Using groundwater models in decision making, Kansas experience

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Association of Western State Engineers
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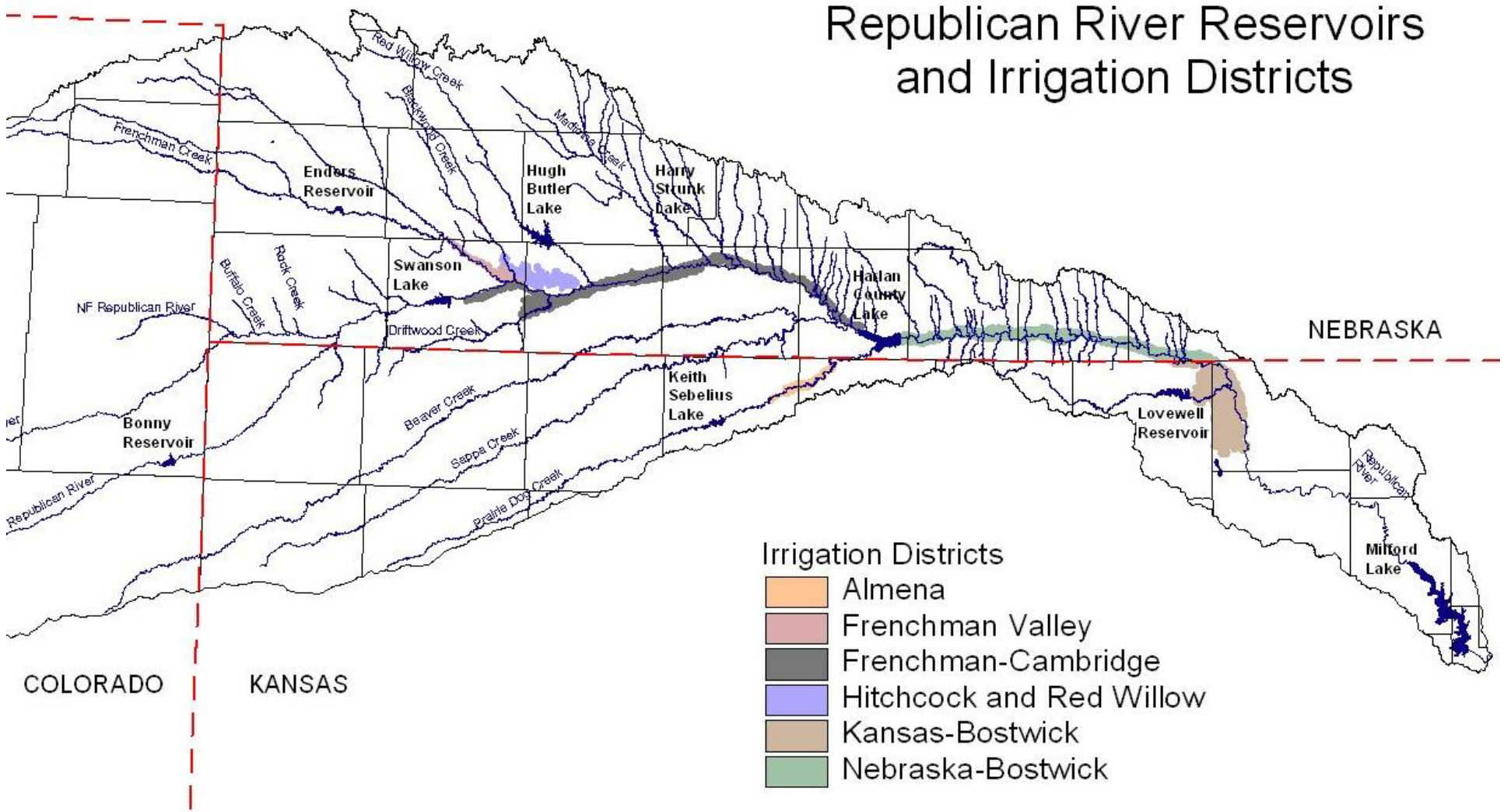
Kansas
Department of Agriculture
Division of Water Resources

Introduction

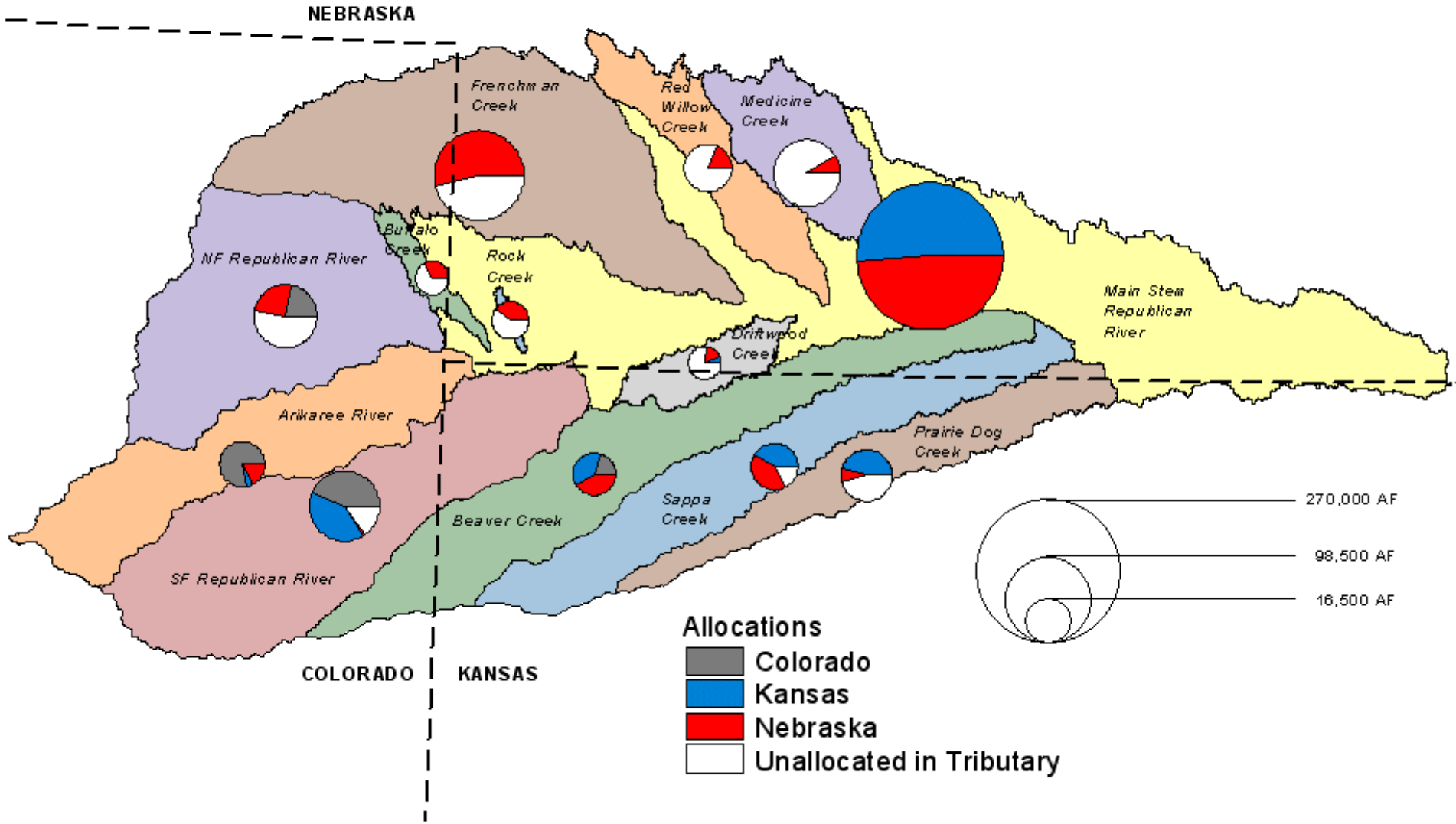
- Models have been around for a long time but, at least in Kansas, their **use in water resources decisions** were limited until last 10-15 years.
- Outline of presentation:
  - Discuss evolution in groundwater model development process enhancing **their actual use**.
  - **Example uses** of Kansas groundwater models
  - **Directions** in model development.

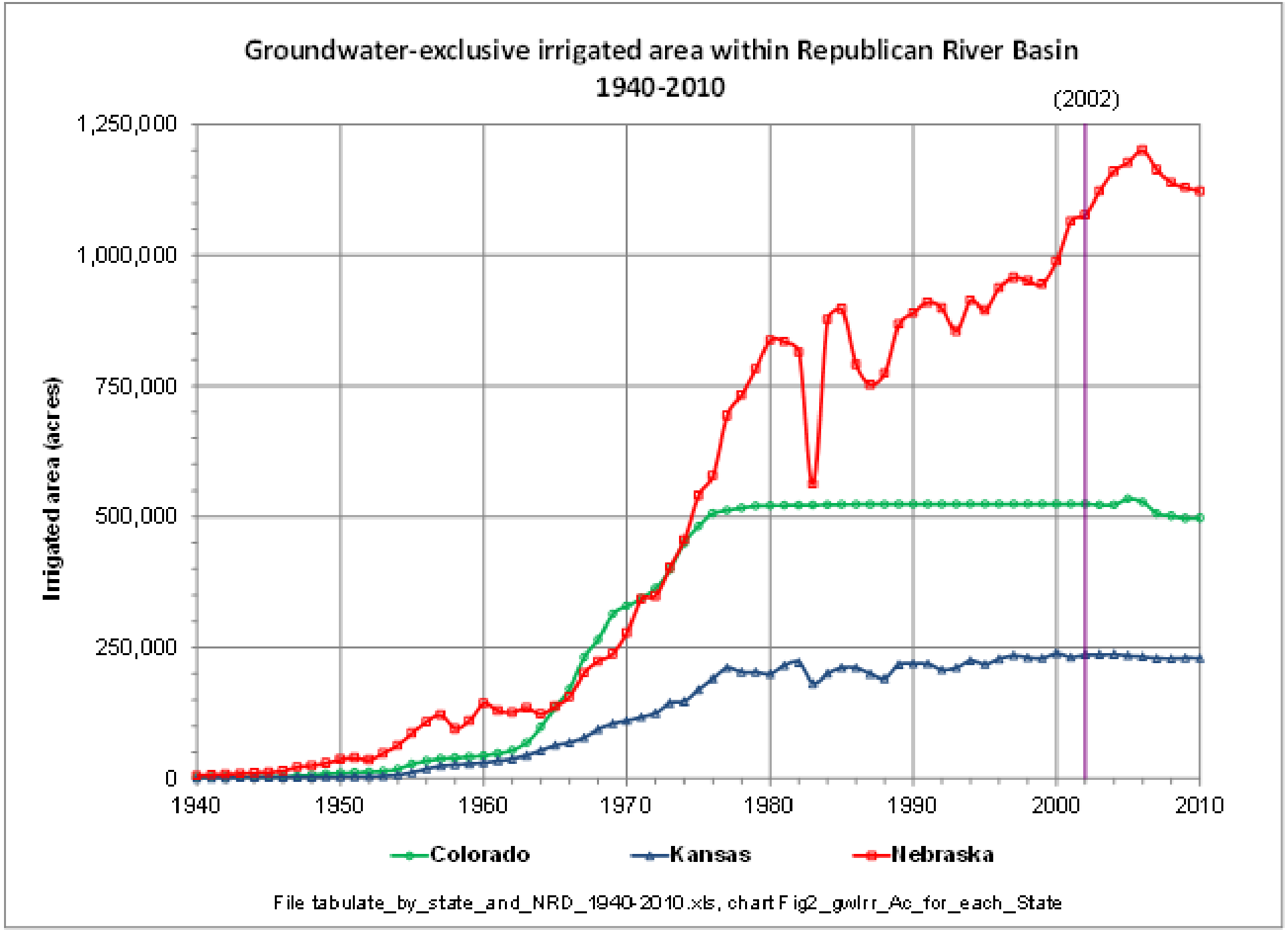
The Republican River Compact Administration (RRCA) Groundwater Model

