Crop irrigation requirements: 2006 update

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Summary of results

Crop irrigation requirements (CIR) were calculated for 2006 on the basis of daily weather data from eight stations in Kansas and Nebraska, and groundwater irrigation use reports for Kansas. From the groundwater irrigation use reports, crop distributions and irrigation return flow fractions were evaluated for fifteen counties as shown in Table 1; corresponding values for 2005 are shown in Table 2 for comparison. Crop distributions and irrigation return flow fractions for nine of these counties were used to calculate CIR as indicated by the rightmost column of Tables 1 and 2.

Daily weather data (see "Data sources and procedures," below, for list of stations) were used to evaluate potential evaporation for a tall (0.5 m) reference crop, beginning and ending dates for crop growth, and consumptive use for each crop at each station. Crop distributions were used as weighting functions to evaluate average consumptive use in each county for each crop. Return flow fractions were used to evaluate pumping requirements, or crop irrigation requirements (CIR). Table 3 shows potential consumptive use, consumptive use, pumping (CIR), effective precipitation and actual precipitation in 2006 for each county. Table 3 also shows both weighted and arithmetic average values, where the weight function is irrigated area within each county. Table 4 shows corresponding values in 2005 for comparison. Note that differences between weighted and arithmetic averages appear negligible for 2006 in Table 3, but more significant for 2005 in Table 4.

Table 5 compares crop irrigation requirements (CIR) with reported water use in 2006 for each county. Reported water use is shown both in inches (12AF/acre) and as a percent of CIR the corresponding percent of CIR. Taken over all Kansas counties within the RRCA model domain, reported water use is 13.32 inches, or 76.6 percent of CIR. Additionally, the last two columns of Table 5 show reported water use after adjustment for estimated over-reporting by unmetered wells. Details of this adjustment are described elsewhere; see "Water use analysis." Adjusted reported water use taken over all counties is 12.84 inches, or 73.8 percent of CIR, a 2.8 percent reduction in reported use as a percent of CIR. Note, however, that the adjustment for unmetered wells is not applied in the procedure to prepare 2006 pumping, recharge and irrigated area files for the RRCA model.

Table 1. Crop distributions and corresponding return flow fractions in 2006.

County	Alfalfa	Corn	Soybeans	Grain Sorghum	Sunflowers	Wheat	Return flow fraction	Used for CIR
CN	6.75%	70.18%	4.20%	1.11%	0.98%	16.77%	13.33%	Yes
DC	18.01%	62.18%	5.67%	2.94%	3.48%	7.73%	16.22%	Yes
GH	8.59%	67.28%	13.37%	2.69%	0.00%	8.06%	14.36%	No
GO	3.78%	65.57%	7.48%	13.13%	0.00%	10.03%	13.48%	No
JW	3.08%	83.34%	13.58%	0.00%	0.00%	0.00%	17.28%	No
LG	1.76%	79.94%	2.18%	2.43%	1.63%	12.06%	12.71%	No
NT	4.98%	69.06%	21.21%	1.07%	0.00%	3.69%	19.65%	Yes
PL	5.99%	49.59%	41.79%	0.00%	0.00%	2.63%	19.61%	Yes
RA	16.80%	48.13%	13.78%	4.62%	0.16%	16.52%	14.23%	Yes
RP	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	21.80%	No
SD	3.30%	81.95%	8.08%	1.25%	0.82%	4.60%	13.24%	Yes
SH	3.85%	71.82%	2.25%	2.03%	6.46%	13.59%	12.82%	Yes
TH	1.35%	77.50%	10.03%	2.96%	0.59%	7.57%	12.51%	Yes
TR	2.45%	42.66%	24.32%	9.47%	0.00%	21.10%	14.02%	Yes
WA	6.26%	71.97%	0.00%	15.50%	0.00%	6.26%	14.59%	No
Avg all counties	4.52%	73.01%	7.73%	2.60%	2.20%	9.95%	13.32%	

Table 2. Crop distributions and corresponding return flow fractions in 2005.

County	Alfalfa	Corn	Soybeans	Grain Sorghum	Sunflowers	Wheat	Return flow fraction	Used for CIR
CN	7.55%	57.10%	8.02%	1.30%	11.98%	14.05%	13.78%	Yes
DC	15.74%	60.25%	8.30%	2.13%	5.66%	7.92%	16.64%	Yes
GH	6.88%	69.42%	7.04%	2.80%	0.00%	13.86%	13.74%	No
GO	2.59%	68.12%	8.00%	7.03%	1.49%	12.77%	14.50%	No
JW	5.80%	43.79%	50.41%	0.00%	0.00%	0.00%	17.21%	No
LG	3.12%	73.42%	7.41%	1.79%	3.31%	10.95%	13.10%	No
NT	7.38%	59.97%	24.71%	2.90%	0.00%	5.04%	20.61%	Yes
PL	5.54%	68.90%	25.31%	0.25%	0.00%	0.00%	20.13%	Yes
RA	19.26%	53.17%	8.55%	4.89%	4.47%	9.66%	14.20%	Yes
RP	0.00%	55.23%	44.77%	0.00%	0.00%	0.00%	30.00%	No
SD	2.92%	80.74%	7.52%	1.03%	3.07%	4.72%	13.47%	Yes
SH	4.25%	63.83%	3.49%	1.03%	11.46%	15.93%	13.07%	Yes
TH	1.19%	78.93%	7.41%	1.84%	2.96%	7.67%	12.70%	Yes
TR	8.41%	44.34%	10.60%	17.28%	12.63%	6.75%	13.43%	Yes
WA	7.99%	64.81%	0.00%	0.00%	0.00%	27.20%	14.22%	No
Avg all counties	4.73%	69.67%	7.40%	1.85%	6.07%	10.29%	13.57%	

Table 3. Summary of CIR calculations for 2006[1].

county	Irrig area Acres	Irrig area fraction	potential consump-tive use composite 2006 in	Consump-tive use composite 2006 in	Pumping (CIR) in 2006 in	effective precip composite 2006 in	actual precip 2006 in
Cheyenne	34895	0.1145	27.45	18.21	17.58	9.23	22.37
Decatur	9568	0.0314	27.40	18.81	18.46	8.59	21.85
Norton	8312	0.0273	27.24	17.21	17.21	10.02	24.93
Phillips	4430	0.0145	25.59	15.68	15.22	9.92	23.51
Rawlins	13777	0.0452	29.72	20.31	20.32	9.41	24.27
Sheridan	62875	0.2063	27.06	18.80	17.79	8.26	23.86
Sherman	86083	0.2824	27.12	16.13	15.00	11.00	24.81
Thomas	82984	0.2723	26.92	19.59	19.05	7.33	21.09
Trego	1867	0.0061	24.36	17.11	15.92	7.24	25.56
Sum or wtd. avg[2]	304791	1	27.18	18.16	17.39	9.02	23.19
arith. avg3			26.98	17.98	17.39	9.00	23.58

[1]From range a1:g11, sheet summary_COUNTY in KSCIR_update2006.xls
[2]Total irrigated area over model domain is 416,230 acres (preliminary); the sum over the nine representative counties is 335,141 acres, or 80.5% of the total irrigated area, and excludes Graham, Gove, Jewell, Logan, Republic and Washington counties. Weighted average values shown with units of inches are weighted by the irrigated area fraction. [3]Arithmetic average values are shown for comparison.

