Volume 2

A PC Based Computer Program To Calculate Water Rights and Water in Storage in a 2-mile Radius Circle

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VOLUME2

INTRODUCTION

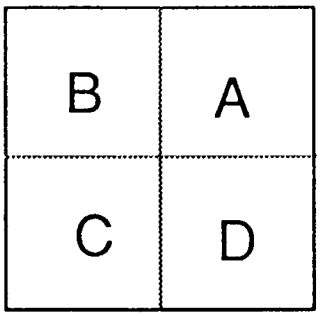
Volume2 is a program to calculate the amount of water available in storage within a 2 mile radius circle from a given location. The program uses data stored in two separate files to do this; a saturated thickness data file and a water rights data file. The saturated thickness file has a value assigned for every section in the district. The water rights file is set up as a binary file with each water right assigned an x,y coordinate within the Kansas state parameters.

To run the program the following four parameters must be defined:

1. Location of the quarter section (township, range, section, quarter section)
2. Porosity (default is 0.20)
3. Saturated thickness data file (default is sathick.dat)*
4. Water rights data file (default is wttrght.dat)*

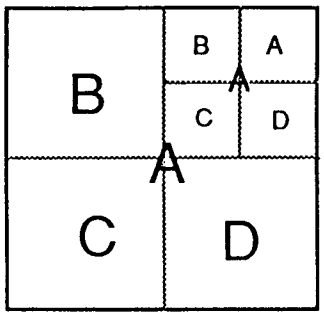
* Note: These files must be located on the same floppy or hard disk as Volume2.

Given these input data, Volume2 will generate the results calculated for the sixteen 10 acre locations in the specified quarter section. Quarter sections are lettered by the following convention:



For example, if the given quarter is 4S 38W 3A, Volume2 will calculate the results for the following points:

4S 38W 3 AAA	4S 38W 3 AAB	4S 38W 3 AAC	4S 38W 3 AAD
4S 38W 3 ABA	4S 38W 3 ABB	4S 38W 3 ABC	4S 38W 3 ABD
4S 38W 3 ACA	4S 38W 3 ACB	4S 38W 3 ACC	4S 38W 3 ACD
4S 38W 3 ADA	4S 38W 3 ADB	4S 38W 3 ADC	4S 38W 3 ADD



An additional program required for running Volume2 is LEOBASE.DAT. This program is used in the conversion of the township and range data into x,y coordinate locations. LEOBASE.DAT must be located on the same floppy or hard disk as Volume2. This program was provided on the same disk as the other required programs. For more information regarding LEOBASE.DAT, see associated Kansas Geological Survey documents.

OUTPUT DATA

The basic data for the sixteen 10 acre locations will be stored in a file called VOLUME.OUT. The output data will consist of three columns; the first being the section, including the location within the quarter section (for example AAA), the second being the amount of water in storage in the two mile radius circle centered on that 10 acre location, and the third is the sum of the individual water rights allocated within that circle. Volume in storage and water rights data are given in acre-feet.

The second output file is called THICKNESS.OUT, and provides a method to review which sections are involved in the saturated thickness calculations and what percentage of their area is inside the 2 mile radius circle. The file shows (for each of the sixteen 10 acre locations): column 1; the 81 sections under consideration*, column2; the acres of overlap of each section by the circle, column3; the percentage of the section within the circle, and, column4; the associated saturated thickness. The sum of (column2*column4*porosity) for the 81 sections should equal the

value given for that quarter section in VOLUME.OUT. *Note that these 81 sections are the same for each 10 acre location and are the same sections discussed later in this document (see fig. 1).

The third output file is called RIGHT.OUT. This file is a listing of the water rights summation for each section, giving the x,y location of each water right , the associated value, and the sum of these values. This sum should equal column 3 in VOLUME.OUT.

These files are accessed by typing the following letter at the "do you wish to see the output?" prompt after termination of the program: "V" for VOLUME.OUT, "T" for THICKNESS.OUT, and "R" for RIGHT.OUT. If these files need to be viewed at a later time, they must be accessed in the normal manner, by either "listing" of "typing" the files.

Files on old locations are not retained by the program. If a new location is specified and data calculated, output for all old locations is overwritten. Therefore, for permanent records a hard copy is recommended. An example of each of these three output files is given at the end of this document.