A Model Groundwater Model Development Process


Republican River Reservoirs
and Irrigation Districts
Red Willow Creek
Blackwood Creek
Medicine Creek
Frenchman Creek
Enders Reservoir
Hugh Butler Lake
Harry Strunk Lake
Swanson Lake
Harlan County Lake
Buffalo Creek
Rock Creek
NF Republican River
Driftwood Creek
NEBRASKA
Keith Sebelius Lake
Bonny Reservoir
Beaver Creek
Seppa Creek
Prairie Dog Creek
Republican River
Lovewell Reservoir
Republican River
Milford Lake
COLORADO
KANSAS
Irrigation Districts
Almena
Frenchman Valley
Frenchman-Cambridge
Hitchcock and Red Willow
Kansas-Bostwick
Nebraska-Bostwick

Republican River Compact Allocations




Groundwater-exclusive irrigated area within Republican River Basin
1940-2010
(2002)
1,250,000
1,000,000
750,000
500,000
250,000
0
Irrigated area (acres)
1940
1950
1960
1970
1980
1990
2000
2010
Colorado
Kansas
Nebraska
File tabulate_by_state_and_NRD_1940-2010.xls, chart Fig2_gwIrr_Ac_for_each_State

RRCA methods of determining groundwater impacts, prior to model

- The RRCA methods initially estimated groundwater impacts to streamflows as 75% of **alluvial** streamflow pumping.
- With the massive development of the Ogallala, Kansas objected to the failure to account for Ogallala depletions.

RRCA groundwater model development context

Year	Issue
1980s - 1990s	Nebraska begins to overuse its share. Kansas seeks to address concerns via RRCA
1998	Kansas files suit in U.S. Supreme Court. Nebraska asserts that the Compact does not include groundwater.
2000-2002	Court rules that groundwater pumping must be accounted for; States negotiate comprehensive settlement
As groundwater use is up to 65-75% of basin's total use, a key component of the settlement was the **jointly developed groundwater model.**	

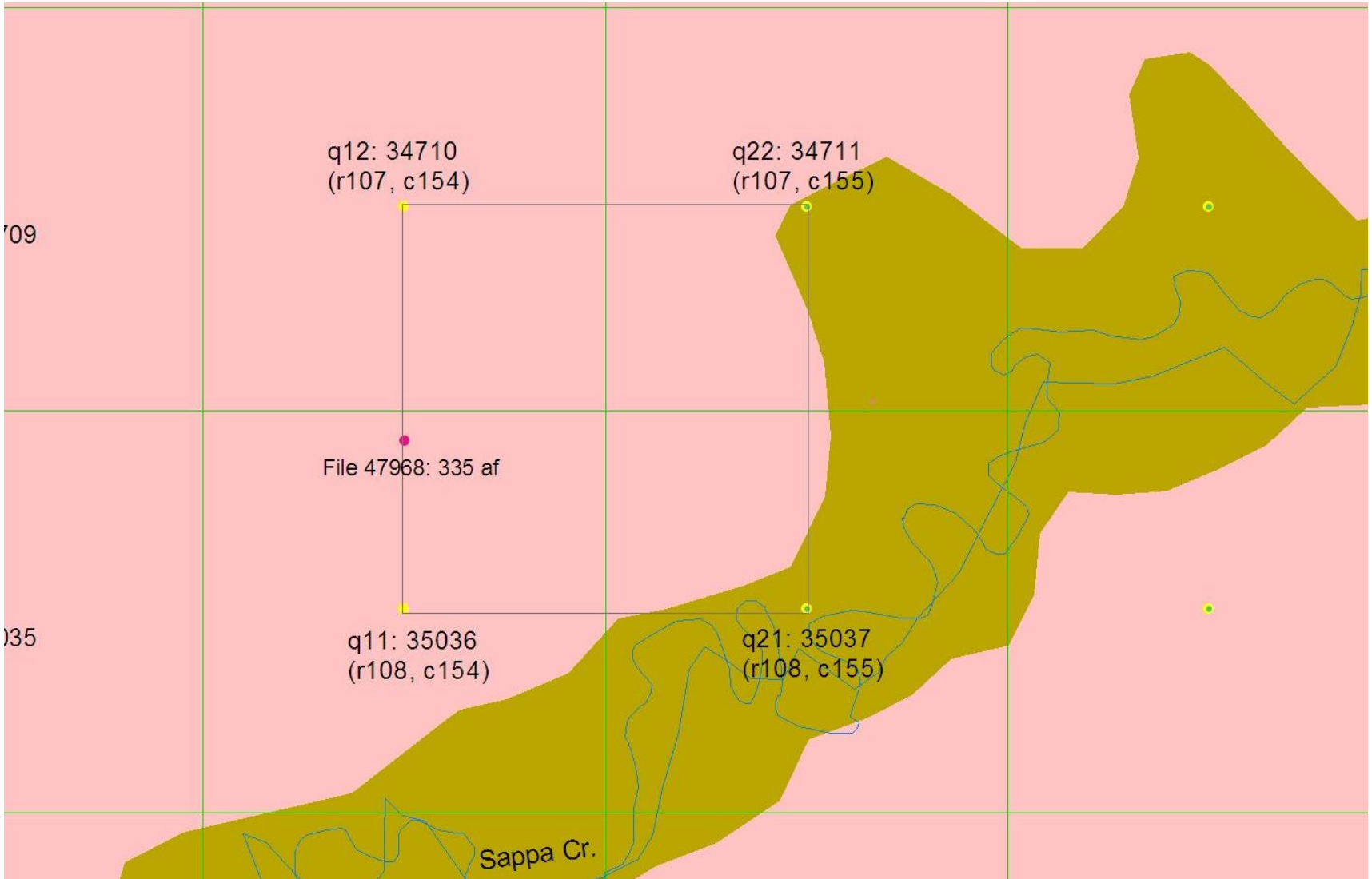
The RRCA groundwater model development process

- Model development team: states' experts hired for litigation.
- Early agreements are model purposes and calibration targets (baseflows, groundwater levels)
- Lead modeler implementing agreed model changes
- Robust and continuous review involving state's expert modeler
- Rigorous joint data development and review
- Process allowed for testing of alternate model processes to determine the most appropriate

RRCA model development result

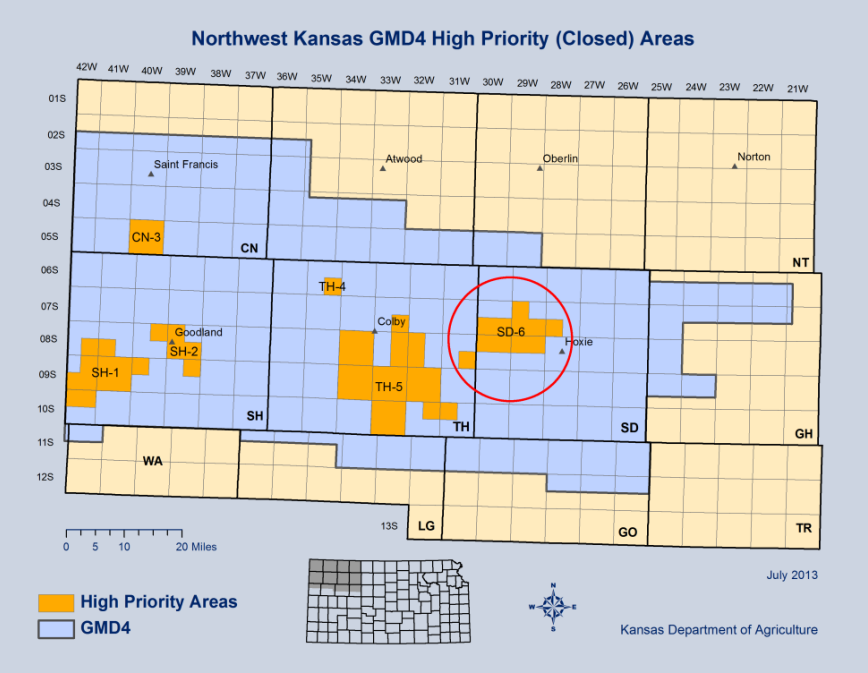
- Model adopted by the states as part of its settlement
- Model now used annually in compact accounting to determine use of basin's water supply by groundwater use
- States also use Model to assess future compliance requirements
- The Model has been an essential part of recent agreements on Colorado and Nebraska compliance plans

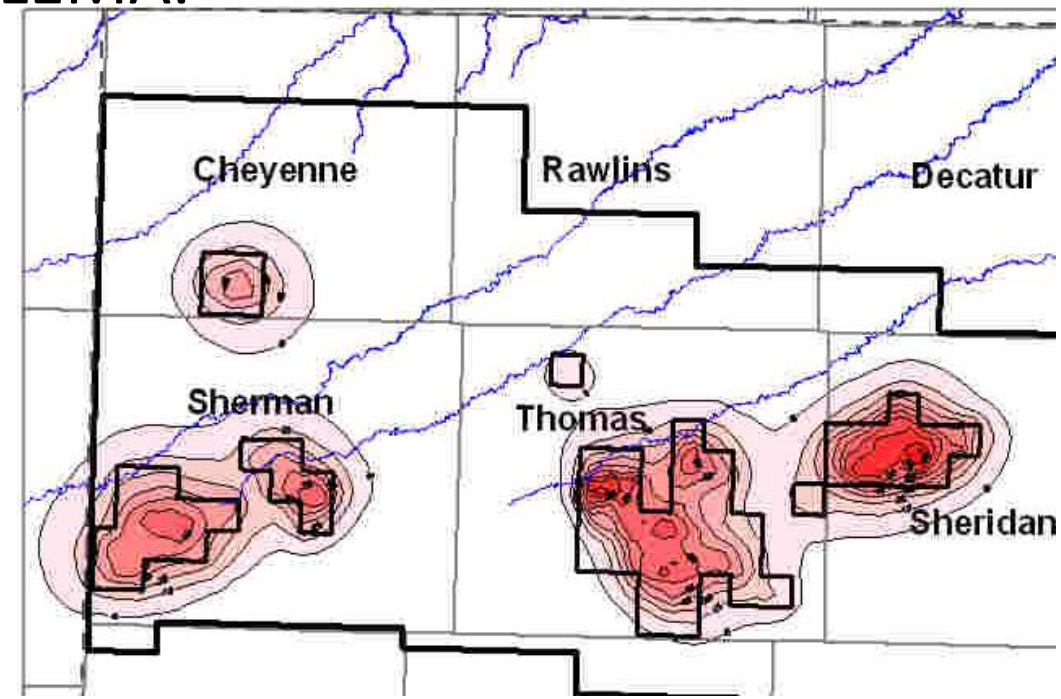
RRCA Model used to evaluate new applications for “significant hydraulic connection”



