No Markup Version

1320 Research Park Drive
Manhattan, Kansas 66502
(785) 564-6700

Kansas
Department of Agriculture
agriculture.ks.gov

900 SW Jackson, Room 456
Topeka, Kansas 66612
(785) 296-3556

Jackie McClaskey, Secretary

Governor Sam Brownback

May 28, 2016

Attached is the second draft of the initial report by the chief engineer for the impairment investigation requested by the U.S. Fish and Wildlife Service (Service) related to its Water Right File No. 7,571 for the Quivira National Wildlife Refuge. The revisions in this second draft of the report are responsive to comments we received during the comment period.

We appreciate all who took the time to review the report and provide comments. Comments received were posted to our web site at: agriculture.ks.gov/Quivira on May 17. The second draft is provided as a markup from the first version to make clear the changes made.

Many comments received provided the Kansas Department of Agriculture's Division of Water Resources with input on overall water right administration, policy and potential alternatives to address the future water supply in the Rattlesnake Creek basin. While these comments do not directly impact the findings of the impairment investigation report, we will continue to review the comments and share additional clarifying information, as appropriate, to the web address shown above.

As outlined in the timeline below, the review period for this second draft will close on July 1, 2016. During this review period, we welcome and encourage feedback and comments from the constituents of the Rattlesnake Creek Basin and the Service.

- May 13, 2016, end of review period for Initial Report. (*Complete)*
- May 30, 2016, KDA-DWR to publish second draft of Initial Report. (*Complete)*
- July 1, 2016, end of review period for second draft of Initial Report.
- July 15, 2016, KDA-DWR to publish Final Report.
- August 15, 2016, basin plan to implement remedy submitted to chief engineer.

We remain committed to work with the Service, Big Bend Groundwater Management District No 5. (GMD 5) and basin stakeholders to explore options for resolving the underlying concerns from the impairment investigation.

Sincerely,

David W Barfield

pc: GMD5
WaterPack

Initial Report of the Chief Engineer

Prepared pursuant to K.A.R. 5-4-1

Concerning a Claim of Water Right Impairment

In the Matter of

Water Right File No. 7,571

Owned and operated by

U.S. Fish and Wildlife Service

◆

May 28, 2016
David W. Barfield, P.E.
Chief Engineer
Division of Water Resources
Kansas Department of Agriculture

This initial report provides the results of DWR's impairment investigation requested by the U.S. Fish and Wildlife Service related to their water right for the Quivira Refuge, Water Right File No. 7,571.

The United States Fish & Wildlife Service (Service) holds Water Right File No. 7,571; a surface water right near the bottom of the Rattlesnake Creek for its Quivira National Wildlife Refuge. The Refuge's water right entitles it to take water from Rattlesnake Creek at three points of diversion at a combined maximum diversion rate not in excess of 300 cubic feet per second and a quantity not to exceed 14,632 acre-feet of water per calendar year for recreational use. The Refuge is located along the Central Flyway and consists of 7,000 acres of wetlands. The Refuge uses water primarily to provide habitat for several hundred species of birds and other animals, including several federally protected endangered species.

Over the last three decades, the Service has alleged that junior groundwater pumping above the Refuge has resulted in periods of significant water shortages at the Refuge. For more than 15 years, the Service worked with the Rattlesnake Partnership, seeking to bring about voluntary reductions in use to improve its supply. On April 8, 2013, the Service requested this impairment investigation.

DWR reviewed existing records and gathered additional information on the Refuge's infrastructure, historical use and shortages, and the pattern of water needs at the Refuge as part of this investigation. DWR used the GMD 5 groundwater model to determine the magnitude and timing of streamflow depletions due to upstream, junior groundwater pumping on water availability at the Refuge. Finally, DWR compared the streamflows that would have been available but for the effects of junior groundwater pumping with the seasonal needs of the Refuge to estimate the magnitude and frequency of impairment in the record reviewed.

A technical report on the investigation and data analyses is attached hereto.

Based on our impairment investigation, I make the following findings and conclusions.

Findings

Upstream, junior groundwater pumping within the Basin is and has been significantly reducing water availability at the Refuge on the order of 30,000-60,000 acre-feet per year over the recent record (1995-2007). This does not mean that the Refuge is being impaired by 30,000-60,000 acre-feet per year, but rather that junior groundwater pumpers are taking that much out of the stream; water that would have otherwise flowed through or past the Refuge.

In comparing the seasonal needs of the Refuge, within the scope of its water right, with water that would have been available at the Refuge but for the effect of junior pumping, I find that the Refuge's water supply has been regularly and substantially impacted by junior groundwater pumping (see Figures 5-8 and Figure 9 of the report). Over the 34 years reviewed, shortages — when junior groundwater pumping prevented the Refuge from exercising its water right — were greater than 3,000 acre-feet in 18 years, particularly during periods of limited water supply.

As evidenced by various scenarios reviewed in the modeling report, while it will take years, reductions in groundwater pumping will restore streamflow at the Refuge.

DWR's analysis of water right data, water use data, and groundwater modeling analysis indicates that, due to the relatively small amount of pumping adjacent to the stream and the multi-year lag between pumping reductions and streamflow enhancement, real-time administration of junior groundwater pumping (i.e. curtailment only during periods of shortage) is unlikely to restore streamflow quickly enough to prevent impairment at the Refuge. Long-term reductions in upstream, junior groundwater pumping and/or the use of augmentation appear to be the only practical physical remedies to the impairment of the Refuge's water right.

My finding of impairment is based on historical simulations using the GMD 5 groundwater model and a retrospective analysis of the Service's needs. While I find this sufficient to conclude that impairment has occurred in the past and will occur in the future, the actual magnitude and timing of future impairment will depend on the specific circumstances. For instance, the Service has acknowledged that significant drought periods, and the resulting water shortages, are part of the natural hydrologic cycle, and DWR's impairment analysis does not directly factor in the Service's use of storage in Little Salt Marsh, which, in practice, may help to reduce some shortages to a limited degree.

Based on the historical analysis, and assuming that the basin's hydrology will not significantly change, for better or worse, in the next several decades, it appears that, to relieve the impairment of the Service's water right, groundwater reductions and/or augmentation will be needed to increase available streamflow at the Refuge by 3,000-5,000 acre-feet on a regular basis.

Conclusion

Based on the results of this investigation, I conclude that upstream, junior groundwater pumping regularly and significantly impairs the Service's ability to use its Water Right File No. 7,571.

Further, I find this impairment is not substantially due to regional overall lowering of the water table, but is principally due to ongoing impacts of junior groundwater pumping and the associated reduction in outflows from the groundwater system to the stream system.

Pursuant to K.A.R. 5-4-1, this second draft of this initial report is posted on the agency's website as of May 30, 2016: agriculture.ks.gov/quivira.

Technical Report

Prepared pursuant to K.A.R. 5-4-1

on a Claim of Water Right Impairment
In the Case of

Water Right File No. 7,571
owned and operated by

United States Department of the Interior
Fish & Wildlife Service
Quivira National Wildlife Refuge

◆

May, 2016

Division of Water Resources
Kansas Department of Agriculture

i. Executive Summary

Quivira National Wildlife Refuge ("Refuge") is located in south-central Kansas and primarily gets its water supply from Rattlesnake Creek which runs into and through the Refuge. The Refuge is located midway along the Central Flyway and consists of about 7,000 acres of wetlands. The Refuge uses water primarily to grow feed crops and maintain wetlands at certain depths to provide habitat for several hundred species of birds and other animals, including several federally protected endangered species. The Refuge is owned and operated by the United States Fish & Wildlife Service (Service), a part of the United States Department of the Interior.

After nearly three decades of expressing concerns that junior groundwater appropriators upstream of the Refuge are depleting the streamflow in Rattlesnake Creek, and working with local water users and the groundwater management district to try to find solutions to their concerns, the Service lodged an impairment complaint with the Kansas Department of Agriculture Division of Water Resources (KDA-DWR) in an April 8, 2013, letter.

The Service owns Water Right File No. 7,571; which is senior in priority to about 95% of the water rights in the basin, and which entitles the Refuge to divert up to 14,632 acre-feet of surface water each year from Rattlesnake Creek, when water is available.

Results from KDA-DWR's simulations using a groundwater model commissioned by Big Bend Groundwater Management District #5 ("GMD5") and built by groundwater modeling consultants, show that junior groundwater pumping upstream of the refuge has significantly reduced streamflow available to the Refuge over the years.

Using the modeling results and the Service's operational guide, which lays out the Refuge's seasonal water needs, KDA-DWR finds that junior groundwater pumping in Rattlesnake Creek impaired the Refuge's water right, to varying degrees, in 26 of the 34 years 1974-2007. The results showed that the impairment was greater than 3,000 acre-feet in 18 of the 34 years. However, the results also showed that, because groundwater moves very slowly, shutting off junior groundwater pumping would take two or more years to significantly benefit streamflow.

Since there have been no substantial long-term changes to pumping levels or precipitation trends in the region of the basin closest to the Refuge, it is reasonable to conclude that the impacts to streamflow caused by pumping will continue into the foreseeable future.

ii. Procedure, Content and Nature of this Report

This report was developed pursuant to the duties and responsibilities of the chief engineer and KDA-DWR set forth in the Kansas Water Appropriation Act, including but not limited to K.S.A. 82a-702, 82a-706, 82a-706b, 82a-707, and 82a-711a, and the procedures set forth in K.A.R. 5-4-1.

This technical report was developed to support the initial report of the chief engineer as described in 5-4-1(c)(2).

This report is intended to present the facts analyses performed to inform the chief engineer's finding on water right impairment. This report is not intended to evaluate or prescribe any particular remedy or resolution of any impairment observed.

iii. Table of Contents

iv. List of Figures

v. List of Tables

1. Introduction and Background

After several decades of expressing concerns that junior groundwater pumpers were interfering with and harming the management operations of the Quivira National Wildlife Refuge (Refuge) by depleting the streamflow in Rattlesnake Creek which supplies the Refuge, in an April 8, 2013, letter, the United States Fish & Wildlife Service (Service) lodged an impairment complaint with the Kansas Department of Agriculture Division of Water Resources (KDA-DWR). This report summarizes KDA-DWR's resulting investigation. See Attachments 1 and 2.

In the late 1980s, the Service began to express concerns to KDA-DWR and Big Bend Groundwater Management District #5 (GMD5), that junior appropriators were reducing the flows in Rattlesnake Creek such that the Refuge was prevented from exercising its water right and its operations were being negatively impacted. In 1994, the Service entered into the Rattlesnake Creek Partnership (Partnership) with GMD5, KDA-DWR, and a group of local water users called the Water Protection Association of Central Kansas (WaterPACK) to find a way to address the Service's concerns. In 2000, the Partnership finalized a 12-year plan (Management Plan) to address USF&W's concerns and submitted the plan to the KDA-DWR's chief engineer who approved it. The Management Plan called for KDA-DWR to prepare and submit a report every four years on the progress made towards the plan's goals. Three four-year reviews of the Rattlesnake Creek Partnership Management Plan were prepared and are available at dwr.kda.ks.gov/impairment/RSC.Quivira/TechReport.Attachments/

Near the end of 2008, GMD5 began work on developing a hydrologic model of the district (GMD5 Model), including the Rattlesnake Creek Basin and the Refuge. KDA-DWR participated in the peer review of the model development. The GMD5 Model was completed in 2010.

In 2012, the last four-year review of the Management Plan was conducted by KDA-DWR and submitted to the Partnership for approval. KDA-DWR found that over the course of the Management Plan water savings from incentive-based programs and enhanced compliance and enforcement, yielded 2,804 acre-feet, just over 10% of the goal of 27,346 acre-feet of savings laid out by the Partnership. There was no significant reduction in irrigated acres and the amount of irrigation water applied per acre has remained generally constant when factoring in the effects of precipitation. GMD5 and WaterPACK did not accept KDA-DWR's 2012 review report.

After receiving the Service's 2013 impairment complaint, KDA-DWR began using the GMD5 Model to evaluate the historical impacts that junior appropriators have had on Rattlesnake Creek streamflow. Simulations using the GMD5 Model show that stream depletions (depletions to baseflow) caused by junior appropriators are on the order of approximately 30,000 acre-feet to 60,000 acre-feet per year for the period 1995-2007. This does not mean that the Refuge is being impaired by 30,000-60,000 acre-feet per year, but rather that junior groundwater pumpers are taking that much out of the stream; water that would have otherwise flowed through or past the Refuge.

A retrospective analysis added the streamflow depletions to the observed streamflow record gaged at Zenith to simulate how much streamflow would have been measured at the Zenith gage if there had been no pumping junior to the Service's right. Comparing the simulated "no junior pumping" record to the observed record and then evaluating how the seasonal needs of the Refuge within its water right would have been fulfilled in the simulated and observed cases shows that the Refuge's water right was impaired by upstream junior groundwater pumping in 26 of the 34 years of the simulation period 1974-2007. Further, the simulations also show that because of the relatively slow movement of groundwater, the time between when a pumping well is reduced or shut off and when the water that would have been streamflow but for the pumping is restored to the stream is on the order of two or more years, or even decades, depending on the well's distance from the stream.

2. Hydrogeologic Setting

The descriptions below are taken in large part from “A Computer Model for Water Management in the Rattlesnake Creek Basin, Kansas” (Kansas Geological Survey, The University of Kansas and Department of Civil Engineering, Kansas State University, 1997). Internal citations are omitted.

The Rattlesnake Creek basin is approximately 1,317 square miles in area and is located within the Great Bend Prairie of south-central Kansas. It is approximately 95 miles long and 18 miles wide with the long axis oriented in a southwest-to-northeast direction. Parts of Rice, Barton, Reno, Stafford, Pawnee, Edwards, Kiowa, Pratt, Ford, and Clark counties are included in the basin, with Stafford, Kiowa, and Edwards counties covering more than 82% of the watershed area.

The watershed is located in two physiographic regions. The upper 85% of the watershed is located in the Arkansas River lowlands (Great Bend Prairie region); it is a relatively flat alluvial plain characterized by sand-dune topography with moderate slopes and small hills separated by small basins. The upper 15% of the watershed belongs to the High Plains region, which is also a comparatively flat alluvial plain dissected by intermittent streams and exhibiting shallow depressions and gentle swells. Much of the sand-dune area of the watershed is covered by vegetation, and a large part of it is farmed; the watershed is primarily agricultural.

The watershed is drained by the Rattlesnake Creek, which is a meandering stream flowing from the High Plains region northeasterly into the Great Bend lowlands area where it empties into the Arkansas River. A number of smaller streams merge into the Rattlesnake Creek throughout its course from the highlands to the Arkansas River.

The primary source of recharge to the system is infiltration from precipitation, which varies spatially within the basin. Recharge varies with the soil type. The Rattlesnake Creek and its tributaries are a source of water to the ground-water system in the western parts of the watershed, where surface runoff into the stream eventually percolates into the subsurface. In the north-eastern parts of the watershed, the Rattlesnake Creek is essentially a gaining stream as recharge is discharged into the stream system from approximately Macksville downstream. The Quivira marsh in the lower reaches of the basin acts as a drainage outlet for the ground-water system.

Figure 1 illustrates the effect of groundwater pumping on streamflow.

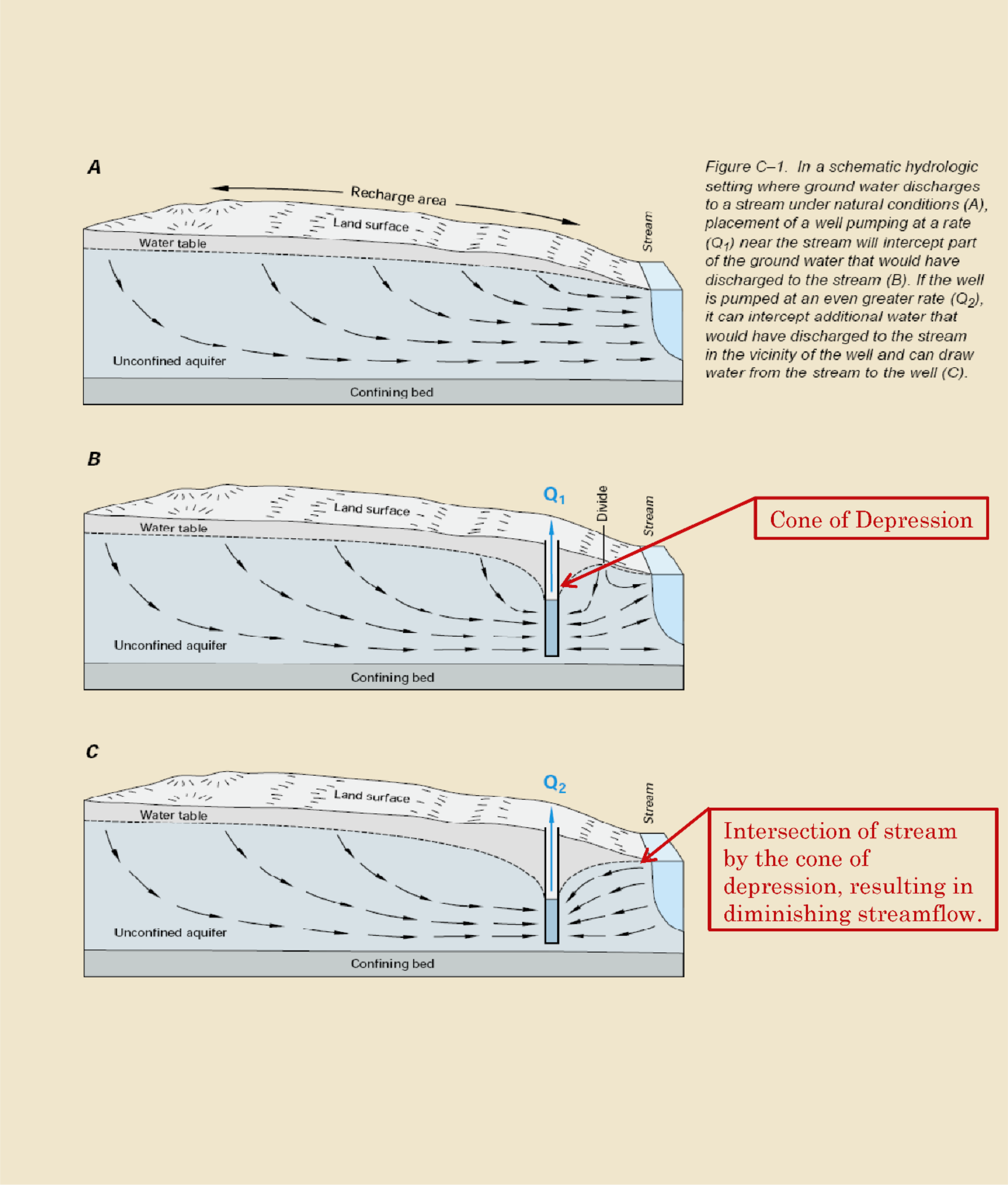


Figure C–1. In a schematic hydrologic setting where ground water discharges to a stream under natural conditions (A), placement of a well pumping at a rate (Q_1) near the stream will intercept part of the ground water that would have discharged to the stream (B). If the well is pumped at an even greater rate (Q_2), it can intercept additional water that would have discharged to the stream in the vicinity of the well and can draw water from the stream to the well (C).

Cone of Depression

Intersection of stream by the cone of depression, resulting in diminishing streamflow.

Source: United States Geological Survey, Circular 1139, *Ground Water and Surface Water: A Single Resource* (1998), Figure C-1, p. 15 (Figure title and boxed annotations in red added).

Figure 1 - Effect of Groundwater Pumping on Surface Water

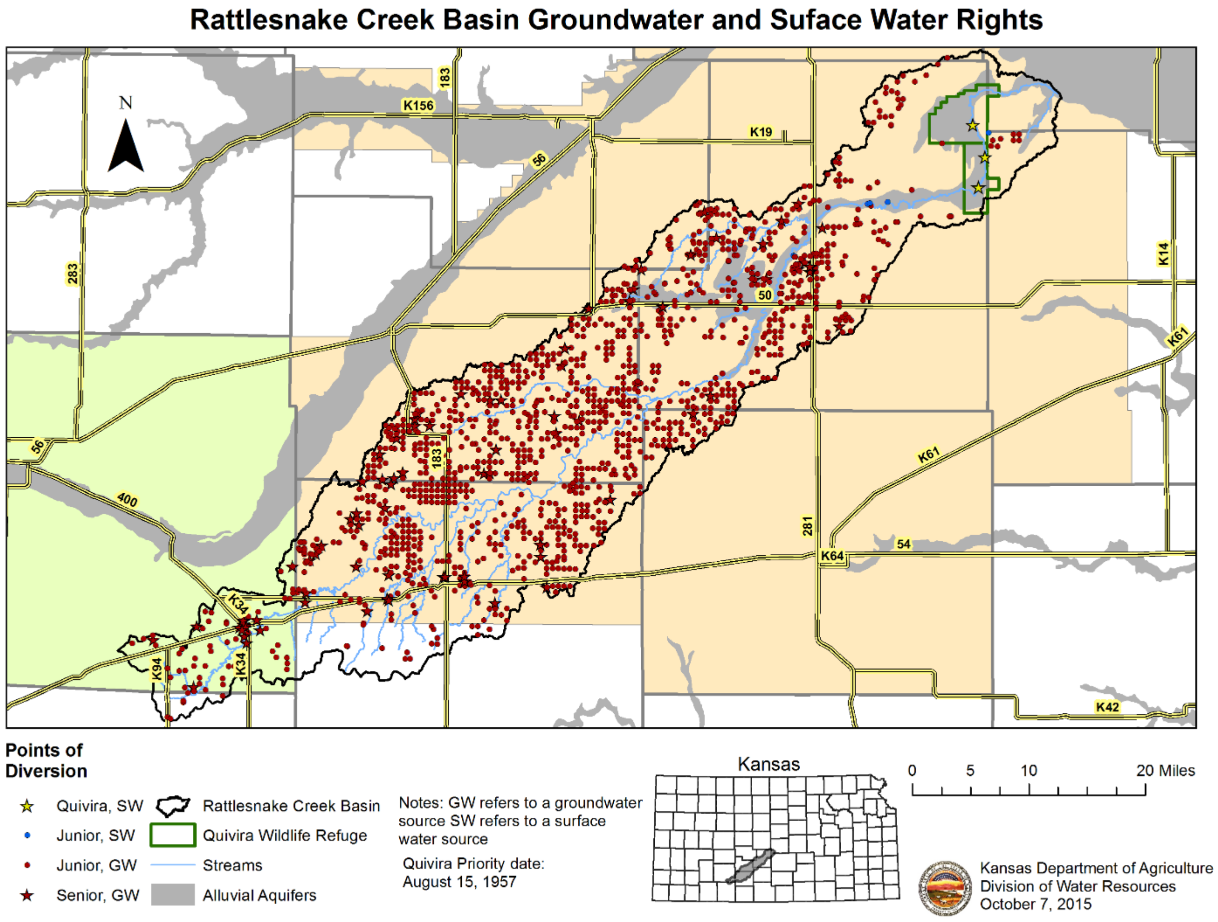
3. Water Use Summary

Year of record	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
# of Water Rights *												
Groundwater	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,680
Surface Water	10	10	10	10	10	10	10	10	10	10	10	10
Quivira (included in Surface	1	1	1	1	1	1	1	1	1	1	1	1
Junior to Quivira	1,599	1,599	1,599	1,599	1,599	1,599	1,599	1,599	1,599	1,599	1,599	1,599
Senior to Quivira	90	90	90	90	90	90	90	90	90	90	90	90
# of Water Rights Reporting Use												
Groundwater	1,374	1,371	1,367	1,368	1,379	1,378	1,376	1,375	1,376	1,377	1,381	1,381
Surface Water	5	5	5	5	5	5	5	5	5	5	5	5
Quivira (included in Surface	1	1	1	1	1	1	1	1	1	1	1	1
Junior to Quivira	1,304	1,301	1297	1298	1,309	1,308	1,306	1,305	1,306	1,307	1,311	1,311
Senior to Quivira	74	74	74	74	74	74	74	74	74	74	74	74
Water Use (AF)												
Groundwater	208,499	167,241	169,229	200,386	152,764	175,749	169,163	190,372	251,259	212,251	172,422	174,368
Surface Water	1,747	9,701	4,591	4,907	31	3,329	1,766	8,539	3,351	2,275	2,728	2,199
Quivira (included in Surface	1,727	9,679	4,559	4,875	0	3,323	1,760	8,526	3,320	2,249	2,712	2,178
Total water use (AF)	210,246	176,941	173,820	205,293	152,795	179,078	170,929	198,911	254,610	214,525	175,150	176,567
Authorize Quantity (AF)*												
Groundwater	252,258	252,258	252,258	252,258	252,258	252,258	252,258	252,258	252,258	252,258	252,258	252,258
Surface	14,902	14,902	14,902	14,902	14,902	14,902	14,902	14,902	14,902	14,902	14,902	14,902
Quivira (included in Surface	14,632	14,632	14,632	14,632	14,632	14,632	14,632	14,632	14,632	14,632	14,632	14,632
Total	267,160	267,160	267,160	267,160	267,160	267,160	267,160	267,160	267,160	267,160	267,160	267,160
% of Authorized Quantity Used*												
Groundwater	83%	66%	67%	79%	61%	70%	67%	75%	100%	84%	68%	69%
Surface	12%	65%	31%	33%	0%	22%	12%	57%	22%	15%	18%	15%
Quivira (included in Surface	12%	66%	31%	33%	0%	23%	12%	58%	23%	15%	19%	15%
Total	79%	66%	65%	77%	57%	67%	64%	74%	95%	80%	66%	66%
# of Irrigated Acres												
Groundwater	160,692	161,606	157,722	160,660	158,168	160,400	160,129	160,867	161,316	160,274	158,510	158,765
Surface	21	0	0	0	0	0	0	0	0	0	0	0

Table 1 - Summary of Rattlesnake Creek Basin Water Rights

Table 1 summarizes the basin's water rights and water use information over 2003-2014. Over 98% of the water use in the basin is from groundwater. The Refuge's surface water right accounts for 98% of all the surface water appropriated in the basin and is senior in priority to about 95% of all the water rights in the RSC Basin — groundwater and surface water.

The Water Right Information System database from which Table 1 was compiled does not contain records of the years in which water rights were dismissed. Water rights dismissed during 2003-2014, if any, are not represented in Table 1. The same is true for authorized quantity associated with dismissed rights.



Notes: GW refers to a groundwater source SW refers to a surface water source

Quivira Priority date: August 15, 1957

Figure 2 - Rattlesnake Creek Basin map of water rights

4. The Refuge's Water Right

The Refuge's Water Right File No. 7,571 was filed Aug. 15, 1957. The application requested 22,200 acre-feet at a diversion rate of 300 cubic feet per second. The Refuge's water right application was approved May 9, 1963, and specified a perfection date of Dec. 31, 1968. Citing ongoing construction and funding delays, on Nov. 29, 1968, the Service requested that the perfection period be extended to Dec. 31, 1973. This and the remaining documents referenced in this section are included in the electronic water right file available online at agriculture.ks.gov/quivira.

In a May 2, 1973, memorandum to the State Board of Agriculture, DWR Stafford Water Commissioner J. Maurice Street reported on a meeting held in St. John where an attorney representing the Service asserted that the Service held vested rights to some Rattlesnake Creek streamflow based in its acquisition of property from a gun club that had used water for recreational purposes prior to 1945.