BASIC ALGORITHM

The basic algorithm of the program can be described as follows (code lines 396--474)*. *Hereafter, code line # are represented in the following manner: (396-474):

I. Get input data from user and check its validity (396-435).
    a. center location for calculation (400-411).
    b. porosity (413-417).
    c. saturated thickness data file name (419-426).
    d. water rights data file name (428-435).
II. Prepare output data file (437-442).
III. For all sixteen points do (444-460).
    a. find amount of water from saturated thickness and porosity.
    b. find amount of water allocated to water rights.
IV. Show results (463-474).

Before we discuss the details of the algorithm, we need to understand how points are represented in the program. The saturated thickness data file is a list of section, township amd range numbers with an associated saturated thickness value for each section. These legal locations

need to be converted into x,y coordinates so the program can read them. Two programs are needed; LeoConv2 to convert from legal location to longitude and latitude coordinates, and Project2 to convert the long-lat to x,y. The projection used for Project2 is the Standard Kansas Projection at 1:500000. The term "Standard Kansas" refers to the type of map projection used and the latitude and longitude parameters for the state. Standard Kansas uses a Lambert Conformal projection with the following latitude and longitude parameters: North = 40.125, South = 36.875, East = -94.5, West = -102.125.

For Kansas, there are 35 townships from north to south, 43 ranges west and 25 ranges east (total of 68 ranges). One township-range contains 36 sections. The area of the state can, therefore, be represented approximately by 210 x 408 rectangles (sections). The rectangle with the coordinates (1,1) is located at the upper left corner of the state and rectangle (210,480) is at the lower right corner. The procedures SecToRC (109-115) and SecToAbsRC (118-129) convert the section from its legal location into the absolute row and column equivelant.

The water rights file is already in x,y coordinates, so no conversion is necessary.

DATA RETRIEVAL & CALCULATION (MAIN PROGRAM)

WATER RIGHTS

The water rights data is stored in binary format, because of the large size of the data file. To scan this entire file sixteen times for sixteen 10 acre locations is impractical. Therefore, a series of calculations are made (327-367) to efficiently retrieve the required values.The amount of water allocated to water rights can be found by summing the values which lie within the 2-mile radius circle with center at one of the sixteen positions. We know that all sixteen positions lie within one section (within one mile of each other). Therefore, we can scan the water rights data file one time, retrieving all points within a 2 mile radius circle from the center of the original, given section (procedure: LocateWTRights, 334-353). These values are stored in the global variable WtrData, which is scanned instead of the large water rights file during execution of the program.

SATURATED THICKNESS

To calculate the volume of water available from saturated thickness, we scan the data file and keep only the data that we need in memory, following a procedure similiar to that for the water rights. The procedure LocateArea (134-157) does this. Each section is about 1 square mile. Therefore, in most cases, for a given point location, the sections we are concerned with lie within 2 sections in any direction of the given point (see figure 1 below). Notice that we never need more than 25 sections for the required calculation in this case. However, in cases where the location is

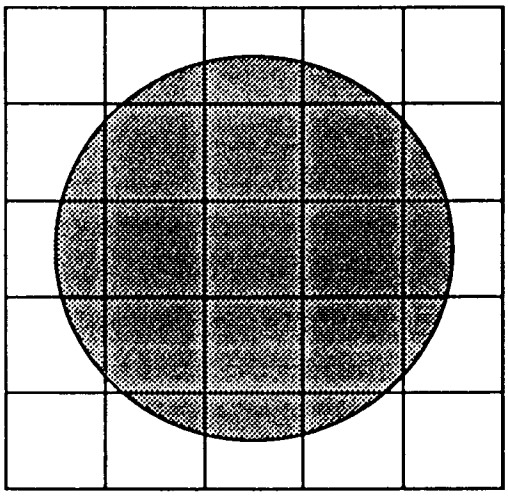


figure 1: 25 x 25 grid (sections) with circle. Demonstrates general case.