RRCA model used to evaluate and support enhanced management in Northwest Kansas

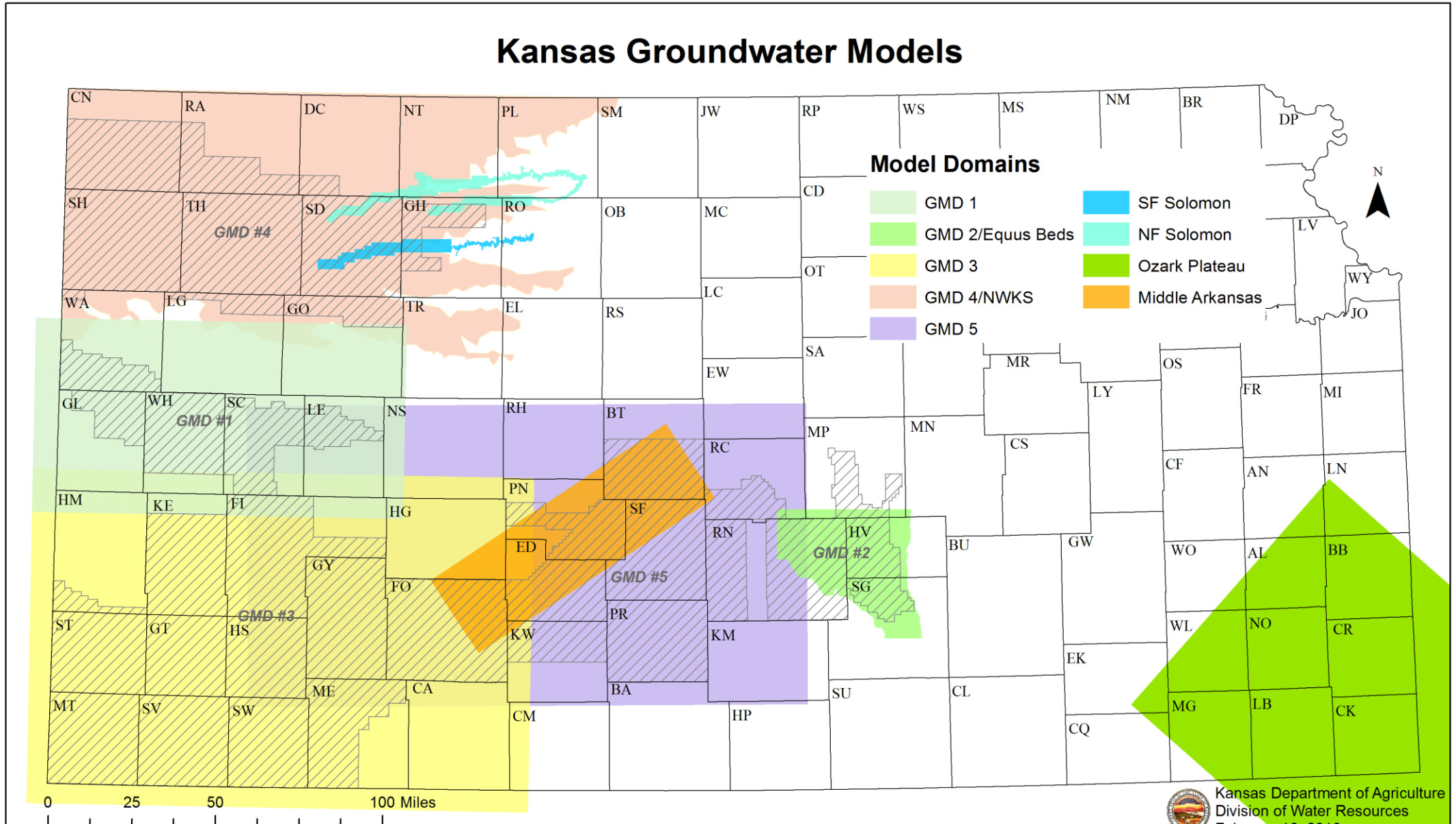
- NW KS GMD No. 4 identified high priority areas
- Model demonstrated that benefits of pumping reductions stay put (i.e. they don't propagate far)
- "Sheridan 6" LEMA formed 2013; now looking at potential district-wide LEMA.





Kansas development and use of groundwater models

Kansas Intra-state model development

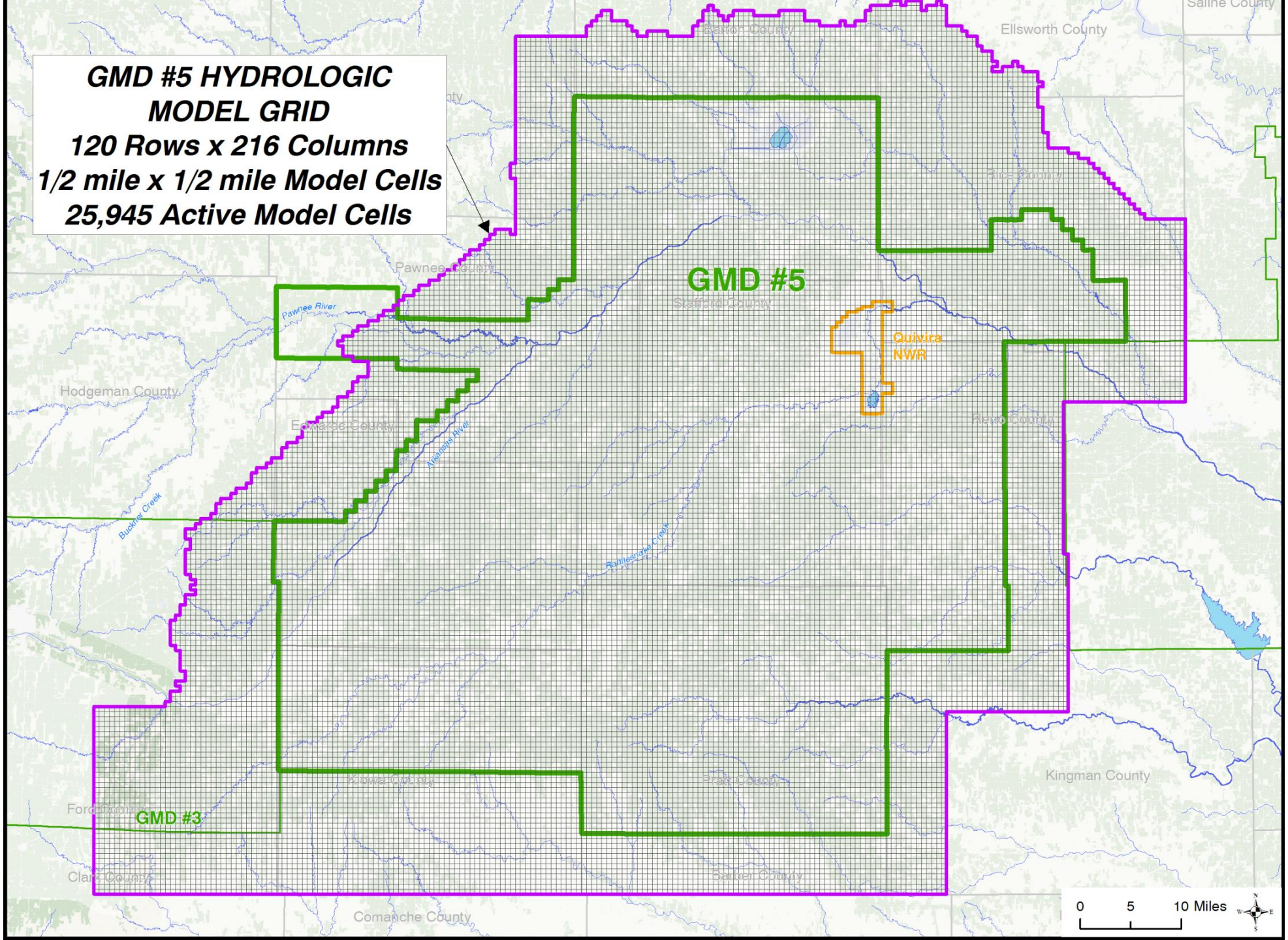


Kansas use of groundwater models

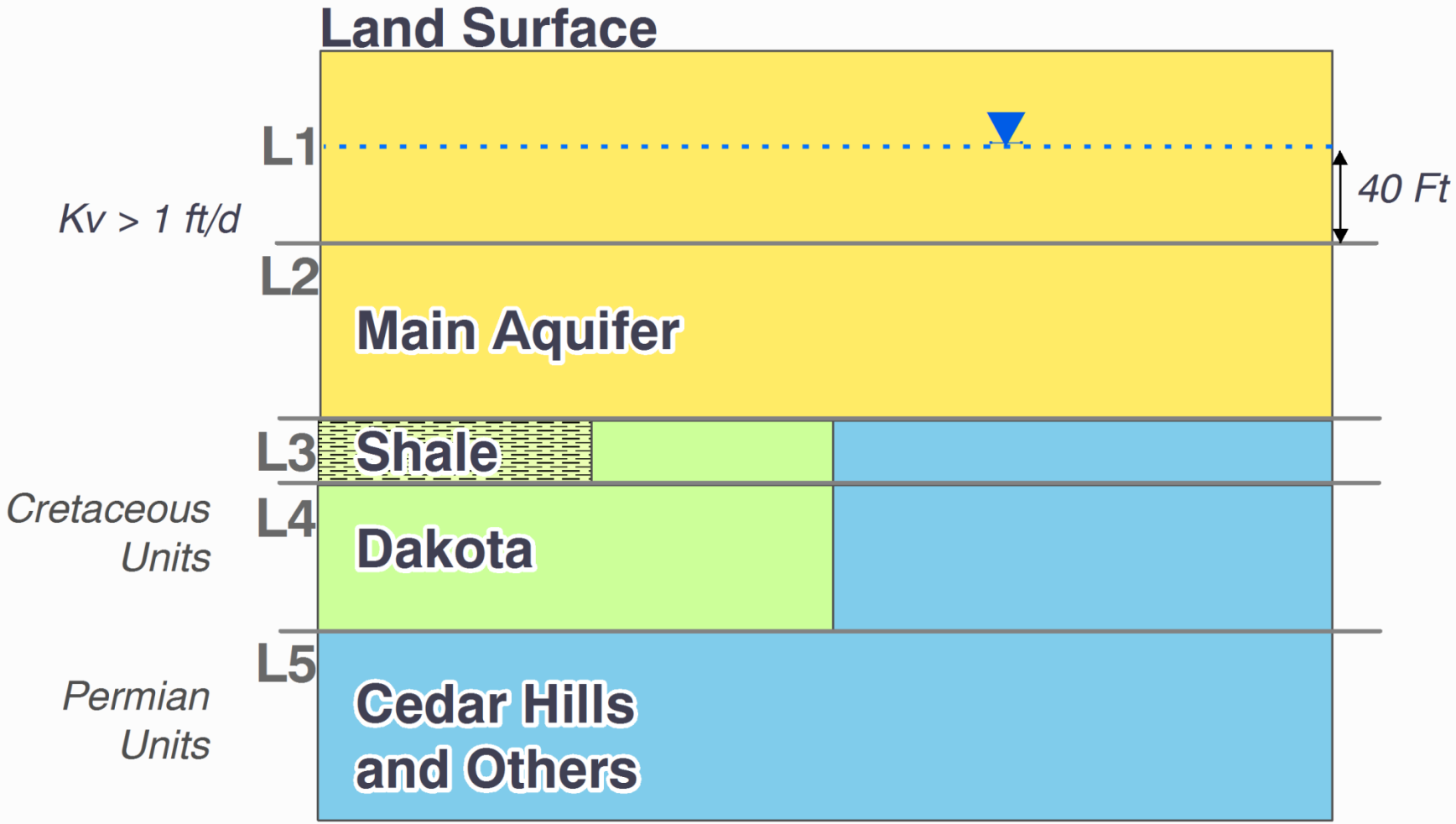
- Improve estimates of recharge and safe yield for new application decisions (Ozark, Lower Arkansas)
- Forecast expected response and benefits to alternate future conditions, esp. in over-appropriated systems (Sheridan LEMA).
- Assist in groundwater impairment investigations (Quivira National Wildlife Refuge)
- Assist in evaluating larger, more complex change applications (Hays water transfer)