In its July 17, 1973, letter, the Service described progress made in developing the Refuge and noted that the Refuge construction was 80% complete. The letter requested that the perfection period be extended to Dec. 31, 1978. In a March 20, 1974, letter the chief engineer noted that the Refuge was complete.

DWR notified the Service by March 20, 1974 letter that it considered the Refuge construction complete, that it had determined that the Refuge's 1971 water use report, along with the other documentation already compiled in the water right file was sufficient to fulfill the Notice and Proof requirements of K.S.A. 82a-714, and that the perfection period was extended to Dec. 31, 1978. The 1971 water use report showed that 10,063 acre-feet were used on the refuge.

Citing funding delays, the Refuge in its Dec. 22, 1978, letter requested the perfection period of its water right be extended to Dec. 31, 1983. DWR's receipt and approval of that request was not located in the paper file, nor was any subsequent request or approval for extending the perfection period to include the year of record 1987.

However, in order to catch up on a backlog of files pending certification, in August 1989, DWR implemented Administrative Policy 89-9 which, among other things, allowed for extensions of the perfection period for good cause shown for applications with a priority date on or before May 1, 1978. The perfection period of the Refuge's water right was extended to 1978 under the guidelines of this policy whose principles later became regulation K.A.R. 5-8-7 and are still in force today.

DWR's certification memorandum of Feb. 8, 1993, which is excerpted below, explains why 1987 was chosen as the year of record and notes that an extension would need to be granted by DWR. K.A.R. 5-8-7 allows the Chief Engineer to extend the perfection period of a water right if other records or information are available for a period after the original perfection period that would reasonably represent the application of water to beneficial use in accordance with the terms, conditions, and limitations of the permit. A USGS gage was installed at Zenith in 1973. The Refuge's diversion works were not fully functional until 1978. The 10-year perfection period after 1978 was extended until 1987. The USGS gage at Zenith established a good, verifiable water flow record which was used in part to help quantify the Refuge's water right.

On Oct. 31, 1986, the Service sent a letter to DWR claiming that Rattlesnake Creek streamflow was declining due to junior diverters, especially groundwater development. The Service was especially concerned about the increasing lack of streamflow in late summer and early fall when there is the greatest need for water on the refuge. In its letter, the Service also references K.S.A. 42-306 which says, "No person shall be permitted to take or appropriate the waters of any subterranean supply which naturally discharge into any superficial stream, to the prejudice of any prior appropriator of the water of such superficial channel."

DWR issued the draft certificate and its Feb. 8, 1993, Certification Memorandum, File 7571 laid out the chronology of events that led to finalizing the Refuge's water right and summarized the process:

> *File 7571 was approved in 1963. During the time period 1963 to 1972 many of the water use reports were estimated and during that time the diversion works were reported to be only 80% complete. An actual water measurement program may not have been in place prior to 1973. In 1973, a year of torrential rainfall, the diversion works and control structures at Quivira were destroyed. It was not until 1978 that the damage was finally repaired. The year 1978 was, therefore, the first year that the diversion works were complete and ready to divert and store water according to management plans. Assuming that the water requirements of the refuge are best represented by years after 1978, the year 1987 has been selected as the year of record. Using 1987 will require that an extension of time to perfect be granted to that year.*

> *During 1987 the U.S. Fish and Wildlife Service reported that 10129.7 acre feet of water was diverted from the Rattlesnake Creek and that the refuge was "full all year." … the measurements do not reflect the amount stored and the subsequent evaporation in the Little Salt Marsh. Using an area of 950 acres in the Little Salt Marsh, and a capacity of 2260 acre feet, one would assume 2850 acre feet of evaporation during a calendar year (36 inches of net evaporation). The proposed certified quantity for file 7571 would then be the sum of the acre feet reported in 1987, the amount stored in the Little Salt Marsh: 10129.7 acre feet + 2260 acre feet + 2850 acre feet = 15240 acre feet. It is also proposed that all of the 15240 acre feet be shown as direct use and that the "quantity to be accumulated in reservoirs" as stated in the approval be dropped from the certificate.* (internal references omitted)

The Service's Nov. 12, 1993, letter raised several issues with DWR's draft certificate. The Service noted that the original application was for 22,000 acre feet of water and that hydrologic modeling performed by the Kansas Geological Survey (KGS Open File Report 93-7) estimated that by 1987, junior groundwater pumping — modeled at 70% of authorized — had depleted the streamflow in Rattlesnake Creek by at least 8,456 acre feet, some or all of which could have been used by the Refuge. As noted below, DWR has used the groundwater model developed by GMD5 to evaluate pumping impacts on Rattlesnake Creek streamflow. Figure 11 shows that the GMD5 model estimates that by 1987, junior groundwater pumping had depleted Rattlesnake Creek streamflow by about 38,000 acre-feet.

In a May 27, 1994, letter, Chief Engineer David Pope acknowledged the streamflow at the Refuge may have been reduced by groundwater pumping and that the Refuge may have been able to divert and beneficially use more water but for those reductions. However, DWR's position was that it was constrained by K.S.A. 82a-714 and K.A.R. 5-3-8 which, among other things, limits certification of a water right to no more than the amount actually diverted and used by the water user.

The Service and DWR exchanged several more letters over the next two years expressing their views on how the Refuge's water right should be certified. On April 10, 1996, DWR issued the final Certificate of Appropriation for File No. 7,571.

In a subsequent memorandum, KDA-DWR noted and recommended correcting a 45 acre-foot transposition error in the original certification memorandum. The corrected quantity was ultimately certified. See Attachment 3.

The Refuge's water right entitles it to take water from Rattlesnake Creek at three points of diversion at a combined maximum diversion rate not in excess of 300 cubic feet per second and a quantity not to exceed 14,632 acre-feet of water per calendar year for recreational use. This is the volume of water used in 1987 to operate the wetlands areas including filling Little Salt Marsh (1,865 acre-feet), evaporation from Little Salt Marsh (2,592 acre-feet), and filling the Refuge's management areas to meet wildlife feed crop demands (10,175 acre-feet). See Figure 3 below and Attachment 4.

Like all Kansas water rights, the Refuge's water right does not guarantee the availability of any certain amount of water, rather it entitles the Refuge to its authorized rate and quantity subject to prior and vested rights, and the natural availability of water. And, just like the water rights held by its irrigator neighbors, the Refuge's water right entitles it to divert the water at the times when it is most beneficial. Even though a quantity in excess of the Refuge's annual water right might pass by the Refuge's point of diversion in any given year, the test for whether the Refuge's water right has been diminished in value or utility — impaired — is whether the Refuge could have more fully exercised its water right if junior diverters had not taken the streamflow out of priority.

The owner of a water right can adjust the operation of his or her right once the right is perfected and certified, as long as the operation of the right stays within the terms, conditions, and limitations set forth in the certificate (use made of water, point of diversion, place of use, authorized quantity, etc.). The Refuge's water right was applied for, perfected, and has subsequently been exclusively used for recreational use, one of the authorized uses of water in Kansas. In the decades since it was established, the Refuge has adjusted the way it manages its habitat. Modifications to the operations of all water rights are to be expected as technology and best management practices change. For example, if someone perfected an irrigation water right on 160 acres of corn using a flood irrigation system in 1975, then modified their operation by installing a pivot, now watering 130 acres and growing wheat, that owner would not be required to reduce their property right as long as they stayed within the terms, conditions and limitations of the irrigation right. That water right owner would also have the right to go back to flood irrigating corn or another crop if they so choose to do. Likewise, a water right holder could perfect a stock watering right on 1500 head of cattle in a confined feeding operation. They could modify their operation by switching to 2000 head of hogs. No reduction would be required. They also could go back to 1500 head of cattle.

The Refuge water right was developed to manage approximately 7000 acres of wetlands within a refuge area of 22,135 acres (from 2014 CCP). In a letter dated November 12, 1993, the USFW stated that net evaporation based on DWR policy

84-1 using 36” of evaporation and a 6469.6 acres of marshes equates to 19,409 AF which does not include any water to fill the impoundments, which it estimated to be 13,246 AF. The Service recommended the certificate be issued for 20,021 AF year at 300 CFS. Based on managing approximately 7000 acres of wetlands, at 31 inches/year of net evaporation (average year, K.A.R 5-6-3), it would appear that the full authorized quantity could be used in most years, and substantially more than this in critical dry periods.

During both the perfection period and currently, the Refuge seeks to manage approximately 7000 acres in wetlands. As the use for the water and acres has remained the same, we see no evidence of expanded use.

5. The GMD5 Groundwater Model

In 2008, GMD5 commissioned Balleau Groundwater, Inc. to develop a numerical groundwater model of the district. The model was peer reviewed throughout its development by KDA-DWR and KDA-DWR’s consulting expert, Steven P. Larson of S.S. Papadopoulos and Associates. The model was completed in 2010. The Model report and peer review report are available at dwr.kda.ks.gov/impairment/RSC.Quivira/TechReport.Attachments/.

The GMD5 model was built with seven layers, each layer representing a geologic formation at a range of depths below the surface of the ground. One of the principal reasons for using multiple layers in this model was so that the movement of water contamination plumes could be simulated and management strategies to contain those plumes could be evaluated. The complexity of the seven-layer model requires significant computer resources and time to run simulations.

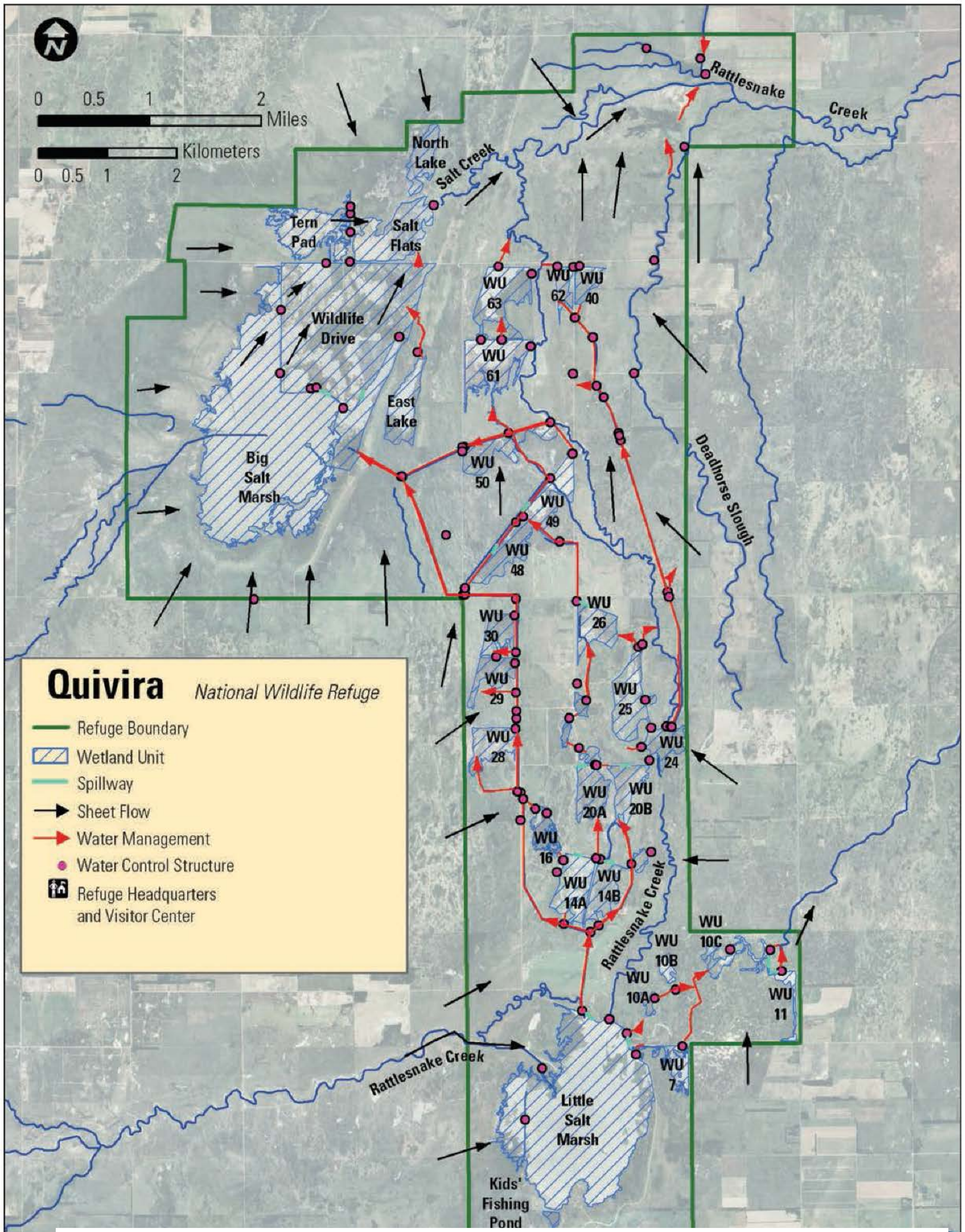


Figure 3 - Refuge features
credit:US Fish & Wildlife Service

To evaluate the effects of pumping on groundwater levels and the discharge of groundwater into the stream system, a one-layer model, if properly designed and calibrated, is sufficient. S.S. Papadopoulos and Associates simplified the GMD5 model by "collapsing" the original seven-layer model into a one-layer model so that it could be used to run scenarios in minutes instead of hours. The conversion from seven-layer model to one-layer model did lose the vertical resolution needed to simulate how contaminant plumes move up towards the surface of the earth and down away from it, but by effectively averaging the aquifer properties across the seven layers, the way that the horizontal movement of water beneath the ground is simulated was not significantly altered.

Beginning in 2014, KDA-DWR used the original seven-layer GMD5 model, and the simplified, one-layer modification of the model to simulate how the Rattlesnake Creek streamflow would respond to several alternative historical pumping scenarios. For instance, one scenario simulated the effect of no pumping anywhere in the basin junior to the Refuge's water right. Another scenario simulated no junior pumping in a corridor along the stream. The work was intended to increase familiarity with and understanding of the model, to show that the original seven-layer model and the simplified one-layer version of the model were functionally equivalent for these kinds of scenarios, and to show the Basin community how and when groundwater pumping affects RSC streamflow.

KDA-DWR presented results for nine alternative historical scenarios at a public meeting in St. John on November 4, 2014. The Appendix documents KDA-DWR's modeling work presented at the meeting. The following observations from this work were made at the meeting:

1. The seven-layer GMD 5 model and the one-layer simplified version of it are functionally equivalent for the purpose of evaluating groundwater pumping impacts to streamflow in Rattlesnake Creek.

2. The GMD5 model shows that junior groundwater pumpers have caused significant reductions to the amount of groundwater that discharges to Rattlesnake Creek. Basin-wide, the depletions are on the order of 30,000-60,000 acre-feet over the period 1995-2007.

3. Pumping reductions near the stream provide the most immediate benefit to Rattlesnake Creek stream flow. However, only about 8% of the junior pumping takes place within two miles of the stream, and only about 3% is within one mile of the stream. This nearby pumping accounts for about 16% (2 miles) and 6% (1 mile) of the impacts to streamflow, respectively [averaged over years 1998-2007 as fractions of impact of scenario 2, from Appendix, Table A3].

4. Depending on the distance from the stream, it takes two or more years for pumping reductions to manifest as increased streamflow in significant amounts and longer to fully recover.

In comments on the First Draft of the Initial Impairment Investigation Report, Balleau Groundwater, Inc. noted what they agreed was a minor issue with the way that DWR's model simulations started — from a "transient" instead of a more correct "steady state" condition. DWR has developed revised model runs accordingly and found discrepancy between the transient and steady-state runs diminished over the period from 1940 to 2008, and were negligible for the purposes of this impairment analysis. Therefore, DWR has not redone the rest of this analysis. Documentation of the resulting work is included as an addendum to the Modeling Appendix of this Second Draft of the report.

Further descriptions and results of these simulations are available at dwr.kda.ks.gov/impairment/RSC.Quivira/TechReport.Attachments/.

6. Determination of Junior Groundwater Pumping Impacts at the Refuge

One of the fundamental elements of an impairment investigation is the determination of the impacts that junior diversions have had, are having, and will likely have on senior water rights. The GMD5 Model was used to evaluate the historical effects of junior groundwater pumping on Rattlesnake Creek streamflow at the Refuge. The results of the modeling analysis were presented at a public meeting in St. John, Kan., on Nov. 4, 2014, and are documented in the Appendix. Below is a summary of the results that are most relevant to this investigation.

To evaluate the effects that junior pumpers upstream of the Refuge have had on the flows of Rattlesnake Creek at the Refuge, two simulations of the model were compared. In one simulation, pumping in the basin junior to the Refuge's water right was "turned off," or omitted from the simulation, and the amount and timing of groundwater that discharged from the aquifer to the stream was observed. This simulation was called "no junior pumping." The other simulation, called the "baseline," simulates the effects on streamflow caused by the actual recorded historical pumping. The "baseline" results were subtracted from the "no junior pumping" results and the effects of junior pumping on Rattlesnake Creek simulated streamflow over time were observed. These simulations show that there would have been significantly more water in Rattlesnake Creek, often at times when the Refuge could have made use of the additional water, if there had been no pumping junior to the Refuge's water right. See Figures 5-9 and Figures A8 and A9 in the Appendix.

KDA-DWR performed other simulations with the GMD5 Model to evaluate how Rattlesnake Creek would respond to targeted pumping reductions close to the stream. The simulations showed that, because of the characteristics of the hydraulic connections between the stream system and the groundwater system, and because of the relatively low volume of pumping in the stream corridor, even targeted reductions close to the stream would take on the order of two to three years to produce significant increases in streamflow. Though such reductions would eventually restore streamflow, they would be ineffective in providing timely, same-year, much less same-season, relief from shortages caused by junior pumping. For example, if the Refuge needed water in August of 2016, restricting upstream pumping by junior water rights in the spring of 2016 would provide limited benefit to the Refuge until the summer of 2018. See Figures A6 and A7 in the appendix on page 43.

7. Observations From Comparing Model Simulations and the Refuge's Operational Water Needs

The Service has documented its management strategies and quantified its goals for providing seasonal habitat in its Comprehensive Conservation Plan. At KDA-DWR's request, Service staff prepared a document explaining the water needs and management at the Refuge and specifying time periods and amounts of water needed within those time periods to accomplish the Refuge's mission within the scope of its water right. An excerpt of the Service's Comprehensive Conservation Plan describing the management goals for Refuge's wetlands and the subsequent documentation of the Refuge's water seasonal needs is in Attachment 5, Table 4. The historical averages from Table 1 of the Refuge's document were not used in this analysis as they represent the Service's use from the significantly depleted supply which has been the focus of the Service's complaints for decades and which led to this impairment investigation. As noted in the section of the report on the Service's water right, it is reasonable to expect that most of the Service's water right will be needed in each year, particularly during critical, dry periods. The Service's complete Comprehensive Conservation Plan is available here: [www.fws.gov/mountain-prairie/planning/ccp/ks/qvr/qvr.html.](www.fws.gov/mountain-prairie/planning/ccp/ks/qvr/qvr.html)

KDA-DWR compared the modeled impacts of junior pumping with the seasonal water needs defined by the Service to determine if there have been times when the Refuge was prevented from exercising its water right because streamflow was taken by junior pumpers. Comments to the initial report were concerned about use of a schedule based on 14,632 acre-feet per year without making allowances for evaporation and storage in Little Salt Marsh (LSM). The analysis compares the Service's schedule with flows at Zenith which is above LSM and thus could measure the water available to supply the storage and evaporation needs at LSM plus the diversion needs below it.

The analysis shows that junior groundwater pumping has prevented the Refuge from exercising its water right regularly in the past. Figures 6-7 show simulated seasonal streamflow that would have been in Rattlesnake Creek but for junior groundwater pumping and actual streamflow over time contrasted against the Refuge's seasonal water needs as defined by the Service in Attachment 5. The dark blue modeled pumping depletions are stacked on the light blue gaged streamflow to show how much streamflow would have been in Rattlesnake Creek but for junior pumping depletions. The green trace represents the Refuge's water needs, which is a repeating pattern over the time period illustrated. The red "impairment" trace shows where the dark blue modeled pumping depletions have intersected the green Refuge needs trace. The orange trace on the graphic shows the Refuge's reported historical diversions. The reported diversions are understated to varying degrees because they are measured after water from Rattlesnake Creek has been impounded and released from Little Salt Marsh, and therefore do not include evaporation from the Marsh, which would be counted as use. The surface area of the Little Salt Marsh is approximately 950 acres; 2,850 acre-feet of evaporation from the Marsh was assumed in the year of record for the certificate.

Note that the evaluation shows that the Refuge was impaired in 1987, the year of record for its water right certificate. The amount of simulated impairment is very small (220 acre feet); close to zero when compared to the amount of impairment simulated in other years, but it should be zero by definition. The small impairment simulated in 1987 is an artifact of imposing the Refuge's present operational plan on the historical record.

It is reasonable to assume that effects of the same magnitude seen in the year of record and caused by applying the Service's current operational plan to the historical record are present in all years in the simulation. No analysis was performed to compare differing management plans. Applying the Service's present operational plan on the historical record comes to within 1.5% of the seasonal and total water use in the year of record and indicates that the evolution of the Refuge's operations has not increased its water demand.

The historical impairment evaluation also does not explicitly take into account any mitigating effects that storage in Little Salt Marsh might have on the

Refuge's water needs. Figure 8, for instance, shows that in the two management periods May-June and July-September 1995, there is an abundance of water flowing at the Zenith gage. The expectation is that the Refuge would maximize their storage capabilities to the extent possible within the constraints of their primary mission to create and maintain habitat.

The historical impairment evaluation during dry periods such as 1990-1992 and 2001-2006 indicate that the pumping depletions to streamflow caused by junior groundwater pumping exceeded the actual measured streamflow, providing little to no opportunity to fill storage or fulfill the Refuge's water right. It is in these periods of pumping-induced shortages that the Refuge's water right was most severely impaired: 5730-8580 acre-feet in 1990-1992 and 4220-7930 acre-feet in 2001-2006. See Figure 10.

Unless groundwater pumping operations change significantly in the Rattlesnake Creek Basin, it is reasonable to assume that junior groundwater pumping will prevent the Refuge from exercising its water right regularly in the future.

Figure 4 below shows the method for determining the retrospective impairment illustrated in Figure 6-8.

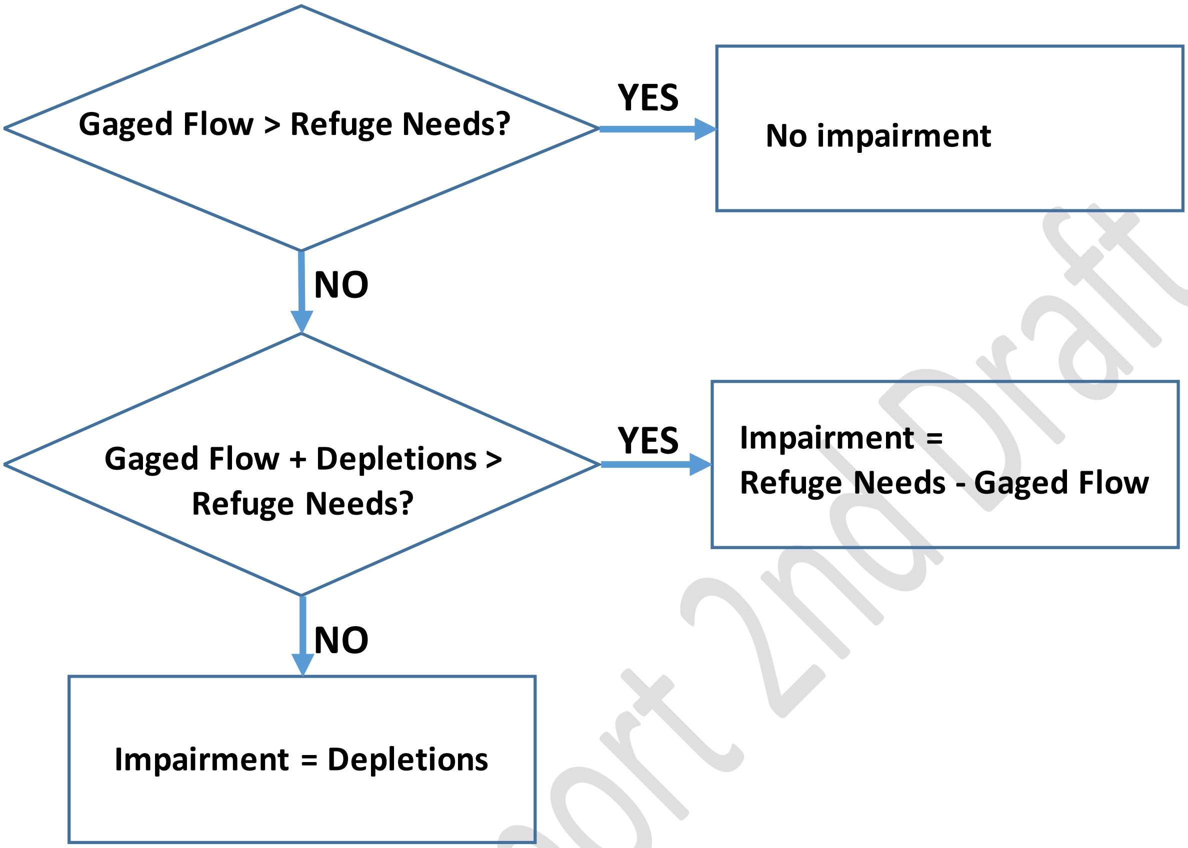


Figure 4 - Method for determining historical simulated impairment to the Refuge's water right based on the USGS gage at Zenith

