Barfield, David [KDA]

From:	Barfield, David [KDA]
Sent:	Monday, January 7, 2019 4:19 PM
To:	Orrin Feril; Preheim, Lynn (lynn.preheim@stinsonleonard.com); Darrell Wood (dnwfarm@gmail.com)
Cc:	Titus, Kenneth (Kenneth.Titus@ks.gov); Letourneau, Lane [KDA]; Beightel, Chris [KDA]; Lanterman, Jeff [KDA]; Tom Stiles [KDHE]; mike_oldham@fws.gov
Subject:	KDHE Initial analysis of water quality aspect of an augmentation project to supply Quivira
Attachments:	KDHE_2018_Initial_Water_Quality_Analysis_of_Augmentation_at_Quivira_National_Wildlife_Refuge.pdf

Orrin and GMD Board,

As part of our on-going evaluation and support for GMD 5's proposed augmentation project, we requested KDHE to review the area, available pertinent data, and your draft concepts for the augmentation project to provide its assessment and recommendations for requirements to insure any augmentation project developed will not create water quality problems.

KDHE has conducted this review and provided its initial assessment and recommendations in the attached document. Please be aware this is KDHE's initial assessment based on available data and is subject to change with additional information.

I intend to rely on KDHE's recommendations in permitting any augmentation project. Subject to additional data and analysis, necessary permitting requirements including real-time monitoring, it would appear that an augmentation project of the scale proposed can be developed in the area while preventing the upwelling of deep aquifer water laden with high concentrations of chloride.

If you have questions or comments related to the initial assessment, please let us know.

Thanks.

David

David W. Barfield, P.E.
Chief Engineer
Kansas Department of Agriculture, Division of Water Resources
1320 Research Park Drive, Manhattan, KS 66502
David.Barfield@ks.gov
785-564-6670
http://agriculture.ks.gov/dwr
http://agriculture.ks.gov/dwr-updates
https://twitter.com/KSChiefEngineer

Initial Water Quality Analysis of Augmentation at Quivira National Wildlife Refuge

December 21, 2018

Introduction

To partly offset losses of historic water supply provided by Rattlesnake Creek to the Quivira NWR, GMD #5 has proposed a series of use reductions in the ground water basin along with an augmentation plan to provide water to the refuge from ground water supplies outside the refuge and basin. The current proposal is to use a series of 45 shallow wells in the Peace Creek headwaters to supply a pipeline to the Little Salt Marsh, which acts as a staging reservoir to supply the other wetland complexes in the refuge, including Big Salt Marsh. The question has arisen over whether such augmentation is permissible from a water quality standpoint and under what conditions may augmentation be used to supplement supplies from Rattlesnake Creek.

Refuge Seasonal Water Needs for Beneficial Use

According to the Impairment Investigation carried out by the Division of Water Resources in 2016, the Refuge's authorized quantity of 14,632 acre-feet per year is distributed seasonally to accommodate annual life cycle requirements of wildlife. A reasonable scenario for periods within the normal range of precipitation would be: the winter months of December thru February have the lowest need of 2000 acre-feet (500 af – Dec; 1500 af – Jan & Feb); the springtime migration, breeding and nesting months of March thru June need 5500 acre-feet (3500 af – Mar 7 Apr; 2000 af – May & Jun) and the fall migration of shorebirds, cranes and waterfowl over July thru November comprises the greatest need for water at 7132 acre-feet (3500 af – Jul-Sept; 3632 af – Oct & Nov).

Analysis by DWR matching seasonal period inflows measured at the USGS gaging station on Rattlesnake Creek near Zenith over 1974 – 2007 indicated the greatest deficits to overcome came during the Fall migration for waterfowl and cranes in October and November (61.8% of the 34 years). The Fall migration for shorebirds over July thru September had similar shortfalls (47.1% of the years). Taken together, over half (54.4%) of the Fall season periods were short on water, indicative of the highest demand for relief in the future. Overall, across the 204 seasonal periods analyzed over 1974 – 2007, 58 or 28.4% were short on water.

Shortages for the other four seasonal periods ranged from 8.8% (Dec) to 29.4% (Mar & Apr). The Spring migration period (March thru June) was short on water for 20.6% of the periods over the 34 years. Winter shortages only occurred in 10.3% of the Dec and Jan – Feb periods and will not be a point of emphasis in this analysis.

To determine a threshold flow that might trigger augmentation to Little Salt Marsh, the stated demand for the Spring and Fall migration periods were divided by the number of days comprising the months within each period. For the Spring months of March thru June, the demand of 5500 af averages to a daily flow at Zenith of 22.8 cfs. For the Summer-Fall months of July thru November, the demand of 7132 af averages to 23.5 cfs. Therefore, for this analysis and possible consideration in future management of augmentation operations, a flow threshold of 23 cfs at the Zenith gage will be used. That flow occurred 45% of the time between 1975 – 2018, so the occurrence of shortages is to be expected. However, that flow percentile has declined over time, flows were over 23 cfs 57% of the time before 2001 and only

28% of the time the past 18 years. Similarly, median flows at Zenith have gone from 27 cfs (1975- 2000) to 12 cfs (2001 – 2018) (see supplemental information).

Expected Water Quality

Two chloride Total Maximum Daily Loads (TMDLs) are in place for Quivira (2013) and Rattlesnake Creek (2001). Those TMDLs recognized there was elevated ambient chloride in the surface water in the creek below St. John and within the marshes of the Quivira refuge. Those levels would routinely exceed the acute aquatic life criterion of 860 mg/l chloride. Kansas Water Quality Standards, at K.A.R. 28-16-28e(b)(9), allow for background concentrations to exceed the criterion:

In stream segments where background concentrations of naturally occurring substances, including chlorides and sulfates, exceed the water quality criteria, …, at ambient flow, the existing water quality shall be maintained, and the newly established numeric criteria shall be the background concentration …

Background concentrations were calculated as 1400 mg/l on Rattlesnake Creek at the KDHE site near Hudson, upstream of Zenith, and 1675 mg/l within Little Salt Marsh in the Quivira Refuge. The 20% increase in chloride between Zenith and the Little Salt Marsh likely results from a combination of upwelling ground water with high chloride content entering the creek and evapotranspiration (ET) by the open surface water and wetland vegetation at the marsh. The loss of fresh water through ET as the creek traverses the wetland complexes and marshes of the refuge is reflected in greater elevations in chloride. Background concentrations in the Big Salt Marsh farther downstream within the refuge reach 3033 mg/l and the Rattlesnake Creek outlet from the refuge near Raymond typically saw chlorides average 3660 mg/l before entering the Arkansas River.

Two additional samplings in 2014 and 2017 have updated data from the two main marshes in Quivira since the refuge's TMDL was completed in 2013. Average chloride in Little Salt Marsh increased to 1750 mg/l while chlorides in Big Salt Marsh decreased in average to 2970 mg/l. Additionally, chloride data on Rattlesnake Creek have been regularly collected in the 17 years since the 2001 TMDL was done. There is likely an increase in chlorides moving downstream from Hudson to Zenith because of diminished inflow of fresh water from the High Plains aquifer along with increased mineral intrusion into the creek from the underlying saline ground water downstream of Hudson.

Data are now being gathered by the Groundwater Management District #5 (GMD#5) from locations along Rattlesnake Creek as well as the headwaters of Peace Creek where the proposed augmentation wells may be sited. All these data were analyzed to update the evaluation of chloride in Rattlesnake Creek by flow condition and season. Furthermore, projections were made of representative chloride at the Zenith gage since it represents the primary water supply and chloride load entering prior to diversion at Little Salt Marsh.

