School of Irrigation

Texas A&M AgriLife Extension

Landscape Water Budgeting

(Class Manual for Online Training)

Currently Pending Approval for
TCEQ Landscape Irrigation Credits

For Questions and Course Content:
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This course and associated training materials were developed by the Texas A&M School of Irrigation – Texas A&M AgriLife Extension Service under the direction of Dr. Guy Fipps and Charles Swanson. All materials were developed for Educational Purposes Only.

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Please note that students who complete this course as a requirement for TCEQ Landscape Irrigation Licensing Programs Continued Education may only do so once every licensing period. Students who repeat the training within the same renewal period will not receive training credit.

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Table of Contents

Section 1

What is a Water Budget?

Water Budgeting vs. Irrigation Scheduling

Water budgeting is usually an estimate of the amount of water to allocate to landscape irrigation used for determination of:

- **Maximum Applied Water Allowance**
- **Estimated Applied Water Budgets**
- **Water Use Tracking**

Water Budget versus Irrigation Scheduling

- Irrigation scheduling calculations
  - Can be complicated
  - Are usually based on running a daily balance on ET, soil moisture levels and other factors
- Water budgeting calculations
  - Can be as simple or as complicated as is needed
  - Are usually based on a monthly or annual analysis

Water Budgeting

- **Maximum Applied Water Allowance** (or a "do not exceed")
  - Set by a regulatory agency
  - As measured by a water meter
- **Estimated Applied Water Budgets**
  - For a worst case (zero rain)
  - Expected use (normal rainfall) basis
  - Maximum water conservation
- **Water Use Tracking**
  - To compare actual monthly water use to one or more of the above

Water Budgeting versus Irrigation Scheduling

Irrigation schedule is a daily or weekly detailed water balance analysis to determine the amount of water needed to:

- Optimize plant growth and quality,
- Maintain plants/landscapes at a desired level,
- Ensure the survival of plants/landscapes, and/or
- Other specified goals

Water Budget vs. Irrigation Scheduling

Today, we will start with irrigation scheduling and use it as a starting point for conducting water budgeting.

Water Budgeting
↑
Irrigation Scheduling

Allowable Stress

- A factor reflecting an "acceptable" turf quality when water supply is reduced
- Research shows that turf water supply can be reduced by 40% or more and still maintain an acceptable appearance

Section 2

Determining the Water Requirements of Landscapes

Evapotranspiration, ET

- Measurement of the total requirements of plants and crops
- The word, **evapotranspiration** is a combination of the words, "evaporation" and "transpiration"
- Very difficult to measure directly
- Can be calculated using weather data

Evapotranspiration, ET

- Many methods have been proposed to calculate ET from weather data
- Methods that use solar radiation have proven to be the most accurate

Solar Radiation

There are many different types of solar radiation, including solar radiation measured above the atmosphere, solar radiation that is scattered, diffused or reflected from clouds and solar radiation at the earth surface. For calculation of ET, we need to know the solar radiation at the earths surface or Rs.

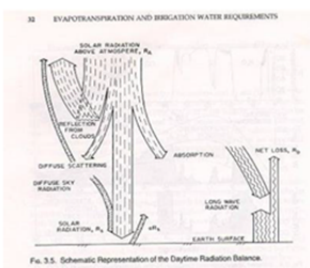


Fig. 3.5. Schematic Representation of the Daytime Radiation Balance.

Reference Evapotranspiration, ETo

- The standardized Penman-Monteith Equation is considered the most accurate
- Requires hourly or daily data on solar radiation, temperature, relative humidity and wind speed
- Calculates the water requirements of a hypothetical cool season grass growing 4-inches tall under well watered conditions

Reference Evapotranspiration, ETo

- Also is called the "Potential ET" (PET)
- Used as a reference from which the water requirements of all other plants can be determined
- Note: ETo = PET
- ETo is the potential evapotranspiration (PET) of a cool season reference grass growing 4-inches tall under well watered conditions

Crop Coefficient (Kc)

- Crop coefficients (Kc) are used to relate ETo to the water requirements of specific plants and crops
- Percentage of plant water use of ETo
- Sometimes referred to as the plant coefficient, turf coefficient, etc.
- May be written as Kc (plant coefficient), Tc (turf coefficient), Lc (landscape coefficient), etc.

Crop Coefficient (Kc)

- Kc varies depending on the type of plant/crop and growth stage
- Kc may also be adjusted for such factors as:
  - Plant density
  - Desired plant quality
  - Level of stress
  - Site conditions
  - Micro-climates
  - Etc.

Turf Coefficient, Tc

- A factor used to relate ETo to the actual water use by a specific type of turf
- Reflects the percentage of ETo that a specific turf type requires for maximum growth

Turf Coefficients	
Warm Season	0.6
Cool Season	0.8
Sports Turf	0.8

Adjustment Factor, Af

- A modification to the crop coefficient
- Used to reduce water application for allowable stress or reflect a desired plant quality

Plant Quality Adjustment Factor, Af	
Plant Quality	Af
Maximum	1.0
High	0.8
Normal	0.6
Low	0.5
Minimum	0.4

Equation for Calculating Water Requirements (WR)

WR = ETo x Kc x Af

- **Example:** What is the Water Requirement (WR) the first week of Dallas in 2007 for a warm season turf with a desired low plant quality? ETo = 1.59 inches (1st week of August, 2007 in Dallas, taken from the Texas ET network) Kc = 0.6 (warm season turf) Af = 0.5 ("Low plant quality" adjustment)

- WR = 1.59 x 0.6 x 0.5

- WR = 0.48 inches (1st week in Aug.)

Effective Rainfall (Rainf)

- The portion of rainfall that does not runoff, but becomes available for plant water use
- A simplified method to account for the complex relationships between infiltration and runoff during rain events
- Includes the effects of slope, soil type, surface roughness (i.e., "depressional storage") and other factors
- Does not consider how wet or dry the soil is

Effective Rainfall (Rainf)

- Should be estimated based on actual site conditions
- When using long-term averages (monthly or yearly average rainfall data), can assume Rainf is about 2/3 (67%) of normal rainfall
- DO NOT use 2/3 for individual storm events or daily/weekly actual rainfall data
- Most landscape (home sites, parks, commercial properties) have very shallow root zone depths which may limit the effective rainfall

Effective Rainfall (Rainf)

For individual storms or weekly totals of actual irrigation and in absence of site-specific data for homes and commercial sites:

Effective Rainfall	
0 – 0.10 inches	Rainf = o
0.10 – 1.0 inches	Rainf = "full amount"
1.0 – 2.0 inches	Rainf = 0.67 x total
> 2.0 inches	Rainf = 0

Effective Rainfall (Rainf)

- **Example:** During the 1st week in Aug. 2007, Dallas received 0.04 inches of rainfall
  - Since the total rainfall is less than 0.1 inches, we assume no rainfall fell

Water Requirements with Rainfall

- **Problem:** During the 1st week in Aug. 2007, Dallas received 0.04 inches of rainfall, what is our total WR (previous example)
  - Since the total rainfall is less than 0.1 inches, we use a Rainf = 0
  - WR = (ETo x Kc x Af) – Rainf
  - WR = (0.48 inches) – 0
  - WR = 0.48 inches

Irrigation System Efficiency Water requirements (WR) can be adjusted for irrigation system efficiency.

- Application efficiency (AE)
  - Spray/evaporative losses before the water reaches the ground
- Distribution efficiency (also known as the distribution uniformity –DU)
  - How even the water is applied over the area

Irrigation System Efficiency

- Spray/evaporative losses typically range from 20-30% -(application efficiency of 70-80%)
- Distribution efficiency (or distribution uniformity) varies widely (40-90+%) Agrilife Extension recommendations are:
- Generally, do not adjust WR for DU
  - Use DU as a tool for defining the condition of the irrigation system
- Use professional judgment for adjustments by the application efficiency (AE)
  - Generally not when producing irrigation schedules
  - May be necessary in some water budgeting applications

How to Adjust for Irrigation Efficiency

- WRa = WR / AE
- **Example:** Our irrigation system in Dallas has an estimated AE of 80%
  - WRa = 0.48 / 0.8
  - WRa = 0.60 inches for the first week in Aug.

Quiz 1:

1. ***KC may also be adjusted for such factors as:***

   A. Plant density

   B. Desired plant quality

   C. Level of stress

   D. Site conditions

   E. Micro-climates

   F. All of the above

2. ***Evapotranspiration, (ET) can't be calculated using weather data.***

   - True
   - False

3. ***Effective Rainfall includes the effects of slope, soil type, surface roughness and other factors.***

   - True
   - False

4. ***The methods that use solar radiation to calculate ET have proven to be the most accurate.***

   - True
   - False

5. ***Evapotranspiration, (ET) is very easy to measure directly.***

   - True
   - False

6. ***The Adjustment Factor (Af): (Check all that apply)***

   - Is a modification to the crop coefficient
   - Is used to balance or equations
   - Is used to reduce water application for allowable stress

7. ***Water budgeting is usually an estimate of the amount of water to allocate to landscape*** irrigation used for determination of: (Check all that apply)

- o Estimated Applied Water Budgets
- o Water wasted
- o Water Use Tracking
- o Maximum Applied Water Allowance

8. Irrigation scheduling calculations

A. Usually based on running a daily balance on ET, soil moisture levels and other factors

B. Usually based on a monthly or annual analysis

9. Water budgeting calculations

A. Usually based on running a daily balance on ET, soil moisture levels and other factors

B. Usually based on a monthly or annual analysis

10. Reference Evapotranspiration, ETo is also called the "Potential ET" (PET).

- o True
- o False

11. Crop coefficients (Kc) are used to relate ETo to the water requirements of specific plants and crops.

- o True
- o False

12. The word evapotranspiration is a combination of the words "evaporation" and "transpiration".

- o True
- o False

13. If during the 1st week in Aug. 2007, Dallas received 0.04 inches of rainfall:

A. Since the total rainfall is equal to 0.04 inches, we assume no rainfall fell

B. Since the total rainfall is less than 0.1 inches, we assume no rainfall fell

C. Since the total rainfall is more than 0.01 inches, we assume no rainfall fell

D. Since the total rainfall is less than 0.3 inches, we assume no rainfall

14. Kc varies depending on the type of plant/crop and growth stage.

- o True
- o False

15. Water requirements (WR) can be adjusted for irrigation system efficiency using Application efficiency (AE) and/or the Distribution.

- o True
- o False

16. ***The portion of rainfall that does not runoff, but becomes available for plant water use is also known as _______.***

A. Total Rainfall

B. Effective Rainfall

C. Rainfall Runoff

17. The Standardized Penman-Monteith Equation is considered the <u>less</u> accurate to calculate ETo.

- o True
- o False

18. Effective Rainfall considers how wet or dry the soil is.

- o True
- o False

Section 3

Scheduling Concepts

Irrigation Frequency
The process is to:

- First calculate the Plant Available Water (PAW)
- Then calculate the Irrigation Frequency (I) and station runtime (RT)

Irrigation Frequency

- The soil and root zone depth determines the frequency of irrigation
- The practice is to:
  - Wait to irrigate until the plants have depleted the water in the root zone
  - Run the irrigation system just long enough to fill back up the root zone
- Usually, these calculations are done on a weekly basis

Definitions

- Plant Available Water (PAW)
  - The amount of water in the effective root zone available for plant uptake
- Effective root zone (D)
  - The depth of the root zone that contains about 80% of the total root mass
- Soil Water Holding Capacity (SWHC)
  - The amount of water that can be held or stored in the soil
  - Usually measured as inches of water per foot of soil
- Managed Allowable Depletion (MAD)
  - How dry the soil is allowed to become between irrigations (50% for most plants)

How to Calculate Plant Available Water

- PAW = D x SWHC x MAD
  - PAW = Plant Available Water in root zone
  - D = Effective root zone depth
  - SWHC = Soil Water Holding Capacity
  - MAD = Managed Allowable Depletion

Effective Root Zone

- The depth containing about 80% of the total root mass
- Excludes "tap" and "feeder" roots
- Easily measured with a soil probe

Soils

Typical Water Holding Capacity (inches of water per foot of soil)

Soil Texture	At Field Capacity	At Permanent Wilting Point	Soil Water Holding Capacity	Plant Available Water (@ MAD = 50%)
Sand	1.0-1.4	0.2-0.4	0.8-1.0	0.45
Sandy Loam	1.9-2.3	0.6-0.8	1.3-1.5	0.70
Loam	2.5-2.9	0.9-1.1	1.6-1.8	0.85
Silt Loam	2.7-3.1	1.0-1.2	1.7-1.9	0.90
Clay Loam	3.0-3.4	1.1-1.3	1.9-2.1	1.00
Clay	3.5-3.9	1.5-1.7	2.0-2.2	1.05

Plant Available Water for Three Root Zone Depths at 50% MAD

Soil Texture	Soil Water Holding Capacity inches of water per foot of soil	Available Water @ 50% MAD (inches of water **per foot of soil**)	Available Water @ 50% MAD (inches of water **per inch of soil**)	Total Plant Available Water (inches water)		
				2" Root Zone	4" Root Zone	6" Root Zone
Sand	0.90	0.45	0.038	0.08	0.15	0.23
Loam	1.70	0.85	0.71	0.14	0.28	0.48
Clay	2.10	1.05	0.088	0.18	0.35	0.53

Note how much water is available in a 2 inch, 4 inch, and 6 inch soil.

Calculating the Plant Available Water Dallas Example, Checking the Units

The turf has 5 inch roots in loam soil (SWHC = 1.8 inches / ft.)

- Step One: Check units for root depth and SWHC
- Convert units of rooting depth if necessary
  - SWHC = 1.8 inches / ft
  - Root zone depth = 5 inches = 5 /12 ft = 0.42 ft

Calculating Station Runtime Definitions:

- Precipitation Rate – measurement in inches per hour of how fast an irrigation system applies water to a landscape
- Station – sprinkler group on a common valve that may be part of an automated irrigation system that operates at the same time.
- Runtime – how long a station is operated during an irrigation event

Plant Available Water Dallas Example

- PAW = D x SWHC x MAD
  - D = (Effective root zone depth) = 0.42 ft
  - SWHC = (Soil Water Holding Capacity) = 1.8 in / ft
  - MAD = (Managed Allowable Depletion) = 0.5
- PAW = 0.42 x 1.8 x 0.5
- PAW = 0.38 inches

How to Calculate Irrigation Frequency

- I = WR / PAW
  - I = Number of Irrigations Per Week
  - WR = Water Requirement
  - PAW = Plant Available Water
- I = 0.59 / 0.38
- I = 1.55 times / week → 2 times

* Note: Always round up to the next irrigation event

Station Runtime

- RT=(WR x 60) / (I x PR)
  - RT – Station Runtime (minutes)
  - WR – Water Requirement (inches per week)
  - I – Number of Irrigations per week
  - PR – Precipitation Rate (inches per hour)

Station Runtime
Dallas Example

- RT = (WR x 60) / (I x PR)
  - WR = 0.58 inches per week
  - I = 2
  - PR = 0.5 inches per hour
- RT = (0.58 x 60) / (2 x 0.5)
- RT = 34.8 minutes for each irrigation

Irrigation Scheduling Worksheet

USEFUL EQUATIONS

1. Water use = PET x Ax K_c
2. Available water = AWHC x Effective root zone depth

1. Refer to the ETo Table for 19 cities in Texas to answer the following questions.

   a) What is the average monthly water requirement (in inches) in Dallas for a bermudagrass turf growing in July with a turf coefficient of 0.6 and an adjustment factor of 0.6?

   b) What is the average daily water requirement (in inches)?

2. a) If a loam soil has an available water holding capacity of 1.8 in/ft, how much water can be held within a 6-inch root zone?

   b) With an managed allowable depletion (MAD) of 50%, how much water can be depleted between irrigations?

c) With a average daily water use of 0.15 inches, how many days can you go between irrigations?

d) How much water (in inches) should be applied during each irrigation event?

3. a) Station 1 has a precipitation rate of 0.50 inches per hour. How long (in minutes) must station 1 run for each irrigation in order to meet the turf water requirement 0.45 inches?

b) If station 2 has a precipitation rate of 0.75 inches per hour, how long must it be operate to apply 0.45 inches?

c) If station 3 has a precipitation rate of 0.50 inches per hour and has an application efficiency of 75%, how long must station 3 run to apply 1 inch of water over the entire area?

<u>Quiz 2:</u>

1. It determines the frequency of irrigation: (Check all that apply)

- Soil Type
- Weather
- Location
- Root zone depth

2. The concept of irrigation frequency is to: (Check all that apply)

- Wait to irrigate until the plants have depleted the water in the root zone
- Irrigate frequently to save water
- Irrigate as frequently as possible
- Run the irrigation system just long enough to fill back up the root zone

3. Irrigation frequency calculations are usually done on a monthly basis.

- True
- False

4. The process of irrigation frequency is:

A. First, calculate Irrigation Frequency (I), then, station runtime (RT) and the Plant Available Water (PAW).

B. First, calculate Irrigation Frequency (IF), then, Running Time (RT) and the Plant Average Water (PAW).

C. First, calculate the Plant Available Water (PAW), then calculate the irrigation Frequency (I) and Station Runtime (RT).

5. On the equation for Plant Available Water PAW = D x SWHC x MAD:

PAW is used for____

D is used for ____

SWHC is used for____

MAD is used for____

A. The amount of water in the effective root zone available for plant uptake

B. The depth of the root zone that contains about 80% of the total root mass

C. The amount of water that can be held or stored in the soil

D. How dry the soil is allowed to become between irrigations (50% for most plants)

6. Effective Root Zone:

A. The depth containing about 80% of the total root mass

B. Excludes “tap” and “feeder” roots

C. Easily measured with a soil probe

D. All of the above

7. The amount of water that can be held or stored per <u>yard</u> of soil depth is the soil water holding capacity.

- o True
- o False

8. Station Runtime definitions:

Precipitation Rate

A. How long a station is operated during an irrigation event

B. Sprinkler group on a common valve that may be part of an automated irrigation system that operates at the same time

C. Measurement in inches per hour of how fast an irrigation system applies water to a landscape

Station

A. How long a station is operated during an irrigation event
B. Sprinkler group on a common valve that may be part of an automated irrigation system that operates at the same time
C. Measurement in inches per hour of how fast an irrigation system applies water to a landscape

Runtime

A. How long a station is operated during an irrigation event
B. Sprinkler group on a common valve that may be part of an automated irrigation system that operates at the same time
C. Measurement in inches per hour of how fast an irrigation system applies water to a landscape

9. The following equation I = WR / PAW is:

- o True
- o False

10. The amount of water in the effective root zone "available" for plant uptake is the plant available water.

- o True
- o False

Section 4

Zoning Concepts

Zone vs. Station

- A zone in an irrigation system is defined by such factors as:
  - Plant water needs
  - Soil characteristics
  - Sun exposure / micro-climates
- A station is determined by:
  - Available flow and pressures
  - Application device (sprinkler type)

Zone vs. Station

- Characteristics of a poorly zoned landscape include:
  - Plant types of mixed water requirement and growth characteristics
  - Impractical turf areas
  - Impractical shrub and tree plantings
- Characteristics of a poorly designed station include:
  - Excessive pressure loss in the pipe system
  - Inadequate flow rate for the number of sprinkler heads
  - Mixed sprinkler heads (types)
  - Precipitation rate inappropriate for the soil type
  - Poor Distribution Uniformity

Zoning

- Defined by:
  - Plant water needs
  - Soil characteristics
  - Seasonal growth response
  - Maintenance requirements
  - Exposure to sun
  - Size / shape of the landscape

Grouping Plants by Water Use

- Regular Watering Zone
- Occasional Watering Zone
- Natural Watering Zone

Regular Watering Zone

- Requires watering once every week or more ONCE ESTABLISHED, not recently planted, in the absence of rain
- Plants include:
  - Turfgrasses
  - Annual flowers

Occasional Watering Zone

- Requires watering once every two or three weeks ONCE ESTABLISHED, in the absence of rain
- Plants include:
  - Perennial flowers
  - Tender woody shrubs
  - Vines

Natural Watering Zone

- Requires only natural rainfall ONCE ESTABLISHED
- Plants include:
  - Tough woody shrubs
  - Vines
  - All trees

Quiz 3:

1. Inadequate flow rate for the number of sprinkler heads is a:

A. Characteristic of a poorly zoned landscape
B. Characteristic of a poorly designed station

2. Mixed sprinkler heads (types) is a:

A. Characteristic of a poorly zoned landscape
B. Characteristic of a poorly designed station

3. The zoning is defined by the Annual Growth Response.

- True
- False

4. The zoning is defined by the characteristics of the soil.

- True
- False

5. Impractical turf areas are a:

A. Characteristic of a poorly designed station
B. Characteristic of a poorly zoned landscape

6. A station is determined by: (Check all that apply)

- Soil characteristics
- Available flow and pressures
- Plant water needs
- Application device (sprinkler type)
- Sun exposure / micro-climates

7. Precipitation rate inappropriate for the soil type is a:

A. Characteristic of a poorly zoned landscape
B. Characteristic of a poorly designed station

8. Impractical shrub and tree plantings are a:

A. Characteristic of a poorly designed station
B. Characteristic of a poorly zoned landscape

9. Grouping plants by water use:

Regular Watering Zone____

Occasional Watering Zone____

Natural Watering Zone____

A. Requires watering once every week or more ONCE ESTABLISHED, in the absence of rain
B. Requires watering once every two or three weeks ONCE ESTABLISHED, in the absence of rain
C. Requires only natural rainfall ONCE ESTABLISHED except for periods of drought

10. For Regular Watering Zone, the plants included are turfgrasses and flowers.

- o True
- o False

11. The zoning is defined by:

A. Maintenance requirements
B. Exposure to sun
C. Size/shape of the landscape
D. All of the above

12. Excessive pressure loss in the pipe system is a:

A. Characteristic of a poorly designed station
B. Characteristic of a poorly zoned landscape

13. A zone in an irrigation system is defined by such factors as: (Check all that apply)

- o Application device (sprinkler type)
- o Sun exposure/micro climates
- o Soil characteristics
- o Plant water needs
- o Available flow and pressures

14. Plant types of mixed water requirements and growth characteristics are:

A. Characteristics of a poorly designed station
B. Characteristics of a poorly designed landscape

15. The zoning is defined by the Plant Water Needs.

- o True
- o False

16. For Natural Watering Zones the plants included are: vines, tough woody shrubs and established shade trees.

- o True
- o False

17. Poor DU is a:

A. Characteristic of a poorly designed station
B. Characteristic of a poorly zoned landscape

Section 5

Precipitation Rate

Determining Precipitation Rate
3 Common Methods:

- Catch Can Method
- Area Flow Method
- Meter Method

Steps to Calculating Precipitation Rate Using the Catch Can Method

1. Select catch device
2. Determine Throat Area (At)
3. Identify station and location of heads
4. Lay out catch devices
5. Run each station
6. Record Catch Volumes (V)
7. Calculate Precipitation Rate (PR)

Calculating the Throat Area (At) of the Catch Can (Use for Circular Catch Cans)

- $At = \frac{\pi \times d\ 2}{4}$
  - At – Throat Area (square inches)
  - Π – Pi (3.14)
  - d – diameter (inches) of can

*Note: If the catch can is square or rectangular, calculate the area of the opening.

  - Area = length (inches) x width (inches)

How to Calculate the Precipitation Rate from Catch Cans Recorded in Milliliters (ml)

- $PR = \frac{\Sigma V \times 3.6612}{n \times At \times RT}$
  - PR – Precipitation Rate
  - ΣV – Summation of catch can volumes, ml
  - 3.6612 – Conversion factor
  - N – Number of catch devices
  - At – Throat Area of catch device
  - RT - Test Runtime

How to Calculate Precipitation Rate Using the Area Flow Method

- Determine the Flow Rate of each station
  - Reference manufacturers specifications
- Determine Coverage Area
  - Square feet
- Calculate Precipitation Rate

Basic Precipitation Rate Equation

- $PR = \frac{96.25 \times GPM}{A}$
  - PR – Station Precipitation Rate
  - 96.25 – Constant converts GPM to inches per hour
  - GPM – Total Flow Rate through the station
  - A – Area of Coverage

How to Calculate the Precipitation Rate Using the Meter Method

- Determine Coverage Area
- Record Initial Meter Reading
- Run station
- Record Final Meter Reading
- Calculate Precipitation Rate

Calculate Flow Rate in GPM

- Final Meter Reading – Initial Meter Reading
  Test Runtime
  - Meter Reading – gallons
  - Test Runtime – minutes
  - 1 cubic foot = 7.48 gallons

Calculate the Precipitation Rate

- PR=96.25 x GPM
  A
  - PR – Station Precipitation Rate
  - 96.25 – Constant converts GPM to inches per hour
  - GPM – Total Flow Rate through the station
  - A – Area of Coverage

Precipitation Rate Worksheet

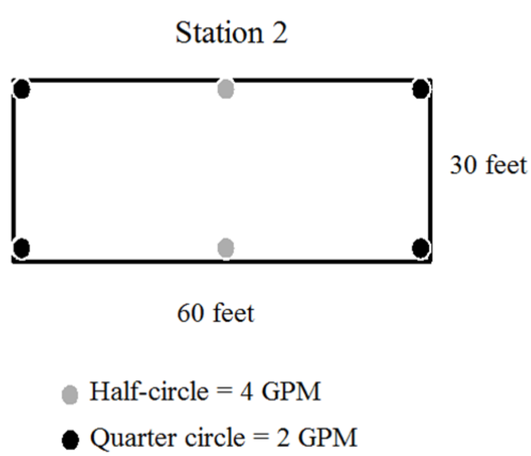
Area/Flow Method

1. Station 1 on an irrigation system applies water over a rectangular area 50 feet wide by 100 feet long. Station 1 is set to run 30 minutes and the following meter readings were taken. What is the estimated precipitation rate (in inches per hour) for station 1?

   Initial meter reading: 3580 gallons

   Final meter reading: 4600 gallons

2. Determine the precipitation rate (in inches per hour) for station 2.



Catch Can Method

1. A catch can test was conducted for station 4 using a conical shaped catch device with a "throat" opening area of 15 square inches. The following catch can volumes were recorded (in milliliters) over a 10 minute period:

Catch Can Volumes (milliliters)

45 32 43 33 39 54 23 51 28 22 43 22

What is the precipitation rate (in inches per hour) for station 3?