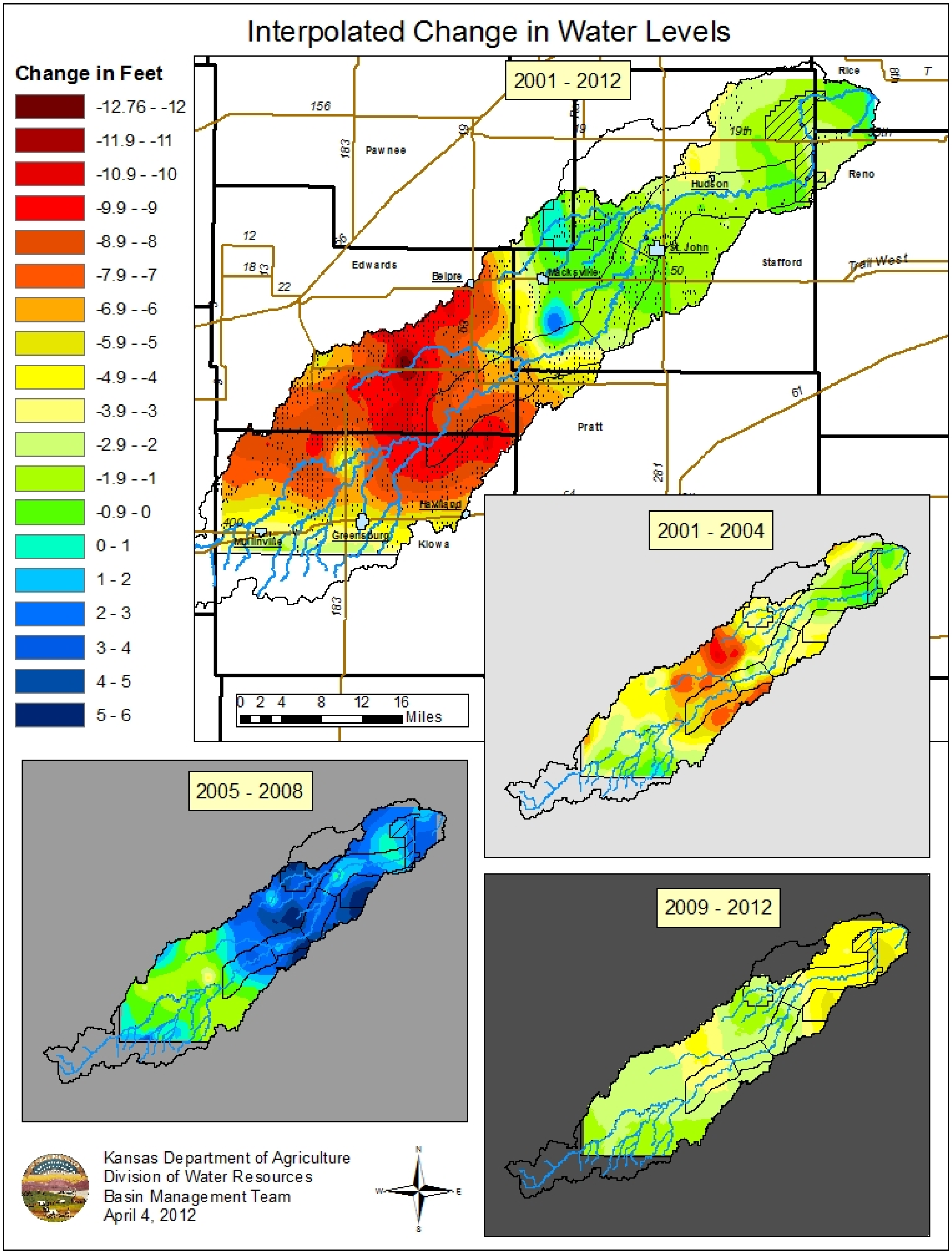
USFW Management Period	Year	Zenith Gaged Flow	Modeled Impacts to RSC	Refuge Reported Diversions	Refuge Needs	Amount short of needs
Jan/Feb	2003	1860	7340	1180	1500	0
Mar/Apr	2003	4720	9640	320	3500	0
May/Jun	2003	2770	5690	0	2000	0
Jul/Aug/Sep	2003	650	4040	120	3500	2850
Oct/Nov	2003	840	4290	40	3600	2760
Dec	2003	540	2800	80	500	0
Jan/Feb	2004	1050	5140	970	1500	450
Mar/Apr	2004	2300	6270	2840	3500	1200
May/Jun	2004	1500	5430	370	2000	500
Jul/Aug/Sep	2004	2960	13070	4370	3500	540
Oct/Nov	2004	1690	7640	550	3600	1910
Dec	2004	1080	3220	580	500	0
Jan/Feb	2005	2490	7820	2130	1500	0
Mar/Apr	2005	2390	5630	130	3500	1110
May/Jun	2005	3000	7280	0	2000	0
Jul/Aug/Sep	2005	3620	8230	1660	3500	0
Oct/Nov	2005	900	5510	0	3600	2700
Dec	2005	740	2540	640	500	0
Jan/Feb	2006	1760	3710	1870	1500	0
Mar/Apr	2006	1940	4020	1240	3500	1560
May/Jun	2006	1060	4910	790	2000	940
Jul/Aug/Sep	2006	940	7970	750	3500	2560
Oct/Nov	2006	730	5150	220	3600	2870
Dec	2006	640	3650	0	500	0
Jan/Feb	2007	1670	7400	1690	1500	0
Mar/Apr	2007	10540	9530	1420	3500	0
May/Jun	2007	32510	14730	130	2000	0
Jul/Aug/Sep	2007	16420	14710	1720	3500	0
Oct/Nov	2007	2510	7580	1670	3600	1090
Dec	2007	3280	5240	830	500	0

Table 2 - Gaged flow, Refuge needs, and calculated shortfall

Table 2 above shows the recorded flow at the USGS gage at Zenith, the modeled groundwater pumping impacts to Rattlesnake Creek, the seasonal needs of the Refuge, and amounts, if any, that the pumping depletions impaired the Refuge's ability to execute its management plan. The table showing the entire simulation period from 1974-2007 is in Attachment 6.

The record shows that Rattlesnake Creek Basin experiences periodic dry cycles, when groundwater levels and streamflow decline, and wet periods when groundwater levels largely recover and streamflow is more plentiful. Figure 5 shows interpolated changes in water levels over the three review periods of the Rattlesnake Creek Management Plan. 2001-2004 was a dry period, but 2005-2008 saw widespread recovery to water levels. 2001-2012 shows declines in water levels on the order of 10 feet or more in the southwestern part of the basin, but in the northeastern part of the basin where the water table is shallower and more connected to the surface water system, declines are generally in the 0 ft. to -3 ft. range.

As demonstrated in the groundwater modeling work and the analysis above, water shortages to the Refuge are related to the impacts of junior groundwater pumping intercepting recharge which otherwise would show up as streamflow. These impacts are most pronounced during the dry periods.



Kansas Department of Agriculture
Division of Water Resources
Basin Management Team
April 4, 2012

Figure 5 - Interpolated Change in Water Levels in Rattlesnake Creek Basin

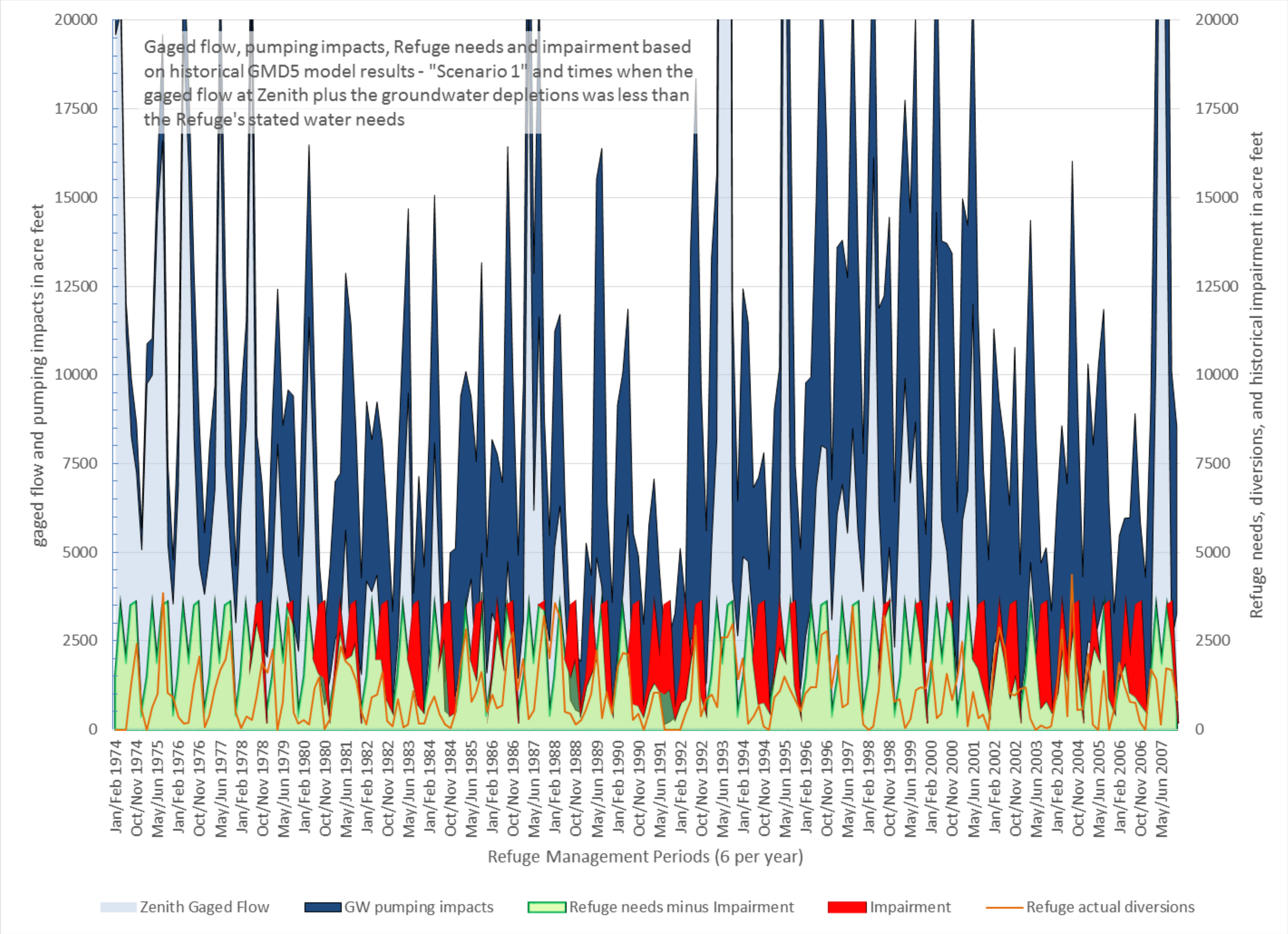


Figure 6 - Simulated evaluation of impairment to the Refuge's water right 1974 - 2007

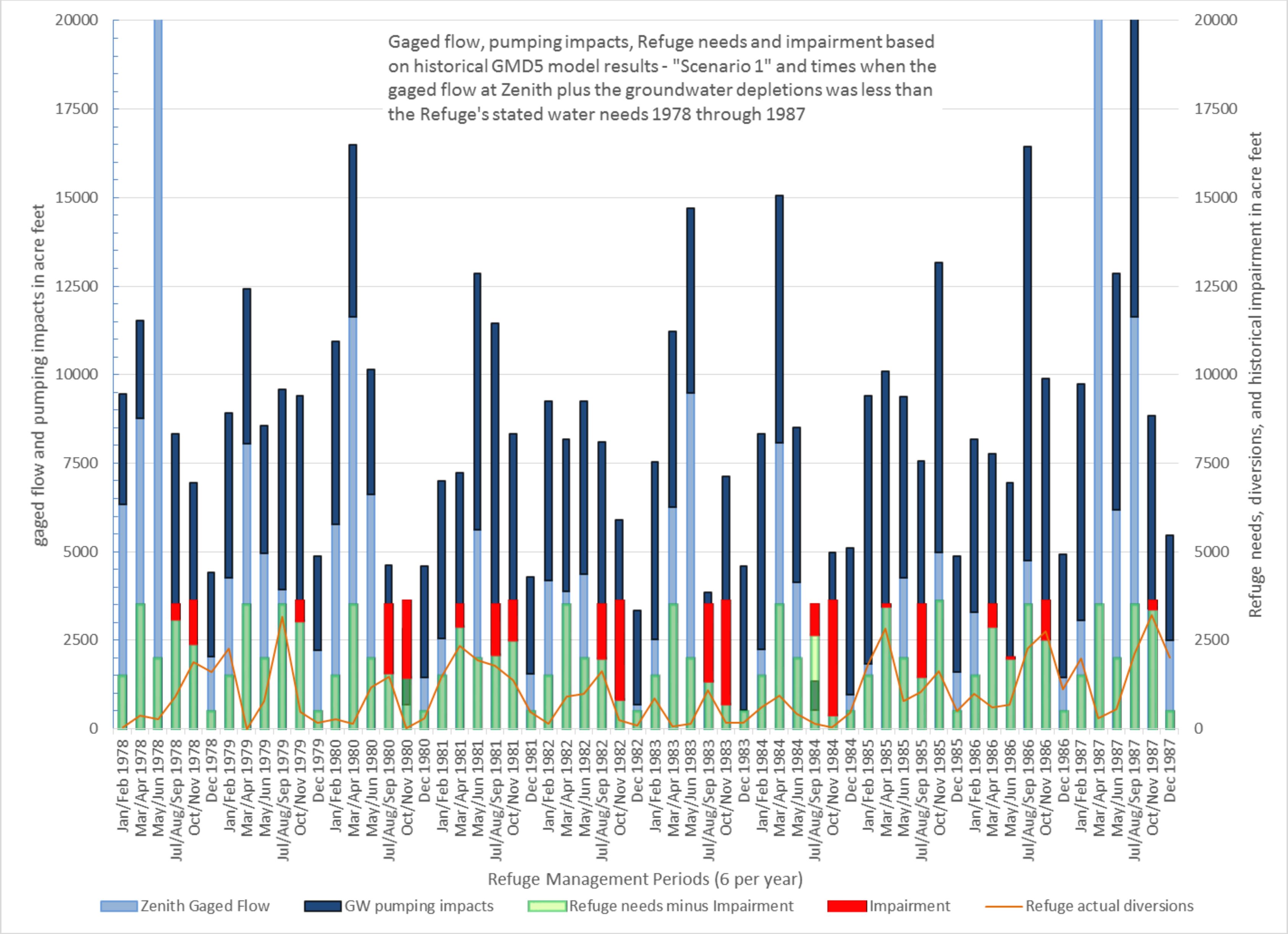


Figure 7 - Simulated evaluation of impairment to the Refuge's water right 1978 - 1987

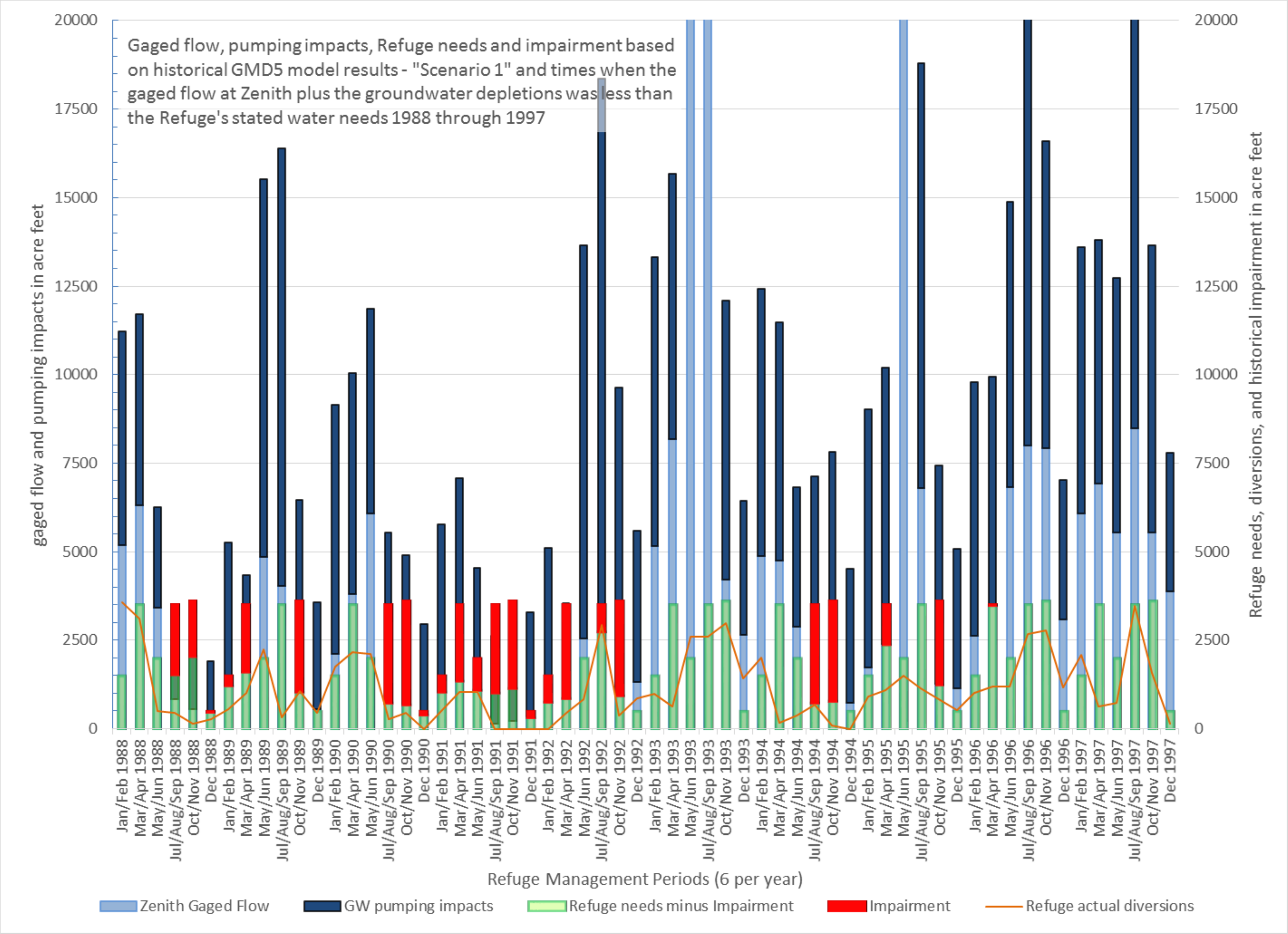


Figure 8 - Simulated evaluation of impairment to the Refuge's water right 1988 - 1997

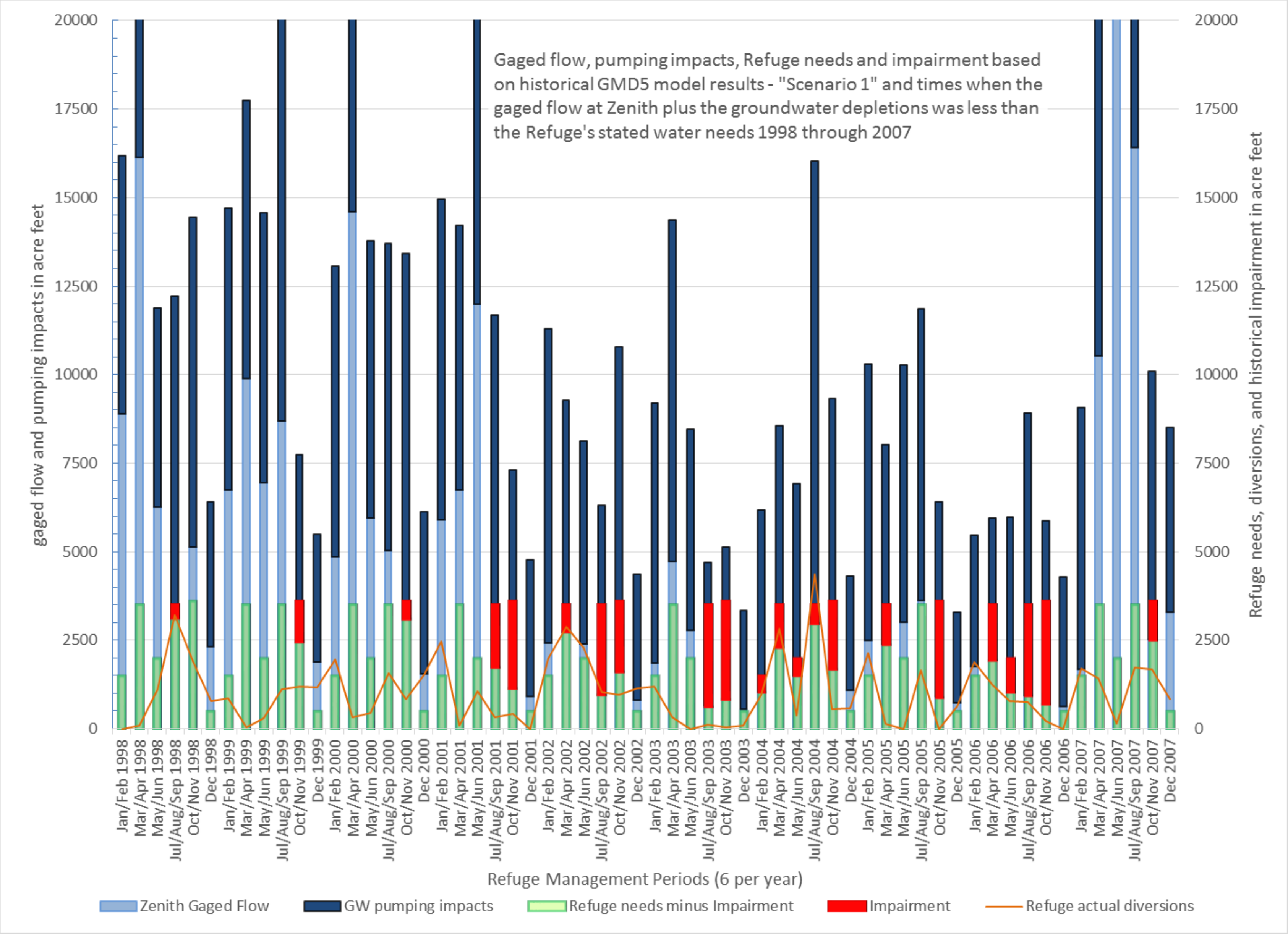


Figure 9 - Simulated evaluation of impairment to the Refuge's water right 1998 - 2007

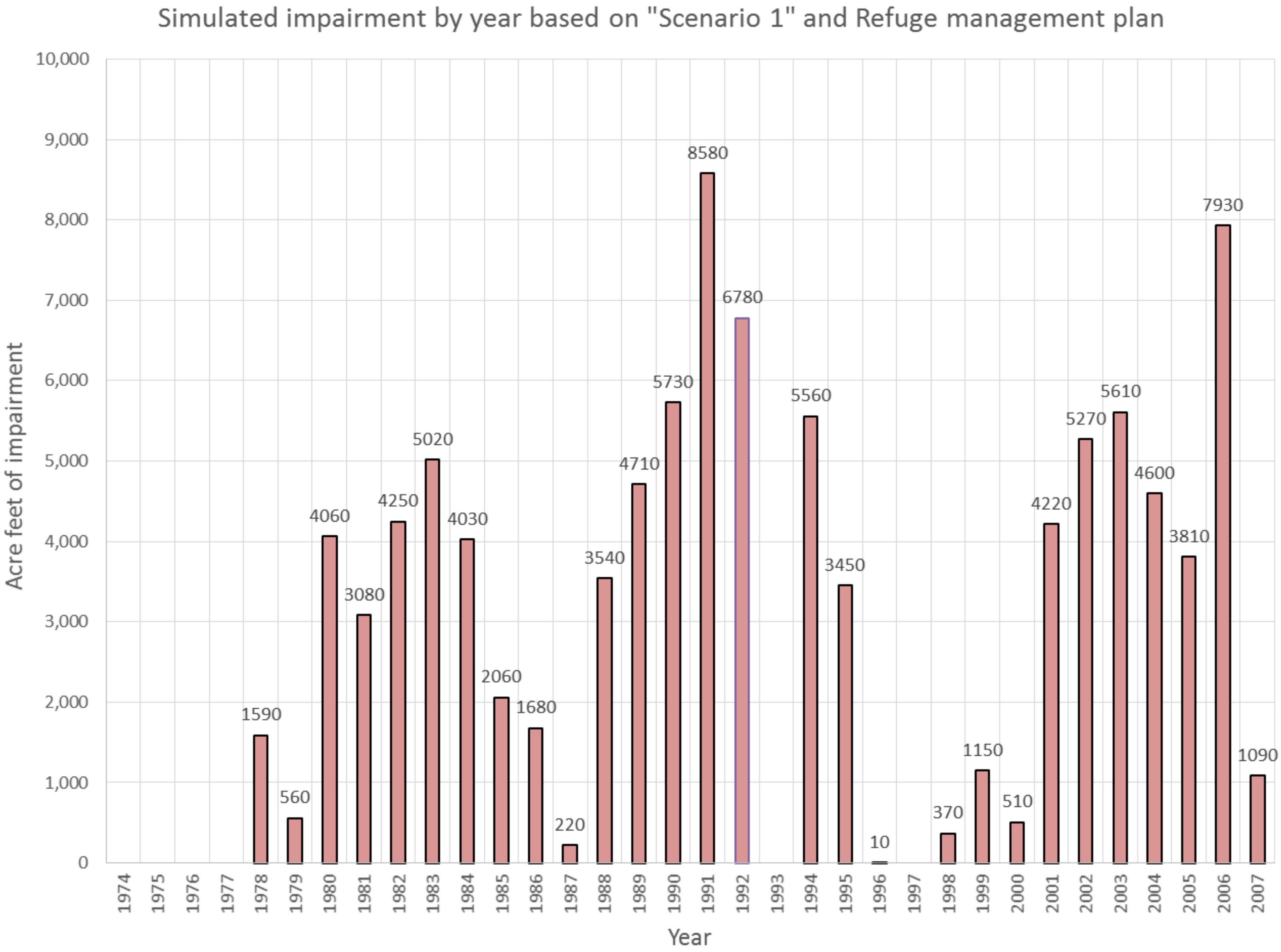


Figure 10 - Simulated amount of impairment to the Refuge's water right by year

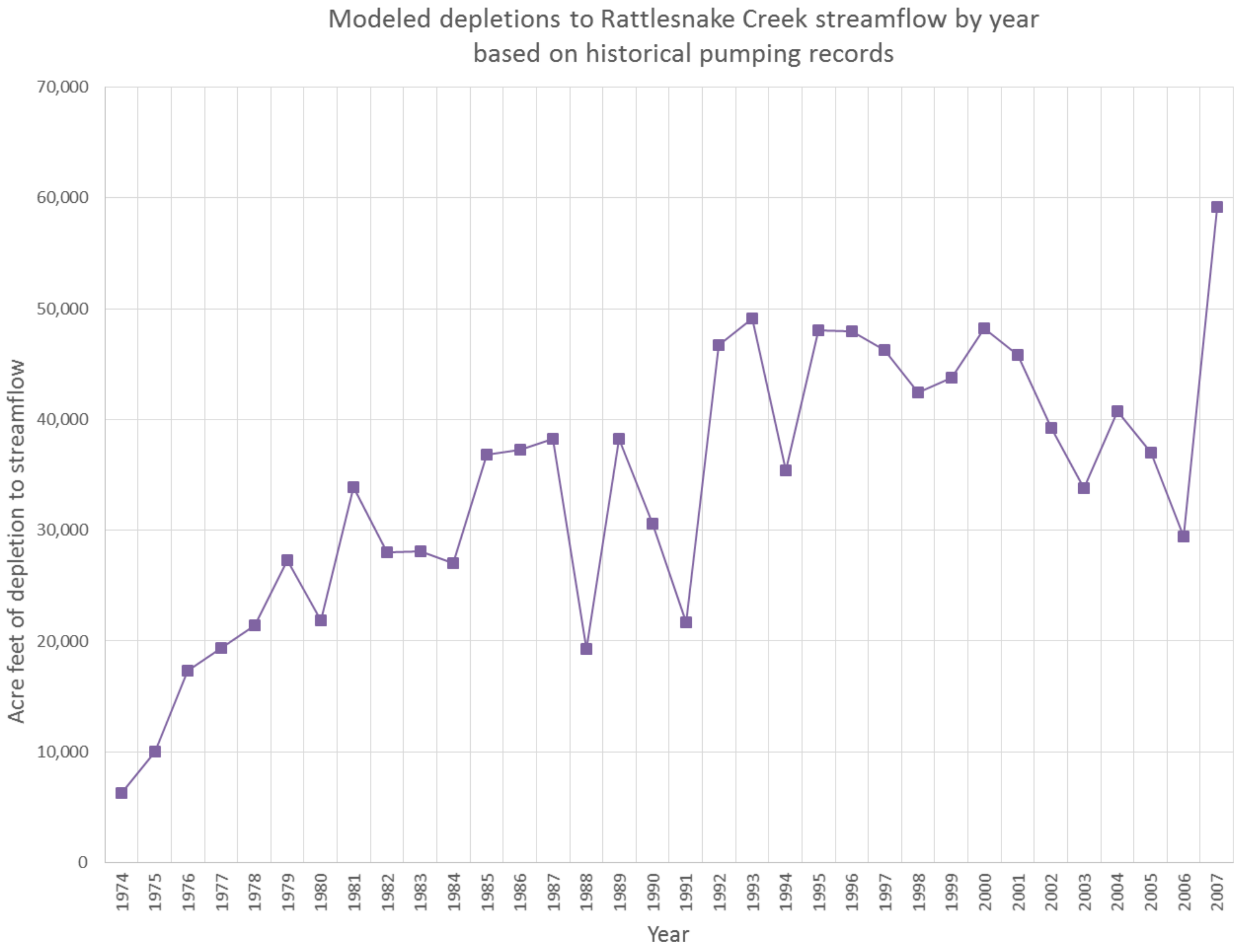


Figure 11 - Modeled depletions to Rattlesnake Creek 1974 - 2007

8. List of References

Kansas Statutes Annotated, Chapter 82a, Article 7
www.ksrevisor.org

Kansas Administrative Regulations, Chapter 5, Article 4
www.kssos.org

Kansas Department of Agriculture – Division of Water Resources, Rattlesnake Creek Third Four-Year Review of the Management Program 2009-2012, 2012

Kansas Department of Agriculture – Division of Water Resources, Rattlesnake Creek Second Four-Year Review of the Management Program 2005-2008, 2008

Kansas Department of Agriculture – Division of Water Resources, Addendum Rattlesnake Creek Four-Year Review of Management Plan, 2008

Balleau, Peter W.; Romero, David M.; Silver, Steven E.; *Hydrologic Model of Big Bend Groundwater Management District No. 5 and Appendices*, 2010

Larson, S. P.; *Big Bend GMD5 Model Peer Review*, 2011

9. List of Attachments

Appendix: November 2015 GMD5 groundwater model scenarios developed by KDA-DWR

Attachment 1: March 5, 2013, letter from United States Fish & Wildlife Service to Kansas Department of Agriculture Division of Water Resources

Attachment 2: April 8, 2013, letter from United States Fish & Wildlife Service to Kansas Department of Agriculture Division of Water Resources

Attachment 3: Feb. 8, 1993, Certification Memorandum, File 7571; Kansas State Board of Agriculture

Attachment 4: April 9, 1996, Certificate of Appropriation for Beneficial Use of Water; Water Right File No. 7,571; Priority Date August 15, 1957; Kansas Department of Agriculture – Division of Water Resources

Attachment 5: Oct. 23, 2013, Excerpt from Comprehensive Conservation Plan, Quivira Nation Wildlife Refuge; Unites States Fish & Wildlife Service

Attachment 6: December 2015 GMD5 Model; KDA-DWR Scenario 1 analysis results table; KDA-DWR

Modeling Appendix

GMD5 groundwater model scenarios developed by KDA-DWR
Sam Perkins and Ginger Pugh, KDA-DWR
November 12, 2015

Introduction

KDA-DWR staff developed and evaluated historical pumping scenarios with the Big Bend Groundwater Management District No. 5 (BBGMD5) groundwater model as part of this impairment investigation. The pumping scenarios are variations on pumping conditions specified for input to the historical simulation for the period 1940-2007. The purpose for developing the pumping scenarios was to quantify impacts of groundwater pumping within Rattlesnake Creek basin on Rattlesnake Creek streamflow, with a focus on inflow to the Quivira National Wildlife Refuge (Refuge) near the gage at Zenith, Kan.