Table 4. Summary of CIR calculations for 2005[1].

county	Irrig area Acres	Irrig area fraction	potential consumptive use composite 2005 in [1]	consumptive use composite 2005 in [2]	Pumping (CIR) in 2005 in [3]	effective precip composite 2005 in [4]	actual precip 2005 in [6]
Cheyenne	46500	0.1211	26.67	17.75	16.48	8.93	19.97
Decatur	11344	0.0296	25.39	14.11	12.29	11.28	26.02
Norton	9758	0.0254	26.35	14.81	12.89	11.54	28.75
Phillips	5169	0.0135	25.40	14.83	13.31	10.57	24.40
Rawlins	18730	0.0488	29.65	18.55	17.71	11.10	22.63
Sheridan	74192	0.1933	26.37	15.92	14.29	10.45	24.57
Sherman	113513	0.2957	27.49	19.94	19.45	7.54	16.08
Thomas	102137	0.2661	27.00	17.89	16.89	9.11	20.09
Trego	2486	0.0065	24.84	14.70	12.26	10.14	24.86
Sum or wtd. avg[2]	383829	1	27.01	17.88	16.82	9.13	20.36
arith. avg3			26.57	16.50	15.06	10.07	23.04
Avg from reports[4]					10.95 (72.7%)		

[1]From range a1:g11, sheet summary_COUNTY in KSCIR_update2005.xls

[2]Total irrigated area over model domain is 383,829 acres; the sum over the nine representative counties is 91.35% of this total, excluding Graham, Gove, Jewell, Logan, Republic and Washington counties. Weighted average values shown with units of inches are weighted by the irrigated area fraction. [3]Arithmetic average values are shown for comparison.
[4]Adjusted total use reduced to account for overreporting by unmetered wells; from col. aa in sheet metered vs unmetered use, PumpRech8901_part2.xls in I:\RRCA_GM\KSData\ForScenarios\.

Table 5. Comparison of 2006 CIR with reported use.

county	Pumping (CIR) in 2006 in	reported gw irr use 2006 inches	Pct irrig demand met	reported gw irr use 2006 inches (adj.)	Pct irrig demand met by adj. use[2]
Cheyenne	17.58	14.63	83.22%	14.08	80.09%
Decatur	18.46	13.08	70.86%	13.00	70.42%
Norton	17.21	11.98	69.61%	11.91	69.20%
Phillips	15.22	10.44	68.59%	10.44	68.59%
Rawlins	20.32	12.83	63.14%	12.37	60.88%
Sheridan	17.79	12.61	70.88%	12.21	68.63%
Sherman	15.00	13.27	88.47%	12.66	84.40%
Thomas	19.05	14.24	74.75%	13.73	72.07%
Trego	15.92	12.79	80.34%	12.25	76.95%
weighted avg[2]	17.39	13.32	76.61%	12.84	73.83%

[1]From range a1:g11, sheet summary COUNTY in KSCIR_update2006.xls
[2]Adjusted total use reduced to account for overreporting by unmetered wells; from col. aa in sheet metered_vs_unmetered_use, PumpRech8901_part2.xls in I:\RRCA_GM\KSData\ForScenarios\.

Data sources and procedure

The procedure followed to calculate CIR is outlined in the sheet NOTES of KSCIR_update2006.xls, as developed by Spronk Water Engineers (SWE), except that reference evaporation according to the Hargreaves method is also calculated in the same workbook using the procedure described by Snyder and Eching (2002) [see pdf file PMdayDoc.pdf in I:\RRCA_GM\KSData\For2006\CIR\from_UCDavis\ ]. The update begins by setting the year to 2006 in cell c2 of sheet NOTES in KSCIR_update2006.xls.

A query of 2006 irrigation groundwater use report data was made by Kelly Emmons on April 10, 2007 [file RRCS_Overlap_Groups_2006_Prelim.xls in I:\RRCA_GM\KSData\For2006\Prelim\ ]. Crop distributions and irrigation return flow fractions that were estimated from an earlier version of the data were updated on the basis of the above query.

Daily weather data (precipitation, inches; and minimum and maximum temperature, deg F) for 2006 were obtained 4/2/2007 from Mary Knapp, State Meteorologist, KSU, for the stations in Kansas and Nebraska that are used to calculate crop irrigation requirements (CIR). The stations and their elevations and locations used in the calculations are listed in Table 6.

Table 6. Weather stations, elevations and locations.

StaName	State	County	Elev ft	Lat deg	Long deg	Sheet
ATWOOD 2 SW	KS	RAWLINS	2862	39.78333	-101.06667	Atwd07
COLBY 1 SW	KS	THOMAS	3170	39.38333	-101.06667	Colby07
GOODLAND WFO	KS	SHERMAN	3654	39.35000	-101.70000	Goodlnd07
NORTON 9 SSE	KS	NORTON	2360	39.73333	-99.83333	Norton07
OBERLIN	KS	DECATUR	2605	39.81667	-100.51667	Oberln07
WAKEENEY	KS	TREGO	2460	39.01667	-99.86667	Wakny07
HARLAN COUNTY LAKE	NE	HARLAN	2000	40.08333	-99.20000	Harlanl07
BENKELMAN	NE	DUNDY	3025	40.05000	-101.53333	Benkl07

The daily weather data were used both in reference evaporation and CIR calculations in the spreadsheet KSCIR_update2006.xls in I:\RRCA_GM\KSData\For2006\CIR\. Additionally, daily weather data including calculated ET based on the FAO-56 method (Penman-Monteith) were downloaded from the KSU Weather Data Library website for Colby, and compared with values calculated in the above spreadsheet.

Daily precipitation and minimum and maximum temperatures in sheet input_CLIMATE reference the sheets corresponding to the stations listed above in Table 6. This sheet was copied to input_CLIMATE_C, in which temperatures are converted to degrees Celsius for ET calculations. As noted in sheet NOTES, intermediate ET calculations (equations 1-4 from Snyder and Eching) are contained in sheet etRad, and Hargreaves-Samani ETo for a short (0.12 m) reference crop (eqn 23, Snyder and Eching) is given by columns D:K of sheet input_ET. ETr (reference ET for a tall crop, columns L:S of sheet input_ET) are calculated as before: the Hargreaves ET for each station is multiplied by a corresponding monthly calibration ratio developed by SWE ("stPM ETr/Hargreaves Eto") and given in range d3:o10 of the same sheet for the eight stations.