2. A catch can test was conducted for station 4. The following 12 can depths were recorded over a 30 minute period:

Catch Can Depth - Inches

0.7 0.8 0.5 0.6 0.5 0.9 0.4 0.5 0.6 0.6 0.7 0.7

What is the precipitation rate (in inches per hour) for station 4?

Section 6

Landscape Water Budgeting

Water Budgeting

- Will usually be less involved than producing an irrigation schedule
- Goal is to determine volume of water needed not runtimes
- Seek a balance between accuracy and time/effort requirements
- Spreadsheets/databases are usually used to organize data and perform calculations
- Cities typically use GIS (geographical information systems) for city-wide water budgeting

Water Budgeting App-Rate Software

- Software developed to assist TCEQ on establishment of application rates for wastewater disposal permitting
- Conducts a monthly water balance
- Determines if a chosen application rate will work
- Includes soil moisture tracking
- Used monthly ETo data (http://texaset.tamu.edu)
- Software is available as a free download at http://itc.tamu.edu

Water Budgeting
Typical Data Needs

- Monthly water records
  - Separate meter for irrigation, or
  - Adjust meter records for non-irrigation water use
- Landscape/irrigated area
  - Actual area, or
  - Calculated as a typical ratio for:
  - hard space vs. landscape area
- Monthly ETo and rainfall data

Accounting for Non-Irrigation Use

- Indoor use based on the number of occupants
- Indoor use based on type of facility (residence, apartment, etc.)
- Winter vs. Summer Utility records

Accounting for Non-Irrigation Use

- Estimating indoor use
  - Average person uses 80-100 gallons a day
- Largest use
  - Flushing toilets
  - Average toilet = 2.9 gallons per flush
  - Ultra low flow toilets = 1.6 gallons per flush
- Second largest
  - Showers and baths
  - Most faucets use 1.5 gpm

Determining Kc to Use Grouping Plants By Water Use

- For a single or small number of properties, determine the total area of:
  - Turf
  - Regular Watering Zone
  - Occasional Watering Zone
  - Natural Watering Zone
- For a large number of properties:
  - Use total area and
  - Estimates of the percentage of each plant grouping

3

Accounting For Rainfall

- Typically use average rainfall and an effective rainfall percentage
- Slopes and hard spaces complicate the analysis due to runoff
- Soils have a maximum water holding capacity, so don't over compensate for rainfall and runoff

Water Budgeting Worksheet

1. **What is the total landscape area for my residence located in Bryan, Texas (in ft^2)?**

   - Lot size - 1/3 acre
   - residence - 2200 ft^2
   - detached garage - 1520 ft^2
   - hard space (driveway, patio, walkways) - 30% of yard area

2. The landscape area of my residence is primarily turf (St. Augustine):

Produce an Estimate Applied Water Budget for the month of July for the following three cases:

A. Worst Case
B. Expected Use
C. Maximum Conservation

3. Considering indoor water use, what is my total expected water use in July considering expected in-door use?

Average Monthly Reference Evapotranspiration (ET_o) for Major Texas Cities (inches per month)

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Abilene	2.08	2.57	4.14	5.48	6.47	7.65	8.36	7.46	5.48	4.21	2.67	2.08	**58.65**
Amarillo	1.84	2.27	3.73	5.06	5.89	7.51	8.08	7.29	5.61	4.05	2.40	1.78	**58.65**
Austin	2.27	2.72	4.34	5.27	6.39	7.15	7.22	7.25	5.57	4.38	2.74	2.21	**57.51**
Brownsville	2.65	3.03	4.48	5.17	6.03	6.32	6.68	6.65	5.21	4.34	3.01	2.59	**56.16**
College Station	2.20	2.71	4.22	5.20	6.25	6.89	7.10	6.85	5.60	4.30	2.80	2.20	**56.32**
Corpus Christi	2.42	2.95	4.28	5.17	5.95	6.43	6.68	6.65	5.21	4.34	3.01	2.59	**55.68**
Dallas/Ft Worth	2.00	2.46	3.96	5.14	6.21	7.06	7.40	7.25	5.49	4.19	2.59	2.10	**55.85**
Del Rio	2.47	3.01	4.76	6.01	6.98	7.41	7.57	7.41	5.77	4.35	2.91	2.36	**61.01**
El Paso	2.74	3.53	6.07	8.19	9.83	11.12	9.19	8.94	7.69	5.89	3.58	2.49	**79.26**
Galveston	2.20	2.60	4.10	5.00	6.11	6.60	6.20	6.00	5.50	4.20	2.80	2.30	**53.61**
Houston	2.36	2.83	4.32	5.01	6.11	6.57	6.52	6.08	5.57	4.28	2.90	2.35	**54.90**
Lubbock	2.35	2.63	4.41	5.53	6.93	7.73	7.63	7.20	5.54	4.19	2.61	2.33	**59.08**
Midland	2.20	2.78	4.46	5.91	7.21	8.20	9.23	8.62	6.95	4.31	2.78	2.16	**64.81**
Port Arthur	2.25	2.63	3.95	5.09	6.12	6.60	5.81	5.61	5.46	4.18	2.76	2.23	**52.69**
San Angelo	2.88	3.13	5.31	7.01	8.48	9.16	9.29	8.49	6.60	5.08	3.37	2.54	**71.34**
San Antonio	2.42	2.90	4.42	5.47	6.47	6.97	7.31	6.99	5.64	4.44	2.85	2.36	**59.93**
Uvalde	2.44	2.95	4.62	5.85	6.70	7.21	7.50	7.31	5.70	4.40	2.89	2.36	**59.93**
Victoria	2.35	2.87	4.29	5.77	6.39	6.70	6.92	6.70	5.36	4.41	2.93	2.33	**57.02**
Waco	2.13	2.62	4.03	5.31	6.45	7.15	7.40	7.50	5.70	4.41	2.70	2.17	**54.05**
Weslaco	2.50	2.57	3.96	4.90	6.12	6.53	7.00	6.58	4.79	3.96	2.85	2.29	**54.05**
Wichita Falls	1.94	2.46	4.07	5.50	6.70	7.54	7.97	7.72	5.79	4.30	2.62	1.95	**58.56**

Section 7

GIS- Based Tools for Water Budgeting

Identifying Design Restrictions

- Locating the water source
  - Do multiple sources exist?
- Working around obstacles
  - Sidewalks
  - Trees
- Do slopes exist?

Determining Required Materials

- How large is the yard?
  - Calculate the area of yard, ft2
- Any abnormally shaped areas?
- Identify spray patterns
  - Number of heads needed

Software Programs

- Microsoft Paint
- Microsoft Word or Excel
- RainCAD/Pro Contractor Studio
- ESRI ArcGIS

What is GIS?

- A geographic information system (GIS) integrates computer technologies, people and detailed information about location that lets you visualize relationships, patterns and trends in maps for better decisions

Orthophotos

- Are aerial (digital) photographs that have been "orthorectified" using ground elevation data to correct displacements caused by differences in terrain relief and camera tilt
- Gives the photo the accuracy of a map
- Useful for updating maps and studying the surface

Sources: Where to Get Aerial Photography and GIS Data

- Internet search engines – Google it!
  - http://maps.google.com
- City pages
  - North central Texas Council of Governments
  - www.nctcog.org/index.asp
  - www.dfwmaps.com
- City of Austin
  - http://map.mapnetwork.com/destination/austin

Sources: Where to Get Aerial Photography and GIS Data

- City pages
  - TAMU http://campusmaps.tamu.edu/
  - College station - www.cstx.gov/home/index.asp?page=1996
  - Dallas/Fort Worth – www.dfwmaps.com
  - San Antonio – http://maps.sanatonio.gov
  - Houston – http://pwegis.pwe.ci.houston.tx.us
  - Austin – www.ci.austin.tx.us/maps

Aerial Photography and GIS Data Links

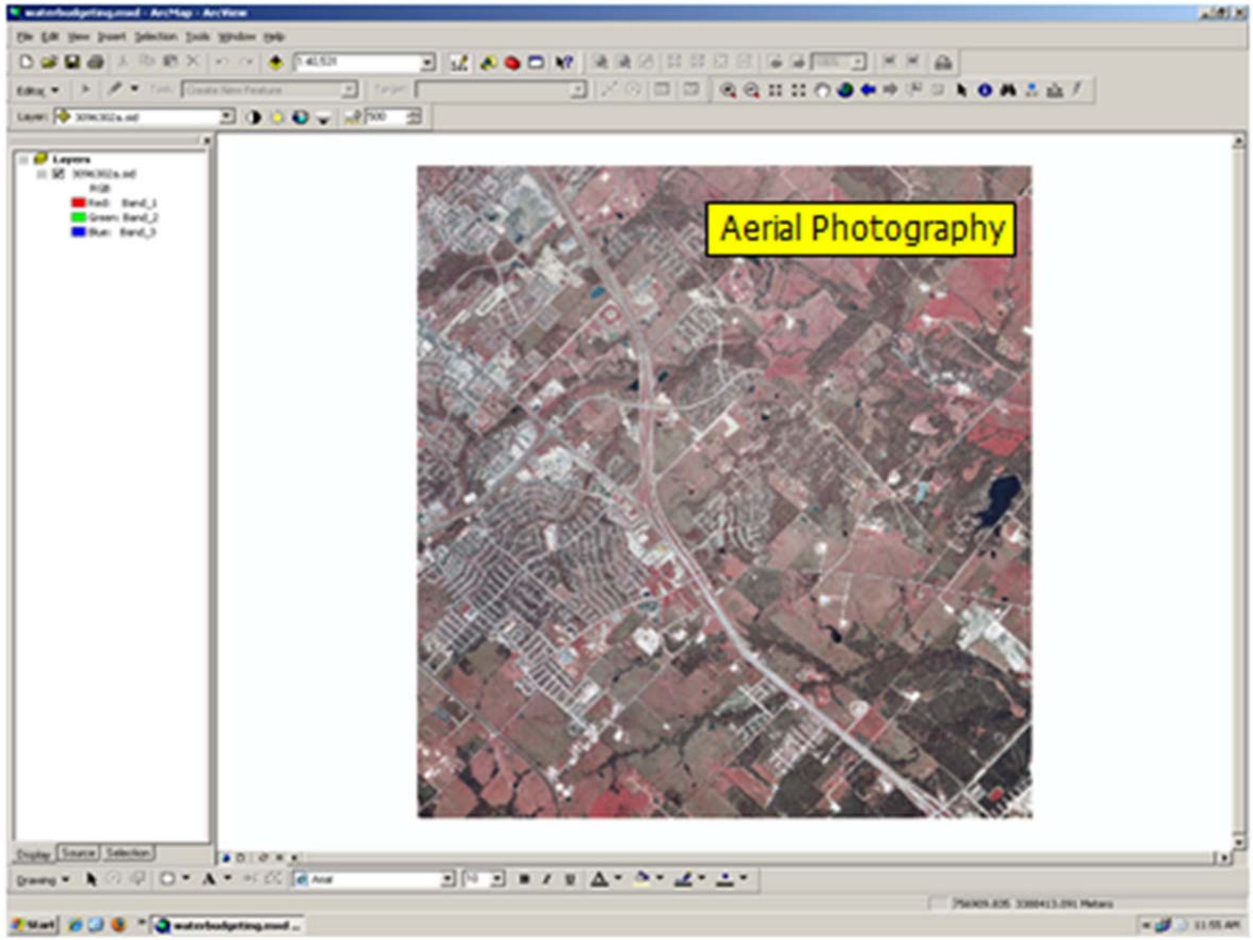
- TNRIS – Texas Natural Resources Information System
  - www.tnris.state.tx.us
- U.S. Census Bureau
  - www.census.gov/geo/www/cob/bdy_files.html
- U.S. Geological Survey

GIS Software & Resource Links

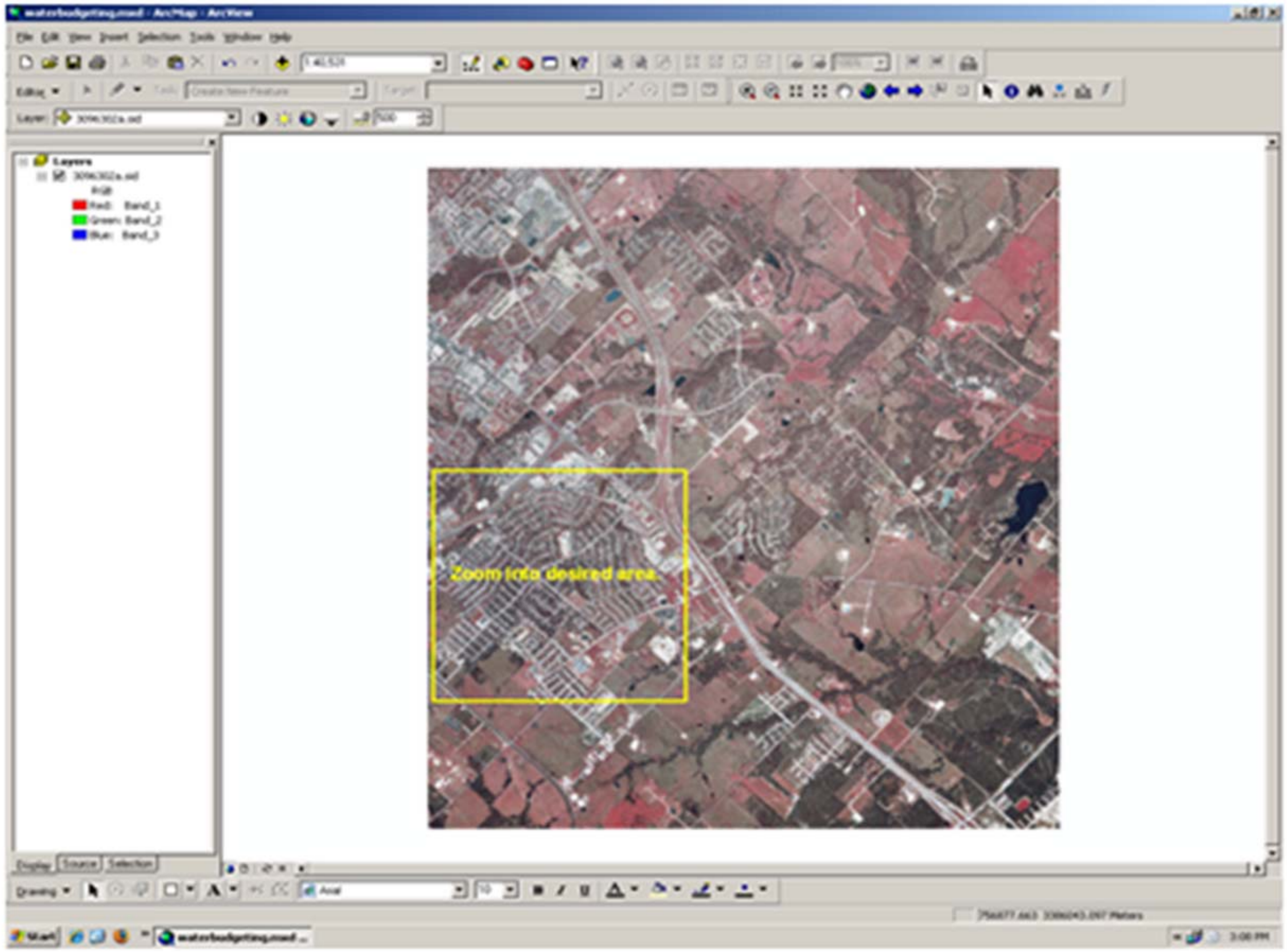
- ESRI ArcGIS (60 day trial version)
  - www.esri.com
- Other resources
  - www2.geoplan.ufl.edu/software.html

Section 8

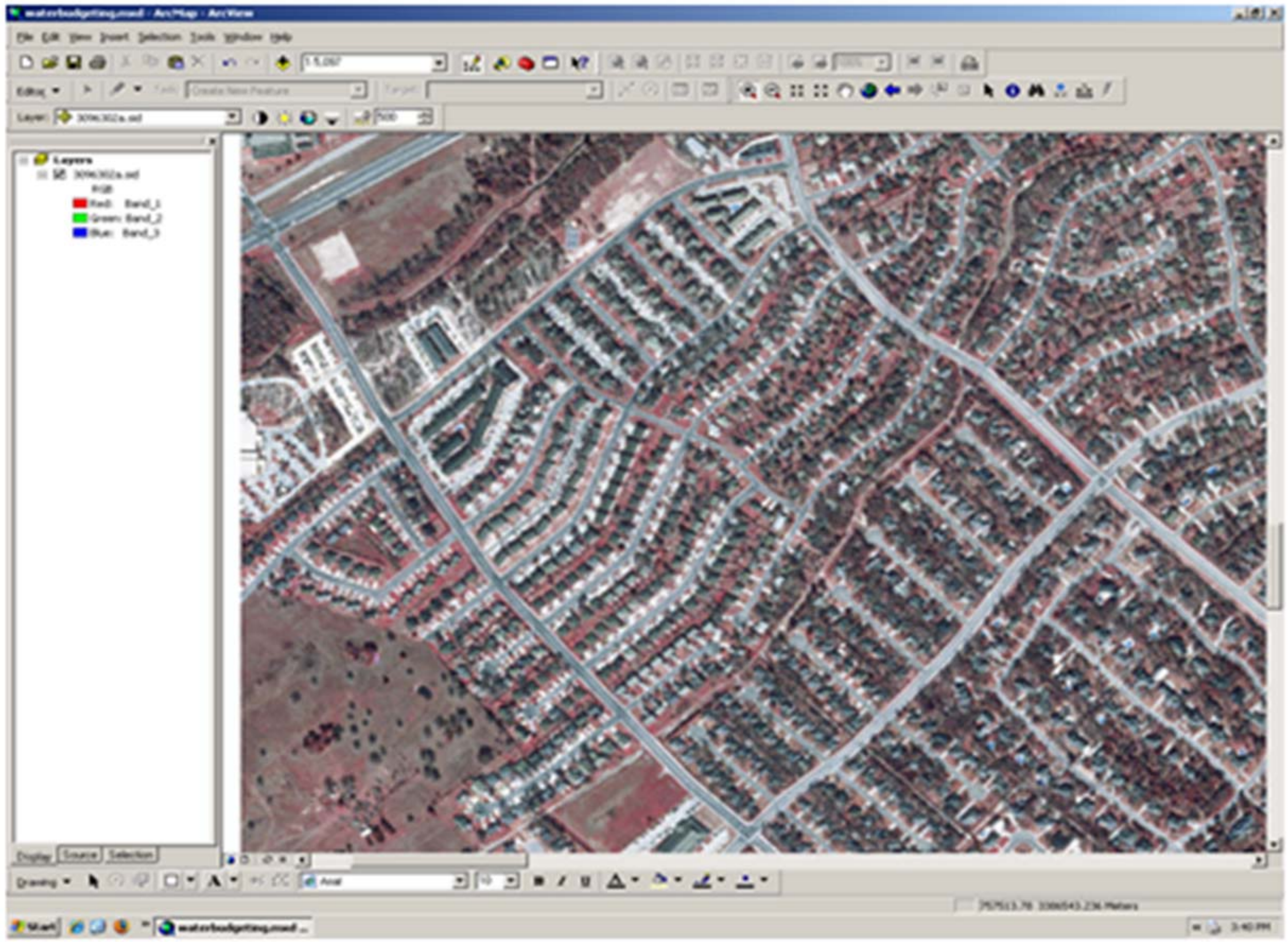
Example of Water Budgeting on a Small Area for City Use



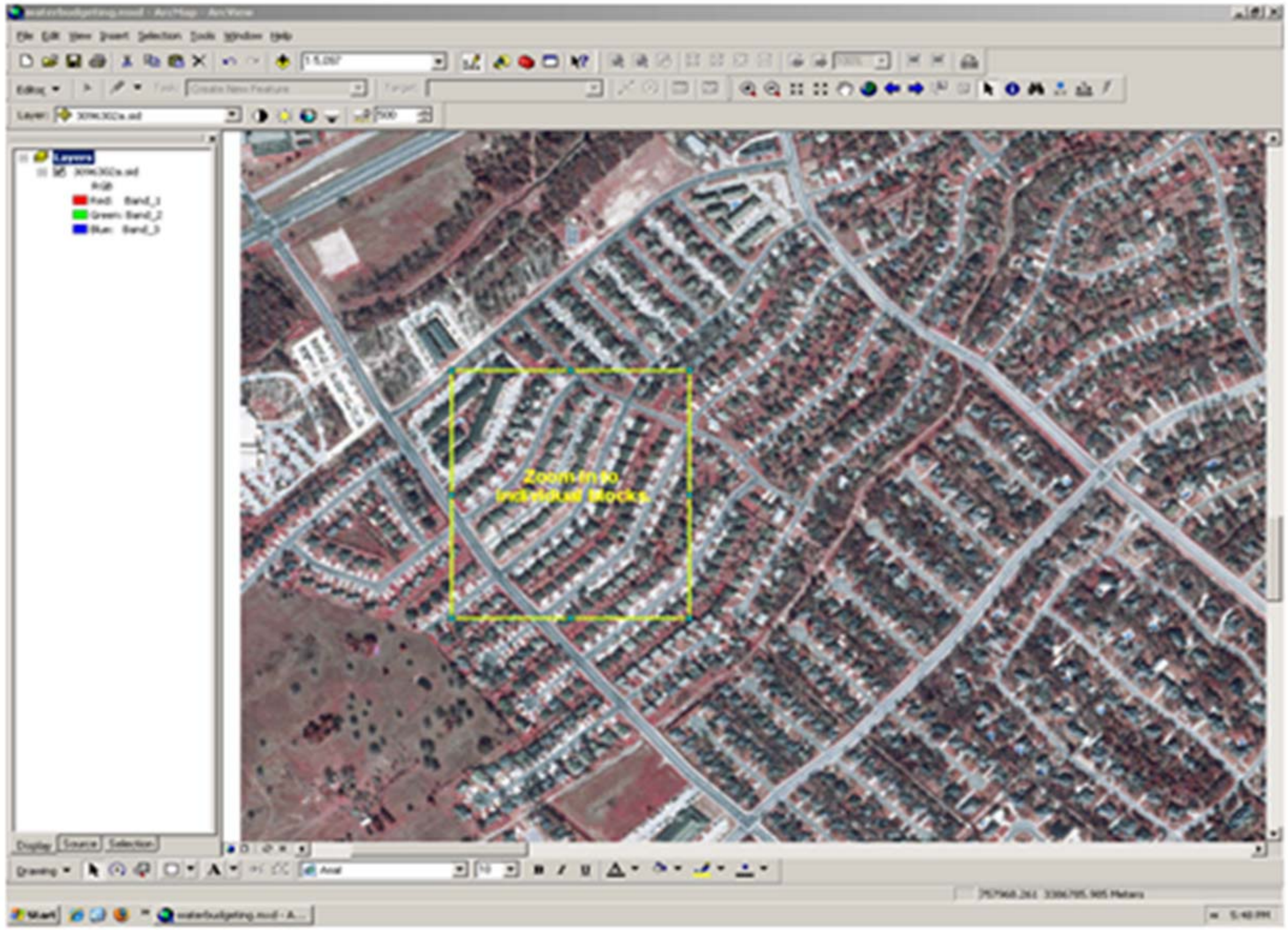
1. This image shows an aerial photography of the small city and surrounding area. In the left menu is the ID number of the aerial photograph. Also, as shown in the left menu, we are viewing the image in all three colors



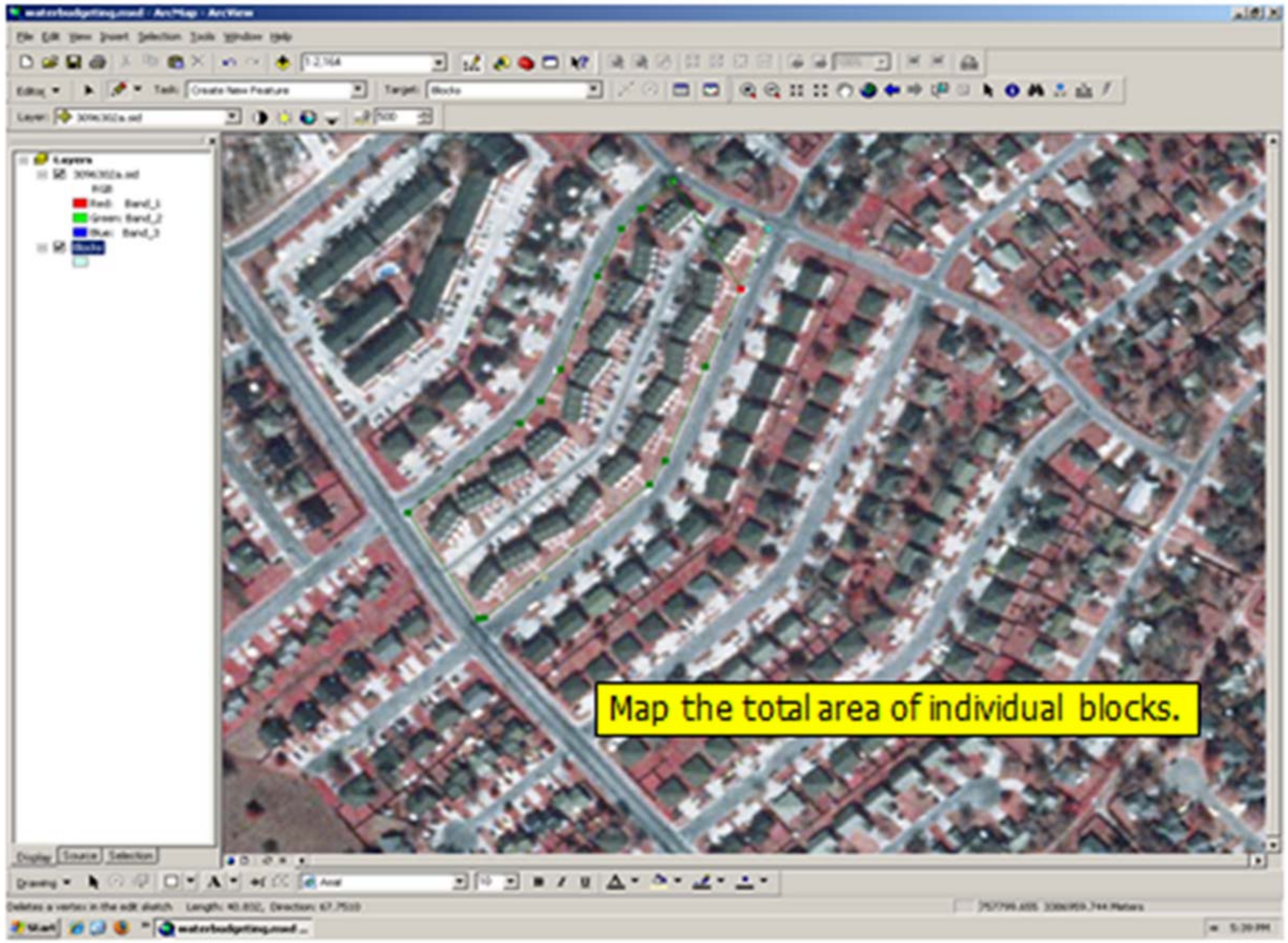
2. First we select the area of interest as shown in the yellow box, then will use the GIS zoom tool