Big Bend GMD No, 5 Groundwater Model

- Developed for GMD No 5 by Balleau Groundwater, Inc.
- Peer review by a committee including Kansas expert Steve Larson of SSPA.
- Complex surface water – groundwater interactions. Significant recharge and groundwater outflows to surface system
- Areas of upwelling of poor quality groundwater, led to development of 7-layer model


GMD #5 HYDROLOGIC
MODEL GRID
120 Rows x 216 Columns
1/2 mile x 1/2 mile Model Cells
25,945 Active Model Cells
GMD #5
GMD #3
Quivira
NWR
Pawnee River
Arkansas River
Buckner Creek
Rattlesnake Creek
Ellsworth County
Saline County
Rice County
Reno County
Kingman County
Pawnee County
Stafford County
Hodgeman County
Edwards County
Kiowa County
Pratt County
Barton County
Ford County
Clark County
Comanche County
0
5
10 Miles

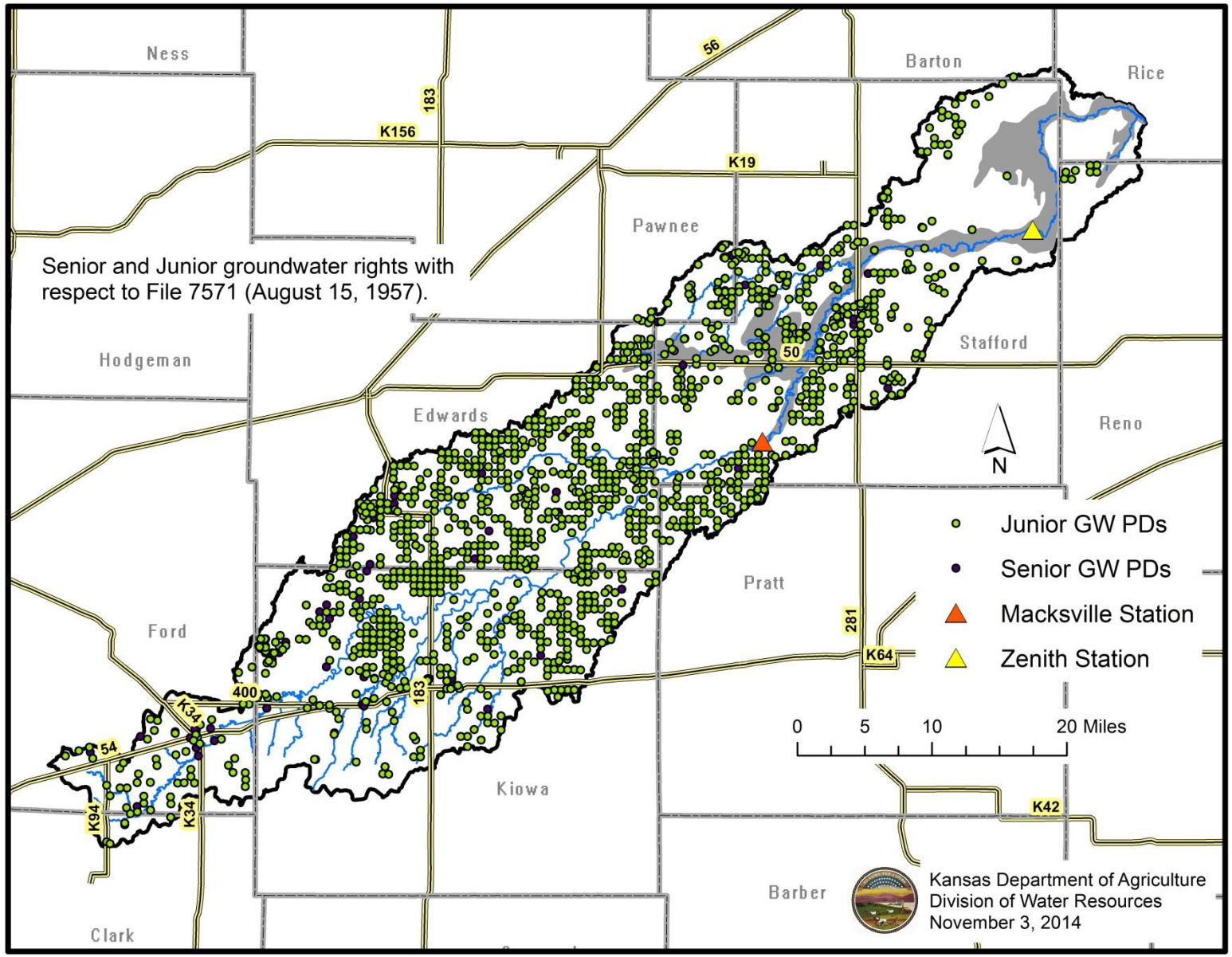
LAYERS



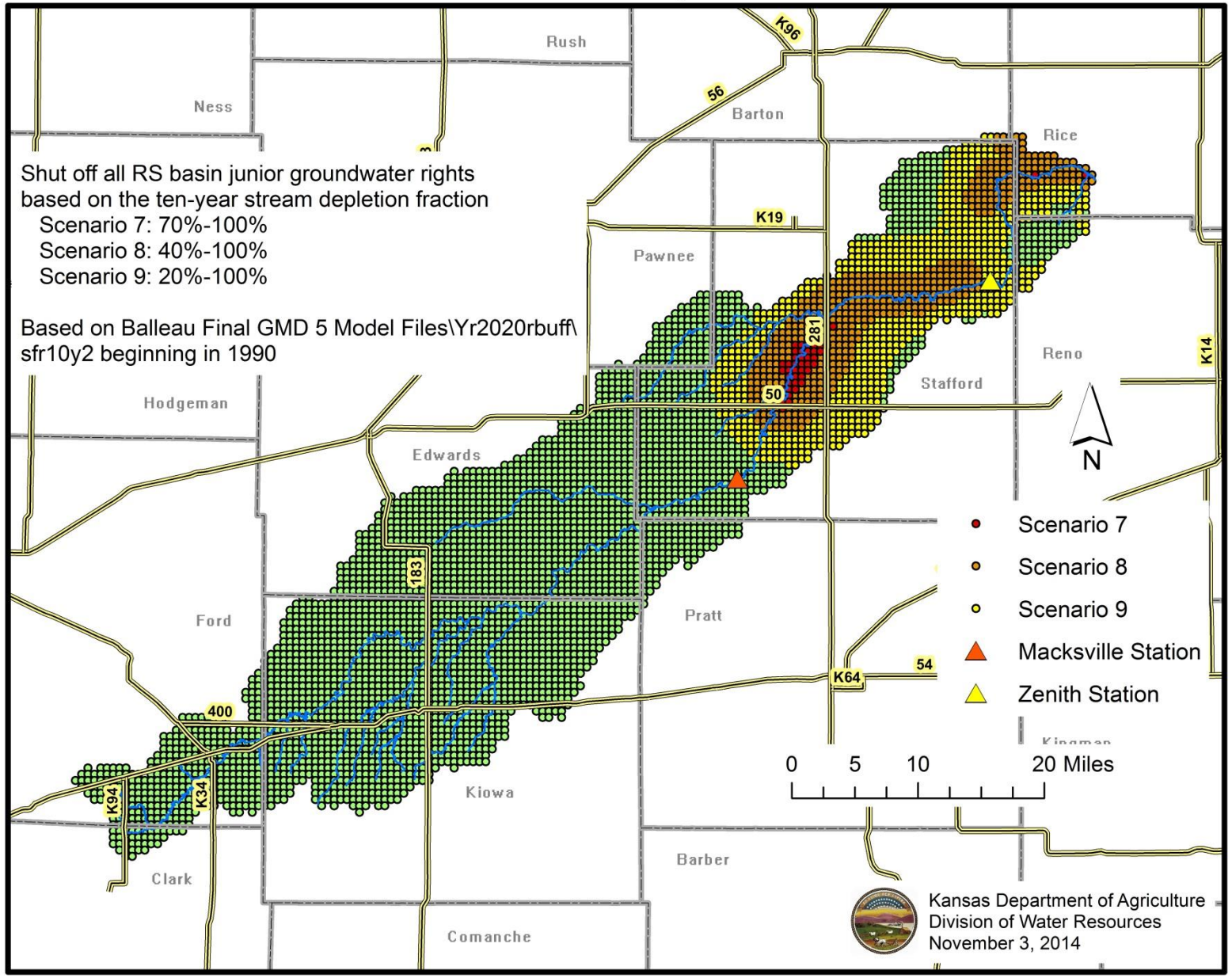
- Crooked Creek Fault Truncates Dakota, Absent in East.
- Perimeter GHB Reference Head by History.

Quivira National Wildlife Refuge: Use of GMD5 GW Model to evaluate impairment claim