Table 7. Potential evaporation for a tall (0.5 m) reference crop

month	Atwood[1]	Colby[1]	Goodland[1]	Norton[1]	Oberlin[1]	Wakeeny[1]	NE - Harlan[1]	NE – Benkel-man[1]	Colby[2]	Colby discrep.
1	4.17	3.92	3.58	3.71	3.13	3.68	3.35	3.27	4.26	-0.34
2	3.43	3.35	3.35	3.23	2.49	3.18	2.86	2.85	3.95	-0.60
3	5.43	5.45	5.11	5.20	4.20	5.39	4.73	4.59	6.87	-1.42
4	8.12	7.99	8.11	7.82	7.36	8.12	7.63	7.74	9.55	-1.56
5	8.91	8.98	8.86	8.72	8.56	8.26	8.46	8.89	12.03	-3.05
6	10.52	10.20	10.16	10.38	9.48	10.09	10.07	9.77	13.55	-3.35
7	11.05	10.48	10.47	10.77	9.93	10.47	9.76	10.43	13.10	-2.62
8	9.28	8.99	8.87	8.72	7.72	8.61	8.30	8.37	8.94	0.05
9	7.32	7.24	6.78	6.84	6.16	6.78	6.31	6.58	7.17	0.07
10	5.58	5.59	5.36	5.33	4.44	5.36	4.93	4.93	4.89	0.70
11	3.98	3.88	3.83	3.67	3.15	3.70	3.36	3.44	3.70	0.18
12	2.75	2.61	2.47	2.54	2.15	2.52	2.48	2.34	2.07	0.54
Yr (in)	80.54	78.70	76.94	76.94	68.78	76.16	72.23	73.20	90.08	-11.38
Yr (ft)	6.71	6.56	6.41	6.41	5.73	6.35	6.02	6.10	7.51	-0.95

[1]calculated according to procedure developed by Spronk Water Engineers (SWE).
[2]calculated according to Penman-Monteith method by KSU Weather Data Library.

Independently calculated Penman Etr values were available from the KSU Weather Data Library for Colby in 2006. These values and corresponding discrepancies are shown in the two rightmost columns of Table 7. The two sets of numbers for Colby compare reasonably well.

Crop distributions, return flow fractions and water use estimates

Pivot tables were created in the water use data query file as follows:

Sheet Rech_screened: reported pumping by county (rows) and irrigation system type (columns) in range N17:X34. Mean return flow fractions taken over reports with known system types were calculated for each county and over all reports in range L19:L34 of this sheet.

Sheet Crops: total irrigated area by crop (rows) and county (columns) in range B2:R53. The pivot table was copied and pasted by value into file ReportedCropsByCountyFor2006.xls, sheet ReportedCropsbyCo_2006.

The following rule for multiple crops was previously defined by Spronk Water Engineers (see memo by Dale Book and Melissa Geis Mitarotonda, Oct 28, 2004: Republican River Model; 2003 Kansas CIR):

> "For all multiple cropping codes that include corn, acreage should be allocated 80% to corn and 20% to remaining crops. Otherwise, if corn is not included, acreage is divided equally among multiple crops." Additionally, if a multiple crop includes "Other", the weight associated with the other crop is set to zero and is left out of the distribution of unknown crops.

The above rule is implemented by multipliers in range T1:AA52 of sheet ReportedCropsbyCo_2006, which is shown below in Table 8. The multipliers themselves are calculated; for further details, see the formulas in the spreadsheet cells. [Range aa4:aa52 shows the sums over these multipliers for each crop code. Irrigated areas corresponding to unidentified crops (including the "Other" component of multiple crops and crop codes 15-17) are excluded by zero-valued multipliers.

Irrigated areas were condensed into six crop categories (alfalfa, corn, soybeans, grain sorghum, sunflowers and wheat) for each county by taking sums over the products of columns of the pivot table (range c4:q52) and the multiplying factors (range u4:z52). To do this, Excel's SumProduct function was applied in range c56:q61, which shows the total estimated area for each of the six crops within each county. These areas were divided by the total irrigated area for each county (range c62:q62) to give normalized crop distributions for each county in range c65:q70; the sum over the terms of each distribution equals 1 (range c71:q71). The crop distributions are copied from range c65:q70 transposed into range b4:g18 of sheet CropDistribution_2006. These are compared with 2005 crop distributions in range j4:p18 of the same sheet. Irrigated areas were also copied from range c56:q61 and transposed into range b54:g68 of sheet CropDistribution_2006, which is shown below as Table 9.

Crop distributions and corresponding mean return flow fractions for nine counties were selected from these as shown in ranges b26:g34 and i26:i34 for the CIR calculations. These ranges were pasted into sheet results_COUNTY of file KSCIR_update2006.xls, where they were referenced for the 2006 CIR update. The crop distributions and corresponding return flow fractions for the selected counties are shown above in Tables 1 and 2 for 2006 and 2005, respectively.

Table 8. Crop multipliers used to condense reported crops into six representative crops.

Crop	code	Alfal-fa	Corn	Soy-bean	Grain Sorg-hum	Sun-flower	Wheat	sum
Not specified by report	0	0	0	0	0	0	0	0
Alfalfa	1	1	0	0	0	0	0	1
Corn	2	0	1	0	0	0	0	1
Grain Sorghum	3	0	0	0	1	0	0	1
Soybeans	4	0	0	1	0	0	0	1
Wheat	5	0	0	0	0	0	1	1
Oats	6	0	0	0	0	0	0	0
Barley	7	0	0	0	0	0	0	0
Rye	8	0	0	0	0	0	0	0
Dry Beans	9	0	0	0	0	0	0	0
Sunflowers	10	0	0	0	0	1	0	1
Golf Course	11	0	0	0	0	0	0	0
Truck Farm	12	0	0	0	0	0	0	0
Nursery	14	0	0	0	0	0	0	0
Other	15	0	0	0	0	0	0	0
More than one type of crop	16	0	0	0	0	0	0	0
Double Crop	17	0	0	0	0	0	0	0
Alfalfa & Corn	18	0.2	0.8	0	0	0	0	1
Alfalfa & Grain Sorghum	19	0.5	0	0	0.5	0	0	1
Alfalfa & Soybeans	20	0.5	0	0.5	0	0	0	1
Alfalfa & Wheat	21	0.5	0	0	0	0	0.5	1
Alfalfa & other	22	0.5	0	0	0	0	0	0.5
Corn & Grain Sorghum	23	0	0.8	0	0.2	0	0	1
Corn & Soybeans	24	0	0.8	0.2	0	0	0	1
Corn & Wheat	25	0	0.8	0	0	0	0.2	1
Corn & Other	26	0	0.8	0	0	0	0	0.8
Grain Sorghum & Soybeans	27	0	0	0.5	0.5	0	0	1
Grain Sorghum & Wheat	28	0	0	0	0.5	0	0.5	1
Grain Sorghum & Other	29	0	0	0	0.5	0	0	0.5
Soybeans & Wheat	30	0	0	0.5	0	0	0.5	1
Soybeans & Other	31	0	0	0.5	0	0	0	0.5
Wheat & Other	32	0	0	0	0	0	0.5	0.5
Alfalfa, Corn & Grain Sorghum	33	0.1	0.8	0	0.1	0	0	1
Alfalfa, Corn & Soybeans	34	0.1	0.8	0.1	0	0	0	1
Alfalfa, Corn & Wheat	35	0.1	0.8	0	0	0	0.1	1
Alfalfa, Corn & Other	36	0.1	0.8	0	0	0	0	0.9
Alfalfa, Grain Sorghum & Other	39	0.333	0	0	0.333	0	0	0.667
Alfalfa, Wheat & Other	42	0.333	0	0	0	0	0.333	0.667
Corn, Grain Sorghum & Wheat	44	0	0.8	0	0.1	0	0.1	1
Corn, Grain Sorghum & Other	45	0	0.8	0	0.1	0	0	0.9
Corn, Soybeans & Wheat	46	0	0.8	0.1	0	0	0.1	1
Corn, Soybeans & Other	47	0	0.8	0.1	0	0	0	0.9
Corn, Wheat & Other	48	0	0.8	0	0	0	0.1	0.9
Grain Sorghum, Soybeans & Wheat	49	0	0	0.333	0.333	0	0.333	1
Grain Sorghum, Soybeans & Other	50	0	0	0.333	0.333	0	0	0.667
Grain Sorghum, Wheat & Other	51	0	0	0	0.333	0	0.333	0.667
Soybeans, Wheat & Other	52	0	0	0.333	0	0	0.333	0.667
Alfalfa, Corn, Wheat & Other	58	0.0667	0.8	0	0	0	0.0667	0.933
Corn, Grain Sorghum, Soybeans & Wheat	63	0	0.8	0.0667	0.0667	0	0.0667	1