Analysis of Rattlesnake Creek Chlorides

Three data sets were used to analyze chloride conditions along Rattlesnake Creek and form the basis of regression estimates of chloride at the Zenith gage. The first data set is KDHE's data from its Hudson site (SC660). Sampling and analysis of chloride has occurred on a typical 4-year rotational basis starting in 1992. Subsequent samplings occurred in 1996, 2000, 2004, 2008 and 2016. Thirty-one samples and corresponding data values made up this data set.

The second data set is chloride, flow and specific conductivity collected by the U.S. Geological Survey (USGS) at their gaging station on the creek near Zenith. These data spanned a relatively short time period (1998 – 2000) with some miscellaneous samplings in 1973, 1977 – 1979 and 2003. Sample size for these data numbered 24 samples.

The final data set is currently being collected by GMD#5 at various locations along Rattlesnake Creek. The District has been collecting chloride and specific conductivity data since April 2015. Sampling locations on Rattlesnake Creek included just upstream of the saline ground water upwelling zone near Highway 281, KDHE's Hudson site, the Zenith gage and the Raymond gage at the outlet from the Quivira refuge. Fourteen samplings in duplicate have been collected. In 2018, the District began sampling for chloride and conductivity at six locations in the Peace Creek headwaters. As of July, nine samplings had taken place. This data set is critical because it is the only one that has concurrent values at Hudson and Zenith.

The following table displays the measures of central tendency for the various locations. The USGS data at Zenith are adjusted to discount values taken at higher (Q>200 cfs) flows. The GMD#5 data align with the KDHE data for Hudson quite well. Earlier USGS data at Zenith tend to be lower than the recent values seen by the GMD#5 sampling. Only seven of the 24 samples taken by USGS were at flows below the designated threshold flow of 23 cfs, so the resulting chlorides tended to be more dilute. Conversely, all the GMD#5 data were taken at flows below 23 cfs, so chlorides tended to be more elevated.

Measure/Site	KDHE Hudson	USGS Zenith (all flows)	USGS Zenith (flows<200)	GMD#5 HI way 281	GMD#5 Hudson	GMD#5 Zenith
Average [Cl]	1280 mg/l	1030 mg/l	1169 mg/l	62 mg/l	1377 mg/l	1722 mg/l
Median [Cl]	1420 mg/l	792 mg/l	823 mg/l	60 mg/l	1415 mg/l	1775 mg/l

Regression Estimates of Chloride

To build a large data set of estimated chloride, a suite of regression equations was developed to estimate chloride concentration at the gage near Zenith, which is viewed as the gateway of water and chloride transfer into Quivira. Given the three data sets, the following regressions were derived:

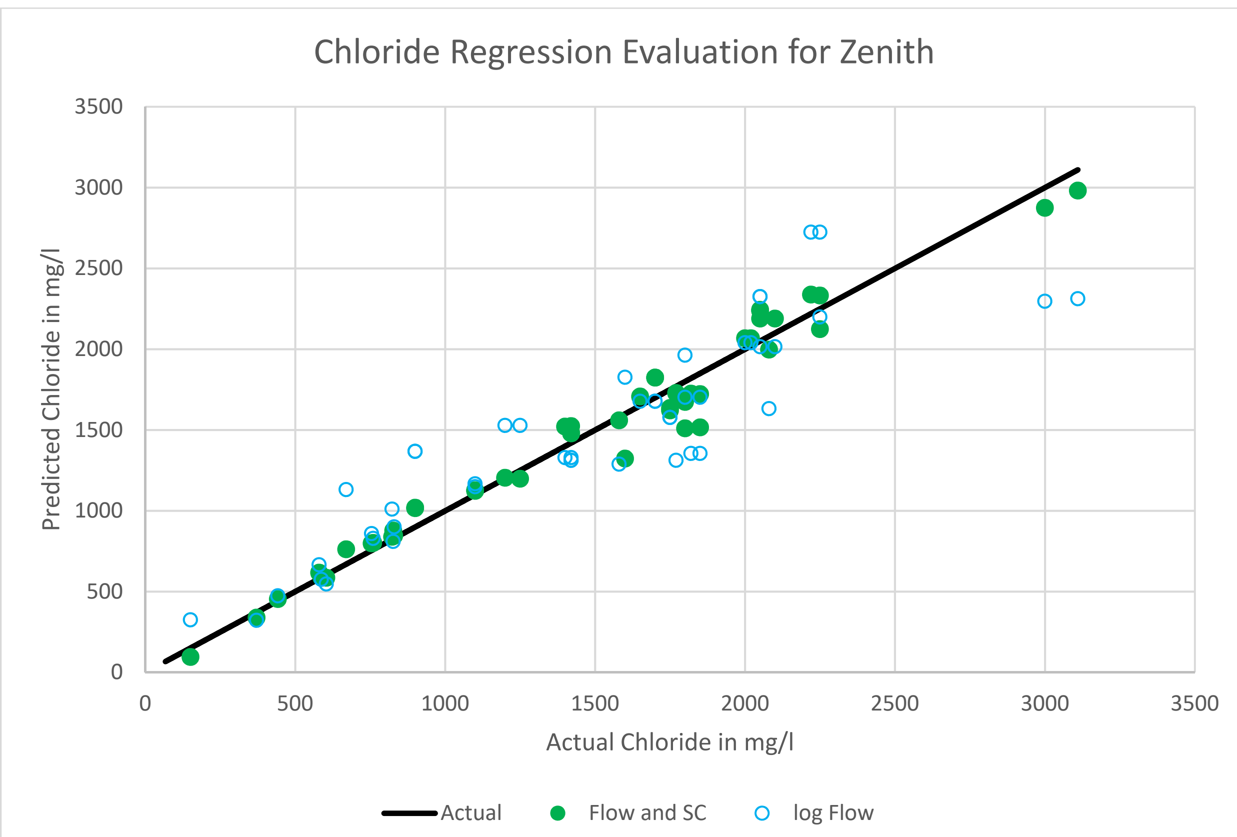
1. With USGS and GMD#5 data, regress Zenith Chloride concentrations on Zenith Conductivity and Flow
2. With USGS and GMD#5 data, regress Zenith Chloride concentrations on Zenith Flow when no conductivity data are available
3. With GMD#5 data, regress Zenith chloride concentrations on concurrent Hudson Chloride and Zenith Flow data