Rattlesnake Creek Basin
Groundwater Points of Diversion



Rattlesnake Creek Basin
Scenarios 7, 8 and 9

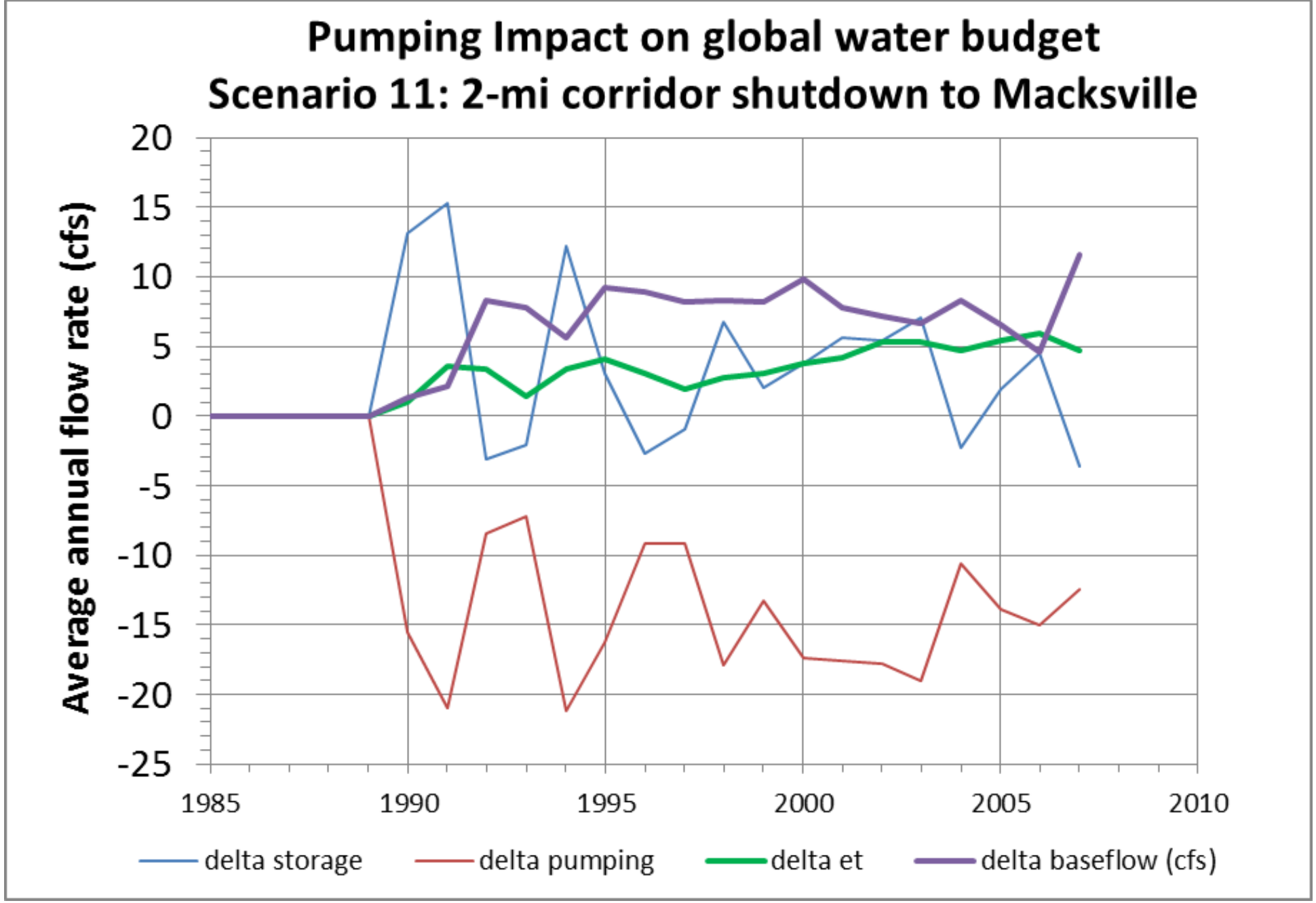


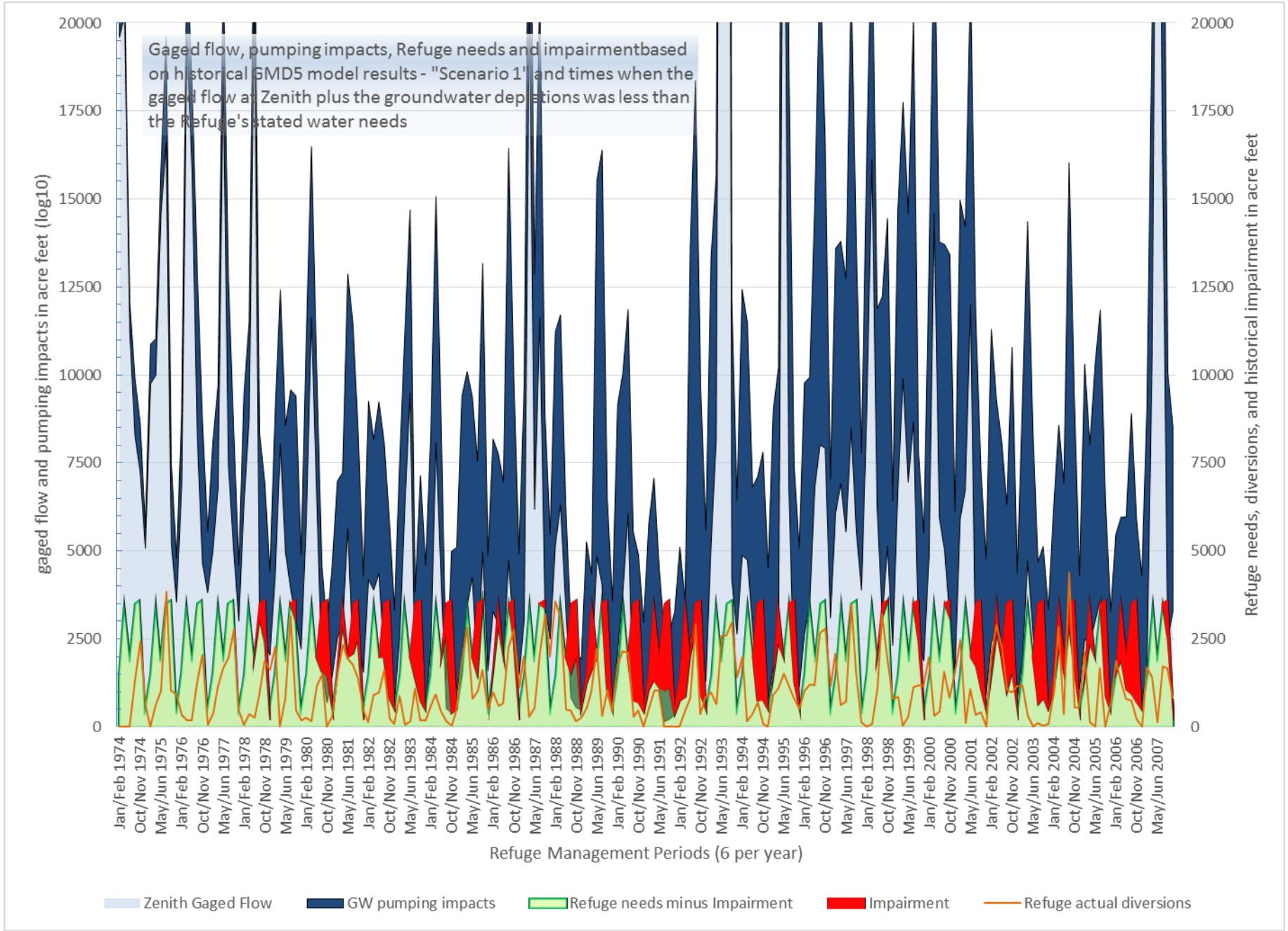
Rattlesnake Creek Basin impacts

average: 1998-2007 acre-feet/yr

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.


Pumping Impact on global water budget
Scenario 11: 2-mi corridor shutdown to Macksville
Average annual flow rate (cfs)
20
15
10
5
0
-5
-10
-15
-20
-25
1985
1990
1995
2000
2005
2010
delta storage
delta pumping
delta et
delta baseflow (cfs)