Table 9. Irrigated areas for six specified crops in each county. Also shown are sums over specified crops, total reported irrigated area in each county, and areal fraction of specified crops.

crop: county	Alfalfa	Corn	Soy-bean	Grain Sorg-hum	Sun-flower	Wheat	sum	pivot sum	Repre-sented fraction
CN	2357	24489	1467	388	342	5853	34895	45266	77.1%
DC	1723	5949	543	281	333	739	9568	11322	84.5%
GH	841	6586	1309	264	0	789	9788	10277	95.2%
GO	456	7901	901	1582	0	1208	12050	14416	83.6%
JW	37	1008	164	0	0	0	1209	1209	100.0%
LG	106	4805	131	146	98	725	6011	7412	81.1%
NT	416	5769	1772	89	0	308	8353	9679	86.3%
PL	278	2298	1937	0	0	122	4634	5260	88.1%
RA	2322	6651	1904	638	22	2283	13820	18912	73.1%
RP	0	227	0	0	0	0	227	227	100.0%
SD	2077	51529	5078	786	515	2890	62875	75199	83.6%
SH	3315	61911	1944	1746	5572	11715	86203	111383	77.4%
TH	1121	64217	8310	2454	485	6277	82864	100077	82.8%
TR	46	796	454	177	0	394	1867	2423	77.1%
WA	67	766	0	165	0	67	1064	2316	46.0%
sum	15160	244903	25913	8717	7367	33370	335429	415378	80.8%
Sum over represented counties[1]	13653	223609	23408	6559	7269	30581	305079	379521	80.4%

[1]Sum over the nine counties represented for CIR: CN DC NT PL RA SD SH TH TR.

References

Book, Dale and Melissa Geis Mitarotonda, 2004. Memo (Oct 28): Republican River Model; 2003 Kansas CIR. Pdf file 04Oct_KSCIR.pdf in I:\RRCA_GM\KSData\For2003\SWE_CIR\ .

Snyder, R.L. and S. Eching, 2002. Penman-Monteith daily (24-hour) reference evapotranspiration equations for estimating ET_0, ET_r and HS ET_0 with daily data. Created Jan 6, 2002; revised Feb 2007, copyright Regents of the University of California. Available as a pdf document PMdayDoc.pdf as provided in the first paragraph of a page with a related article by Snyder and Eching at http://www.cimis.water.ca.gov/cimis/publications/evapotranspiration/DYPMexe/DYPM.htm .

2006 water use update (April 12, 2007)

Summary of 2006 water use reports by county

sum over counties	AF PUMPED	gw irr rech af	Irrig acres	rech pct	gw irr use (in)	nonirr gw use af	sw irr use af	sw irr rech af	sw irr acres
CN	55181	7356	45266	13.33%	14.63	923	0	0	0
DC	12342	2001	11322	16.22%	13.08	720	0	0	0
GH	10045	1442	10277	14.36%	11.73	370	0	0	0
GO	14234	1919	14416	13.48%	11.85	933	0	0	0
JW	842	146	1209	17.28%	8.36	439	403	76	759
LG	7294	927	7412	12.71%	11.81	783	0	0	0
NT	9663	1899	9679	19.65%	11.98	740	45	14	110
PL	4578	898	5260	19.61%	10.44	59	94	19	200
RA	20223	2879	18912	14.23%	12.83	435	7	1	60
RP	211	46	227	21.80%	11.13	0	373	64	128
SD	79011	10463	75199	13.24%	12.61	1317	46	6	90
SH	123160	15792	111383	12.82%	13.27	2035	0	0	0
TH	118776	14859	100077	12.51%	14.24	3028	0	0	0
TR	2582	362	2423	14.02%	12.79	681	0	0	0
WA	3044	444	2316	14.59%	15.77	0	23	3	27
sum	461184	61433	415378	13.32%	13.32	12464	991	182	1374

Unmetered water use summary and estimated over-reporting by county

sum over counties	unmetered gw irr use af	unmetered area acres	est. over-reported use af	adj.use (af)	adj. use (inches
CN	28414	22737	2066	53115	14.08
DC	954	879	80	12262	13.00
GH	3469	3820	347	9698	11.32
GO	6669	6761	614	13619	11.34
JW	335	378	34	808	8.02
LG	3330	3172	288	7006	11.34
NT	644	624	57	9607	11.91
PL	56	31	3	4575	10.44
RA	8641	7944	722	19501	12.37
RP	0	0	0	211	11.13
SD	28832	26431	2467	76544	12.21
SH	72432	60533	5650	117510	12.66
TH	57349	46363	4234	114542	13.73
TR	1243	1187	108	2474	12.25
WA	936	722	66	2978	15.43
sum	213303	181582	16735	444450	12.84

Comparison of results for programs pumpRechv5 and PumpRech_puse

Program PumpRechv5 was run from folder I:\RRCA_GM\KSData\For2006\Prelim\gw\ to produce a preliminary version of Kansas 2006 groundwater use files for input to RRPP on April 11, 2006.