within 2 miles (2 sections) of a horizontal county boundary, we need considerably more than 25 sections to perform the required calculations. The reason for this is the offset occurring across the horizontal boundary. Figure 2 is an example of a location requiring the maximum grid size of 81 sections (4 sections are required in the southwest corner). This corresponds to a 9 x 9 grid. Since this is the maximum size, all locations are processed using the 9 x 9 grid. This accounts for the large amount of sections containing zero areas in the output. (Note: There are some areas of

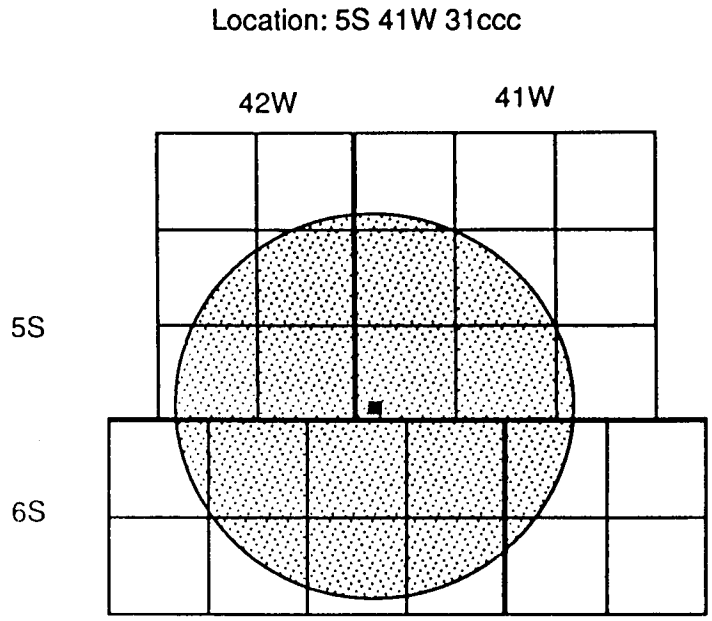


figure 2: Sections and circle demonstrating special case.

Kansas where the sections are considerably larger or smaller than one square mile. However, we need not be concerned with them here).

An important difference between the water rights file and the saturated thickness file is that the saturated thickness data are associated with an area, while the water rights data are associated with a point. This makes finding the volume in storage for the circle considerably more complicated than finding the associated water rights. This complication arises because it is necessary to find the overlapped area of each partial section within the circle. The program allows for three different cases for the 81 sections under consideration:

Case 1: Overlapped area is zero (292).
This case occurs when the section is completely outside the circle. All four corners of the section are further than 2 miles from the center point. This section is not used in calculation of volume in storage.

Case 2: Overlapped area completely within the circle (293).
This case occurs when the section is completely inside the circle. That is, all four corners of the section lie within 2 miles of the center point.

Case 3: Overlapped area is partially within the circle.
The three possibilities for overlap are shown below. In case a, the intersection points are on opposite sides of the section square. In case b they are on the same side, and in case c they are on adjacent sides. Case b is unlikely and, therefore, is discarded.

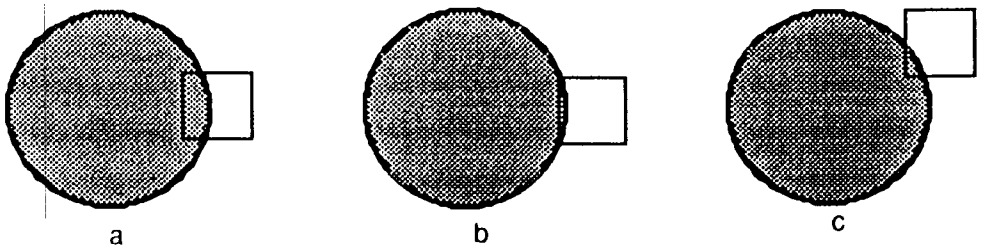


figure 3: examples of overlapping areas.

Once we have found the overlap area of each of the 81 sections we can use the following equation to determine the volume in storage:

volume-of-each-section = overlap-area * saturated thickness.

Summing the volumes thus obtained gives the desired volume in storage for the 2 mile radius circle. Following is a discussion of the calculation for case 3. The partial areas for this case are calculated as outlined below:

I. Locate the intersection points (263-275).
II. Locate the reference points (277-289).
III. Calculate the partial area (297-301
IV. Calculate the curve area (303-370)
V. Calculate overlapped area from partial and curve area (309-313).