Gaged flow, pumping impacts, Refuge needs and impairmentbased on historical GMD5 model results - "Scenario 1" and times when the gaged flow at Zenith plus the groundwater depletions was less than the Refuge's stated water needs
gaged flow and pumping impacts in acre feet (log10)
Refuge needs, diversions, and historical impairment in acre feet
20000
17500
15000
12500
10000
7500
5000
2500
0
Jan/Feb 1974
Oct/Nov 1974
May/Jun 1975
Jan/Feb 1976
Oct/Nov 1976
May/Jun 1977
Jan/Feb 1978
Oct/Nov 1978
May/Jun 1979
Jan/Feb 1980
Oct/Nov 1980
May/Jun 1981
Jan/Feb 1982
Oct/Nov 1982
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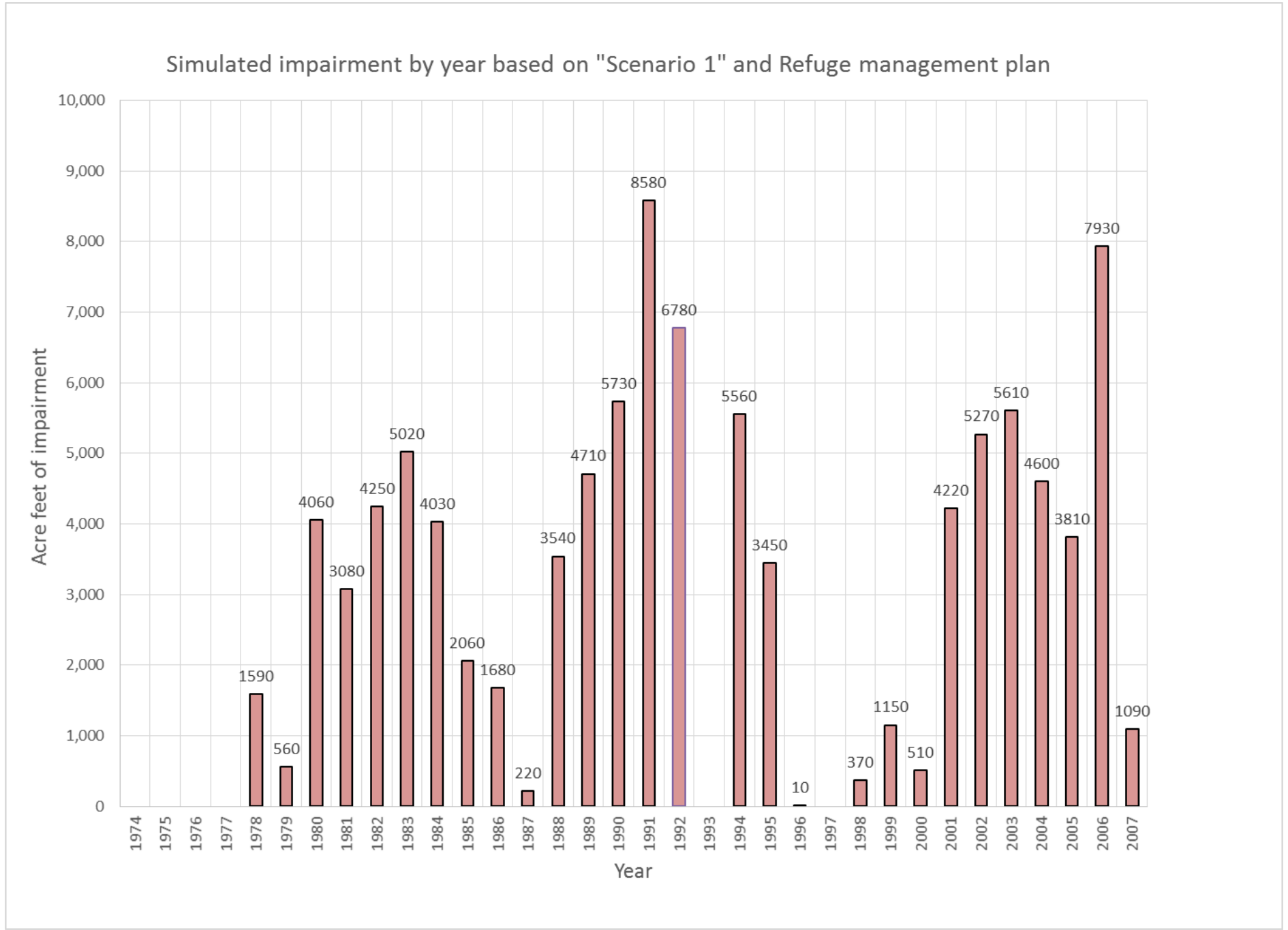
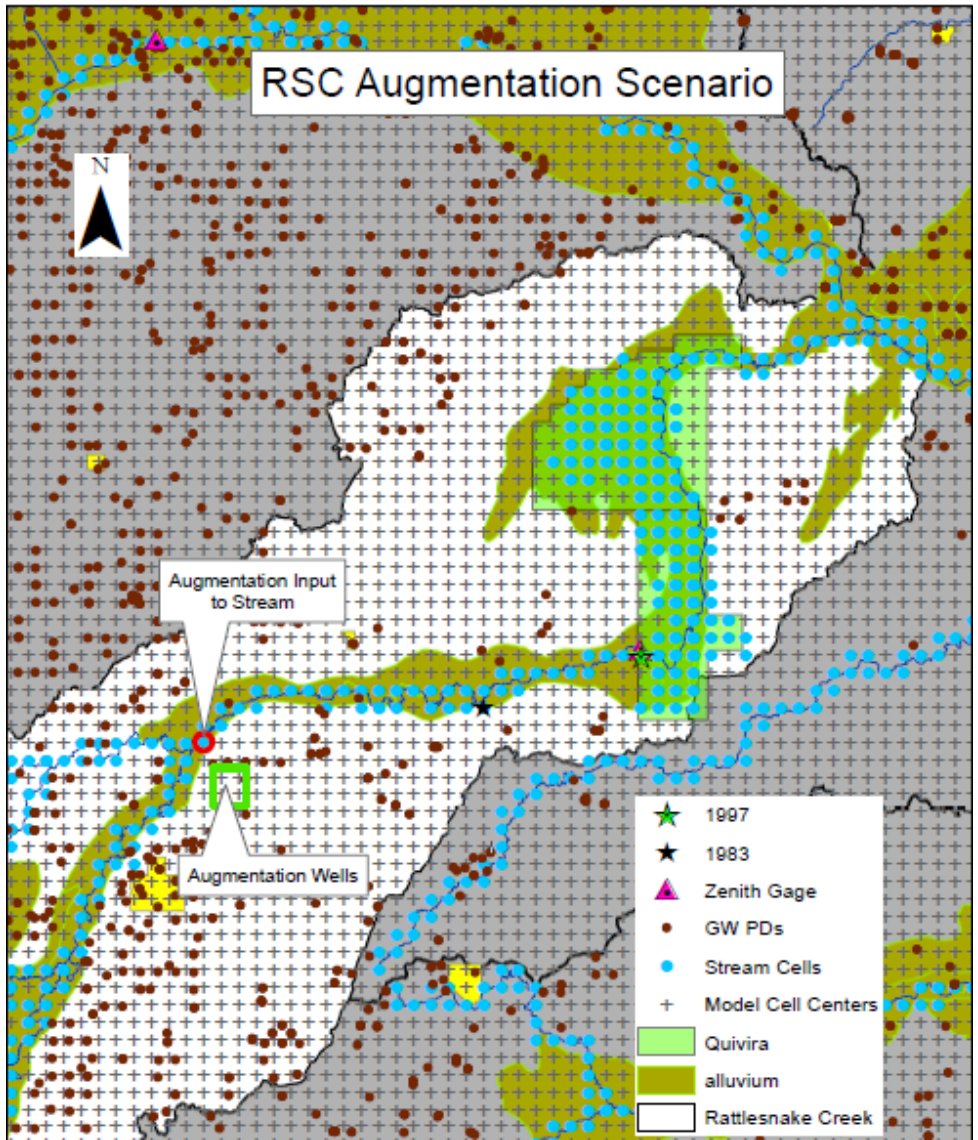
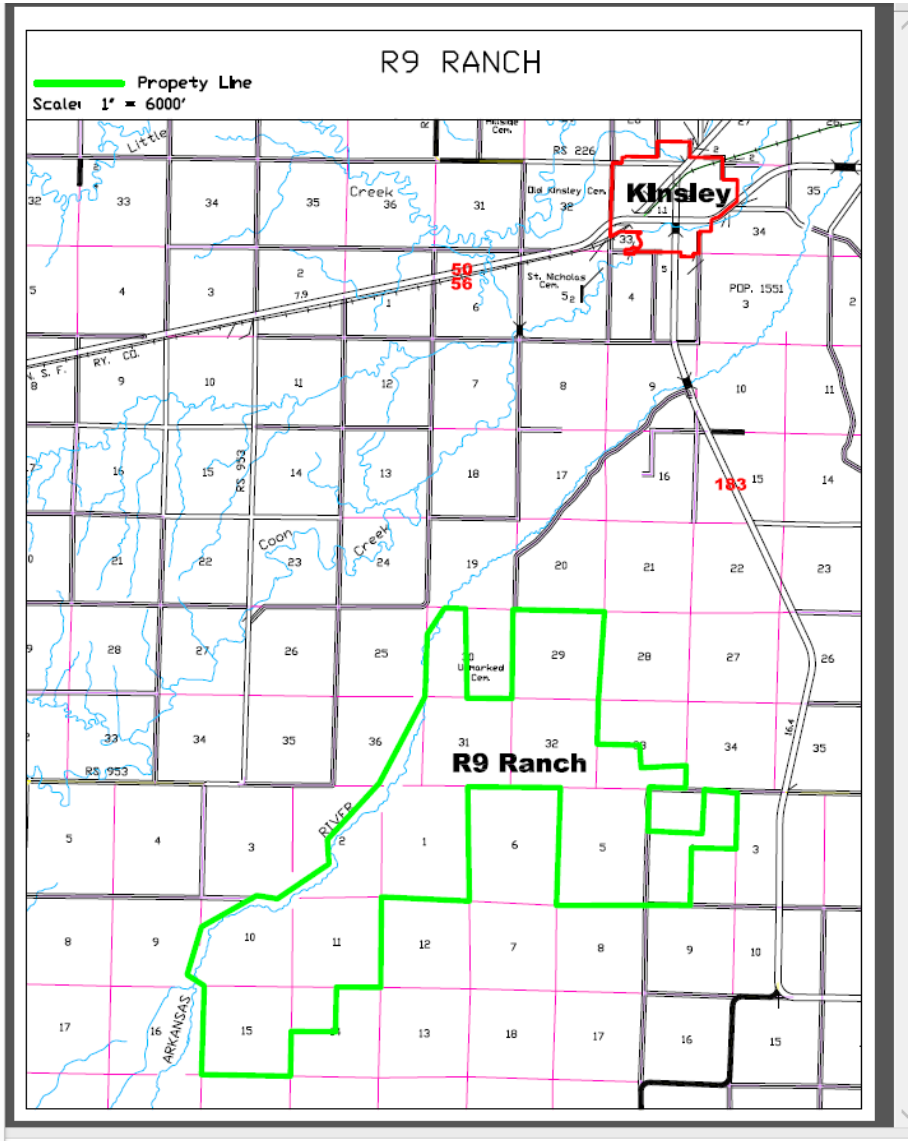
Jan/Feb 1998
Oct/Nov 1998
May/Jun 1999
Jan/Feb 2000
Oct/Nov 2000
May/Jun 2001
Jan/Feb 2002
Oct/Nov 2002
May/Jun 2003
Jan/Feb 2004
Oct/Nov 2004
May/Jun 2005
Jan/Feb 2006
Oct/Nov 2006
May/Jun 2007
Refuge Management Periods (6 per year)
Zenith Gaged Flow
GW pumping impacts
Refuge needs minus Impairment
Impairment
Refuge actual diversions

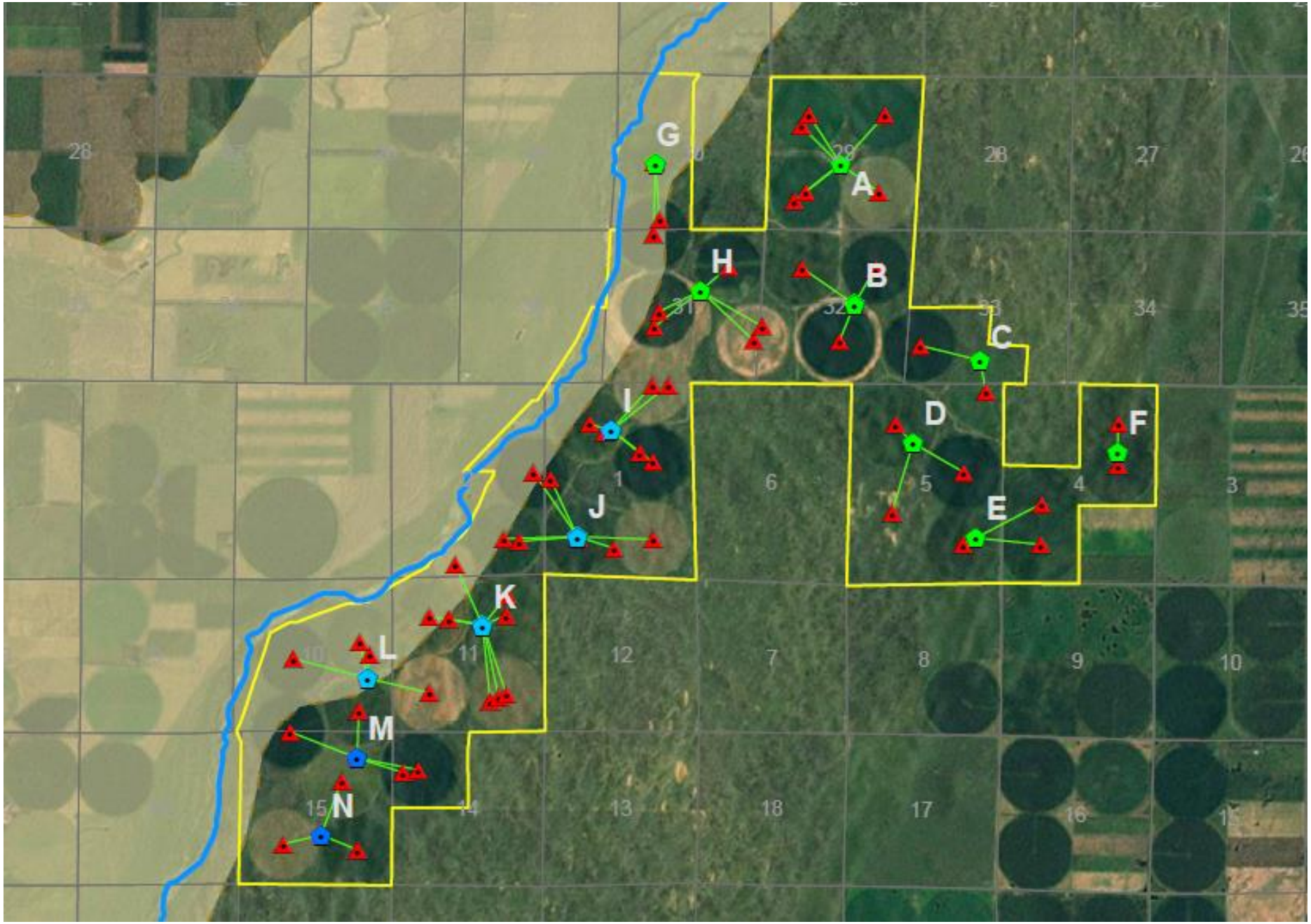

Simulated impairment by year based on "Scenario 1" and Refuge management plan
Acre feet of impairment
Year
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007
1590
560
4060
3080
4250
5020
4030
2060
1680
220
3540
4710
5730
8580
6780
5560
3450
10
370
1150
510
4220
5270
5610
4600
3810
7930
1090