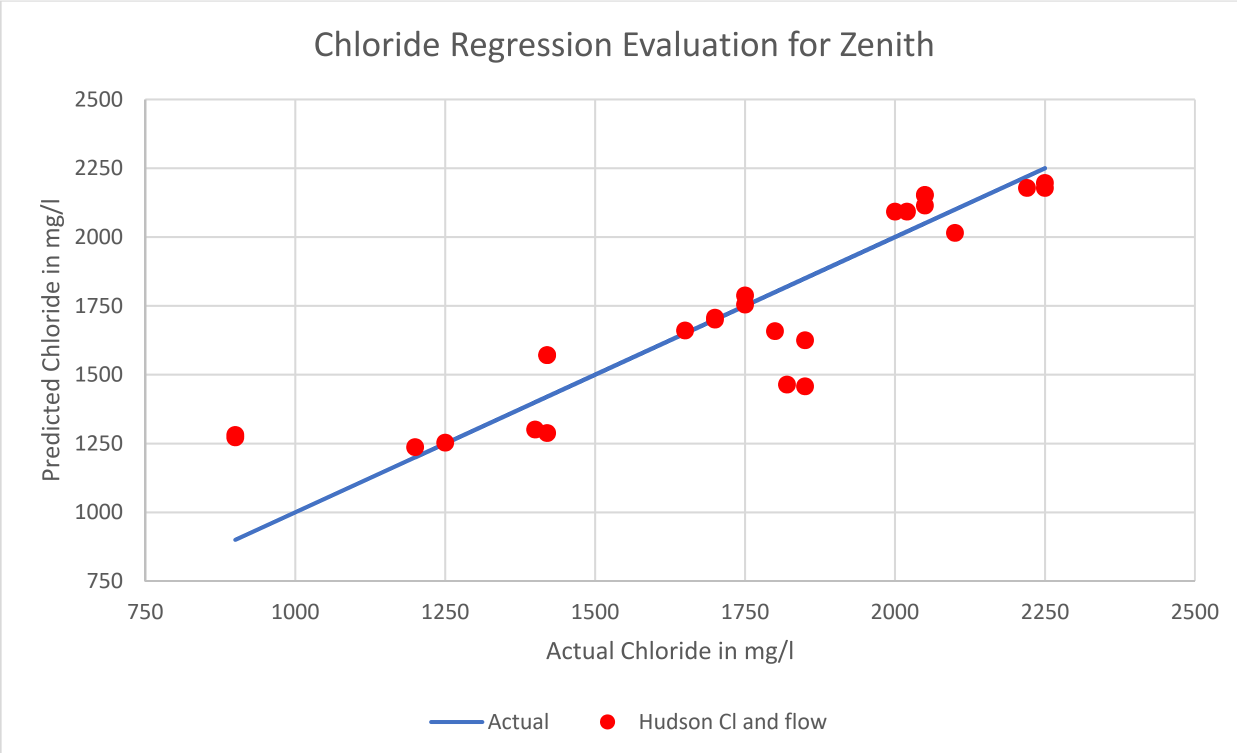
Data associated with flows over 200 cfs at Zenith were discounted because they extended regressions out to an extent where the data collected in the flow regime of interest (0.1 – 40 cfs) were viewed as a single point and were not well represented by the regression line. The following regressions were then developed from the remaining data. Since conductivity and Hudson chloride data are sporadic, a regression of Zenith chloride on Zenith flow is necessary to expand the sample size of estimated chloride entering Quivira. The best relationship comes from conductivity and flow measurements at Zenith.

Chloride and conductivity are strongly related to one another, whereas chloride concentrations tend to decrease with increasing flow. Chloride at Zenith is also strongly correlated with chloride at Hudson.

Regression	R-squared	Mean Square Error	Degrees of Freedom
$Chloride_{Zenith} = 0.2906*Cond - 0.915*Q - 8.6$	96.84%	14695	46
$Chloride_{Zenith} = 2944 - 1213.5*\log Q$	81.06%	86274	46
$Chloride_{Zenith} = 0.661*Chloride_{Hudson} - 539*\log Q + 1336$	79.36%	33354	25

Displaying the predicted chloride at Zenith with actual measurements provides a good measure of the reliability of each of the regressions. As seen in the figure below, using flow and conductivity at Zenith produces very accurate estimates of chloride. The estimates from flow alone are reasonable but do have some scatter that lends uncertainty in those estimates. The regression using Hudson chloride data and Zenith flow also plots adequately but does have scatter among its estimated values.





Estimating Chloride at Zenith Over 1975 – 2018

Flow measurements at the Zenith gage, conductivity measurements at Zenith and chloride data at Hudson were collated over the 44 years between January 1975 and August 2018, comprising almost 15,950 days. Within that period of record, 108 days had zero flow at Zenith, 39 days had insignificant flow of less than 0.1 cfs and 715 days had high flow over 100 cfs. The regressions were applied to the balance of days to estimate chloride concentrations at Zenith.

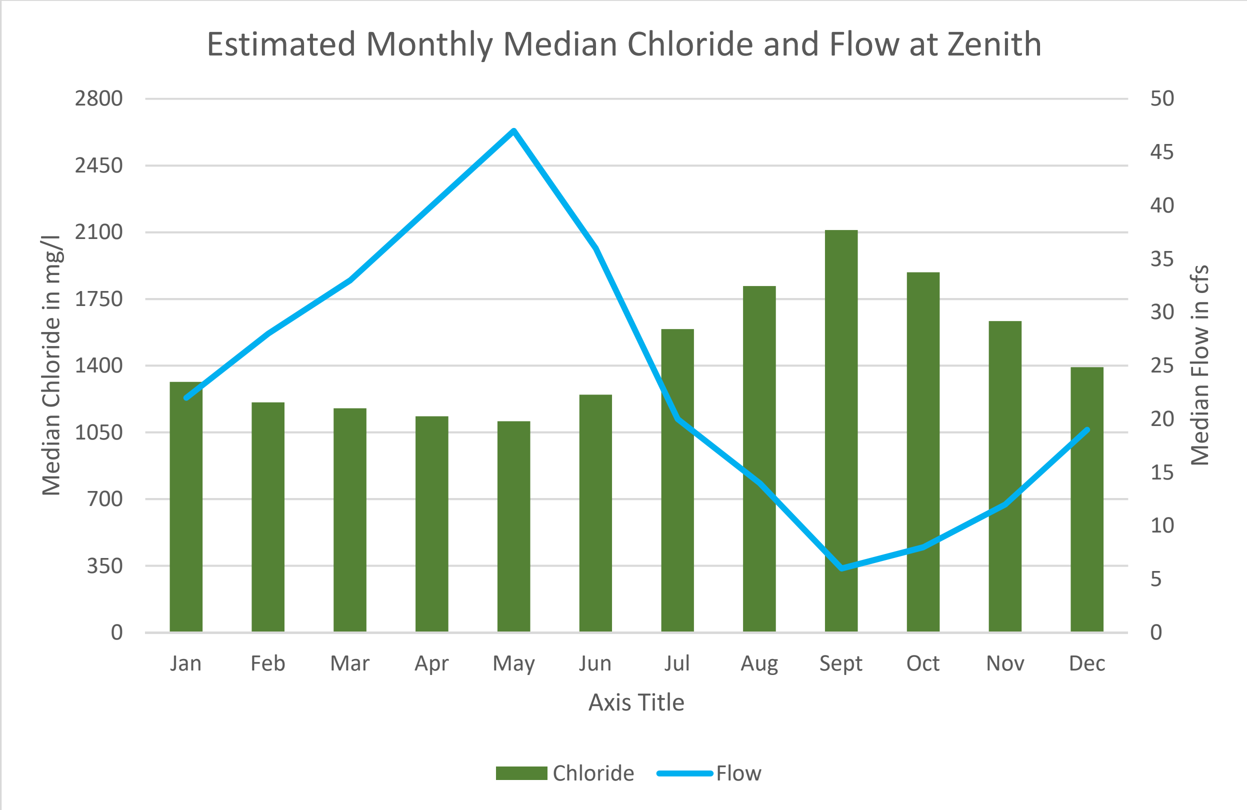
The estimated values were then tabulated by season and flow condition. Seasons were delineated by the management seasons at the refuge: Winter habitat maintenance, Spring migration and Summer – Fall breeding and migration. Flow conditions were segregated by the upper and lower quartile flows seen in the record at Zenith over the 44 years. Low flow conditions were designated at daily flows below the lower quartile flow of 8 cfs. High flow conditions were designated for daily flows above the upper quartile flow of 40 cfs. Typical flows were those daily flows in the 8 – 40 cfs range.

Median chloride concentrations were computed for the nine season and flow combinations as well as overall season and flow conditions.

Median Chlorides at Flow Conditions	Flow Condition	Seasons		
		Dec – Feb	Mar – June	July – Nov
2151 mg/l	Low < 8 cfs	1954 mg/l	1974 mg/l	2255 mg/l
1365 mg/l	Typical 8 – 40 cfs	1376 mg/l	1315 mg/l	1392 mg/l
842 mg/l	High > 40 cfs	852 mg/l	822 mg/l	870 mg/l
Overall Median Chloride = 1398 mg/l	Seasonal Median Chloride Concentrations	1310 mg/l	1169 mg/l	1797 mg/l

General observations from these results confirm that the highest chloride concentrations occur at low flows and during the Summer – Fall period. The flow demand threshold of 23 cfs lies within the typical flow conditions which have a consistent tendency to see chlorides in the 1300 – 1400 mg/l range across all seasons. This corroborates the desired background condition that was to be maintained in the creek per the 2001 Rattlesnake Creek Chloride TMDL. That range should be the limiting factor on chlorides coming into the refuge via Rattlesnake Creek as well as a limit on the amount of chloride that could be transferred from an augmentation supply to Little Salt Marsh.