Pumping impacts are defined as the difference between water budget terms for a given pumping scenario and baseline conditions specified for the calibrated model for the simulation period 1940-2007. Water budget terms with significant impacts in response to alternative groundwater pumping scenarios include groundwater storage, streamflow and evapotranspiration.

This Appendix parallels, in part, a presentation on Nov. 4, 2014, by the Chief Engineer and KDA-DWR staff to basin stakeholders in St. John, Kan., (Barfield and others, 2014). The Appendix also documents in greater detail than was presented in St. John, modeling results for Scenario 1, which were used in the impairment analysis. This scenario was run to calculate pumping impacts on streamflow by all groundwater rights upstream from the Rattlesnake Creek gage at Zenith, Kan., and junior to USFW Water-Right File No. 7,571 with priority date Aug. 15, 1957, a surface water right to diversions from Rattlesnake Creek to the Refuge (Refuge's right).

GMD5 groundwater model

Balleau Groundwater, Inc. (BGI), of Albuquerque, N.M. developed the regional groundwater flow model, referred to here as the BBGMD5 model (Balleau and others, 2010). The model extent includes all of GMD5 and a considerable region to the west of GMD5, including upstream basins drained by the Arkansas River and its tributaries, the Pawnee River and Rattlesnake Creek (Fig. A1). The model was calibrated to simulate transient groundwater flow for the historical period 1940-2007, with stress periods corresponding roughly to months and each stress period simulated with three equal time steps. The model extends 167.5 miles west to east, from near Garden City on the west to six miles east of the eastern GMD5 boundary, and 90 miles south to north on a regular grid of cells ½ mile on a side (335 x 180 cells). The BBGMD5 model is composed of seven layers representing hydrogeologic units from the land surface to bedrock, including river alluvium, Pliocene and Quaternary sediments, Cretaceous shales, Dakota, Cedar Hills sandstone and underlying Permian bedrock. The Cedar Hills sandstone is considered to be a source of significant saline water, and interest in tracing movement of saline water through the aquifers helped motivate development of the multilayer model. Runtime for the historical simulation with the multilayer model ranged from five to twelve hours on KDA-DWR computers, depending on factors such as server response time.

A single-layer version of the multilayer model was developed by Steve Larson and staff at S.S. Papadopulos and Associates (SSPA). Mr. Larson served as peer reviewer for KDA-DWR and member of the Technical Advisory Committee (TAC) during development of the BBGMD5 model for KDA-DWR. His report documents the single-layer model version (Larson, 2011).

Conversion of the multilayer BBGMD5 model into a single-layer model involved primarily equating the aquifer property of transmissivity of the single-layer model to the sum of transmissivity over the seven layers of the BBGMD5 model. Evapotranspiration and recharge inputs for the single-layer model are the same as those for the BBGMD5 model. The single-layer model version was found to be a satisfactory substitute for the BBGMD5 model, based on comparisons of global water budgets, computed water levels and streamflow. It has the advantage of shorter run times of 30 to 60 minutes for the historical simulation on KDA-DWR computers. The single-layer model version was used to evaluate the pumping scenarios described here, one of which (Scenario 11, below) was run with both model versions to compare computed pumping impacts.

Mr. Larson (2011) also developed an alternative calibration of the single-layer model in which recharge was reduced by 20 percent and evapotranspiration was reduced by 40 percent, and for whose calibration performance was similar or improved on the BBGMD5 model. This alternative version of the single-layer model was not used by KDA-DWR in the analysis of pumping impacts under scenarios presented here.

Baseline and scenario pumping conditions

Baseline pumping and return flow conditions are specified for the historical simulation by an input file that is read by the MODFLOW Well package (Harbaugh and others, 2000). The data were prepared as described in the BBGMD5 model report (“Well and Water Management Operations,” p. 62-65) and summarized in the BGI report, Table 3, lines 20-34. Irrigation pumping is specified as an extraction from groundwater at grid cell containing the pd, and the corresponding return flow is specified as an injection into groundwater at the grid cell containing the place of use (pu). Pumping for non-irrigation use is similarly represented, but return flow is neglected; domestic pumping is excluded from the model.

The WELL package input file (pumping file) does not identify the type of water use or the water right associated with each pd or pu. Pumping scenarios developed as variations on the baseline pumping file. Consequently, the pumping scenarios were restricted to spatial and temporal variations of the baseline pumping file, and were applied without distinguishing type of water use. Input files for pumping scenarios were produced by preprocessors that read the baseline pumping file and wrote a pumping scenario file that included wells meeting the spatial and temporal criteria of the scenarios. The preprocessors are variations on one developed by Steve Larson that converted the historical pumping file for the multilayer model (file bbgmdmod_v6.wel) into one for the single-layer model (file bbgmdmod_v6_1Layer.wel).

Description of pumping scenarios

Pumping conditions and impacts for nine scenarios presented at the St. John meeting are described below, while additional scenarios that were examined are also identified. The nine scenarios include four basin-wide curtailments and five spatially focused curtailments, which are explained as follows.

The map in Fig. A2 identifies points of diversion for all groundwater rights in Rattlesnake Creek basin (dots) and distinguishes between those that are senior (solid) and junior (hollow) to USFW Water-Right File No. 7,571. Fig. A2 also identifies the Macksville and Zenith gaging stations along Rattlesnake Creek, which is typically gaining below the Macksville gage. The Zenith gage captures most flow generated in the basin and lies about two miles upstream from the first of three Refuge intakes (USFW File 7,571) from Rattlesnake Creek below the Zenith gage. Fig. A3 identifies these intakes and centers of the model's regular grid of cells that are ½ mile on a side.

Basin-wide pumping curtailments

The basin-wide scenarios curtail pumping to all wells in Rattlesnake Creek basin (Scenarios 1, 2, 2.5 and 2.75). Scenario 1 excludes all pumping at points of diversion within Rattlesnake Creek basin that lie upstream from the Quivira intakes and are junior to the date of the Refuge's water right, Aug 15, 1957. Pumping and return flow for these wells are shut down from the beginning of 1958 through the remainder of the simulation. All other scenarios are variations or subsets of this scenario.

For the purpose of the impairment analysis, the effect of pumping by rights junior to File 7,571 is represented by Scenario 1.

Scenario 2 applies to the same wells as Scenario 1, but excludes pumping and return flow beginning in 1990 instead of 1958, so that pumping under Scenario 2 is the same as baseline conditions until 1990.

Scenarios 2.5 and 2.75 apply to the same wells as Scenario 2, but instead of shutting the wells down beginning in 1990, pumping and return flow for those wells are multiplied by factors of 0.5 for Scenario 2.5 (a 50 percent reduction), 0.75 for Scenario 2.75 (a 25 percent reduction).

Targeted pumping curtailments

The targeted scenarios curtail pumping only within areas that are expected to produce faster streamflow response, based either on response zones reported by Balleau et al. (2011) or on distance to Rattlesnake Creek Scenarios.

Scenarios 7-9 are based on stream depletion response zones computed by Balleau et al. (2011), shown in Fig. A4 and in the Balleau report as Fig. 51. These scenarios shut off all junior pumping within computed areas of stream response exceeding 70 percent (Scenario 7), 40 percent (Scenario 8) and 20 percent (Scenario 9). Fig. A4 shows that, within the Rattlesnake Creek basin, all areas of depletion response exceeding 20 percent lie downstream of the Macksville gage.

Scenarios 10 and 11 shut off all junior pumping within one mile (Scenario 10) or two miles (Scenario 11) of Rattlesnake Creek. Fig. A5 maps these zones, and shows that they begin at the Macksville gage and proceed downstream. The Balleau response map suggests little would be gained by continuing these corridors upstream.

Scenario 11-ML identifies a version of Scenario 11 that was run with the multilayer BBGMD5 model version. Scenario 11 impacts under single- and multilayer model versions are compared below.

Other scenarios investigated

Other scenarios evaluated as part of the investigation of streamflow response to pumping curtailments, but not presented at the meeting in St. John include:

Scenario 3: 1-mi curtailment corridor for the entire length of Rattlesnake C.

Scenario 4: shut off junior pumping within Rattlesnake Creek alluvial extent as delineated by a GIS coverage from USGS within the state of Kansas. This alluvial extent is shown in Fig. A3 with a light blue shading, and in Fig. A4 for a smaller area in the vicinity of the Zenith gage and Quivira NWR. Fig. A3 shows that relatively few points of diversion lie within the alluvial extent, limiting the potential impact of curtailments.

Scenarios 5-6: These curtail pumping within preliminary versions of the Balleau response zones, and were superseded by Scenarios 7-9.

Scenarios delaying pumping curtailment until 2000.

Scenarios that were run using the single-layer model with the alternative calibration (recharge reduced by 20 percent and evapotranspiration reduced by 40 percent; Larson, 2011).

Model results

Scenario 1: Impact of pumping by rights junior to Water Right File No. 7,571 on streamflow

Impacts of pumping on Rattlesnake Creek streamflow as described in the Quivira Impairment Report and shown in Figs. 2 and 3 of the report are based on differences in the basin water budgets for Scenario 1 and a baseline model run for the historical period. The basin water budget refers to the water budget restricted to the Rattlesnake Creek basin as opposed to the global budget for the entire model domain. Some impacts of pumping from within Rattlesnake Creek basin by rights junior the Refuge Right eventually propagate outside the basin boundaries, so that baseflow impacts that pass through the Zenith gage are somewhat less than this total.

The Quivira Refuge management periods described in the Impairment Report are 1-3 months in duration. The baseflow impact for a given management period is the sum over impacts for corresponding time steps (about ten days each) according to the basin water budget. Budgets restricted to Rattlesnake Creek basin were extracted from model results for each year, but not for each simulated time step. Basin-only water budgets for each time step could be extracted from model output by modifying a postprocessor and re-processing model results, but baseflow impacts within the basin for each time step can also be reasonably approximated by reducing global baseflow impacts for each time step by the ratio for the corresponding year of basin-only and global baseflow impacts. This approximation was used to represent baseflow impacts restricted to Rattlesnake Creek basin for each time step.

Table A1 compares annual pumping impacts on a water budget for Rattlesnake Creek basin with a global water budget, i.e. for the entire model domain, averaged over years 1998-2007. The Greek letter delta (Δ) symbolizes the change in a quantity for a given scenario with respect to the baseline, or calibrated historical model run. The comparison shows that for the averaged period 1998-2007, the baseflow impact restricted to the Rattlesnake Creek basin is only 74.4 percent of the impact over the entire model domain. The rightmost column is the ratio of baseflow impact to pumping reduction. The column labeled "Balance" is the sum over the four columns to its left (changes in storage, pumping, ET and baseflow). The water imbalance over the model domain of –116 acre-feet per year (afy) is attributed to impacts at constant heads (26 afy) and numerical error (90 afy). The balance, or sum over budget impacts restricted to Rattlesnake Creek basin is –8584 afy, and much larger than for the model domain.

Fig. A6 plots annual impacts on global water budget terms 1958-2007 for Scenario 1. Fig. A7 plots corresponding impacts restricted to Rattlesnake Creek basin. Comparison of the two figures shows that ET and baseflow impacts are reduced in Fig. A7 for the basin-only impacts, but show similar behavior in the two budgets; only storage impacts show significant differences. Fig. A8 shows baseflow impact from the global water budget for each stress period. Fig. A8 superimposes the annual ratio of basin-only and global baseflow impacts (right axis). As mentioned above, the basin-only impact on baseflow for each time step was approximated by the product of the global-budget baseflow impact and the ratio of basin-only and global baseflow impacts for the corresponding year (Fig. A8).

Fig. A9 plots Refuge flow deficiency (flow deficit) and baseflow depletion by the basin's junior water rights. The flow deficit is given by the Quivira refuge requirement (needs) minus Zenith gaged flow, when that difference is positive, and is otherwise zero. When a flow deficit exists, the deficit is exceeded by baseflow depletion in all management periods except six that occurred prior to 1992.

Table A2 lists selected management periods from a worksheet that calculates impairment based on baseflow depletions within the Rattlesnake Creek basin. Spreadsheet calculations behind Table A2 are expressed in the table headings. Table A2 lists results for two sets of management periods. (a) In the first six periods, Refuge flow deficit exceeds baseflow depletion, in which case the deficit is attributed to predevelopment flow conditions and not to depletion by pumping. This situation occurred in only six management periods, all predating 1992. (b) The last six periods are for 2007, and illustrate more typical conditions, when flow deficits are either zero or are less than baseflow depletions. In this case, any flow deficits are attributed to baseflow depletion. The summary of spreadsheet calculations at the bottom of Table A2 show that, for 1974-1991, 87.67 percent of Refuge flow deficits are attributed to pumping depletion in the basin, while 12.33 percent of deficits are due to low-flow conditions that would have existed with no depletion by pumping, i.e. predevelopment low-flow conditions. In the years since 1991, however, all flow deficits are attributed to depletion by pumping, and none to predevelopment low-flow conditions.

Summary of results presented by Barfield and others (2014)

Pumping impacts on water budgets are first summarized as average change in water budget terms over years 1998-2007 in Table A3 for the basin-wide and targeted scenarios of interest, and in Table A4 for comparison of impacts under the single- and multilayer model versions for Scenario 11. An explanation of these tables is followed by graphs showing temporal response for some of the pumping scenarios. See Figs. A6 – A14. Streamflow response statistics of interest in these results include average baseflow increase for 1998-2007, the ratio of baseflow increase to pumping reduction (or bang for the buck), and response time, or lag between pumping reduction and significant baseflow increase, which is presented qualitatively in the graphs.

Tables A3 and A4 are shown below as they were presented in 2014. The table columns are first explained as follows.

Columns 1 and 2 summarize scenario descriptions given above. In the remaining column headings, the Greek letter, delta (Δ) is used to symbolize the change in a quantity for a given scenario with respect to the baseline, or historical conditions for the calibrated model. Column 3, Δpumping is the change in pumping (acre-feet/year) for each scenario, denoted as reduction by parentheses and red type. The remaining columns summarize the water budget response for each scenario. Columns 4, 7 and 8 are responses of the significant water budget terms corresponding to change in baseflow, evapotranspiration and groundwater storage (acre-feet/year). Column 5 expresses the baseflow response in cubic feet/sec, a unit conversion of Column 4. Column 6 is the ratio of the baseflow response (col. 4) to pumping reduction (col. 3), and quantifies the relative efficacy, or bang for the buck, of each scenario; for now, the term "relative baseflow yield," or "relative yield" as shorthand will be used for column 6.

Tables A3 and A4 differ in the type of water budgets that they reference. Table A3 summarizes impacts on water budgets restricted to the Rattlesnake Creek basin. Water budget balances within basins are not enforced, and water budgets indeed do not balance within the Rattlesnake Creek basin. Water budget impacts within the basin were summarized with the intent of better characterizing the baseflow impact at the Zenith gage.

Table A4 summarizes global water budget impacts, which are based on balanced water budgets over the entire active model domain, and which are balanced as a result of convergence of the solution for computed heads for each time step. The distinction between global and basin-only budget impacts was discussed previously for Scenario 1 results. Table A4 compares global water budget impacts for Scenario 11 based on the single- and multilayer model versions instead of impacts limited to Rattlesnake Creek basin because the multilayer model output does not provide the necessary data for that comparison without modifying the model's output control instructions.

Of the basin-wide pumping scenarios, Scenarios 1 and 2 show the same pumping reduction average over years 1998-2007; the scenarios differ only in the date when shutoffs are applied (1958 for Scenario 1 and 1990 for Scenario 2, both of which predate the impact averaging period). Scenario 1 quantifies baseflow depletion by rights in the basin junior to the Refuge's water right, and is used in the impairment analysis described in the report. Scenario 2 characterizes what might have happened had such management action been taken in 1990.

The basinwide pumping scenarios curtail far greater pumping than the targeted pumping scenarios but yield relatively little baseflow. Scenario 2.75 with 25 percent basinwide pumping reduction has the lowest relative yield, i.e. producing only about 15 acre-feet of baseflow for each 100 acre-feet of curtailment (delta baseflow / delta pumping, col. 6). Scenario 2.5 with 50 percent basinwide pumping reduction is a close second yielding only about 19 acre-feet per 100 acre-feet of curtailment.

The targeted pumping scenarios in Table A4 show relative baseflow yields ranging from 43 to 63 percent, which correspond to response zone curtailment scenarios 9 and 7, respectively. Relative baseflow yields for stream corridor curtailment scenarios 10 and 11 fall in the middle of the targeted pumping scenarios at 54 and 50 percent, respectively.

Scenario 11: Comparison of impacts for single- and multilayer model versions

Scenario 11 was selected to run with the multilayer model version for comparison because it shows a significant baseflow impact of 5,560 afy or 7.7 cfs and a high relative baseflow yield, 50 percent. Line 3 of Table A4 shows small differences in budget impacts between the model versions averaged over years 1998-2007. Based on the similarity of computed impacts for the single- and multilayer model versions for Scenario 11, we expect that multilayer model versions of the other scenarios would also compare closely with the single-layer model versions that we have depended on for comparing scenarios.

Temporal response of water budgets to pumping curtailment for selected scenarios

Annual response of Rattlesnake Creek water budget terms to pumping curtailments are shown for basinwide curtailment under Scenario 2 and for targeted curtailment under Scenarios 9 and 11.

The temporal response to basinwide shutoff of pumping in 1990 (Scenario 2) is plotted on an annual basis in Fig. A10 for global water budget terms, and in Fig. A11 for Rattlesnake Creek water budget terms. Comparison of the two graphs shows similar behavior between the two budgets except for storage; the dissimilarity for storage is attributed to an imbalance in the Rattlesnake Creek basin budget, whereas the global budget is balanced as part of the model solution. Both Figs. A10 and A11 show that despite a large, immediate change in pumping and corresponding change in storage in 1990, baseflow response is negligible in the first two years of the shutoff, and is significant only beginning in 1992.

Fig. A12 shows the annual response of global water budget terms under Scenario 9, which shuts off pumping within zones of 20 percent or greater response. Baseflow response in the first two years of shutdown is greater than for Scenario 2, but is significant only beginning in 1992.

Figs. A13 and A14 show annual response of global water budget terms under Scenario 11 for single- and multilayer model versions. Again, baseflow response in the first two years of shutdown is greater than for Scenario 2, but is significant only beginning in 1992. Comparison of Figs. A13 and A14 shows that the single- and multilayer model versions of Scenario 11 exhibit very similar responses on an annual basis.

Conclusions

The single and multi-layer models are functionally equivalent for determining pumping impacts on streamflow.

GMD5 model results for the pumping shutoff scenarios show that baseflow reductions due to junior pumping are significant.

Scenario 1, which shuts off all pumping junior to Water Right File No. 7,571 in Rattlesnake Creek basin beginning in 1958, quantifies baseflow reductions in the basin, which would appear at the Zenith gage were it not for the pumping by juniors.

Pumping reductions near the stream produce faster baseflow response. However, none of the pumping shutoff scenarios produce an effective baseflow response for two to three years.

Response to Technical Comment

This section describes modeling work and results in response to the only technical comment from Balleau Groundwater, Inc. on modeling work that could have a bearing on the report. To summarize, a correction was applied as suggested by Balleau Groundwater modelers such that the initial model solutions are treated correctly. Here we describe the correction and the model runs to test its effects, and show that the correction has negligible effects on stream depletion calculations that are referenced in the original report.

Technical comment number 5 [from the file 2016-05-13 GMD5 Comments Final.pdf] reads,

"**The starting head condition used in the model scenarios is not steady. Beginning the simulations with an initial condition that is not in steady state should be corrected.**"

Chris Beightel and Sam Perkins discussed this comment on Friday, May 20, with Dave Romero and Steve Silver of Balleau Groundwater, Inc. to clarify its meaning. Chris first verified in that discussion that the above comment was the only one related to model runs that underlie the report.

With respect to the above comment, Dave and Steve explained that the unsteady initial conditions would affect the model budget terms (i.e., storage, streamflow, ET, and flows at specified-head boundary cells), and that their comment applies to the single-layer model version, but not to the multi-layer version, for which they said that initial conditions were represented correctly. The implication was that the model should be re-run with this correction to calculate stream depletion impacts of pumping by junior right holders in the Rattlesnake Creek basin under Scenario 1. Dave and Steve suggested that a simple way to correct this would be to extend the length specified for the first stress period from 30 days (more accurately, 365.25/12 days) to, say, ten billion days, or a little over 27 million years. By extending the first stress period length in this way, the change in storage for the first stress period should be drastically reduced in magnitude, so that even though the first stress period is transient, it should be a good approximation for steady state conditions, under which change in storage is zero. (More accurately, the equation that Modflow solves under steady state conditions does not include a storage term; i.e., there is no change in storage under steady state conditions.)

Two additional simulations were run in order to respond to technical comment number 5. These include re-running the base case and Scenario 1 with the initial stress period redefined to approximate steady state conditions as described in the preceding paragraph. We used the additional model runs to determine the discrepancy introduced by the original unsteady initial conditions on (a) the global water budget for the base case, and (b) the stream depletions due to pumping by junior water right holders in the Rattlesnake Creek basin under Scenario 1.

Results: Impact of initial transient conditions for historical base case (1-layer model):

Global budgets for the original and corrected versions of the base case were compared, and show that by extending the stress period length from 30 to ten billion days, the change in storage by the end of the first stress period is reduced from a flow rate of 399 ac-ft/day to 4.52e-7 ac-ft/day, which is approximately zero using single-precision calculations. That is, setting the length of the first stress period to ten billion days is a convenient way to closely approximate steady state conditions. (At the same time, this approach avoids possible convergence problems that arise sometimes when the first stress period is specified as steady-state.)

Figures A15 and A16 plot the budget impacts due to changing the initial stress period to give a steady-state solution. Figure A15 plots the budget impacts for each 10-day time step of the simulation 1940-2007; Figure A16 plots an annual summary of the same budget impacts. Both figures show large budget impacts of the unsteady conditions of initial heads for the single layer model, although the impacts slowly decay over time. The time period of interest for the pumping and augmentation scenarios, particularly for Scenario 1 with full basin shutoff of junior rights, is 1958-2007.

Global impact of pumping on streamflow under Scenario 1 based on model runs beginning with steady state conditions, and comparison with original calculations

Pumping impacts, in particular streamflow depletion, were then calculated for Scenario 1 based on the model runs beginning with the quasi-steady state stress period (length set to ten billion days in both base case and impact case), and were compared with depletions calculated for the original model runs.

Fig. A17 shows streamflow depletion based on model runs that begin with a quasi-steady state stress period (blue line), and the discrepancy in the original calculation of streamflow depletion (thin red line, right axis), i.e. the original streamflow depletion minus the recalculated value. The discrepancy lies within a range from -0.3 and +0.9 cfs for 1958-2007 (mean -0.16 cfs, std deviation 0.25 cfs), so the discrepancy is negligible.

This comparison shows that pumping impacts on streamflow for the original and corrected versions of Scenario 1 are nearly identical, as we interpret the differences shown in Fig. A17 to be negligible. Based on this interpretation, we conclude that the original depletions calculated for the impairment report under Scenario 1 are acceptable.

References

Balleau, W. Peter, Dave M. Romero and Steven E. Silver, 2010. Hydrologic model of Big Bend Groundwater Management District No. 5. Balleau Groundwater, Inc., Albuquerque, N.M.