Augmentation Pumping Scenarios
1. Apr-Jun, 2. Aug-Sep, from layer 1 or 2

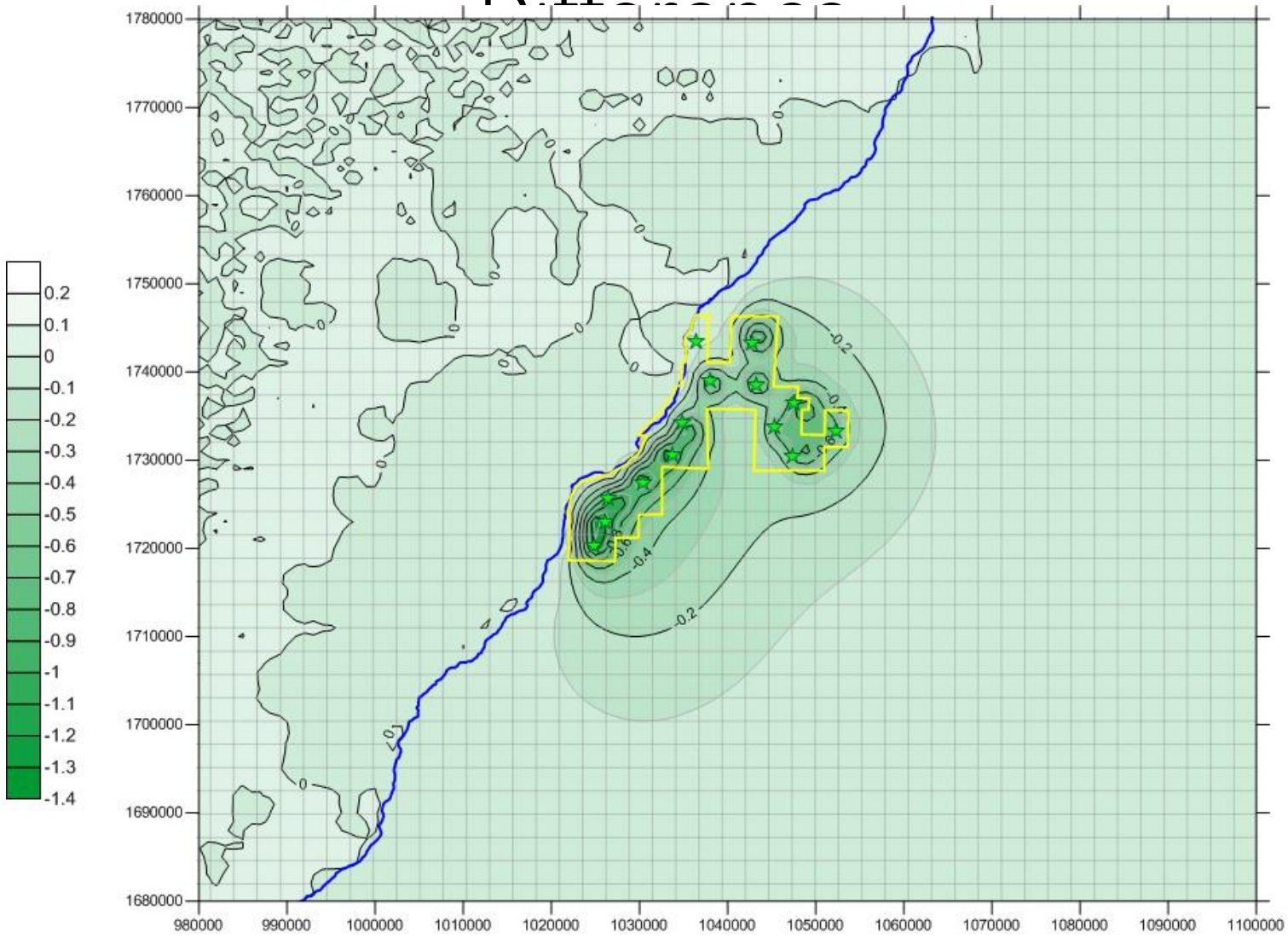


Hays/Russell changes/water transfer 7000+ acre-feet; 80 miles.




A
B
C
D
E
F
G
H
I
J
K
L
M
N

4800 AF Scenario Modeled Drawdown Difference



Difference between the baseline drawdown and drawdown from 1991 – 2007 with 14 municipal wells pumping a total of 4800 acre-ft per year 24/7.

Directions in model development

Keys to credible groundwater model development

- KS wateruse data has been key in developing credible models (enhanced program since 1989, fees for non-report, follow)
- Paying attention to model development process.
  - Active, transparent model development process
  - Encourage on-going, peer-review by modelers during development.
  - Rigorous data development and review
- Continuous improvement of models
  - E.g. integrate best of well logs into model geometry
  - KS Modeling Maintenance Program

Hydrostratigraphic Drilling Record Assessment (HyDRA)

GRAVEL PACK INTERVALS: From 25 ft. to 200 ft.

6 GROUT MATERIAL: 1 Neat cement 2 Cement grout X Bentonite 4 Other

Grout Intervals: From 5 ft. to 25 ft.

What is the nearest source of possible contamination:

X Septic tank 4 Lateral lines 7 Pit privy X Livestock pens 14 Abandoned water well

2 Sewer lines 5 Cess pool 8 Sewage lagoon 11 Fuel storage 15 Oil well/Gas well

3 Watertight sewer lines 6 Seepage pit 9 Feedyard 12 Fertilizer storage 16 Other (specify below)

13 Insecticide storage

Direction from well? How many feet? 500

FROM	TO	LITHOLOGIC LOG	FROM	TO	PLUGGING INTERVALS
0	1	top soil			
1	21	brown clay			
21	53	brown clay & gypsum			
53	57	fine sand			
57	81	brown clay & gypsum			
81	87	fine to medium sand			
87	113	brown clay, few sand streaks			
113	122	medium to coarse sand, clay streaks			
122	142	medium to coarse sand, small gravel			
142	160	fine to medium sand			
160	163	brown clay			
163	172	fine to medium sand			
172	192	medium to coarse sand, small gravel			
192	197	coarse sand & gravel			
197	200	yellow shale			

7 CONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was (1) constructed, (2) reconstructed, or (3) plugged under my jurisdiction and was completed on (mo/day/year) 12-6-96 and this record is true to the best of my knowledge and belief. Kansas Water Well Contractor's License No. [redacted] This Water Well Record was completed on [redacted] under the business name of [redacted] by (signature) [redacted]

INSTRUCTIONS: Use typewriter or ball point pen. PLEASE PRESS FIRMLY and PRINT clearly. Please fill in blanks, underline or circle the correct answers. Send top three copies to Kansas Department of Health and Environment, Bureau of Water, Topeka, Kansas 66620-0001. Telephone: 913-296-5545. Send one to WATER WELL OWNER and retain one for your records.

Good log

GRAVEL PACK INTERVALS: From 20 ft. to 75 ft.

6 GROUT MATERIAL: 1 Neat cement 0 2 Cement grout 20 3 Bentonite 4 Other

Grout Intervals: From 0 ft. to 20 ft.

What is the nearest source of possible contamination:

1 Septic tank 4 Lateral lines 7 Pit privy 10 Livestock pens 14 Abandoned water well

2 Sewer lines 5 Cess pool 8 Sewage lagoon 11 Fuel storage 15 Oil well/Gas well

3 Watertight sewer lines 6 Seepage pit 9 Feedyard 12 Fertilizer storage 16 Other (specify below)

13 Insecticide storage

Direction from well? South How many feet? 60

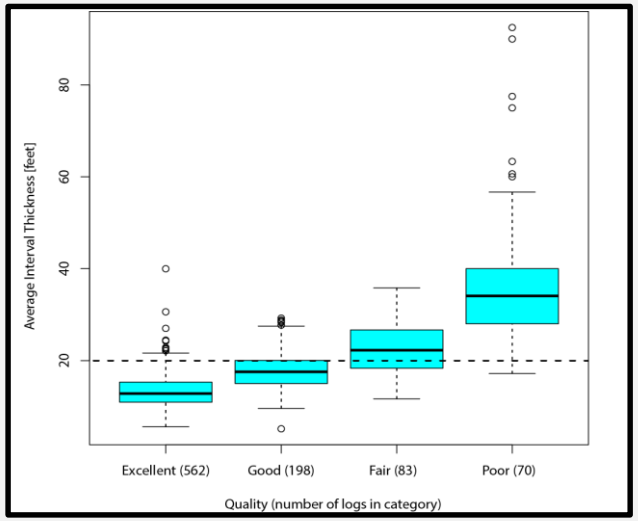
FROM	TO	LITHOLOGIC LOG	FROM	TO	LITHOLOGIC LOG
0	20	Clay			
20	185	Sand and gravel with clay streaks			

7 CONTRACTOR'S OR LANDOWNER'S CERTIFICATION: This water well was (1) constructed, (2) reconstructed, or (3) plugged under my jurisdiction and was completed on (mo/day/year) 7/3/87 and this record is true to the best of my knowledge and belief. Kansas Water Well Contractor's License No. [redacted] This Water Well Record was comp[redacted] under the business name of [redacted] by [redacted]

INSTRUCTIONS: Use typewriter or ball point pen. PLEASE PRESS FIRMLY and PRINT clearly. Please fill in blanks, [redacted] Department of Health and Environment, Bureau of Water Protection, Topeka, Kansas 66620-7320. Telephone: 913-[redacted] records.

No so good log

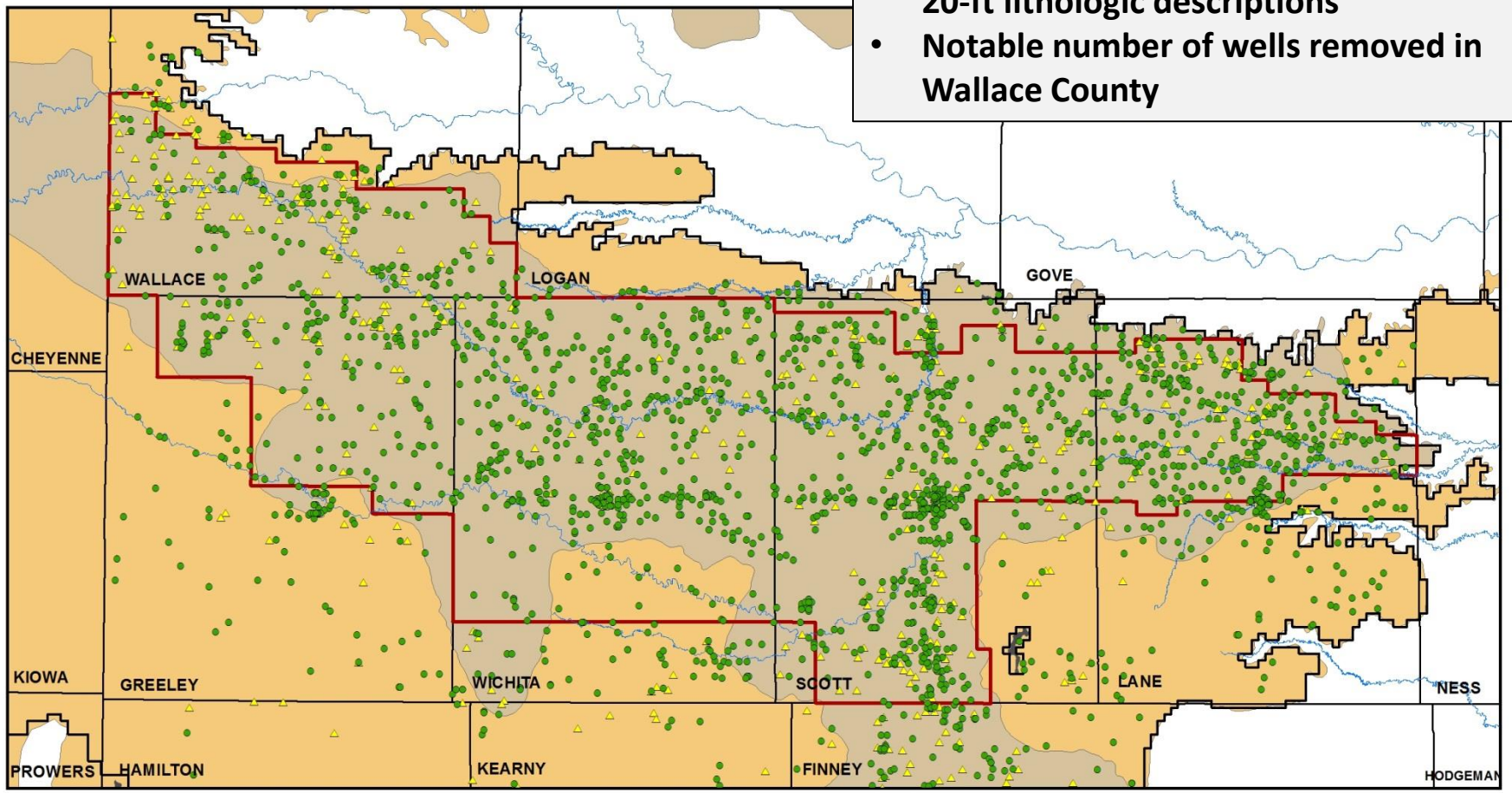
- **913 Well logs manually rated for quality in Scott County**
- **20 ft or less average interval thickness**



