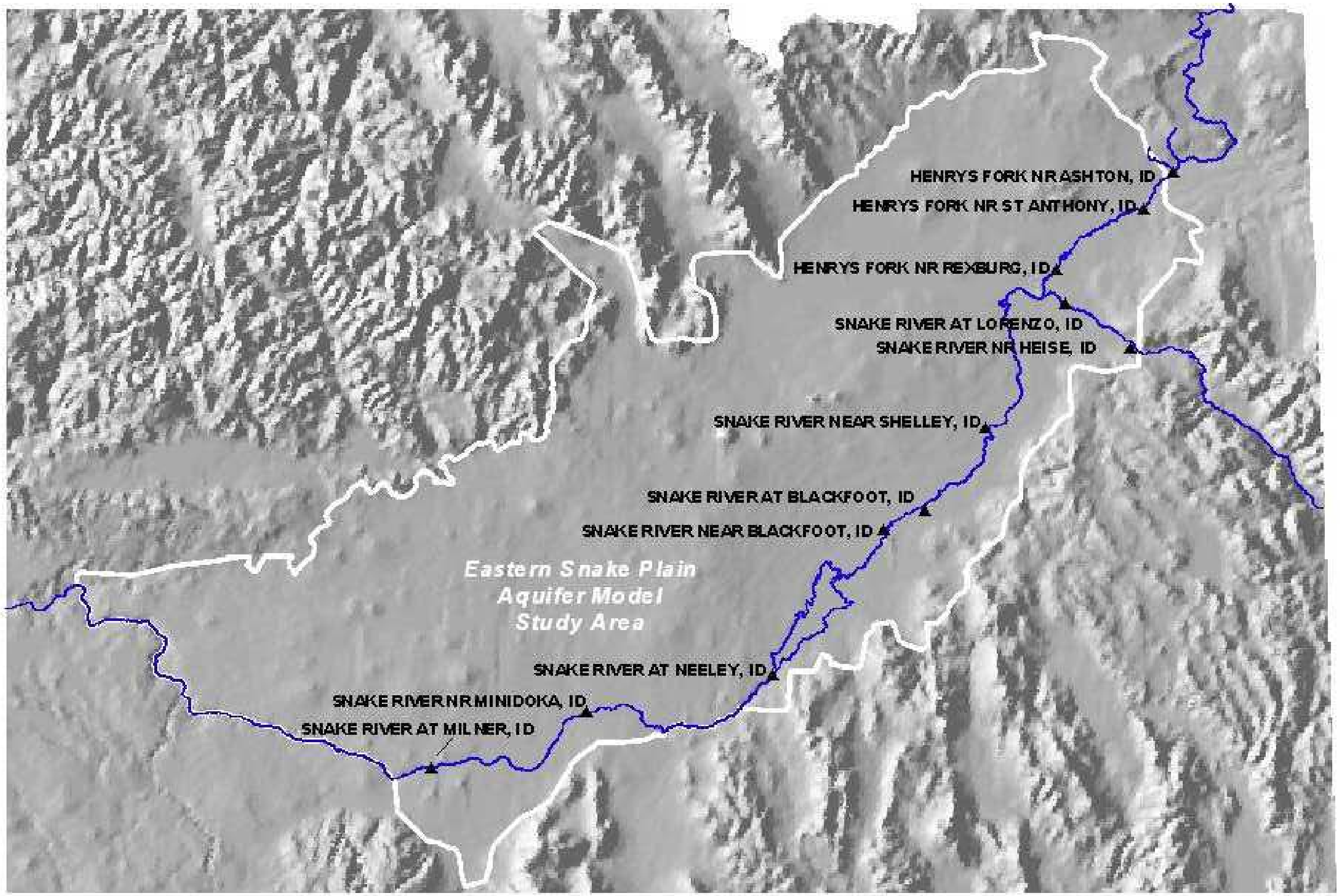

Figure 1. River reaches for which reach gain and loss estimates were calculated: Eastern Snake Plain Aquifer Model.

WATER BUDGET ANALYSIS FROM HEISE AND ASHTON TO MILNER

The inflows and outflows are described for each of the reaches. Graphs are presented that show estimates of reach gain and loss by month and also by six-month period. The six-month periods were selected to conform with the stress periods of the Eastern Snake River Plain aquifer model. A pair of lines is also presented on these graphs to show how the estimated reach gains and losses compare to 5% of the flow of the Snake River at the upstream gage. Five percent of discharge is used as an index to possible errors in stream discharge measurement. If gains and losses are large relative to this index then we have increased confidence in their relative accuracy. Gains and losses that are small relative to the index are more uncertain. Kjelstrom (1995b) presented gains and losses in a similar fashion, but selected an index of 2% of the river flow. Kjelstrom's selection of 2% was based on findings of Rantz, et al. (1982) that repeated measurements at a number of sites had a standard error of 2.2%. Recognizing, however, that these errors exist at the upstream river gage, downstream gage, and also in measurements and estimates of diversions, tributary inflows, return flows, and evaporation (from American Falls reservoir) we have selected a more conservative index of five percent. The accuracy of the daily discharge estimates of individual gages is reported by the USGS. Assuming some of this error has a random component, then monthly or six-month average flows are more accurate than the percentage reported by the USGS. The collective error within a reach affects the reliability of the reach gain and loss estimate. An idea of the sensitivity of the reach gain and loss estimate to these factors may be partially inferred by the average magnitude of these budget items that are also presented graphically.

REACH 1: NEAR ASHTON TO AT ST. ANTHONY

River Inflow

The Henrys Fork river gage Near Ashton (station 13046000) has been partially operational from 1890 to 1926 and continuously operational from 1927 to the current year and consequently provides complete coverage for the aquifer model calibration period of 1980 through 2002. During this model period, the average flow was about $1.5x10^8$ ft^3/d (1242 K-AF/yr), with discharge during winter averaging approximately 62% of average summer flow ($1.8x10^8$ ft^3/d) (767 K-AF/6-month period) (Figure 2). The USGS has rated the Near Ashton station as generally providing records of “good” quality. This has been interpreted as meaning reported mean daily discharge is within +/- 10% of the true discharge.

River Outflow

The Henrys Fork river gage At St. Anthony (station 13050500) has been in operation from 1919 to present and consequently provides complete coverage for the aquifer model calibration period. Average flow from 1980 through 2002 was about $1.7x10^8$ ft^3/d (1458 K-AF/year), with the winter flow averaging about 77% of the summer flow of $2.0x10^8$ ft^3/d (822 K-AF/6-month period) (Figure 2). The USGS rates the station as generally providing “good” records. This is interpreted as meaning that daily discharge is within +/- 10% of the true value.

Tributary Inflows

The Falls River is tributary to the Henrys Fork between Ashton and St. Anthony. This inflow is accounted for in the reach gain calculation, using gage station 13049500, Discharge of Falls River near Chester.

Diversions and Return Flow

Diversions in this river reach are substantial (Figure 2). The total diversions during summer average about $7.8x10^7$ ft^3/day (328 K-AF/6-month period), which is about 43% of the reach inflow at the Near Ashton gage during the summer. Diversions included in the Reach Gain and Loss water budget analysis are identified in Appendix A. Surface water return flows in this reach are very small relative to the other water budget components (Figure 2), and are also listed in Appendix A.

Estimated Gains and Losses

The graphs of reach gains/losses over time indicate that this reach is a gaining and losing reach throughout the 22-year period of analysis (Figures 3 and 4). When the gains and losses are grouped into six-month stress periods (irrigation vs. non-irrigation), there is no apparent seasonality between the irrigation season (May through October) and non-irrigation season (November through April) (Figure 4). The estimated 22-year average reach gains are $1.9x10^6$ ft^3/day (8 K-AF/6-month period) during the irrigation season, and $5.5x10^6$ ft^3/d (23 K-AF/6-month period) (Figure 2) during the non-irrigation season. These values are small relative to the measured river discharge at St. Anthony (Figure 2). The gains appear larger than estimated surface return flows. Estimates of river gain and loss are likely most sensitive to errors in estimates of river inflow and outflow and diversions.

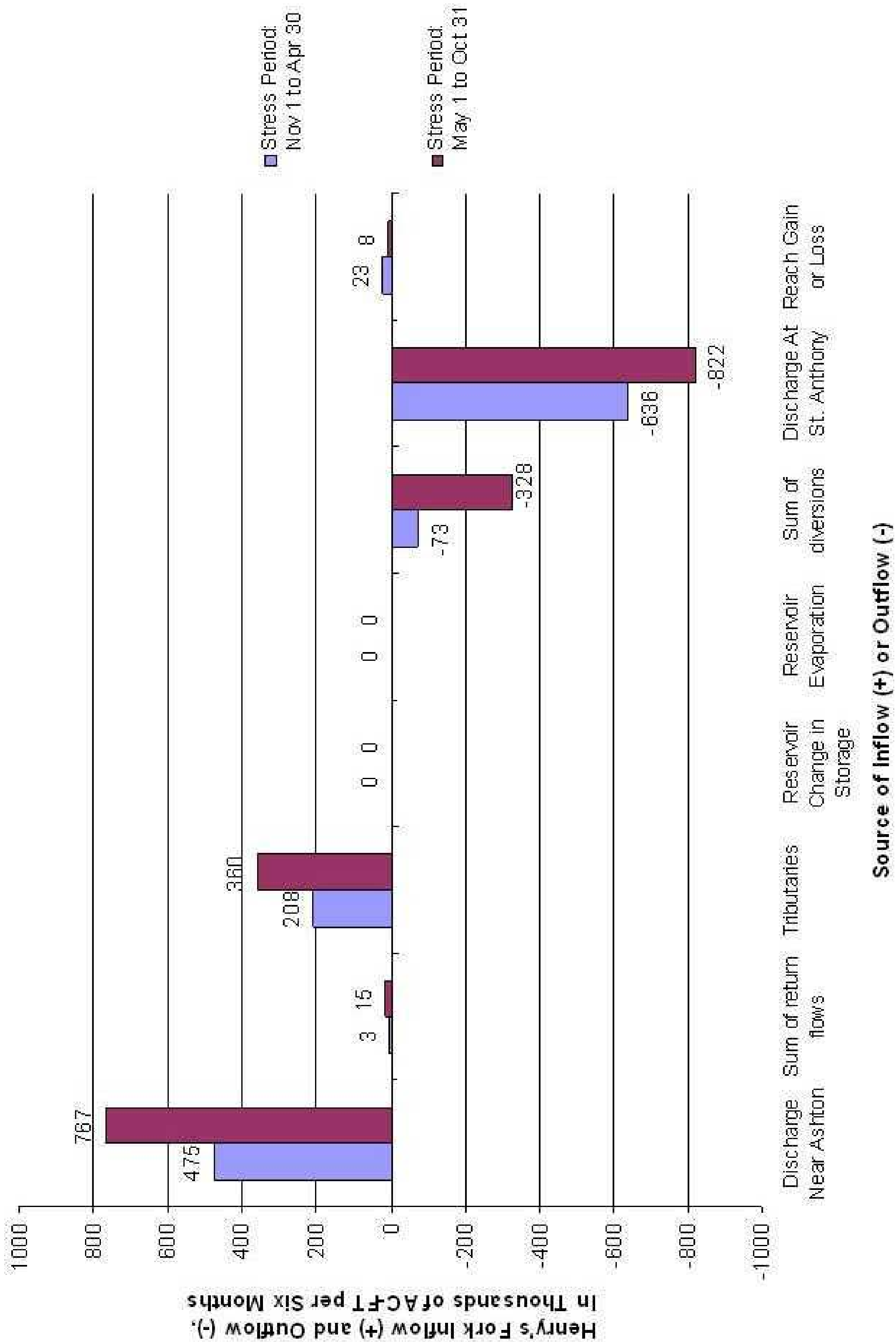

Figure 2. Henry's Fork Inflows and Outflows by Stress Period Averaged Over 22-Year Period from May 1, 1980 to April 30, 2002: Near Ashton to At St. Anthony

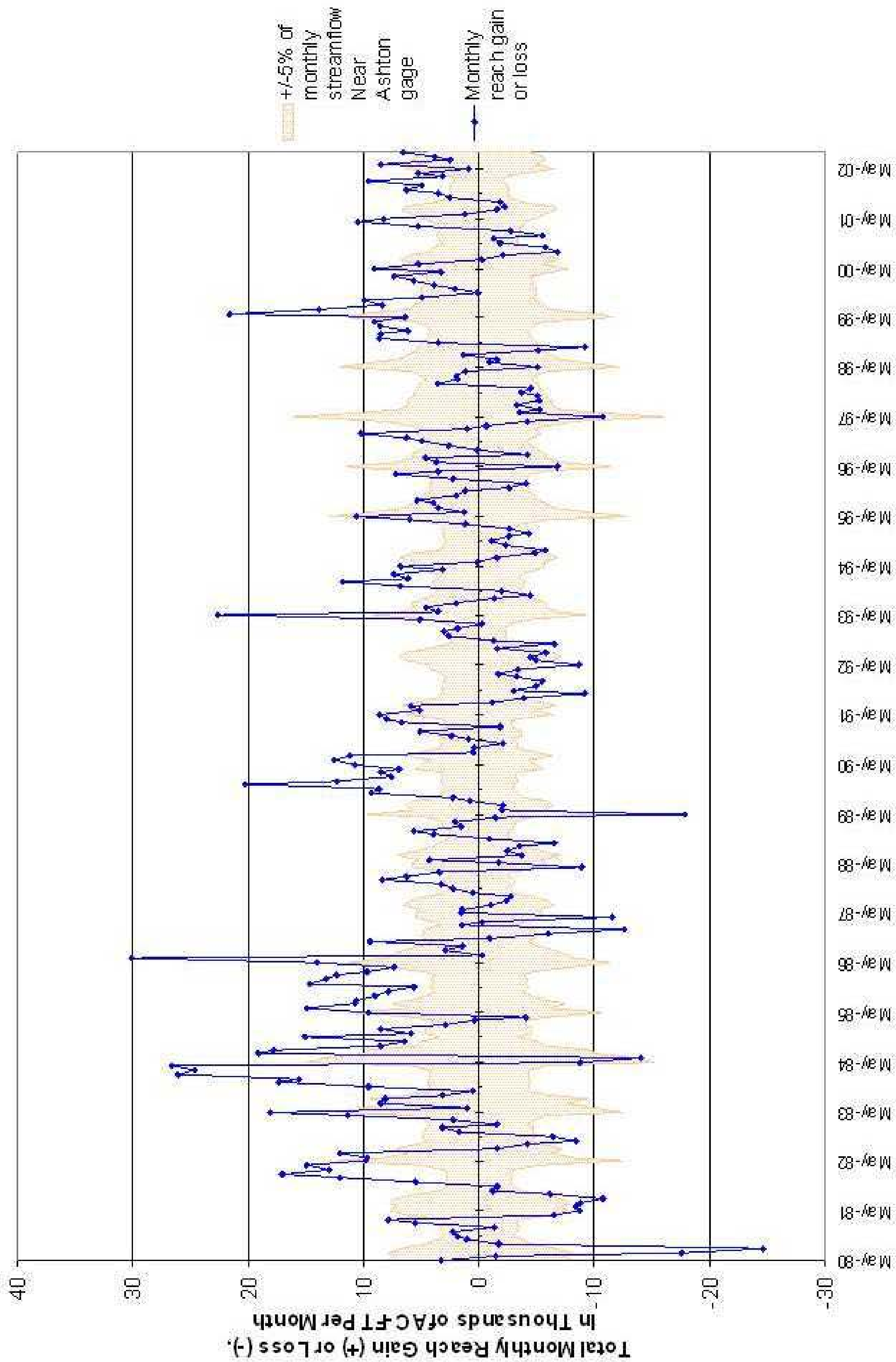

Figure 3. Monthly Henry's Fork Gains and Losses:
Near Ashton to At St. Anthony

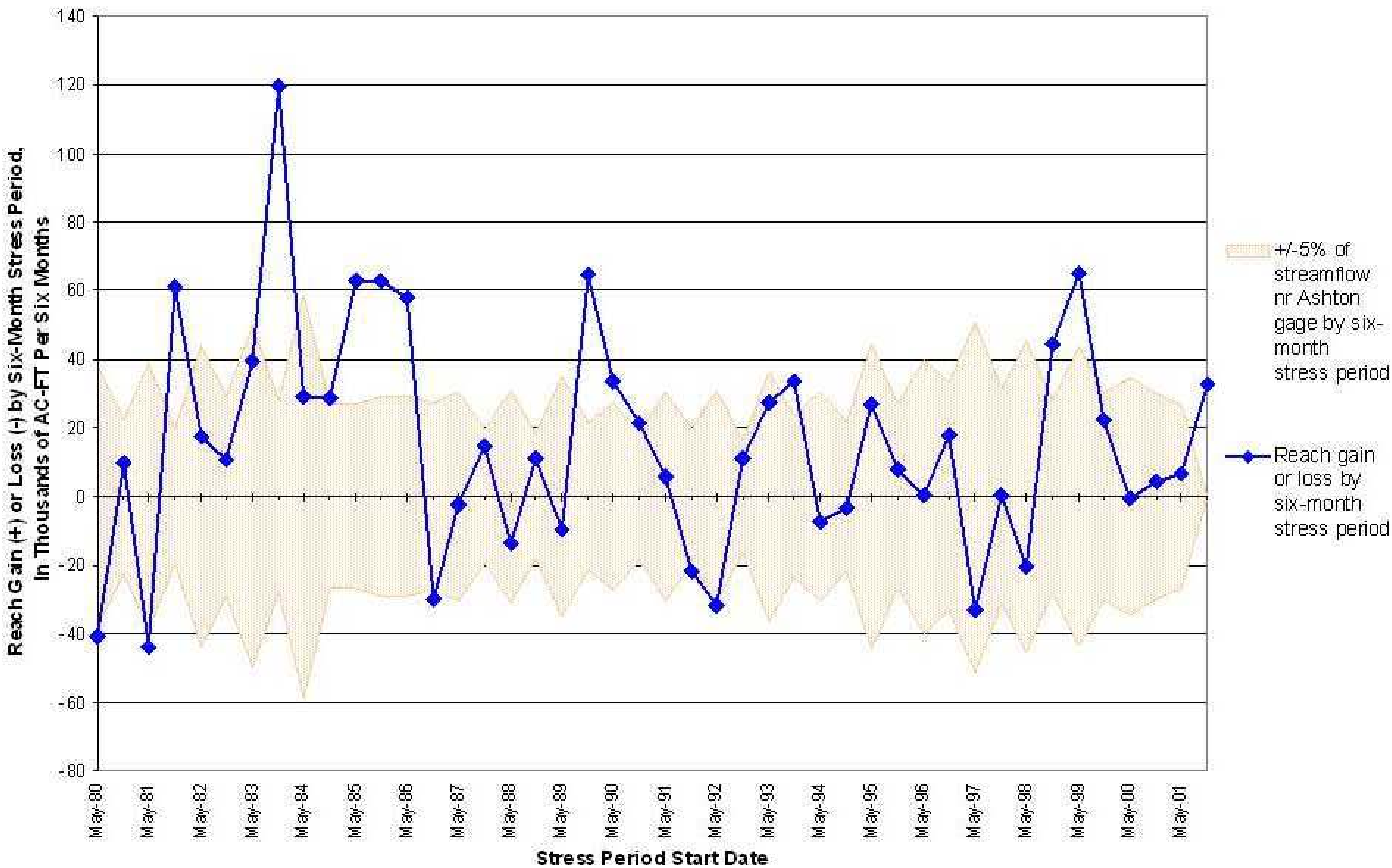

Figure 4. Henry's Fork Gains and Losses Aggregated into Six-Month Stress Periods: Near Ashton to At St. Anthony

REACH 2: AT ST. ANTHONY TO NEAR REXBURG

River Inflow

The Henrys Fork river gage At St. Anthony (station 13050500) has been operational from 1919 to the current year and consequently provided complete coverage for the aquifer model calibration period of 1980 through 2002. During this period, the average flow was about 1.7×10^8 ft^3/day (1458 K-AF/year), with the winter flow averaging about 77% of the summer flow of 2.0×10^8 ft^3/day (822 K-AF/6-month period) (Figure 5). The USGS has rated the At St. Anthony station as generally providing records of "good" quality. This has been interpreted as meaning reported mean daily discharge is within +/- 10% of the true discharge.

