TURFGRASS ET FROM SMALL LYSIMETERS IN NORTHEAST COLORADO

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ABSTRACT

Small weighing lysimeters were planted to 11 different turfgrass varieties in 2010. Only one of the 11 turfgrasses selected was warm-season, the remaining 10 were cool-season. There are four replicates of each turfgrass. Results are compared to ETos calculated from an adjacent weather station using the standardized Penman-Monteith equation. The first season results from 44 small weighing lysimeters are presented.

Each lysimeter is centered in a 4 ft by 4 ft plot of the same grass variety. The lysimeters each consist of a PVC shell containing a 12-inch diameter free draining sandy loam soil core having a 20-inch rooting depth. The lysimeters are continuously weighed in-place by electronic load platforms connected to a data logger. Irrigation is applied via high uniformity sprinklers and measured through a flow meter monitored by a data logger. All turfgrasses receive the same irrigation treatment and are managed to avoid soil moisture induced stress. All grasses are mowed to the same height.

The purpose of the study is to quantify evapotranspiration of several varieties of turfgrass, under well watered conditions and with adequate fertility.

Differences in measured turfgrass evapotranspiration are included in the summary. Quantification of turfgrass ET with increased accuracy is especially important in regards to water conservation, agricultural to urban water transfers, and water rights administration.

INTRODUCTION AND BACKGROUND

Interest in different varieties of turfgrasses and their water usage has increased in recent years. Although general statements of lower water requirements are readily attached to some turfgrasses, quantitative assessments based on ETos from the standardized Penman-Monteith equation are rare. The use of lysimeters to directly measure turfgrass ET provides a defensible basis for quantifying and comparing actual water use. This information will provide municipalities with information needed in developing landscaping standards in support of efficient water use and conservation. It should also assist in more accurate quantification of irrigation return flows from urban landscapes and the in-stream flow credits claimed by Colorado municipalities under water rights administration.

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Previous Studies

Jensen et al. (1990) stated that “differences in grasses appear to be even greater than those for alfalfa, with clipping height having a pronounced effect on ET rates. In addition, large differences in peak period ET may exist between warm- and cool-season grass types . . .”

Feldhake et al. (1983) reported results from a three year turf study (1979 to 1981) of eight small weighable lysimeters at Fort Collins, Colorado. Mowing was two to three times per week with a height of 0.8 inches standard. Grasses included Merion Kentucky bluegrass (three years), Rebel tall fescue (one year), and common buffalograss (one year). Moisture levels in all lysimeters were maintained for maximum ET (irrigated three times per week). Reference ET was taken to be the measured ET from the Kentucky bluegrass lysimeters – irrigated three times/week, mowed to 0.8 inches, and maintained with adequate fertility (0.8 lbs/1,000 ft^2/month). In 1979 (July 13 to October 4), bluegrass mowed at 2.0 inches resulted in 13% higher ET. Concerns about oasis effects from the mini-plots with higher mowing height prompted observations using an infrared thermometer. These showed a “substantial temperature gradient” across mini-plot (8.2 ft x 8.2 ft) borders, but “essentially a constant temperature” inside a distance of 1.2 ft. In 1980 (June 20 to August 28), bluegrass with deficient fertility resulted in 14% lower ET. In 1981 (June 8 to August 16), tall fescue had 2% higher ET and buffalograss had 21% lower ET.

Brown et al. (2001) affirmed the following factors to affect turf water use and thus Kc: turf species and/or variety (cool-season – higher ET, warm-season – lower ET), canopy characteristics, mowing height (increased – higher ET, decreased – lower ET), nutrition (adequate – higher ET, deficient – lower ET), irrigation frequency (increased – higher ET, decreased – lower ET particularly for surface applied irrigation), and the procedure used to estimate ETo.

Jensen et al. (1990) also stated “an average ETr/ETo ratio of 1.2 to 1.25 may have been more representative of the 11 lysimeter sites evaluated” in ASCE Manual No. 70. This would provide a factor of 0.80 to 0.83 to convert alfalfa reference to a cool-season grass reference.