Program PumpRech_puse was run from folder I:\RRCA_GM\KSData\ForScenarios\gw\ to produce comparable scenario files for input to RRPP for year 2006 under the standard option. Under this option, conditions were set to be the same as for the annual updates, so that files written to the folders ks_standard\ should be the same as those created for the preliminary 2006 update. To determine whether this is so, program compare_rrpp_files_v2 was run to compare the two sets of gw files in the above two folders. The program reads both versions of each file and compares them by calculating the sum, average, maximum and minimum of differences taken over all active grid cells (ibound <>0). The program was run as follows:

Run program compare_rrpp_arrays_v2 from I:\RRCA_GM\KSData\ForScenarios\gw\:

- src\compare_rrpp_arrays_v2 >compare_rrpp_arrays_v2.log

[enter year of interest (2006) after the above command to respond to program prompt for year]

Results of the comparison for 2006 are listed below.

```
Read ibound array file from input\
30655.0000  nonzero grid cells
Compare rrpp input files in two folders:
Paths from I:\RRRCA_GM\KSData\ForScenarios\gw\ :

Folder 1 path = I:\RRCA_GM\KSData\For2006\Prelim\gw\
Folder 2 path = ks_standard\
Enter year of files to compare:
Compare file versions for year 2006
Differences:
mo       sum      max      min      avg file name
 5      0.00     0.00     0.00    0.000 2006.05.pmp
 5      0.00     0.00     0.00    0.000 2006.05.rcg
 6      0.00     0.00     0.00    0.000 2006.06.pmp
 6      0.00     0.00     0.00    0.000 2006.06.rcg
 7      0.00     0.00     0.00    0.000 2006.07.pmp
 7      0.00     0.00     0.00    0.000 2006.07.rcg
 8      0.00     0.00     0.00    0.000 2006.08.pmp
 8      0.00     0.00     0.00    0.000 2006.08.rcg
 9      0.00     0.00     0.00    0.000 2006.09.pmp
 9      0.00     0.00     0.00    0.000 2006.09.rcg
10      0.00     0.00     0.00    0.000 2006.10.pmp
10      0.00     0.00     0.00    0.000 2006.10.rcg
11      0.10   199.30 -199.20    0.000 2006.agw
11      0.00     0.00     0.00    0.000 2006.mi
```

The above results indicate that files created by the two program versions (pumprechv5 and pumprech_puse) are the same except for the irrigated acres file, which shows max and min differences of +/-199.30 acres, respectively. These differences appear to be due to an accumulation of irrigated area at grid cell (row,col=131,102) that exceeds 640 acres by 199.3

acres, and which is transferred to a neighboring cell by the program pumprech_puse but not by program pumprechv5. This indicates that the scenario version of the program, PumpRech_puse, is duplicating results for the standard case as desired for 2006 pumping data. The scenario version of the program should therefore be suitable for running the updates in 2006 and future years for the groundwater files. The program swrechv2 was used as before to produce the surface water files.

Table 1. Summary of reported irrigation groundwater use, return flow, acres irrigated, and associated factors 1990-2006 [1]

year	count	AF USED	Recharge	ACRES IRR	almena factor [2]	Irr sys type reporting use frac [3]	gwret fract [4]	exp (gwret fract) [5]	gwirr Aqfract [6]
1990	4456	566374	126403	394554	0.273920	0.000463	0.27537	0.23075	0.98285
1991	4435	528165	114748	397733	1.000000	0.997219	0.21726	0.22250	0.98291
1992	4435	291376	59899	373792	1.000000	0.998983	0.20557	0.21454	0.98291
1993	4435	281258	57041	374880	0.192952	0.998992	0.20281	0.20688	0.98320
1994	4435	431165	83944	403071	0.257029	0.998900	0.19469	0.19948	0.98407
1995	4417	402135	76865	393220	0.312114	1	0.19114	0.19235	0.98513
1996	4491	398847	73443	409719	0.268311	0.997543	0.18414	0.18547	0.98656
1997	4502	452003	76564	420913	0.350641	0.999041	0.16939	0.17884	0.98903
1998	4546	414466	65789	419084	0.338365	0.993294	0.15873	0.17245	0.99018
1999	4541	361263	56352	418213	0.346541	0.975275	0.15599	0.16629	0.99109
2000	4567	534368	79229	428718	0.515766	0.980815	0.14827	0.16034	0.99425
2001	4659	454382	66034	421811	0.393780	0.980115	0.14533	0.15461	0.99658
2002	4389	569191	80875	429597	0.231046	0.971911	0.14187	0.14909	0.99786
2003	4418	520768	72524	428348	0.746556	0.975100	0.13935	0.14376	0.99935
2004	4451	518373	71192	425135	1.000000	0.968740	0.13756	0.13862	1
2005	4469	426043	57823	420413	1.000000	0.980314	0.13574	0.13366	1
2006	4388	461184	61433	415378	1.000000	0.990182	0.13321	0.12888	

[1] sheet Summary, file PumpRech8901_part2.xls, folder i:\RRCA_GM\KSData\ForScenarios\

[2] almena factor: irrigated area within Almena district supplied only by groundwater diversions as fraction of total reported irrigation area within Almena district; see Table 3 for details. From Almena_qq01-03.xls, sheet 2001-3ReturnFlows: [col. e] / [col. d].

[3] irrigation system type: fraction of reported water use for which irrigation system type was identified.

[4] gwret fract: gw irrigation return flow as fraction of reported pumping. Calculated as weighted avg over assumed return flow fractions by system type, weighted by reported water use, in sheet Rech of wu8901_irr.xls for years 1989-2001 (range m19:m35) and in sheet Rech of RRCS_Overlap_Groups_ForYYYY.xls for each year 2002-2005; see folder i:\RRCA_GM\KSData\ForScenarios\, and sheet Rech in this file.

[5] exp(gwretfract): regression estimate of gw irrigation return flow as fraction of reported pumping (see [5]). Regression estimate is used for 1990 instead of value calculated in sheet Rech (previous column) because the fraction of reports identifying irrigation system type was nearly zero in 1990, whereas it was nearly one thereafter; see note [4]. The regression estimate was calculated in sheet Rech

of wu8901_irr.xls using $r(y) = a\exp(bk)$ for y from 1990 to 2005 with k = y-1988, a = 0.2393, b = -0.0364, based on years 1991-2005 (n = 15, r^2 = 0.9693, s.e. = 0.004562).

[6] gwirr_aqfract: groundwater irrigation authorized quantity at the end of each year as a fraction of authorized quantity at the end of 2005. This is an approximation based on a pd shapefile snapshot of authorized quantities dated May 16, 2006 [pds_nwks_2006may16.shp in I:\GIS\ks\pds\], and calculated in a copy of RRCS_Overlap_Groups_For2005_Final_all.xls, sheet months [range i42:i57 for years 1990-2005].