The monthly distribution of median chloride concentrations at Zenith is inverse to distribution of monthly median streamflows. Median chlorides stay below the desired upper bound over December through June but rise above that level in the critical breeding-migration period of July through November. From the perspective of refuge demands, the timing of highest chlorides coincides with the period that needs the most water and sees the most shortages. The balance between flow and chloride needs for the refuge focuses on water being present for the marshes to function ecologically, with chlorides not to be so high as to cause toxic impacts to the macroinvertebrate community and other lower trophic level fauna residing in the marshes, yet not so low that the diluted condition in the marshes invites encroachment of undesirable stands of cattails and phragmites.



Water Quality Authorities

Kansas Surface Water Quality Standards contain provisions for Antidegradation of the water quality of the Waters of the State. Those waters are categorized in one of four tiers depending upon their heritage, ecological value, unique attributes, and ambient concentrations of a given pollutant. Tier 3 is the most protective and stringent of the categories and prohibits the introduction of pollutants by new and expanding sources of those pollutants.

Kansas Administrative Regulation 28-16-28b(aaa) refers to these Tier 3 waters as Outstanding National Resource Waters defined as *"any of the surface waters or surface water segments of extraordinary recreation or ecological significance identified in the surface water register, as defined in this regulation, and afforded the highest level of water quality protection under the antidegradation provisions and mixing zone provisions of K.A.R. 28-16-28c."*

K.A.R. 28-16-28c(a)(3) states *"Whenever surface waters of the state constitute an outstanding national resource water, existing uses and existing water quality shall be maintained and protected. New or expanded discharges shall not be allowed into outstanding national resource waters."*

K.A.R. 28-16-28c(b)(6) states, *"Mixing zones may be allowed by the secretary for existing permitted discharges in surface waters re-designated as outstanding national resource waters in the "Kansas surface water register" pursuant to K.A.R. 28-16-28g but shall be evaluated on an individual permit basis to prevent the degradation of the outstanding national resource waters."*

The Little Salt Marsh and the Big Salt Marsh in the Quivira National Wildlife Refuge are both classified as Outstanding National Resource Waters, because of the critical habitat they provide to migratory shorebirds, Whooping Cranes and waterfall along the Central Flyway traversing the High Plains north to south. This designation reflects their importance in ecological support more so than their ambient water quality which is poor relative to the expectations expressed in the numeric water quality criteria in Kansas for its waters of the state. While the regulations will accommodate existing dischargers such as the City of St. John since its wastewater discharged to Rattlesnake Creek provides marginal contributions of flow and pollutants to the Quivira marshes, no new discharger would be allowed near Quivira. However, if a discharger did not degrade the existing water quality of the marshes of Quivira, i.e., did not cause chloride levels to increase, that discharger may be accommodated.

Discharges of pollutants are regulated in Kansas through National Pollutant Discharge Elimination System permits (NPDES). These permits must conform to Federal and Kansas regulations. One of the Federal regulations pertains to the permitting of water transfers. 40 C.F.R. § 122.3(i) excludes water transfers from requiring a NPDES permit. Water transfers are defined as *"activities that convey or connect waters of the United States without subjecting the transferred water to intervening industrial, municipal, or commercial use. This exclusion does not apply to pollutant introduced by the water transfer activity itself to the water being transferred."* This regulation, the Water Transfers Rule, has been recently addressed, clarified and supported by the Second Circuit Court of Appeals (Catskills III; Docket No. 14-1823) with the Supreme Court subsequently refusing to take certiorari over the case on appeal.

Additionally, KDHE is prohibited from exerting authority in matters under the jurisdiction of the Chief Engineer of the Division of Water Resources. K.S.A. 65-171d states: *"In no event shall the secretary's [of*

KDHE] authority be interpreted to include authority over the beneficial use of water, water quantity allocations, protection against water use impairment of a beneficial use, or any other function or authority under the jurisdiction of the Kansas water appropriation act, K.S.A. 82a-701, and amendments thereto."

Finally, the opening goals of the Clean Water Act includes a policy within Section 101 that states:

b. It is the policy of the Congress to recognize, preserve, and protect the primary responsibilities and rights of States to prevent, reduce, and eliminate pollution, to plan the development and use (including restoration, preservation and enhancement) of land and water resources, and to consult with the Administrator in the exercise of his authority under this Act., and,

g. It is the policy of Congress that the authority of each State to allocate quantities of water within its jurisdiction shall not be superseded, abrogated or otherwise impaired by this Act. It is the further policy of Congress that nothing in this Act shall be construed to supersede or abrogate rights to quantities of water which have been established by any State. Federal agencies shall co-operate with State and local agencies to develop comprehensive solutions to prevent, reduce and eliminate pollutions in concert with programs for managing water resources.

The Quivira augmentation proposal examines several aspects that touch on these laws:

1. The proposal emanates from a request by the U.S. Fish and Wildlife Service to the Chief Engineer to administer their water right to appropriate water for recreational use in the Quivira National Wildlife Refuge, under the Kansas Water Appropriation Act.
2. The augmentation water will be obtained from shallow ground water likely located in the headwaters of Peace Creek near the Stafford-Reno County Line.
3. Peace Creek is known to have ambient levels of chloride far above the acute aquatic life criterion in the Kansas Surface Water Quality Standards.
4. Ground water is not a Water of the United States; therefore, EPA's Water Transfer Rule may not directly apply.
5. The U.S. Fish and Wildlife Service has indicated that any increased water supply to the refuge needs to maintain the historic balance of water quality characteristic of Rattlesnake Creek entering the refuge, which are a naturally dynamic range of conditions that sustain the health and productivity of the associated wetland systems.

   Given these aspects, KDHE will evaluate any proposal to augment water supply to the Quivira National Wildlife Refuge as follows:

1. If the augmentation water supply taken from the Peace Creek headwaters (or any other location), in combination with the ambient chloride loads delivered by Rattlesnake Creek, monitored at Zenith, results in inflows to Little Salt Marsh having chlorides exceeding 1400 mg/l, that discharge is contrary to the Kansas Antidegradation Policy of the Kansas Surface Water Quality Standards and cannot be allowed.

2. If the augmentation water supply, in concert with Rattlesnake Creek, produces inflows to the Quivira refuge with chlorides below the threshold of 1400 mg/l chloride, that operation abides by the Kansas Antidegradation Policy, and is conducted under the guise and jurisdiction of the

Kansas Water Appropriation Act administered by the Chief Engineer of the Division of Water Resources.

3. As such, KDHE will not need to issue a permit, NPDES or otherwise, for the delivery and discharge of the augmentation water, but instead will advise the Chief Engineer to place conditions in any administrative order issued under his authority permitting the augmentation supply to the Quivira National Wildlife Refuge, such that the Little Salt Marsh, and subsequently, the Big Salt Marsh, within the refuge are sufficiently safeguarded from detrimental impacts caused by excessive chlorides.