The University of Idaho REF-ET software recognizes that the ratio of ETr to ETo can range from 1.15 to 1.25, with 1.25 as the recommended default. This ratio provides a factor of 0.80 to covert alfalfa reference to cool-season grass reference, with an assumed grass height of 4.7 inches.

Jensen et al. (1990) included Table 6.11 that provided a ratio of 1.28 for 1982 Kimberly Penman ETr to lysimeter measured ET for clipped ryegrass (3-6 inches) for May through August at Kimberly, Idaho (1983-1984). This ratio would provide a factor of 0.78 to convert alfalfa reference to actual ryegrass ET. Their Table 6.9 provides the same 0.78 mean Kc factor for use directly with alfalfa reference ETr (120 days during mid-season).

Allen et al. (2007) converted the mean crop coefficients from Kimberly, Idaho for use directly with alfalfa reference ETrs obtained from the ASCE standardized Penman-Monteith equation. Their Table 8.7 provides an updated Kcs of 0.80 for perennial ryegrass during mid-season (60 days) and 0.55 for the beginning and end of season.

Devitt et al. (1992) provided monthly Kc values for over seeded perennial ryegrass in Las Vegas, Nevada. The basis was a two year study (1987 to 1989) of common bermudagrass over seeded with perennial ryegrass on three sites (two golf courses and one park). Each site was equipped with two vacuum drained lysimeters and a weather station. Ryegrass was over seeded the third week of September and reached mowing height the second week of October. The ryegrass was mowed to an average of 0.7 inches at the golf course sites and to two inches at the park site. For the November through April period (when ryegrass fully dominated) the average monthly Kc values from the golf course sites ranged from 0.43 in February to 0.81 in November, averaging 0.62. In contrast, the corresponding monthly Kc from the park site ranged from 0.33 in February to 0.60 in November, averaging 0.46. Reference ETo was calculated using the 1973 Penman equation. The significant increase in Kc at the golf course sites was largely attributed to increased fertility levels with 3 to 5 times the nitrogen fertilizer applied as compared to the park site. If the mowing height at the golf course sites had been two inches (same as the park site) further increased Kc factors may have resulted.

Hill (1998) reported a crop coefficient for turf of 0.56 applied to 1972 Kimberly Penman derived alfalfa reference. The applicable season was April-Oct (210 days). The basis was field research from two lysimeters in the Logan, Utah Country Club Golf Course during two seasons, 1991-1992.

Allen et al. (1998) provided a mid-season to end crop coefficient for cool-season turfgrass (bluegrass, ryegrass, and fescue with height of 2.4 to 3.1 inches) of 0.95 for FAO Penman-Monteith grass reference. The corresponding mid season to end crop coefficients for alfalfa hay were 1.20 and 1.15. The basis for these crop coefficients was a two year study (1971-1972) at Davis, California involving two large sensitive lysimeters planted to alfalfa and 'Alta' tall fescue grass. A procedure was provided for deriving a reference conversion ratio for more arid sites, such as Kimberly, Idaho. Application of this procedure results in a ratio of 1.24 for ETr at Kimberly to ETo at Davis. Consequently, also adapting the FAO-56 crop coefficients for cool-season grass to Kimberly, Idaho (Kc now equals 0.98) and combining with the ETr/ETo factor – provides a factor of 0.79 to convert ETr to cool-season grass ET for Kimberly.

Allen et al. (2007) updated the FAO-56 mean crop coefficient to 0.90 for cool-season turfgrass. Utilizing the 1998 procedure, this would provide factors of 0.75 to 0.78 to convert ETr for Kimberly to cool-season grass ET.

Ervin et al. (1998) reported crop coefficients of 0.70 (0.60 to 0.80) for Kentucky bluegrass and 0.60 (0.50 to 0.80) for tall fescue applied to 1982 Kimberly-Penman derived alfalfa reference. The basis was field research from a line source sprinkler irrigation study at Fort Collins, Colorado, 1993-1994. Mowing was twice weekly at 2.5

inches. This study showed that reduced irrigation levels did maintain acceptable turfgrass quality.