River Outflow

The Henrys Fork Near Rexburg gage (station 13056500) has been in operation from 1909 to present and consequently provides complete coverage for the aquifer model calibration period. Average flow from 1980 through 2002 was about 2.1×10^8 ft^3/day (1757 K-AF/year), with the winter flow averaging about 75% of summer flow of 2.4×10^8 ft^3/day (1005 K-AF/6-month period) (Figure 5). The USGS rates the station as generally providing "good" records, except for estimated daily discharges, which are "fair." This is interpreted as meaning the measured daily discharges are within +/- 10% of the true value and the estimated daily discharges are within +/- 15% of the true value. This gage is downstream from all tributaries to the Henrys Fork, except inflow from ground water and irrigation returns.

Tributary Inflows

The Teton River is tributary to the Henrys Fork between St. Anthony and Rexburg. This inflow is accounted for in the reach gain calculation, using data from gage station 13055000, Discharge of Teton River near St. Anthony. Average inflow over the 22-year study period from 1980 to 2002 is about 4.3×10^7 ft^3/day (182 K-AF/6-month period) during the winter period (November through April) and 1.1×10^8 ft^3/day (461 K-AF/6-month period) during the summer period (May through October) (Figure 5).

Diversions and Return Flow

Diversions in this river reach are substantial (Figure 5). The total diversions during summer average about 1.1×10^8 ft^3/day (445 K-AF/6-month period), which is about 54% of the reach inflow at St. Anthony during the summer. Diversions included in the Reach Gain and Loss water budget analysis are identified in Appendix B. Surface water return flows in this reach during the summer average about 2.9×10^6 ft^3/day (12 K-AF/6-month period) and are also listed in Appendix B.

Estimated Gains and Losses

The graphs of reach gains/losses over time indicate that this reach was a consistently gaining reach (with lower gains in winter than in summer) until about water year 1993. Around 1993 the reach began gaining during the summer period (May through October) and losing during the winter period (November through April) (Figures 6 and 7). The seasonal pattern appears consistent with the general pattern of increased aquifer water levels in summer and lower aquifer water levels (presumably increasing hydraulic gradient from the river) in winter.

The estimated 22-year average reach gains are $3.7x10^7$ ft^3/day (154 K-AF/6-month period) during the May through October period, and $8.4x10^6$ ft^3/day (35 K-AF/6-month period) during the November through April period. The diversions in this reach are approximately 40-50% of the measured outflow and inflows, respectively (Figure 5). Estimates of river gain are likely most sensitive to errors in streamflow and diversion measurements.

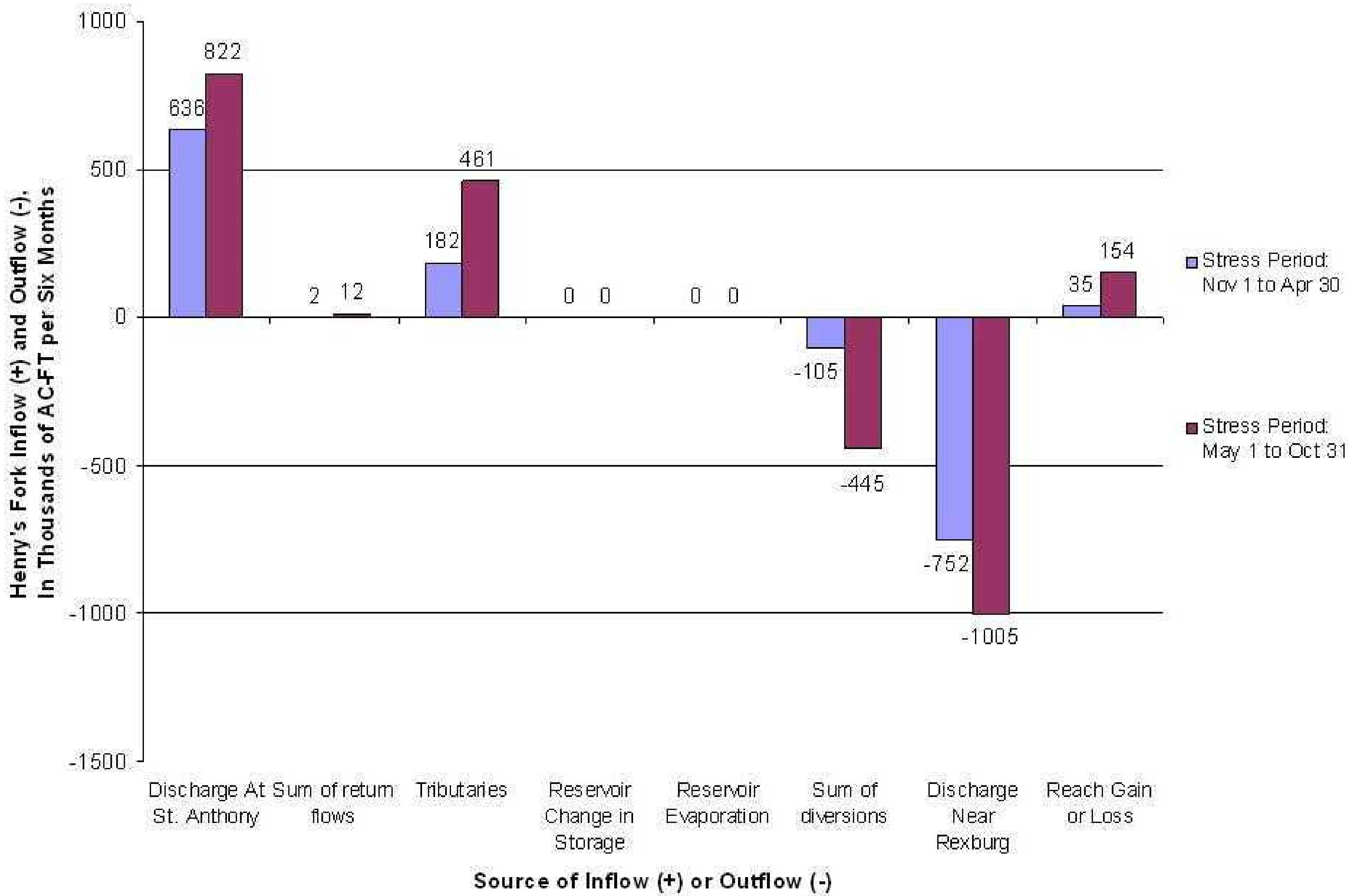

Figure 5. Henry's Fork Inflows and Outflows by Stress Period Averaged Over 22-Year Period from May 1, 1980 to April 30, 2002: At St. Anthony to Near Rexburg

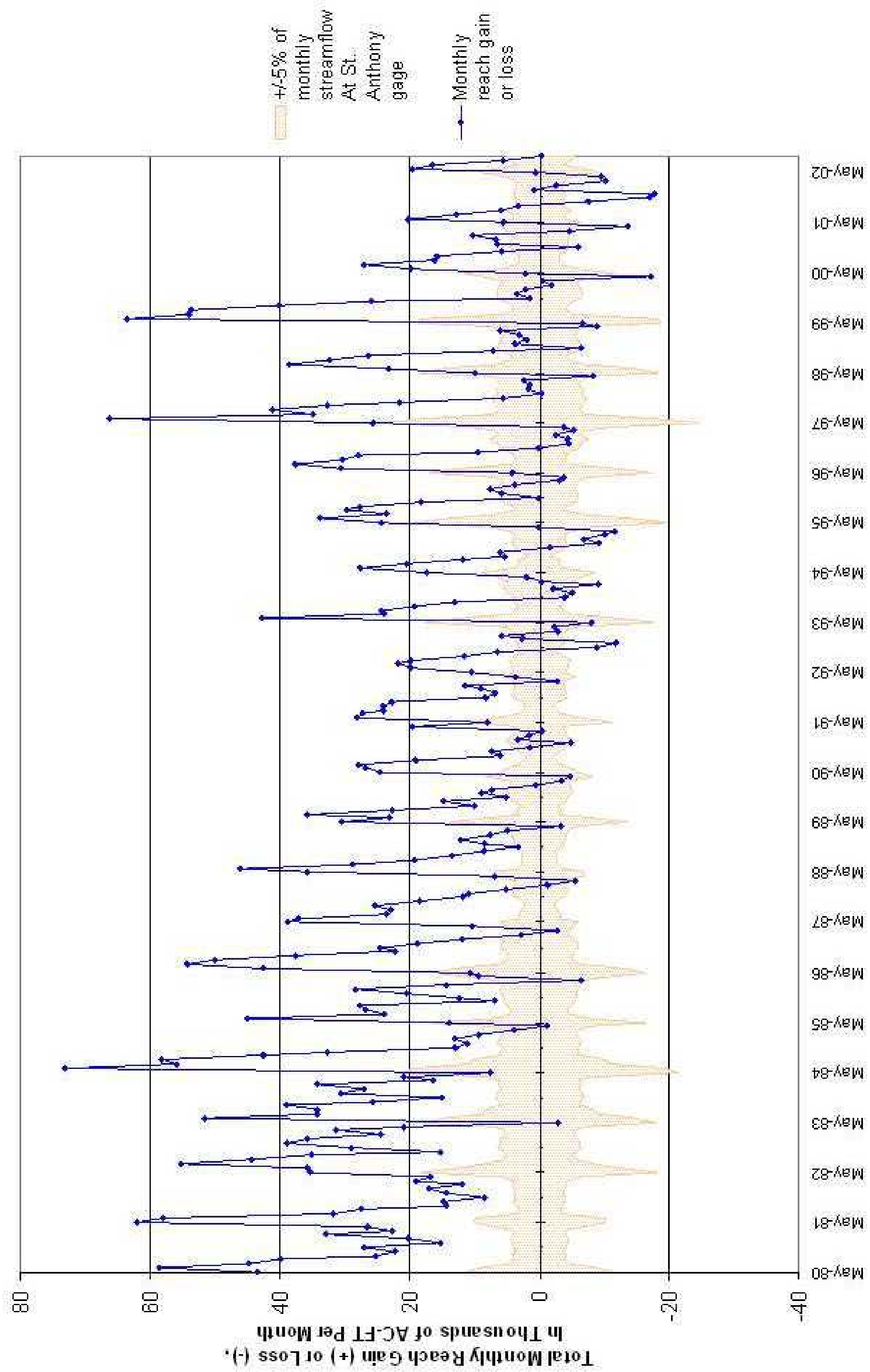

Figure 6. Monthly Henry's Fork Gains and Losses:
At St. Anthony to Near Rexburg

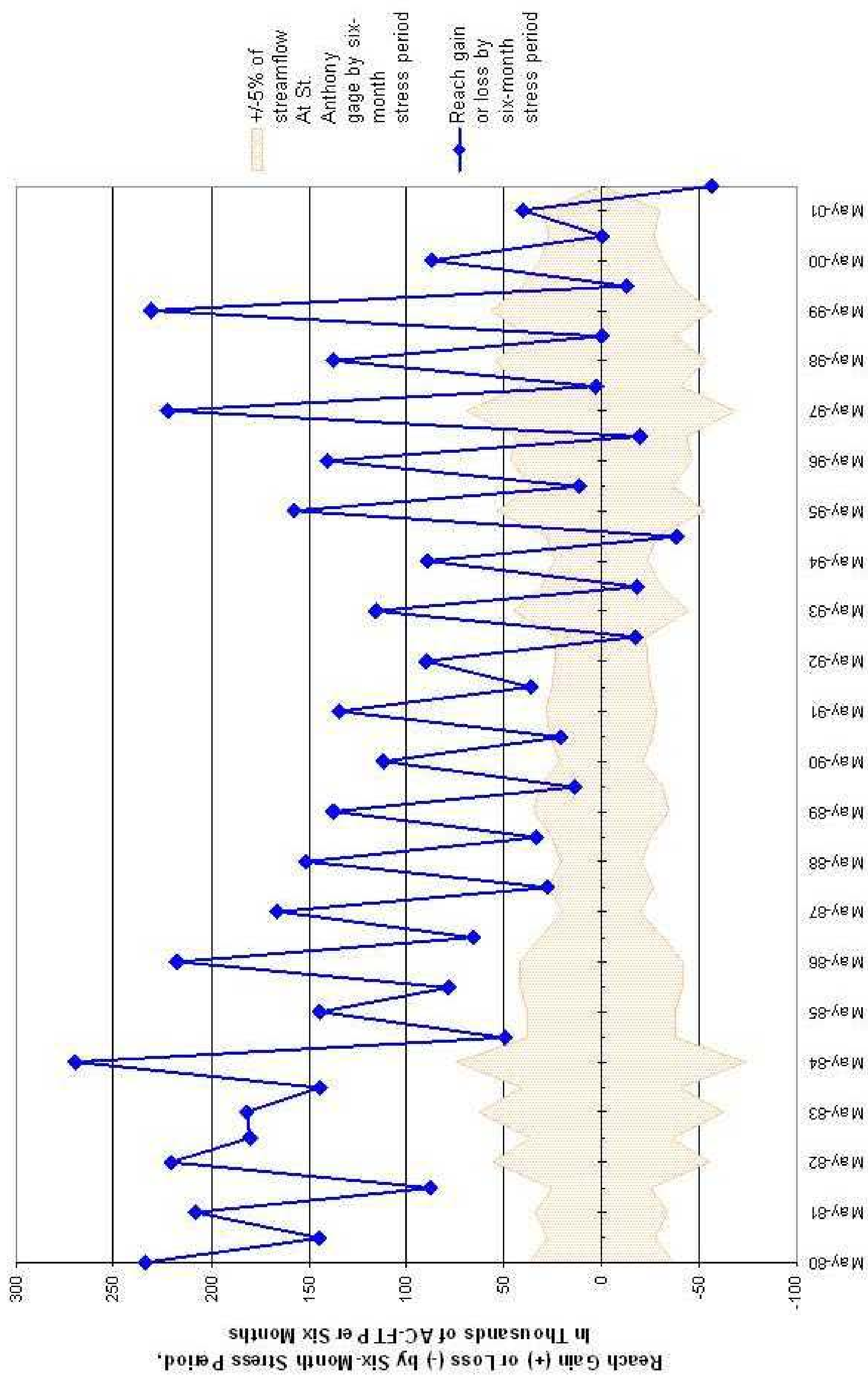

Figure 7. Henry's Fork Gains and Losses Aggregated into Six-Month Stress Periods: At St. Anthony to Near Rexburg

REACH 3: NEAR HEISE TO AT LORENZO

River Inflow

The Snake River enters the area defined as overlying the Snake River Plain aquifer at Heise. The river gage Near Heise (station 13037500) has been operational from 1910 to the current year and consequently provides complete coverage for the aquifer model calibration period of 1980 through 2002. During this period, the average flow was about $6.2x10^8$ ft^3/day (5179 K-AF/year), with average winter flow equaling about 34% of summer flow of $9.2x10^8$ ft^3/day (3870 K-AF/6-month period) (Figure 8). The USGS has rated the Heise station as generally providing records of "good" quality. This has been interpreted as meaning reported mean daily discharge is within +/- 10% of the true discharge. The Heise gage is located in a canyon with little potential for subsurface flow in alluvial sediments to bypass the gaging station. The unmeasured inflow contribution at this location is not thought to be significant.

River Outflow

The At Lorenzo gage (station 13038500) has been in operation from 1978 to present and consequently provides complete coverage for the aquifer model calibration period. Average flow from 1980 through 2002 was about $3.7x10^8$ ft^3/day (3108 K-AF/year), with average winter flow equaling about 46% of summer flow of $5.1x10^8$ ft^3/day (2131 K-AF/year) (Figure 8). The USGS rates the station as generally providing "fair" records. This is interpreted as meaning that daily discharge is within +/- 15% of the true value. The Lorenzo gage is located on a relatively extensive bed of coarse alluvial deposits. It is expected that local ground water flow in the alluvium may allow several million ft^3/day to bypass the gage. This may cause overestimation of losses in this reach and estimation of excessive gains in the Lorenzo to Shelley reach.

Tributary Inflows

There are no tributaries to the Heise to Lorenzo reach.

Diversions and Return Flow

Diversions in this river reach are substantial (Figure 8). The total diversions during summer average about $4.0x10^8$ ft^3/day (1671 K-AF/6-month period), which is about 43% of the reach inflow at Heise during the summer. Diversions included in the Reach Gain and Loss water budget analysis are identified in Appendix C. There are no surface water return flows in this reach (Figure 8).

Estimated Gains and Losses

The graphs of reach gains/losses over time indicate that this reach is primarily a losing reach throughout nearly all of the 22-year period of analysis (Figures 9 and 10). The graph of monthly reach gains and losses (Figure 9) indicates that in some summers particularly in wet years such as 1984 and 1997, this was a gaining reach. During most of the period, the losses appear to be greatest in winter and least in summer. This appears consistent with the general pattern of increased aquifer water levels in summer and lower aquifer water levels (presumably increasing hydraulic gradient from the river) in winter.

Kjelstrom (1995b) found that this reach was gaining during summer and losing during winter in the October 1978 through September 1980 period. He also found good correlation between estimated gains and losses and aquifer water levels in a well near Lorenzo (4N-39E-

16DAD1). The losses produced by the reach gain and loss program appear consistent with Kjelstrom's estimates, in that the losses are greater in winter than in summer. The seasonal distribution of river losses might be more strongly associated with aquifer water levels than with the flow in the river.

The estimated 22-year average reach losses are $1.6x10^7$ ft^3/day (68 K-AF/6-month period) during the May through October period, and $6.8x10^7$ ft^3/day (283 K-AF/6-month period) during the November through April period. The average summer reach loss value is small relative to the measured river discharge at Heise and Lorenzo and relative to irrigation season diversions (Figure 8). The average winter reach loss value is significant relative to the measured river discharge at Heise and Lorenzo. Both summer and winter losses appear substantially larger than estimated surface return flows. Estimates of river loss are likely most sensitive to errors in estimates of river inflow and outflow and diversions. The potential for subsurface flow bypassing the Lorenzo gage (possibly several million ft^3/day) may have a significant impact on the estimated losses of this river reach.