Step I: Intersection Points.

Intersection points (fig. 3, p1,p2) can be found by solving the circle and line equations (226-243). The circle will intersect the section side only if one corner of the side is inside the circle and the other is outside (266-267).

Step II: Reference Points

For case 3a (fig. 3a), the reference points are the adjacent corners either inside or outside the circle. For case 3c (fig. 3c), the reference point is the point inside the circle.

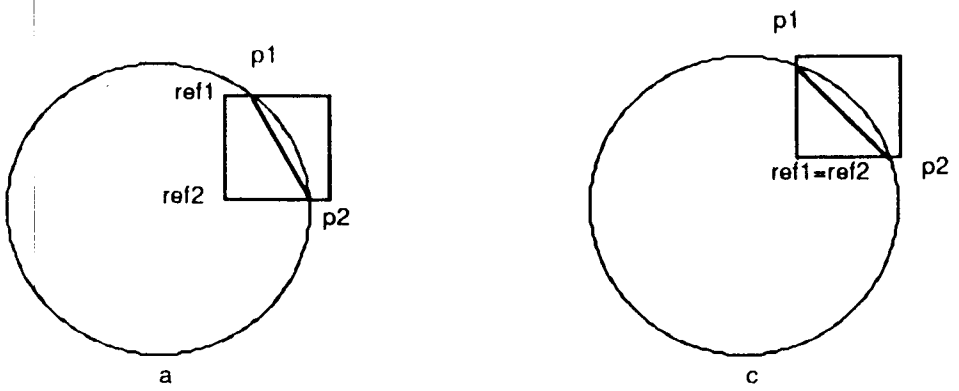


figure 4: Reference and intersection points for partial and curve areas

Step III: Partial Areas

From figure 3, the partial areas are defined as the area enclosed by the reference points and the intersection points. These partial areas can be calculated from the following formulas:

Case a: partial area = distance(ref1,ref2) * (distance (ref1,p1) + distance (ref2,p2))/2

Case c: partial area = distance (ref1,p1) * distance(ref2,p2)/2.

Step IV: Curve Area

The curve area is defined as the area enclosed by line p1-p2 and the arc of the circle. Since the size of the circle is fixed, the area depends only on the length of line p1-p2. In other words, the curve area can be calculated by determining the area of the pie sector p1-0-p2 minus the area of triangle p1-0-p2:

$$\text{curve area} = 2 * \theta r^2 - \left(\frac{d}{2} * h\right)$$

where $\theta = Tan^{-1}\left(\frac{d}{2h}\right)$ in radians

d = distance between p1 and p2

$h = \sqrt{r^2 - (.5d)^2}$

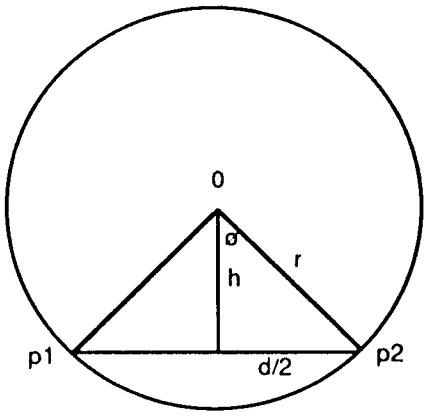


figure 5: Calculation of curve area.

Step V: Overlapped Area

To determine the overlapped area we need to know whether the reference points are located inside or outside the circle:

if inside overlap area = partial area + curve area

if outside overlap area = full area - partial area + curve area.

Figure 6 shows the calculations above graphically. Figure 6a demonstrates the reference points being inside the circle and 6b shows the reference points outside the circle.

After the overlapped area is found, the volume in storage is calculated from the overlapped area * saturated thickness * porosity.