Brown et al. (2001) provided monthly Kc for over seeded 'Froghair' intermediate ryegrass that ranged from 0.78 in January to 0.90 in April. The basis was a three year study (1994-1997) in Tucson, Arizona utilizing two large weighing lysimeters with bermudagrass during June through September, which was then over seeded to ryegrass in October, with the November through May (180 days) data utilized to develop the ryegrass Kc. Reference ETo was calculated using the FAO-56 Penman-Monteith equation. Irrigation was daily and the ryegrass was mowed two times per week at a height of one inch.

Although many previous studies are in relatively close agreement for ET from well-irrigated cool-season turfgrass with adequate fertility, differences between cool-season turfgrasses is lacking. Additionally, the difference in mowing height and lack of reference to ETos from the standardized Penman-Monteith equation curtails their transferability from one region to another. The Northern Water lysimeter study will compare turfgrasses under the same climate conditions with similar mowing heights to the standardized Penmen-Monteith ETo at Berthoud, CO.

MATERIALS AND METHODS

In 2009, Northern Water commenced construction and installation of a 30-ft x 30-ft study plot for turfgrass lysimeters within its Conservation Gardens at its headquarters in Berthoud, Colorado. The turfgrasses were seeded starting May 28th and finishing June 2nd, 2010.

The lysimeter plot was divided into 4-ft x 4-ft sub-plots, separated by 1-inch x 6-inch PVC plastic composite decking/edging material. This edging clearly delineates the subplots and helps prevent the spread of one grass variety into another subplot. It also provides support for foot traffic by study technicians without damage to turf or compaction of the soil. Turfgrasses were planted into 44 of the 49 sub-plots, with the four corners and center sub-plots excluded from the study, but planted to a bluegrass blend to maintain fetch. The lysimeter plot was divided into four blocks, with each block containing 11 randomized sub-plots with lysimeters, one of each turfgrass variety included in the study. Consequently, the study includes four replicates of each of the following 11 turfgrasses:

Kentucky bluegrass blend:
- 50% - Rampart
- 25% - Touchdown
- 25% - Orfeo

Drought hardy Kentucky bluegrass:
- 33% - Rugby
- 33% - America
- 33% - Moonlight

Fine fescue blend:
- 25% - Covar Sheep
- 25% - Intrigue Chewings
- 25% - Cindy Lou Creeping Red
- 25% - Eureka Hard

Reubens Canada bluegrass

Tall fescue – Major League blend

Ephraim crested wheatgrass

'Low Grow' mix:
- 29% - Creeping Red fescue
- 27% - Canada bluegrass
- 24% - Sheep fescue
- 16% - Sandburg bluegrass

Perennial ryegrass - Playmate blend

Texas hybrid bluegrass blend:
- 50% - Reveille
- 50% - SPF 30

'Natures Choice' - Arkansas Valley mix:
- 70% - Ephraim Crested wheatgrass
- 15% - Hard fescue
- 10% - Perennial ryegrass
- 5% - Kentucky bluegrass

Blue gramma – buffalograss mix:
- 70% - Blue Gramma
- 30% - Buffalograss

EQUIPMENT

The weighing platform for each lysimeter includes a Revere PC6-100kg-C3 load cell transducer. Each load cell is connected to one of three AM 16/32 multiplexers, each connected to a Campbell Scientific CR10X data logger. Figure 1 is a diagram of the small turfgrass lysimeters and their arrangement within the lysimeter plot.