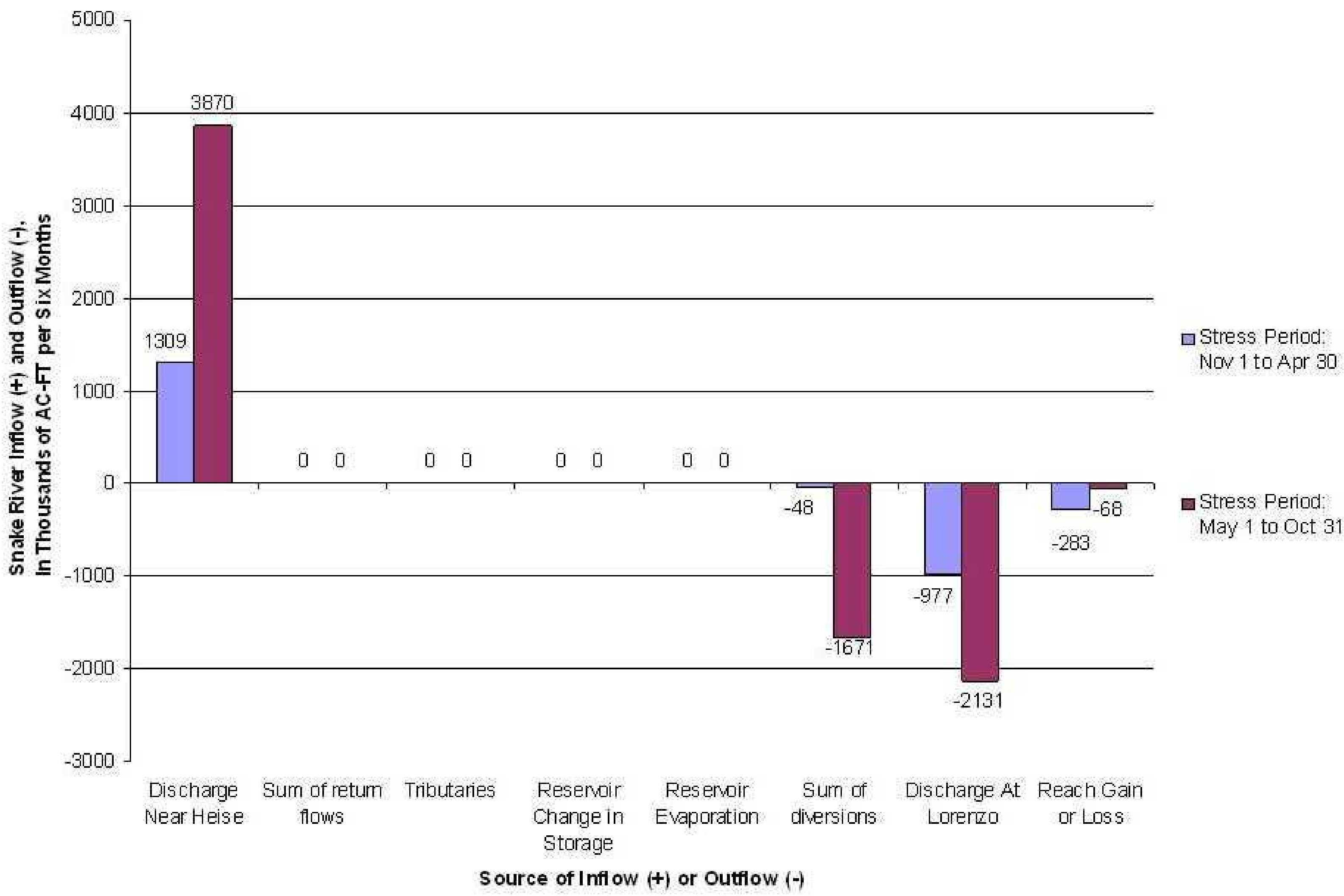

Figure 8. Snake River Inflows and Outflows by Stress Period Averaged Over 22-Year Period from May 1, 1980 to April 30, 2002: Near Heise to At Lorenzo

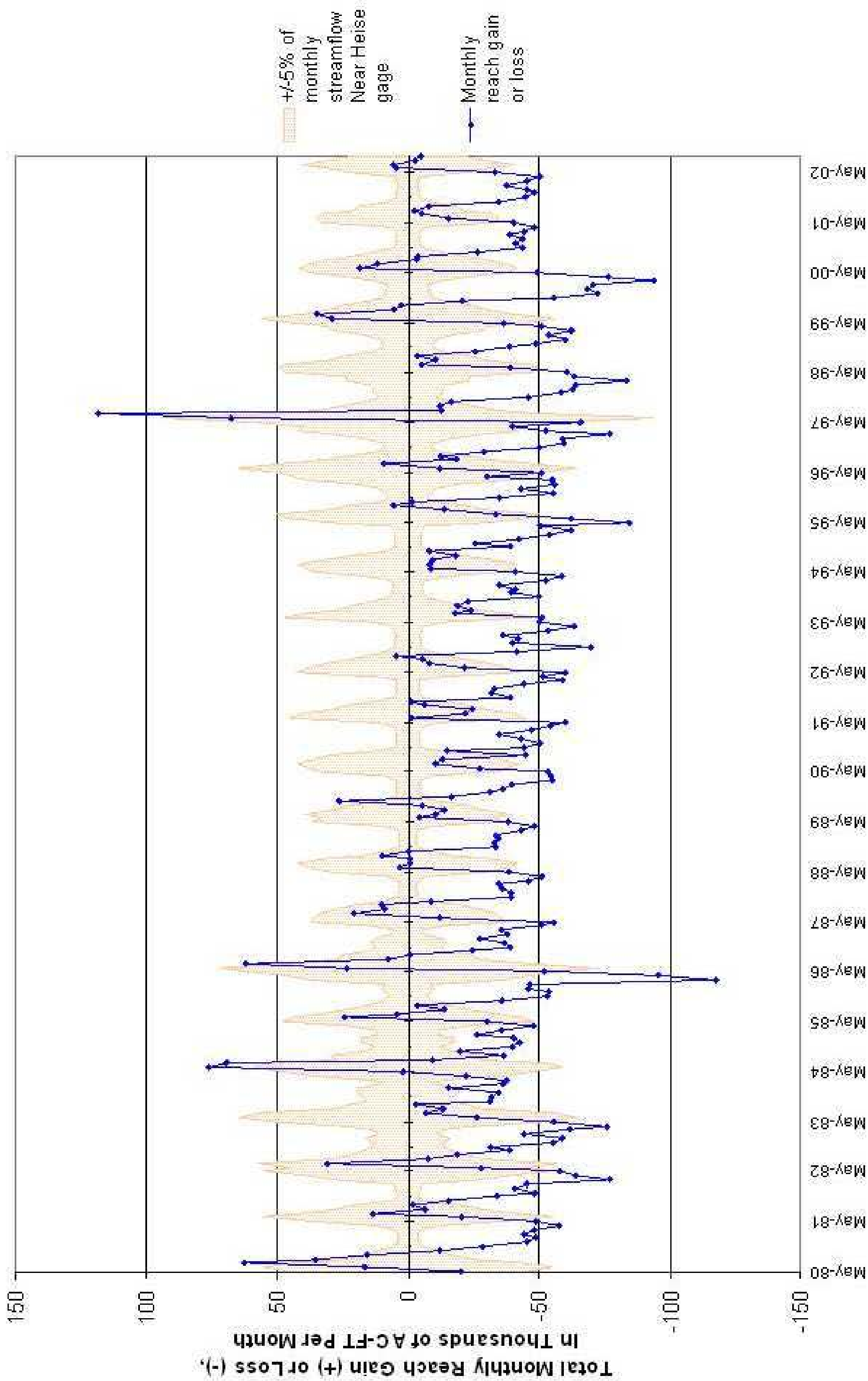

Figure 9. Monthly Snake River Gains and Losses: Near Heise to At Lorenzo

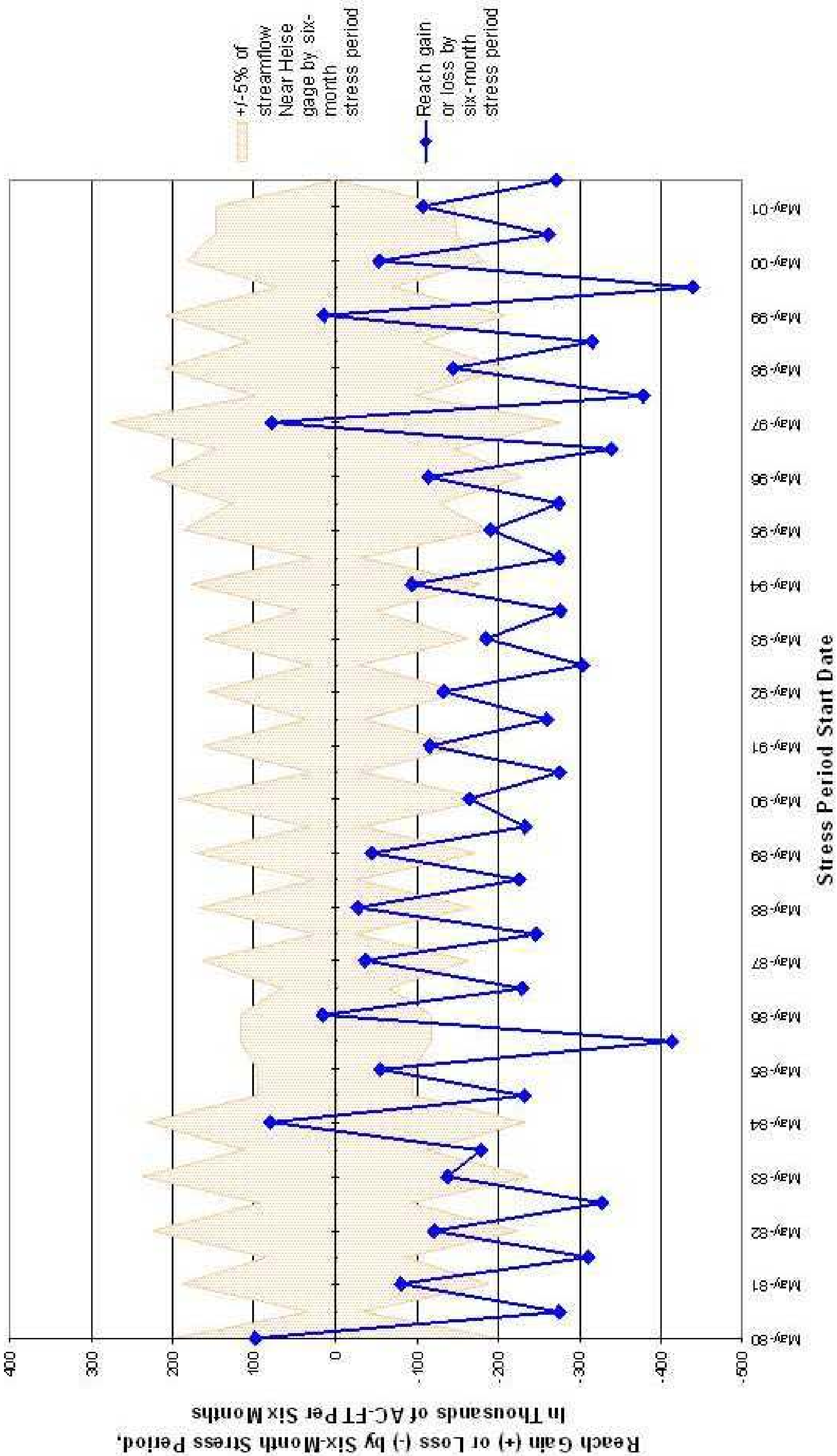

Figure 10. Snake River Gains and Losses Aggregated into Six-Month Stress Periods: Near Heise to At Lorenzo

REACH 4: AT LORENZO TO NEAR SHELLEY

River Inflow

The river gage At Lorenzo (station 13038500) has been operational from 1978 to the current year and consequently provides complete coverage for the aquifer model calibration period of 1980 through 2002. During this period, the average flow was about 3.7×10^8 ft^3/day (3108 K-AF/year), with average winter discharge equaling about 46% of average summer discharge of 5.1×10^8 ft^3/day (2131 K-AF/6-month period) (Figure 11). The USGS has rated the At Lorenzo station as generally providing records of "fair" quality. This has been interpreted as meaning reported mean daily discharge is within +/- 15% of the true discharge. The At Lorenzo gage is located on a relatively extensive bed of coarse alluvial deposits. It is expected that local ground water flow in the alluvium may allow millions of ft^3/day to bypass the gage. This may cause overestimation of losses in the Heise to Shelley reach and excessive gain estimation in the Lorenzo to Shelley reach.

River Outflow

The Near Shelley gage (station 13060000) has been in operation from 1915 to present and consequently provides complete coverage for the aquifer model calibration. Average flow from 1980 through 2002 was about 5.5×10^8 ft^3/day (4596 K-AF/year), with average winter flow equaling about 61% of average summer flow of 6.8×10^8 ft^3/day (2851 K-AF/6-month period) (Figure 11). The USGS rates the station as generally providing "good" records, except for estimated daily discharges, which are "fair". This is interpreted as meaning that the daily discharge records are within +/- 15% of the true value.

Tributary Inflows

Both the Henrys Fork and Willow Creek are tributary to the Snake River in the Lorenzo to Shelley reach. These tributaries are accounted for in the reach gain and loss calculation (Figure 11) using data from gaging stations 13056500, Discharge of Henrys Fork near Rexburg, and 13058530, Discharge of Willow Creek below Floodway Channel near Ucon.

Spring Creek is also tributary to the Snake River in the Lorenzo to Shelley reach, but is not accounted for in the reach gain and loss calculation.

Diversions and Return Flow

Diversions in this river reach are substantial (Figure 11). The total diversions during summer average about 1.7×10^8 ft^3/day (733 K-AF/6-month period), which is about 34% of the average summer inflow at Lorenzo. Diversions included in the reach gain and loss water budget analysis are identified in Appendix D. Average summer surface water return flows in this reach over the 22-year study period are estimated to be 1.1×10^8 ft^3/day (450 K-AF/6-month period) (Figure 11), and are also listed in Appendix D.

Estimated Gains and Losses

The graphs of reach gains/losses over time indicate that this reach both gains and loses water (Figures 12 and 13). During most of the period, the losses appear to be greatest in winter and least in summer. The estimated 22-year average reach gain is about 9.1×10^6 ft^3/day (38 K-AF/6-month period) during the May through October period, and the 22-year average reach loss is about 8.8×10^6 ft^3/day (37 K-AF/6-month period) during the November through April period.

This is consistent with the general pattern of increased aquifer water levels in summer and lower aquifer water levels (presumably increasing hydraulic gradient from the river) in winter.

These reach gain and loss values are small relative to the measured river discharges at Lorenzo and Shelley, to the return flow component, and relative to diversions (Figure 11). Estimates of river loss are likely most sensitive to errors in estimates of river inflow, outflow, diversions, and return flows. The potential for subsurface flow bypassing the Lorenzo gage (possibly millions of ft^3/day) may have a significant impact on the estimated losses of this river reach.

Kjelstrom (1995b) divided this reach into two smaller reaches, Lorenzo to Lewisville and Lewisville to Shelley. Because the Lewisville gage (13057150) has a measurement period from 1978 to 1983, further reach discretization of the Lorenzo to Shelley reach was not performed for the purpose of reach gain and loss calculation. For the Lorenzo to Lewisville reach, Kjelstrom (1995b) found that the Snake River gains from ground water during most of the measurement period from October 1978 to September 1980, and gains more water during the irrigation season than the non-irrigation season.

In the Lewisville to Shelley reach, Kjelstrom (1995b) found that for the October 1978 to September 1980 period, the Snake River generally lost water to the aquifer. By examining reach gains and losses in the river with water levels from periodic measurements in a nearby well (2N-38E-16ADD1, water years 1979-1980), Kjelstrom (1995b) determined that river losses decreased as ground water levels rose due to canal seepage and percolation of irrigation water.

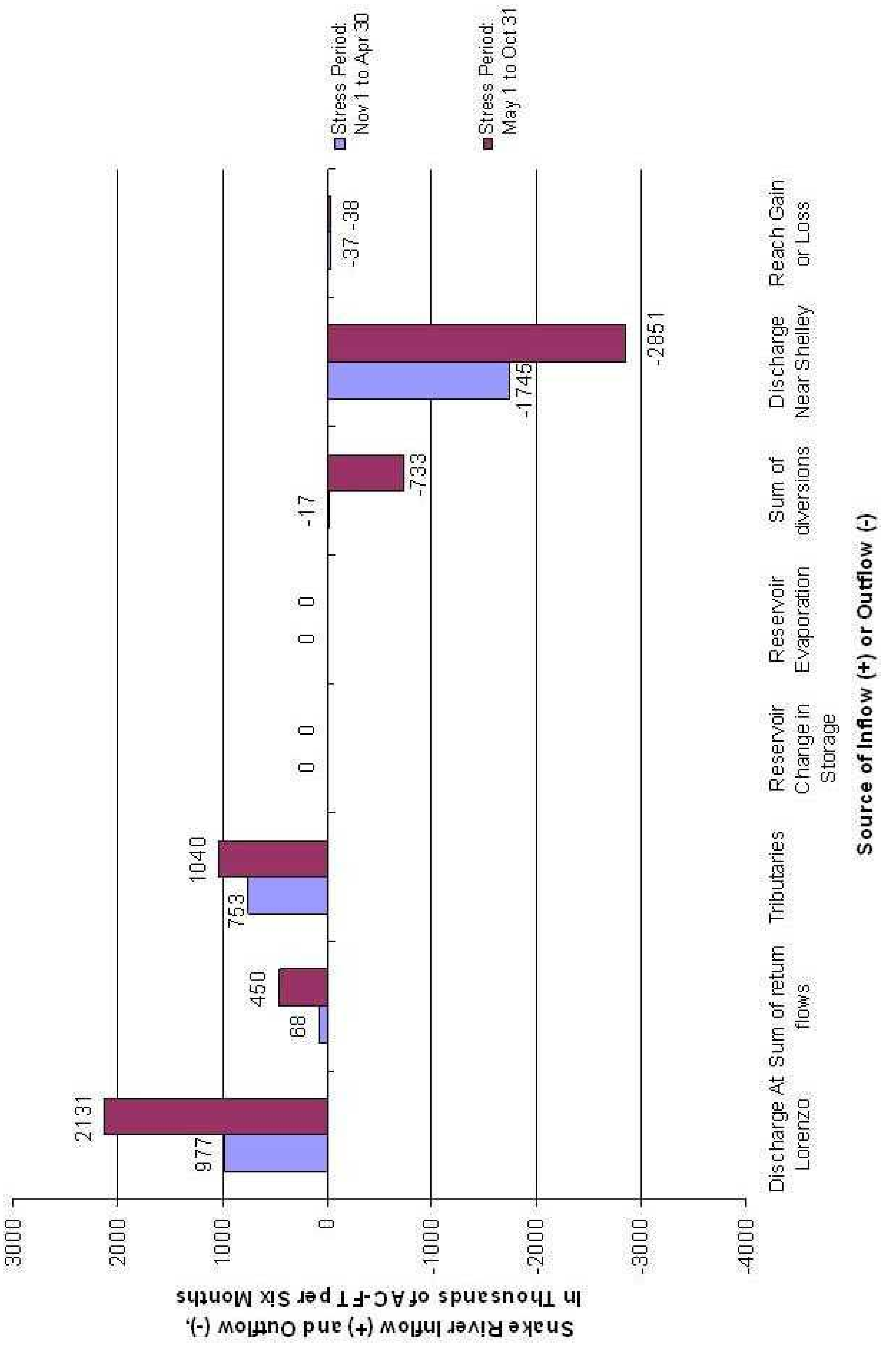

Figure 11. Snake River Inflows and Outflows by Stress Period Averaged Over 22-Year Period from May 1, 1980 to April 30, 2002: At Lorenzo to Near Shelley