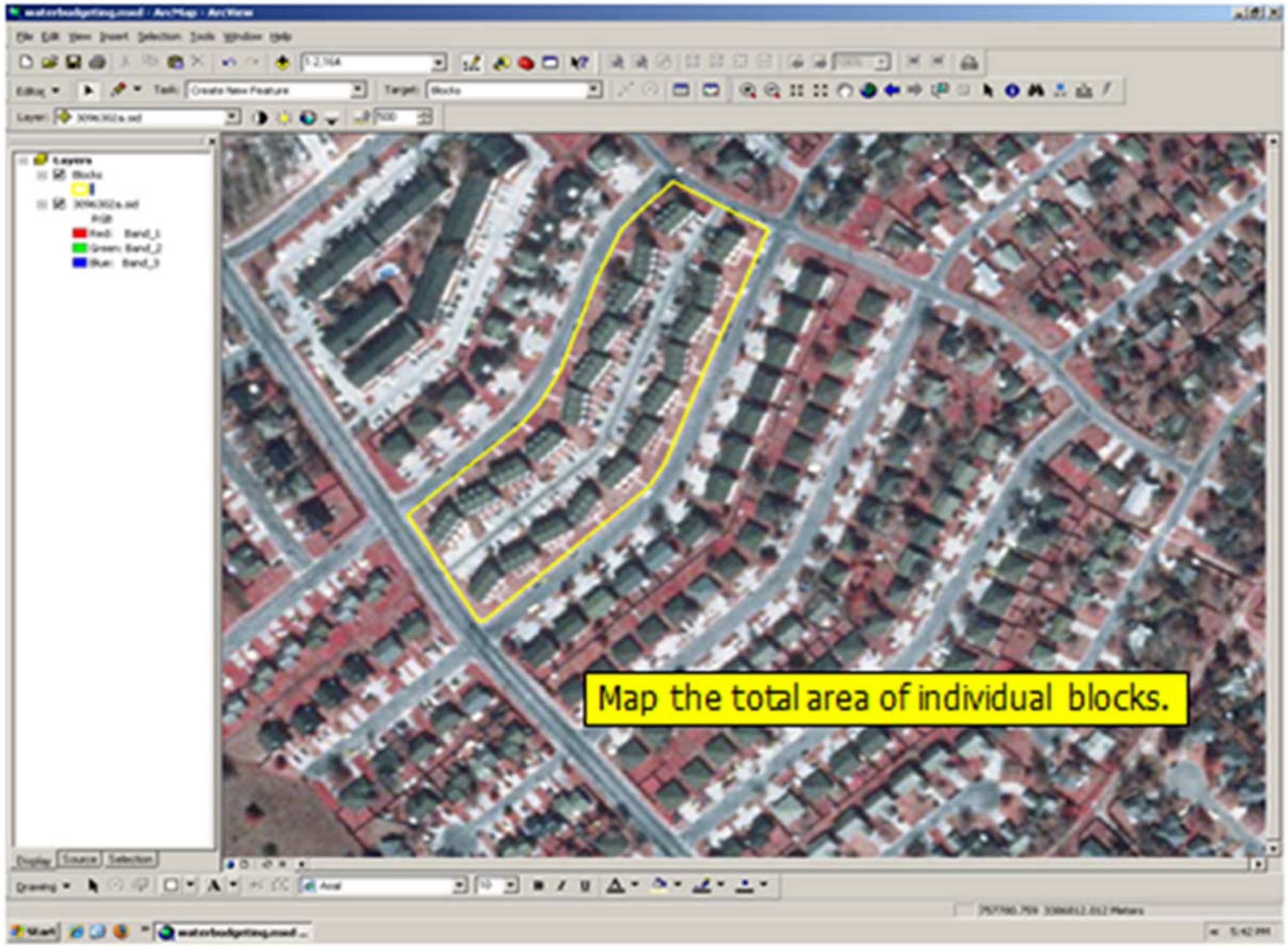
3. Now we can make out the streets and individual houses and yards. We will select a smaller area to work with



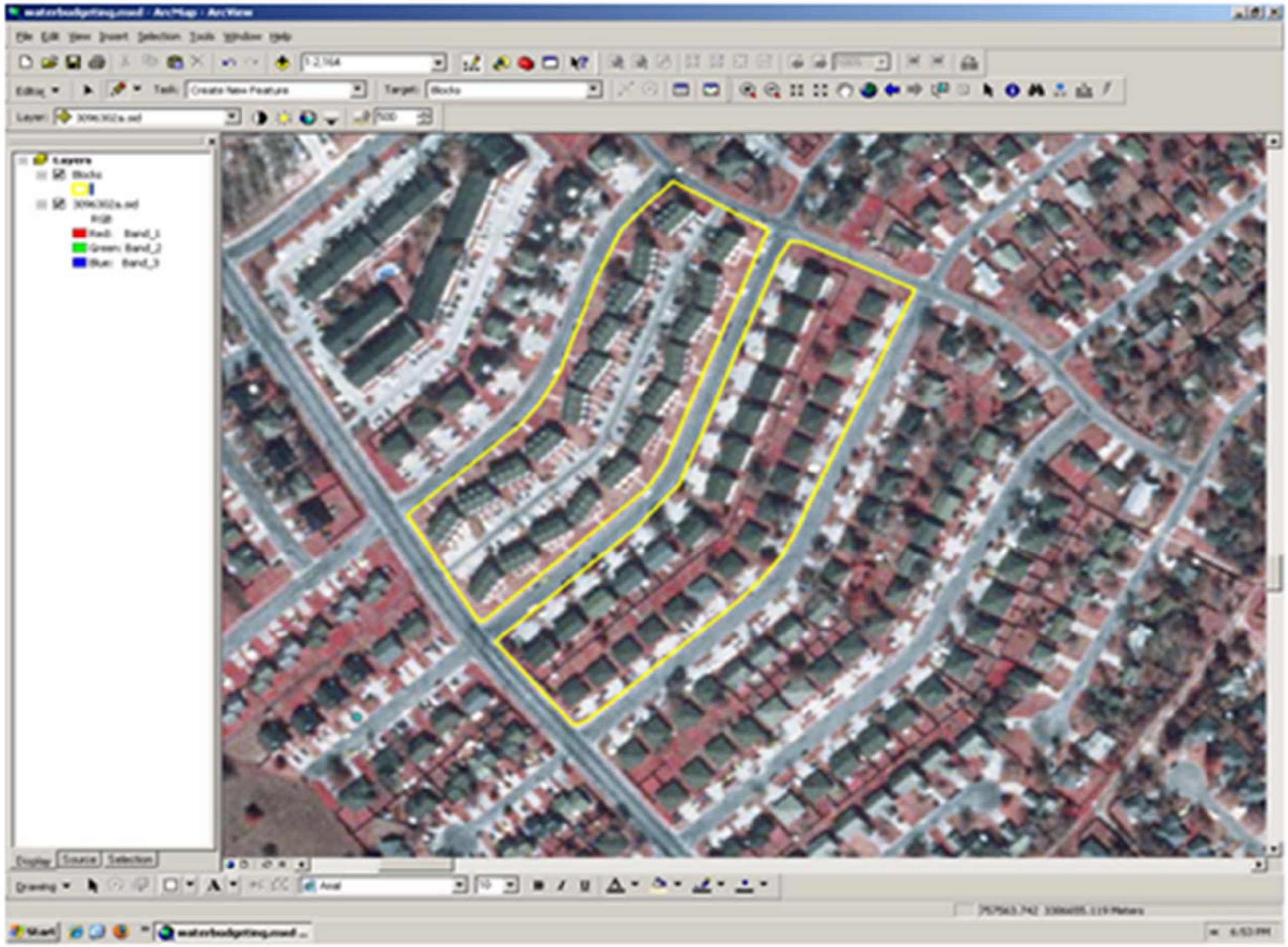
4. The area highlighted in yellow is where we will conduct our analysis. We again use the GIS zoom tool to display this area.



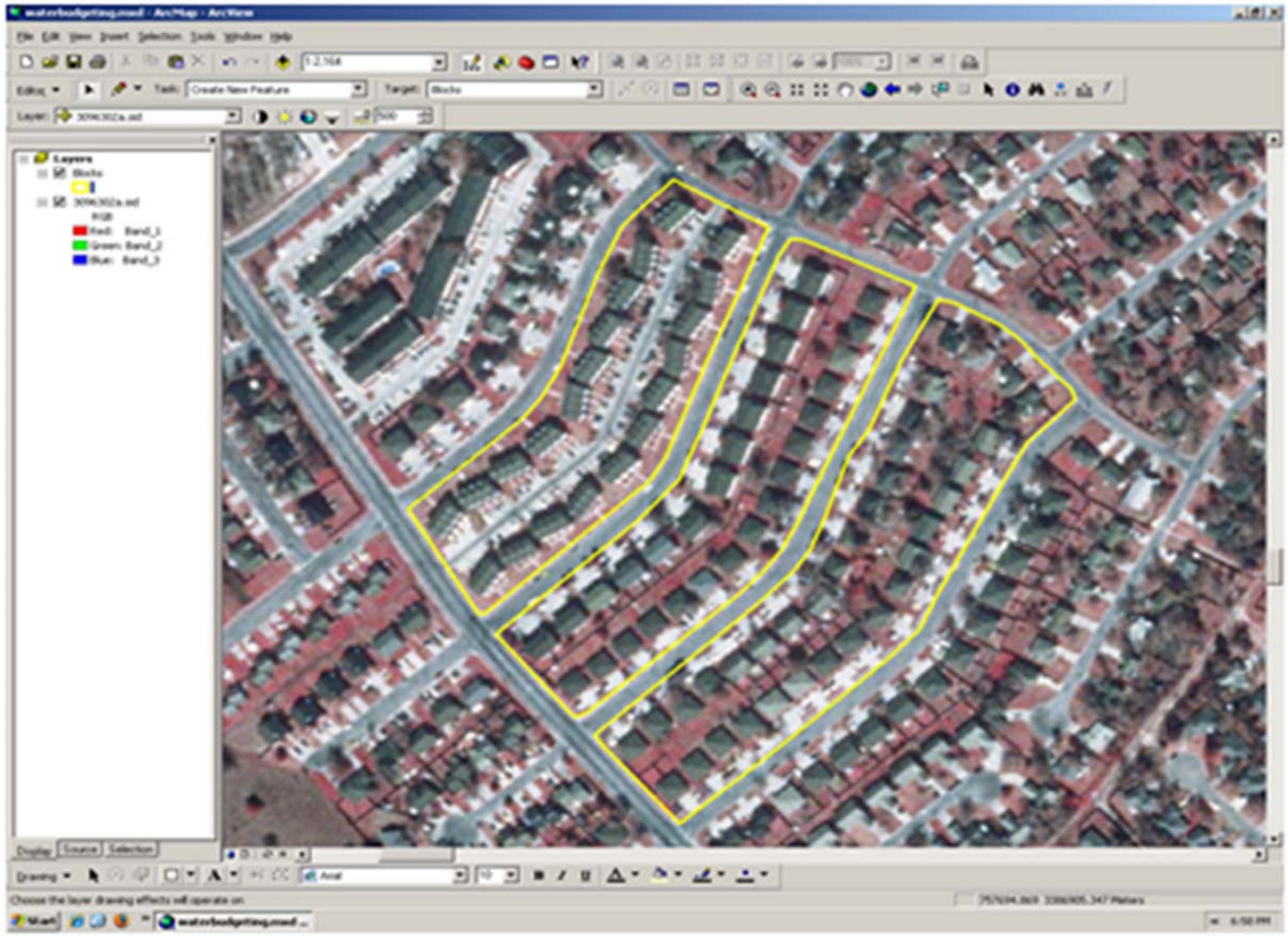
5. In this area, all the streets, houses and yards are laid out in the same pattern.



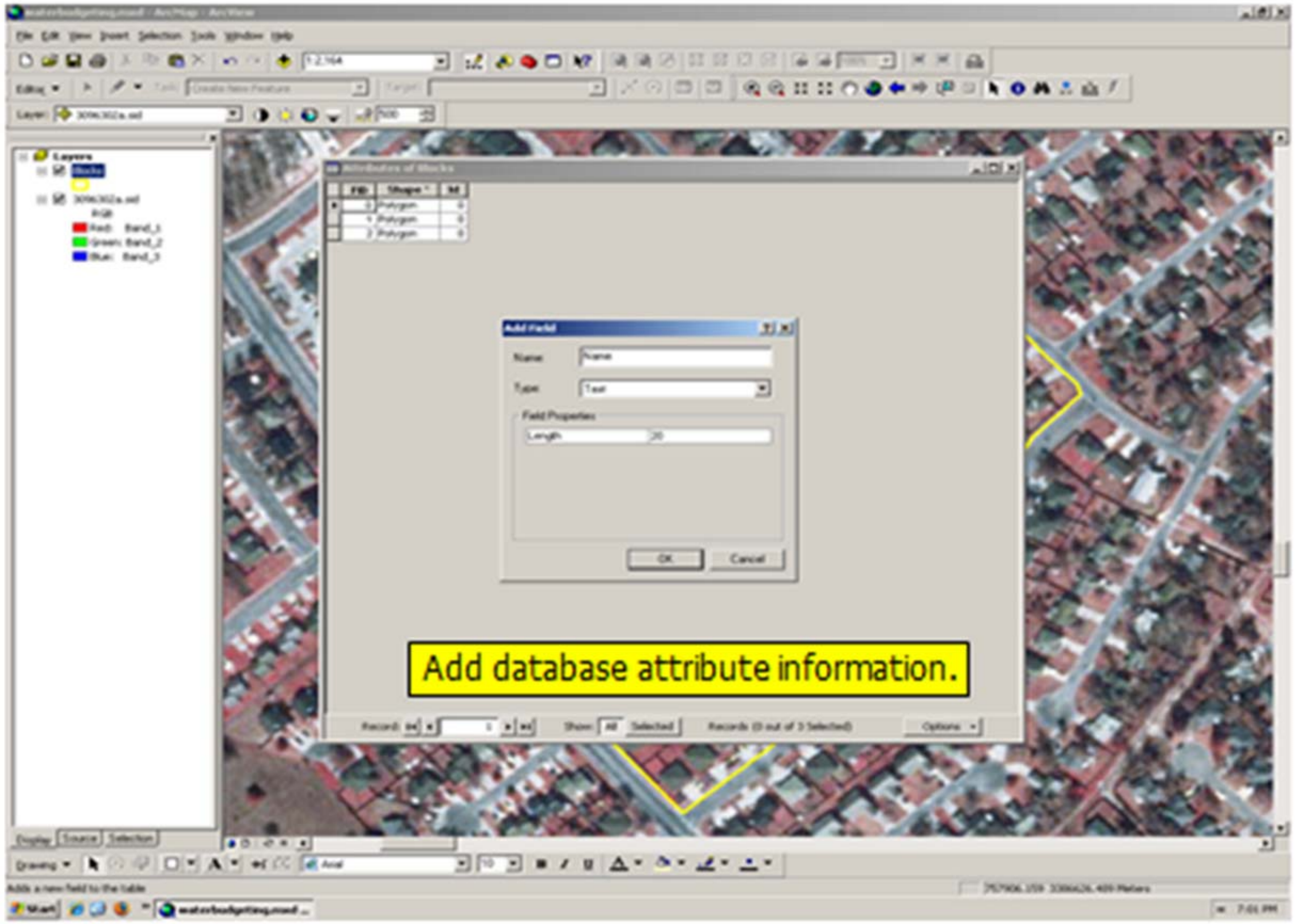
6. The area highlighted in yellow is the first of three areas (or blocks) of houses and yards that we will use. Using the GIS drawing tool, we map this area and add the block layer to the GIS as seen in the left menu.



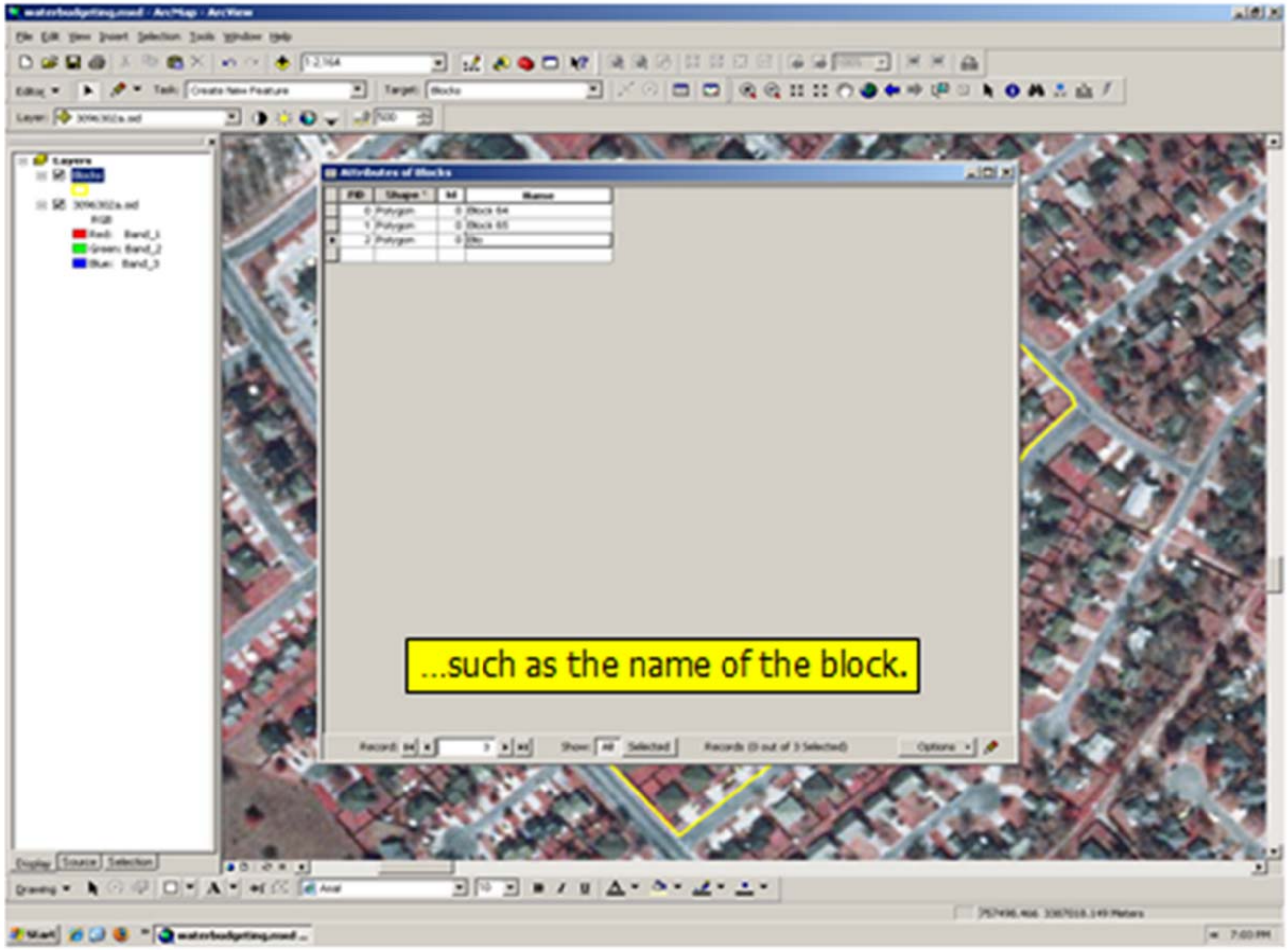
7. We map the next area



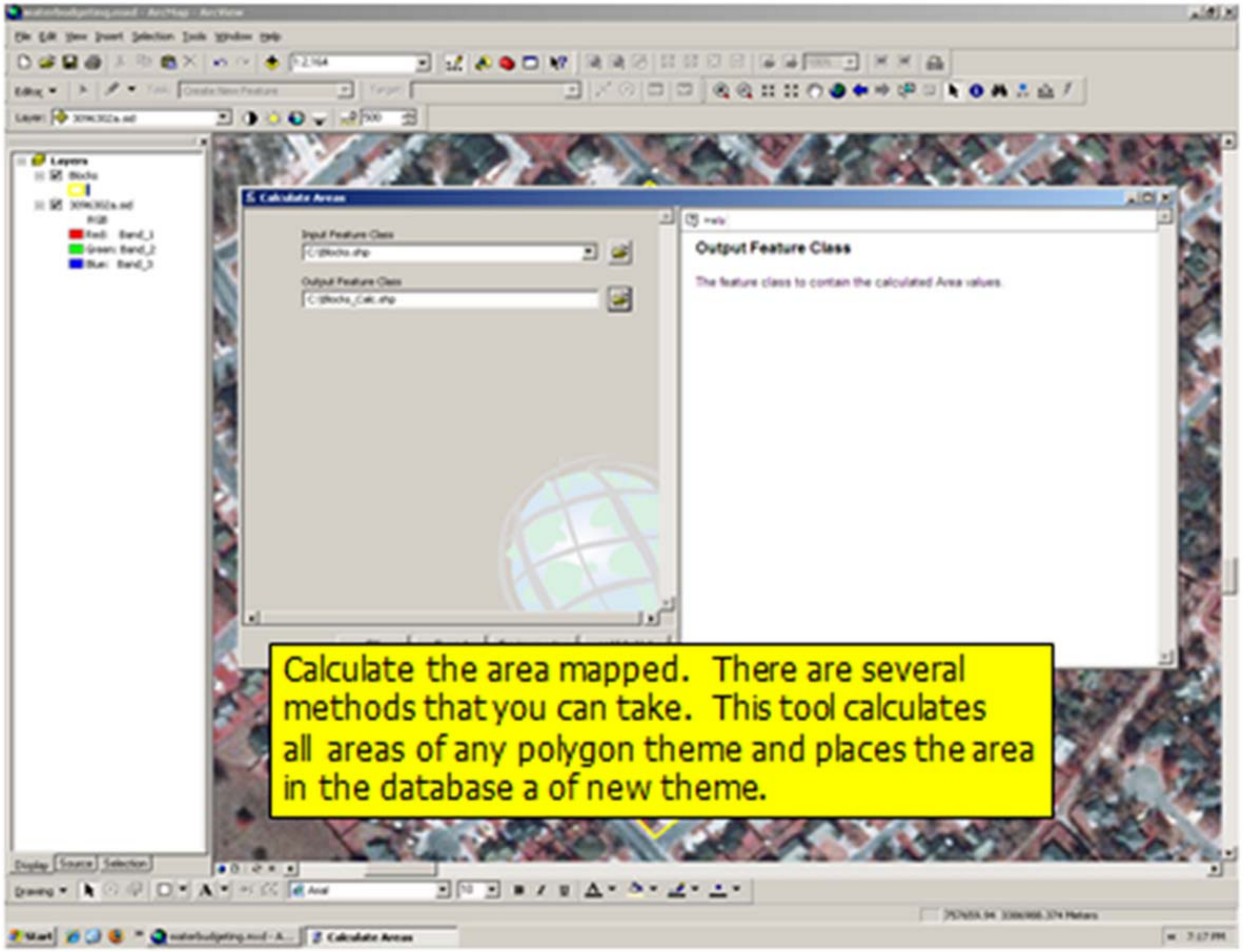
8. We map the final area.