Barfield, David, Sam Perkins and Ginger Pugh, 2014. Power Point presentation on Nov. 4, 2014, to Basin Stakeholders at the St. John, Kan., library (file GMD5.ModelingScenarios.KDA-DWR.pdf, referenced in the Quivira impairment report).

Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G., 2000, MODFLOW-2000, the U.S. Geological Survey modular ground-water model -- User guide to modularization concepts and the Ground-Water Flow Process: U.S. Geological Survey Open-File Report 00-92, 121 p. Link: http://water.usgs.gov/nrp/gwsoftware/modflow2000/modflow2000.html

Larson, Steve, 2011. Big Bend GMD5 Model Peer Review. S.S. Papadopulos and Associates, Bethesda, Md.

Backup Excel spreadsheet file:
RS_pumping_impact_scenario_1_cbc_RSMask_cwb_20150923_sp_revised _2015_1112.xlsm

Tables

Table A1. Comparison of Scenario 1 pumping impacts on global and basin-only water budget (1998-2007 average).

budget extent	∆storage	∆Pumping	∆ET	∆Baseflow	Balance	∆B/∆P
RS Basin	70,505	(143,529)	22,387	42,053	(8,584)	29.3%
model (global)	61,464	(143,529)	25,426	56,523	(116)	39.4%
RS Bsn / model			88.0%	74.4%		

Table A2. Selected refuge management periods from the period of impairment analysis, 1974-2007.

refuge mgmt period	year	u: annual basin depl / global depl	v: Refuge Needs	w: Zenith Gaged Flow	x=max(0, v-w): inflow deficit (refuge needs > Zenith gaged flow), af	y: baseflow depletion (approx. basin budget)	z=max(0, v-(w+y)): predev flow deficit	aa=x-z: impaired by depletion af
Oct/Nov	1980	0.9084939	3600	690	2910	2150	760	2150
Jul/Aug/Sep	1984	0.8769227	3500	520	2980	830	2150	830
Jul/Aug/Sep	1988	0.8061852	3500	830	2670	1960	710	1960
Oct/Nov	1988	0.8061852	3600	550	3050	1560	1490	1560
Jul/Aug/Sep	1991	0.8473867	3500	150	3350	2470	880	2470
Oct/Nov	1991	0.8473867	3600	220	3380	2460	920	2460
Jan/Feb	2007	0.7499378	1500	1670	0	7400	0	0
Mar/Apr	2007	0.7499378	3500	10540	0	9530	0	0
May/Jun	2007	0.7499378	2000	32510	0	14730	0	0
Jul/Aug/Sep	2007	0.7499378	3500	16420	0	14710	0	0
Oct/Nov	2007	0.7499378	3600	2510	1090	7580	0	1090
Dec	2007	0.7499378	500	3280	0	5240	0	0
					sum(x)	sum(y)	sum(z)	sum(aa)
sum 1974-1991					56020	462860	6910	49110
sum 1992-2007					50360	693230	0	50360
volumetric fraction:							sum(z)/ sum(x)	sum(aa)/ sum(x)
1974-1991							0.1233	0.8767
1992-2007							0	1

From cols a:b and u:aa in sheet cwb_QNWRGrp, file RS_pumping_impact_scenario_1_cbc_RSMask_cwb_20150923_sp_revised_cwb_lookup_2015_1112.xlsm.

Table A3. Pumping impacts on water budget within Rattlesnake Creek basin (1998-2007 average) for basin-wide (Scenarios 1–2.75) and targeted (Scenarios 7–11) pumping curtailments.

scenario	Scenario definition	Δpumping	Δbaseflow	ΔB cfs	ΔB/ΔP	Δstorage	Δ et
1	basinwide shutoff from 1958 on	(143,529)	42,053	58.0	29.3%	70,505	22,387
2	basinwide shutoff from 1990 on	(143,529)	34,420	47.5	24.0%	76,837	18,007
2.5	basinwide 50% pumping	(71,765)	13,366	18.4	18.6%	34,019	8,662
2.75	basinwide 75% pumping	(35,882)	5,475	7.6	15.3%	18,200	4,265
7	response zone >70%	(1,059)	661	0.9	62.4%	77	253
8	response zone >40%	(9,701)	4,646	6.4	47.9%	1,442	2,597
9	response zone >20%	(19,604)	8,326	11.5	42.5%	3,350	4,975
10	RSC 1-mi corridor to Macksville	(3,932)	2,115	2.9	53.8%	410	1,094
11	RSC 2-mi corridor to Macksville	(11,230)	5,560	7.7	49.5%	1,396	3,086
Notes:	[1] Restrict selections to Rattlesnake C basin wells junior to Aug 15 1957 (USF&W File 7571).						
	[2] Scenario 1 selection begins Jan 1958 (str per 218); others begin Jan 1990 (str per 602).						
	[3] Scenarios are specified as input to preprocessor by scenario id and pump scaling factor.						

Table A4. Comparison of single- and multilayer model versions of Scenario 11: pumping impacts on global water water budget (1998-2007 average).

scenario id	Scenario definition [1,2,3]	Δpumping ac-ft/y	Δbaseflow ac-ft/y	Δbaseflow cfs	ΔB/ΔP pct	Δstorage ac-ft/	Δ ET ac-ft/yr
11	RSC 2-mi corridor to Macksville	(11,230)	5,729	7.9	51.0%	2,253	3,275
11 ML [4]	RSC 2-mi corridor to Macksville	(11,230)	5,464	8	48.7%	2,404	3,379
difference	[multi - single] layer versions	0	(265)	(0)	-2.4%	150	104

Figures

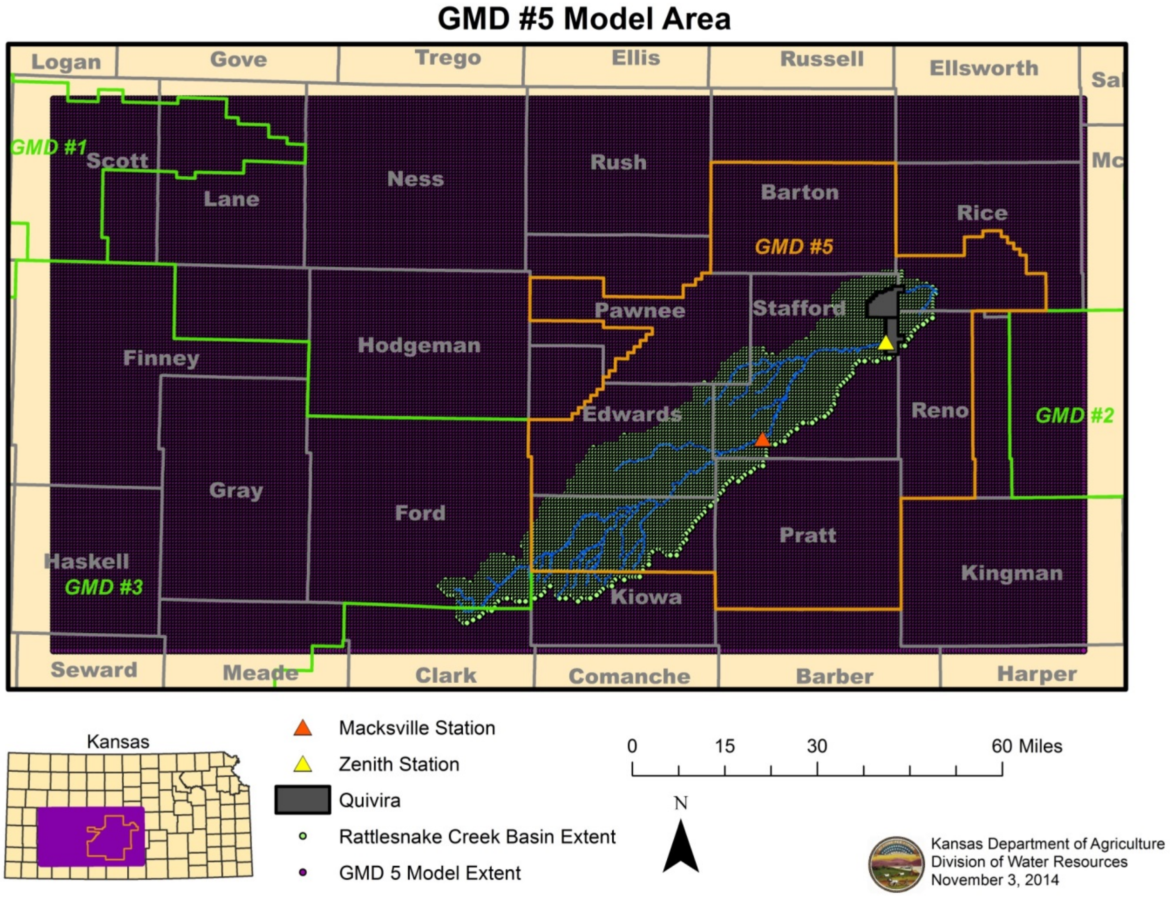


Fig. A1. GMD5 model extent. (Slide 6, Barfield et al., 2014)

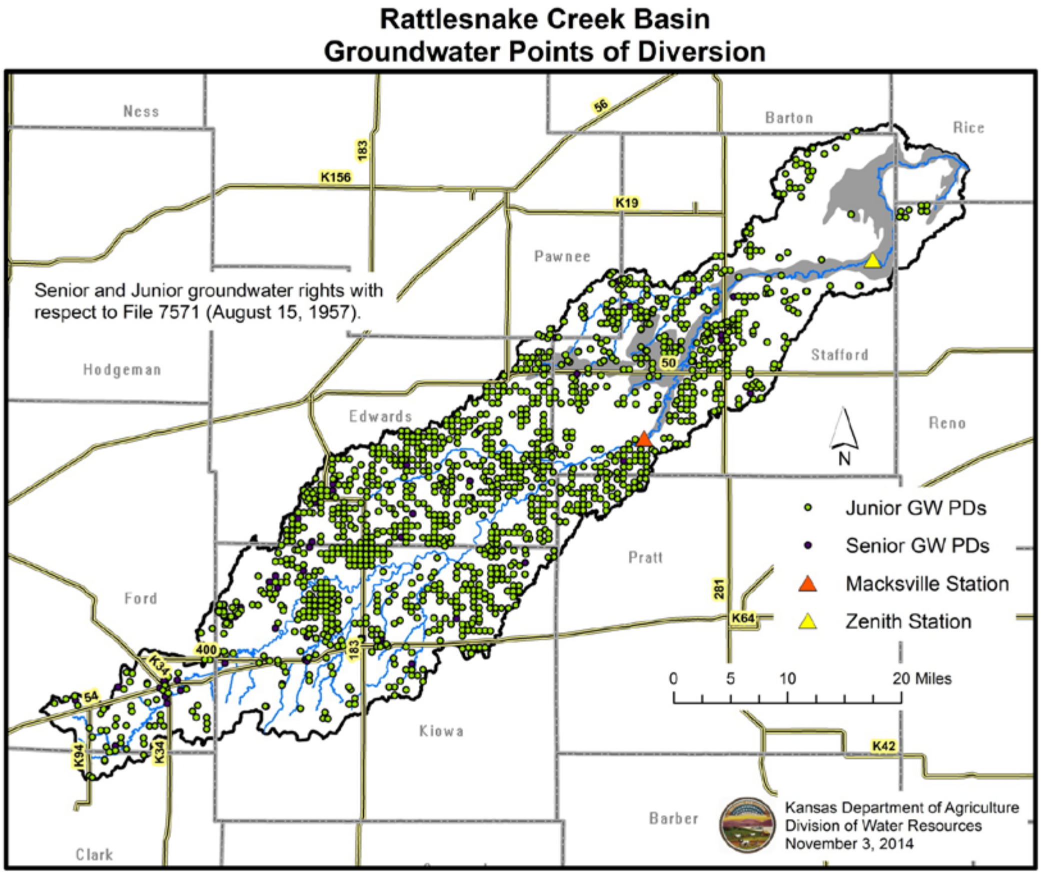


Fig. A2. Groundwater points of diversion in Rattlesnake Creek Basin. (Slide 7, Barfield et al., 2014)

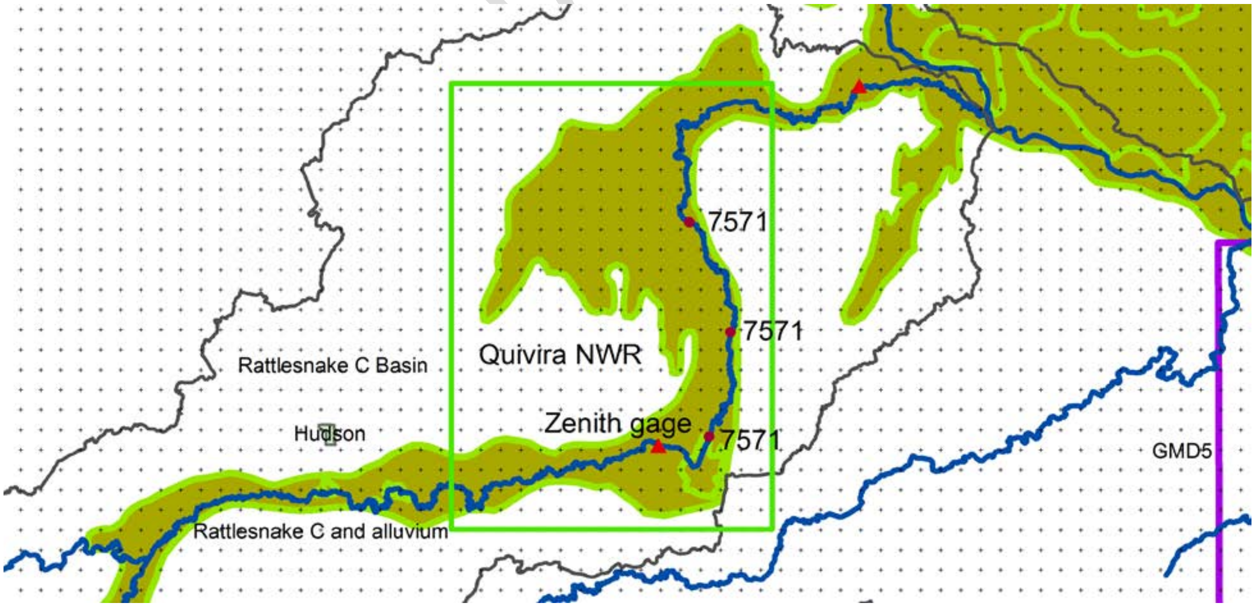


Fig. A3. Vicinity of Quivira National Wildlife Refuge and intakes from Rattlesnake Creek (USFW Water Right File No. 7,571) downstream from Zenith gage.

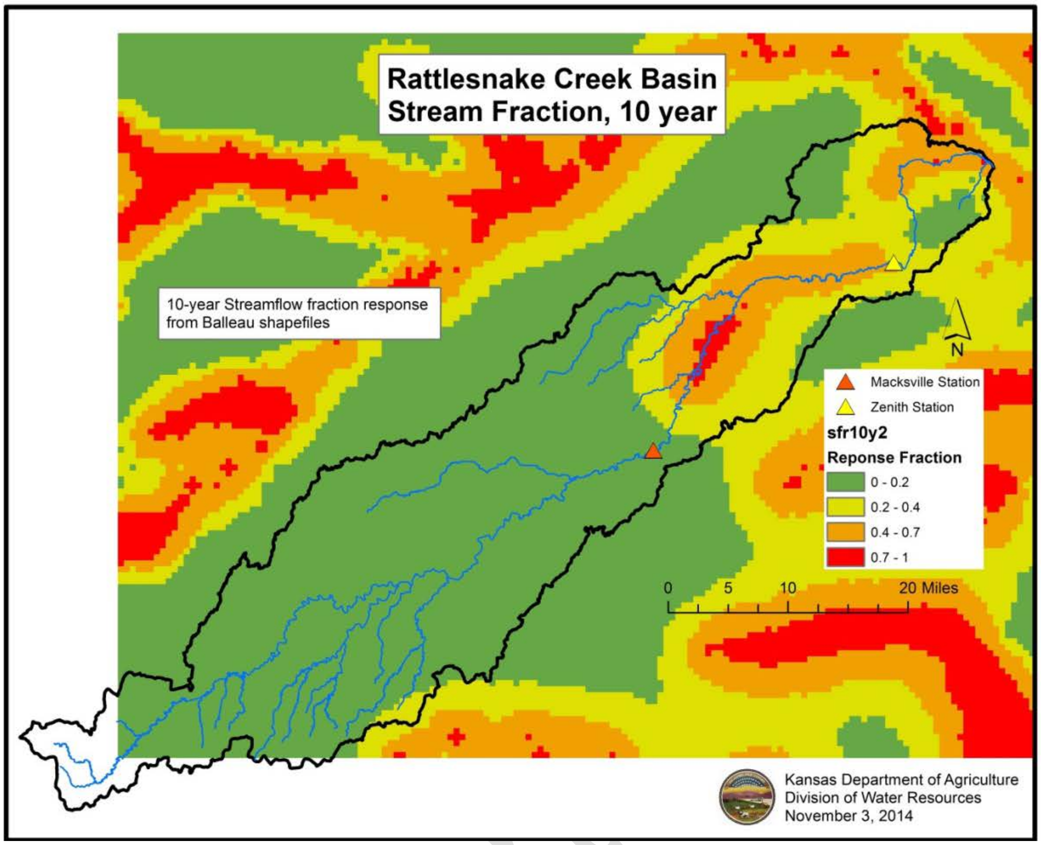


Fig. A4. Map of 10-year streamflow response, the fraction of Rattlesnake streamflow at the Zenith gage depleted by ten years of pumping, evaluated at each model grid cell within the mapped area. (See also Fig. 51, Balleau et al., 2010)

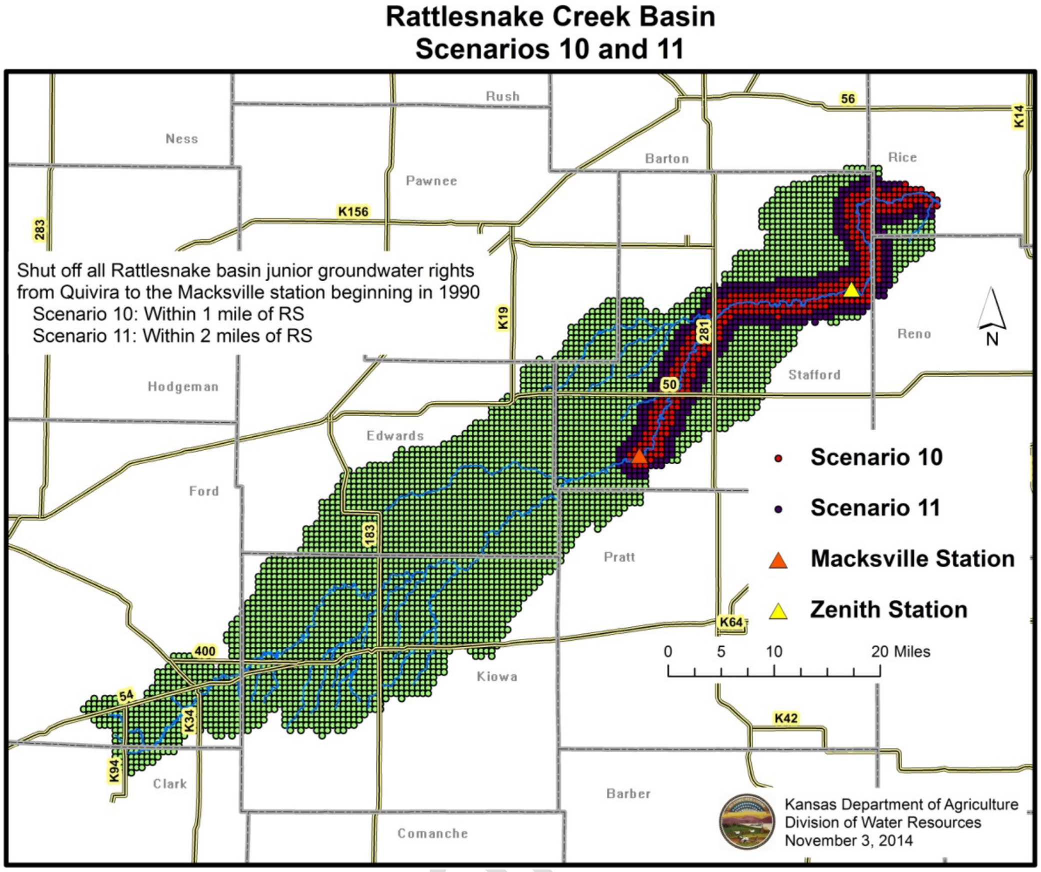


Fig. A5. Map showing one-mile and two-mile corridors along Rattlesnake Creek within which all junior pumping is shut off for Scenarios 10 and 11, respectively.

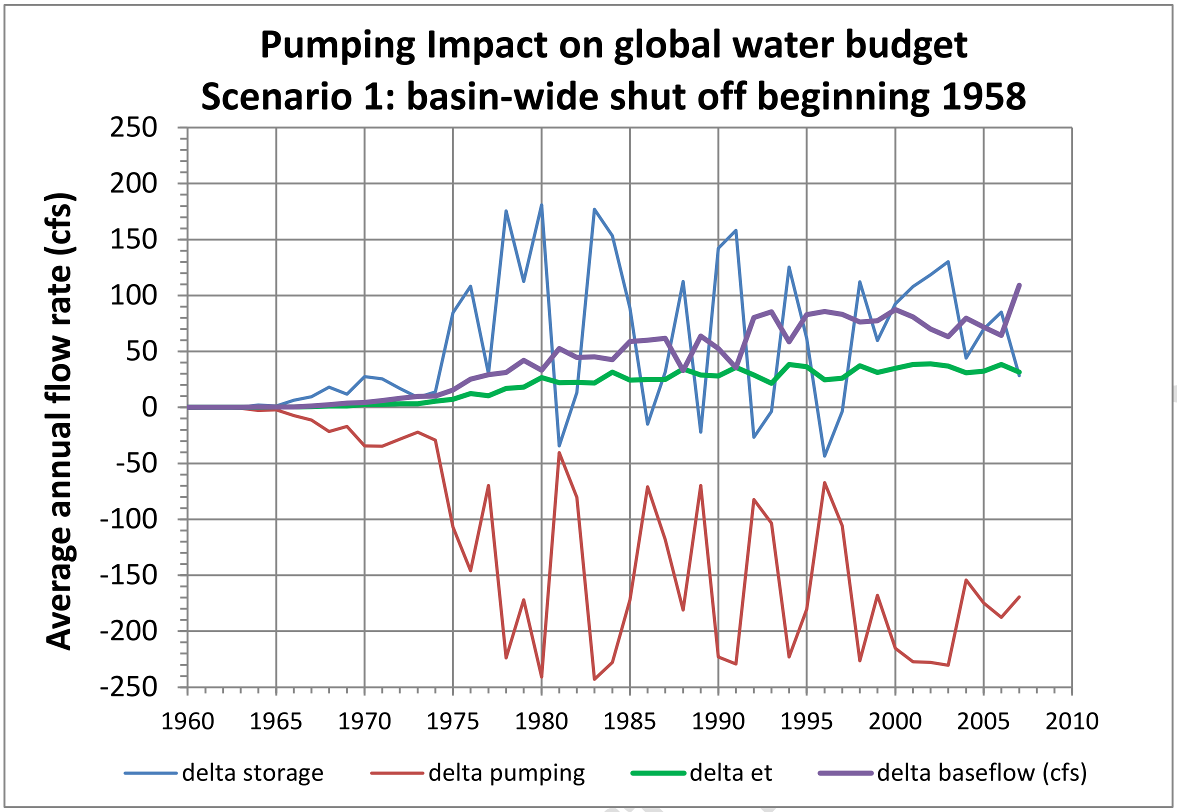


Fig. A6. Global water budget impacts 1958-2007 for Scenario 1 as flow rates, cu. ft/sec.

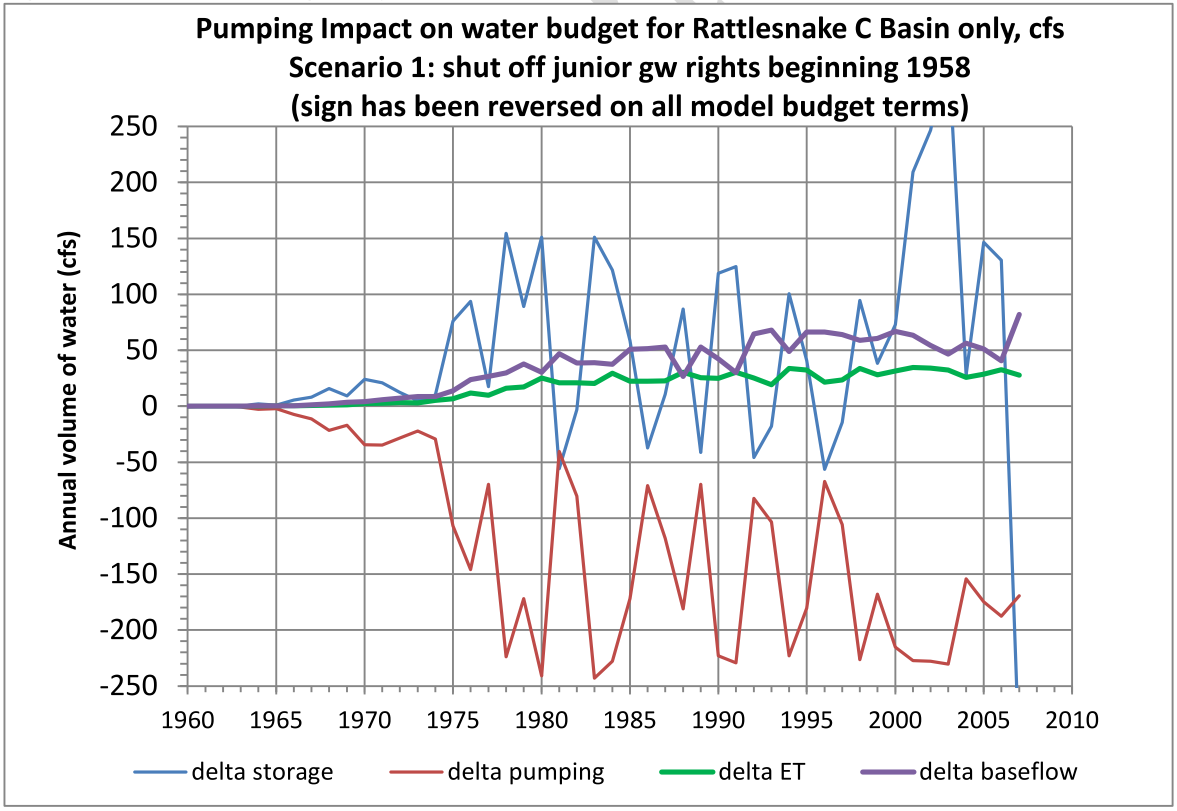


Fig. A7. Rattlesnake Creek Basin water budget impacts 1958-2007 for Scenario 1 as flow rates, cu. ft/sec.