	Average Thickness	
	<20ft	>20ft
Excellent	539	21
Good	146	49
Fair	29	52
Poor	3	63

Distribution of lithologic logs using 20-ft intervals

- 2,216 of 2,757 logs selected based on 20-ft lithologic descriptions
- Notable number of wells removed in Wallace County



Standardized Lithologies

Category	Type and color of material	From	To
Topsoil	Top soil	0	4
Clay, Fine Sand	Tan clay with fine sand	4	45
Fine Sand, Clay	Fine sand and clay	45	70
Fine Sand	Fine sand	70	80
Sandy clay, Sand	Sandy tan clay and sand	80	105
Find to Medium Sand	Fine to medium sand	105	140
Fine to Coarse Sand, Medium Gravel	Fine to coarse sand medium gravel	140	225
Clay, Sand	Yellow clay with sand streaks	225	245
Clay	Blue clay	245	258
Medium Sand and Gravel	Medium sand and gravel	258	328
Clay	Blue clay	328	345
Fine to Medium Sand, Gravel	Fine to medium sand and gravel	345	358
Clay	Blue clay	358	380
Sandy clay, Sand	Sandy tan clay and sand	380	395
Medium to Coarse Sand, Fine to Coarse Gravel, Clay	Medium sand to coarse gravel clay streaks	395	425
Sandy clay, Fine Sand	Sandy tan clay little fine sand	425	500

(use a second sheet if needed)

___ in. to ___ ft. depth

8 Screen: Manufacturer Foster, Brown, Cook
Type Millslot, Louver wire wrap Dia. 16"
Slot/gauze 1/8" Length 167
Set between 258 ft. and 425 ft.
Fittings:
Gravel pack ☒ Yes ☐ No Size range of material 1.2mm to 9mm

9 Static water level:
195 ft. below land surface Date 8-23,75

10 Pumping level below land surfaces: No test
___ ft. after ___ hrs. pumping ___ g.p.m.
___ ft. after ___ hrs. pumping ___ g.p.m.
Estimated maximum yield ___ g.p.m.

11 Water sample submitted:
☐ Yes ☒ No Date ___

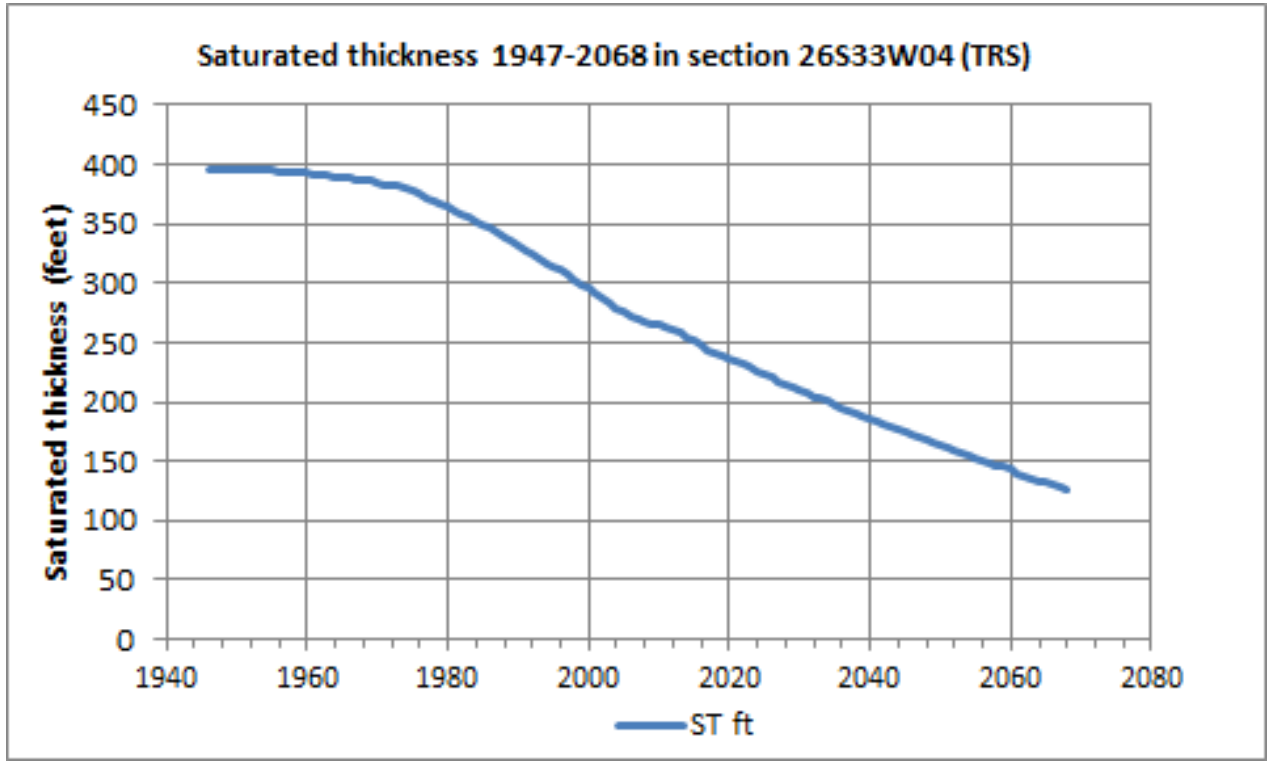
12 Well head completion:
☐ Pitless adapter ☒ Inches above grade

13 Well grouted? ☒ Yes ☐ No
☐ Neat cement ☒ Bentonite ☐ ___
Depth: From 0 ft. to 10 ft.

14 Nearest source of possible contamination: unk
ft. ___ Direction ___ Type ___
Well disinfected upon completion? ☒ Yes ☐ No

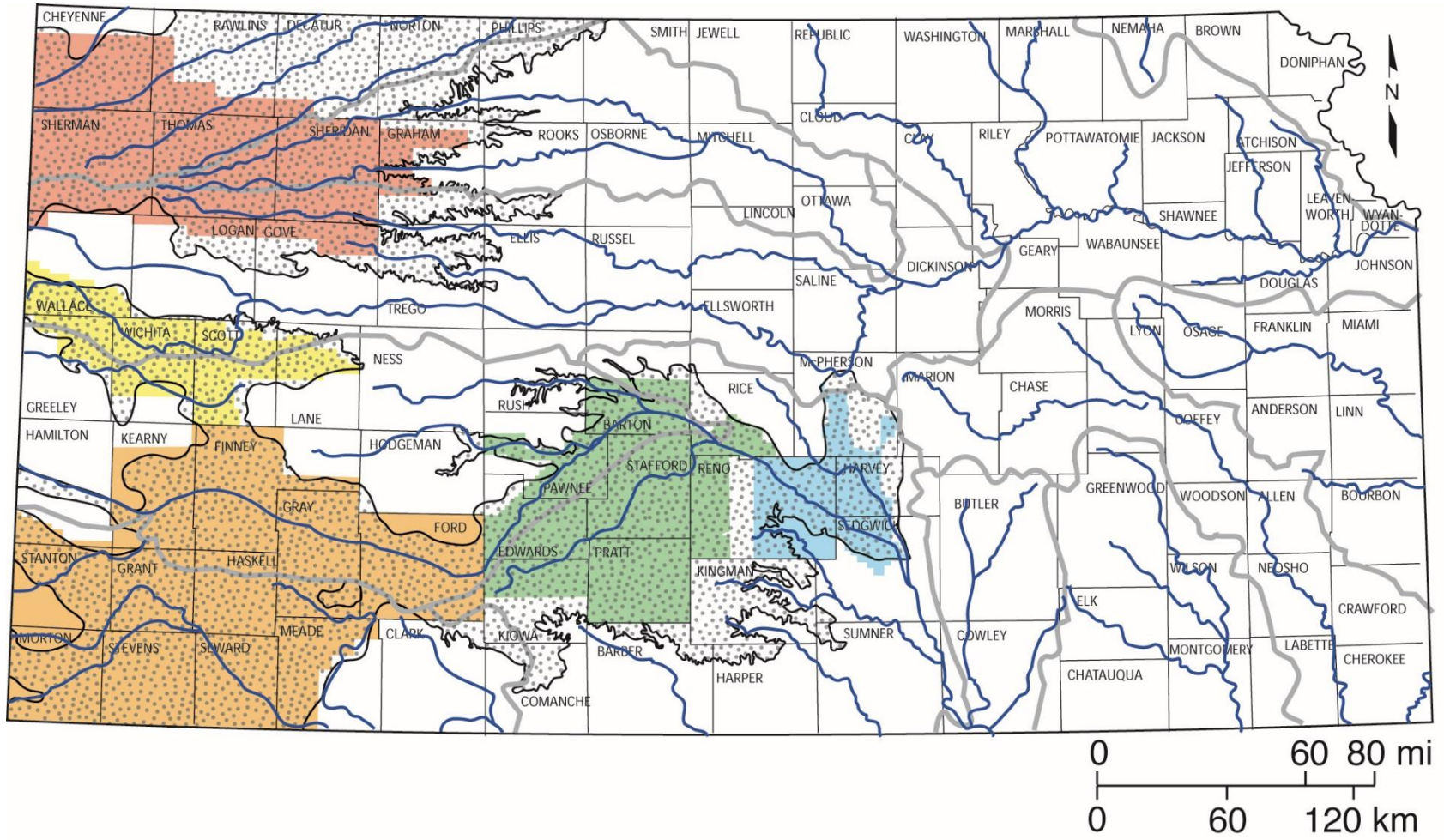
15 Pump: ☐ Not installed
Manufacturer's name Peerless
Model number ___ HP ___ Volts ___
Length of drop pipe 240 ft. capacity 1400 g.p.m.
Type:
☐ Submersible ☒ Turbine
☐ Jet ☐ Reciprocating
☐ Centrifugal ☐ Other

Projected ST, K, T, Sy in GMD3



year	ST ft	K ft/d	T sq.ft/d	Sy
1947	395	70	27611	0.21
2016	248	68	16979	0.19
2041	184	59	10920	0.27
2066	130	40	4915	0.24

DEVELOPMENT OF THE KANSAS HIGH PLAINS AQUIFER MODELING FRAMEWORK



MODELING FRAMEWORK: TASK OVERVIEW

1. GMD2 Modeling
    a. Sustainability Assessment
    b. Groundwater Model Expansion and Update
2. GMD4 Groundwater Model Update and Enhancement
3. GMD3 Groundwater Model Update and Enhancement
4. Results Assessment for High Plains Aquifer Modeling

- - - - - - - - - - - -

Aquifer Modeling Maintenance Program Following Above

Questions