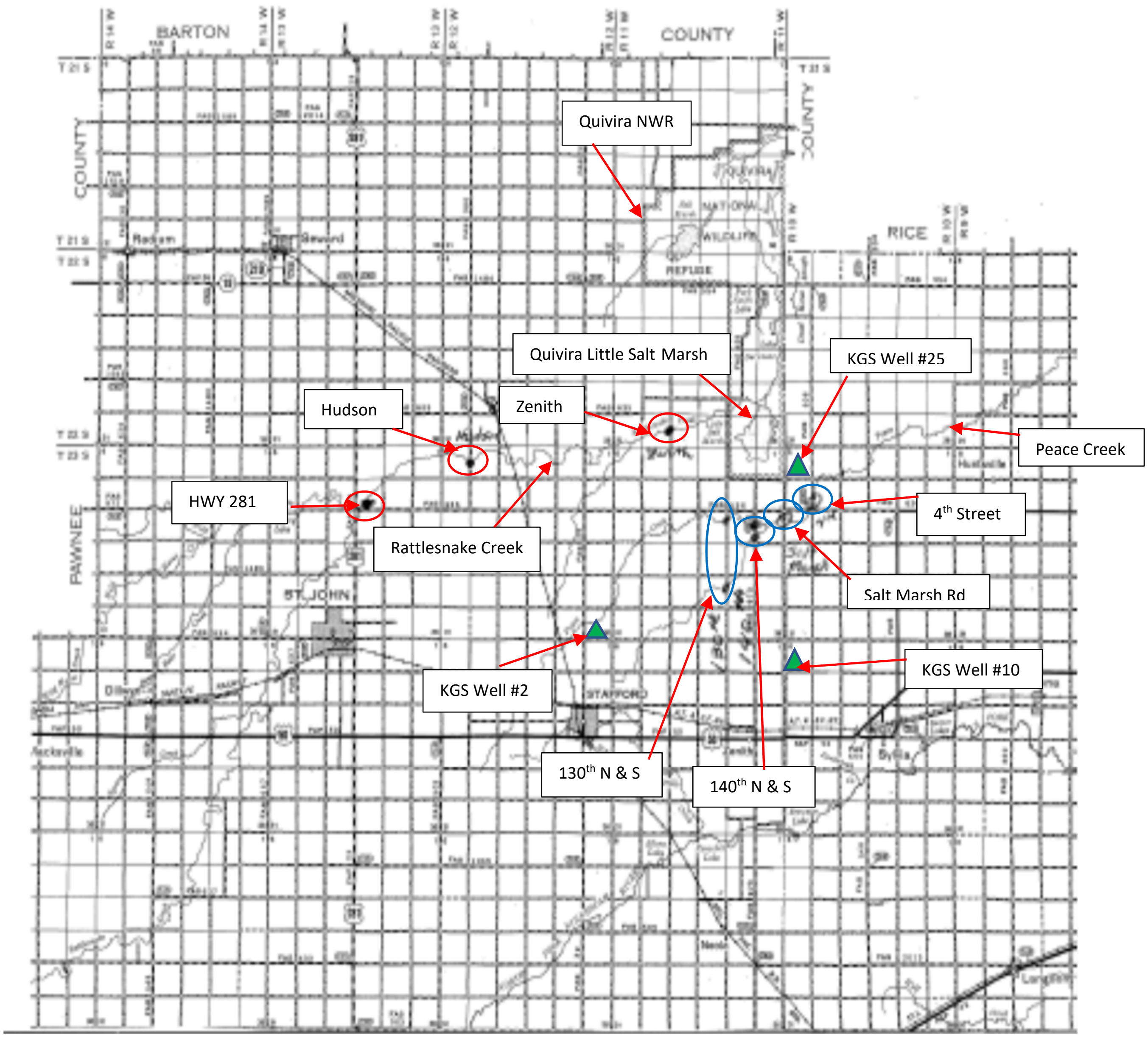
4. Such a condition might read as: "Augmentation water supply must not exceed 1400 mg/l of chloride and any combination of augmentation water supply with ambient streamflow measured on Rattlesnake Creek at the Zenith gaging station must similarly have a chloride content below 1400 mg/l prior to being diverted into Little Salt Marsh while augmentation is occurring."

Preliminary Assessment of Water Quality from the Peace Creek Headwaters

Peace Creek originates in eastern Stafford County from the discharge of ground water from the High Plains aquifer within its watershed headwaters. The salinity of the creek derives from upward intrusion of saltwater from the Permian bedrock underlying much of the High Plains aquifer in the watersheds of Peace Creek, Rattlesnake Creek and the Quivira refuge. KDHE has sampled Peace Creek on a 4-year rotational basis since 1992, near its confluence with the Arkansas River near Sterling. Those samples reveal extensive mineral intrusion surfacing as baseflow into the creek with median chloride concentrations of 2000 mg/l over seven separate years between 1992 and 2016. If these concentrations represented the chloride content of potential augmentation water in the headwater area, discharge of flow from this area into Quivira would not be allowed. However, measurements by the Kansas Geological Survey and GMD#5 in the early 1980's, early 1990's and early 2000's hinted that shallow depths of ground water in this area may be more moderate (< 800 mg/l) in chloride content than either deeper depths of the High Plains aquifer in proximity to the Permian bedrock or ground water to the north and east.

The Division of Water Resources, at the behest of KDHE, requested GMD#5 begin sampling the surface waters in the Peace Creek headwater area under baseflow conditions. The premise is that baseflow emanates from the shallow ground waters underlying the stream channels and reconnaissance samples of that flow will be a good representation of the quality of the shallow ground water. Samples were not to be taken during or in the aftermath of a runoff event to sample baseflow discharging to the streams from the surrounding ground water. These baseflow samples do not forego the need to sample ground water at depth to ascertain the chloride content of those waters since those supplies will be delivered directly via pipeline to the refuge. This sampling routine provides a reconnaissance on the possibility that relatively fresh water might be obtained in the targeted area of augmentation supply.

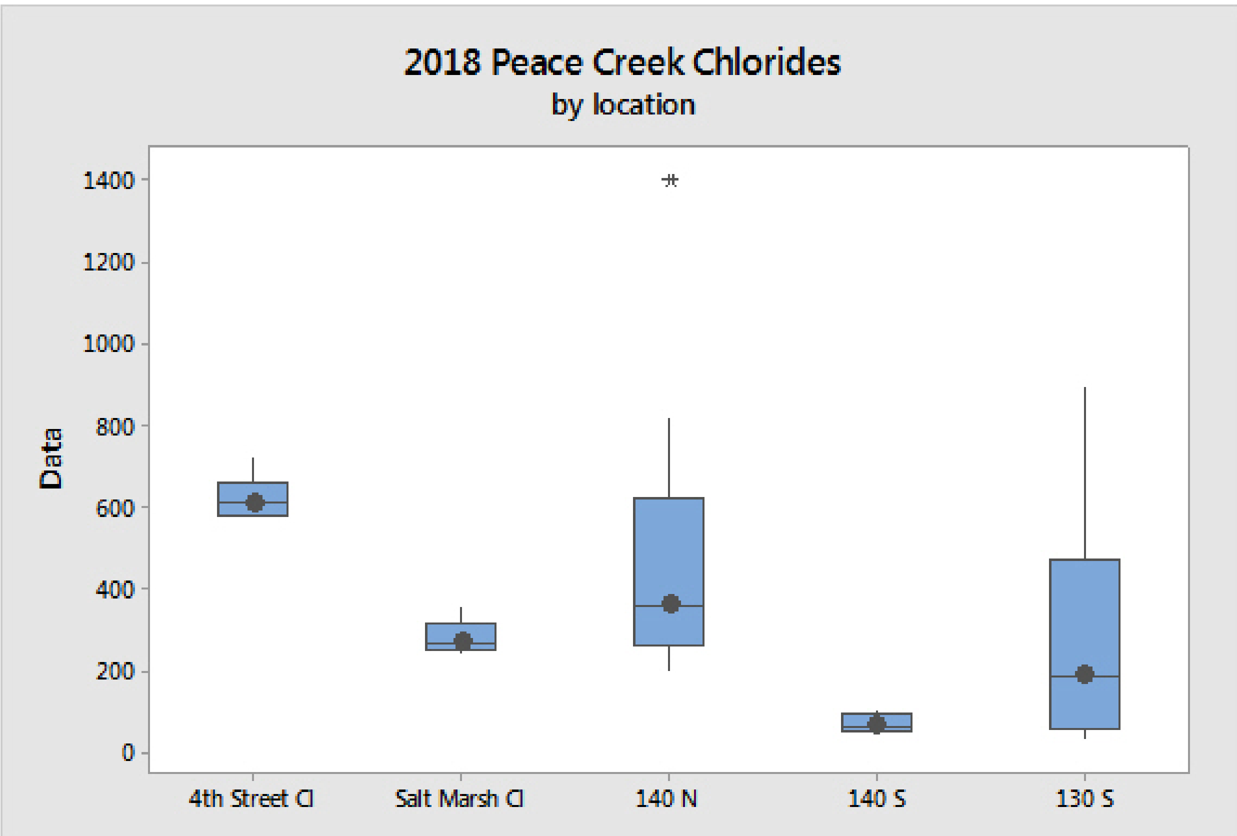
Starting in February 2018, GMD#5 began sampling the upper reaches of Peace Creek in six locations. The following map shows sampling locations on Rattlesnake and Peace Creeks where chloride samples are being collected by GMD#5. Also shown are three Kansas Geological Survey/GMD#5 observation wells sampled in the early 1980's and 1990's near the proposed area for augmentation supply.