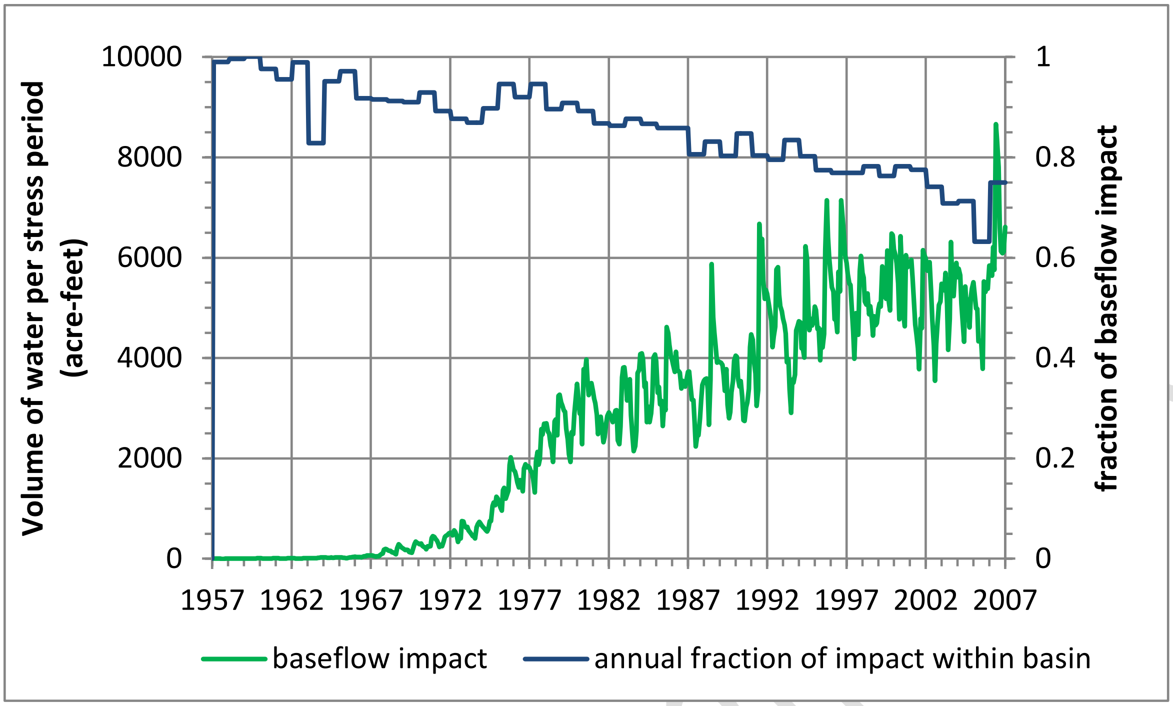


Fig. A8. Scenario 1 global pumping impact on baseflow per stress period, acre-feet (left axis) and annual fraction of global impact on baseflow within basin (right axis). Stress periods approximate months (365.25/12 = 30.4375 days). [Chart at AD822, Impacts_RS_wells_scenario_1_bgw, backup file]

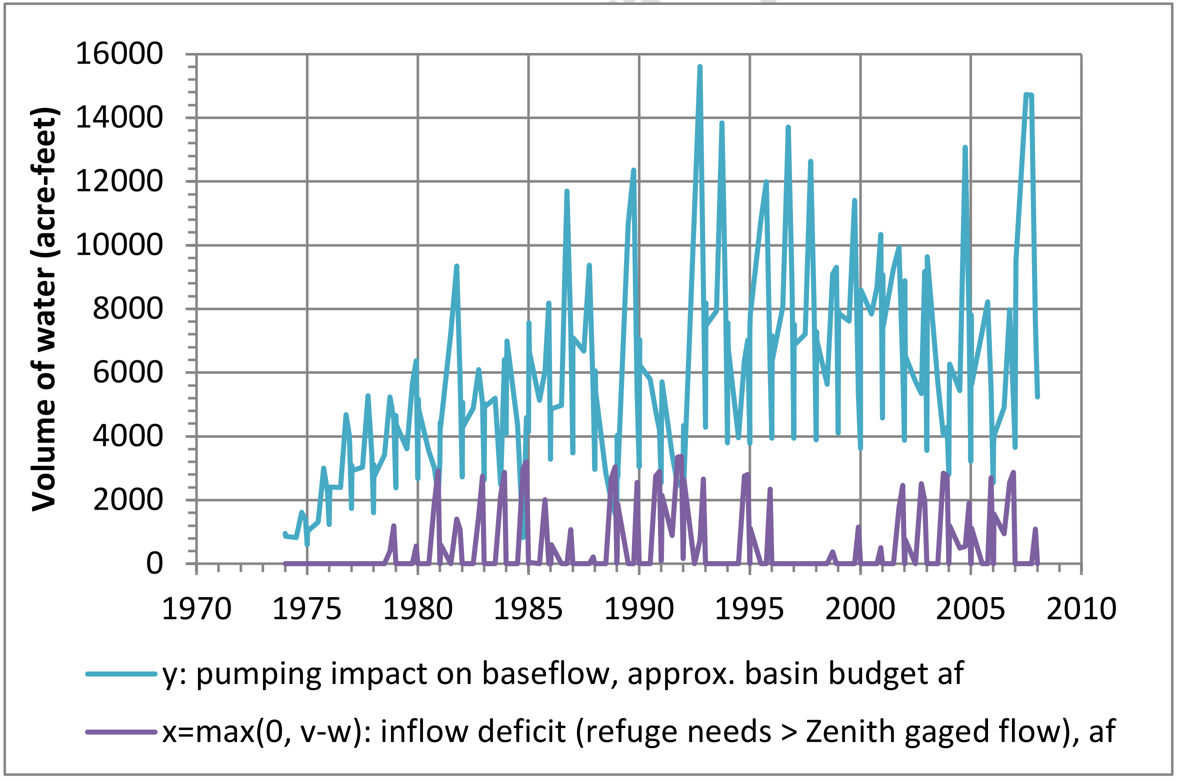


Fig. A9. Deficit in Refuge requirement (purple) and baseflow depletion by pumping (blue), for each Refuge management period. [Chart at w220 in sheet cwb_QNWRGrp of backup file]

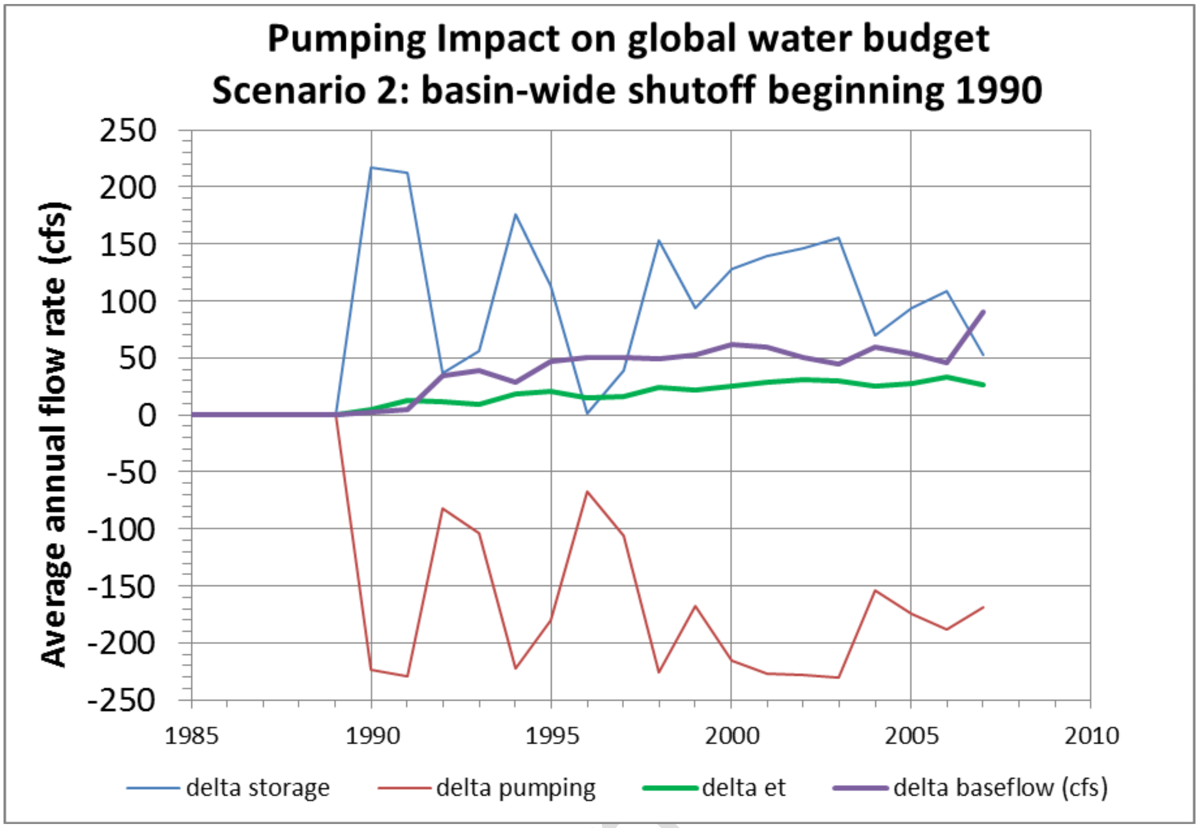


Fig. A10. Pumping impacts on global water budget for Scenario 2: basinwide shutoff beginning 1990.

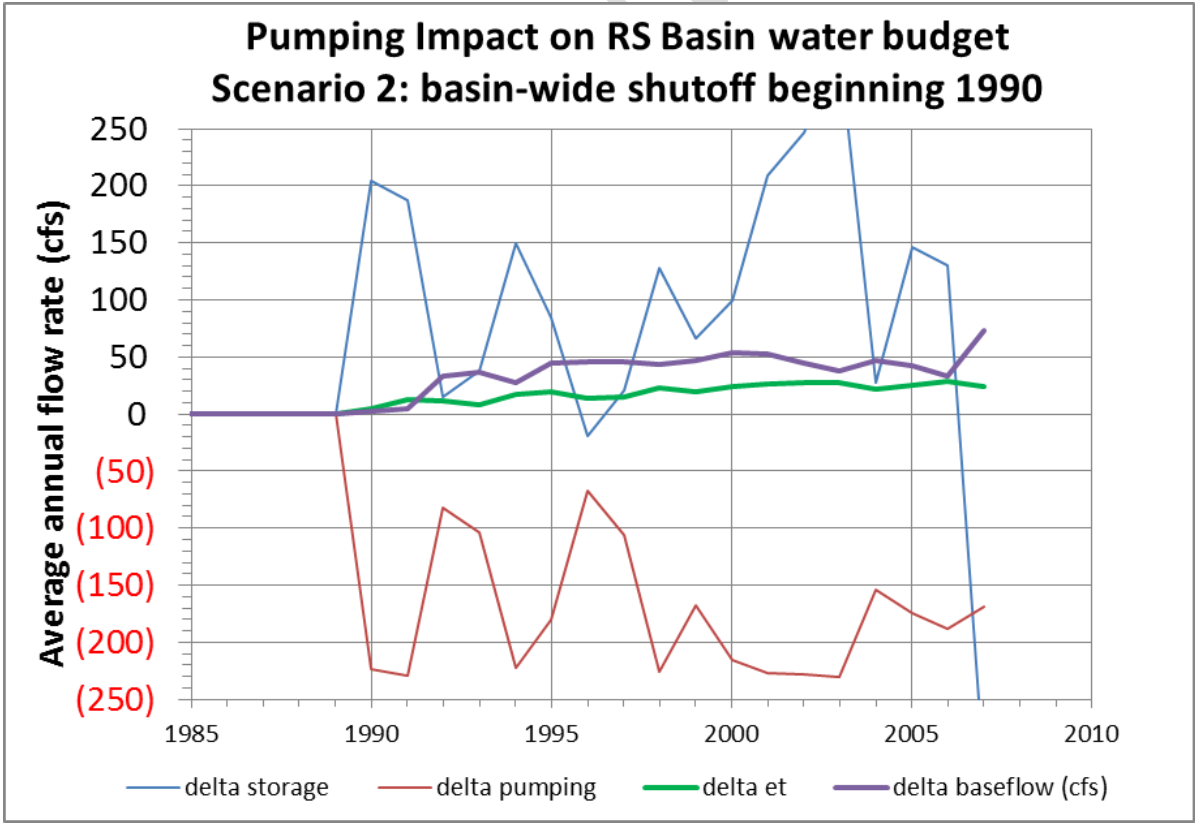


Fig. A11. Pumping impacts on RS Basin water budget for Scenario 2: basinwide shutoff beginning 1990.

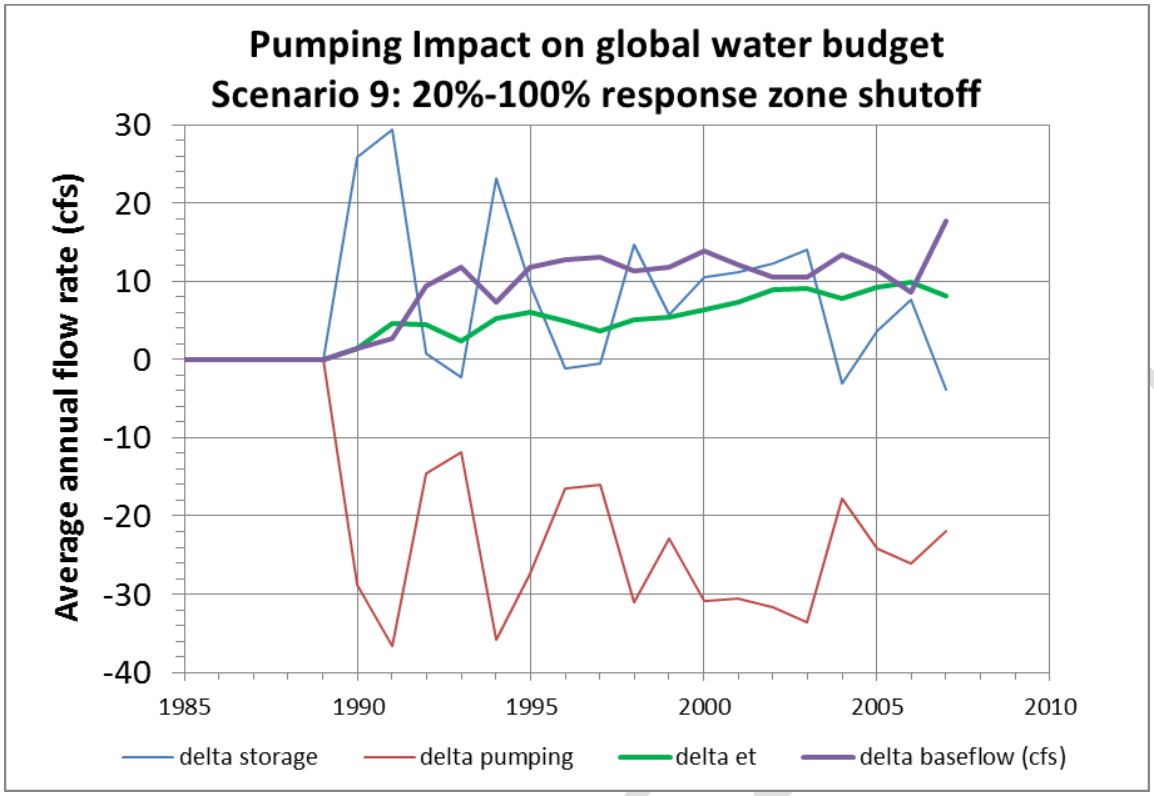


Fig. A12. Pumping impacts on global water budget for Scenario 9: targeted shutoff of wells within 20 percent or greater response zones beginning 1990. (response zones by Balleau and others, 2010)

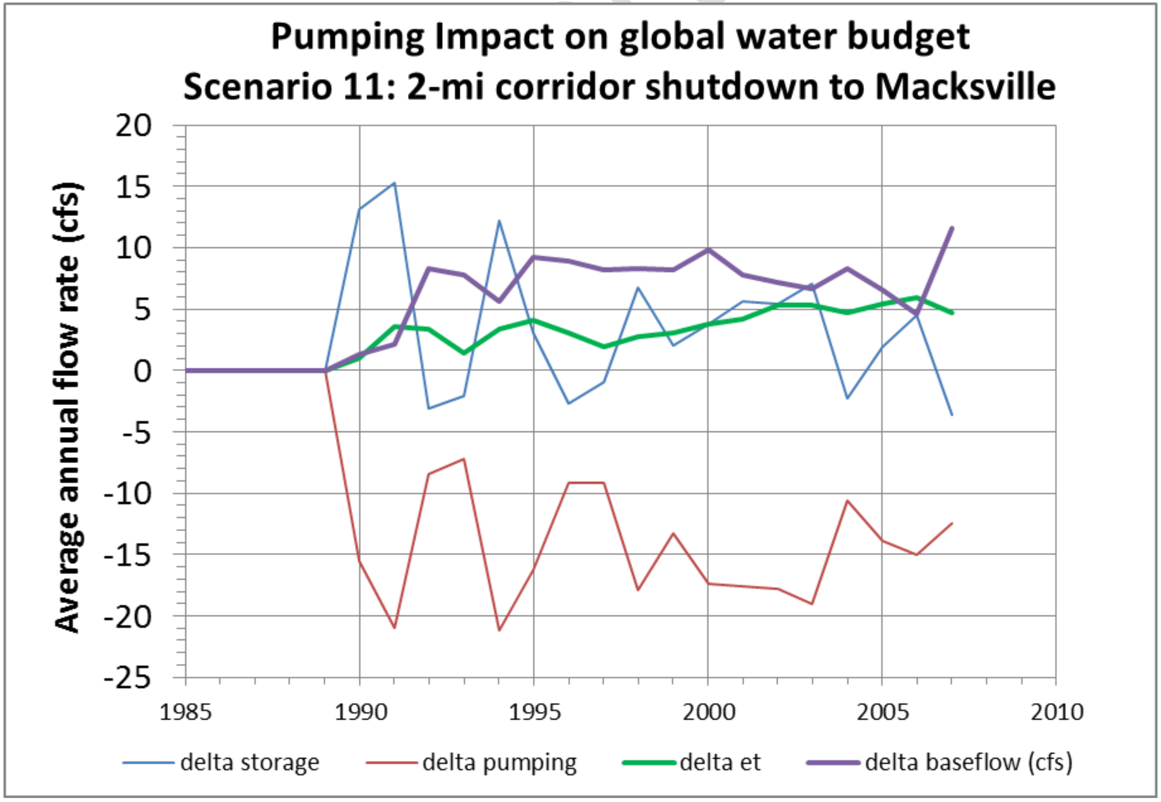


Fig. A13. Pumping impacts on global water budget for Scenario 11 (single-layer model version): targeted shutoff of wells within two miles of Rattlesnake Creek beginning 1990.

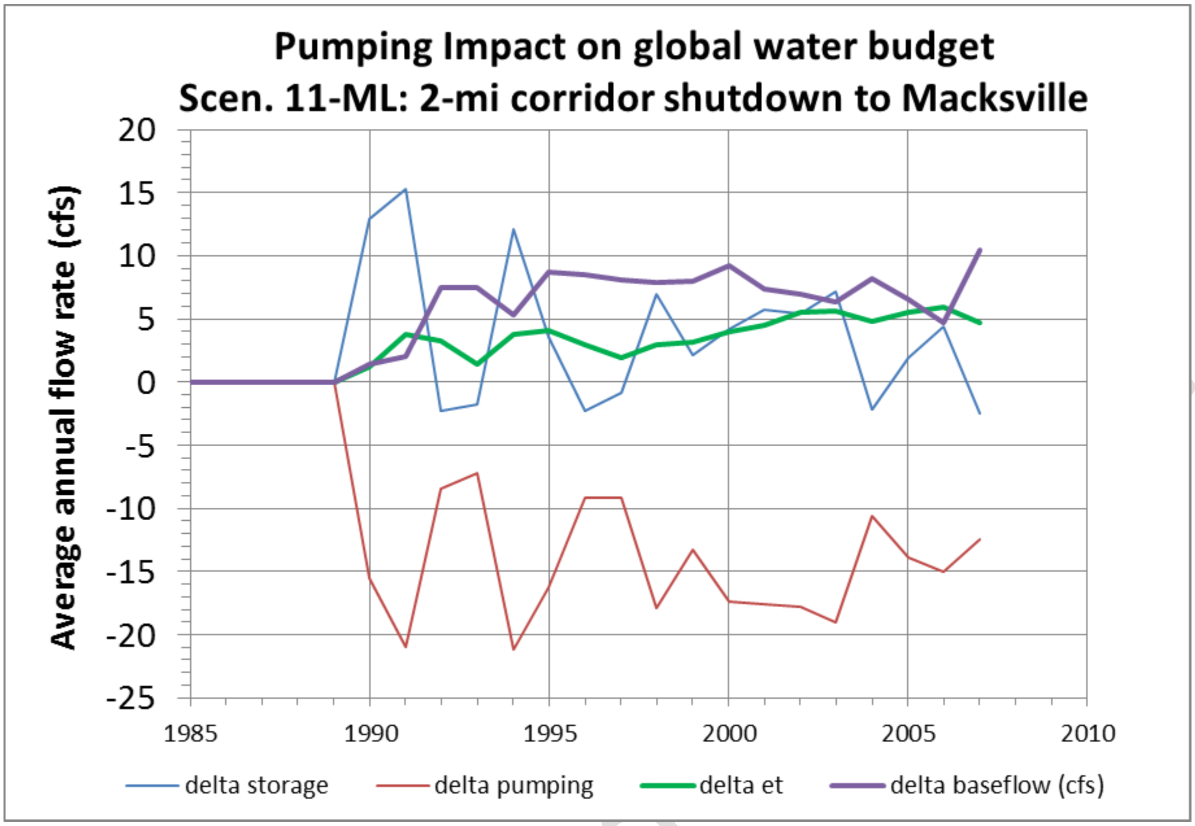


Fig. A14. Pumping impacts on global water budget for Scenario 11-ML (multilayer model version): targeted shutoff of wells within two miles of Rattlesnake Creek beginning 1990.

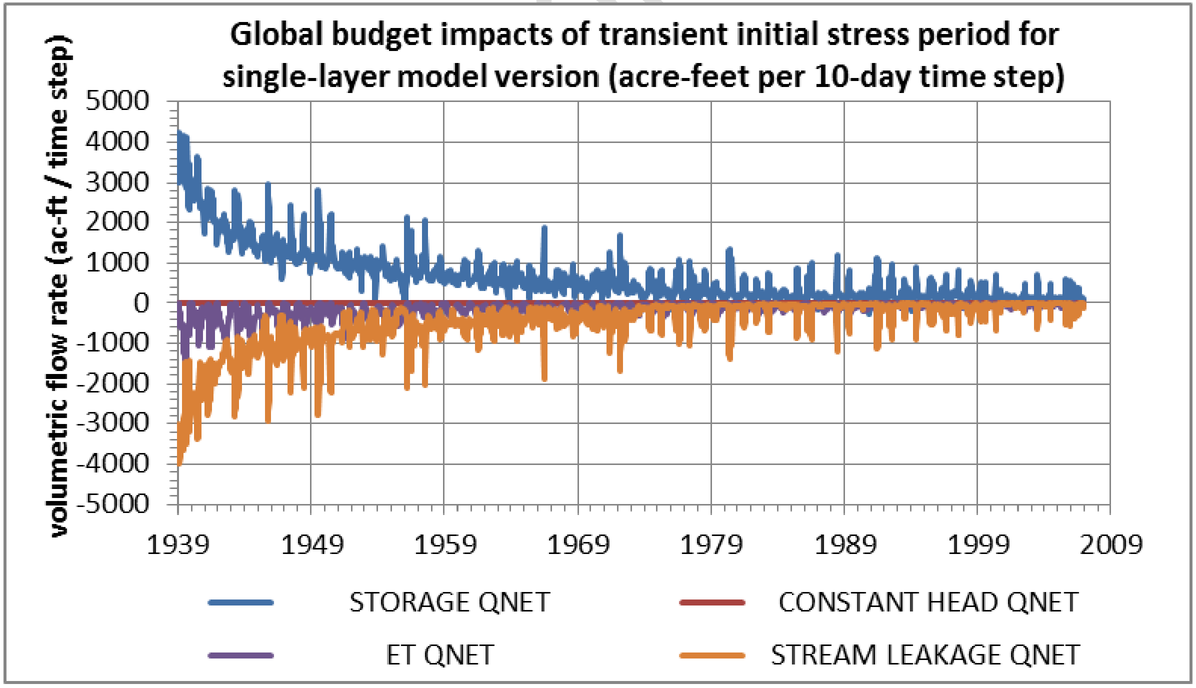


Fig. A15. Global budget impacts (acre-feet per ten-day time step) introduced by transient conditions in first stress period for the historical base case simulation 1940-2007 (single-layer model version).

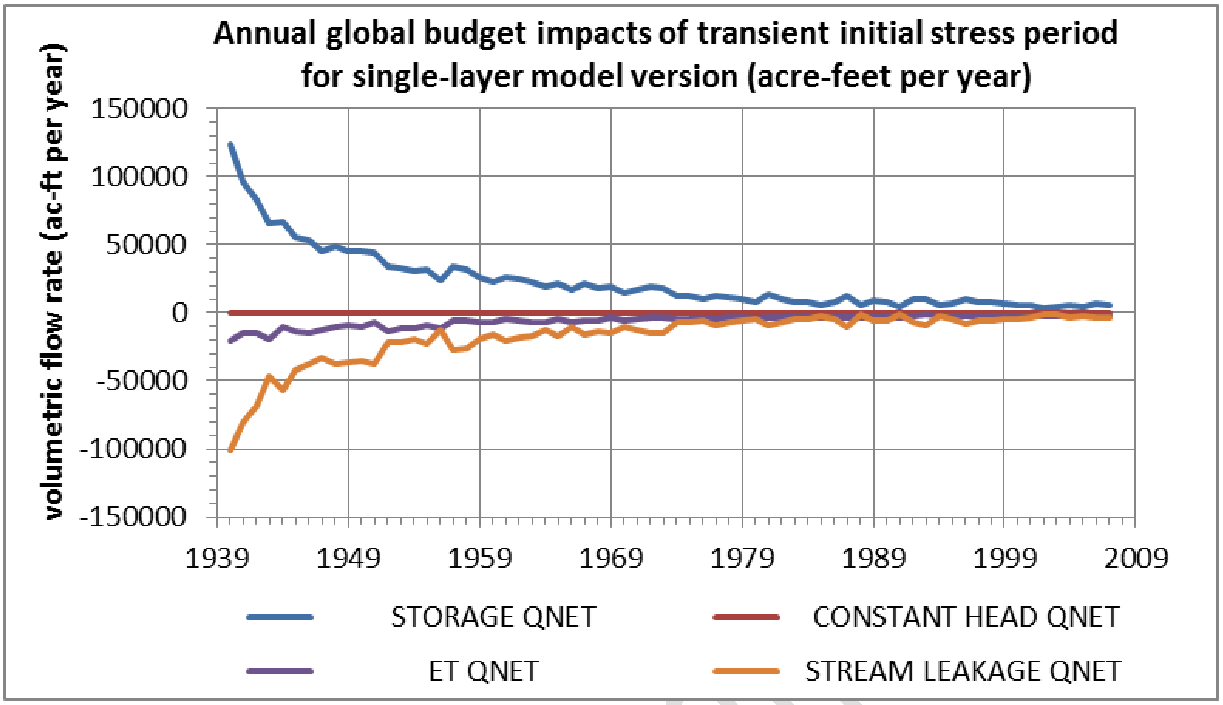


Fig. A16. Annual budget impacts (acre-feet per year) introduced by transient conditions in first stress period for the historical base case simulation 1940-2007 (single-layer model version).