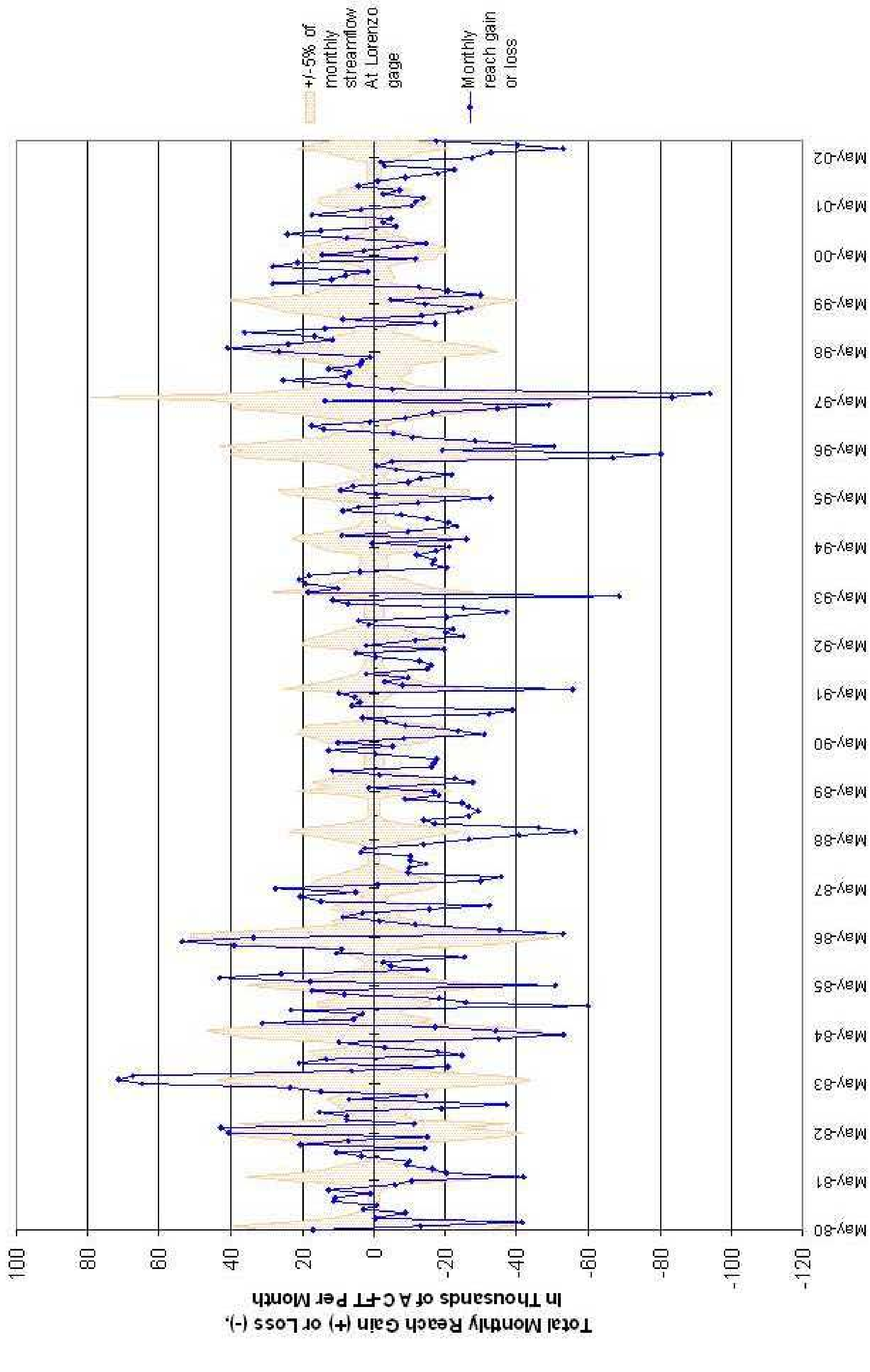

Figure 12. Monthly Snake River Gains and Losses: At Lorenzo to Near Shelley

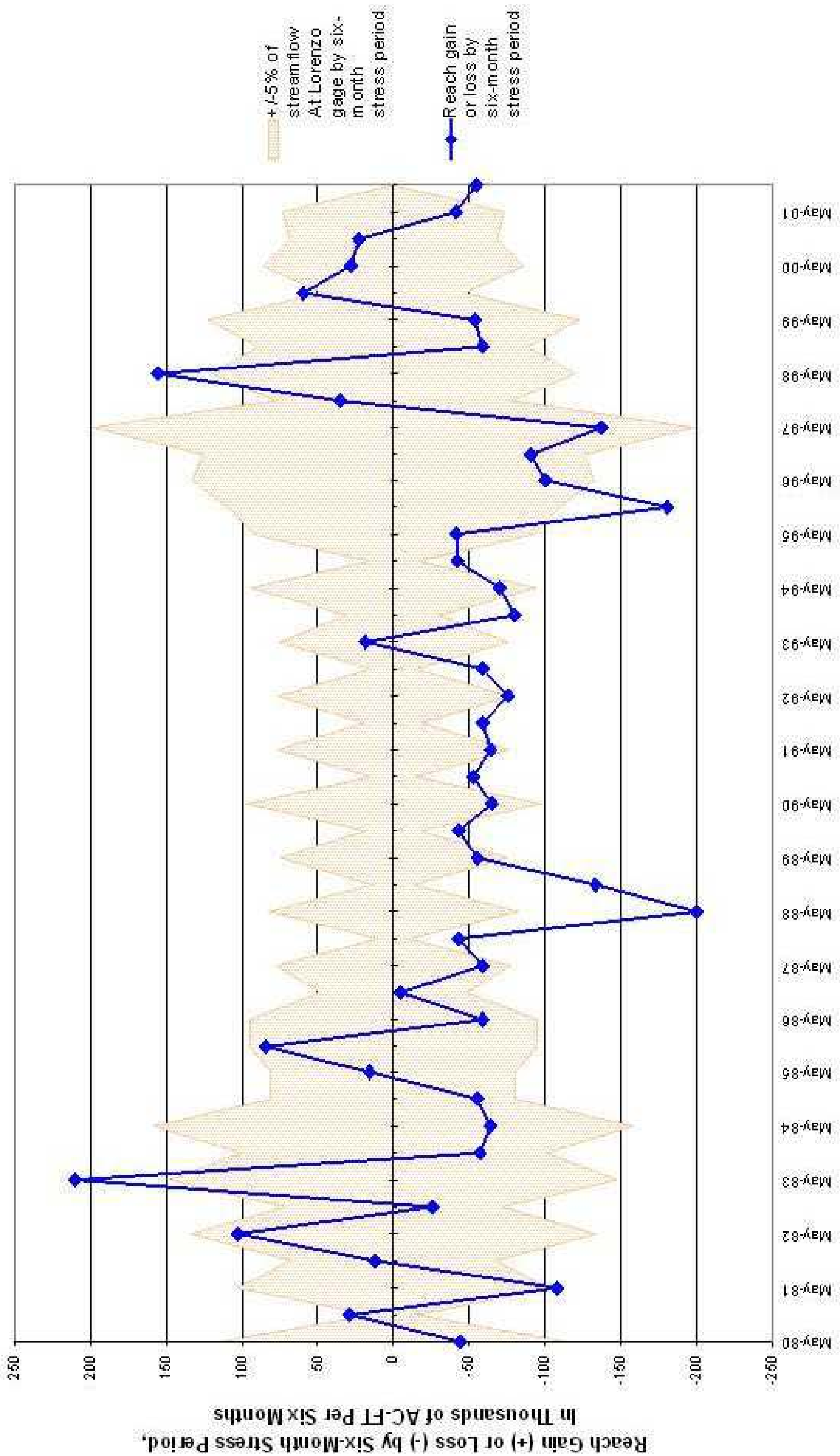

Figure 13. Snake River Gains and Losses Aggregated into Six-Month Stress Periods: At Lorenzo to Near Shelley

REACH 5: NEAR SHELLEY TO AT BLACKFOOT

River Inflow

The Snake River Near Shelley gage (station 13060000) has been operational from 1915 to present and consequently provides complete coverage for the aquifer model calibration period of 1980 through 2002. During this period, the average flow was about 5.5×10^8 ft^3/day (4596 K-AF/year), with average winter flow equaling about 61% of average summer flow of 6.8×10^8 ft^3/day (2851 K-AF/6-month period) (Figure 14). The USGS rates the Near Shelley station as generally providing records of "good" quality, except for estimated daily discharges, which are of "fair" quality. This is interpreted as meaning the measured daily discharges are within +/- 10% of the true value and the estimated daily discharges are within +/- 15% of the true value.

River Outflow

The Snake River At Blackfoot gage (station 13062500) has been in operation from 1978 to present and consequently provides complete coverage for the aquifer model calibration period. Average flow from 1980 through 2002 was about 4.4×10^8 ft^3/day (3699 K-AF/year), with average winter flow equaling about 76% of average summer flow of 5.0×10^8 ft^3/day (2103 K-AF/6-month period) (Figure 14). The USGS rates the At Blackfoot station as generally providing "good" records, except for estimated daily discharges, which are "fair". This is interpreted as meaning the measured daily discharges are within +/- 10% of the true value and the estimated daily discharges are within +/- 15% of the true value.

Tributary Inflows

There are no tributaries to the Snake River between the Snake River near Shelley gage and the Snake River at Blackfoot gage.

Diversions and Return Flow

Irrigation season diversions in this reach of the Snake River are substantial (Figure 14). The average diversions during the summer period (May through October) average about 1.8×10^8 ft^3/day (773 K-AF/6-month period), which is about 27% of the summer period reach inflow at the Near Shelley gage. Diversions included in the reach gain and loss water budget analysis are identified in Appendix E. Surface water return flows in this reach averaged about 5.0×10^7 ft^3/day (209 K-AF/6-month period) during the summer period over the 22-year study period (Figure 14), and are also listed in Appendix E.

Estimated Gains and Losses

The graphs of reach gains/losses over time indicate that this reach has generally been a losing reach between water years 1987 and 2002, and both a gaining and losing reach between water years 1980 and 1986 (Figure 15 and 16). Extreme river loss to the aquifer (relative to the average monthly reach loss) occurred in June 1997, which is consistent with significant flooding during the spring of 1997. When reach gain and loss estimates are aggregated into six-month stress periods (May through October, and November through April), it is observed that a change occurs in the seasonality of the reach gain or loss between water years 1986 and 1987. Prior to water year 1987, losses were greatest during the winter stress period (Figure 16). Starting in water year 1987, losses were often greatest during the summer stress period (Figure 16). The reason for this change in seasonality is unknown.

For water years 1979 and 1980, Kjelstrom (1995b) noted that during the irrigation season, ground water levels rise and the Snake River gains from ground water, and during the non-irrigation season, ground water levels decline and the Snake River loses to ground water. This is consistent with the seasonal reach loss observation for water years 1980 to 1986 of the current study, but inconsistent for water years 1987 to 2002.

For the model period, the reach was, on the average, a losing reach. Average summer losses were $4.4x10^7$ ft^3/day (183 K-AF/6-month period). Average winter losses were $3.5x10^7$ ft^3/day (148 K-AF/6-month period) (Figure 14).

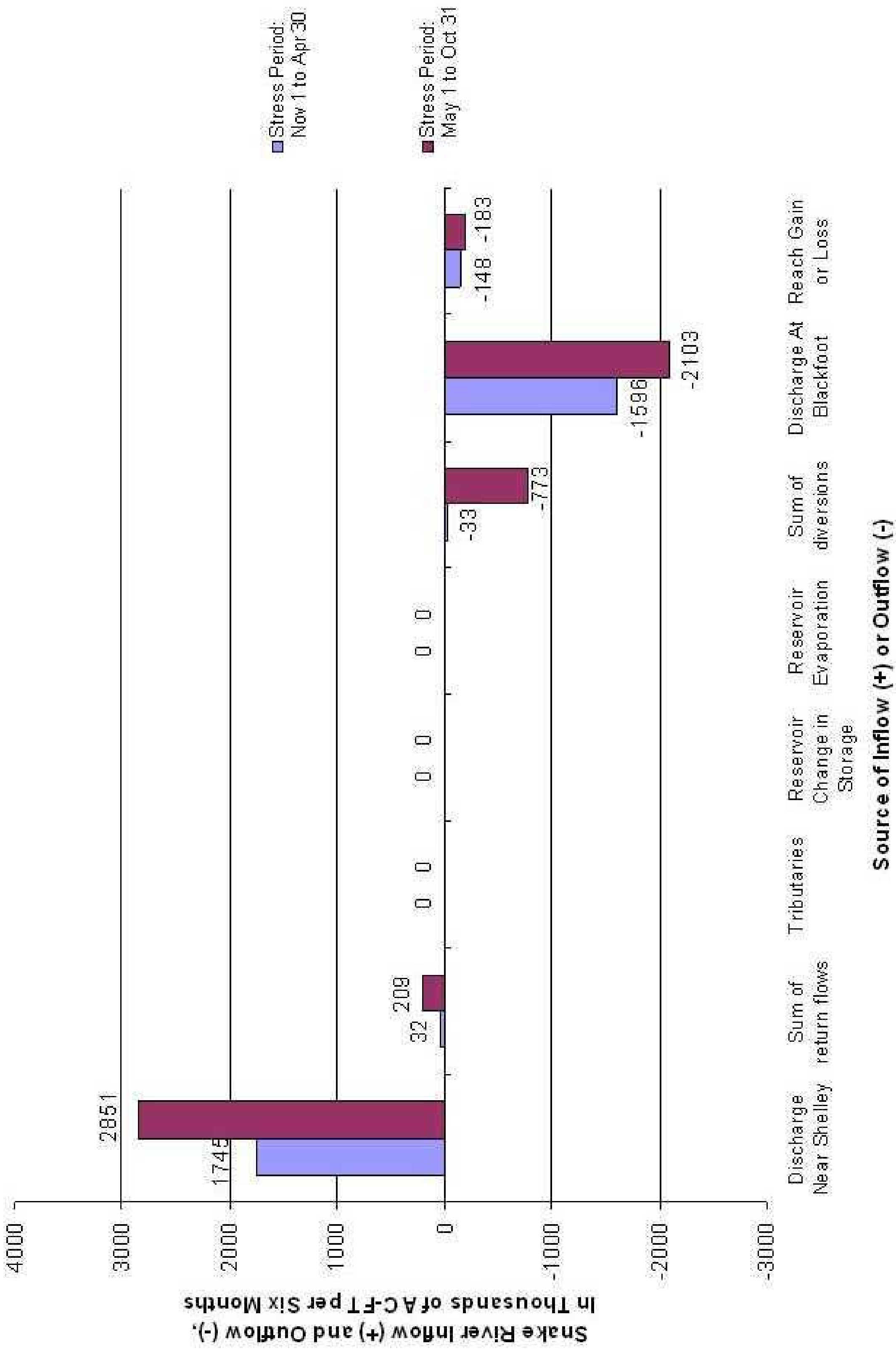

Figure 14. Snake River Inflows and Outflows by Stress Period Averaged Over 22-Year Period from May 1, 1980 to April 30, 2002: Near Shelley to At Blackfoot

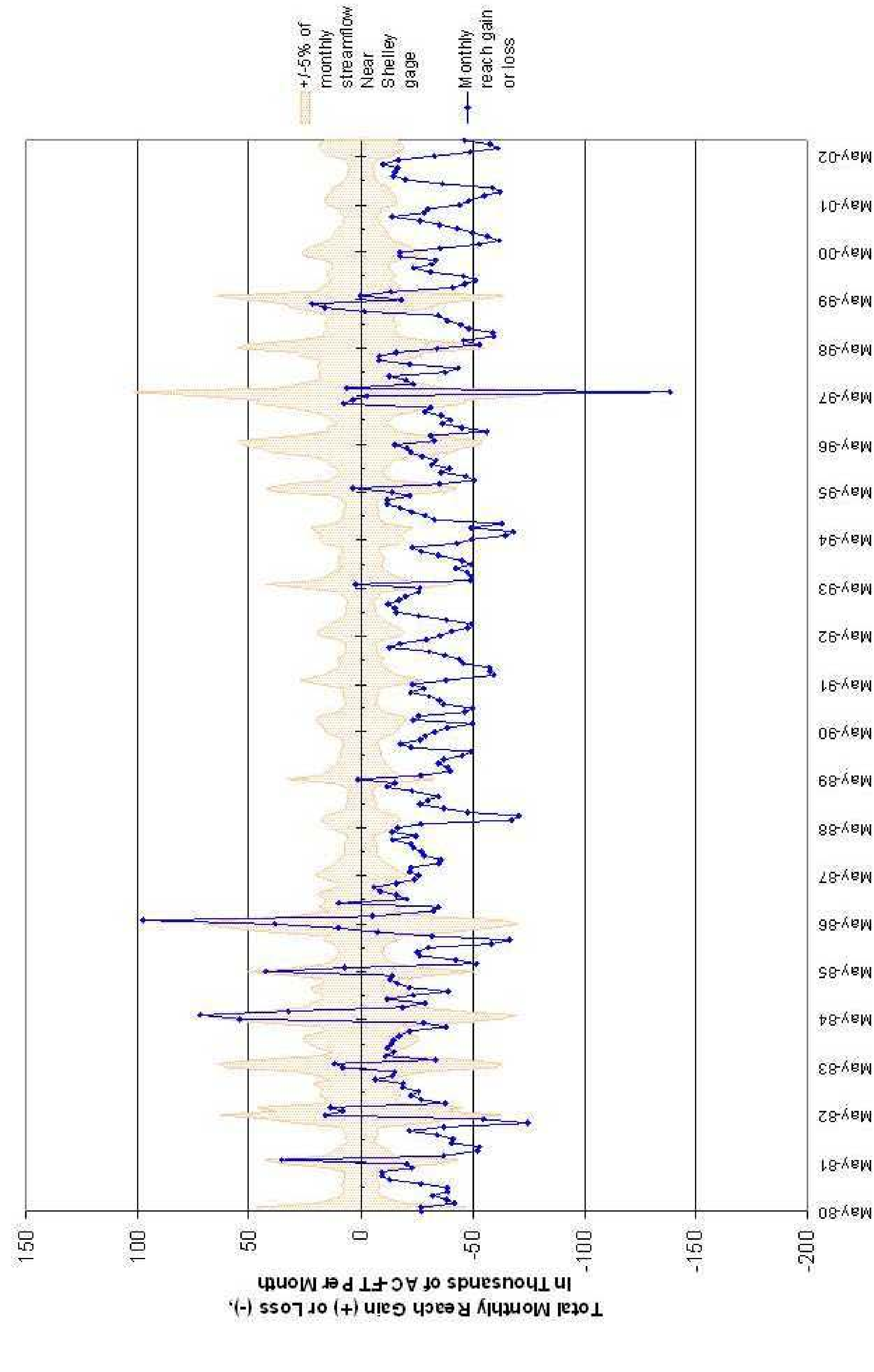

Figure 15. Monthly Snake River Gains and Losses: Near Shelley to At Blackfoot

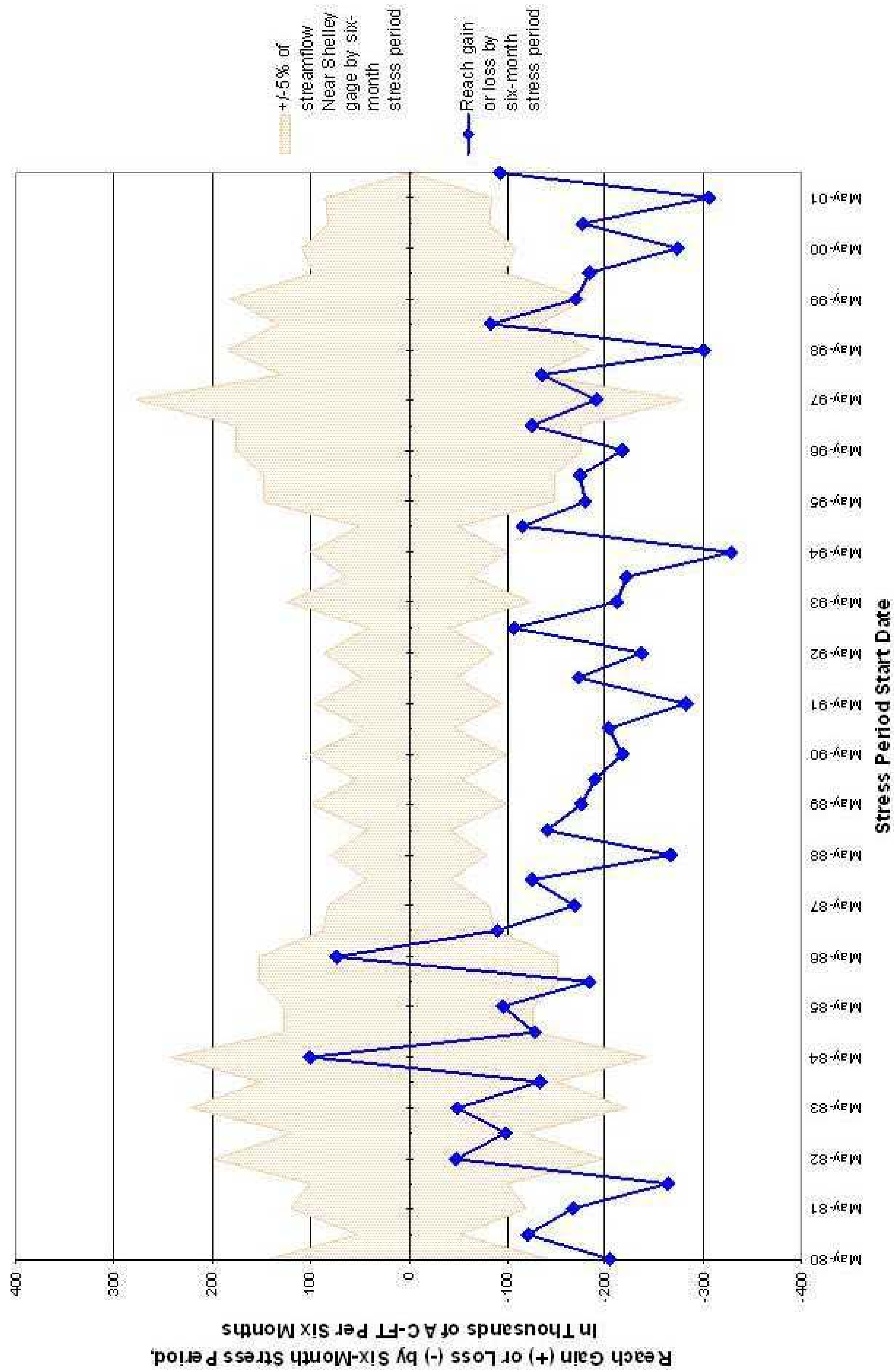

Figure 16. Snake River Gains and Losses Aggregated into Six-Month Stress Periods: Near Shelley to At Blackfoot

REACH 6: AT BLACKFOOT TO NEAR BLACKFOOT

River Inflow

The Snake River At Blackfoot gage (station 13062500) has been operational from 1978 to present and consequently provides complete coverage for the aquifer model calibration period of 1980 through 2002. During this period, the average flow was about 4.4×10^8 ft^3/day (3699 K-AF/year), with average winter flow equaling about 76% of average summer flow of 5.0×10^8 ft^3/day (2103 K-AF/6-month period) (Figure 17). The USGS rates the near Shelley station as generally providing records of "good" quality, except for estimated daily discharges, which are of "fair" quality. This is interpreted as meaning the measured daily discharges are within +/- 10% of the true value and the estimated daily discharges are within +/- 15% of the true value.