Nine samplings have been made of the Peace Creek stations between February and July of 2018. The following table summarizes the chloride concentrations seen at five of the stations. No samples have yet been collected from the north station on 130th Road because of lack of flow. Overall, the average chloride from all samples was 343 mg/l with a median of 278 mg/l. The largest concentration occurred at the North station on 140th Road in July. While more sampling is needed to confirm these initial results, the preliminary results indicate the shallow ground water underlying the Peace Creek headwaters which supply the baseflow to Peace Creek is sufficiently low in chloride to provide suitable augmentation supply to water to Quivira, either as a mix from multiple wells or dependent on select

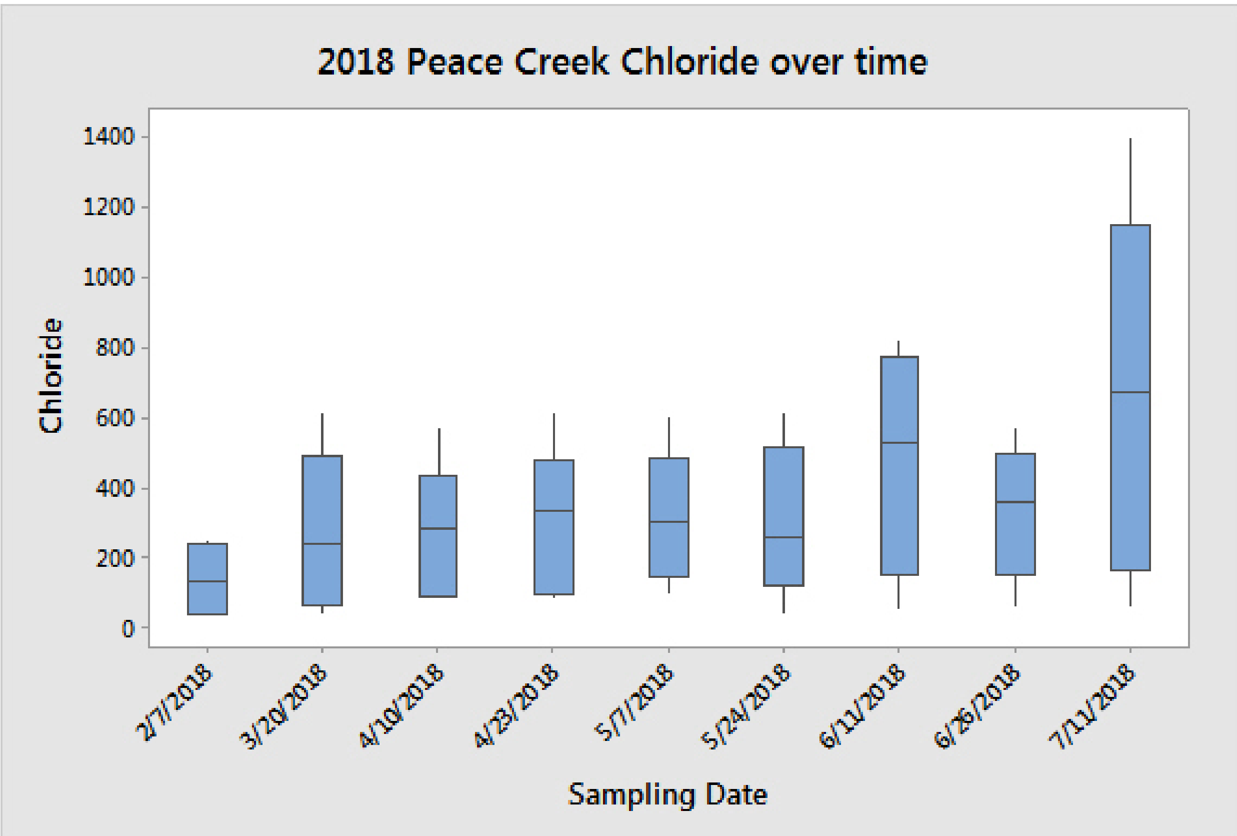
Station	Number of Samples	Average Chloride Concentration	Median Chloride Concentration	Maximum Chloride Concentration
4th Street	8	623 mg/l	612 mg/l	724 mg/l
Salt Marsh Road	9	282 mg/l	270 mg/l	362 mg/l
140th Road North	9	493 mg/l	360 mg/l	1400 mg/l
140th Road South	9	72 mg/l	65 mg/l	105 mg/l
130th Road South	9	274 mg/l	190 mg/l	899 mg/l