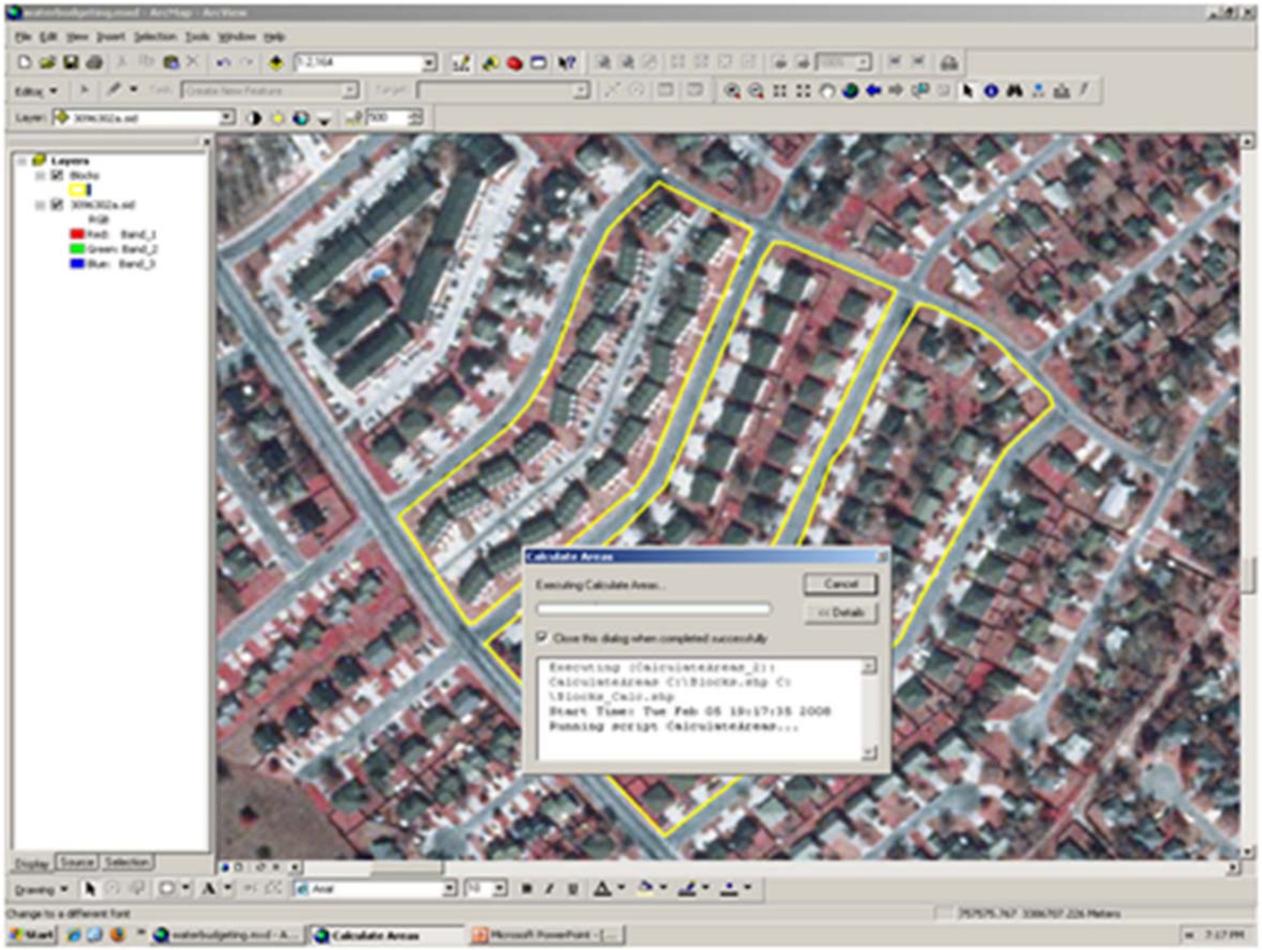
9. These mapped areas are referred to as polygons. We then can use the GIS attribute box to add information about the blocks



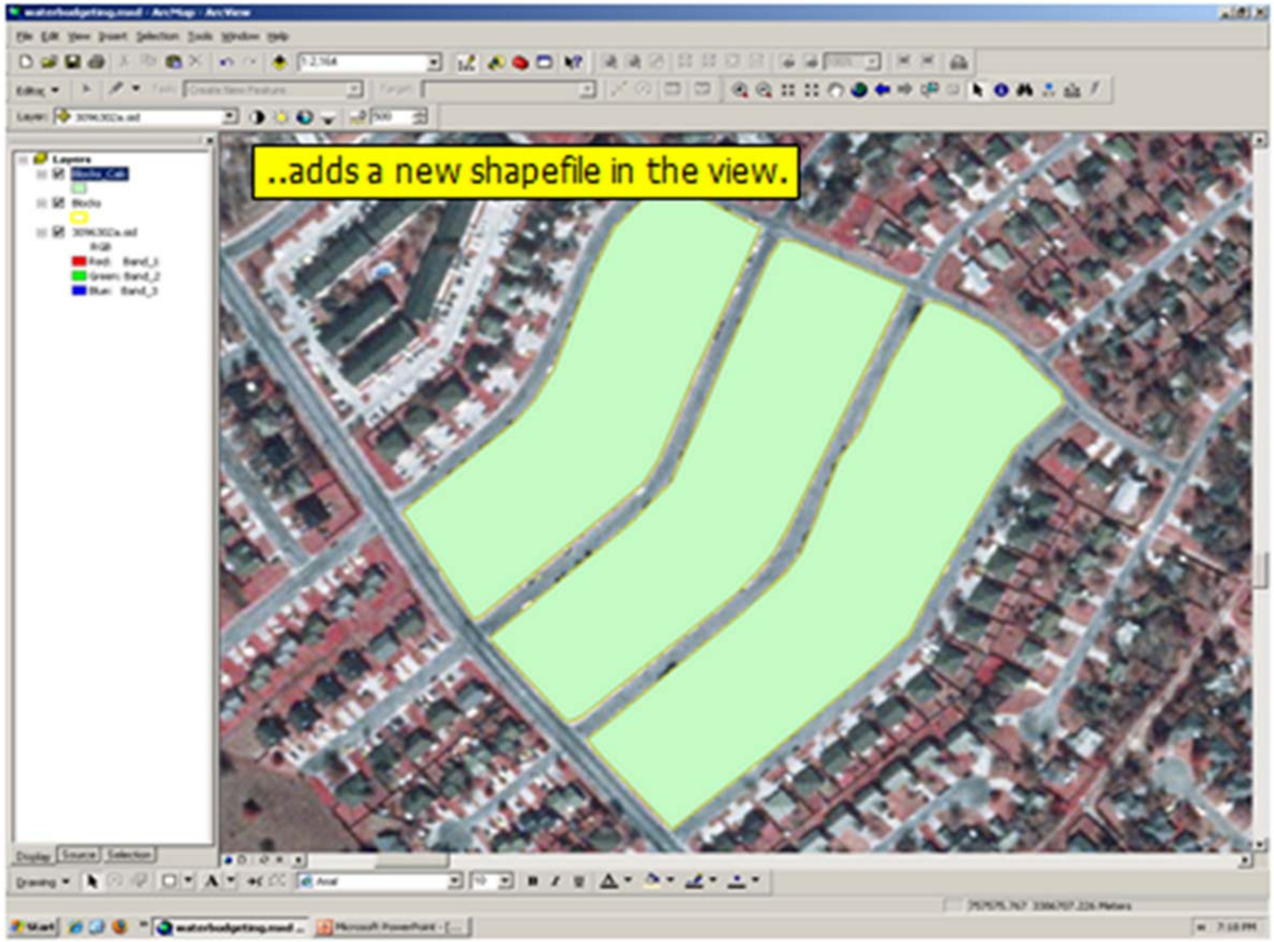
10. The name or location of the block is usually entered. Here we will label these as blocks 64, 65 and 66.



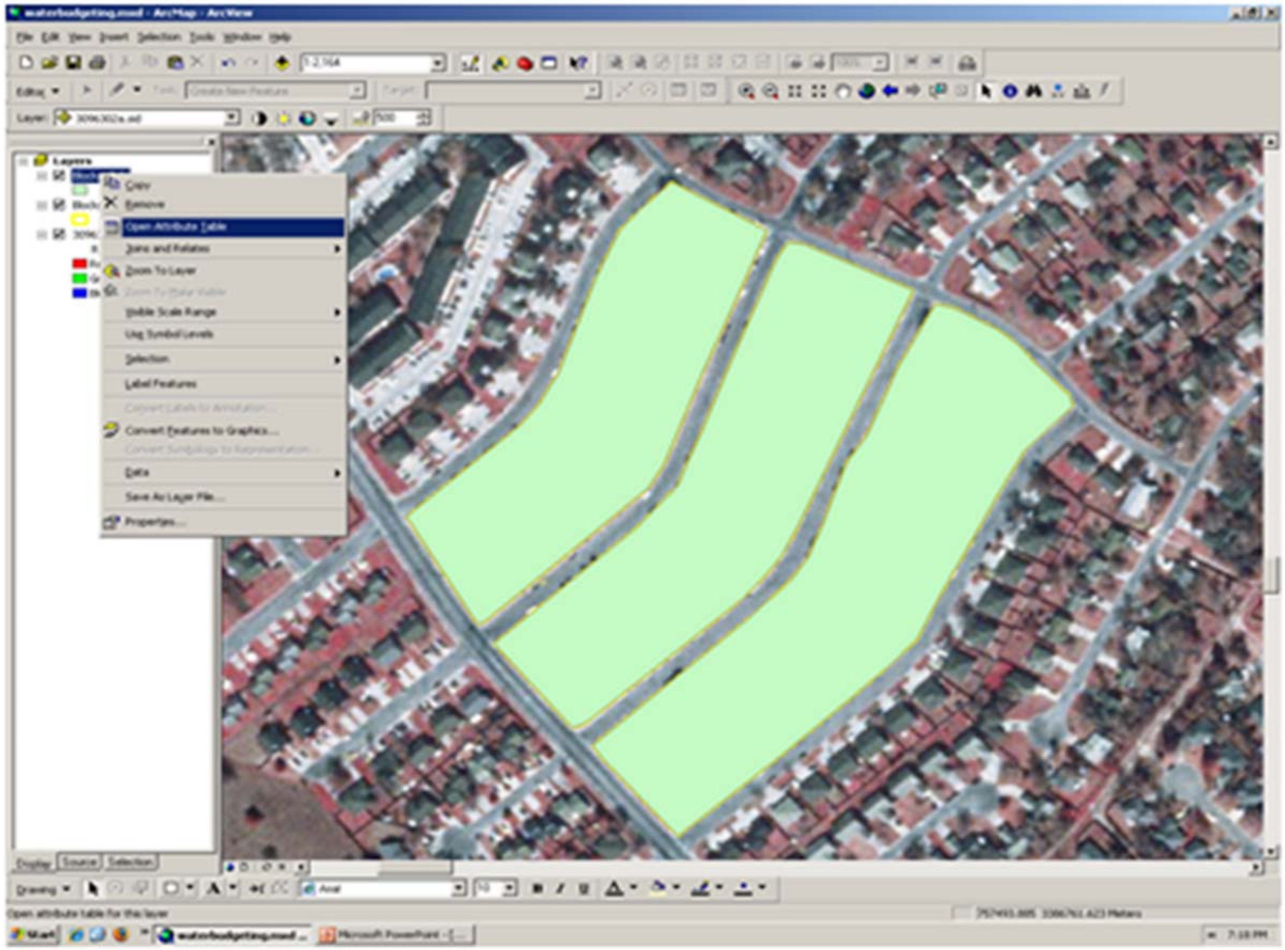
11. For water budgeting, we need to determine the landscape area. First we will determine the total area of each block. There are several different ways to do this in GIS. Here, we are using the calculate area tool.



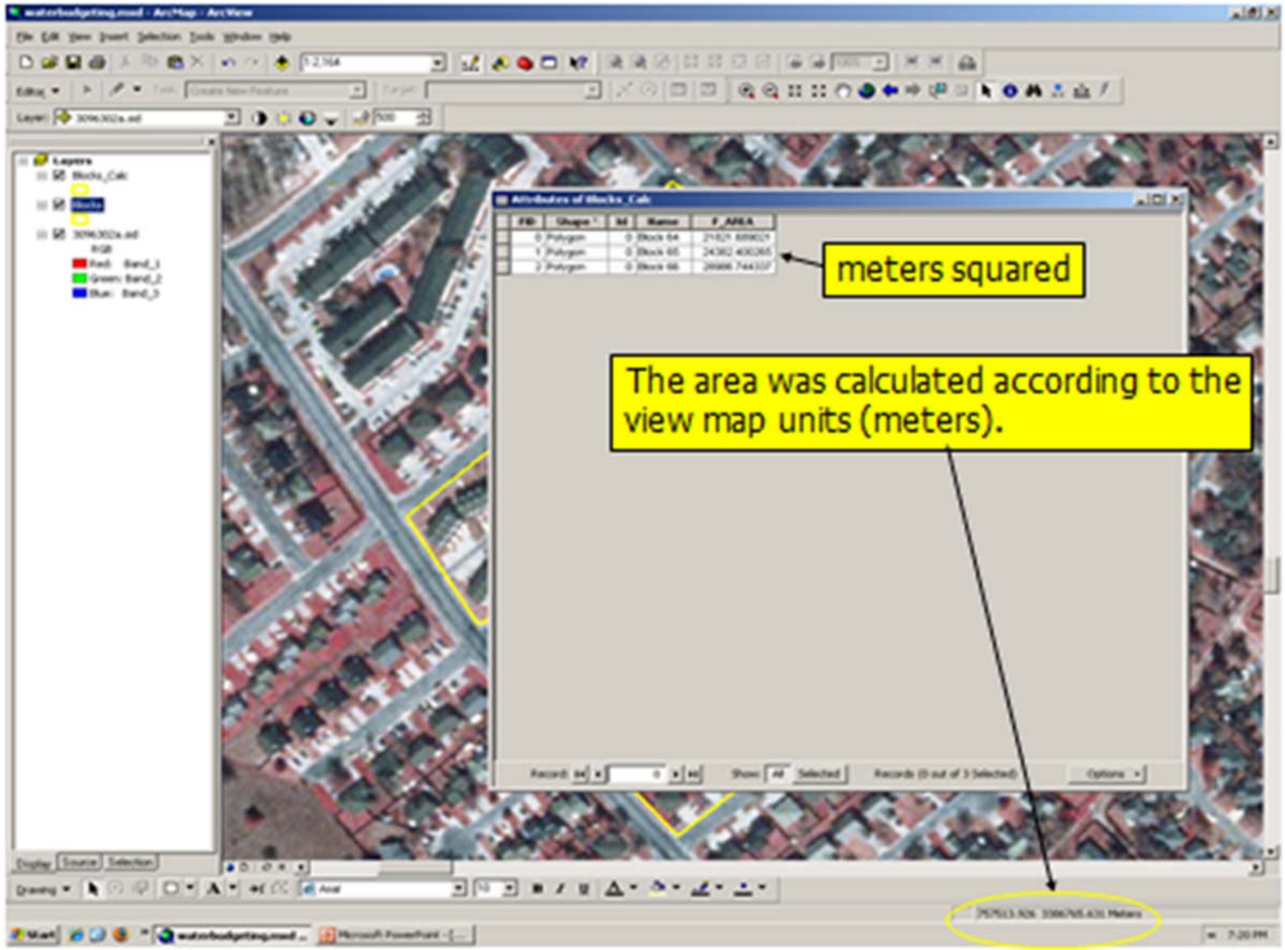
12. As area is calculated, a status box is displayed.



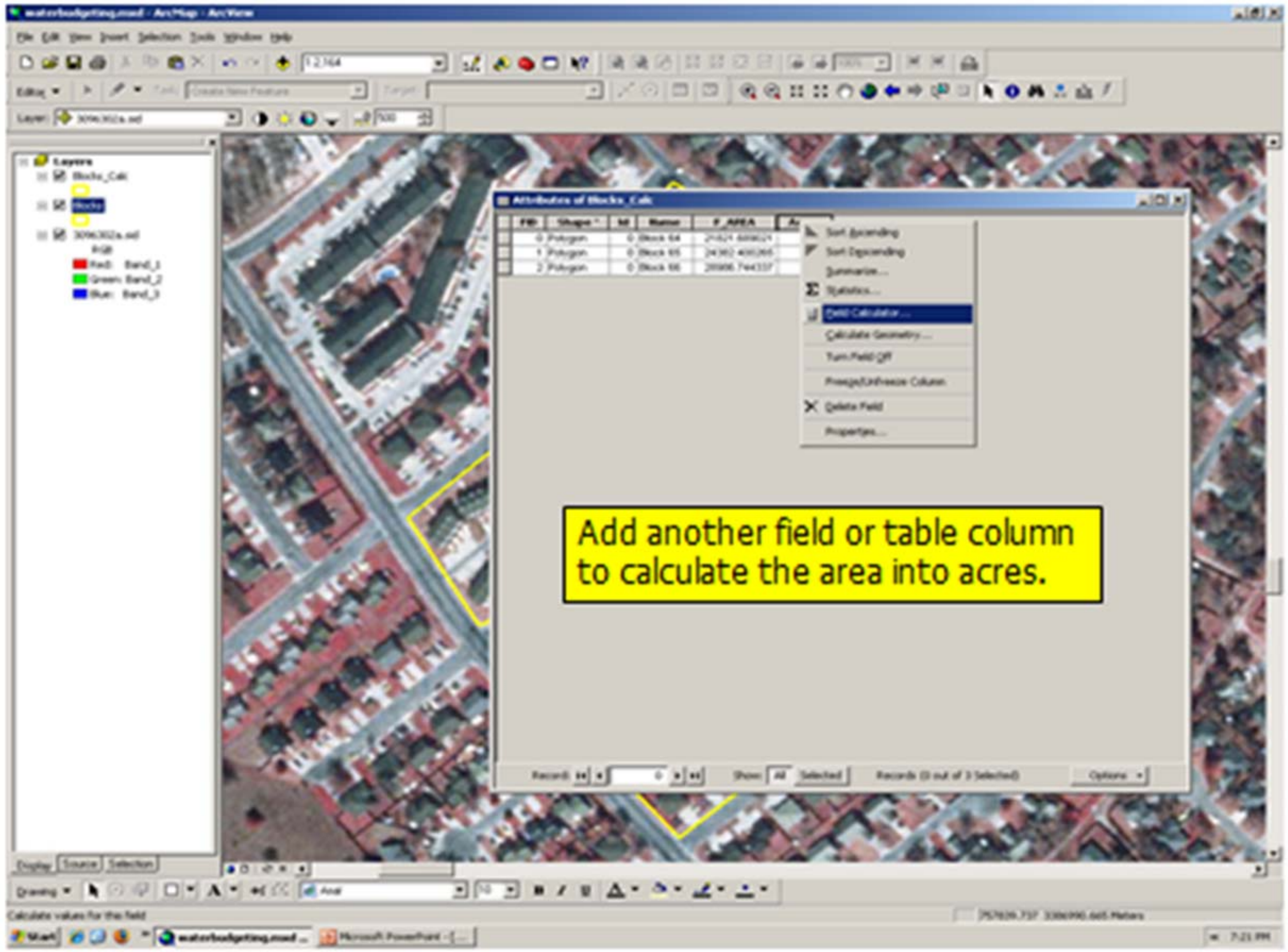
13. We now have a new map (or shapefile) which is added to our GIS containing the boundaries and area of each block.



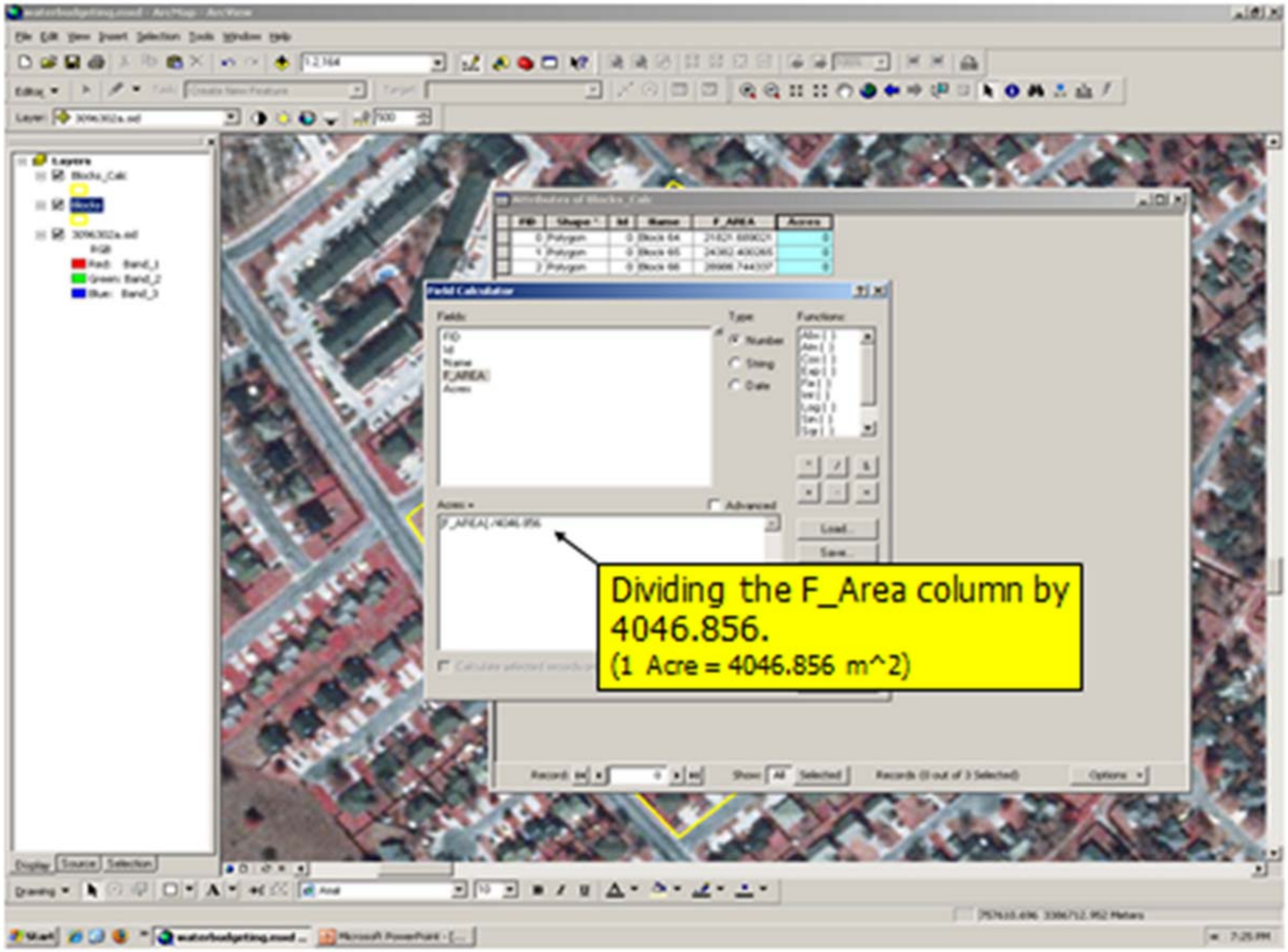
14. Right clicking on the shapefile brings up a menu with several options. Here we select the Open Attribute Table option



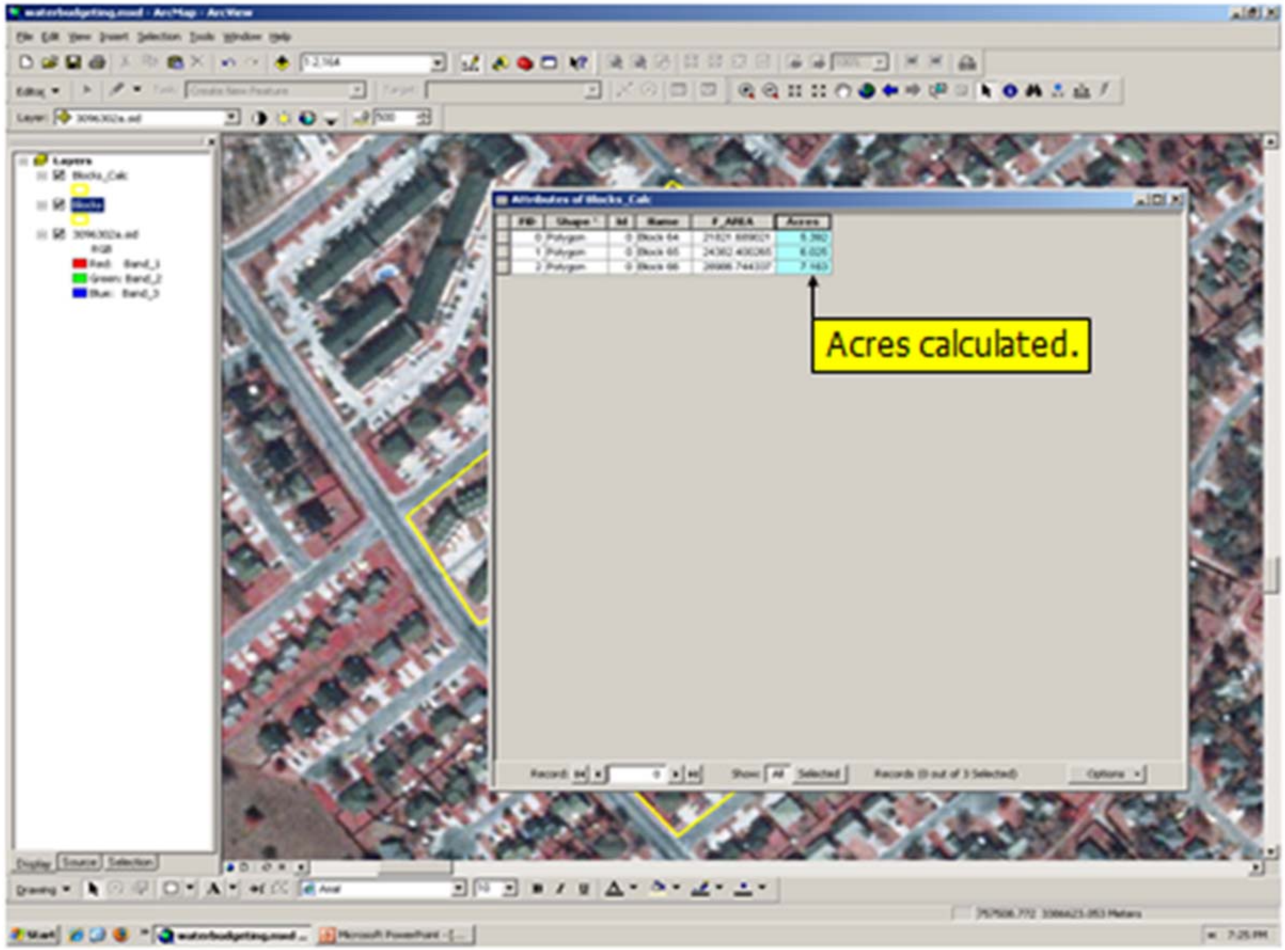
15. The area of each block was calculated in square meters. This was done automatically based on the units defined in the map view.



16. Using the shapefile dialog menu, we can add another column to our attribute table to change the units from square meters to acres.