River Outflow

The Snake River Near Blackfoot gage (station 13069500) has been in operation from 1910 to present and consequently provides complete coverage for the aquifer model calibration period. Average flow from 1980 through 2002 was about 4.4×10^8 ft^3/day (3680 K-AF/year), with average winter flow equaling about 78% of average summer flow of 4.9×10^8 ft^3/day (2072 K-AF/6-month period) (Figure 17). The USGS rates the Near Blackfoot station as generally providing "good" records, which is interpreted to mean the measured daily discharges are within +/- 10% of the true value.

Tributary Inflows

The Blackfoot River is tributary to the Snake River in the At Blackfoot to Near Blackfoot river reach. This inflow is accounted for in the reach gain calculation using station 13068501, Discharge of Blackfoot River near Blackfoot and Bypass. Average inflow over the 22-year study period from 1980 to 2002 is about 1.9×10^7 ft^3/day (80 K-AF/6-month period) during the winter period (November through April) and about 2.5×10^7 ft^3/day (105 K-AF/6-month period) during the summer period (May through October) (Figure 17).

Diversions and Return Flow

Diversions in the At Blackfoot to Near Blackfoot river reach are minimal, and averaged about 1.2×10^7 ft^3/day (50 K-AF/6-month period) during the summer (May through October) from 1980 to 2002 (Figure 17). Surface water return flows in this reach are larger than the amount of water diverted reflecting returns from diversions made from upstream reaches, and averaged about 1.5×10^7 ft^3/day (64 K-AF/6-month period) during the summer from 1980 to 2002 (Figure 17). Diversions and surface water return flows included in the reach gain and loss water budget analysis for this reach are identified in Appendix F.

Estimated Gains and Losses

The graphs of reach gains/losses over time indicate that this reach is a consistently losing reach throughout most of the 22-year period of study (Figures 18 and 19), even though there are springs that discharge to the river between the At Blackfoot and Near Blackfoot gages.

During most of the study period, the losses appear to be greatest in summer and least in winter. The average summer period reach loss from 1980 to 2002 was about 3.6×10^7 ft^3/day (150 K-AF/6-month period) and the average winter period reach loss was about 1.8×10^7 ft^3/day (76 K-AF/6-month period) (Figure 17).

Kjelstrom (1995b) noted that discharge from springs in this reach mitigates streamflow loss, and that spring discharge is greatest when ground water levels in surface water irrigated areas are highest, at the end of an irrigation season, and lowest prior to the next irrigation season. Kjelstrom compared water levels in a nearby well with spring discharge for water years 1979 to 1980, and found that water levels generally corresponded with seasonal changes in spring discharge.

Diversion, tributary inflows and return flows are all small relative to total reach flow, so it is anticipated that the error in estimating the reach gains/losses will primarily be derived from gage errors at the inflow and outflow.

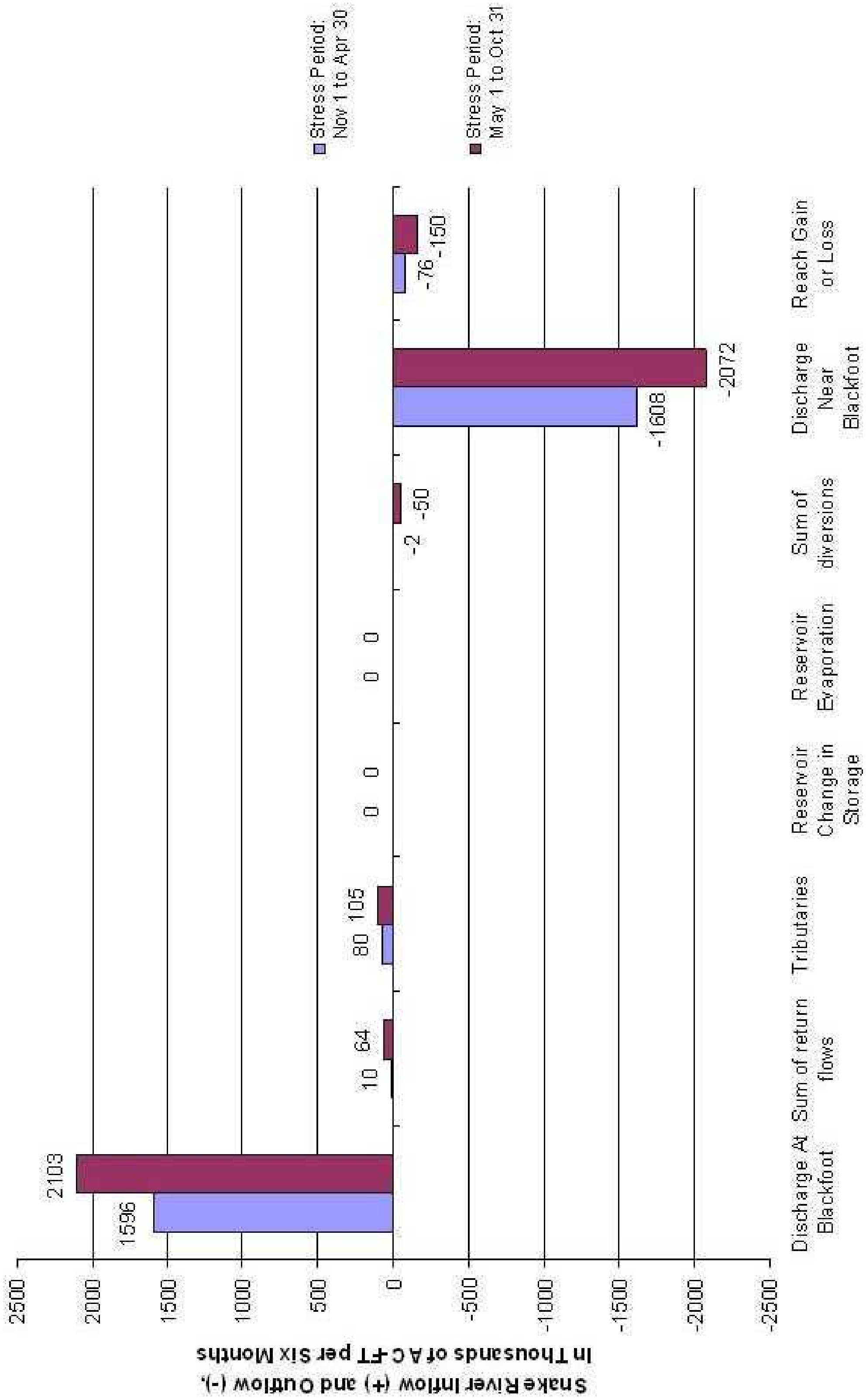

Figure 17. Snake River Inflows and Outflows by Stress Period Averaged Over 22-Year Period from May 1, 1980 to April 30, 2002: At Blackfoot to Near Blackfoot

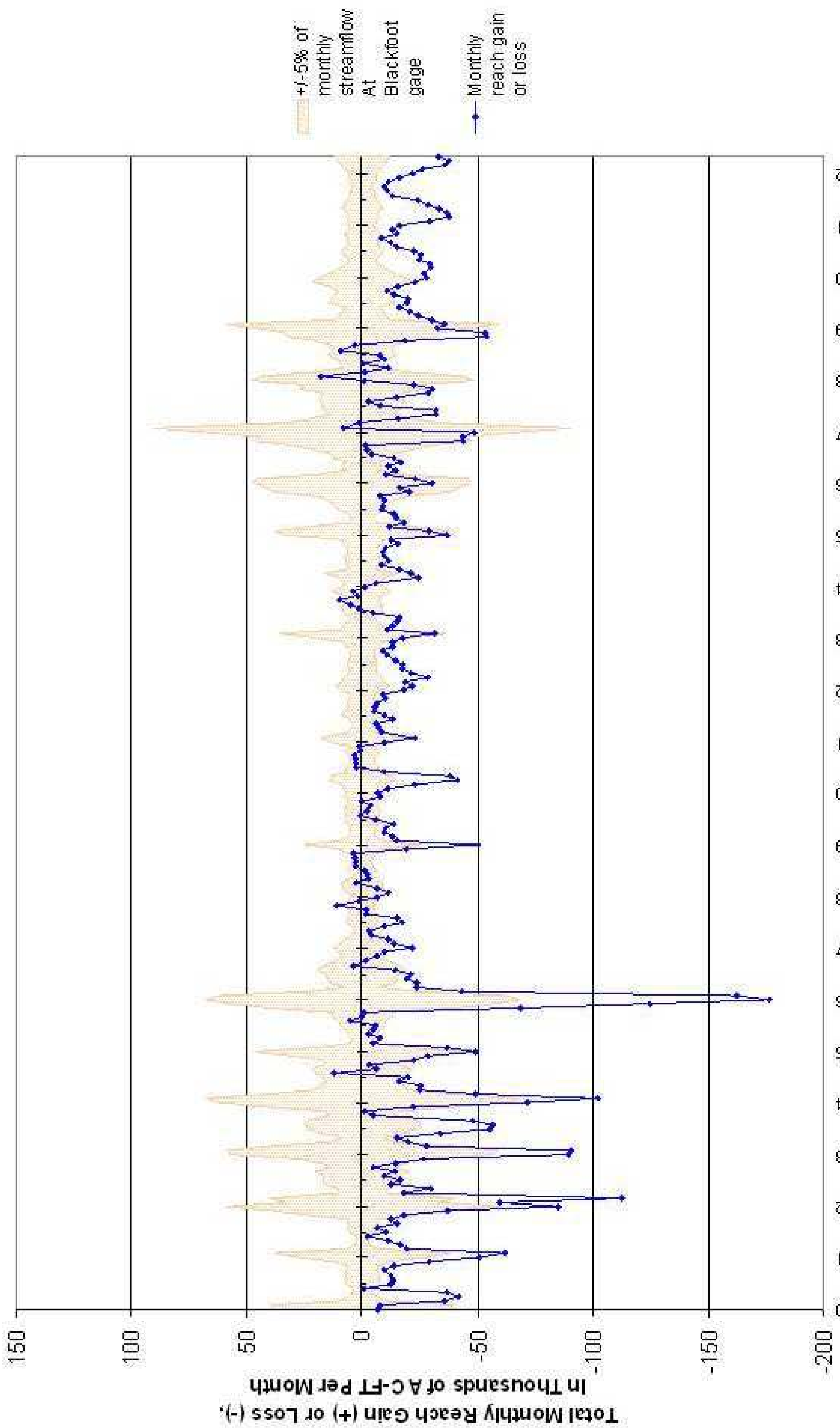

Figure 18. Monthly Snake River Gains and Losses: At Blackfoot to Near Blackfoot

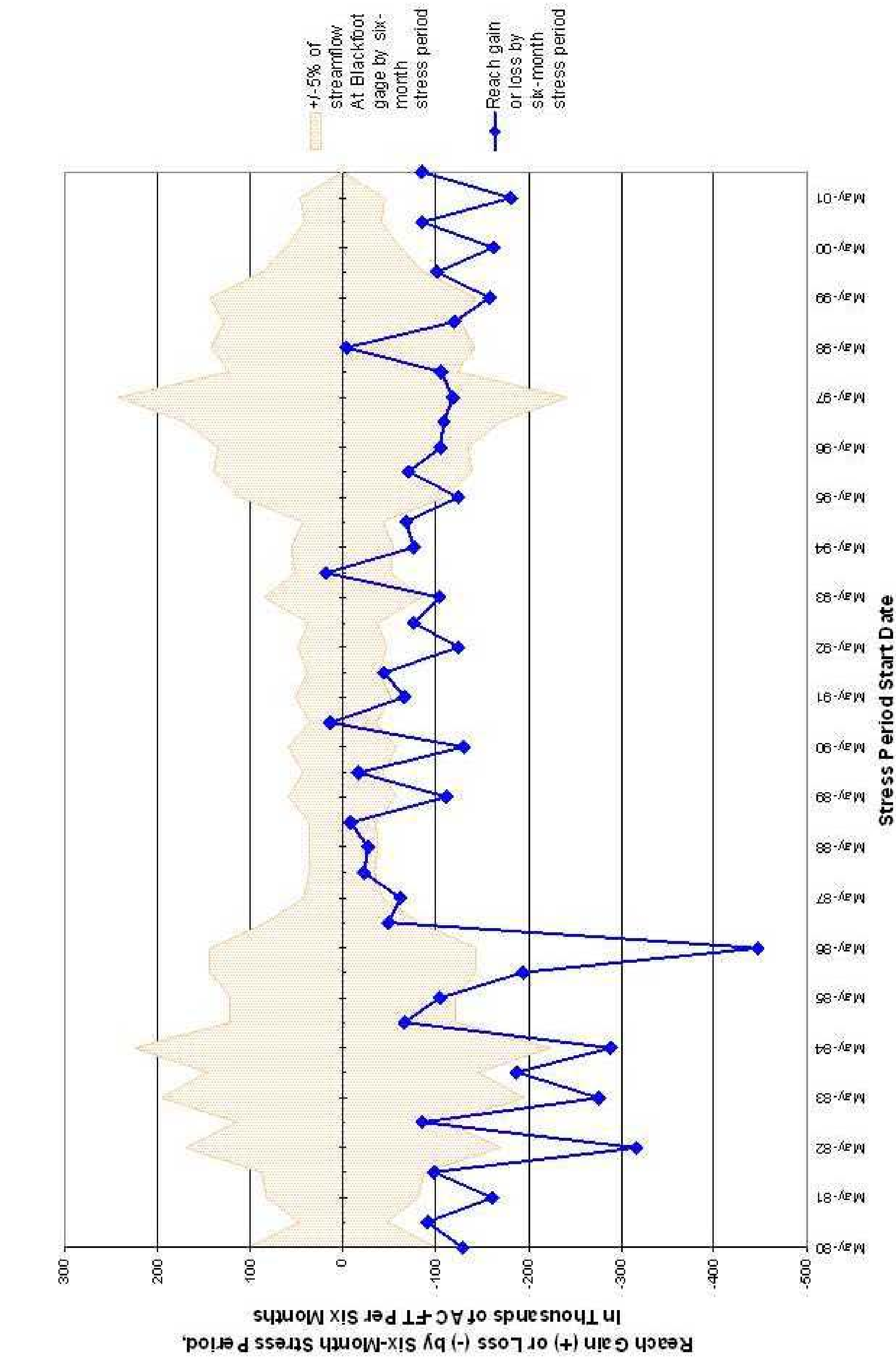

Figure 19. Snake River Gains and Losses Aggregated into Six-Month Stress Periods: At Blackfoot to Near Blackfoot

REACH 7: NEAR BLACKFOOT TO AT NEELEY

River Inflow

The river gage Near Blackfoot (station 13069500) has been operational from 1910 to the current year and consequently provides complete coverage for the aquifer model calibration period of 1980 through 2002. During this period, the average flow was about 4.4×10^8 ft^3/day (3680 K-AF/year), with average winter flow equaling about 78% of average summer flow of 4.9×10^8 ft^3/day (2072 K-AF/6-month period) (Figure 20). The USGS has rated the Near Blackfoot station as generally providing records of “good” quality. This has been interpreted as meaning reported mean daily discharge is within +/- 10% of the true discharge.

River Outflow

The At Neeley gage (station 13077000) has been in operation from 1906 to present and consequently provides complete coverage for the aquifer model calibration period. Average flow from 1980 through 2002 was about 6.8×10^8 ft^3/day (5677 K-AF/year), with average winter flow equaling about 42% of average summer flow of 9.6×10^8 ft^3/day (4004 K-AF/6-month period) (Figure 20). The USGS rates the station as generally providing “good” records. This is interpreted as meaning that daily discharge is within +/- 10% of the true value. The USGS notes that considerable water leaks into the Snake River Plain aquifer above the At Neeley station, some of which bypass the Near Blackfoot gage and returns above American Falls Reservoir in the Near Blackfoot to At Neeley reach.

Tributary Inflows

The Portneuf River is tributary to the Snake River in the Near Blackfoot to At Neeley river reach. This inflow is accounted for in the reach gain calculation using station 13075500, Portneuf River at Pocatello. Average inflow over the 22-year study period from 1980 to 2002 is about 3.1×10^7 ft^3/day (128 K-AF/6-month period) during the winter period (November through April), and 2.3×10^7 ft^3/day (97 KAF/6-month period) during the summer period (May through October) (Figure 20).

Reservoirs

American Falls Reservoir is located on the Snake River between the Near Blackfoot and Neeley gages, and has been gaged from 1926 to present. Using data for station 13076500, American Falls Reservoir at American Falls, reservoir evaporation and change in storage was calculated. These water budget components are accounted for in the reach gain and loss calculation for the Near Blackfoot to Neeley reach.

Diversions and Return Flow

Diversions in this river reach were minimal (Figure 20). The total diversions during the summer period (May through October) averaged about 1.4×10^7 ft^3/day (58 K-AF/6-month period over the 22-year study period, which is less than three percent of the average summer reach inflow at the Near Blackfoot gage. Diversions included in the reach gain and loss water budget analysis are identified in Appendix G. Surface water return flows in this reach were 1.1×10^7 ft^3/day (47 K-AF/6-month period) during the summer and are also minimal relative to streamflow (Figure 20), and are also listed in Appendix G.

Estimated Gains and Losses

The graphs of reach gains/losses over time indicate that this reach is a consistently gaining reach throughout all of the 22-year period of analysis (Figures 21 and 22). Average reach gain for the summer period (May through October) over the 22-year study was about $2.3x10^8$ ft^3/day (975 K-AF/6-month period) and about $2.2x10^8$ ft^3/day (920 K-AF/6-month period) for the winter period (November through April) (Figure 20). The estimates of monthly reach gains far exceed the five percent of streamflow band for the Near Blackfoot gage (Figure 21), meaning that the reach gain is less sensitive to gaged inflow than many of the other reaches analyzed for this study. There appears to be some seasonality to the reach gain estimates. By comparing aggregated six-month stress period reach gain totals, summer stress period reach gains are generally greater than winter stress period reach gains (Figure 22).

Kjelstrom (1995b) also found that this reach was a consistently gaining reach of the Snake River. He found that during water year 1980, this reach gained about 1.9 M-AF of ground water, largely from springs. This estimate is consistent with results for the current study, which estimates a reach gain of about 1.86 M-AF of ground water for the Near Blackfoot to Neeley reach for water year 1981 (Figure 22).

Measurement of several springs in the Near Blackfoot to Neeley reach began with the completion of American Falls Dam in 1926, because it was necessary to segregate stored water from spring discharge to accommodate the complex water-rights system (Kjelstrom, 1995b). Kjelstrom estimated streamflow gains from water-budget analyses, and compared the estimated gains with monthly mean streamflow in Spring Creek, which contributes about one-fifth of the total ground water discharge to this reach, and Danielson Creek for water year 1980. He found that the combined monthly mean streamflow for Spring and Danielson Creeks ranged from about 20 K-AF to 30 K-AF. Much of the reach gain between Near Blackfoot to Neeley is attributed to ground water discharge of springs.