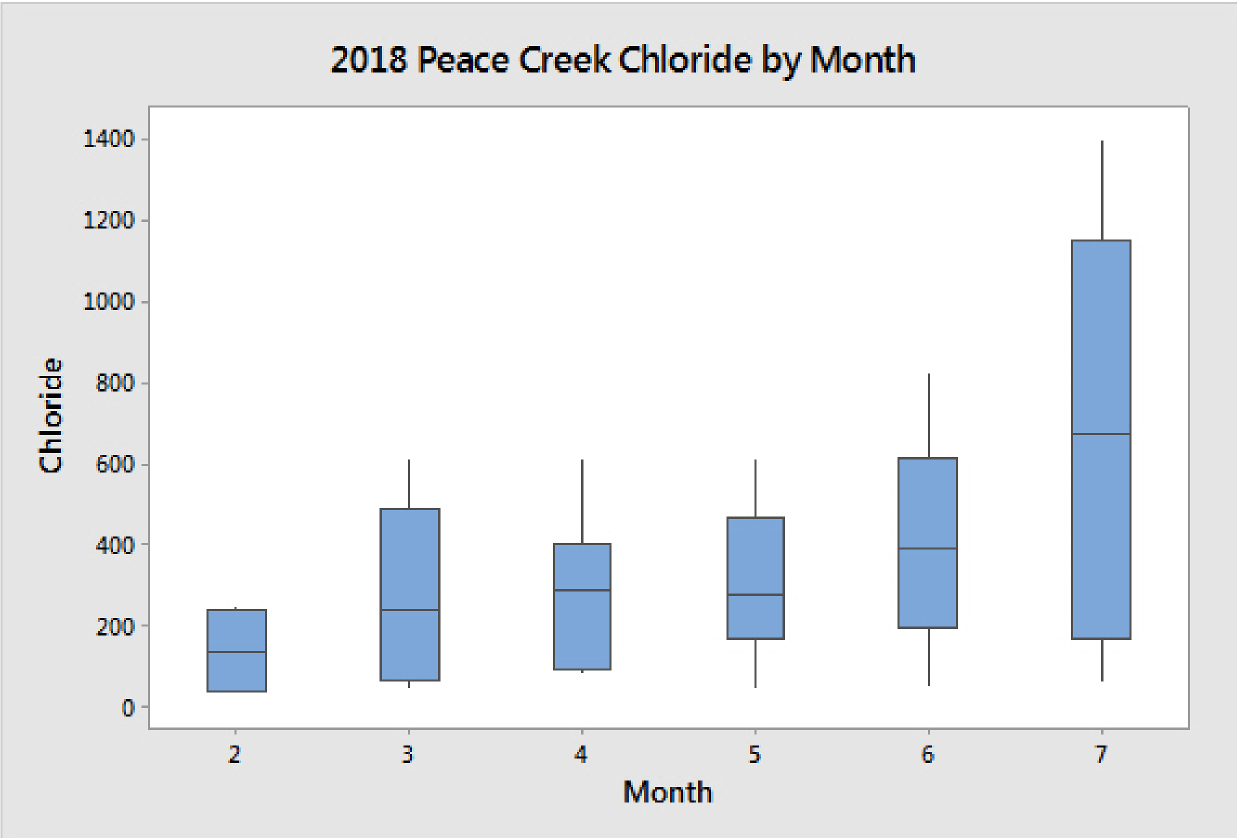
wells in low chloride ground water. The distribution of chloride among the stations is varied with higher chloride typically seen east of Salt Marsh Road or along the north reach of Peace Creek. However, results from additional sampling in late summer and fall need to be examined to see if chloride levels increase in time, either as result of natural hydrologic cycles or lagged effects from regional pumping.



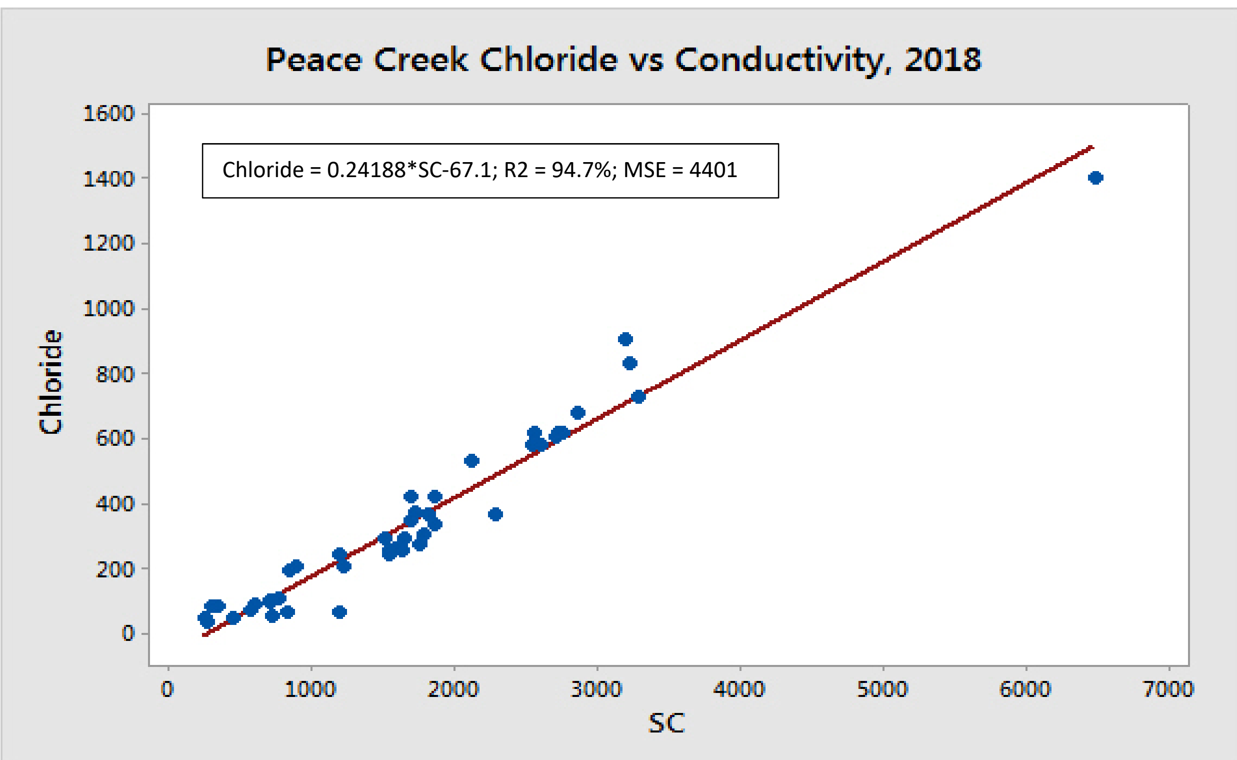
Two follow-up issues need to be evaluated: 1) just how much do the chlorides rise over time, noting that chloride concentrations were on the increase with the July samples; and 2) as pumping ensues, either regionally or because of the augmentation project, what level of chlorides will be present within the targeted depths where augmentation water will be pumped? Since the augmentation water will be needed most often during the Fall migration months, samples of ground water taken over September to November will better inform the usability of the proposed ground water supply. Some stations showed increasing chloride into the summer while others saw declining chlorides. There did not appear to be any strong relationship among the Peace Creek stations' chloride and corresponding flow in Rattlesnake Creek near Zenith.

There is a strong relationship between chloride and specific conductivity among the Peace Creek samples. This relationship provides a useful tool for monitoring any augmentation water by estimating chloride content from conductivity sensor readings. Taken in concert with similar conductivity readings from the Zenith gaging station, estimates of chloride loading to Little Salt Marsh can be made to ensure concentrations in the water supply do not exceed 1400 mg/l. There is the possibility of a supporting conductivity sensor on Rattlesnake Creek, operated by the Environmental Protection Agency, and located where Rattlesnake Creek crosses the boundary of Quivira National Wildlife Refuge, just west of Little Salt Marsh.





2018 Peace Creek Chloride by Month
Chloride
1400
1200
1000
800
600
400
200
0
2
3
4
5
6
7
Month



Peace Creek Chloride vs Conductivity, 2018
Chloride = 0.24188*SC-67.1; R2 = 94.7%; MSE = 4401
Chloride
1600
1400
1200
1000
800
600
400
200
0
0
1000
2000
3000
4000
5000
6000
7000
SC

Reconnaissance of Ground Water near Peace Creek

Currently, no observation wells have been sampled in the targeted area proposed to serve as the augmentation source of supply within the Peace Creek headwaters. However, in the mid-1980's, a network of observation wells was installed by the Kansas Geological Survey in cooperation with GMD#5 throughout the mineral intrusion area of GMD#5. Three observation well nests, each with multiple wells screened at different depths, essentially create a triangular bracket of the Peace Creek headwaters and proposed augmentation well fields. The KGS sampled those wells at each of their screened depths for chloride content. The following table displays the chloride content of each well at selected depths.

KGS/GMD#5 Observation Well	Location	Depth of Screen in Wells	Chloride in mg/l
2	SE corner of T23S, R12W, near Stafford	35 – 38'	127
		99 – 104'	725
10	NW corner of T24S, R11W, near Zenith	74 – 79'	179
		100 – 105'	598
		143 – 148'	1340
		160 – 165'	1710
25	NW corner of T23S, R10W, near the Refuge	44 – 49'	23100
		95 – 100'	24900
		120 – 124'	17400

These data corroborate the baseflow data sampled from Peace Creek through July. Ground water with high chlorides which would violate antidegradation and be prohibited are seen at the lower depths associated with the Permian bedrock (observation well site #10) as well as throughout the geologic column near the refuge (observation well site #25). Conversely, ground water located west of the proposed target area is relatively moderate in chloride content (observation well site #2) as is the shallow depths of ground water located southeast of the targeted area (observation well site #10). Follow up sampling of these and other observation wells in and around the targeted area is warranted to assure the intended supply will not invoke antidegradation prohibitions.