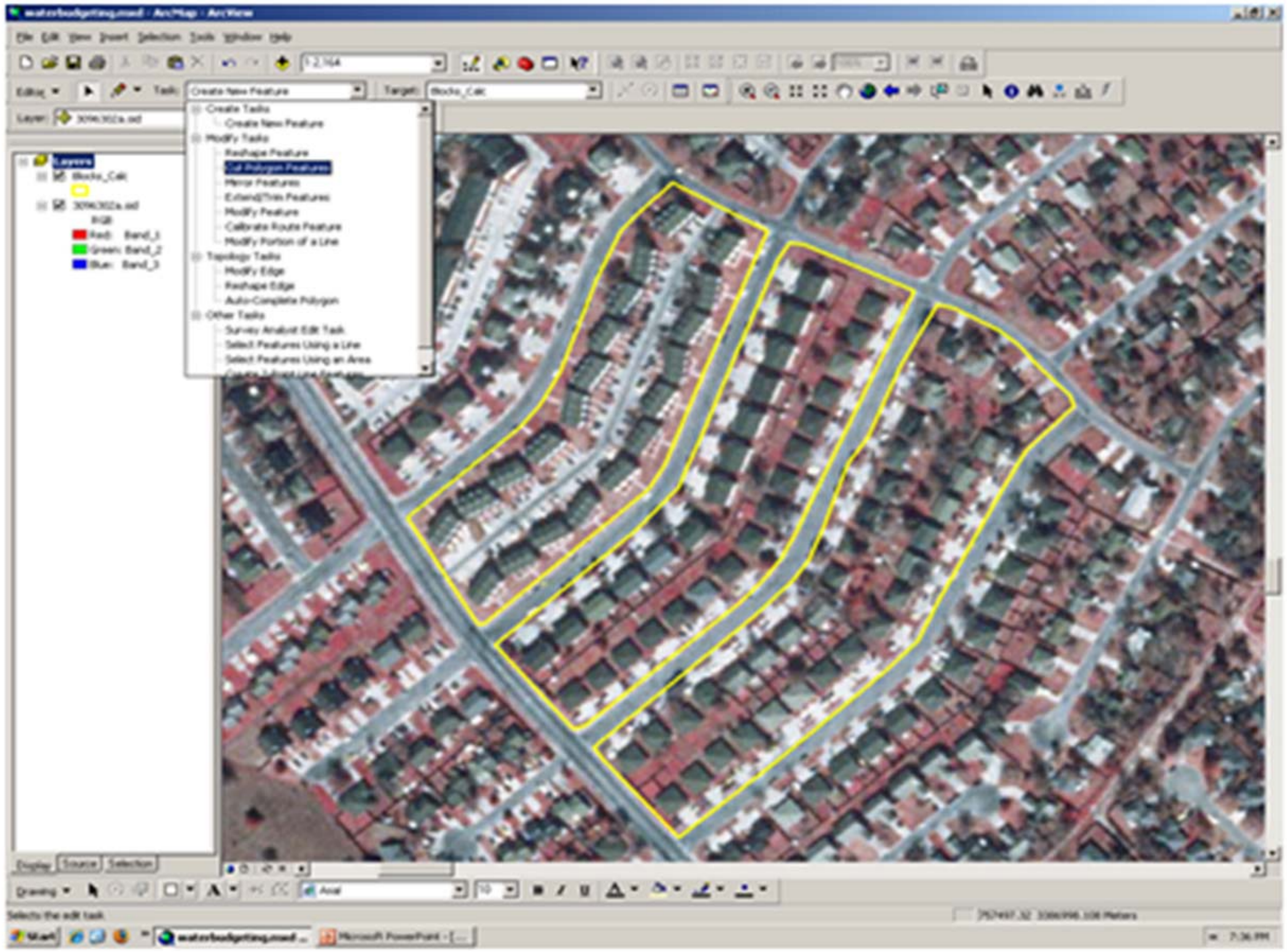
17. In the field calculation dialog menu, we can add equations to do any calculation we wish. Here we use the conversion factor for square meters to acres.



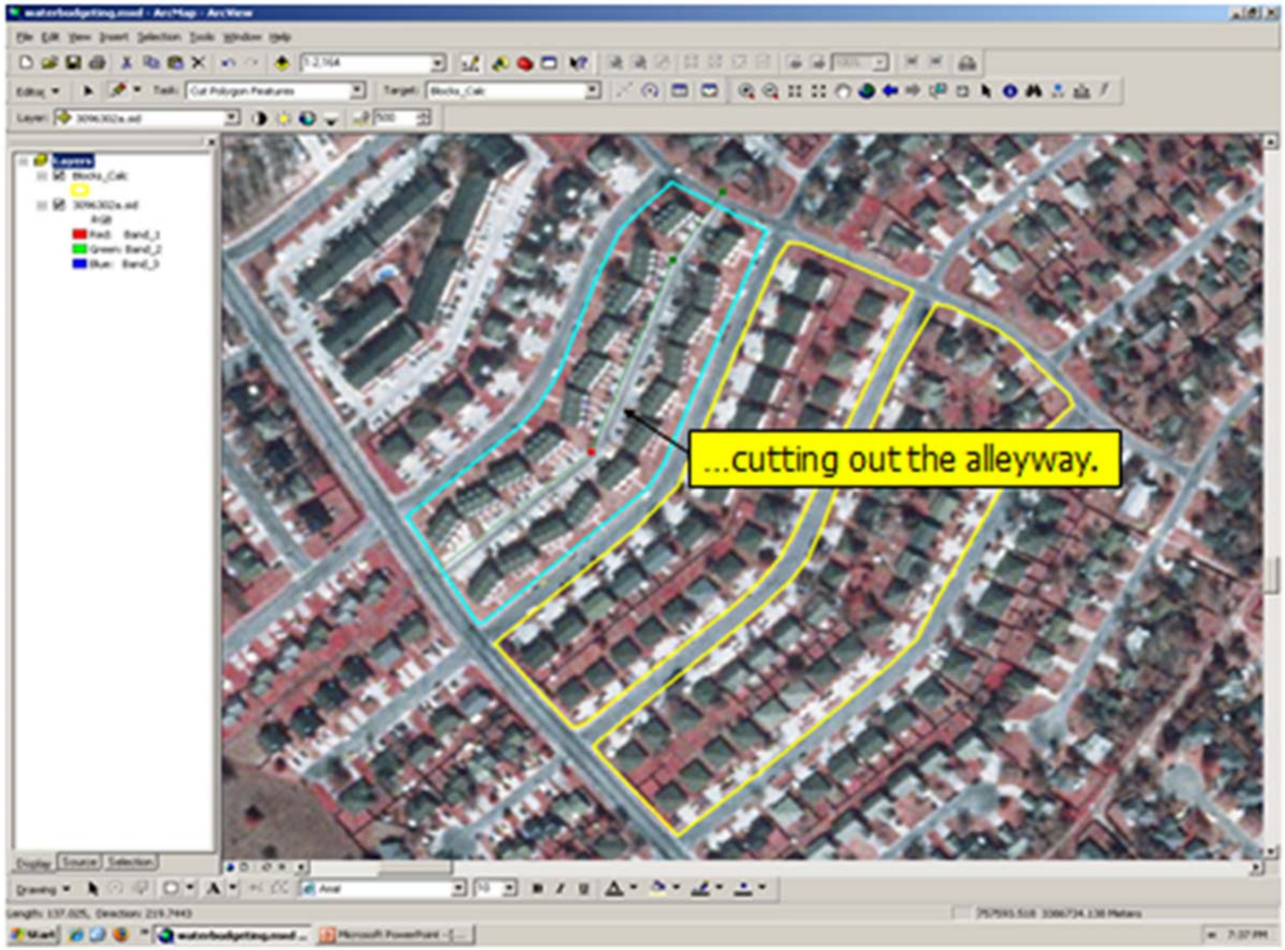
18. The area of each block in acres has been added to our attribute table.

Determining the Irrigation Acreage vs. Total Acreage

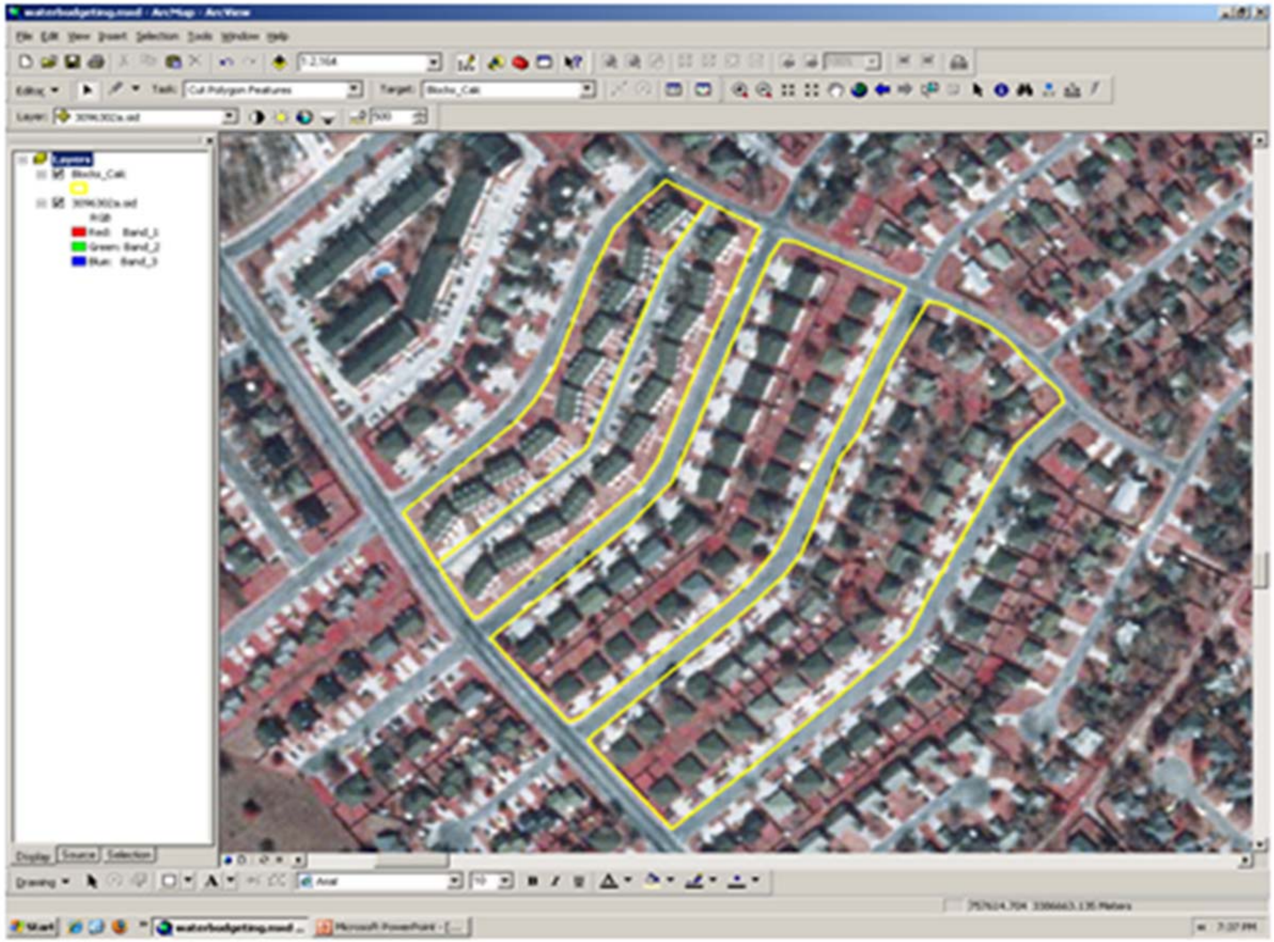
- Method 1: Using the tool to cut the polygon into pieces is one way to separate out lawn vs. hard surface areas



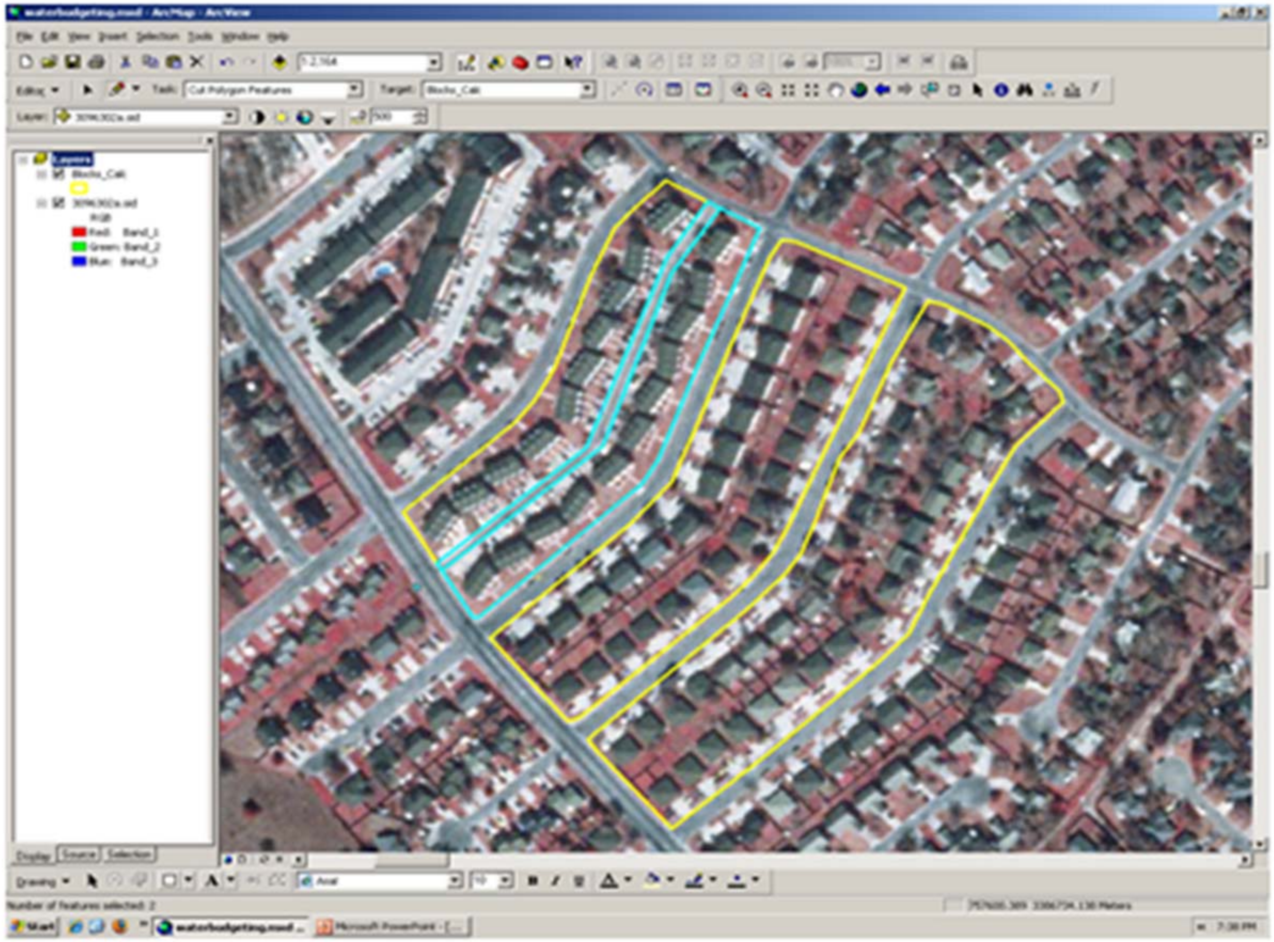
For water budgeting, we need to know the total landscape area. So, we need to remove the areas covered by houses, driveways, sidewalks and other hard spaces. We will use the Cut Polygon Features tool to do this.



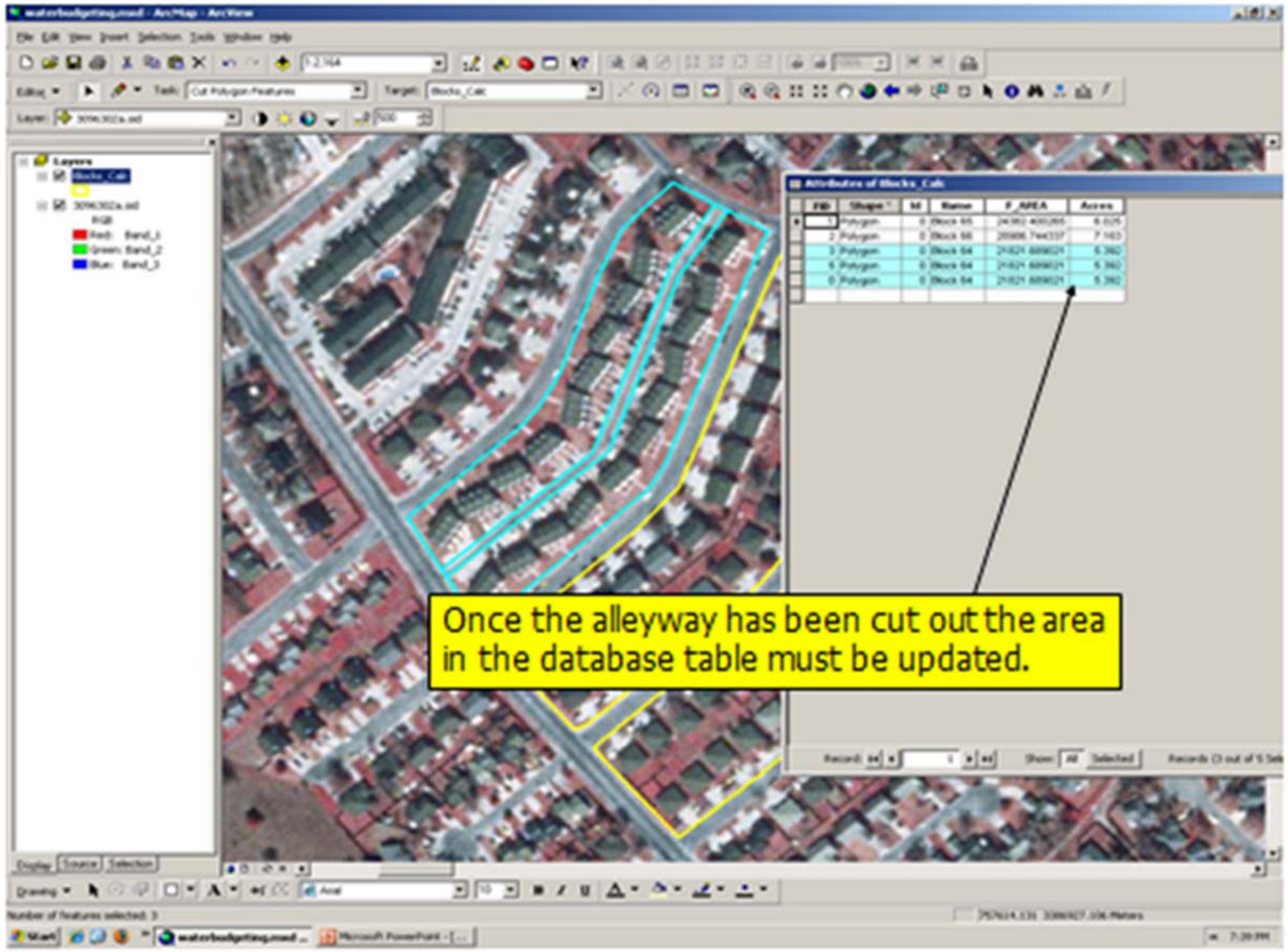
Using the cut tool, we draw out the upper boundary of the alley.



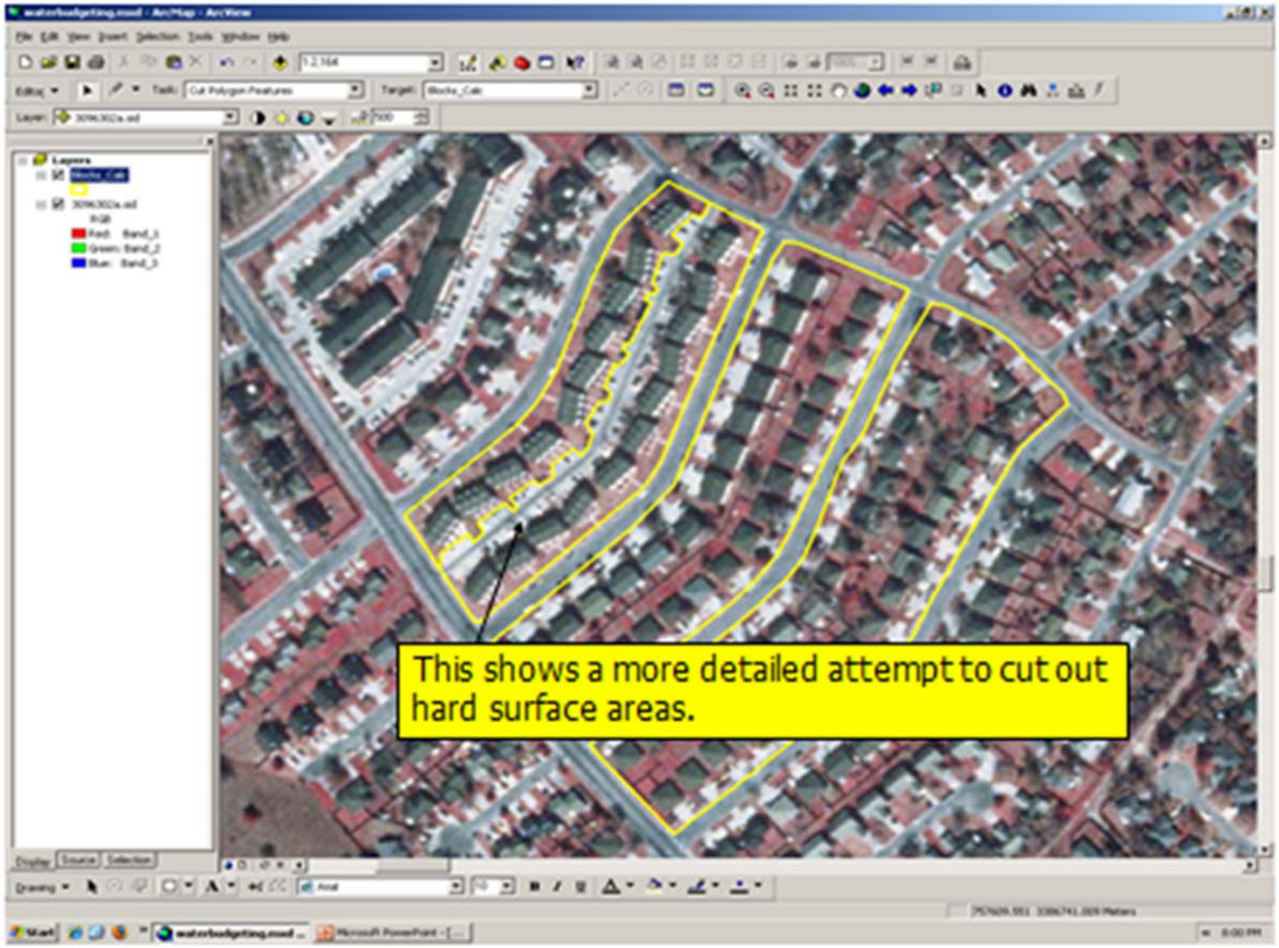
The upper boundary of the alley has been removed.



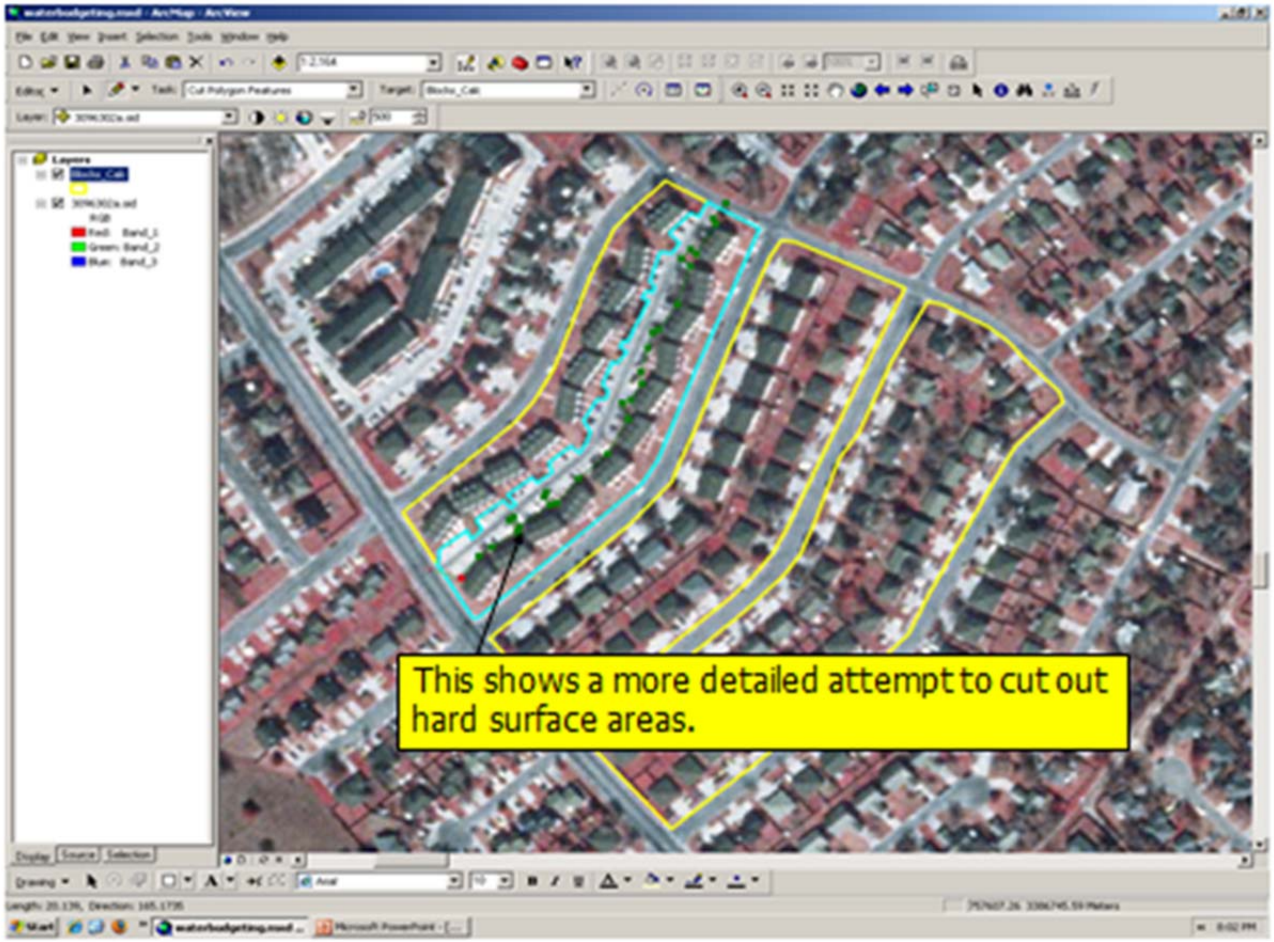
We repeat the process for the lower boundary of the alley.