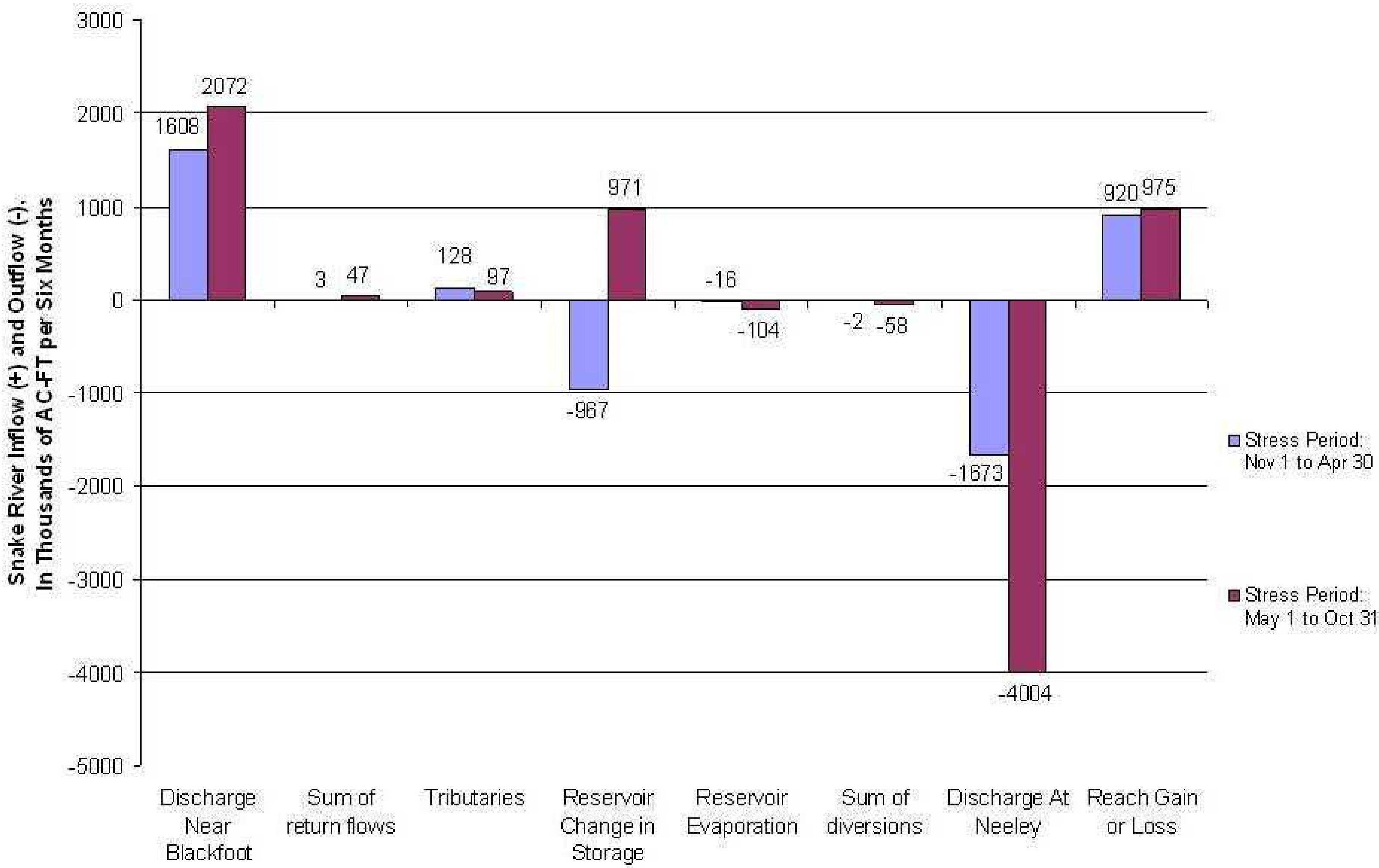

Figure 20. Snake River Inflows and Outflows by Stress Period Averaged Over 22-Year Period from May 1, 1980 to April 30, 2002: Near Blackfoot to At Neeley

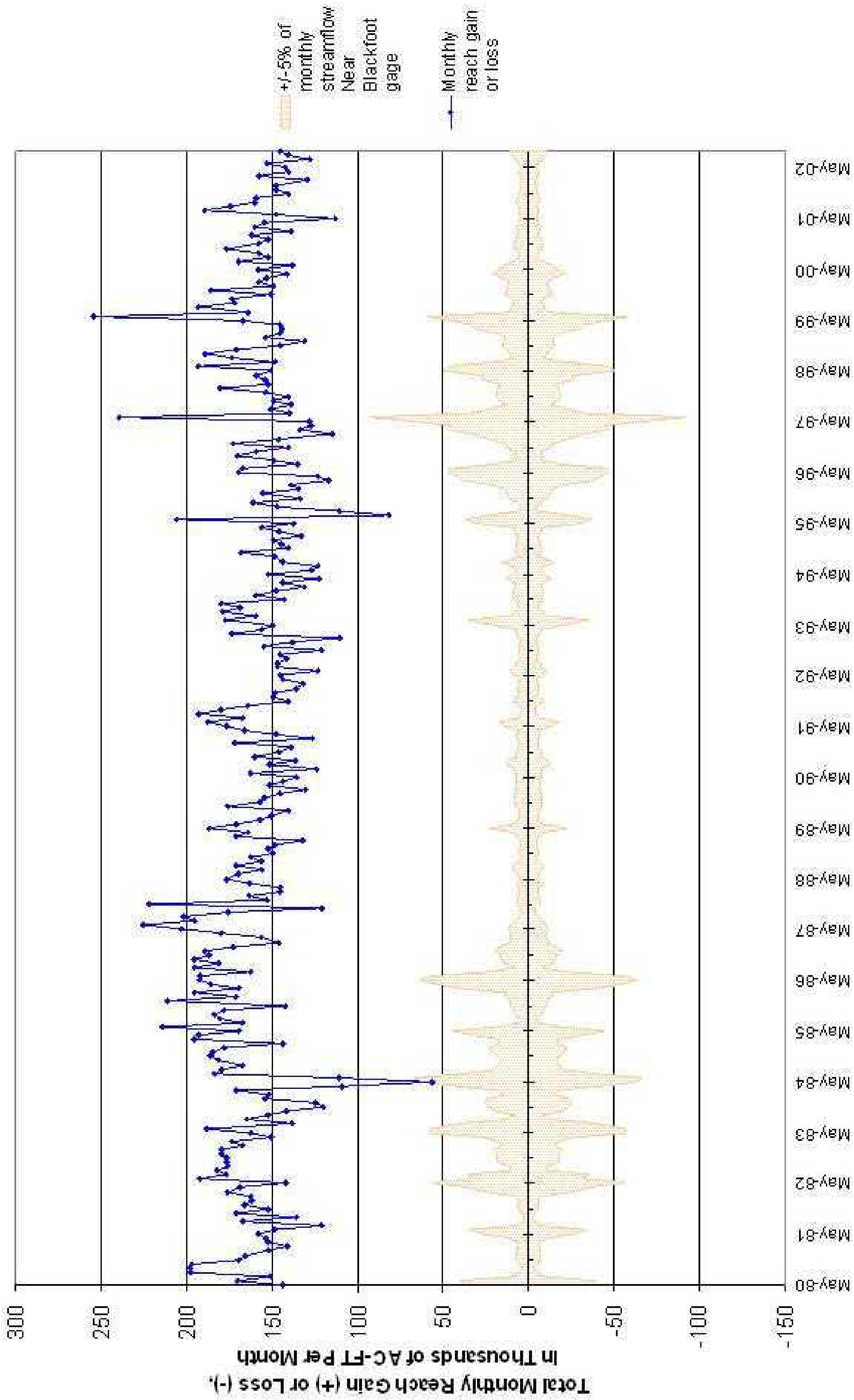

Figure 21. Monthly Snake River Gains and Losses: Near Blackfoot to At Neeley

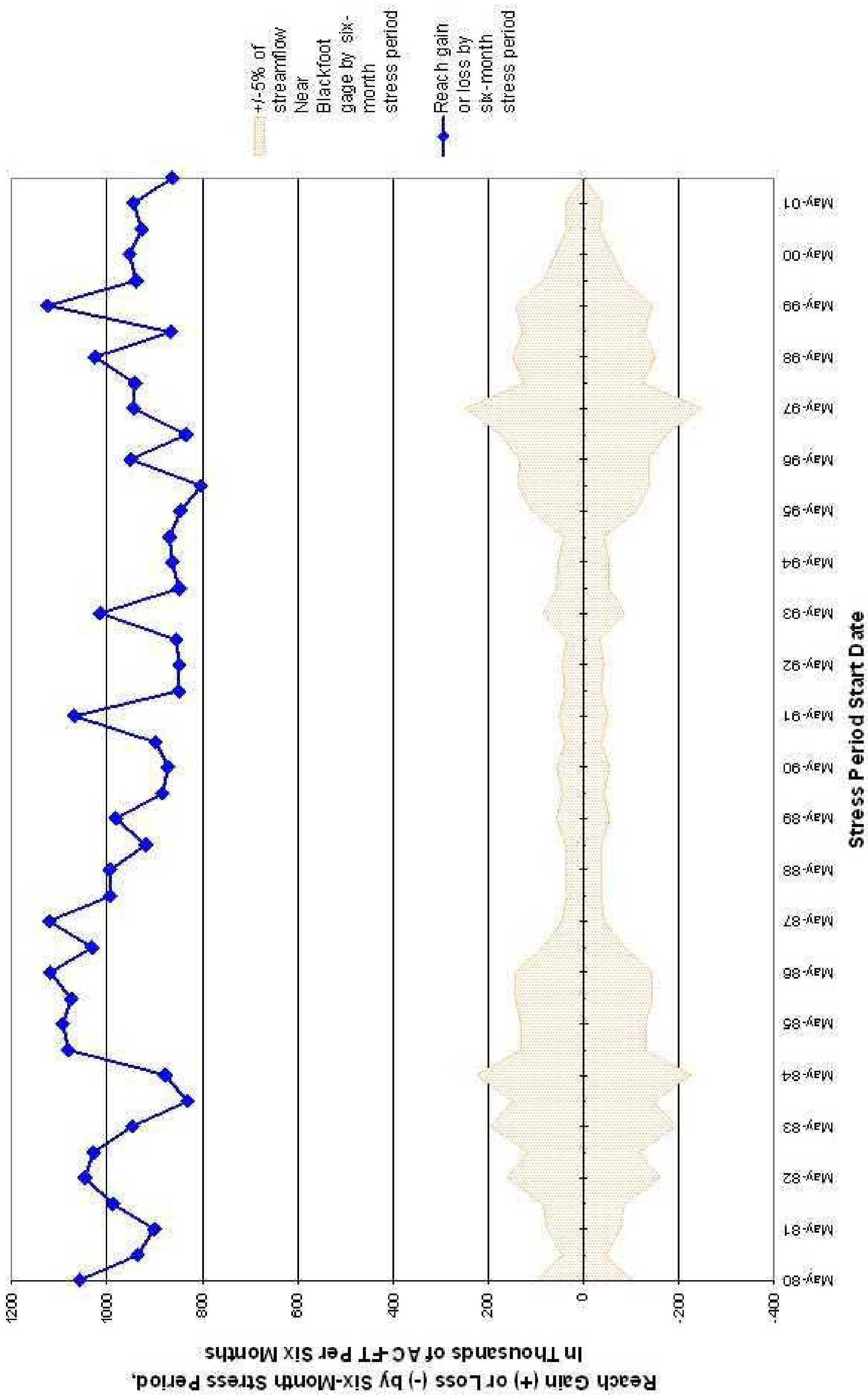

Figure 22. Snake River Gains and Losses Aggregated into Six-Month Stress Periods: Near Blackfoot to At Neeley

REACH 8: AT NEELEY TO NEAR MINIDOKA

River Inflow

The river gage At Neeley (station 13077000) has been operational from 1906 to the current year and consequently provides complete coverage for the aquifer model calibration period of 1980 through 2002. During this period, the average flow was about $6.8x10^8$ ft^3/day (5677 K-AF/year), with average winter flow equaling about 42% of average summer flow of $9.6x10^8$ ft^3/day (4004 K-AF/6-month period) (Figure 23). The USGS has rated the At Neeley station as generally providing records of "good" quality. This has been interpreted as meaning reported mean daily discharge is within +/- 10% of the true discharge. The USGS notes that considerable water leaks into the Snake River Plain aquifer above the At Neeley station, some of which returns above American Falls Reservoir, upstream of the At Neeley station.

River Outflow

The Near Minidoka gage (station 13081500) has been in operation from 1910 to present and consequently provides complete coverage for the aquifer model calibration period. Average flow from 1980 through 2002 was about $6.1x10^8$ ft^3/day (5078 K-AF/year), with average winter flow equaling about 48% of the average summer flow (Figure 23). The USGS rates the station as generally providing "good" records. This is interpreted as meaning that daily discharge is within +/- 10% of the true value.

Tributary Inflows

Raft River is tributary to the Snake River between Neeley and Minidoka. Station 13079901, Raft River Near Mouth at Raft River, Idaho, was measured for water years 1985 to 1989. These discharge measurements are rated as "fair" quality by the USGS, interpreted as meaning daily discharge is within +/- 15% of the true value. The USGS notes that many diversions are taken out of Raft River above station 13079901. Discharge measurements from 1985 to 1989 reflect minimal contribution to the Snake River, typically less than $6.0x10^5$ ft^3/day (2.5 K-AF/6-month period). Due to lack of a full data set and minimal contribution to the Snake River, Raft River was not included in the reach gain and loss calculation.

Reservoirs

Lake Walcott is located on the Snake River between Neeley and Minidoka, and has been gaged from 1909 to present. Using data for station 13081000, Lake Walcott Near Minidoka, reservoir evaporation and change in reservoir storage were calculated. These water budget components are accounted for in the reach gain and loss calculation for this reach (Appendix H).

Diversions and Return Flow

Irrigation season diversions in this river reach averaged only 15% of the streamflow at Neeley over the 22-year study period (Figure 23). The total diversions during the irrigation season average $1.4x10^8$ ft^3/day (602 K-AF/6-month period). Diversions included in the reach gain and loss water budget analysis are identified in Appendix H. There are no surface water return flows accounted for in the Neeley to Minidoka reach.

Estimated Gains and Losses

The graphs of reach gains/losses over time indicate that the Snake River both gains and loses water in the Neeley to Minidoka reach during the 22-year period of analysis (Figures 24 and 25). When the gains and losses are grouped into six-month stress periods, there is some seasonality apparent between the summer (May through October) and winter (November through April) stress periods. Over the study period, the river gains are generally greatest during the winter stress period and least during the summer stress period (Figure 25). The estimated 22-year average reach gains are 7.2×10^5 ft^3/day (31 K-AF/6-month period) during the summer period, and 1.5×10^7 ft^3/day (62 K-AF/6-month period) during the winter period. This appears inconsistent with the general pattern of higher aquifer water levels in summer and lower aquifer water levels (presumably increasing hydraulic gradient from the river) in winter. Seasonal distribution of losses in this reach appears to be more strongly associated with the flow in the river, rather than aquifer water levels.

Kjelstrom (1995b) found that this reach both gains and loses water, and annual gains almost always have exceeded losses since the American Falls Reservoir dam (just upstream of the Neeley gage) was completed in 1926. He notes that in the lower half of Lake Walcott, the water table is below river stage and the Snake River loses to ground water. Kjelstrom’s water budget analysis indicates that this reach gained about 4.8×10^7 ft^3/day (200 K-AF/year) from ground water in water year 1980, compared with our estimate of about 8.6×10^7 ft^3/day (360 K-AF/year). The reason for the difference is unknown. Kjelstrom notes that large gains in early-summer months of 1980 are largely due to above-normal precipitation. This is consistent with the larger gains seen in water year 1980 in the current study.

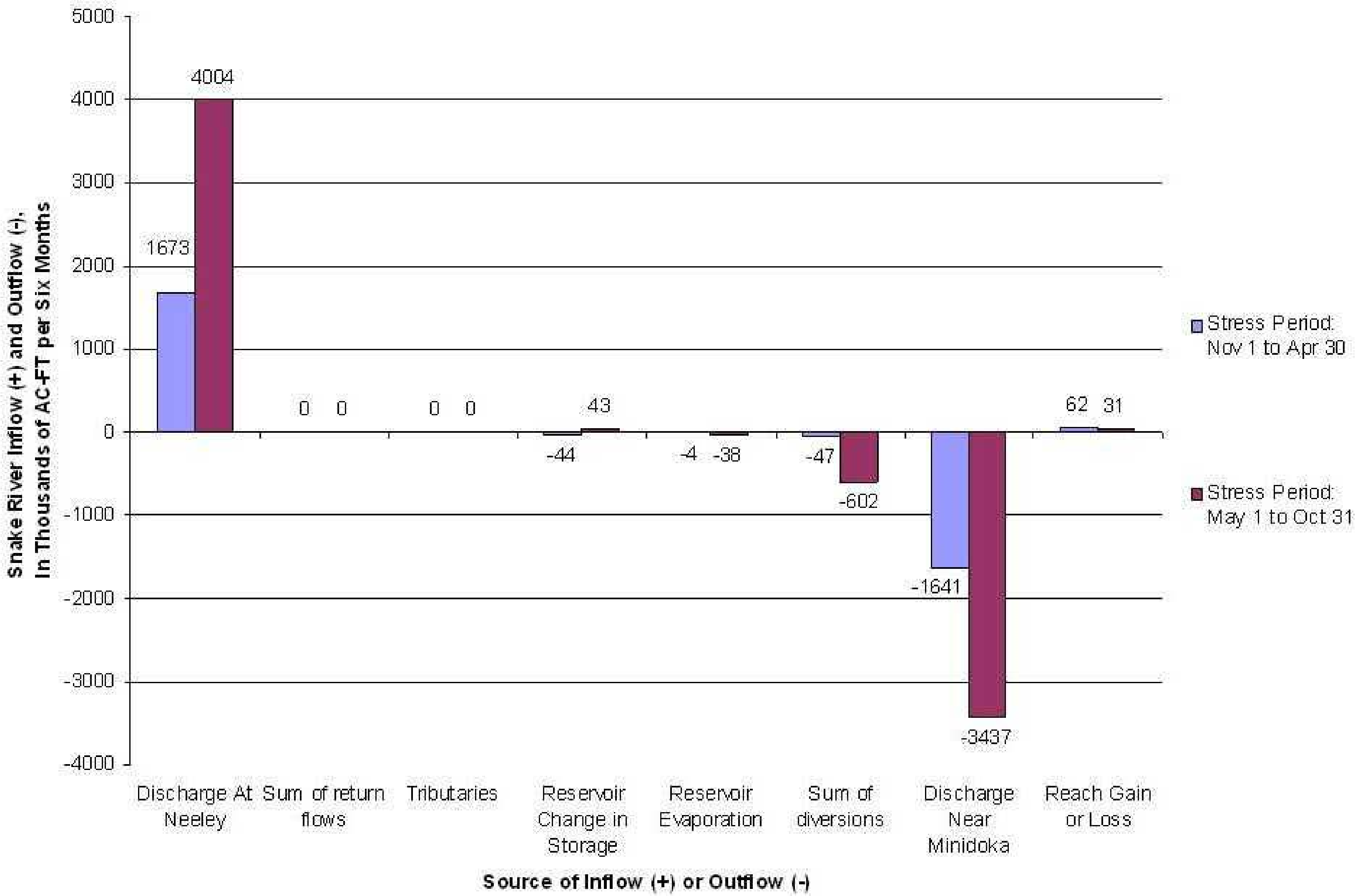

Figure 23. Snake River Inflows and Outflows by Stress Period Averaged Over 22-Year Period from May 1, 1980 to April 30, 2002: At Neeley to Near Minidoka