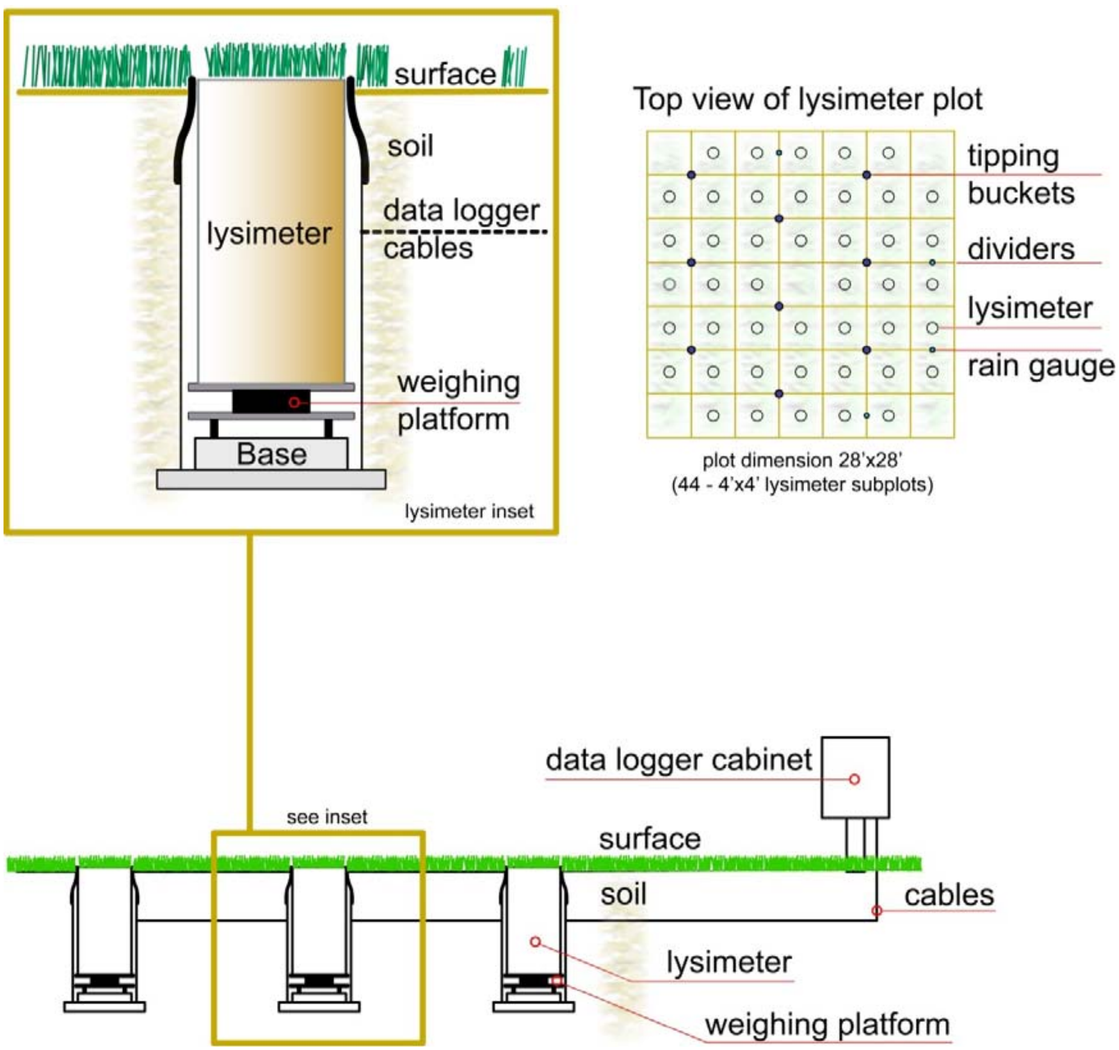

Figure 1. Diagram of Small Turfgrass Lysimeters

Every three seconds a measurement is taken from each load cell and these measurements are averaged every 60 seconds. This one minute average is time-stamped and stored in the data logger at the end of each 15-minute period. Stored data is automatically downloaded every 15 minutes to a desktop PC via an RF401 spread-spectrum radio. Differences in lysimeter weight are calculated as the difference in the measurement at the end of each hour. These hourly values are compared to calculated ETos obtained from the REF-ET software (http://www.kimberly.uidaho.edu/ref-et/) utilizing data from the adjacent Campbell Scientific ET-106 weather station. The weather instruments are each calibrated annually.

The weighing platforms for each lysimeter were calibrated in-place (without the lysimeter) in September 2009 over their full load range using steel weights. They were again re-calibrated in-place during 2010, but only over their operational range (from dry soil to wet soil). No problems were identified during the re-calibration and all weighing platforms were measuring lysimeter weights properly.