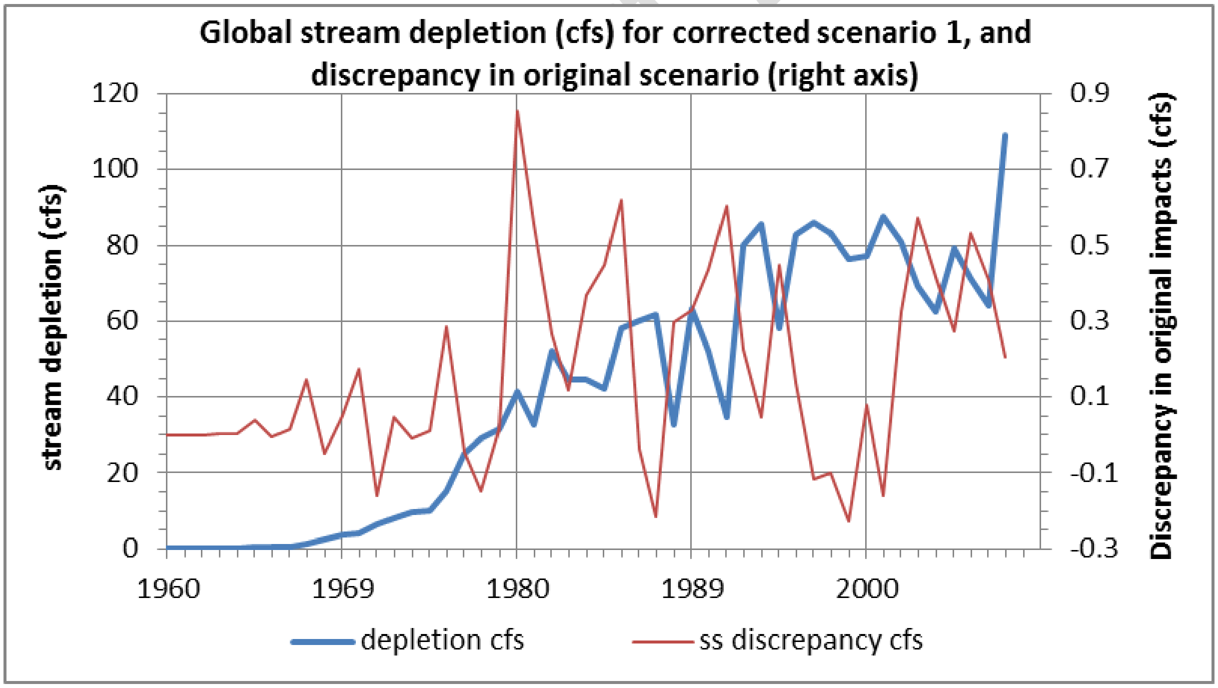


Fig. A17. Global stream depletion by Rattlesnake C Basin rights junior to File 7571 according to single-layer model runs beginning from steady state conditions as recommended by Balleau Groundwater, Inc., and discrepancy in original impact calculations (right axis).

Attachment 1

United States Department of the Interior
FISH AND WILDLIFE SERVICE
Mountain-Prairie Region

IN REPLY REFER TO:
BA WTR
WR KS
Mail Stop 60189

MAILING ADDRESS:
Post Office Box 25486
Denver Federal Center
Denver, Colorado 80225-0486

STREET LOCATION:
134 Union Blvd.
Lakewood, Colorado 80228-1807

MAR 04 2014

David Barfield, Chief Engineer
Kansas State Board of Agriculture
Division of Water Resources
109 SW 9th Street, 2nd Floor
Topeka, Kansas 66612-1280

Dear Mr. Barfield:

Staff from Quivira National Wildlife Refuge (Refuge) and the U.S. Fish & Wildlife Service Region 6 Division of Water Resources (Service) recently attended the monthly board meeting for Big Bend Groundwater Management District No. 5 (GMD#5). At the request of the Service, they met with Jeff Lanterman and yourself afterwards to discuss the ongoing impairment investigation and impacts to the Refuge's senior surface Water Right, File No. 7571.

It appears that the investigation and report generation may take a considerable amount of time to complete. Kansas statutes do not address a specific time period that the Chief Engineer has to complete the investigation and report. The Service recognizes that your agency may be dealing with other water right or resource issues, however, the Service raised concerns as early as 1971 about potential impairment to our senior water right, and they have not been addressed to date. At the meeting, you requested that the Service answer questions contained in your October 21, 2013, letter regarding impairment. The Service indicated that much of the information you were seeking was contained in the 1998 Burns and McDonnell study, Quivira National Wildlife Refuge Water Resource Study. You indicated that you have not reviewed the report and the Service came away with the impression that your office has committed little focus to the impairment investigation. You suggested that we could provide you with the location of the information in the report that we believe provides information regarding your questions. The Service feels very strongly that answers to these questions have been provided numerous times over the past 25 years, both in letters and in reports paid for using Service resources. If the Service agrees to spend time and resources to review and mark up the Burns and McDonnell report, we expect you to make a commitment to a definite time period to complete the impairment investigation and report.

Both the Service and the water users continue try to plan for the future with great uncertainty concerning the availability of water. It is in the interest of all water users within the Rattlesnake

Creek Subbasin, the thousands of visitors to the Refuge, and the State of Kansas that progress be made toward reaching a long-term solution to protecting and sustaining water resources. During the February meeting of GMD#5, the Service first learned that GMD#5 submitted a proposal for a 5-year water management plan to your office. It was equally interesting to learn that WaterPACK is active again after years of being relatively inactive. The Service was proceeding under the impression that there is still a functioning Partnership. Under the terms of the Partnership, communication should be transparent and all partners should be kept informed concerning the activities of the other Partners.

The Service has been an active and patient partner as attempts were made to implement the programs identified in the 12-year Rattlesnake Creek Subbasin Management Plan. The 12-year review conducted by your office concluded that water reduction targets were not met, groundwater use has increased, groundwater levels continue to decline, the target flow for January for the Rattlesnake Creek at the USGS Zenith gage is not being met, and junior irrigators continue to pump. The Chief Engineer's office was a signatory to the Plan, as well as GMD#5 and WaterPACK. The Plan was not developed solely to address the impairment of the Refuge's water right, and the water use reductions identified were meant to address other issues such as the high decline areas. Section VIII. Alternative Action Management Strategies states: "If, after the 12-year time line, the goals have not been achieved, then sufficient reductions in water rights would be imposed to achieve the goals. Reductions in appropriations will be calculated by dividing the remaining amount of water use needed to reach the goal by 72%." This section goes on to describe the goals and present alternatives to put into effect if these reductions do not result in meeting these goals, including the possible establishment of an Intensive Groundwater Use Control Area. It has now been over 13 years since the Partners, including your office, signed this agreement. We respectfully request that the groundwater use reductions agreed to by all of the Partners be achieved now. The impairment investigation being conducted by your office can continue concurrently.

Enclosed are copies of Kansas Geological Survey Open-File Reports 92-6 and 92-37 that may assist you in the impairment investigation. These are examples of studies that were funded by the Service. We also strongly encourage you to schedule a visit to the Refuge to help you better understand how the Refuge operates and manages its water resources to support wildlife and its associated habitat for current and hopefully future generations.

If you have any questions, please contact me at meg_estep@fws.gov or call (303) 236-4491.

Sincerely,

Megan A. Estep, Chief
Division of Water Resources

Enclosures

Enclosures

cc:
- Project Leader, Quivira NWR
- Refuge Supervisor, CO/KS/NE
- Rocky Mountain Region Solicitor's Office
- Water Commissioner, Stafford Field Office
- Manager, Big Bend Groundwater Management District #5
- WaterPACK

United States Department of the Interior
FISH AND WILDLIFE SERVICE
Mountain-Prairie Region

MAILING ADDRESS:
Post Office Box 25486
Denver Federal Center
Denver, Colorado 80225-0486

STREET LOCATION:
134 Union Blvd.
Lakewood, Colorado 80228-1807

IN REPLY REFER TO:
BA WTR
WR KS
Mail Stop 60189

APR 0 8 2013

David Barfield, Chief Engineer
Kansas State Board of Agriculture
Division of Water Resources
109 SW 9th Street, 2nd Floor
Topeka, Kansas 66612-1280

Dear Mr. Barfield:

The U.S. Fish and Wildlife Service (Service) owns and manages the Quivira National Wildlife Refuge (Refuge). The Refuge holds Water Right No. 7571, priority date August 15, 1957, at a combined diversion rate not to exceed 300 cubic feet per second and a quantity not to exceed 14,632 acre-feet per calendar year for recreational use. Based on available studies and the results of the Rattlesnake Creek Subbasin Management Plan, the Service believes that our water right is impaired by junior well use. We hereby request that your office commence an impairment investigation.

The Refuge is important to natural resource conservation not only regionally and nationally, but globally as well. The Refuge is designated as a Western Hemisphere Shorebird Network site, a Wetland of International Importance (RAMSAR site), an Important Bird Area (American Bird Conservancy), and is critical habitat for federally endangered whooping cranes. The federally endangered piping plover and interior least tern also use the refuge and the State has designated refuge lands (waters) as critical habitat for the western snowy plover and Arkansas darter, both of which are state listed as threatened species.

Surface water originating from Rattlesnake Creek and groundwater discharge from the shallow, saline Precambrian bedrock are critical to sustaining Refuge wetlands that attract and support the vast variety of associated migratory and resident bird species. Without both of these components, groundwater upwelling or sufficient streamflow, the ecology of the entire system will change. The Refuge and its values will not be sustained unless the aquifer system is brought into balance.

Like a farmer, the Refuge needs water during critical time periods. The values of wetlands on refuge lands for migratory birds can only be sustained by providing flooded conditions at proper times during the year, particularly during spring and fall migration. Simply because 14,632 ac-ft

WATER RESOURCES
RECEIVED
APR 10 2013
KS DEPT OF AGRICULTURE

Attachment 2

is available on an annual basis in most years does not meet Refuge habitat management needs. Water is typically unavailable in the late summer and early fall when the Refuge is trying to flood migration habitat for birds. Irrigation pumping is usually greatest during this time as well. Water shortages typically occur during the months of July, August and September, when as little as a few hundred acre-feet may be available.

The Service has been patient as the 12-year Rattlesnake Creek Subbasin Management Plan was allowed to run its course. The Service was a supportive and sincere partner in the effort to utilize an incentive-based plan to reduce groundwater use. At the end of the 12 years, groundwater use has increased, groundwater levels have not improved, and streamflow goals have not been met. Streamflow continues to decline, and junior irrigators are allowed to continue to pump. We respectfully request that you conduct your investigation and take whatever administrative actions are necessary to protect the Service's senior water right and, we believe, the ability of the Rattlesnake Creek watershed to support all current land uses over the long term.

Please contact me at meg_estep@fws.gov or a call if you have any questions at (303) 236-4491.

Sincerely,

Megan A. Estep, Chief
Division of Water Resources

cc:
Refuge Manager, Quivira NWR
Refuge Supervisor, CO/KS/NE
Rocky Mountain Region Solicitor's Office
Water Commissioner, Stafford Field Office
Manager, Groundwater Management District #5
Water Pack

Attachment 3

CERTIFICATION MEMORANDUM, FILE 7571

The certification of application to appropriate water, File 7571 actually began in July of 1991. A tour of the refuge was made in the company of Patrick D. Gonzales, assistant manager of Quivira National Wildlife Refuge. Mr. Gonzales reviewed the basic operations at the refuge and detailed how water was used among the various management units within the refuge proper. Copies of missing water use reports (exhibit A) were obtained from the U.S. Fish and Wildlife Service in Denver. These reports filled in all the missing gaps in the water use history of the refuge. In February of 1992, contact was made with representatives from U.S. Fish and Wildlife Service (USFWS) headquarters. It was learned that a detailed survey of the refuge was to be conducted in the near future. The survey would include cross sections of each management pool in the refuge and more accurately define the total water holding capacity of the entire project. As of February 1, 1993, the survey has been completed, but the information has not been tabulated or made available for review. Since the new survey has not been completed in a timely manner, older information that was originally computed from aerial photos is being used to prepare the certificate. Much of this information was already in the files and additional information was obtained from USFWS itself (exhibit B).

The <u>Water Resources Data of Kansas</u> published yearly by the U.S. Geological Survey was consulted for the years 1963 through 1990. These publications give the streamflow values for permanent gaging stations on the Rattlesnake Creek at Macksville, Kansas and Raymond, Kansas. The Macksville station gives interesting results, but it is over 30 miles upstream from the diversion points authorized by this file. On a stream such as the Rattlesnake that is often gaining base flow in some areas and losing base flow to the aquifer in other areas, depending on the immediate section of the stream being analyzed, a gaging station over 30 miles away is not of much value as it relates to this project. The Raymond, Kansas gage was also analyzed. This gage should have been useful since it is situated at the outflow from Quivira Refuge. What complicates the readings from this gage is that artesian saltwater flows on the north edge of the refuge enter the stream (referred to as Salt Creek at this location) and are recorded at the gaging station. The result is that at times flow is recorded at the gage even when operations at Quivira are using the entire upstream flow of the Rattlesnake Creek. Flood flows, artesian groundwater, and occasionally normal streamflows reach the Raymond gage, unfortunately, it is impossible to distinguish where the recorded flows may have come from.

In May of 1973 a gaging station was put into service at Zenith, Kansas. This gage is approximately 1 1/2 miles upstream from the first diversion structure at Quivira Wildlife Refuge. This gage has the potential to provide the most pertinent data in regards to the certification of File 7571. Since the Zenith gage was not installed until 1973 there is no actual data for that location during prior years. For that reason Jim Bagley, of the Division of Water Resources, prepared streamflow regression analysis charts (exhibit C). While these charts are definitely an asset in obtaining the total picture of past streamflow and appear to correlate exceptionally well with actual flow records at the other gaging stations, Mr. Bagley warns against depending on the regression analysis too much. On a related note, Marios Sophocleaus states in his KGS open file report 92-10 that 19625 acre feet is the average annual streamflow at the Zenith gage during the years 1981 through 1990.

Hydrographs were prepared (exhibit D) to visually display the monthly and annual flows recorded, in acre feet, at all of the above gaging stations from 1963 to 1990. The 1963 to 1973 flows estimated from regression analysis at the Zenith gage were also plotted. In addition, the annual reported quantity of water used at Quivira was plotted against the streamflow quantities. If nothing else, the hydrographs reveal that the water use reports submitted for Quivira do not exceed the quantity shown to have been provided by the Rattlesnake Creek.

Next, information from the area and capacity information (exhibit B) and the Annual Water Management Plan (exhibit E) were combined into one table. This table is titled "Typical Annual Water Use at Quivira Wildlife Refuge" (exhibit F). The purpose of the tabulation is to demonstrate the maximum amount of water the refuge might use if it had sufficient water available and it was able to fulfill all of the management options listed in its Annual Water Management Plan. The tabulation is actually less than the maximum water needs as it does <u>not</u> include unmanaged areas that are often flooded to a depth of two to three inches; it also does <u>not</u> include evapotranspiration by moist soil plants, seepage, lake evaporation through fall and winter months, or transit losses in canals or within the streambed itself. One other item that is not calculated is the fact that at certain times it may be beneficial to drain one management unit, utilizing the drained water into a second unit in need of water, although in most instances the units are allowed to evaporate naturally. Additionally, large salt flats at the north end of the refuge, and the northern end of the Big Salt Marsh itself, appear to receive a portion of their water supply from the artesian seeps and springs that flow into the refuge from the west.

Exhibit F demonstrates that when considering the permanent management pools only, operated under the guidelines of existing management plans, that the quantity of water reported since 1963 appears not only to have been reasonable, but also possible.

On December 21, 1992 and January 28, 1993, Mr Dave Hilley, Manager of Quivira Wildlife Refuge, was contacted for additional information concerning operations at the refuge. The methods used by the refuge to measure water flows were observed, tested, and recorded in a memorandum labeled exhibit G. This document outlines specifically what instrument is used to measure flows, how it works, how quantities are calculated for annual water use reports, and states the one discrepancy found in the water reporting method. That discrepancy was the fact that the quantity of water stored and evaporated from the Little Salt Marsh was not reflected in the refuge's reporting methods. The information obtained on both visits, combined with previously gathered data, were compiled to form exhibit H, which is a detailed map of each management unit, the canals connecting each unit, control structures used to move water within the refuge, and the diversion points on the Rattlesnake Creek.

SUMMARY

Based on the above information and attached exhibits a certificated of appropriation for file 7571 is proposed as follows:

File 7571 was approved in 1963. During the time period 1963 to 1972 many of the water use reports were estimated and during that time the diversion works were reported to be only 80% complete. An actual water measurement program may not have been in place prior to 1973. In 1973, a year of torrential rainfall, the diversion works and control structures at Quivira were destroyed. It was not until 1978 that the damage was finally repaired. The year 1978 was, therefore, the first year that the diversion works were complete and ready to divert and store water according to management plans. Assuming that the water requirements of the refuge are best represented by years after 1978, the year 1987 has been selected as the year of record. Using 1987 will require that an extension of time to perfect be granted to that year.

During 1987 the U.S. Fish and Wildlife Service reported that 10129.7 acre feet of water was diverted from the Rattlesnake Creek and that the refuge was "full all year." As pointed out above and in exhibit G, the measurements reported do not reflect the amount stored and the subsequent evaporation in the Little

Salt Marsh. Using an area of 950 acres in the Little Salt Marsh, and a capacity of 2260 acre feet, one would assume 2850 acre feet of evaporation during a calendar year (36 inches of net evaporation). The proposed certified quantity for file 7571 would then be the sum of the acre feet reported in 1987, the amount stored in the Little Salt Marsh, and the amount evaporated from the Little Salt Marsh: 10129.7 acre feet + 2260 acre feet + 2850 acre feet = 15240 acre feet. It is also proposed that all of the 15240 acre feet be shown as direct use and that the "quantity to be accumulated in reservoirs" as stated in the approval be dropped from the certificate.

It is proposed that the rate of diversion be certified as natural flows not needed for prior downstream diversions. The diversion should be limited to a maximum of 300 c.f.s. Flows of 300 cfs can be verified from streamflow records at the Zenith station (see exhibit I).

Finally, the description of the point of diversion noted as "diversion A" is being proposed differently than originally approved. The stream is not located in that ten acre tract. Therefore it is proposed to correct that description when the certificate is issued.

It is the recommendation of the Stafford Field Office that U.S. Fish and Wildlife Service be required upon issuance of this certificate to install a permanent metering system on the Rattlesnake Creek immediately downstream from their last diversion point and that a water conservation plan be prepared for the refuge, both to be completed by December 31, 1995.

FIELD INSPECTION, FILE 7571

LAND TO BE INCLUDED ON CERTIFICATE

The South 80 acres of the SE1/4 of Section 15; the S1/2 of Section 14; the NE1/4, SW1/4, and SE1/4 of Section 29; and all of Sections 13, 21 through 28, and 32 through 36 in Township 21 South, Range 11 West;

and all of Sections 1 through 5, 11 through 14, 23 through 26, and sections 35 and 36 in Township 22 South, Range 11 West;

and all of Sections 1 and 2 in Township 23 South, Range 11 West;

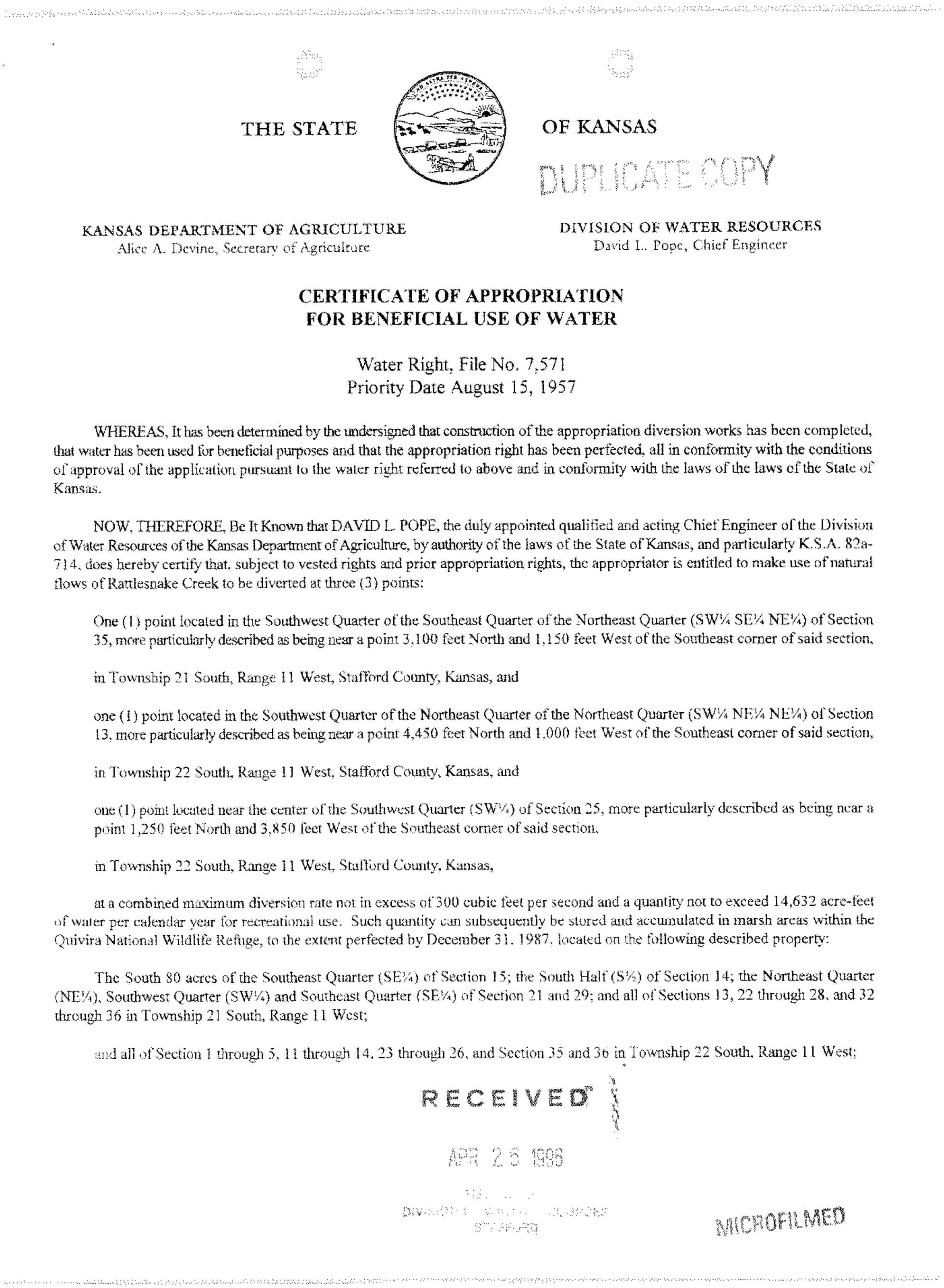
all in Stafford County, Kansas;

Section 18 in Township 21 South, Range 10 West, in Rice County, Kansas;

and Section 30 in Township 22 South, Range 10 West, in Reno County, Kansas.

PLACE OF USE DURING YEAR OF RECORD

Water was applied to and circulated among the various management units within the place of use described above. Those management units are depicted on the map accompanying this field inspection report.



THE STATE OF KANSAS

DUPLICATE COPY

KANSAS DEPARTMENT OF AGRICULTURE
Alice A. Devine, Secretary of Agriculture

DIVISION OF WATER RESOURCES
David L. Pope, Chief Engineer

CERTIFICATE OF APPROPRIATION FOR BENEFICIAL USE OF WATER

Water Right, File No. 7,571
Priority Date August 15, 1957

WHEREAS, It has been determined by the undersigned that construction of the appropriation diversion works has been completed, that water has been used for beneficial purposes and that the appropriation right has been perfected, all in conformity with the conditions of approval of the application pursuant to the water right referred to above and in conformity with the laws of the laws of the State of Kansas.

NOW, THEREFORE, Be It Known that DAVID L. POPE, the duly appointed qualified and acting Chief Engineer of the Division of Water Resources of the Kansas Department of Agriculture, by authority of the laws of the State of Kansas, and particularly K.S.A. 82a-714, does hereby certify that, subject to vested rights and prior appropriation rights, the appropriator is entitled to make use of natural flows of Rattlesnake Creek to be diverted at three (3) points:

One (1) point located in the Southwest Quarter of the Southeast Quarter of the Northeast Quarter (SW¼ SE¼ NE¼) of Section 35, more particularly described as being near a point 3,100 feet North and 1,150 feet West of the Southeast corner of said section,

in Township 21 South, Range 11 West, Stafford County, Kansas, and

one (1) point located in the Southwest Quarter of the Northeast Quarter of the Northeast Quarter (SW¼ NE¼ NE¼) of Section 13, more particularly described as being near a point 4,450 feet North and 1,000 feet West of the Southeast corner of said section,

in Township 22 South, Range 11 West, Stafford County, Kansas, and

one (1) point located near the center of the Southwest Quarter (SW¼) of Section 25, more particularly described as being near a point 1,250 feet North and 3,850 feet West of the Southeast corner of said section,

in Township 22 South, Range 11 West, Stafford County, Kansas,

at a combined maximum diversion rate not in excess of 300 cubic feet per second and a quantity not to exceed 14,632 acre-feet of water per calendar year for recreational use. Such quantity can subsequently be stored and accumulated in marsh areas within the Quivira National Wildlife Refuge, to the extent perfected by December 31, 1987, located on the following described property:

The South 80 acres of the Southeast Quarter (SE¼) of Section 15; the South Half (S½) of Section 14; the Northeast Quarter (NE¼), Southwest Quarter (SW¼) and Southeast Quarter (SE¼) of Section 21 and 29; and all of Sections 13, 22 through 28, and 32 through 36 in Township 21 South, Range 11 West;

and all of Section 1 through 5, 11 through 14, 23 through 26, and Section 35 and 36 in Township 22 South, Range 11 West;

Attachment 4

and all of Sections 1 and 2 in Township 23 South, Range 11 West,

all in Stafford County, Kansas, and

DUPLICATE COPY

Section 18 in Township 21 South, Range 10 West, in Rice County, Kansas;

and Section 30 in Township 22 South, Range 10 West, in Reno County, Kansas.

The appropriator shall maintain in an operating condition, satisfactory to the Chief Engineer, all check valves installed for preventing chemical or other foreign substance likely to cause pollution of the water supply.

The appropriator shall maintain records from which the quantity of water actually diverted during each calendar year may be readily determined. Such records shall be furnished to the Chief Engineer by March 1 following the end of the previous calendar year.

The appropriation right shall be deemed abandoned and shall terminate when without due and sufficient cause no lawful beneficial use is made of water under this appropriation for three (3) successive years.

The right of the appropriator shall relate to a specific quantity of water and such right must allow for a reasonable raising or lowering of the static water level and for the reasonable increase or decrease of the stream flow at the appropriator's point of diversion.