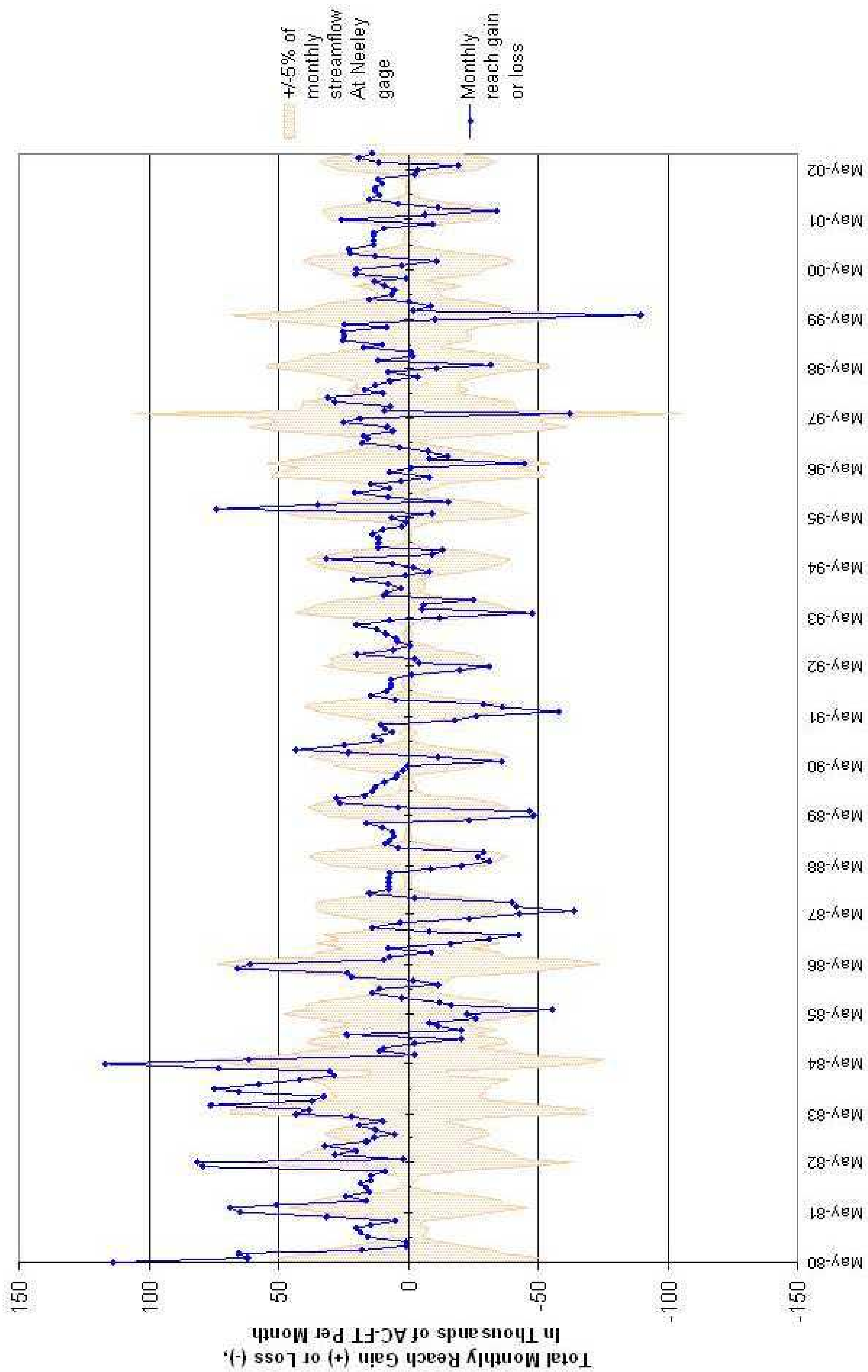

Figure 24. Monthly Snake River Gains and Losses: At Neeley to Near Minidoka

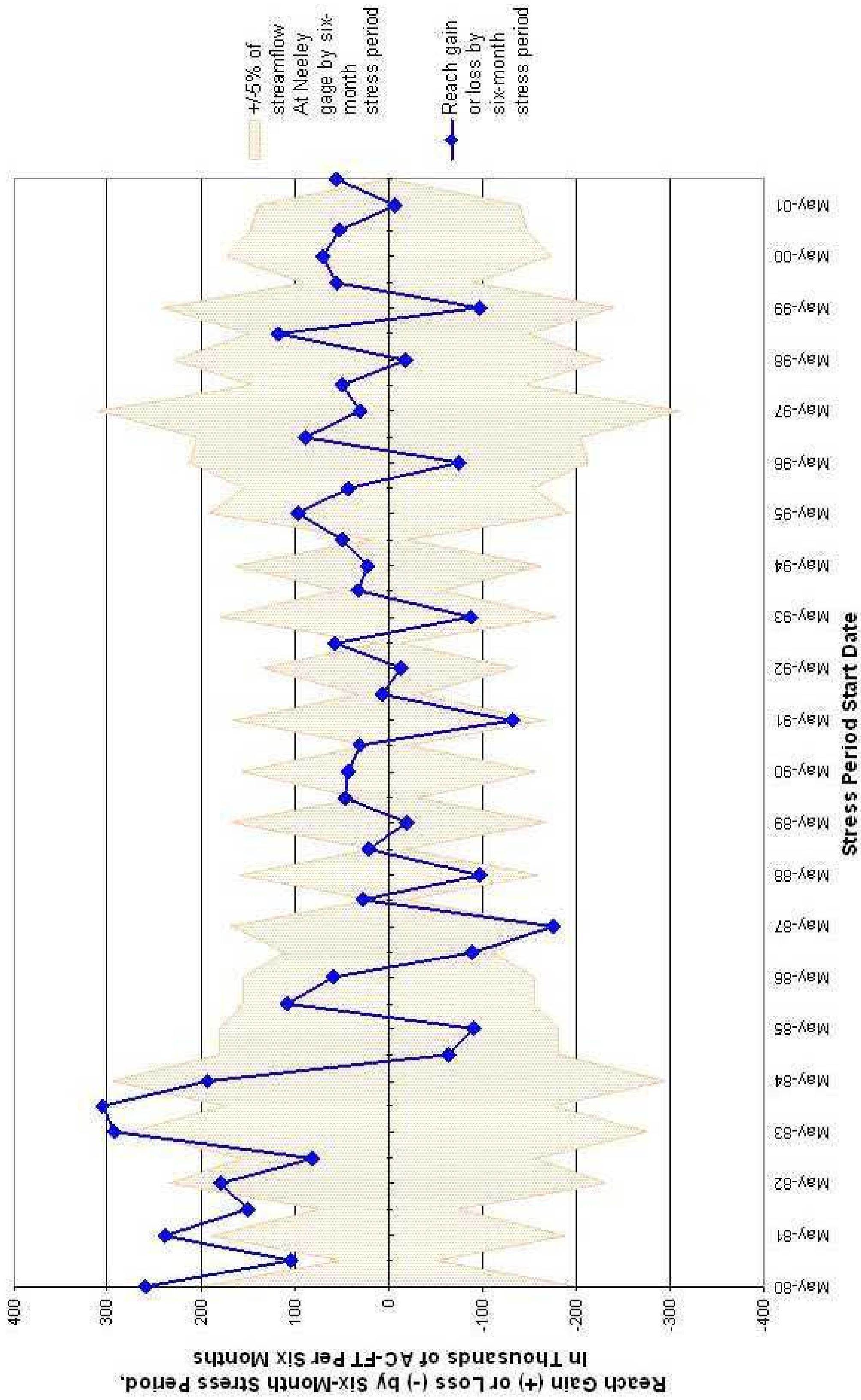

Figure 25. Snake River Gains and Losses Aggregated into Six-Month Stress Periods: At Neeley to Near Minidoka

REACH 9: NEAR MINIDOKA TO AT MILNER

River Inflow

The river gage Near Minidoka (station 13081500) has been operational from 1910 to the current year and consequently provides complete coverage for the aquifer model calibration period of 1980 through 2002. During this period, the average flow was about $6.1x10^8$ ft^3/day (5078 K-AF/year), with average winter flow equaling about 48% of the average summer flow of $8.2x10^8$ ft^3/day (3437 K-AF/6-month period) (Figure 26). The USGS has rated the Near Minidoka station as generally providing records of "good" quality. This has been interpreted as meaning reported mean daily discharge is within +/- 10% of the true discharge.

River Outflow

The At Milner gage (station 13088000) has been in operation from 1909 to present and consequently provides complete coverage for the aquifer model calibration period. Average flow from 1980 through 2002 was about $3.0x10^8$ ft^3/day (2510 K-AF/year), with average summer flow equaling about 68% of average winter flow (Figure 26). The USGS rates the station as generally providing "fair" records. This is interpreted as meaning that daily discharge is within +/- 15% of the true value.

Tributary Inflows

There are no tributaries that contribute to the Minidoka to Milner reach.

Diversions and Return Flow

Irrigation season diversions in this river reach are substantial (Figure 26). The total diversions during summer average about $5.7x10^8$ ft^3/day (2374 K-AF/6-month period), which is about 69% of the reach inflow at the Near Minidoka gage during the summer averaging approximately 68% of inflows. Diversions included in the reach gain and loss analysis are identified in Appendix I. At times prior to the 1993 water year, nearly the entire streamflow was diverted during the irrigation season.

Surface water return flows in this reach are negligible relative to the diversions and streamflow (Figure 26), and are also listed in Appendix I. Return flow from local diversions mostly enters the Snake River downstream, between the At Milner and At King Hill (13154500) stations.

Estimated Gains and Losses

The graphs of reach gains/losses over time indicate that this reach is a consistently gaining reach throughout nearly all of the 22-year period of analysis (Figures 27 and 28). During most of the study period, the river gains appear to be greatest during the end of the irrigation season. This is possibly due to increased water levels in a perched system that has formed as a result of irrigation. Because the water level in the underlying system during irrigation season is higher than the water stage in the river, the river gains water from the aquifer. Similarly, during the non-irrigation season, water levels in the perched system decrease and therefore result in decreased gains during the winter and spring months, and occasionally result in river loss to the aquifer if the water levels in the aquifer are lower than the water stage in the river.

Kjelstrom (1995b) found that this reach lost to ground water in April and May of 1979 and 1980, and continued to lose through the 1980 irrigation season. He also noted that historically, streamflow gains in this reach have exceeded losses, but that ground water levels have declined and the reach has gone from net gaining to net losing. Results from this study are consistent with Kjelstrom's estimates for water year 1980, but for the overall study period from 1980 to 2002, the reach appears to be a net gaining one.

The estimated 22-year average reach gains are 1.3×10^7 ft^3/day (56 K-AF/6-month period) during the May through October period, and 1.4×10^7 ft^3/day (57 K-AF/6-month period) during the November through April period. These values are very small relative to the measured river discharge at the Minidoka and Milner gages and relative to the large volume of diversions (Figure 26). Because the average river gain is of the same magnitude as the average return flow estimate, it is likely that estimates of river gain and loss are most sensitive to errors in estimates of river inflow and outflow and diversions, and not to estimates of return flow.

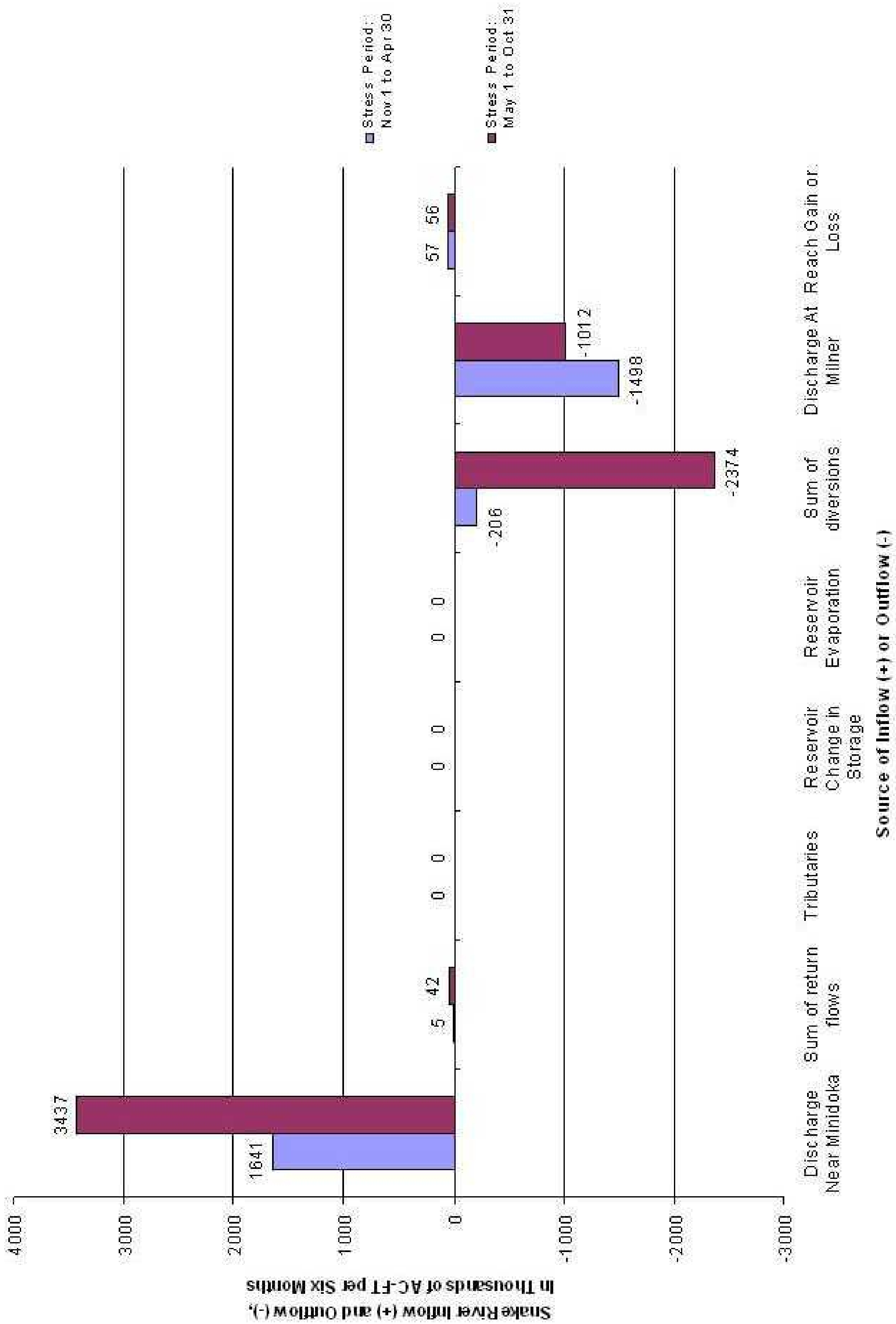

Figure 26. Snake River Inflows and Outflows by Stress Period Averaged Over 22-Year Period from May 1, 1980 to April 30, 2002: Near Minidoka to At Milner

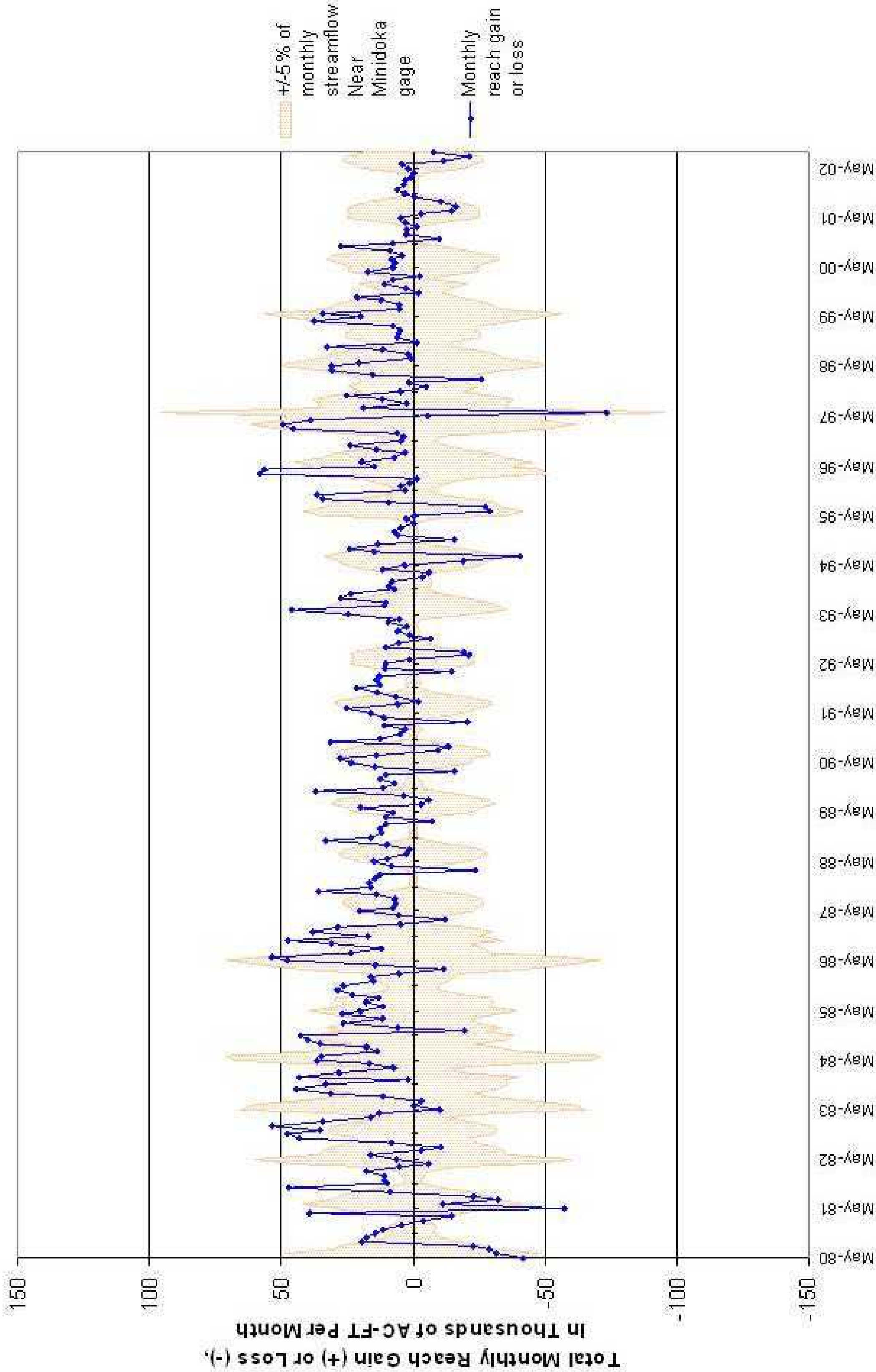

Figure 27. Monthly Snake River Gains and Losses: Near Minidoka to At Milner

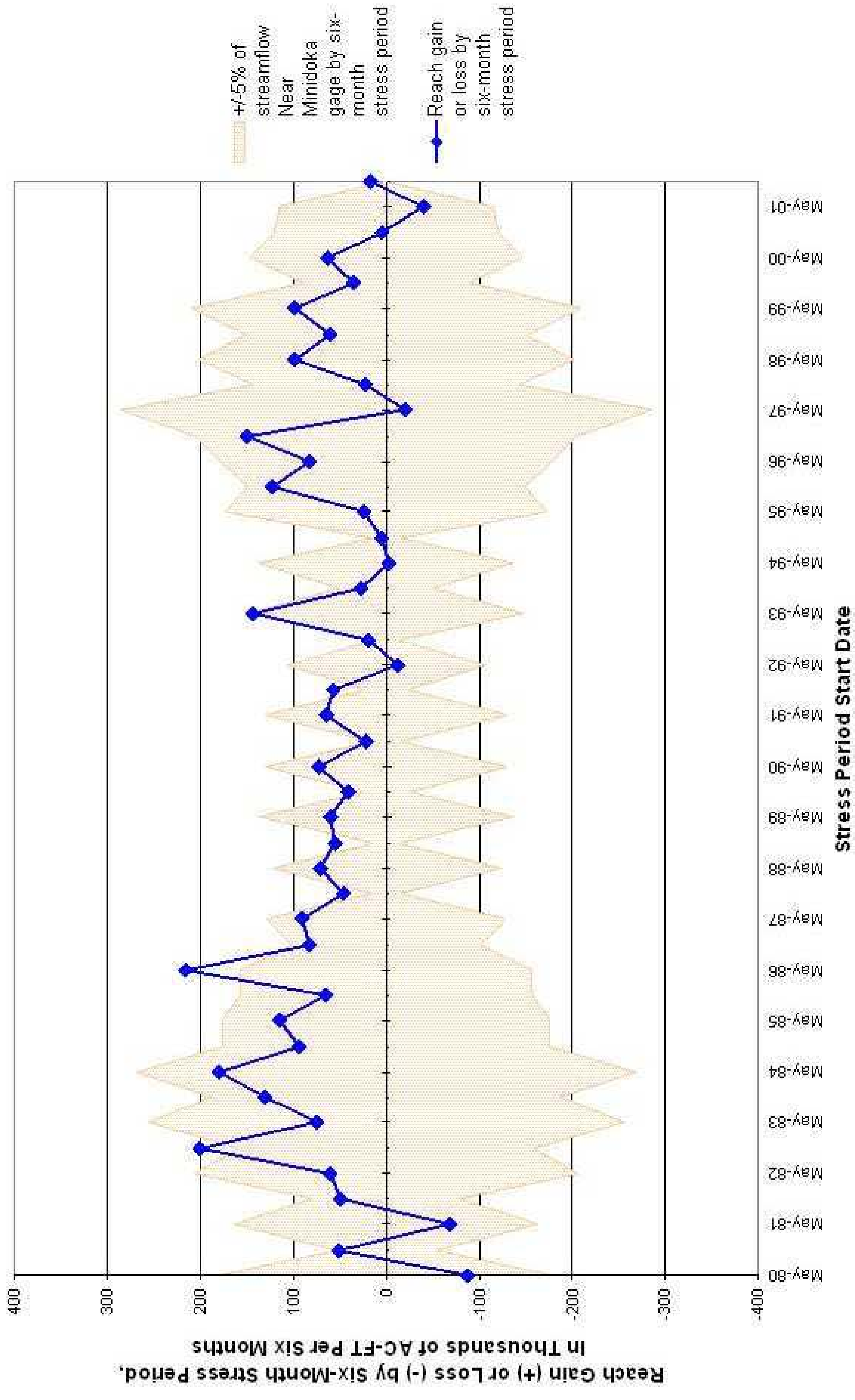

Figure 28. Snake River Gains and Losses Aggregated into Six-Month Stress Periods: Near Minidoka to At Milner