Table 2. Comparison of metered and unmetered groundwater use for irrigation 1989-2006. [1]

year	no. metered	Un-metered use (AF) [2]	Un-metered area (ac) [2]	metered use/area hm (ft) [2]	un-metered use/area hu (ft) [2]	difference d=hu-hm: unmetered-metered (ft)	est.over-reported use d*Au	adjusted total use (AF)	metered use as fraction of reduced total [2]	use_in [3]	adjust-ed total use in [4]
1989	210	556501	370943	1.269	1.500	0.2312	85745	502700	0.060	17.82	15.23
1990	209	535185	368556	1.206	1.452	0.2461	90720	475654	0.061	17.23	14.47
1991	206	500673	371817	1.106	1.347	0.2402	89327	438838	0.058	15.94	13.24
1992	205	276969	348994	0.581	0.794	0.2126	74210	217166	0.055	9.35	6.97
1993	277	261077	341113	0.598	0.765	0.1677	57207	224051	0.080	9.00	7.17
1994	351	389298	358009	0.929	1.087	0.1586	56777	374387	0.107	12.84	11.15
1995	390	357345	343881	0.918	1.039	0.1213	41726	360409	0.124	12.27	11.00
1996	456	350380	352589	0.837	0.994	0.1566	55199	343648	0.133	11.68	10.06
1997	637	384021	347940	0.955	1.104	0.1487	51750	400253	0.167	12.89	11.41
1998	1017	319614	315210	0.920	1.014	0.0935	29464	385002	0.251	11.87	11.02
1999	1030	279305	308410	0.769	0.906	0.1371	42269	318994	0.252	10.37	9.15
2000	1115	394855	307319	1.153	1.285	0.1315	40413	493955	0.288	14.96	13.83
2001	1179	328947	295167	0.948	1.114	0.1663	49094	405289	0.291	12.93	11.53
2002	1230	405398	298116	1.238	1.360	0.1219	36348	532843	0.312	15.90	14.88
2003	1292	367951	295370	1.102	1.246	0.1433	42325	478442	0.316	14.59	13.40
2004	1358	361076	285486	1.115	1.265	0.1498	42777	475595	0.334	14.63	13.42
2005	1447	291469	273064	0.912	1.067	0.1555	42463	383580	0.350	12.16	10.95
2006	2099	213303	181582	1.084	1.175	0.0909	16735	444450	0.556	13.32	12.84
Avg:											
'96-'01	906	342854	321106	0.943	1.068	0.1252	44698	391190	0.233	12.46	11.18
'90-'00	536	368066	342167	0.924	1.076	0.1518	57188	366578	0.145	12.62	10.91
'01-'05	1301	350959	289421	1.061	1.213	0.1518	42611	455132	0.320	14.05	12.85
'90-'05	775	362720	325684	0.993	1.114	0.1208	52632	394251	0.206	13.08	11.54

[1] sheet metered_vs_unmetered_use, file wu8901_irr.xls, folder i:\RRCA_GM\K8Data\ForScenarios\

[2] Calculated values for metered and unmetered use per unit area, hm and hu, and metered use as a fraction of all reported use, are based on sums of use and area restricted to reports with nonzero values for both reported use and area, although this includes almost all reported use and area. [From range p24:p29 of the same sheet: 0.790 as fraction of reports, 0.996 as fraction of reported use, AF; 0.997 as fraction of reported area, acres].

[3] use_in: 12*AF_USED/ACRES_IRR; [4] adjusted use in: reported use is reduced by est. over-reported use (d*Au).

Table 3. Almena factors: analysis of irrigated area within Almena district 1989-2006. [1]

year	almena npds [1]	almena gwuse [2]	almena gwrech [3]	almena gwacres [4]	almena acres [5]	alm gwac only [6]	almena factor [7]
1989	151	13582	3144.2	6447	5,136	1,311	0.203350
1990	151	12186	3190.5	7086	5,145	1,941	0.273920
1991	153	10853	2876.6	7095	0	7,095	1.000000
1992	155	6048.3	1601.7	7334	0	7,334	1.000000
1993	155	4567.5	1197.4	6810	5,496	1,314	0.192952
1994	155	8221.4	2237.9	7505	5,576	1,929	0.257029
1995	156	9344.8	2582	8106	5,576	2,530	0.312114
1996	165	4888.9	1301.5	6649	4,865	1,784	0.268311
1997	169	8293.3	2254.2	7492	4,865	2,627	0.350641
1998	171	7178.8	1959.9	7353	4,865	2,488	0.338365
1999	173	7318.2	1865.2	7445	4,865	2,580	0.346541
2000	176	5867.7	1415.1	7992	3,870	4,122	0.515766
2001	176	6891.9	1718	8200	4,971	3,229	0.393780
2002	159	9138	2250	7228	5,558	1,670	0.231046
2003	157	8074	1993	6605	1,674	4,931	0.746556
2004	156	8465	1979	7294	0	7,294	1.000000
2005	130	6306	1460	6500	0	6,500	1.000000
2006	154	6267	1428	6505	0	6,267	1.000000

[1] number of reporting points of diversion within the Almena irrigation district.
[2] total reported use by points of diversion within the Almena irrigation district.
[3] total estimated return flow by points of diversion within the Almena irrigation district.
[4] total irrigated area reported by points of diversion within the Almena irrigation district.
[5] total irrigated area receiving surface water deliveries from the Almena irrigation district.
[6] total area within the Almena district irrigated only by groundwater (cols. [4] – [5]).
[7] total area within the Almena district irrigated only by groundwater as fraction of total reported irrigated area within Almena district (cols. [4] – [5]).