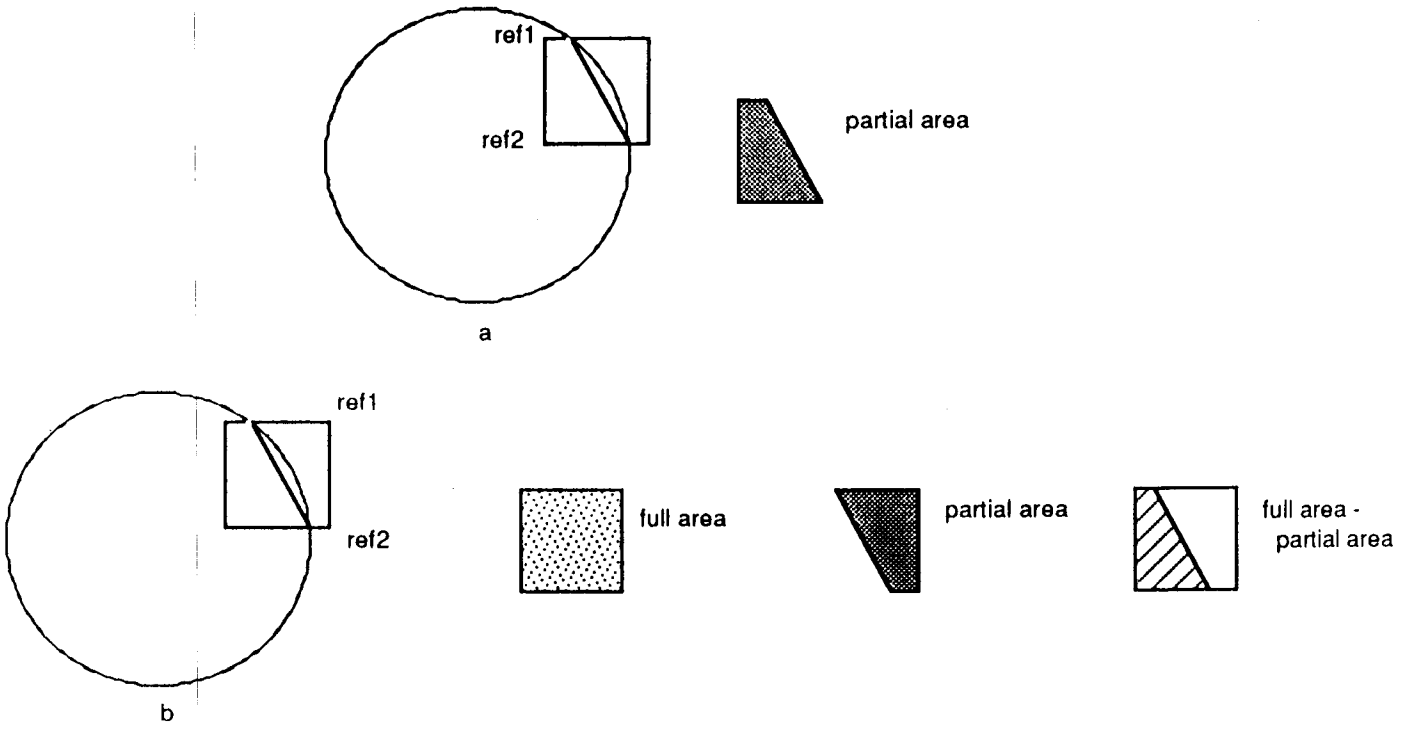


figure 6: Examples of locations of partial areas in relation to their reference points.

INSTALLATION AND OPERATION PROCEDURES

This program comes in the form of 2 51/4 inch floppy disks. The main programs are located on the disk labeled "program disk." The data files are located on the "data disk." To run sucesfully, all these files need to be in one location; that is they cannot be located on 2 separate disks. The following is the advised procedure for installing and running these programs.

1) Create a new directory on a hard disk where these files can be placed.
2) Copy both floppy disks provided into this new directory.
3) Type "volume2." This begins the program.
4) Use the procedure outlined earlier to access output upon completion of the program.
5) Type <Return> to exit the listing prompt.
6) Obtain a hard copy of the output data.
7) This program can be stored permanently on the hard drive or copied at each use.