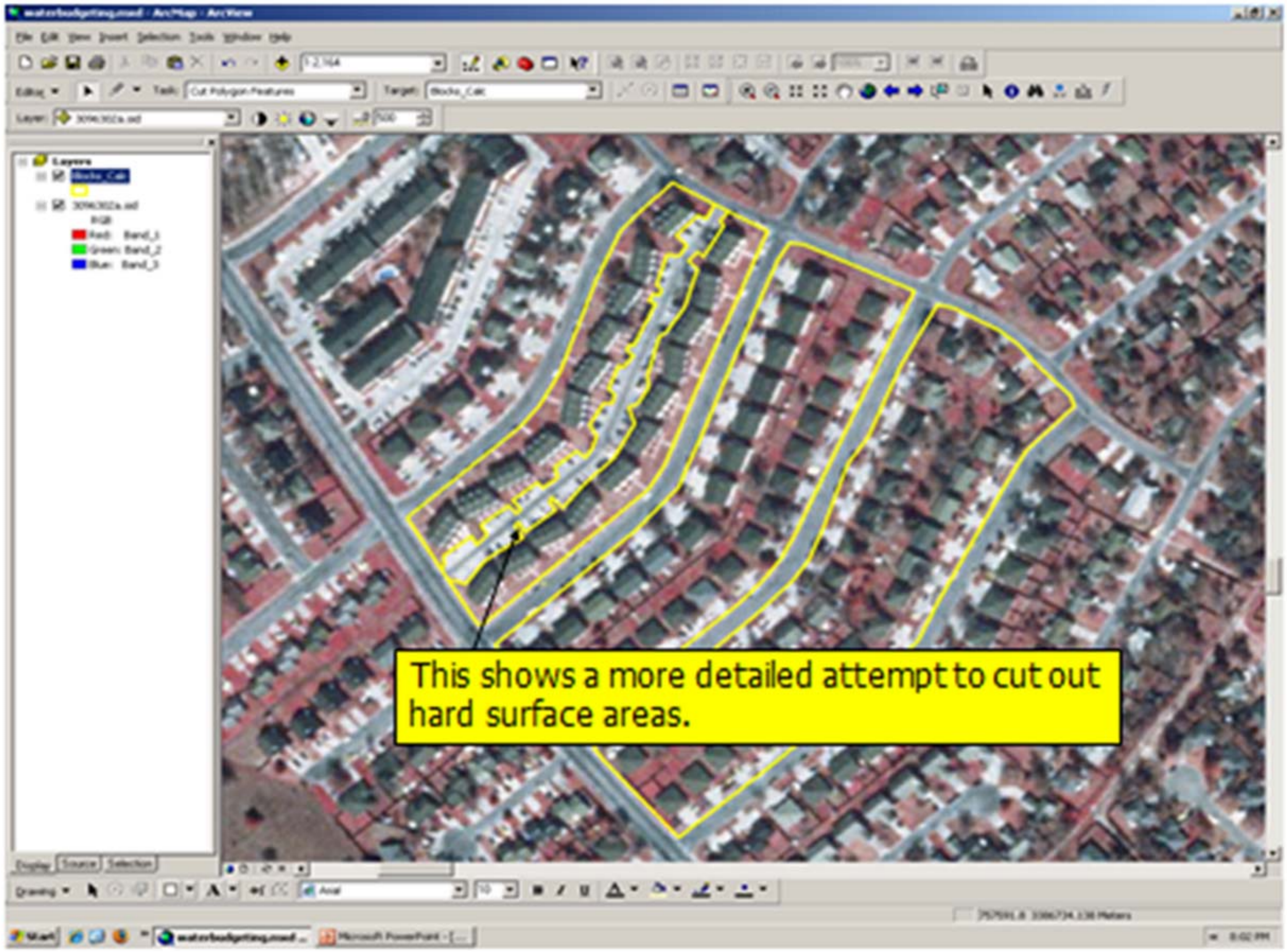
Now that the alley has been cut out of the area, the attribute table is updated with the new area.



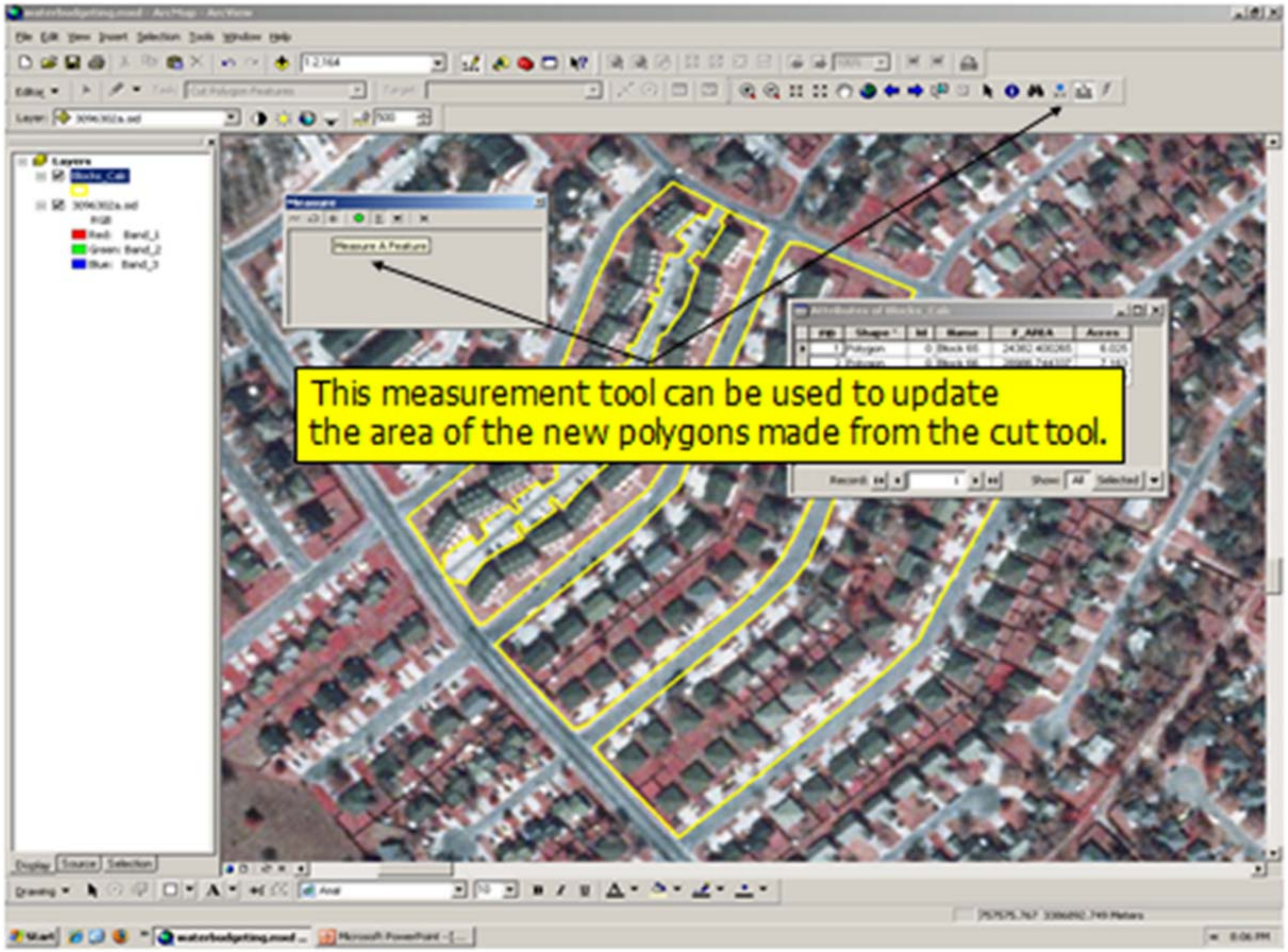
Usually, just the general boundaries of the alley are good enough for city-wide calculations. However, we can improve the accuracy by excluding the driveways and parking areas for each house.



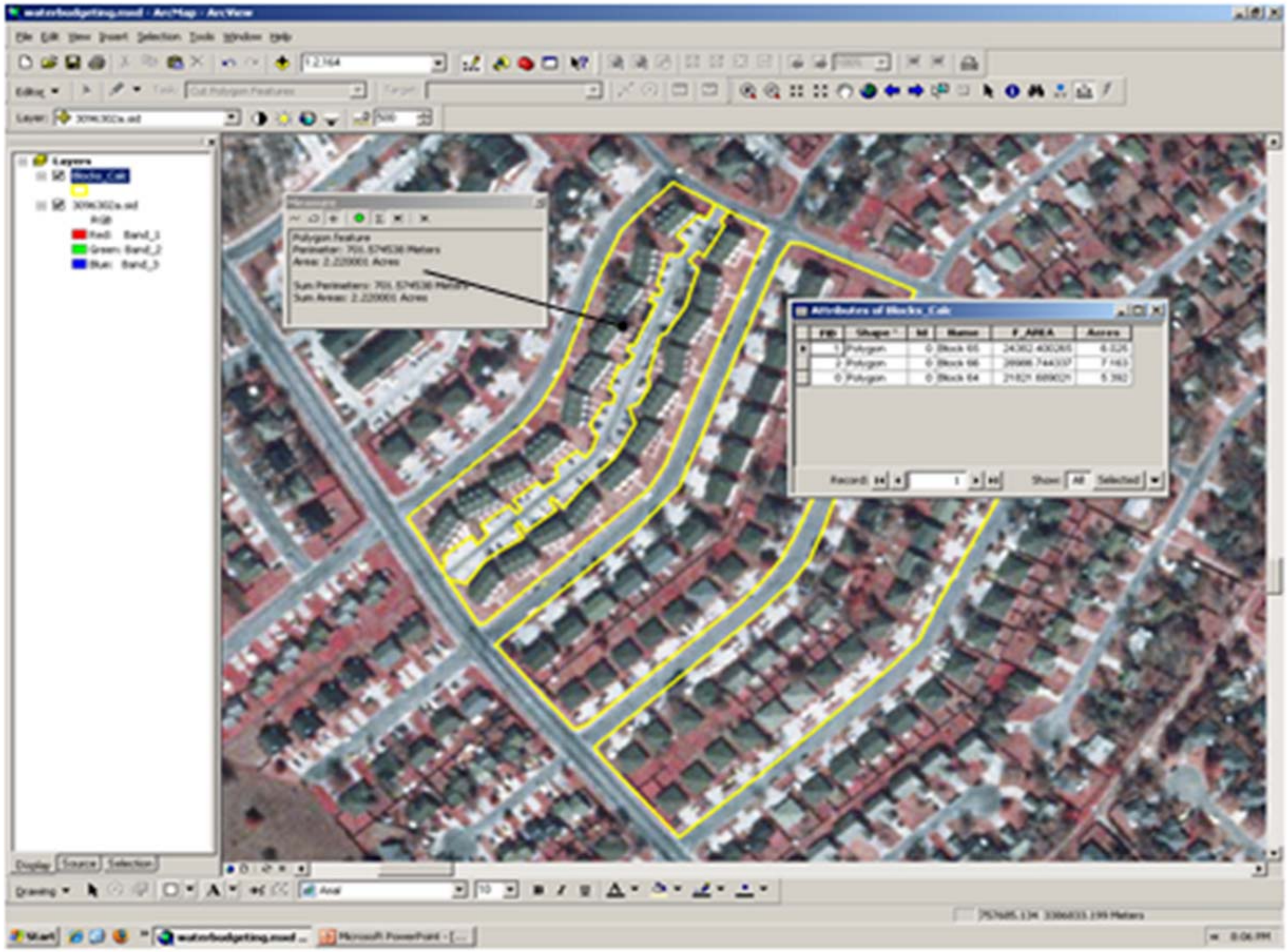
For this example, we will use a different procedure, mapping of the alley and driveways. First, we will draw the boundaries of the driveways along one side of the alley.



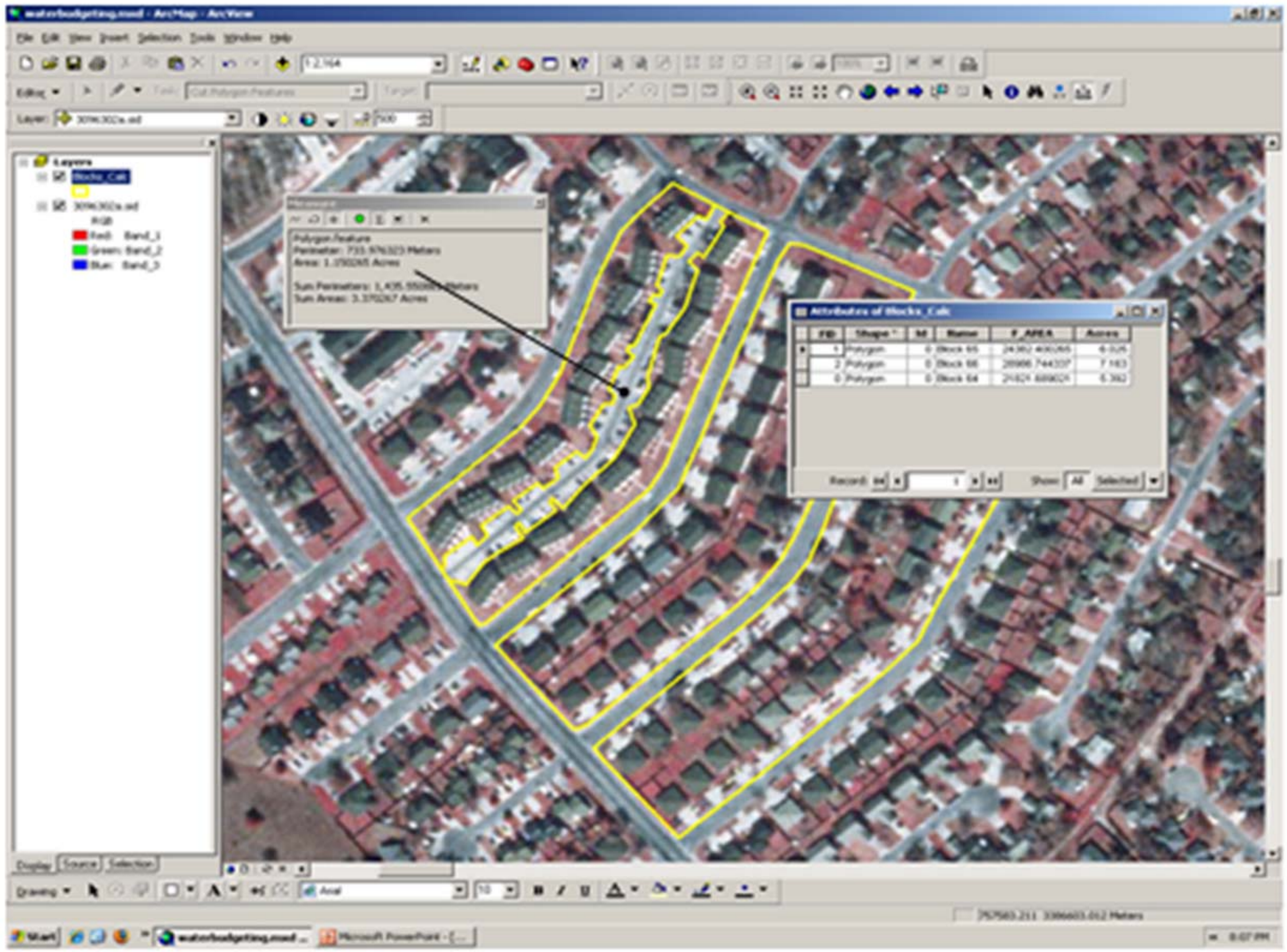
and we complete the map of the alley and driveways by drawing the boundaries along the lower side.



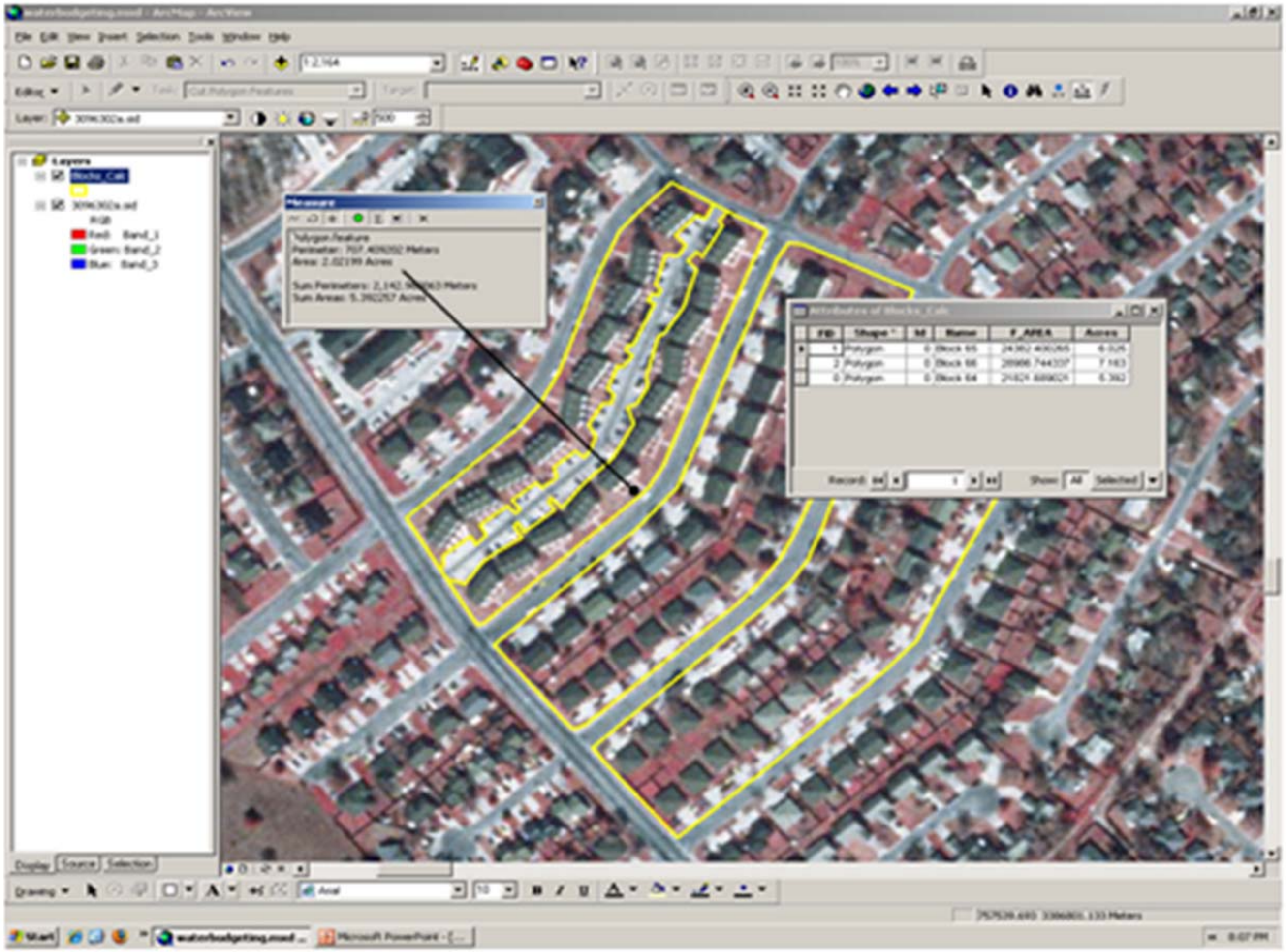
This map or outline of the alley and driveways is referred to as a polygon in GIS. Using the measure tool, we can determine the areas.



The area of the houses and yards shown is 2.2 acres.



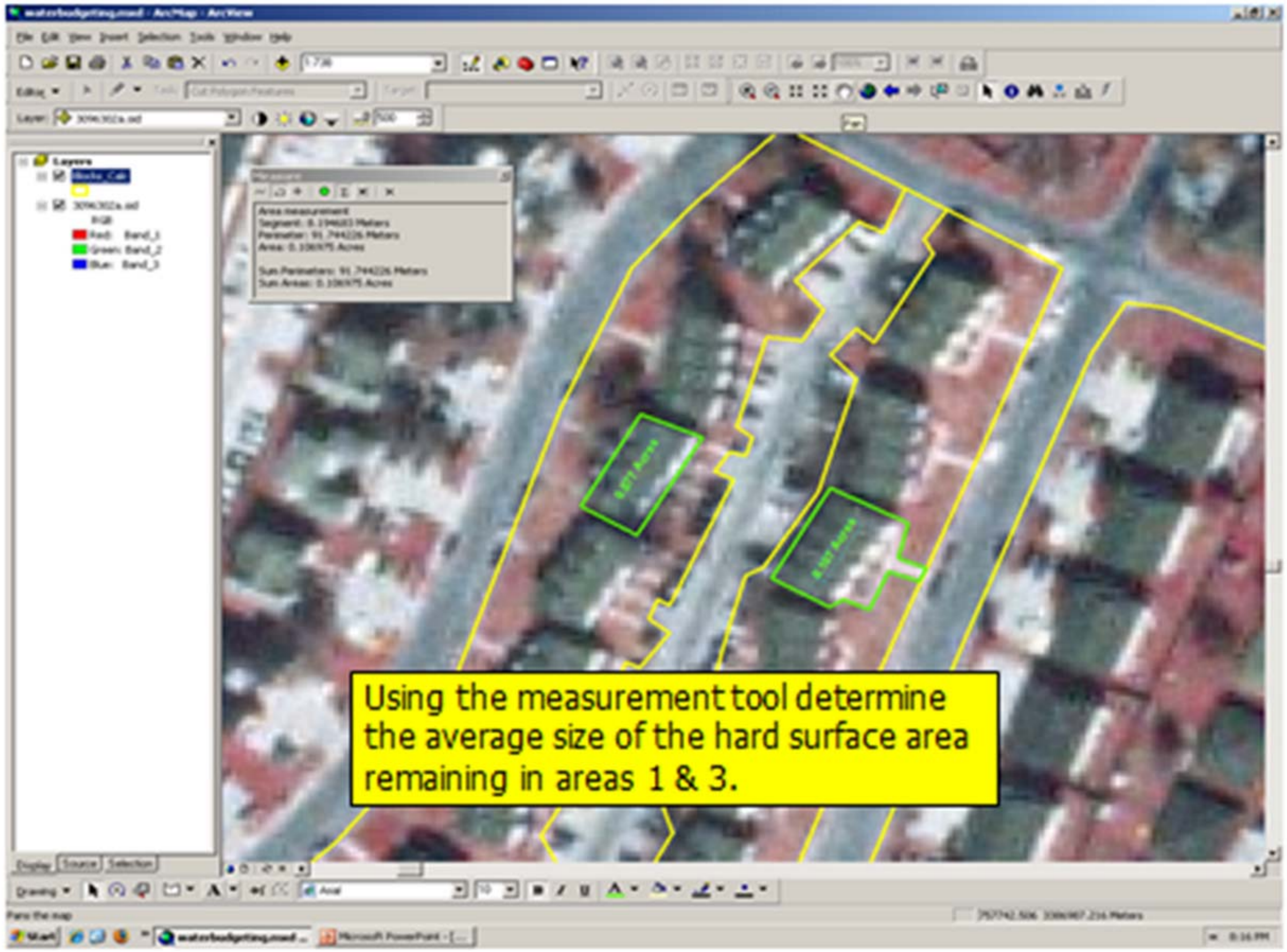
The area of the alley and driveway is 1.15 acres.



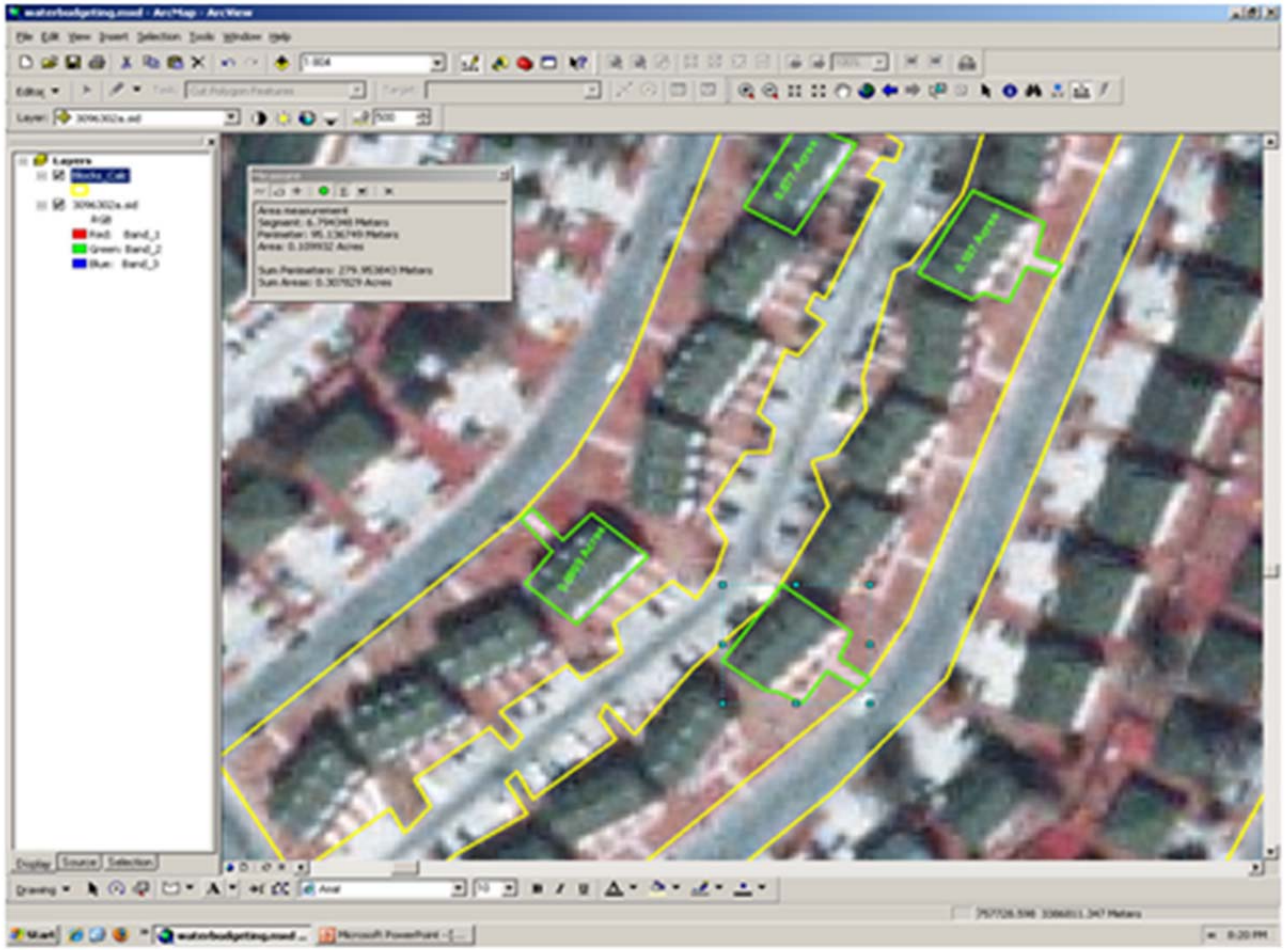
The area of the bottom row of houses and yards is 2.02 acres.