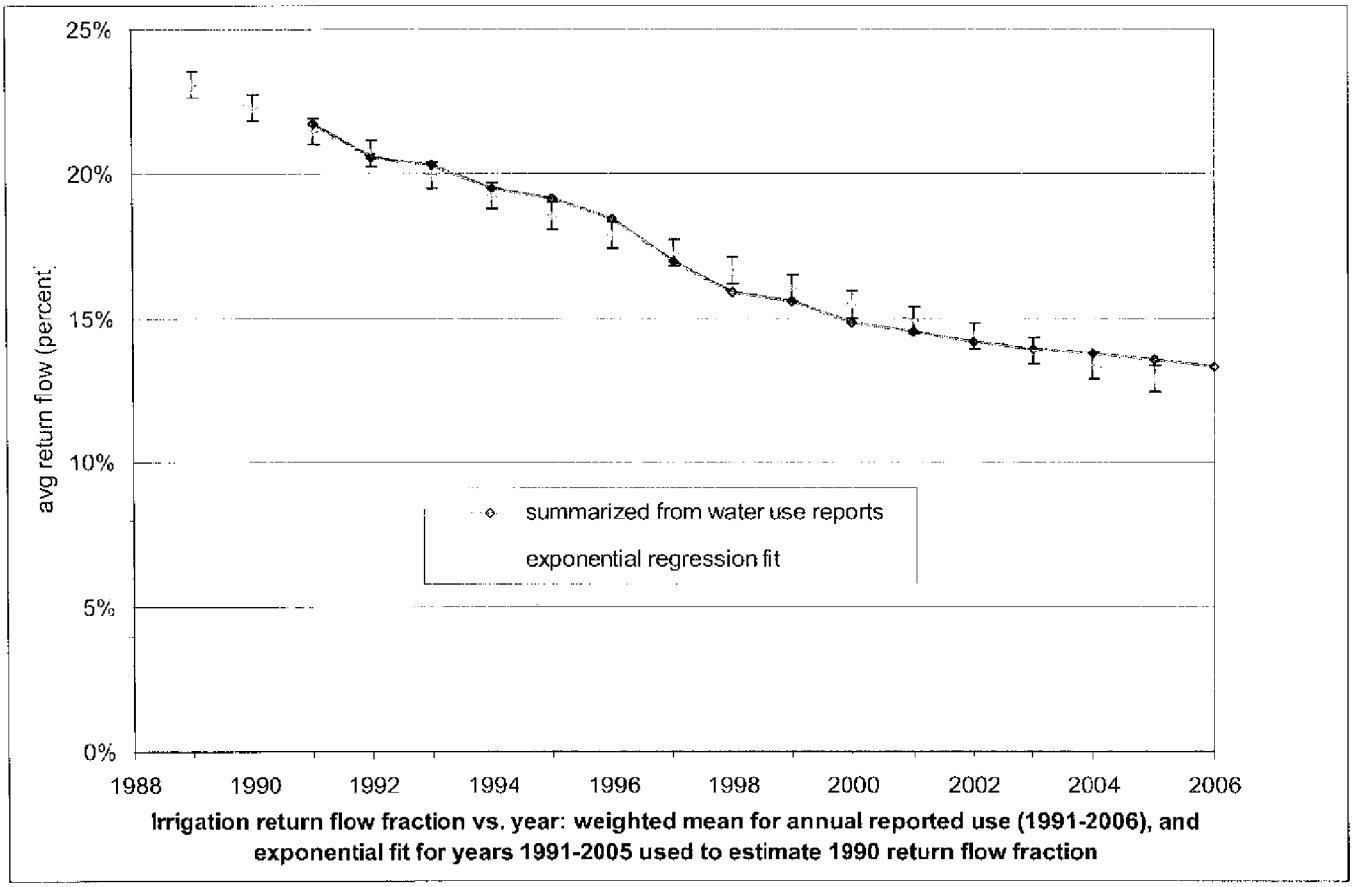

Fig. 1. Irrigation return flow fraction vs. year. Chart ChReturnFlowPct_vs_year, file wu8901_irr.xls, folder i:\RRCA_GM\KSData\ForScenarios\

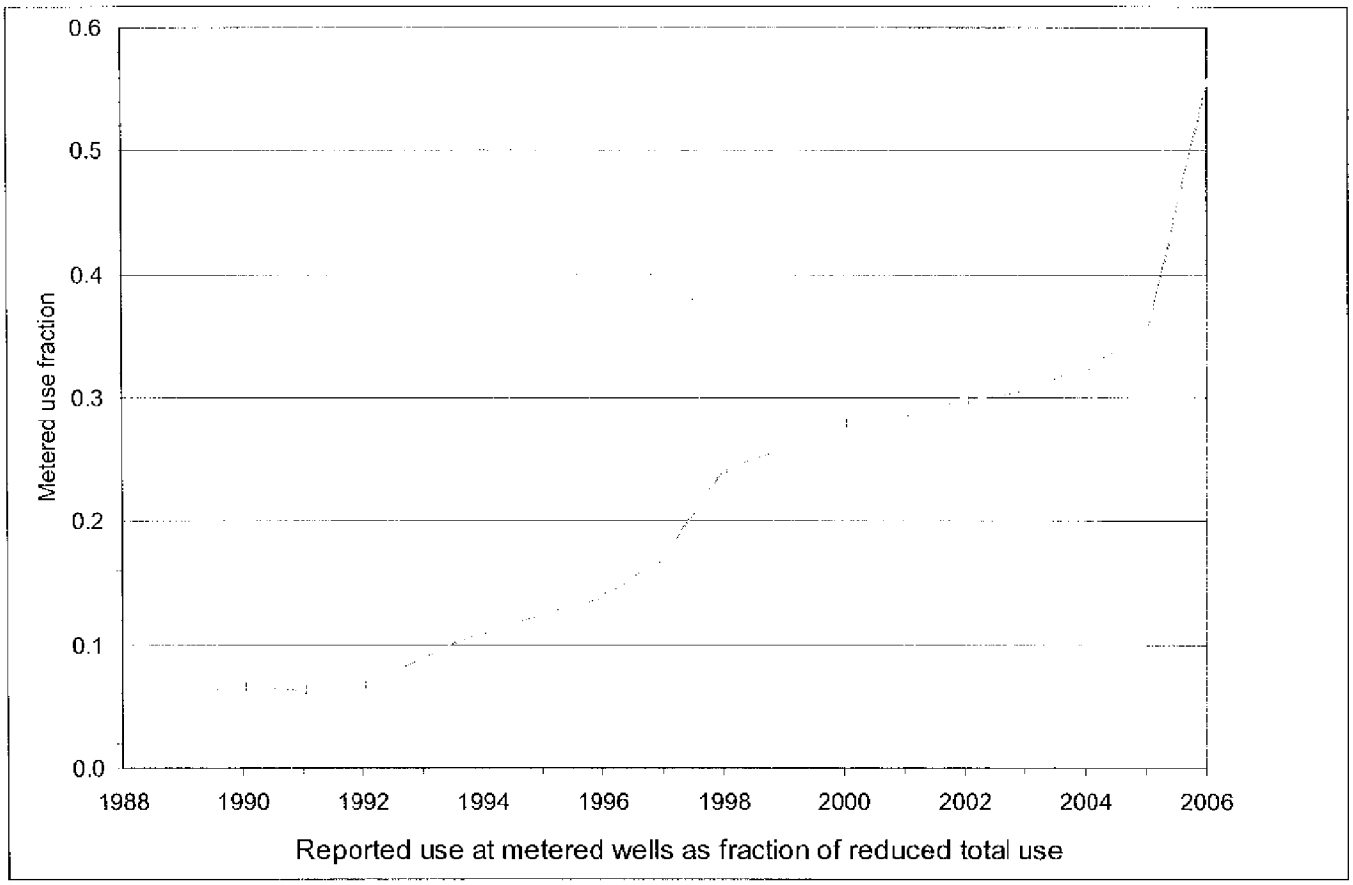

Fig. 2. Metered use as fraction of reduced total use; total use is reduced by estimated over-reported use by unmetered wells. Chart ChMeteredUse_Fraction_of_total, file PumpRech8901_part2.xls, folder i:\RRCA_GM\KSData\ForScenarios\