Output file: volume.out

Legal Location	Volume(Acr.Ft)	WaterRights(Acr.Ft)
T04S R38W Sec 03AAA	182313	2138
T04S R38W Sec 03AAB	181569	2138
T04S R38W Sec 03AAC	183489	2138
T04S R38W Sec 03AAD	184610	1828
T04S R38W Sec 03ABA	180614	2138
T04S R38W Sec 03ABB	179751	2444
T04S R38W Sec 03ABC	181708	2050
T04S R38W Sec 03ABD	182642	2138
T04S R38W Sec 03ACA	185011	2138
T04S R38W Sec 03ACB	184080	1995
T04S R38W Sec 03ACC	186478	1685
T04S R38W Sec 03ACD	187435	1740
T04S R38W Sec 03ADA	186890	1828
T04S R38W Sec 03ADB	185891	1828
T04S R38W Sec 03ADC	188520	1828
T04S R38W Sec 03ADD	189041	1828

Output file: right.out

WATER RIGHTS BREAKDOWN:

FOR T04S R38W Sec 03AAA:

X	Y	WATER RIGHTS(AcR-Ft.)
5.656	25.932	310
5.605	25.839	306
5.746	25.803	288
6.002	25.856	88
6.001	25.840	55
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 2138

FOR T04S R38W Sec 03AAB:

X	Y	WATER RIGHTS(AcR-Ft.)
5.656	25.932	310
5.605	25.839	306
5.746	25.803	288
6.002	25.856	88
6.001	25.840	55
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 2138

FOR T04S R38W Sec 03AAC:

X	Y	WATER RIGHTS(AcR-Ft.)
5.656	25.932	310
5.605	25.839	306
5.746	25.803	288
6.002	25.856	88
6.001	25.840	55
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 2138

FOR T04S R38W Sec 03AAD:

X	Y	WATER RIGHTS(AcR-Ft.)
5.605	25.839	306
5.746	25.803	288
6.002	25.856	88
6.001	25.840	55
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 1828

FOR T04S R38W Sec 03ABA:

X	Y	WATER RIGHTS(AcR-Ft.)
5.656	25.932	310
5.605	25.839	306
5.746	25.803	288
6.002	25.856	88
6.001	25.840	55
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 2138

FOR T04S R38W Sec 03ABB:

X	Y	WATER RIGHTS(AcR-Ft.)
5.593	25.918	306
5.656	25.932	310
5.605	25.839	306
5.746	25.803	288
6.002	25.856	88
6.001	25.840	55
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 2444

FOR T04S R38W Sec 03ABC:

X	Y	WATER RIGHTS(AcR-Ft.)
5.656	25.932	310
5.605	25.839	306
5.746	25.803	288
6.001	25.840	55
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 2050

FOR T04S R38W Sec 03ABD:

X	Y	WATER RIGHTS(AcR-Ft.)
5.656	25.932	310
5.605	25.839	306
5.746	25.803	288
6.002	25.856	88
6.001	25.840	55
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 2138

FOR T04S R38W Sec 03ACA:

X	Y	WATER RIGHTS(AcR-Ft.)
5.656	25.932	310
5.605	25.839	306
5.746	25.803	288
6.002	25.856	88
6.001	25.840	55
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 2138

FOR T04S R38W Sec 03ACB:

X	Y	WATER RIGHTS(AcR-Ft.)
5.656	25.932	310
5.605	25.839	306
5.746	25.803	288
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 1995

FOR T04S R38W Sec 03ACC:

X	Y	WATER RIGHTS(AcR-Ft.)
5.605	25.839	306
5.746	25.803	288
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 1685

FOR T04S R38W Sec 03ACD:

X	Y	WATER RIGHTS(AcR-Ft.)
5.605	25.839	306
5.746	25.803	288
6.001	25.840	55
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 1740

FOR T04S R38W Sec 03ADA:

X	Y	WATER RIGHTS(AcR-Ft.)
5.605	25.839	306
5.746	25.803	288
6.002	25.856	88
6.001	25.840	55
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 1828
FOR T04S R38W Sec 03ADB:

X	Y	WATER RIGHTS(AcR-Ft.)
5.605	25.839	306
5.746	25.803	288
6.002	25.856	88
6.001	25.840	55
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 1828

FOR T04S R38W Sec 03ADC:

X	Y	WATER RIGHTS(AcR-Ft.)
5.605	25.839	306
5.746	25.803	288
6.002	25.856	88
6.001	25.840	55
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 1828

FOR T04S R38W Sec 03ADD:

X	Y	WATER RIGHTS(AcR-Ft.)
5.605	25.839	306
5.746	25.803	288
6.002	25.856	88
6.001	25.840	55
5.968	25.810	164
5.981	25.747	143
5.790	25.738	320
5.771	25.660	292
5.617	25.728	172

TOTAL WATER RIGHTS: 1828

Output file: thickness.out
Note: This file is only a sample of the thickness.out file. This sample consists of the first of the sixteen 10 acre locations.