Block 64 Area

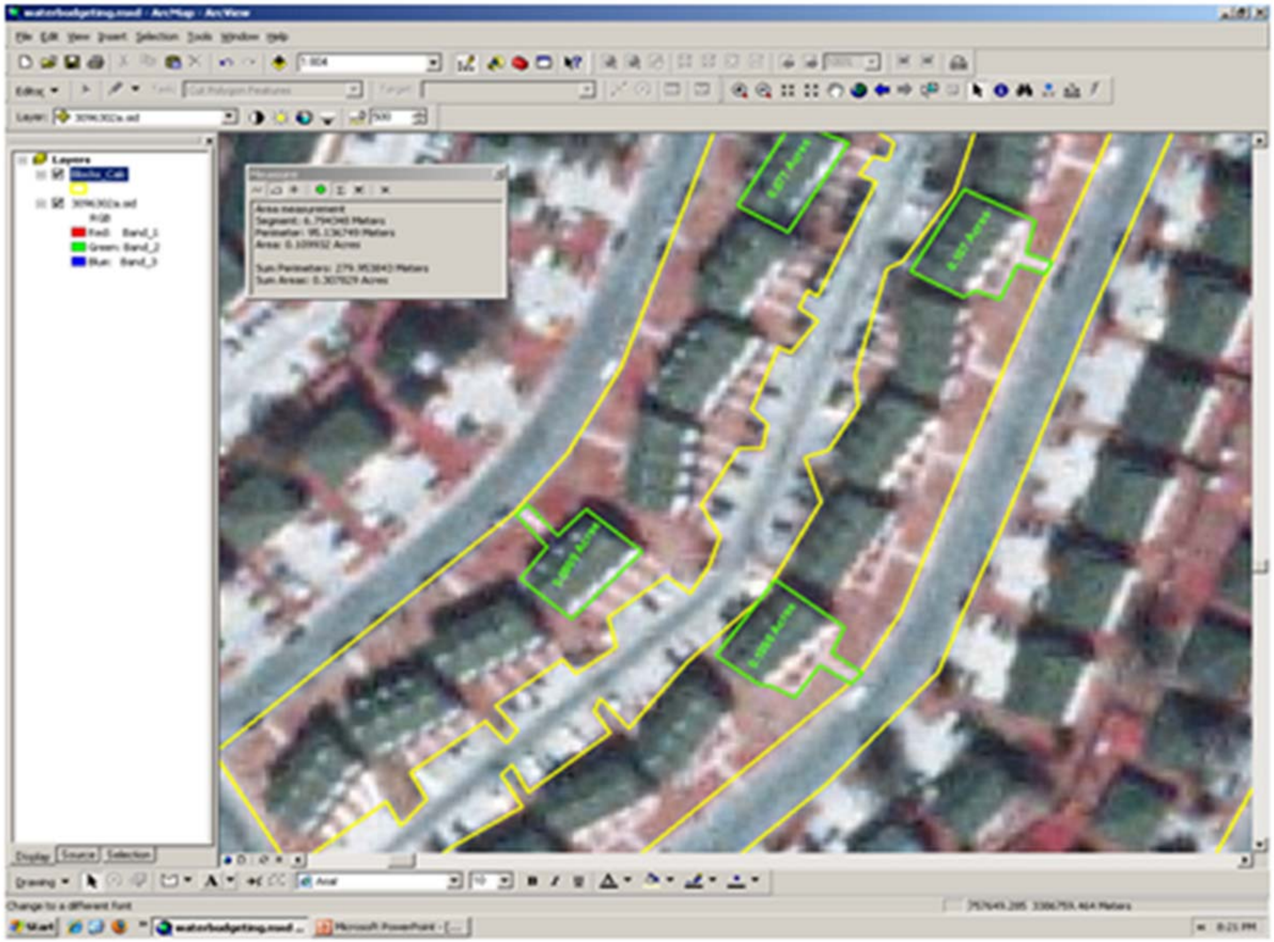
- Area 1 (top): 2.22
- Area 2 (alley): 1.15
- Area 3 (bottom): 2.02
- Total Area: 5.39 acres



The next step is to exclude the areas covered by the houses, walkways and other hard spaces. To do this, we select four properties and map them out with the measurement tool.



The measurement tool gives us the areas of the houses and walkways.



This image shows the four properties we mapped and their corresponding areas.

Calculating Irrigate-able Area

- Assuming an average hard surface area (including houses, sidewalks, etc.) of 0.10 acres
- Add up the total number of home sites: 21
- So 0.10 acres multiplied by 21 home sites:
  - 2.1 acres of hard area

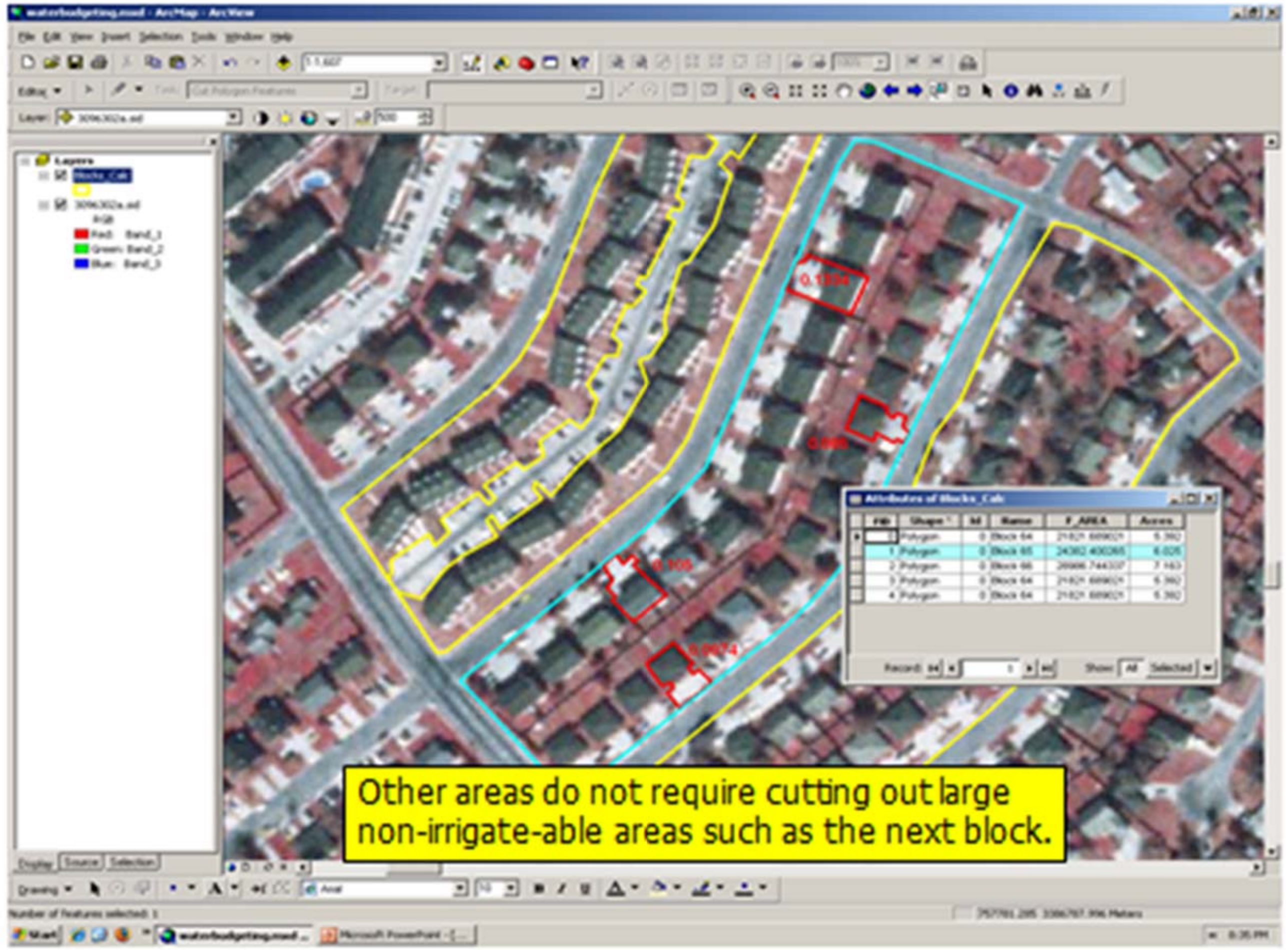
Calculating Irrigate-able Area

- Block 64 Total Area: 5.39 acres
- Subtract out Area 2 (alley): 1.15
- = 4.24 acres (Areas 1 & 3)
- Subtract out the calculated hard areas 2.1
- = 2.14 acres of irrigate-able area

Estimate Percentage of Irrigate-able Cover

- Use your best judgment to estimate the percentage of tree cover in the irrigate-able area. For this example, we are using: 2%.
- Shrubs and landscapes we will estimate at 23%
- Turf: 75%

Irrigate-able Acres	Turf	Trees	Shrubs
	75%	2%	23%
2.14	1.605	0.0428	0.4922
Water Use Rates (Acft/Yr)	4.0	1.0	2.0
Ac-ft/Year	6.42	0.0428	0.9844
Total Ac-ft/year/Block 64			7.45



Other areas do not require cutting out large

non-irrigate-able areas such as the next block.

Appendix A

Irrigation Water Management

Predicting Turf Water Requirements

IRRIGATION WATER MANAGEMENT

PREDICTING TURF WATER REQUIREMENTS

Step 1: Determine Local ET_o
Step 2: Select Crop Coefficient (K_c)
Step 3: Determine Adjustment Factor (A_f)
Step 4: Calculate Water Requirement

Definitions

Adjustment Factor (A_f) - a modification of the crop coefficient (in percent). An adjustment factor is used to reduce water application for allowable stress, for microclimates such as excessive shade or sun, and personal preference of the landscape manager.

Allowable stress - a factor which reflects an "acceptable" turf quality under reduced water supply. Allowable stress varies by individual preference and the requirements of the location. Research has shown that turf water supply can be reduced by 40% or more and still maintain acceptable appearance for most sites.

Cool season turfgrasses - turfgrasses adapted to cooler climates such as tall fescue and ryegrass.

Evapotranspiration (ET) - a measurement of the total water needs of plants including the water lost to the atmosphere through evaporation of water from the soil surface and transpiration through the plant.

Potential evapotranspiration (ET_o) - the potential water use of a cool season grass, growing four inches tall under well-watered conditions. It is used as a reference to which the water requirements of other plants can be related. ET_o varies with climate as a function of temperature, relative humidity, wind speed and solar radiation. Different locations have different ET_o rates due to changes in climate. (ET_o is sometimes written as "PET".)

Crop coefficient (K_c) - a factor used to relate ET_o to the actual water use for a specific plant or turf type. The crop coefficient, K_c, reflects the percentage of ET_o that a specific plant or turf type requires for maximum growth (such as for growing Bermuda grass hay).

Warm season turfgrasses - turfgrasses adapted to warmer climates such as Bermuda grass, St. Augustine grass and Zoysia grass.

QUICK-TABLE A. Turf Water Requirement

#	Variable	Value	Units	Source
1	Potential Evapotranspiration (ET_o)	7.96	inches per month	Appendix A - ET_o Table
2	Crop Coefficient (K_c)	0.6	decimal	Appendix A - K_c Table
3	Adjustment Factor (A_f)	1	decimal	Site specific, professional judgment (shade, slope, etc.)
4	Water Requirement (WR)[1]	4.78	inches per month	#1 x #2 x # 3

[1]Water requirement for a warm season turfgrass grown in San Antonio in the month of July (assuming no rainfall).

Detailed Instructions for Predicting Turf Water Requirements

Step 1: Determine Local ET_o - Appendix A gives average monthly ET_o for 19 major cities in Texas. The Agricultural Program of Texas A&M University System has ET_o networks that report current daily ET_o throughout Texas on the Internet, web address: **http://texaset.tamu.edu.**

Step 2: Select Crop Coefficient (K_c) - Warm season turfgrasses use up to 60% of ET_o, while cool season grasses can use up to 80% of ET_o. Appendix A gives monthly K_c values for the 19 major cities in Texas for warm season, cool season, and warm season turfgrasses overseeded with ryegrass.

Step 3: Determine Adjustment Factor (A_f) - The K_c represents the maximum amount of ET_o that turfgrasses will use. However, many plants, especially turfgrass, exhibit the ability to survive on much less water without showing signs of stress or a reduction in quality. For this reason the crop coefficient is adjusted to represent "allowable stress". For example, buffalo grass has shown to survive on much less water than St. Augustine grass, though they are both warm season grasses. Thus, A_f for buffalo grass may be as low as 0.4, while A_f for St. Augustine grass may only reach 0.6.

Microclimates will also influence water use, especially in small landscapes. Certain areas around buildings or under trees may receive more shade, and therefore require less water than areas under full sun. Wind speed also influences water use. For example, areas between buildings may experience a "venturi effect" resulting in high winds that increase plant transpiration. To make up for such losses, more water must be applied.

Step 4: Calculate Water Requirement - Water use in turfgrasses is calculated using the following relationship:

$$WR = ET_o \times K_c \times A_f \quad \text{(Equation 1)}$$

where:

WR - Water requirement (inches)

ET_o - Potential evapotranspiration $\left(\frac{\text{inches}}{\text{day}}\right), \left(\frac{\text{inches}}{\text{week}}\right), \text{or} \left(\frac{\text{inches}}{\text{month}}\right)$

K_c - Crop coefficient (decimal)

A_f - Adjustment factor (decimal)

Example 1: ET_o = 7.96 inches per month
K_c = 0.6
A_f = 1

WR = 4.78 inches per month

DETERMINING IRRIGATION FREQUENCY

Step 1: Measure Effective Root Zone
Step 2: Determine Soil Type and Soil Water Holding Capacity
Step 3: Calculate Plant Available Water (PAW)
Step 4: Calculate Irrigation Frequency

Definitions

Plant available water - the amount of water in the soil (in inches) that is “available” for plant uptake. (Determined by the difference in moisture content at field capacity and the permanent wilting point times managed allowable depletion or MAD).

Effective root zone - the depth of root zone (in inches) containing approximately 80% of the total root mass.

Irrigation frequency - the number of irrigation events per week.

Managed allowable depletion (MAD) - the process of letting the soil dry out to a prescribed soil moisture level between irrigations (50% for most turfgrasses).

Soil type (texture) - classification of soils into categories such as sand, clay, loam, etc.

Soil water holding capacity - the amount of water (in inches) that can be “held” or stored per foot of soil depth.

QUICK TABLE B. Irrigation Frequency

#	Variable	Value	Units	Source
1	Effective Root Zone Depth (D)	5	inches soil	Soil probe measurements
2	Soil Water Holding Capacity (SWHC)	1.8	inches per foot	Table 1, loam soil
3	Managed Allowable Depletion (MAD)	0.5	decimal	MAD for turf (50%)
4	Plant Available Water (PAW)	0.38	inches of water	(#1 ÷ 12 inches/foot) x #2 x #3
5	Monthly Water Requirement (WR)	4.78	inches per month	QUICK TABLE A
6	Weekly Water Requirement (WR)	1.2	inches per week	#5 ÷ 4 weeks
7	Irrigation Frequency (I)	4	number of irrigations per week	#6 ÷ #4, rounded to next whole number

Detailed Instructions for Determining Irrigation Frequency

Step 1: Measure Effective Root Zone - Many factors restrict root development. Depths may vary because of physiological differences of plants. Other factors that influence root zone depth include high water tables, shallow soils, changes in soil type, compaction, irrigation, fertilization and cultural practices.

For irrigation scheduling, we use the <u>effective</u> root zone depth. This is the depth that contains about 80% of the total root mass and excludes the deeper “tap” or “feeder” roots. In order to obtain an accurate determination of root zone depth, samples should be taken in several locations since the soil type and composition can vary significantly within a landscape.

Step 2: Determine Soil Type and Soil Water Holding Capacity - Soil types vary in the amount of water that can be "stored" or "held" in the root zone. Fine textured soils, such as clays have high soil water holding capacities, while coarse textured soils, such as sands, exhibit low soil water holding capacities. Table 1 gives typical water holding capacities by soil type in inches of water per foot of soil.

Table 1. Approximate water holding capacity (inches of water per foot of soil)

Soil Texture	Water held at field capacity	Water held at permanent wilting point	Soil Water Holding Capacity	Plant Available Water (50% MAD)
Sand	1.0 - 1.4	0.2 - 0.4	0.8 - 1.0	0.45
Sandy Loam	1.9 - 2.3	0.6 - 0.8	1.3 - 1.5	0.70
Loam	2.5 - 2.9	0.9 - 1.1	1.6 - 1.8	0.85
Silt Loam	2.7 - 3.1	1.0 - 1.2	1.7 - 1.9	0.90
Clay Loam	3.0 - 3.4	1.1 - 1.3	1.9 - 2.1	1.00
Clay	3.5 - 3.9	1.5 - 1.7	2.0 - 2.2	1.05

Managed allowable depletion (MAD) - defines the amount of water that the plant can deplete from the soil without causing stress in plants. Many plants can extract only about 50% of the total water available in the root zone without showing stress. Table 2 gives plant available water (in inches) for a MAD of 50% with a 2 inch, 4 inch, and 6 inch root zone for typical sand, loam and clay soils.

Step 3: Calculate Plant Available Water (PAW) - The total amount of water available to a plant is defined by the following relationship:

$$\boxed{PAW = D \times SWHC \times MAD} \qquad \text{(Equation 2)}$$

where:

PAW -	Plant available water in the root zone (inches)
D -	Effective root zone depth (feet)
SWHC -	Soil water holding capacity (inches of water per foot of soil)
MAD -	Managed allowable depletion (decimal)

<u>Example 2:</u> D = 0.42 feet
SWHC = 1.8 inches per foot
MAD = 0.5

PAW = 0.38 inches

Table 2. Plant available water for 3 root zone depths at 50% MAD.

Soil Texture	Soil Water Holding Capacity (inches water per foot of soil)	Available Water @ 50% MAD (inches water per foot of soil)	Available Water @ 50% MAD (inches water per inch of soil)	Total Plant Available Water (inches water)		
				2" Root Zone	4" Root Zone	6" Root Zone
Sand	0.90	0.45	0.038	0.076	0.15	0.23
Loam	1.70	0.85	0.071	0.14	0.28	0.43
Clay	2.10	1.05	0.088	0.18	0.35	0.53

Step 4: Calculate Irrigation Frequency - Irrigation frequency is determined on a weekly basis. The number of irrigations per week is calculated from the total weekly water requirement and the amount of plant available water as follows:

$$I = \frac{WR}{PAW} \qquad \text{(Equation 3)}$$

where:

I - Number of irrigations per week (rounded to next whole number)
WR - Water requirement (inches per week)
PAW - Plant available water in root zone (inches)

Example 3: WR = 1.2 inches per week
PAW = 0.38 inches

I = 4 irrigations per week

DETERMINING STATION RUN TIMES

Step 1: Calculate Turf Water Requirement Step 2: Calculate Plant Available Water (PAW) Step 3: Calculate Irrigation Frequency Step 4: Determine Precipitation Rate (PR) Step 5: Calculate Station Run Time

Definitions

Precipitation rate - measurement of how fast an irrigation system applies water to a landscape in inches per hour.

Stations - group of sprinklers on an automated irrigation system that operate at the same time.

Run time - how long a station is operated during an irrigation event**.**

QUICK-TABLE C. Station Run Times

#	Variable	Value	Unit	Source
1	Turf Water Requirement (WR)	1.2	inches per week	QUICK-TABLE B: #6
2	Irrigation Frequency (I)	3	number of irrigations per week	QUICK-TABLE B: #7
3	Precipitation Rate (PR)	1.0	inches per hour	Measured with catch devices, or other method
4	Station Run Time (RT)	24	minutes	(#1 x 60) ÷ (#2 x #3)

Detailed Instructions for Determining Station Run Time

Step 1: Calculate Turf Water Requirement - (see page 3)

Step 2: Calculate Plant Available Water (PAW) - (see page 5)

Step 3: Calculate Irrigation Frequency - (see page 6)

Step 4: Determine Precipitation Rate (PR) - Precipitation rate is a measurement of how fast an irrigation system applies water to a landscape. There are three primary methods for determining precipitation rates: manufacturers specifications, catch can tests, and meter readings. Details are provided in the next section.

Station precipitation rates often vary within an irrigation system due to such factors as poor sprinkler alignment, spray trajectory and pressure fluctuations. Different types of irrigation equipment have different precipitation rates, it is necessary to determine the precipitation rate of each station on an irrigation system.

Step 5: Calculate Station Run Time - Station run times can be calculated from water requirement, irrigation frequency and precipitation rate using the following equation:

$$RT = \frac{WR}{I \times PR} \times 60 \qquad \text{(Equation 4)}$$

where:

RT -	Station run time (minutes)
WR -	Water requirement (inches per week)
I -	Number of irrigations per week
PR -	Precipitation rate (inches per hour)

<u>Example 4:</u> WR = 1.2 inches per week
I = 3 irrigation per week
PR = 0.5 inches per hour

RT = 48 minutes

DETERMINING PRECIPITATION RATE

Definitions

<u>Catch device</u> - a container used to measure the amount of water an irrigation system applies, commonly referred to as a "catch can".

<u>Coverage area</u> - the landscape area covered by a single sprinkler head or contained within a station, in square feet (ft^2).

<u>GPM</u> - flow rate of water through an irrigation system expressed in gallons per minute (gpm).

Heads - sprinkler application devices used to apply water to a landscape; the most common are sprays, rotors and impacts.

Station - individual or multiple sprinkler heads on an irrigation system usually activated by a single solenoid valve connected to a central controller.

Testing run time - the total time that each station is operated during catch can tests.

Throat area - the surface area of the top of a catch device through which the water falls, in square inches (in^2).

Water meters - devices used to meter the volume of water that flows through a piping system, commonly in units of gallons or cubic feet (ft^3, cf).

A. Catch Can Method

Step 1: Select Catch Device Step 2: Determine Throat Area Step 3: Identify Stations and Locations of Heads Step 4: Lay Out Catch Devices Step 5: Run Each Station Step 6: Record Catch Volumes Step 7: Calculate Precipitation Rate

Step 1: Select Catch Device - A catch device "catches" the irrigation water during a test and holds it for measurement. Catch devices range from special graduated conical cylinders to tuna fish cans. Some devices have raised graduation marks which allow the volume to be read directly. With other devices, the water that is caught is poured into a graduated cylinder, and the volume is then measured. Irrigation depth in straight-sided devices, such as a tuna can, may be estimated directly using a ruler; however, this method is not always practical since it requires long testing run times in order to collect a sufficient depth of water necessary for accurate measurements.

Step 2: Determine Throat Area: The "throat area" is the size of the top of the catch device in square inches. For round catch devices, the throat area is calculated as follows:

$$A = \frac{\pi d^2}{4}$$

where A = throat area (square inches, in^2) and d = diameter (inches, in), and π = 3.14 (constant).

Step 3: Identify Stations and Locations of Heads - Identify the location of each sprinkler head in a station by briefly running each station on the controller. Place colored flags to mark all heads. It is helpful to use a different color for each station (e.g., red flags for station 1, green flags for station 2).

Step 4: Lay Out Catch Devices - Sketch a diagram showing the location of sprinkler heads in each station. Spending a few minutes with the diagram to determine catch device placement can save significant time and confusion in the field.

An effective and efficient pattern used to lay out catch devices is "at-a-head" and "halfway-between-heads." (Note: "at-a-head" refers to placing cans no closer than about 2 feet from spray heads and about 4 feet from rotor and impact sprinklers). This simple placement pattern requires the least number of catch devices while providing adequate coverage over the test area. Figure 1 shows a suggested catch device placement for a rectangular sprinkler pattern. <u>It is important to use a grid layout with all cans roughly equally spaced</u>.

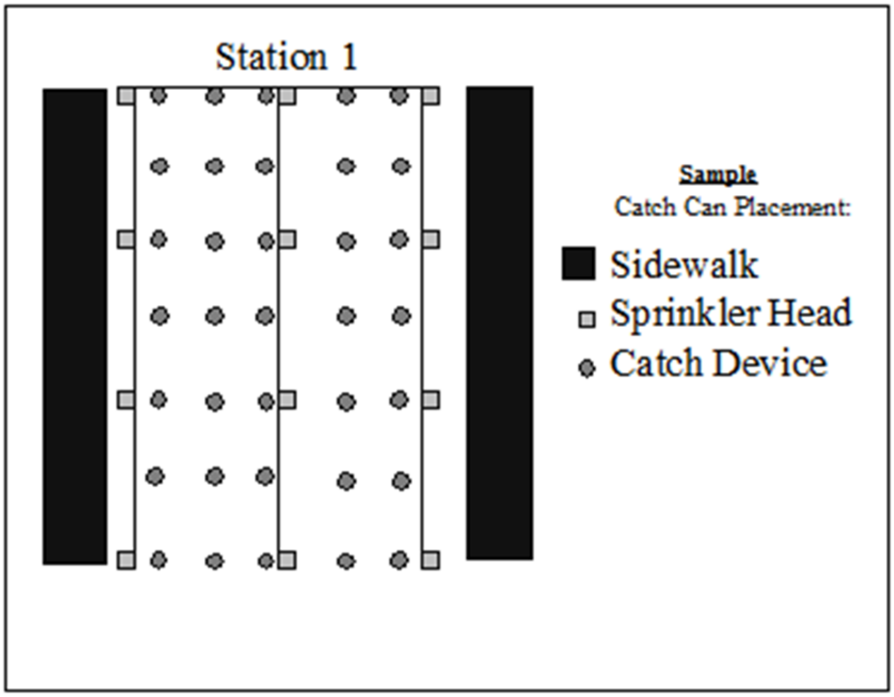


Figure 1. Recommended catch device placement.

Step 5: Run Each Station - Conduct catch can tests under the same conditions (wind, pressure, etc.) at which the system normally operates. In some locations, pressure will fluctuate during the day with changing water demands. Testing run times for large impact sprinklers normally range from 10 to 30 minutes, at least three complete revolutions are recommended. Spray heads usually have higher precipitation rates and usually require no more than 5 to 10 minutes of run time to provide sufficient water for measurement.

Step 6: Record Catch Volumes - Catch volumes are recorded in milliliters (ml). Use either a catch device that measures milliliters directly, or pour the water into a graduated cylinder. To simplify data management, prepare a data sheet in advance to record the results. Collect such information as the date and time of the test, approximate weather conditions, station numbers, testing run times and catch can volumes. Table 3 shows one possible data sheet format. (Blank forms are included in Appendix A.) It is also useful to record individual catch can volumes on the site diagram for identifying problem areas.