The entire lysimeter plot is on a single irrigation zone using MP Rotator 2000 sprinklers on 15-foot spacing. A DLJ ¾”x ¾” brass flow meter w/pulse output connected to a Campbell Scientific data logger which measures all irrigation applications to the lysimeter plot. In addition, nine Texas Electronics tipping bucket rain gauges are installed flush with the turf height throughout the lysimeter plot to measure net irrigation application as well as rainfall.

DEEP PERCOLATION CALCULATIONS

Deep percolation through the lysimeters was not directly measured. Deep percolation from irrigation was calculated as the difference between applied irrigation less the increase in lysimeter weight after free drainage. During the germination period during June-July of 2010, irrigations occurred twice daily during daylight hours. This hourly data was generally excluded from the calculation of turfgrass ET. However, beginning in late July, turf water use during the drainage period was considered negligible as all irrigations were scheduled for just after sundown. Nighttime turf water use was significantly less than during daytime hours and was generally very small. As the lysimeters are free draining with sandy loam soil only 20-inches deep, any deep percolation from irrigation was assumed to be completed before sunrise. During 2010, any excessive percolate that ponded below a lysimeter was removed through a manually controlled vacuum extraction system as needed.

Deep percolation from rain was calculated similarly as for irrigation. However special considerations were required – particularly for significant daytime rain events. Deep percolation from rain was calculated as the difference between measured rainfalls less the increase in lysimeter weight (after stabilization). If the drainage period occurred during daytime hours, the data was generally excluded from the comparison to calculated ETos.

SUMMARY

Measured turfgrass water use in ac-in/ac is summarized in Table 1 for each of the 11 turfgrasses, along with ETos, for June 3rd through July 25th of 2010. The corresponding monthly Kcos crop coefficients are included in Table 2. The turfgrass ET are elevated because of twice daily watering to promote seed germination, which continued from planting in June through most of July, 2010.

Table 1. Summary of 2010 Measured Water Use from Small Turfgrass Lysimeters

	June 3-30	July 1-25	Total
	ac-in/ac	ac-in/ac	ac-in/ac
Kentucky bluegrass blend	6.13	5.90	12.03
Drought hardy Kentucky bluegrass	6.17	5.77	11.94
'Low Grow' mix	6.45	6.05	12.50
Perennial ryegrass blend	6.81	6.00	12.81
Texas hybrid bluegrass blend	6.17	5.86	12.03
Fine fescue blend	6.33	5.73	12.06
Reubens Canada bluegrass	6.09	5.78	11.87
Tall fescue blend	6.83	6.26	13.09
Ephraim crested wheatgrass	6.31	5.11	11.42
'Natures Choice' mix	6.47	5.76	12.23
Blue gramma – buffalograss mix	6.24	5.81	12.05
ETos (reference)	6.06	5.28	11.34

Table 2. Summary of 2010 Calculated Kcos Crop Coefficients for 11 Turfgrasses

	June 3-30	July 1-25	Season-partial
	Kcos	Kcos	Kcos
Kentucky bluegrass blend	1.01	1.12	1.06
Drought hardy Kentucky bluegrass	1.02	1.09	1.05
'Low Grow' mix	1.06	1.15	1.10
Perennial ryegrass blend	1.12	1.14	1.13
Texas hybrid bluegrass blend	1.02	1.11	1.06
Fine fescue blend	1.04	1.09	1.06
Reubens Canada bluegrass	1.00	1.09	1.05
Tall fescue blend	1.13	1.19	1.15
Ephraim crested wheatgrass	1.04	0.97	1.01
'Natures Choice' mix	1.07	1.09	1.08
Blue gramma – buffalograss mix	1.03	1.10	1.06

Photographs of the site location, surrounding gardens, and weather station location are provided in Figures 2-5.