Evaluation of Augmentation Scenarios

A mass balance analysis was done to look at limiting levels of chloride in the augmentation water meant to supplement streamflows moving into Quivira past Zenith. Estimated chloride concentrations were made at various presumed flows at Zenith. Augmentation flow was capped at 15 cfs but otherwise made up for any deficit streamflows at Zenith below the desired average rate of 23 cfs. Based on the initial Peace Creek samples, suggested chloride concentrations for the augmentation water were assumed. The augmentation water and its chloride content were mixed with the streamflow at Zenith and its estimated chloride to determine the chloride concentration of water delivered to Little Salt Marsh (LSM). The maximum concentration of chloride in the augmentation water that would maintain the delivered water to Little Salt Marsh below 1400 mg/l was also estimated.

The following table summarizes the results of the analysis.

Zenith Q in cfs	Zenith [Cl]	Augmented Q in cfs	LSM [Cl] if Augmentation [Cl] = 400 mg/l	LSM [Cl] if Augmentation [Cl] = 700 mg/l	Max [Cl] of Augmentation water to keep LSM < 1400 mg/l	Corresponding Conductivity
1	2984 mg/l	15	562 mg/l	843 mg/l	1294 mg/l	6223
4	2272 mg/l	15	794 mg/l	1031 mg/l	1167 mg/l	5642
8	1884 mg/l	15	916 mg/l	1112 mg/l	1142 mg/l	5525
12	1704 mg/l	11	1080 mg/l	1224 mg/l	1068 mg/l	5190
16	1509 mg/l	7	1171 mg/l	1263 mg/l	1151 mg/l	5567
20	1361 mg/l	3	1236 mg/l	1275 mg/l	1660 mg/l	7894
24	1263 mg/l	0	1263 mg/l	1263 mg/l	N/A	N/A

This analysis indicates that augmentation water should always be less in chlorides than Rattlesnake Creek and when augmentation water dominates the supply to Quivira, i.e., when Zenith is flowing 0 – 8 cfs, the resulting chlorides delivered to Little Salt Marsh will be well below 1400 mg/l. However, when the augmentation water is capped at 15 cfs, as Zenith flows increase from 0 – 1 cfs to 4-8 cfs, the augmentation water must have sufficiently lower chlorides to compensate for the increased delivery of high chlorides provided by Rattlesnake Creek. When the makeup of the water supply is evenly divided between Zenith and augmentation, the augmentation water needs to have a concentration of chlorides in the 1000 – 1100 mg/l range.

After that point, as more of the supply is provided by higher flows at Zenith, e.g., in the 13 – 20 cfs range, and the corresponding need for augmentation diminishes, chlorides in the creek begin to decline on average and the need for lower chloride content in the augmentation water decreases. Once flows at Zenith exceed 20 cfs, chlorides in Rattlesnake Creek are below the acceptable concentration threshold of 1400 mg/l and there is little need for augmentation as either a makeup supply or to offset high chlorides in the creek. Generally, augmentation water needs to have chloride concentrations that are appropriately below 1100-1300 mg/l to offset excessive chlorides delivered by concurrent Rattlesnake Creek flows.

Initially, chlorides from the potential area of augmentation supply which is providing a mixture from multiple well output or relying on one or a few wells may be sufficiently low in chloride concentration to not impose a detrimental impact on the Little Salt Marsh. This initial finding needs to be confirmed and corroborated with subsequent sampling of both baseflow and ground water. If the concentration of the augmentation supply remains below the threshold of 1400 mg/l, an operation such as this does not conflict with the Kansas Antidegradation Policy and may be allowed without need for a permit from KDHE. Compatible augmentation may, thus, be allowed conditionally under the Chief Engineer's administrative orders.

These early conclusions are based on the initial baseflow samplings that have occurred in the first half of 2018. They will need to be revisited as data from the late Summer and Fall seasons are collected from the Peace Creek stations. They will also need to be supplemented with ground water sampling over time to remain assured that relatively moderate chloride is in the potential augmentation supply. These data will be critical to the review of the augmentation proposal, especially since the late summer season coincides with the time of greatest influence of regional pumping on local ground water and the probable period of greatest need for augmented water supply to the marshes of Quivira.

One other issue arises with the prospect of using shallow ground water near Peace Creek for augmenting water supply to Quivira: the impact of those withdrawals on the quality and quantify of surface flow in Peace Creek. Persistent pumping during dry weather is certain to decrease the outflow of ground water with relatively lower chloride content to Peace Creek, leaving the creek more saline and at lower streamflows. While outside the reach of KDHE, the recommendation to the Chief Engineer would be to evaluate the impact of augmentation pumping on the instream and domestic uses of surface water in Peace Creek. This evaluation could be a companion study along with assessing the impact of the proposed pumping to surrounding domestic and irrigation wells.

Recommendations

1. GMD#5 should continue routine sampling of chlorides and conductivity at Zenith and the Peace Creek stations, particularly during the July – November period.
2. Ground water sampling should commence in the targeted area of potential augmentation supply to determine the likely chloride content of those pumped ground waters intended for delivery to the Quivira marshes and change to those levels over time and season.
3. KDHE – BOW will routinely use GMD#5 data collected from baseflow and ground waters to routinely update this analysis as an addendum to this report to the Chief Engineer.
4. Subsequent baseflow data should be used to affirm the regression relationships developed to date and to aid adjusting those regressions with the corresponding larger sample sizes.
5. Ground water sampling should be done under various pumping scenarios to robustly confirm the suitability of the site to have adequate water quality for augmentation.
6. Any water supply provided to Quivira comprising some mixture of augmentation water and flows in Rattlesnake Creek near Zenith should have chloride concentrations below 1400 mg/l.
7. Establishment of conductivity measurements at the Zenith gage and routinely, e.g., weekly, of the augmentation water delivered to Little Salt Marsh should be used to estimate chloride concentrations and to manage the delivery of augmentation supply to maintain acceptable chloride loading to the marsh.
8. Occasional sampling of chlorides should be done in concert with conductivity readings to continually affirm the relationships between flows, conductivity and chlorides at Zenith and chlorides and conductivity in the augmentation water.
9. If augmentation water exceeds 1400 mg/l chloride or the chloride content is too high to sufficiently offset the chlorides in Rattlesnake Creek, augmentation should cease for at least a week.
10. The Service should seasonally monitor chloride conditions as well as biological indicators in Little Salt Marsh to confirm no deleterious impacts are occurring because of the augmentation operation.
11. Should augmentation become a reality, the conditions pertaining to chloride and water quality attached to it will be codified as provisions of the administrative order of the Chief Engineer and not via NPDES permits from KDHE.
12. Such conditions placed on the augmentation water should preclude delivery of chlorides over 1400 mg/l to the refuge and require monitoring procedures of both Rattlesnake Creek and the

augmentation supply to assure the resulting chlorides delivered to the refuge remain below that threshold.

13. In assessing possible well sites to serve as augmentation supplies, preference should be given to shallow depths of ground water and ground water located south of the main stem of Peace Creek, perhaps favoring the west side of the drainage area.
14. Evaluation of the impacts of proposed augmentation pumping on the streamflow and water quality of Peace Creek, as well as impacts to surrounding domestic and irrigation wells near the source water supply for the augmentation project.

Supplemental Information