Table 3. Sample Data Collection Sheet

Site Name: **Beaver Park** Date: **8/8/97**		Start Time: **8:30 a.m.** End Time: **10:30 a.m.**	
Station number	1	2	3
Testing run time (minutes)	10	15	5
Catch volume (milliliters)	24, 22	35, 42	10, 14
	20, 32	54, 43	11, 15
	21, 25	55, 38	16, 8
	30, 28	44, 48	10, 15
	22, 20	40, 42	12, 15
Temperature: 80 F	Wind speed/direction: 0		RH: 60%

Step 7: Calculate Precipitation Rate - Calculate the precipitation rate of each station using the following equation:

$$PR = \frac{\sum \mathbf{V} \times 3.6612}{\mathbf{n} \times a_t \times t_R}$$

(Equation 5)

where:

PR - Precipitation rate (inches per hour)
$\sum V$ - Summation of all catch can volumes (milliliters)
3.6612 - Constant, converts milliliters to cubic inches and minutes to hours
n - Number of catch devices
a_t - Throat area of catch device (square inches)
t_R - Testing run time (minutes)

<u>Example 5:</u> For Station 1 above.

$\sum V$ = 244 milliliters
n = 10
a_t = 16.61 square inches
t_R = 10 minutes

PR = 0.54 inches per hour

B. Area/Flow Method

Step 1: Determine the Flow Rate of Each Station
Step 2: Determine Coverage Area
Step 3: Calculate Precipitation Rate

Step 1: Determine the Flow Rate of Each Station - Sprinklers are rated in gallons per minute (or GPM) and vary by sprinkler type (rotor, spray, impact), nozzles size, and pressure. Ratings for sprinklers are provided in manufacturers' specifications catalogs. In the area/flow method, the total flow into a station is determined by summing the flow rates of each individual sprinkler head. For example, assume that an irrigation system consists of one station, shown in Figure 2.

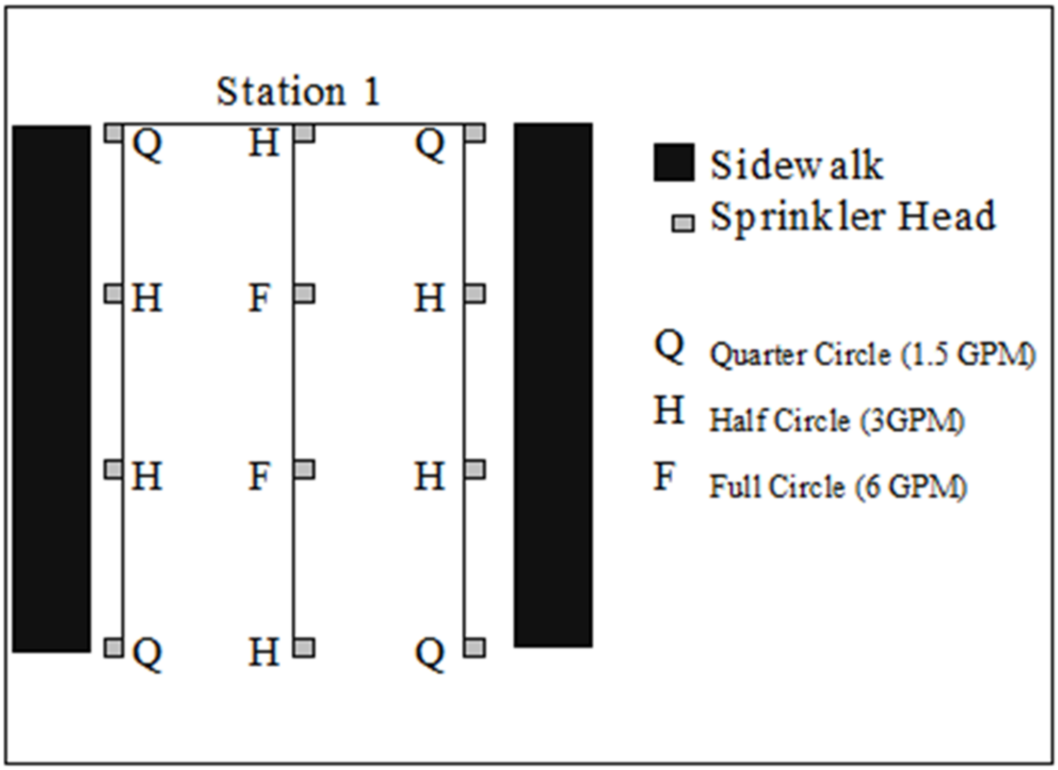


Figure 2. Sprinkler layout and GPM rating.

Station 1 contains four quarter circle heads, six half circle heads and two full circle heads, rated at 1.5 GPM, 3.0 GPM and 6.0 GPM, respectively. The total flow through Station 1 is computed as follows:

Total Flow = (4 x 1.5 GPM) + (6 x 3.0 GPM) + (2 x 6.0 GPM)

Total Flow = 6 GPM + 18 GPM + 12 GPM

Total Flow = 36 GPM

Step 2: Determine Coverage Area - The coverage area (in square feet, ft^2) is the entire landscape area over which the station applies water. If available, obtain an "as-built" or scaled drawing of the irrigation system to determine the dimensions of the landscape area. If maps or drawings are not available, then measure the landscape using a measuring wheel or tape measure. The equations provided in Figure 3 are useful for calculating surface area for common shapes.

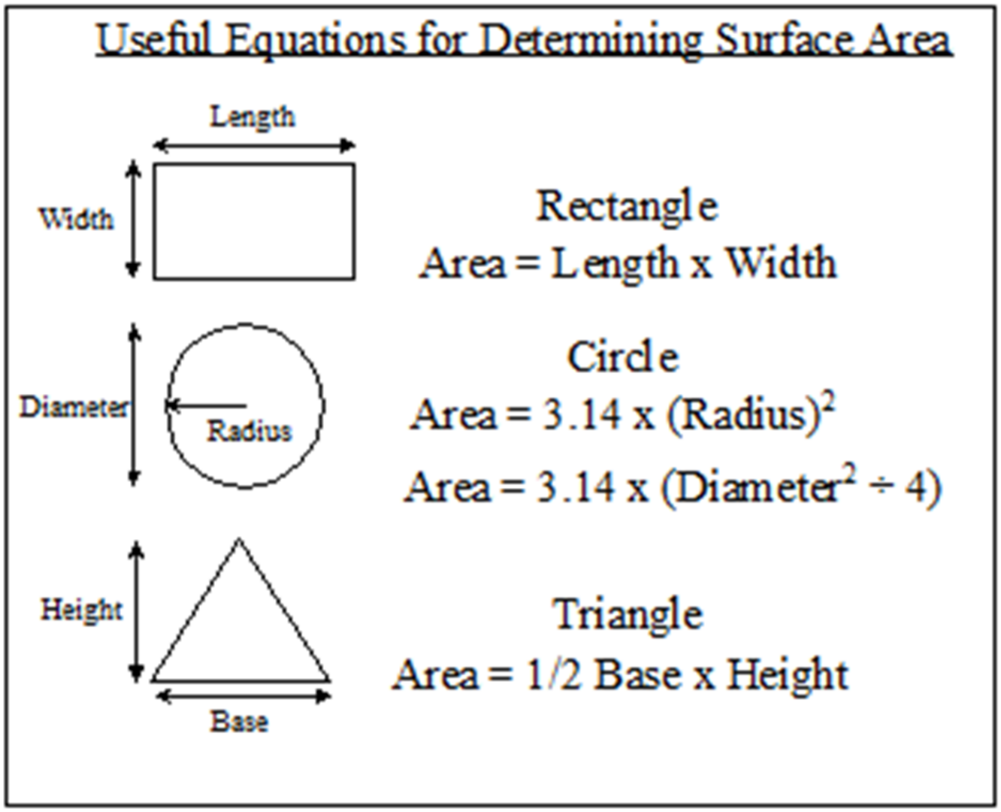


Figure 3. Useful equations for determining surface area.

Figure 4 shows the dimensions for a landscape. The area of coverage for Station 1 can be calculated as follows, using the equation for a rectangular area.

Area = Length x Width
Area = 40 feet x 60 feet
Area = 2400 square feet

Step 3: Calculate Precipitation Rate - Knowing the total flow through the station and area of coverage, the precipitation rate for Station 1 is calculated as follows:

$$PR = \frac{96.25 \times GPM}{A}$$

(Equation 6)

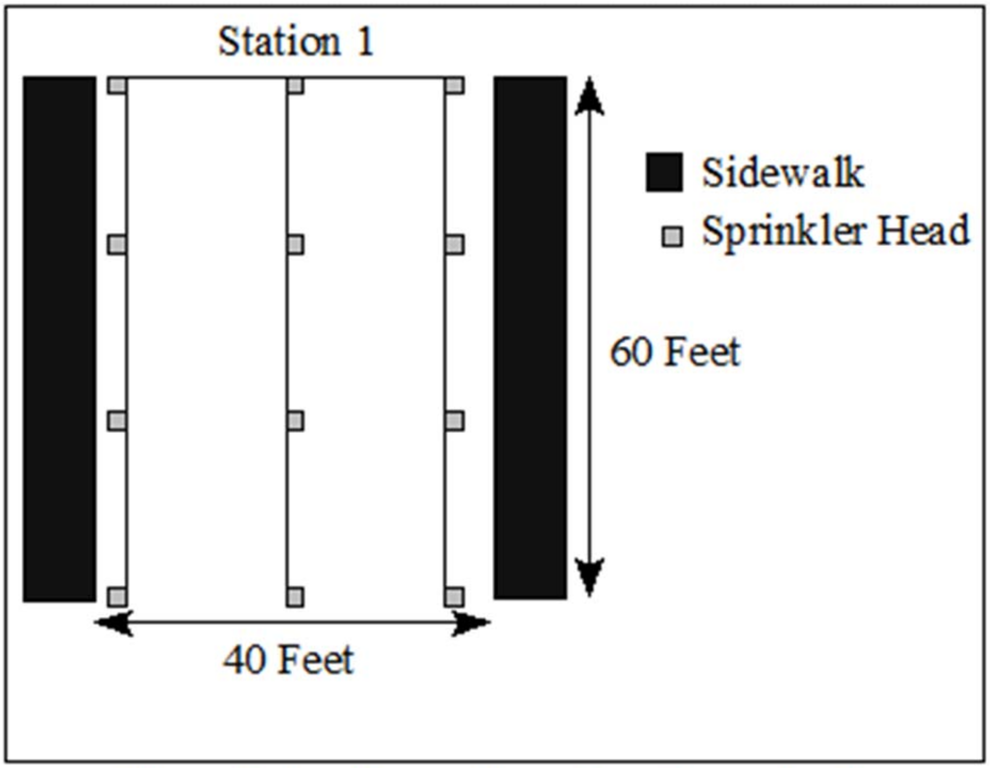


Figure 4. Landscape dimensions for station 1.

where:

PR -	Station precipitation rate (inches per hour)
96.25 -	A constant that coverts gallons per minute to inches per hour. [It is derived from: (60 min per hr x 12 in per ft) ÷ 7.48 gal per min]
GPM -	Total rated flow through the station (gallons per minute)
A -	Area of coverage (square feet, ft^2)

<u>Example 6:</u> For Station 1 above.

GPM = 36 gallons per minute
A = 2400 square feet
PR = 1.44 inches per hour

C. Meter Method

Step 1: Determine Coverage Area Step 2: Record Initial Meter Reading Step 3: Run Station Step 4: Record Final Meter Reading Step 5: Calculate Precipitation Rate

The precipitation rate of irrigation systems can be estimated from water meter readings. This is particularly easy if the irrigation system is equipped with a separate meter. Unfortunately, many sites such as residential properties have only one meter that measures both household and outdoor water use. For these situations, landscape water use can be estimated by determining the average monthly water use in the winter months (December, January and February) when irrigation systems are typically turned off. Then subtract the winter water use from monthly water use during the irrigation season.

Water meters measure the total amount of water flowing through the pipeline system. Water loss due to leaks in pipelines and sprinkler heads and due to wind drift is not accounted for. Thus, meter readings can represent a significantly higher volume of water than what is actually applied to the landscape.

Step 1: Determine Coverage Area - Determine the landscape area (in square feet, ft^2) for each station on the system. This can be computed from a detailed design drawing, or estimated using equations for calculating area as shown in Figure 3.

Step 2: Record Initial Meter Reading - Record the initial meter reading on a data collection sheet, such as the one provided in Table 4.

Table 4. Sample Data Collection Sheet - Meter Method

Site Name: **Clark Field**	Date: **8/9/97**		
Station number:	1	2	3
Test run time (minutes)	25	15	20
Initial reading (1000 gallons)	05015	05016	05018
Final reading (1000 gallons)	05016	05018	05019
Landscape Area (square feet)	5,200	8,000	5,200

Step 3: Run Station - Turn on and operate each station for at least 10 to 15 minutes. It is a good idea to use a stop watch to keep track of the test run time. After the test has ended, record the total run time on the data sheet.

Step 4: Record Final Meter Reading - Take a meter reading at the conclusion of each test and before initiating the next station. The final reading then becomes the initial meter reading for the next station. Continue until each station has been tested, and record all information on the data sheet as shown in Table 4.

Step 5: Calculate Precipitation Rate - Using the meter readings, test run time and area of coverage, the precipitation rate is calculated using the following equation:

$$PR = \frac{96.25 \times \frac{FR - IR}{RT}}{A} \quad \text{(Equation 7)}$$

where:

A - Area of coverage (square feet)
96.25 - Constant
FR - Final meter reading (gallons, or 1000 gallons)
IR - Initial meter reading (gallons, or 1000 gallons)
RT - Test run time (minutes)

Example 7: For Station 1 above.

A = 5200 square feet
FR = 5,016,000 gallons
IR = 5,015,000 gallons
RT = 25 minutes

PR = 0.74 inches per hour

ADDITIONAL EXAMPLE PROBLEMS

Example 1: Calculating Turf Water Requirement (inches)

A bermudagrass turf growing in Brownsville has a crop coefficient of 0.6 and an adjustment factor of 0.8. What is the monthly water requirement for this turf in July?

$$\boxed{WR = ET_o \times K_c \times A_f} \qquad \text{(Equation 1)}$$

ET_o = 7.59 in per month (from Appendix A)
K_c = 0.6
A_f = 0.8

$$WR = 7.59\ in\ /\ month \times 0.6 \times 0.8$$

WR = 3.64 inches for the month of July

Example 2: Calculating Plant Available Water (inches)

A bermudagrass turf has an effective root zone depth of 4 inches and is growing in a loam soil. If the managed allowable depletion is 50%, how much water is available to the turf?

$$\boxed{PAW = D \times SWHC \times MAD} \qquad \text{(Equation 2)}$$

D = 0.33 feet, (4 inches ÷ 12 inches per foot)
SWHC = 1.7 inches per foot (from Table 1, page 5)
MAD = 0.50

$$PAW = 0.33\ ft \times 1.7\ in\ /\ ft \times 0.5$$

PAW = 0.28 inches

Example 3: Calculating Irrigation Frequency (irrigations per week)

The weekly water requirement for a St. Augustine grass is 1 inch per week. If the plant available water is 0.25 inches, how many irrigations per week are recommended?

$$\boxed{I = \frac{WR}{PAW}} \qquad \text{(Equation 3)}$$

WR = 1 inch per week
PAW = 0.25 inches

$$I = \frac{1\ in\ /\ week}{0.25\ inches}$$

I = 4 Irrigations per week

Example 4: Calculating Station Run Time (minutes)

The weekly water requirement for a baseball field is 1 inch per week. The field is irrigated 3 days per week. If Station 1 on the irrigation system has a precipitation rate of 0.5 inches per hour, how long (in minutes) must the station run per irrigation?

$$\boxed{RT = \frac{WR}{I \times PR} \times 60} \qquad \text{(Equation 4)}$$

WR = 1 inch
I = 3
PR = 0.5 inches per hour

$$RT = \frac{1\ inch}{3 \times 0.5\ in\ /\ hour} \times 60\ \text{min}/hour$$

RT = 40 minutes

Example 5: Calculating Precipitation Rate (inches per hour) - Catch Can Method

A catch can test was conducted at Beaver Park on three stations of the irrigation system. Calculate the precipitation rate for station 1 using the data recorded in the table below. The throat area of the catch device is 15 square inches.

Source: Table 3. Sample Data Collection Sheet			
Site Name: **Beaver Park** Date: **8/8/97**		Start Time: **8:30 a.m.** End Time: **10:30 a.m.**	
Station number	1	2	3
Testing run time (minutes)	10	15	5
Catch volume (milliliters)	24, 22	35, 42	10, 14
	20, 32	54, 43	11, 15
	21, 25	55, 38	16, 8
	30, 28	44, 48	10, 15
	22, 20	40, 42	12, 15
Temperature: 80 F	Wind speed/direction: 0		RH: 60%

$$PR = \frac{\sum V \times 3.6612}{n \times a_t \times t_R}$$ (Equation 5)

$$\sum V = 24 + 20 + 21 + 30 + 22 + 22 + 32 + 25 + 28 + 20$$

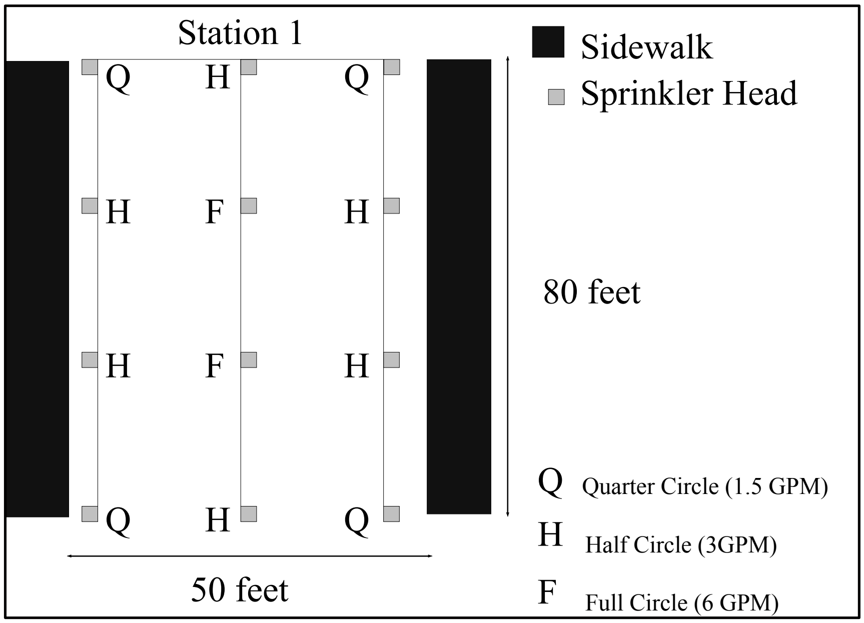
$\sum V$ = 244 milliliters
n = 10
a_t = 15 square inches
t_R = 10 minutes

$$PR = \frac{244\ ml \times 3.6612}{10 \times 15\ in^2 \times 10\ \text{min}}$$

PR = 0.58 inches per hour

Example 6**: Calculating Precipitation Rate (inches per hour) - Area/Flow Method**

Calculate the precipitation rate for Station 1 using the Area/Flow method.



$$PR = \frac{96.25 \times GPM}{A}$$ (Equation 6)

$$GPM = (4 \times 1.5) + (6 \times 3.0) + (2 \times 6.0)$$

GPM = 36 gallons per minute

$$A = 80\ ft \times 50\ ft$$

A = 4000 square feet

$$PR = \frac{96.25 \times 36\ GPM}{4000\ ft^2}$$

PR = 0.87 inches per hour

Example 7: Calculating Precipitation Rate (inches per hour) - Meter Method

Calculate the precipitation rate for Station 1 using data collected below.

Site Name: **Park Place**		Date: **10/20/98**	
Station number:	1	2	3
Test run time (minutes)	15	15	20
Initial reading (1000 gallons)	0525	0527	0529
Final reading (1000 gallons)	0527	0529	0531
Landscape Area (square feet)	18,000	8,500	10,000

$$PR = \frac{96.25 \times \dfrac{FR - IR}{RT}}{A}$$

(Equation 7)

FR = 527,000 gallons (527 x 1000)
IR = 525,000 gallons (525 x 1000)
RT = 15 minutes
A = 7000 square feet

$$PR = \frac{96.25 \dfrac{(527{,}000 - 525{,}000)\ gal}{15 \text{ min}}}{18000\ ft^2}$$

PR = 0.71 inches per hour

Appendix B

ETo and Rainfall Data

APPENDIX

Average Monthly Reference Evapotranspiration (ET_o) for Major Texas Cities (inches per month)

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Abilene	2.08	2.57	4.14	5.48	6.47	7.65	8.36	7.46	5.48	4.21	2.67	2.08	**58.65**
Amarillo	1.84	2.27	3.73	5.06	5.89	7.51	8.08	7.29	5.61	4.05	2.40	1.78	**58.65**
Austin	2.27	2.72	4.34	5.27	6.39	7.15	7.22	7.25	5.57	4.38	2.74	2.21	**57.51**
Brownsville	2.65	3.03	4.48	5.17	6.03	6.32	6.68	6.65	5.21	4.34	3.01	2.59	**56.16**
College Station	2.20	2.71	4.22	5.20	6.25	6.89	7.10	6.85	5.60	4.30	2.80	2.20	**56.32**
Corpus Christi	2.42	2.95	4.28	5.17	5.95	6.43	6.68	6.65	5.21	4.34	3.01	2.59	**55.68**
Dallas/Ft Worth	2.00	2.46	3.96	5.14	6.21	7.06	7.40	7.25	5.49	4.19	2.59	2.10	**55.85**
Del Rio	2.47	3.01	4.76	6.01	6.98	7.41	7.57	7.41	5.77	4.35	2.91	2.36	**61.01**
El Paso	2.74	3.53	6.07	8.19	9.83	11.12	9.19	8.94	7.69	5.89	3.58	2.49	**79.26**
Galveston	2.20	2.60	4.10	5.00	6.11	6.60	6.20	6.00	5.50	4.20	2.80	2.30	**53.61**
Houston	2.36	2.83	4.32	5.01	6.11	6.57	6.52	6.08	5.57	4.28	2.90	2.35	**54.90**
Lubbock	2.35	2.63	4.41	5.53	6.93	7.73	7.63	7.20	5.54	4.19	2.61	2.33	**59.08**
Midland	2.20	2.78	4.46	5.91	7.21	8.20	9.23	8.62	6.95	4.31	2.78	2.16	**64.81**
Port Arthur	2.25	2.63	3.95	5.09	6.12	6.60	5.81	5.61	5.46	4.18	2.76	2.23	**52.69**
San Angelo	2.88	3.13	5.31	7.01	8.48	9.16	9.29	8.49	6.60	5.08	3.37	2.54	**71.34**
San Antonio	2.42	2.90	4.42	5.47	6.47	6.97	7.31	6.99	5.64	4.44	2.85	2.36	**59.93**
Uvalde	2.44	2.95	4.62	5.85	6.70	7.21	7.50	7.31	5.70	4.40	2.89	2.36	**59.93**
Victoria	2.35	2.87	4.29	5.77	6.39	6.70	6.92	6.70	5.36	4.41	2.93	2.33	**57.02**
Waco	2.13	2.62	4.03	5.31	6.45	7.15	7.40	7.50	5.70	4.41	2.70	2.17	**54.05**
Weslaco	2.50	2.57	3.96	4.90	6.12	6.53	7.00	6.58	4.79	3.96	2.85	2.29	**54.05**
Wichita Falls	1.94	2.46	4.07	5.50	6.70	7.54	7.97	7.72	5.79	4.30	2.62	1.95	**58.56**

Average Monthly Rainfall for Major Texas Cities (inches per month)

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Abilene	1.01	1.10	1.19	2.09	3.31	2.90	2.09	2.45	2.75	2.48	1.28	1.04	**23.68**
Amarillo	0.59	0.58	0.93	1.24	2.74	3.40	2.88	2.99	1.89	1.41	0.62	0.57	**19.84**
Austin	2.11	2.41	2.05	3.01	4.38	3.46	2.05	2.23	3.38	3.35	2.28	2.46	**33.16**
Brownsville	1.33	1.31	0.90	1.63	2.31	2.85	1.69	2.46	4.95	3.36	1.61	1.18	**25.58**
College Station	2.87	2.88	2.50	3.77	4.73	3.79	2.24	2.43	4.30	3.64	3.07	3.15	**39.37**
Corpus Christi	1.57	1.88	1.33	2.06	3.09	3.19	1.84	3.33	5.30	3.54	1.56	1.60	**30.30**
Dallas/Ft Worth	1.94	2.44	3.12	3.15	5.43	3.18	2.09	2.10	2.42	4.01	2.43	2.50	**34.82**
Del Rio	0.53	0.91	0.86	1.89	2.39	1.90	1.54	1.72	2.59	1.94	0.85	0.65	**17.76**
El Paso	0.42	0.41	0.30	0.21	0.33	0.72	1.56	1.48	1.42	0.72	0.35	0.62	**8.57**
Galveston	3.33	2.58	2.43	2.55	3.46	4.14	3.77	4.23	5.36	3.17	3.32	3.59	**41.93**
Houston	3.70	2.99	3.48	3.49	5.22	5.13	3.25	3.79	4.45	4.65	3.89	3.64	**47.70**
Lubbock	0.52	0.61	0.82	1.26	2.62	2.67	2.12	2.07	2.53	1.99	0.62	0.64	**18.47**
Midland	0.54	0.61	0.47	0.77	2.02	1.59	1.83	1.65	2.04	1.56	0.58	0.53	**14.18**
Port Arthur	4.86	3.96	3.30	3.86	5.02	5.68	5.31	5.04	5.77	4.20	4.22	5.13	**56.34**
San Angelo	0.83	1.05	0.93	1.68	2.86	2.20	1.16	1.77	2.78	2.21	0.96	0.78	**19.20**
San Antonio	1.61	1.90	1.68	2.53	3.99	3.57	1.83	2.58	3.29	3.29	2.11	1.72	**30.09**
Victoria	2.28	2.12	2.08	2.93	4.95	4.77	3.03	3.08	5.37	3.72	2.51	2.33	**39.17**
Waco	2.07	2.39	2.51	3.43	4.59	2.80	1.88	1.66	3.07	2.91	2.48	2.49	**32.28**
Wichita Falls	1.08	1.31	1.91	2.72	4.59	3.36	2.05	2.16	2.94	2.69	1.55	1.56	**27.93**