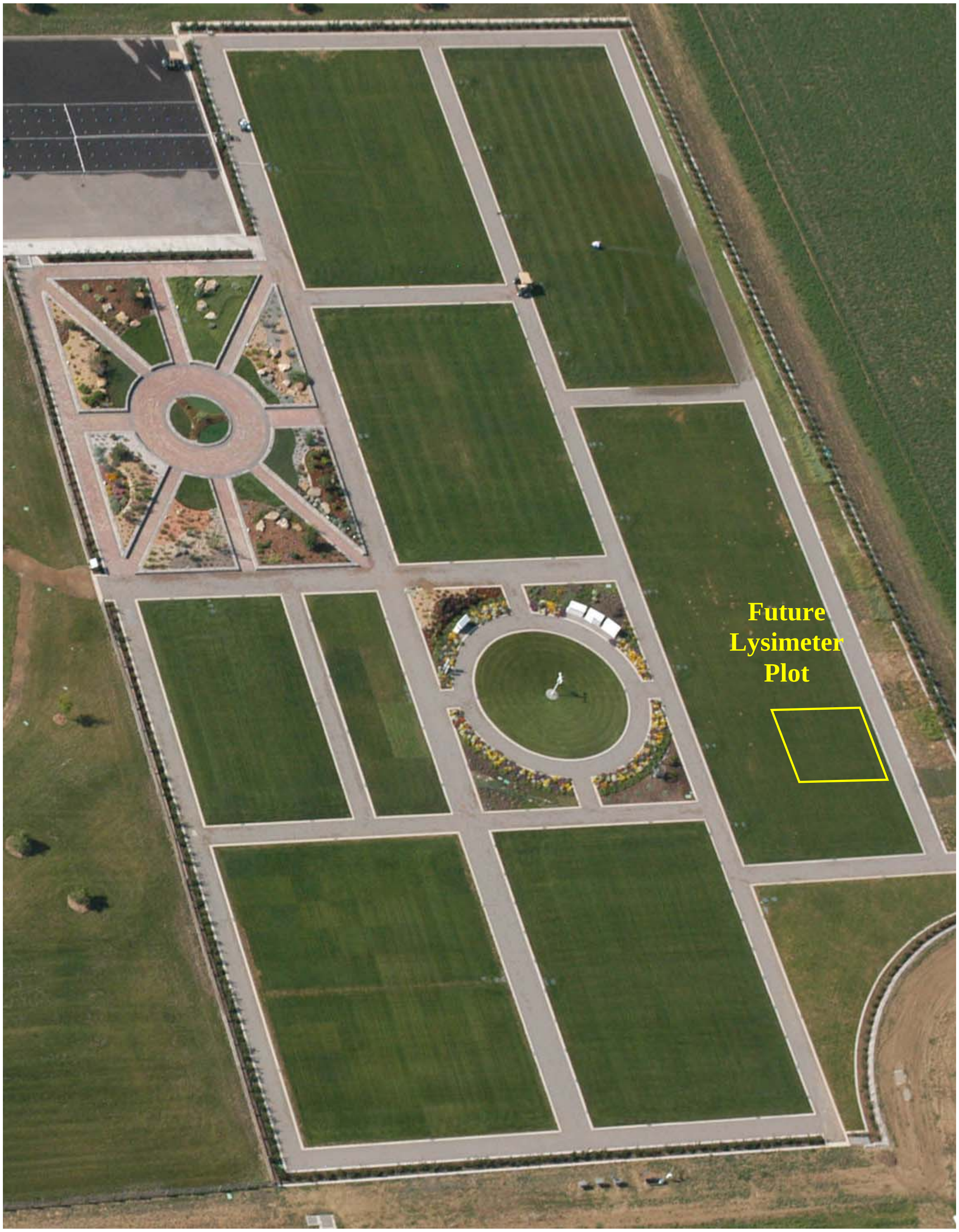

Figure 2. Aerial View of Conservation Gardens at Northern Water – before construction of lysimeter plot.

Figure 3. Conservation Gardens at Northern Water – view towards northwest.

Figure 4. Elevated View to Northwest of Weather Station and Future Lysimeter Plot.

Figure 5. View to Southeast of Weather Station and Lysimeter Plot – under construction.

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