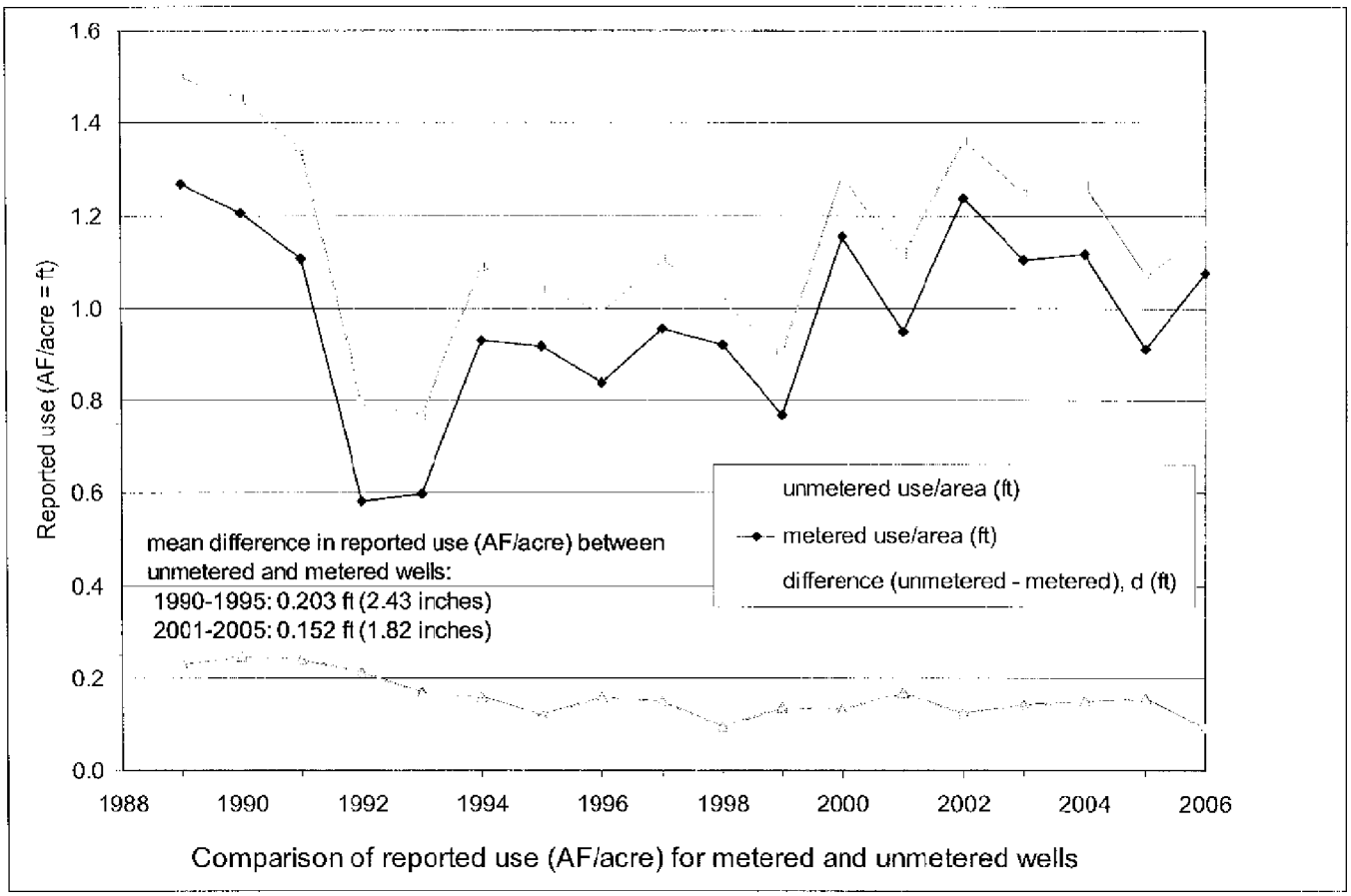

Fig. 3. Reported use (AF/acre) for metered and unmetered wells. Chart ChReportedUse_ft_vs_year, file PumpRech8901_part2.xls, folder i:\RRCA_GM\KSData\ForScenarios\

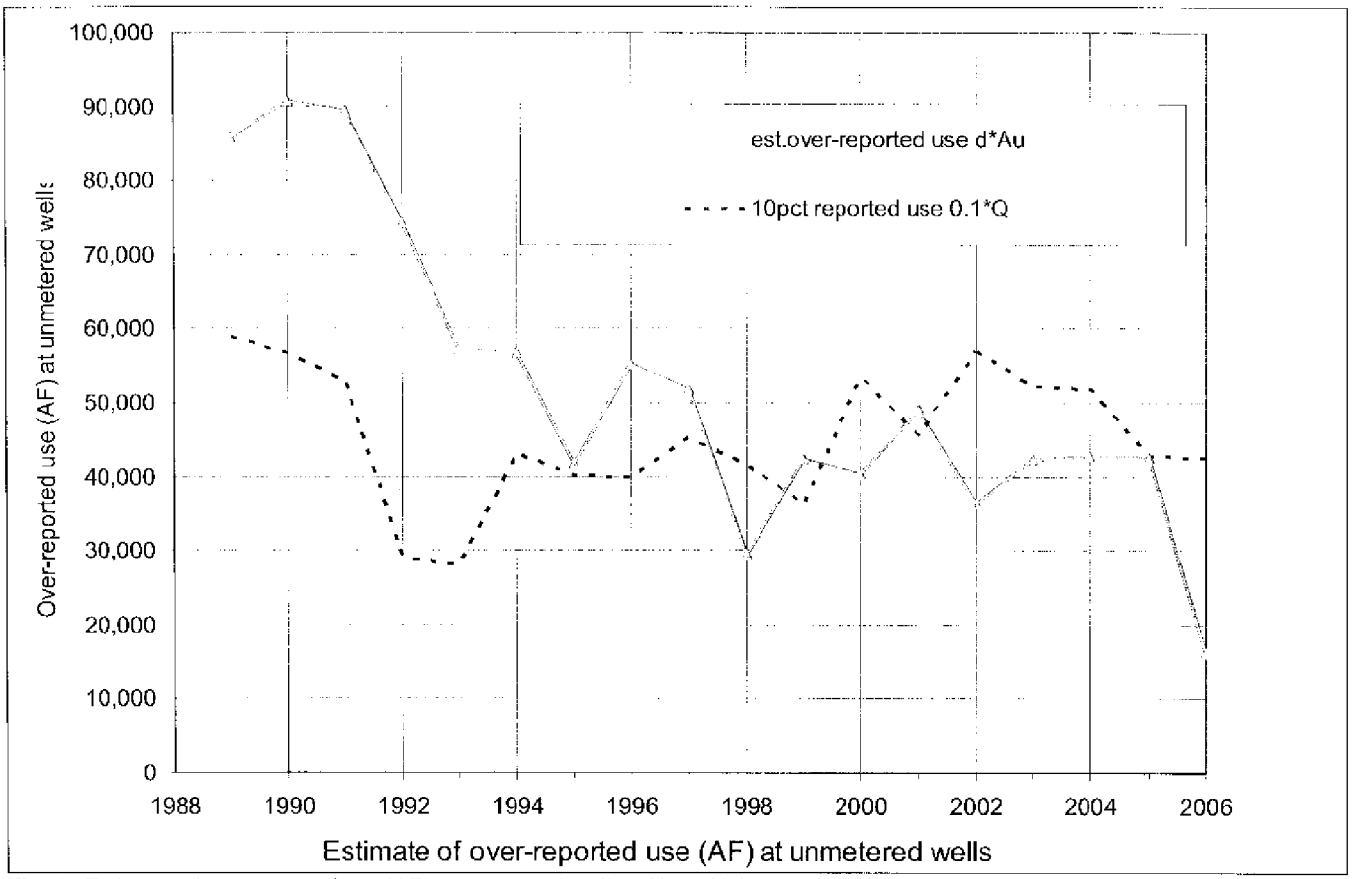

Fig. 4. Estimate of over-reported use (AF) at unmetered wells. Chart ChOverReportedUse_AF_vs_year, file PumpRech8901.xls, folder i:\RRCA_GM\KSData\ForScenarios\