IN WITNESS WHEREOF, I have hereunto set my hand at my office at Topeka, Kansas, this 9th day of April, 1996.

David L. Pope

David L. Pope, P.E.
Chief Engineer
Division of Water Resources
Kansas Department of Agriculture

State of Kansas, Shawnee COUNTY, SS

The foregoing instrument was acknowledged before me this 9th day of April, 1996, by David L. Pope, P.E., Chief Engineer, Division of Water Resources, Kansas Department of Agriculture.

Denise J. Rolfs
Notary Public

My appointment expires: 3-1-98

(Record in the Office of Register of Deeds in the county or counties wherein the point of diversion is located)

CERTIFICATE OF APPROPRIATION
FOR BENEFICIAL USE OF WATER

STATE OF KANSAS

Water Right, File No. 7,571

STATE OF KANSAS, ______ COUNTY, ss.

iled for record this ______ day of ______, 19__

t ______ o'clock ______ m. and

ecorded in Book ______ Page ______

ee $______

Register of Deeds.

Table 17. Estimated greatest potential distribution of wetland habitat conditions (acres by unit and objective) for the proposed alternative for Quivira National Wildlife Refuge, Kansas.

		Mid-February through May spring migration			*May through July summer breeding*		*August–November fall migration*			*November–February winter*
		A1	A2	A3	B1	B2	C1	C2	C3	D
Wetland	*Acres*	Acres bare flats <25% vegetation, flood <6 inches	Acres >75% annual or meadow, flood <15 inches	Acres <25% emerging >20% submerged aquatic vegetation, flood 6–30 inches	Acres of bare flats <25% cover	Acres of 30–60% tall emerging, flood <10 inches	Acres of bare flats <25% vegetation, flood <6 inches,	Acres >75% annual or meadow, flood <15 inches	Acres <25% emerging >20% submerged aquatic vegetation, flood 6–30 inches,	Acres <25% emerging, flood 6–30 inches
Little Salt Marsh	931	181.2	0	662.9	3.8	87.3	181.1	0	662.9	931
Unit 7 (created)	62	15.8	40.5	5.6	15.8	0	15.8	40.5	5.6	62
Unit 10a (created)	19	12.9	12.9	6.3	0	6.3	0	12.9	0	19
Unit 10b (created)	14	0	0	10.3	0	0	3.9	0	10.3	14
Unit 10c (created)	7	6	6.1	0.8	6.1	0	0	6.1	0.8	7
Unit 11 (created)	30	11.9	12	16.3	0	0	0	12	6.3	30
Unit 12b (created)	12	8.8	8.8	2.9	0	11.5	0	8.8	2.9	12
Unit 14a (created)	100	15.5	73.9	0	27.3	0	15.6	73.9	0	100
Unit 14b (created)	45	43.1	43.1	1.7	0	1.7	0	43.1	1.7	45
Unit 16 (created)	14	0	5.8	8.5	0	14.2	0	5.8	8.5	14
Unit 20a (created)	69	60.3	60.4	8.5	0	8.5	0	60.4	8.5	69
Unit 20b (created)	66	0	62.2	3.7	0	3.7	0	62.2	3.7	0
Unit 21 (created)	11	3.9	0	5.9	3.8	1.5	3.8	0	5.9	11
Unit 22 (created)	12	0	0	12.1	0	12.1	0	0	12.1	12
Unit 23 (created)	14	0	0	14.1	0	14.1	0	0	14.1	14
Unit 24 (created)	54	0	0	54.1	0	54.1	0	0	54.1	54
Unit 25 (created)	54	0.6	53.4	0	0	0	0	53.4	0	54
Unit 26 (created)	69	69.1	69.1	0	0	0	0	69.1	0	69
Unit 28 (created)	61	60.8	60.9	0	0	0	0	60.9	0	61

Table 17. Estimated greatest potential distribution of wetland habitat conditions (acres by unit and objective) for the proposed alternative for Quivira National Wildlife Refuge, Kansas.

		Mid-February through May spring migration			*May through July summer breeding*		*August–November fall migration*			*November–February winter*
		A1	A2	A3	B1	B2	C1	C2	C3	D
Wetland	*Acres*	Acres bare flats <25% vegetation, flood <6 inches	Acres >75% annual or meadow, flood <15 inches	Acres <25% emerging >20% submerged aquatic vegetation, flood 6–30 inches	Acres of bare flats <25% cover	Acres of 30–60% tall emerging, flood <10 inches	Acres of bare flats <25% vegetation, flood <6 inches,	Acres >75% annual or meadow, flood <15 inches	Acres <25% emerging >20% submerged aquatic vegetation, flood 6–30 inches,	Acres <25% emerging, flood 6–30 inches
Unit 29 (created)	27	23.7	23.7	3.6	0	0	0	23.7	3.6	27
Unit 30 (created)	42	41.6	41.6	0	0	0	0	41.6	0	42
Unit 37 (created)	50	0	0	49.8	0	49.8	0	0	49.8	50
Unit 40 (created)	36	36.7	36.4	0	0	0	0	36.4	0	36
Unit 48 (created)	55	54.4	54.4	0.8	0	0	0	54.4	0.8	55
Unit 49 (created)	85	83.9	83.9	1.3	83.9	0	83.9	83.9	1.3	85
Unit 50 (created)	91	90.5	90.6	0	0	0	0	90.6	0	91
Unit 57 (created)	89	0	43.4	34.0	11.5	43.4	11.5	0	34	89
Unit 58 (created)	116	67.5	0	48.9	0	48.9	0	0	0	116
Unit 61 (created)	121	121.2	104.2	0	121.2	0	17.2	104.2	0	121
Unit 62 (created)	38	35.7	35.8	1.7	0	0	1.7	35.8	1.7	38
Unit 63 (created)	103	93	93	0	10	0	10.0	93	0	103
Unit 80 N. Lake	393	393.2	0	72.1	393.2	0	0	0	0	393
Marsh Road Meadow	494	267.6	226.2	226.2	267.6	0	0	0	0	0
Wildlife Drive (BSM)	801	723.2	0	107.3	697.1	0	25.1	0	0	801
Big Salt Marsh	1209	408.8	0	800.6	98.3	0	206.4	0	0	1209
Salt Springs	252	0	238.3	0	0	14.7	0	0	14.6	252
Total	5646	2930.9	1580.6	2160	1739.6	371.8	576	1072.7	903.2	5086

NOTE: Table does not include wetlands managed as part of the grassland habitat type.

Seasonal Rattlesnake Creek Water Need Estimates for Quivira National Wildlife Refuge, Prepared May 2015

Background

At the request of Kansas Department of Agriculture, Division of Water Resources (DWR), the U.S. Fish and Wildlife Service (Service) has provided information to increase understanding of *seasonal* water needs to accomplish management objectives of the Quivira National Wildlife Refuge (Refuge). The Refuge's current annual Water Right 7571 on Rattlesnake Creek is 14,632 ac-ft. There is no single estimate that accurately predicts seasonal surface water needs of the Refuge because various factors influence water needs within and among years, such as short- and long-term weather patterns, the timing of wildlife events (e.g., migration), and changing habitat conditions.

Approach

<u>Scenario 1</u> – There was interest by DWR to evaluate the potential of using past water use records to quantify estimates of seasonal water needs to accomplish refuge management objectives. To accomplish this task, Refuge staff compiled 48 years of monthly water-use records and grouped months into seasons based on the life cycle events of waterbirds (timing of migration, relative abundances) and the lag time required to transfer water to wetlands through the ditch infrastructure (Table 1). For example, flooding a wetland to the appropriate depth can require days to weeks depending on location from the diversion, volume of water available, and existing soil moisture conditions (e.g., dry, saturated).

Table 1. Significant annual events largely considered in determining seasonal water needs to accomplish management objectives of Quivira National Wildlife Refuge.

Jan-Feb	Mar-Apr	May-Jun	Jul-Sep	Oct-Nov	Dec
MANAGEMENT TO SUPPORT WILDLIFE FOOD & COVER REQUIREMENTS					
Use water where needed to provide/maintain semipermanent wetland habitat.					
Shallowly flood select units to saturate dry soils that will be used to produce wildlife foods.					
	Dewater select wetlands for suitable germination and growth of desired plants used for wildlife food and cover. Drawdown dates are based on scientific information.				
	Irrigate select wetland units to support survival, growth, and seed production of germinated wildlife food plants.		After seeds mature, gradually increase water levels in wetlands to coincide with the food and cover needs of target species.		
CHRONOLOGY OF SPECIES ANNUAL EVENTS OR WHEN LIFE REQUIREMENTS NEED TO BE AVAILABLE FOR SPECIES USE					
Waterfowl and bald eagle wintering habitat is provided when open water is available (generally where flooded deep and/or where flow prevents ice formation).	Peak spring waterfowl migration (habitat flooded <15 inches). Main spring shorebird migration (habitat flooded <6 inches and mudflat).		Main fall shorebird migration (habitat flooded <6 inches and mudflat).	Peak fall waterfowl migration (habitat flooded <15 inches).	
	Endangered whooping crane spring migration (shoreline & habitat flooded <1 ft).	Breeding-related activities occur for several waterbirds that require flooded habitat for food and/or cover resources, such as for the state-threatened snowy plover, the endangered interior least tern, and for state species in need of conservation (e.g., black rail, black tern).		Endangered whooping crane fall migration (shoreline and habitat flooded <1 ft).	

After reviewing the water use records, Refuge staff made the determination to exclude years (n=28) when total annual water use <u>did not</u> exceed 7,000 ac-ft to prevent extreme bias in estimating seasonal water use due to limited water availability and/or inappropriate timing of available water. For example, during low water years Refuge staff often receive and use water at less than optimal times (e.g., winter) to help increase the odds that at least some wetland habitat is flooded at critical times (e.g., spring waterbird migration). In this case, the average amount of water used during the winter season would be biased high. Conversely, it is common during low water years to not have sufficient water to maintain wetland vegetation, which results in low food production and sparse cover required by wildlife. In this case, the use of water during summer would be biased extremely low. The use of 7,000 ac-ft as a cutoff point was based on approximating 50% of the Refuge water right and, as such, is somewhat arbitrary.

For the 20 years of when total annual water use exceeded 7,000 ac-ft, water use for each year was partitioned into the appropriate seasons and the median, minimum, and maximum seasonal values across all years were calculated (Table 2).

Table 2. Seasonal median, minimum, and maximum water use (ac-ft) values, calculated using 20 years of data where annual use exceeded 7,000 ac-ft. Totals of the median and maximum seasonal water use values are respectively lower and higher than the current annual water right (14,632 ac-ft).

	Jan -Feb	Mar-Apr	May-Jun	Jul-Sep	Oct-Nov	Dec	Total
Median	986	1,115	1,062	2,117	1,781	684	7,746
Minimum	0	89	126	463	151	101	
Maximum	3,557	3,111	2,601	4,374	6,205	2,003	21,851

This Scenario 1 estimate is biased due to the following:

- Historic *use* does not accurately reflect water *needs* during any given year or season.
- Historic water use in a given season may not accurately reflect the volume of water that would have been used if water had been available during that season or, perhaps, previous to that season.
- The use of records that exceeded 7,000 ac-ft was arbitrary and only represents nearly half of the Refuge water right. As such, these estimates likely are biased low.

***Scenario 2* –**

Scenario 2 is based on achieving minimum requirements of CCP objectives following a drought year and water use was not constrained by the current water right (Table 3, Scenario 2). Unlike Scenario 1, seasons in Scenario 2 were defined by CCP habitat-based objectives, as approved in 2013. Data used to develop this scenario included area estimates and area-capacity curves developed by the Service for individual wetlands, published long-term precipitation and pan evaporation data (including the use of a coefficient to account for shallow wetlands), soil infiltration rates calculated based on information in NRCS soil survey data (SSURGO), LiDAR data to estimate volume of ditches, and aerial imagery to estimate surface area of water in the Big and Little Salt Marshes at the beginning of the scenario.

Table 3. Comparison of Rattlesnake Creek surface water use Scenarios 1 and 2 for Quivira NWR.

	Seasonal Water Use Estimates (Acre-Feet)												
Scenario	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	986		1,115		1,062		2,117			1,781		684	7,746
2	3,144	7,427			2,895		4,053				5,881		23,400

This Scenario 2 estimate is biased due to the following:

- Water loss due to plant transpiration was not included in water use estimates (which would increase water needs to meet objectives).
- Water loss due to soil infiltration in some wetlands was underestimated because values for the available water capacity of 2,300 acres of wetland soils were not available (which would increase water needs to meet objectives).

- Water loss due to horizontal seepage in ditches during initial flooding was not estimated (which would increase water needs to meet objectives).
- Estimate based on a "normal precipitation" year following a drought year (all units dry); thus, a large volume of water (3,144 acre-feet) is needed to initially flood the Little Salt Marsh before water can be diverted elsewhere on the Refuge. This volume would be lower in years not preceded by drought.
- Estimate based on initially flooding only units and infrastructure on the south end of the Refuge. If north portion of Refuge were flooded early in the year, water use estimates would increase.
- Seasons are based on habitat objectives and do not always reflect the water management activities/schedules (e.g., time required for water to travel from diversion to wetland of interest).

Results

The seasonal estimates in Table 4 were developed after considering Scenarios 1 and 2 described in the approach above.

Table 4. Seasonal Rattlesnake Creek surface water need estimates for Quivira NWR, given the current water right.

Seasonal Water Use (Acre-Feet)						
Jan-Feb	Mar-Apr	May-Jun	Jul-Sep	Oct-Nov	Dec	Total
1,500	3,500	2,000	3,500	3,632	500	14,632

Although Scenarios 1 and 2 were developed based on quantitative information; these estimates were constrained by limitations that precluded either scenario from being used to directly estimate seasonal water needs. In general, the estimate based on past water use is known to be flawed because the Refuge either did not receive its full annual right of 14,632 ac-ft and/or the seasonal availability of water was not available or lacking, which resulted in the use of water during suboptimal times that often limited or impeded the accomplishment of management objectives. In contrast, the Scenario 2 estimate, based on water needs following drought, exceeded the Refuge water right even though important factors (e.g., water infiltration in ditches, plant transpiration) that would have increased water needs were not included in the estimate. Therefore, the Service used information from both Scenario 1 and Scenario 2 to adjust water use so total annual use matches the current water right of 14,632 ac-ft (Table 4).

Attachment 6: GMD5 Model; KDA-DWR Scenario 1 analysis results table

USFW Management Period	Year	Zenith Gaged Flow	Modeled Impacts to RSC	Refuge Reported Diversions	Refuge Needs	Amount short of needs
Jan/Feb	1974	19590	960	0	1500	0
Mar/Apr	1974	20230	860	0	3500	0
May/Jun	1974	11220	820	0	2000	0
Jul/Aug/Sep	1974	8260	1620	1320	3500	0
Oct/Nov	1974	7240	1390	2430	3600	0
Dec	1974	5070	600	600	500	0
Jan/Feb	1975	9750	1130	0	1500	0
Mar/Apr	1975	9990	1040	630	3500	0
May/Jun	1975	14550	1310	1020	2000	0
Jul/Aug/Sep	1975	16600	3000	3840	3500	0
Oct/Nov	1975	5230	2270	1040	3600	0
Dec	1975	3540	1240	920	500	0
Jan/Feb	1976	6850	2060	340	1500	0
Mar/Apr	1976	19610	2410	180	3500	0
May/Jun	1976	15800	2390	190	2000	0
Jul/Aug/Sep	1976	8240	4680	1270	3500	0
Oct/Nov	1976	4650	4010	2060	3600	0
Dec	1976	3810	1740	70	500	0
Jan/Feb	1977	4990	3080	400	1500	0
Mar/Apr	1977	6780	2920	1140	3500	0
May/Jun	1977	18550	3030	1670	2000	0
Jul/Aug/Sep	1977	7450	5280	1980	3500	0
Oct/Nov	1977	5060	3440	2780	3600	0
Dec	1977	3010	1600	490	500	0
Jan/Feb	1978	6340	3110	50	1500	0
Mar/Apr	1978	8770	2750	360	3500	0
May/Jun	1978	20670	3410	260	2000	0
Jul/Aug/Sep	1978	3100	5240	910	3500	400
Oct/Nov	1978	2410	4540	1870	3600	1190
Dec	1978	2040	2380	1610	500	0
Jan/Feb	1979	4270	4660	2270	1500	0
Mar/Apr	1979	8050	4370	0	3500	0
May/Jun	1979	4960	3610	790	2000	0
Jul/Aug/Sep	1979	3920	5660	3150	3500	0
Oct/Nov	1979	3040	6370	470	3600	560
Dec	1979	2210	2670	180	500	0
Jan/Feb	1980	5780	5170	270	1500	0
Mar/Apr	1980	11630	4860	150	3500	0
May/Jun	1980	6620	3530	1160	2000	0
Jul/Aug/Sep	1980	1590	3020	1480	3500	1910
Oct/Nov	1980	690	2150	20	3600	2150
Dec	1980	1440	3150	300	500	0

Attachment 6: GMD5 Model; KDA-DWR Scenario 1 analysis results table

USFW Management Period	Year	Zenith Gaged Flow	Modeled Impacts to RSC	Refuge Reported Diversions	Refuge Needs	Amount short of needs
Jan/Feb	1981	2540	4450	1480	1500	0
Mar/Apr	1981	2900	4330	2330	3500	600
May/Jun	1981	5630	7240	1940	2000	0
Jul/Aug/Sep	1981	2100	9350	1780	3500	1400
Oct/Nov	1981	2520	5820	1370	3600	1080
Dec	1981	1550	2730	470	500	0
Jan/Feb	1982	4190	5060	140	1500	0
Mar/Apr	1982	3890	4280	900	3500	0
May/Jun	1982	4360	4880	980	2000	0
Jul/Aug/Sep	1982	2000	6090	1620	3500	1500
Oct/Nov	1982	850	5050	240	3600	2750
Dec	1982	690	2640	80	500	0
Jan/Feb	1983	2520	5020	870	1500	0
Mar/Apr	1983	6270	4940	70	3500	0
May/Jun	1983	9490	5200	150	2000	0
Jul/Aug/Sep	1983	1350	2490	1080	3500	2150
Oct/Nov	1983	730	6410	180	3600	2870
Dec	1983	520	4070	180	500	0
Jan/Feb	1984	2230	6090	610	1500	0
Mar/Apr	1984	8080	6990	940	3500	0
May/Jun	1984	4140	4370	430	2000	0
Jul/Aug/Sep	1984	520	830	150	3500	830
Oct/Nov	1984	400	4590	30	3600	3200
Dec	1984	970	4140	460	500	0
Jan/Feb	1985	1840	7560	1840	1500	0
Mar/Apr	1985	3450	6650	2830	3500	50
May/Jun	1985	4250	5130	790	2000	0
Jul/Aug/Sep	1985	1490	6060	1040	3500	2010
Oct/Nov	1985	4980	8190	1630	3600	0
Dec	1985	1590	3280	510	500	0
Jan/Feb	1986	3280	4900	990	1500	0
Mar/Apr	1986	2900	4870	600	3500	600
May/Jun	1986	1990	4970	670	2000	10
Jul/Aug/Sep	1986	4740	11700	2260	3500	0
Oct/Nov	1986	2530	7370	2760	3600	1070
Dec	1986	1440	3480	1120	500	0
Jan/Feb	1987	3050	6700	1990	1500	0
Mar/Apr	1987	20610	7090	300	3500	0
May/Jun	1987	6180	6680	550	2000	0
Jul/Aug/Sep	1987	11640	9380	2120	3500	0
Oct/Nov	1987	3380	5450	3210	3600	220
Dec	1987	2500	2960	2000	500	0

Attachment 6: GMD5 Model; KDA-DWR Scenario 1 analysis results table

USFW Management Period	Year	Zenith Gaged Flow	Modeled Impacts to RSC	Refuge Reported Diversions	Refuge Needs	Amount short of needs
Jan/Feb	1988	5170	6060	3560	1500	0
Mar/Apr	1988	6310	5400	3110	3500	0
May/Jun	1988	3420	2840	490	2000	0
Jul/Aug/Sep	1988	830	1960	460	3500	1960
Oct/Nov	1988	550	1560	150	3600	1560
Dec	1988	480	1440	260	500	20
Jan/Feb	1989	1220	4040	550	1500	280
Mar/Apr	1989	1620	2720	1000	3500	1880
May/Jun	1989	4850	10680	2240	2000	0
Jul/Aug/Sep	1989	4030	12360	310	3500	0
Oct/Nov	1989	1050	5410	1060	3600	2550
Dec	1989	540	3040	440	500	0
Jan/Feb	1990	2110	7040	1750	1500	0
Mar/Apr	1990	3810	6240	2160	3500	0
May/Jun	1990	6070	5790	2110	2000	0
Jul/Aug/Sep	1990	750	4800	280	3500	2750
Oct/Nov	1990	700	4200	460	3600	2900
Dec	1990	420	2540	0	500	80
Jan/Feb	1991	1040	4720	510	1500	460
Mar/Apr	1991	1360	5710	1040	3500	2140
May/Jun	1991	1110	3430	1040	2000	890
Jul/Aug/Sep	1991	150	2470	0	3500	2470
Oct/Nov	1991	220	2460	0	3600	2460
Dec	1991	340	2940	0	500	160
Jan/Feb	1992	770	4340	0	1500	730
Mar/Apr	1992	860	2690	450	3500	2640
May/Jun	1992	2540	11120	830	2000	0
Jul/Aug/Sep	1992	2750	15610	2930	3500	750
Oct/Nov	1992	940	8690	360	3600	2660
Dec	1992	1320	4280	850	500	0
Jan/Feb	1993	5150	8180	990	1500	0
Mar/Apr	1993	8180	7500	640	3500	0
May/Jun	1993	46390	7930	2600	2000	0
Jul/Aug/Sep	1993	72440	13840	2590	3500	0
Oct/Nov	1993	4200	7900	2970	3600	0
Dec	1993	2640	3800	1420	500	0
Jan/Feb	1994	4870	7560	2000	1500	0
Mar/Apr	1994	4740	6740	160	3500	0
May/Jun	1994	2870	3950	370	2000	0
Jul/Aug/Sep	1994	750	6370	690	3500	2750
Oct/Nov	1994	790	7020	80	3600	2810
Dec	1994	740	3780	0	500	0

Attachment 6: GMD5 Model; KDA-DWR Scenario 1 analysis results table

USFW Management Period	Year	Zenith Gaged Flow	Modeled Impacts to RSC	Refuge Reported Diversions	Refuge Needs	Amount short of needs
Jan/Feb	1995	1720	7310	900	1500	0
Mar/Apr	1995	2390	7820	1100	3500	1110
May/Jun	1995	28770	10780	1510	2000	0
Jul/Aug/Sep	1995	6800	11990	1140	3500	0
Oct/Nov	1995	1260	6180	830	3600	2340
Dec	1995	1140	3940	520	500	0
Jan/Feb	1996	2630	7150	1020	1500	0
Mar/Apr	1996	3490	6450	1200	3500	10
May/Jun	1996	6820	8070	1180	2000	0
Jul/Aug/Sep	1996	8010	13710	2670	3500	0
Oct/Nov	1996	7920	8670	2790	3600	0
Dec	1996	3090	3940	1160	500	0
Jan/Feb	1997	6070	7530	2090	1500	0
Mar/Apr	1997	6920	6880	620	3500	0
May/Jun	1997	5540	7200	730	2000	0
Jul/Aug/Sep	1997	8490	12640	3480	3500	0
Oct/Nov	1997	5540	8100	1580	3600	0
Dec	1997	3890	3890	140	500	0
Jan/Feb	1998	8900	7290	0	1500	0
Mar/Apr	1998	16130	7050	90	3500	0
May/Jun	1998	6250	5630	1110	2000	0
Jul/Aug/Sep	1998	3130	9100	3200	3500	370
Oct/Nov	1998	5140	9310	1920	3600	0
Dec	1998	2320	4100	790	500	0
Jan/Feb	1999	6740	7950	850	1500	0
Mar/Apr	1999	9900	7850	30	3500	0
May/Jun	1999	6950	7620	300	2000	0
Jul/Aug/Sep	1999	8680	11410	1120	3500	0
Oct/Nov	1999	2450	5290	1190	3600	1150
Dec	1999	1880	3620	1170	500	0
Jan/Feb	2000	4840	8230	1970	1500	0
Mar/Apr	2000	14590	8590	310	3500	0
May/Jun	2000	5940	7840	450	2000	0
Jul/Aug/Sep	2000	5020	8690	1570	3500	0
Oct/Nov	2000	3090	10340	820	3600	510
Dec	2000	1550	4580	1530	500	0
Jan/Feb	2001	5900	9070	2470	1500	0
Mar/Apr	2001	6740	7470	100	3500	0
May/Jun	2001	12000	9270	1070	2000	0
Jul/Aug/Sep	2001	1740	9930	330	3500	1760
Oct/Nov	2001	1140	6170	420	3600	2460
Dec	2001	900	3880	0	500	0

Attachment 6: GMD5 Model; KDA-DWR Scenario 1 analysis results table

USFW Management Period	Year	Zenith Gaged Flow	Modeled Impacts to RSC	Refuge Reported Diversions	Refuge Needs	Amount short of needs
Jan/Feb	2002	2410	8890	1990	1500	0
Mar/Apr	2002	2740	6530	2890	3500	760
May/Jun	2002	2390	5730	2280	2000	0
Jul/Aug/Sep	2002	980	5340	1050	3500	2520
Oct/Nov	2002	1610	9170	970	3600	1990
Dec	2002	810	3560	1150	500	0
Jan/Feb	2003	1860	7340	1180	1500	0
Mar/Apr	2003	4720	9640	320	3500	0
May/Jun	2003	2770	5690	0	2000	0
Jul/Aug/Sep	2003	650	4040	120	3500	2850
Oct/Nov	2003	840	4290	40	3600	2760
Dec	2003	540	2800	80	500	0
Jan/Feb	2004	1050	5140	970	1500	450
Mar/Apr	2004	2300	6270	2840	3500	1200
May/Jun	2004	1500	5430	370	2000	500
Jul/Aug/Sep	2004	2960	13070	4370	3500	540
Oct/Nov	2004	1690	7640	550	3600	1910
Dec	2004	1080	3220	580	500	0
Jan/Feb	2005	2490	7820	2130	1500	0
Mar/Apr	2005	2390	5630	130	3500	1110
May/Jun	2005	3000	7280	0	2000	0
Jul/Aug/Sep	2005	3620	8230	1660	3500	0
Oct/Nov	2005	900	5510	0	3600	2700
Dec	2005	740	2540	640	500	0
Jan/Feb	2006	1760	3710	1870	1500	0
Mar/Apr	2006	1940	4020	1240	3500	1560
May/Jun	2006	1060	4910	790	2000	940
Jul/Aug/Sep	2006	940	7970	750	3500	2560
Oct/Nov	2006	730	5150	220	3600	2870
Dec	2006	640	3650	0	500	0
Jan/Feb	2007	1670	7400	1690	1500	0
Mar/Apr	2007	10540	9530	1420	3500	0
May/Jun	2007	32510	14730	130	2000	0
Jul/Aug/Sep	2007	16420	14710	1720	3500	0
Oct/Nov	2007	2510	7580	1670	3600	1090
Dec	2007	3280	5240	830	500	0