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APPENDIX A

REACH GAIN AND LOSS CALCULATION COMPONENTS
HENRYS FORK: NEAR ASHTON TO AT ST. ANTHONY

Henrys Fork: Near Ashton to At St. Anthony		
OUTS	INS	DESCRIPTION
	13046000	Discharge: Henrys Fork near Ashton
13046310		Dewey Canal
13046449		Sum of Pump Diversions HF Ashton to at Falls River
	13049500	Discharge: Falls River nr Chester
13049550		Last Chance Canal
13049560		Crosscut Canal
13049705		Farmers Friend Canal
13049725		St. Anthony Union Canal
13049805		Salem Union Canal
13050499		Sum of Misc Diversions HF Ashton to St Anthony
	13046449 Return	Return Flow: HF Ashton to above Falls River
	13047305 Return	Return Flow: Yellowstone Canal
	13047475 Return	Return Flow: Marysville Canal
	13047575 Return	Return Flow: Farmers Own Canal
	13049008 Return	Return Flow: McBee Canal
	13049010 Return	Return Flow: Silkey Canal
	13049015 Return	Return Flow: Curr Canal
13050500		Discharge: Henrys Fork at St. Anthony

APPENDIX B

REACH GAIN AND LOSS CALCULATION COMPONENTS
HENRYS FORK: AT ST. ANTHONY TO NEAR REXBURG

Henrys Fork: At St. Anthony to Near Rexburg		
OUTS	INS	DESCRIPTION
	13050500	Discharge: Henrys Fork at St. Anthony
13050525		Egin Canal
13050530		St. Anthony Union Feeder
13050535		Independent Canal
13050545		Consolidated Farmers Canal
	13055000	Dischg: Teton Rvr nr St. Anthony
13055030		Wilford Canal
13055035		Good Luck Canal
13055040		Teton Irrigation Canal
13055042		Siddoway Canal
13055050		Pioneer Canal
13055060		Stewart Canal
13055205		Pincock-Byington Canal
13055210		Teton Island Feeder Canal
13055245		Salem Union B
13055275		Roxana Canal
13055280		Island Ward Canal
13055295		Saurey Sommers Canal
13055306		McCormick-Rowe Canal
13055311		Pincock-Garner Canal
13055313		Gardner Canal/Pump
13055314		Bigler Slough
13055315		Woodmansee-Johnson Canal
13055323		City of Rexburg Canal
13055334		Rexburg Irrigation Canal
13055499		Sum of Pump Diversions Teton River St. Anthony to Mouth
	13048560 Return	Return Flow: Fall River Canal
	13048705 Return	Return Flow: Chester Canal
	13049550 Return	Return Flow: Last Chance Canal
	13049705 Return	Return Flow: Farmers Friend Canal
	13049710 Return	Return Flow: Twin Groves Canal
	13049725 Return	Return Flow: St. Anthony Union Canal
	13049805 Return	Return Flow: Salem Union Canal
	13050015 Return	Return Flow: Fall River via Crosscut Canal
	13050499 Return	Return Flow: Henrys Fork from Ashton to St. Anthony
	13050525 Return	Return Flow: Egin Canal
	13050530 Return	Return Flow: St. Anthony Union Feeder Canal
	13050535 Return	Return Flow: Independent Canal
	13050545 Return	Return Flow: Consolidated Farmers Canal
	13055030 Return	Return Flow: Wilford Canal

	13055035 Return	Return Flow: Good Luck Canal
	13055040 Return	Return Flow: Teton Irrigation Canal
	13055042 Return	Return Flow: Siddoway Canal
	13055050 Return	Return Flow: Pioneer Canal
	13055060 Return	Return Flow: Stewart Canal
	13055205 Return	Return Flow: Pincock-Byington Canal
	13055210 Return	Return Flow: Teton Island Feeder Canal
	13055245 Return	Return Flow: North Salem
	13055275 Return	Return Flow: Roxanna Canal
	13055280 Return	Return Flow: Island Ward Canal
	13055295 Return	Return Flow: Saurey-Sommers Canal
	13055306 Return	Return Flow: McCormick-Rowe Canal
	13055311 Return	Return Flow: Pincock-Garner Canal
	13055313 Return	Return Flow: Gardner Canal
	13055314 Return	Return Flow: Bigler Slough
	13055315 Return	Return Flow: Woodmansee-Johnson Canal
	13055499 Return	Return Flow: Sum of Pump Diversions Teton River St Anthony to Mouth
13056500		Discharge: Henrys Fork near Rexburg

APPENDIX C

REACH GAIN AND LOSS CALCULATION COMPONENTS
SNAKE RIVER: NEAR HEISE TO AT LORENZO

Snake River: Near Heise to At Lorenzo		
OUTS	INS	DESCRIPTION
	13037500	Dischg. SR nr Heise
13037505		Anderson Canal
13037975		Eagle Rock Canal
13037980		Farmers Friend Canal
13037985		Enterprise Canal
13038025		Butler Island Canal
13038030		Ross and Rand Canal
13038050		Steele Canal
13038055		Harrison Canal
13038065		Cheney Canal
13038080		Butler Island #2 Canal
13038085		Rudy (plus Boomer post-1993) Canal
13038090		Lowder and Jennings Canal
13038095		Boomer (North Rudy) Canal
13038098		Kite and Nord Canal
13038110		Burgess Canal
13038115		Clark and Edwards Canal
13038145		Croft Pump
13038150		East Labelle Canal
13038180		Rigby Canal
13038205		Dilts Canal
13038210		Diversion Island Canal
13038225		West Labelle and Long Island Canal
13038305		Parks and Lewisville Canal
13038315		North Rigby Canal
13038340		White Canal
13038360		Bramwell Canal
13038362		Ellis Canal
13038387		Nelson Canal
13038388		Mattson Craig Canal
13038392		Sunnydell Canal
13038398		Arnsberger Canal
13038426		Lenroot Canal
13038431		Reid Canal
13038434		Texas Feeder
13038436		Hill Petinger Canal
13038437		Nelson Corey Canal
13038499		Sum of misc. div. SR Heise to Lorenzo
13038500		Dischg: SR at Lorenzo

APPENDIX D

REACH GAIN AND LOSS CALCULATION COMPONENTS
SNAKE RIVER: AT LORENZO TO NEAR SHELLEY

Snake River: At Lorenzo to Near Shelley		
OUTS	INS	DESCRIPTION
	13038500	Discharge: Snake River at Lorenzo
	13056500	Discharge: Henrys Fork near Rexburg, ID
13057025		B utte and Market Lake Canal
13057125		Osgood Canal
13057130		Kennedy Canal
13057135		Great Western Canal
13057136		Great Western and Porter Canal
13057139		Bear Island and Smith Canal
13057145		Idaho Canal
13057159		Sum of Pump Diversions SR Lorenzo/Rexburg to abv Willow Crk
13057250		Porter Canal
	13058530	Discharge: Willow Crk below Floodway Channel nr Ucon
13058532		Demick Canal
13059505		Woodville Canal
13059525		Snake River Valley Canal
13059999		Sum of Pump Diversions Willow Crk to Shelley
	13037499 Return	Return Flow: Misc. Div. Irwin to Heise
	13037505 Return	Return Flow: Anderson Canal
	13037975 Return	Return Flow: Eagle Rock Canal
	13037977 Return	Return Flow: Eagle Rock Canal abv Willow Cr nr Ririe (The Dump)
	13037980 Return	Return Flow: Farmers Friend Canal
	13037985 Return	Return Flow: Enterprise Canal
	13038025 Return	Return Flow: Butler Island Canal
	13038030 Return	Return Flow: Ross and Rand Canal
	13038050 Return	Return Flow: Steele Canal
	13038055 Return	Return Flow: Harrison Canal
	13038060 Return	Return Flow: Cheney and Steele Canal
	13038065 Return	Return Flow: Cheney Canal
	13038080 Return	Return Flow: Butler Island #2 Canal
	13038085 Return	Return Flow: Rudy Canal
	13038090 Return	Return Flow: Lowder and Jennings Canal
	13038094 Return	Return Flow: Boomer and Rudy Canals
	13038095 Return	Return Flow: Boomer Canal
	13038098 Return	Return Flow: Kite and Nord Canal
	13038110 Return	Return Flow: Burgess Canal
	13038115 Return	Return Flow: Clark and Edwards Canal
	13038145 Return	Return Flow: Croft Canal
	13038150 Return	Return Flow: East Labelle Canal
	13038180 Return	Return Flow: Rigby Canal

	13038205 Return	Return Flow: Dilts Canal
	13038210 Return	Return Flow: Island Canal
	13038225 Return	Return Flow: West Labelle and Long Island Canal
	13038305 Return	Return Flow: Parks and Lewisville Canal
	13038315 Return	Return Flow: North Rigby Canal
	13038340 Return	Return Flow: White Canal
	13038360 Return	Return Flow: Bramwell Canal
	13038362 Return	Return Flow: Ellis Canal
	13038387 Return	Return Flow: Nelson Canal
	13038388 Return	Return Flow: Mattson-Craig Canal
	13038392 Return	Return Flow: Sunnydell Canal
	13038398 Return	Return Flow: Arnsberger Canal
	13038426 Return	Return Flow: Lenroot Canal
	13038431 Return	Return Flow: Reid Canal
	13038434 Return	Return Flow: Texas Feeder
	13038435 Return	Return Flow: Bannock Jim Slough
	13038436 Return	Return Flow: Hill Petinger Canal
	13038437 Return	Return Flow: Nelson Corey Canal
	13038499 Return	Return Flow: Misc Diversion Heise to Lorenzo
	13055323 Return	Return Flow: City of Rexburg Canal
	13055334 Return	Return Flow: Rexburg Irrigation Canal
	13055499 Return	Return Flow: Misc. Div. Teton River St. Anthony to mouth
	13057025 Return	Return Flow: Butte and Market Lake Canal
	13057125 Return	Return Flow: Osgood Canal
	13057126 Return	Return Flow: Clements Canal Pump
	13057130 Return	Return Flow: Kennedy Canal
	13057139 Return	Return Flow: Bear Island and Smith Canal
	13057258 Return	Return Flow: Misc. Div. Lorenzo/Rexburg to above Willow Creek
	13058290 Return	Return Flow: Orval Avery Canal
	13058380 Return	Return Flow: Roy Cooper Canal
	13058510 Return	Return Flow: Sand Creek above Willow Creek
	13058512 Return	Return Flow: Bean Canal
	13058514 Return	Return Flow: W & O Cooper Canal
	13058515 Return	Return Flow: Sand Creek delivery to Idaho Canal
	13058532 Return	Return Flow: Demick Canal
	13059999 Return	Return Flow: Misc Diversions Willow Creek to Shelley
13060000		Discharge: Snake River near Shelley

APPENDIX E

REACH GAIN AND LOSS CALCULATION COMPONENTS
SNAKE RIVER: NEAR SHELLEY TO AT BLACKFOOT

Snake River: Near Shelley to At Blackfoot		
OUTS	INS	DESCRIPTION
	13060000	Discharge: Snake River near Shelley
13060500		Reservation Canal
13061430		Blackfoot Canal
13061520		New Lava Side Canal
13061525		Peoples Canal
13061610		Aberdeen Canal
13061650		Corbett Canal
13061670		Nielsen-Hansen Canal
13061705		Riverside Canal
13061995		Danskin Canal
13062050		Trego Canal
	13057135 Return	Return Flow: Great Western Canal
	13057136 Return	Return Flow: Great Western and Porter Canal
	13057145 Return	Return Flow: Idaho Canal
	13057250 Return	Return Flow: Porter Canal
	13059505 Return	Return Flow: Woodville Canal
	13059525 Return	Return Flow: Snake River Valley Canal
	13060500 Return	Return Flow: Reservation Canal
	13061430 Return	Return Flow: Blackfoot Canal
	13061650 Return	Return Flow: Corbett Canal
	13061670 Return	Return Flow: Nielsen-Hansen Canal
	13066100 Return	Return Flow: Little Indian Ditch
	13069499 Return	Return Flow: Misc. Div. Shelley to nr Blackfoot
13062500		Discharge: Snake River at Blackfoot

APPENDIX F

REACH GAIN AND LOSS CALCULATION COMPONENTS
SNAKE RIVER: AT BLACKFOOT TO NEAR BLACKFOOT

Snake River: At Blackfoot to Near Blackfoot		
OUTS	INS	DESCRIPTION
	13062500	Discharge: Snake River at Blackfoot
13062503		Wearyrick Canal
13062506		Watson Canal
13062507		Parsons Canal
	13068501	Discharge: Blackfoot River Near Blackfoot and Bypass
13069499		Sum of Misc Diversions SR Shelley to Near Blackfoot
	13061520 Return	RF New Lava Side Canal
	13061525 Return	RF Peoples Canal
	13061705 Return	RF Riverside Canal
	13061995 Return	RF Danskin Canal
	13062050 Return	RF Trego Canal
	13062503 Return	RF Wearyrick Canal
	13062506 Return	RF Watson Canal
	13062507 Return	RF Parsons Canal
13069500		Discharge: Snake River near Blackfoot

APPENDIX G

REACH GAIN AND LOSS CALCULATION COMPONENTS
SNAKE RIVER: NEAR BLACKFOOT TO AT NEELEY

Snake River: Near Blackfoot to At Neeley		
OUTS	INS	DESCRIPTION
	13069500	Discharge: Snake River near Blackfoot
	13075500	Discharge: Portneuf River near Pocatello
13075900		Fort Hall Michaud Canal
13076400		Michaud Canal
	13061610 Return	Return Flow: Aberdeen Canal
	13068005 Return	Return Flow: Fort Hall Main Canal
	13068010 Return	Return Flow: Fort Hall North Canal
13076500 Storage		Change in Storage Calculation: American Falls Reservoir
13076500 Evaporation		Evaporation Calculation: American Falls Reservoir
13077000		Discharge: Snake River at Neeley

APPENDIX H

REACH GAIN AND LOSS CALCULATION COMPONENTS
SNAKE RIVER: AT NEELEY TO NEAR MINIDOKA

Snake River: At Neeley to Near Minidoka		
OUTS	INS	DESCRIPTION
	13077000	Discharge: Snake River at Neeley
13080000		Minidoka North Side Canal
13080500		Burley South Side Canal
13081000 Storage		Change in Storage Calculation: Lake Walcott nr Minidoka
13081000 Evaporation		Evaporation Calculation: Lake Walcott nr Minidoka
13081499		Sum of Pump Diversions Snake River Neeley to Minidoka
13081500		Discharge: Snake River near Minidoka

APPENDIX I

REACH GAIN AND LOSS CALCULATION COMPONENTS
SNAKE RIVER: NEAR MINIDOKA TO AT MILNER

Snake River: Near Minidoka to At Milner		
OUTS	INS	DESCRIPTION
	13081500	Discharge: Snake River near Minidoka
13085500		Historic Diversion Minidoka North Side Pump
13085800		Historic Diversion North Side PA Lateral Pump
13086000		Milner Low Lift Pump near Milner
13086513		Historic Discharge Milner-Gooding Project in Gooding Canal
13086514		Historic Diversion North Side Project Water in Gooding Canal
13087000		North Side Canal at Milner
13087500		South Side Twin Falls Canal at Milner
13087999		Sum of Small Pump Diversions SR Minidoka to Milner
	13080000 Return	Return Flow: Minidoka North Side Canal
	13080500 Return	Return Flow: Burley South Side Canal
	13081499 Return	Return Flow: Misc. Div. Neeley to Minidoka
13088000		Discharge: Snake River at Milner

Note: Because the total diversion for the Milner Gooding Canal at Milner (station 13086500) was not measured at the head gate during the study period, it is appropriate to calculate an estimate for the total diversion using data from existing stations that measure portions of the canal and its offspring canals. Data for 13086513 and 13086514 are calculated and summed and taken to be the best estimate of station 13086500, the total Snake River diversion of the Milner Gooding Canal. Data for 13086513 and 13086514 are based on measured data from stations 13086510, 13086520, and 13086530. A schematic of the gaging stations involved in these calculations is in Figure 29.

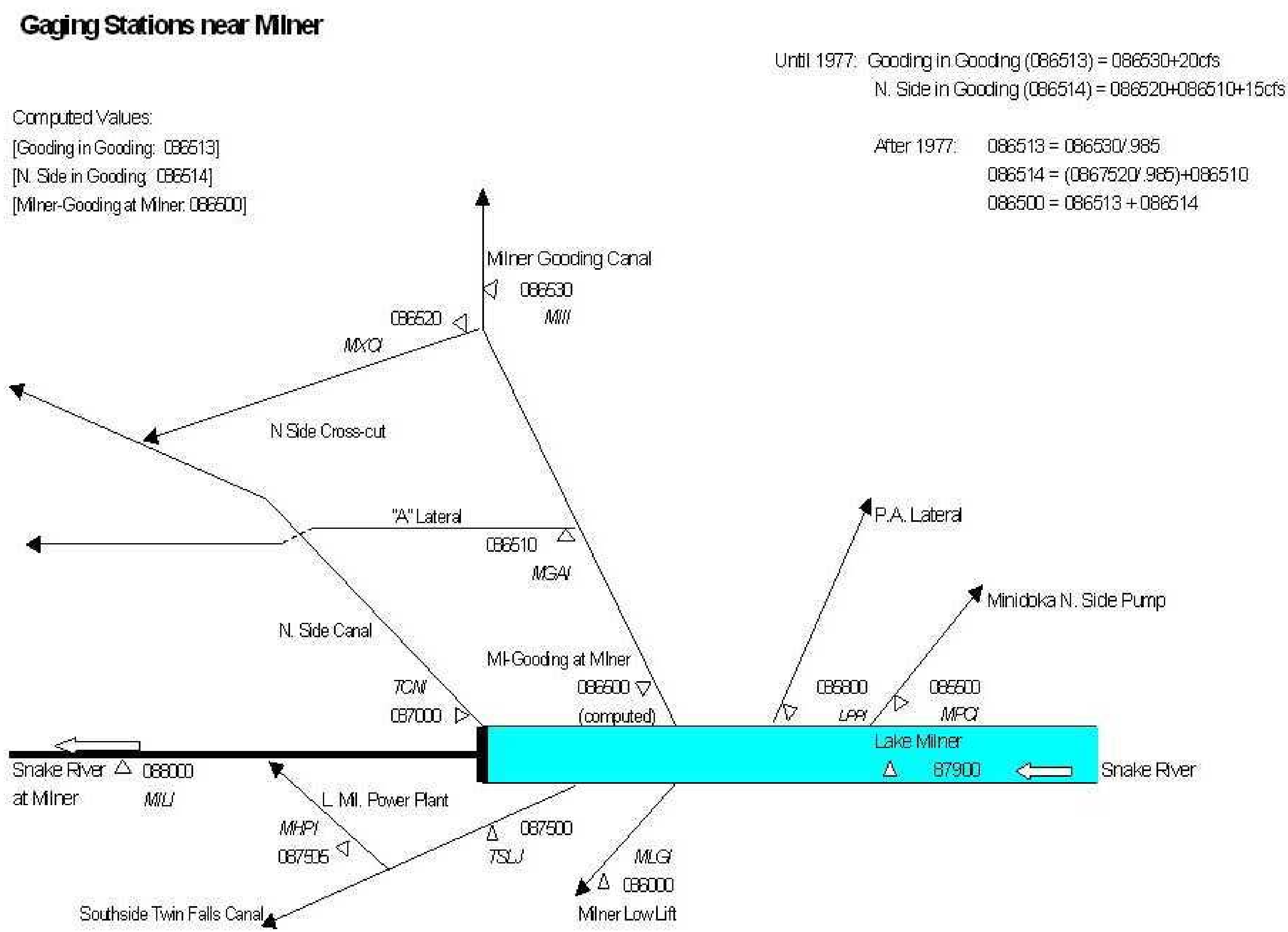

Figure 29. Schematic of gaging stations near Milner.