SATURATED THICKNESS AND OVERLAP AREA BREAKDOWN:

FOR T04S R38W Sec 03AAA:

CONTRIBUTING SECTION.	OVLP. AREA (acres)	% COVERAGE	SAT. THICKNESS
T03S R37W Sec 17	0	0	96
T03S R37W Sec 18	0	0	95
T03S R37W Sec 19	0	0	95
T03S R37W Sec 20	0	0	97
T03S R37W Sec 29	0	0	100
T03S R37W Sec 30	0	0	96
T03S R37W Sec 31	0	0	105
T03S R37W Sec 32	0	0	109
T03S R38W Sec 13	0	0	95
T03S R38W Sec 14	0	0	97
T03S R38W Sec 15	0	0	101
T03S R38W Sec 16	0	0	100
T03S R38W Sec 17	0	0	85
T03S R38W Sec 18	0	0	68
T03S R38W Sec 19	0	0	67
T03S R38W Sec 20	0	0	72
T03S R38W Sec 21	0	0	80
T03S R38W Sec 22	0	0	85
T03S R38W Sec 23	0	0	92
T03S R38W Sec 24	0	0	95
T03S R38W Sec 25	147	23	94
T03S R38W Sec 26	534	83	100
T03S R38W Sec 27	564	88	96
T03S R38W Sec 28	210	33	92
T03S R38W Sec 29	0	0	89
T03S R38W Sec 30	0	0	80
T03S R38W Sec 31	0	0	89
T03S R38W Sec 32	14	2	84
T03S R38W Sec 33	603	95	100
T03S R38W Sec 34	637	100	108
T03S R38W Sec 35	632	100	119
T03S R38W Sec 36	524	83	105
T03S R39W Sec 13	0	0	55
T03S R39W Sec 24	0	0	62
T03S R39W Sec 25	0	0	72
T03S R39W Sec 36	0	0	87
T04S R37W Sec 05	0	0	118
T04S R37W Sec 06	0	0	115
T04S R37W Sec 07	0	0	131

T04S R37W Sec 08	0	0	133
T04S R37W Sec 17	0	0	129
T04S R37W Sec 18	0	0	143
T04S R37W Sec 19	0	0	150
T04S R37W Sec 20	0	0	145
T04S R37W Sec 29	0	0	150
T04S R37W Sec 30	0	0	169
T04S R38W Sec 01	554	88	118
T04S R38W Sec 02	644	100	119
T04S R38W Sec 03	635	100	117
T04S R38W Sec 04	617	97	113
T04S R38W Sec 05	18	3	105
T04S R38W Sec 06	0	0	104
T04S R38W Sec 07	0	0	119
T04S R38W Sec 08	0	0	119
T04S R38W Sec 09	258	41	123
T04S R38W Sec 10	615	97	127
T04S R38W Sec 11	611	95	130
T04S R38W Sec 12	204	32	144
T04S R38W Sec 13	0	0	130
T04S R38W Sec 14	12	2	144
T04S R38W Sec 15	16	2	137
T04S R38W Sec 16	0	0	132
T04S R38W Sec 17	0	0	128
T04S R38W Sec 18	0	0	128
T04S R38W Sec 19	0	0	132
T04S R38W Sec 20	0	0	132
T04S R38W Sec 21	0	0	134
T04S R38W Sec 22	0	0	141
T04S R38W Sec 23	0	0	145
T04S R38W Sec 24	0	0	156
T04S R38W Sec 25	0	0	167
T04S R38W Sec 26	0	0	150
T04S R38W Sec 27	0	0	150
T04S R38W Sec 28	0	0	140
T04S R38W Sec 29	0	0	134
T04S R38W Sec 30	0	0	136
T04S R39W Sec 01	0	0	100
T04S R39W Sec 12	0	0	124
T04S R39W Sec 13	0	0	129
T04S R39W Sec 24	0	0	133
T04S R39W Sec 25	0	0	131