



Water Use at Minnesota Rest Areas

Final Report

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Onsite Sewage Treatment Program
University of Minnesota

CTS 15-11A

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Executive Summary

The Minnesota Department of Transportation (MnDOT) Statewide Rest Area Program is composed of a coordinated system of public rest areas and waysides that are intended to help motorists travel safer. In 1979, MnDOT personnel collected data at rest areas to refine assumptions and improve techniques for design of rest area water supply and sewage treatment designs. They found on average that with water conserving devices people used 2.8 gallons, while non-water-conserving devices used 4.5 gallons. In the following years, water use charts have been informally altered, but no formal study has been conducted. This study evaluated the accuracy of MnDOT design charts and formulas based on plumbing code fixtures and traffic patterns with building type consideration. A total of six rest areas, Culkin Rest Area (R.A.), Frazee R.A., Fuller Lake R.A., Lake Pepin R.A., Central Minnesota Travel Information Center (TIC), and St. Croix TIC, were included in the study, with each site belonging to one of two building categories, interstate or non-interstate. Two study periods were held, the first occurred May 18 – June 1, 2015, and the second June 29 – July 13, 2015. Each site only participated in one of the two study periods. Both study periods included two popular holiday travel weekends, Memorial Day weekend and Independence Day weekend, allowing for some insight into peak usages. Water use estimations were obtained electronically by calculating averages from hourly people counts, hourly water-flow data and hourly traffic counts. All sites in this study had low-flow fixtures and a similar water use average compared to the averages of water conserving devices in the 1979 analysis. Site specific average water use per person ranged from 0.7 gallons to 3.8 gallons. The overall average water use per person was 2.3 gallons. A statistically significant difference was found between the two building types, interstate and non-interstate, with interstate visitors averaging 3.2 ± 0.3 gallons and non-interstate visitors averaging 1.8 ± 0.2 gallons. The difference between building types was not explainable. The 3.5 gallons per person per day volume represents a 95% confidence level. When accounting for variation and error and providing a safety factor, a water use per person of 5 gallons per person per day is recommended for a water consumption design value. While this report intended to validate or redefine the design charts and formulas for rest area septic systems, additional data is needed. The results of this two-week study appear to indicate that the original Federal Highway Administration design values are still valid. The University of Minnesota recommended MnDOT conduct water use studies similar to this prior to the design of new rest area septic systems, but over longer time periods.

Chapter 1: Introduction

The MnDOT Statewide Rest Area Program consists of a coordinated system of public rest areas and waysides aimed at helping motorists travel safer (Figure 1.1). All rest areas fall into one of four different classes (MnDOT, n.d.) Class I are located on the Interstate System, as well as 14 on non-interstate. MnDOT describes Class I rest areas as clean, modern, on 15 to 30 acres and open 24 hour per day. In addition to picnic facilities and lighted parking lots, Class I rest areas have a drinking fountain, display case maps, travel displays, vending machines, and public phones. Travel Information Centers and Regional Welcome Centers are Class I facilities with expanded customer services, including a staffed information counter (MnDOT, n.d.)

Class II rest areas (RA) are smaller, seasonally operated sites, with vault toilet facilities. Class III rest areas are smaller than Class II, seasonally operated, and feature unisex vault or pit toilet facilities. Class IV rest areas are the most simple of the four classes. They do not have toilet facilities, but feature scenic views, historical markers, or other points of interest. Statewide there are ten Travel Information Centers (TIC), three Regional Welcome Centers, 41 Class I Rest Areas, 23 Class II Rest Areas, 13 Class III Rest Areas, and 180+ Class IV Waysides. In addition to the four classes, rest areas are also characterized by their location on an interstate or non-interstate highway.

In 1979, the Minnesota Department of Transportation collected and analyzed water use data at rest areas to refine assumptions and improve techniques for the design of rest area water supply and sewage treatment systems. Charts were developed based on the technology at the time and have, in subsequent years, been informally modified based on new plumbing fixture technologies, but no data has been collected. The purpose of this study is to evaluate the accuracy of the Minnesota Department of Transportation (MnDOT) Federal Highway Administration (FHWA) design charts and formulas based on plumbing code fixtures and traffic patterns with building type consideration.

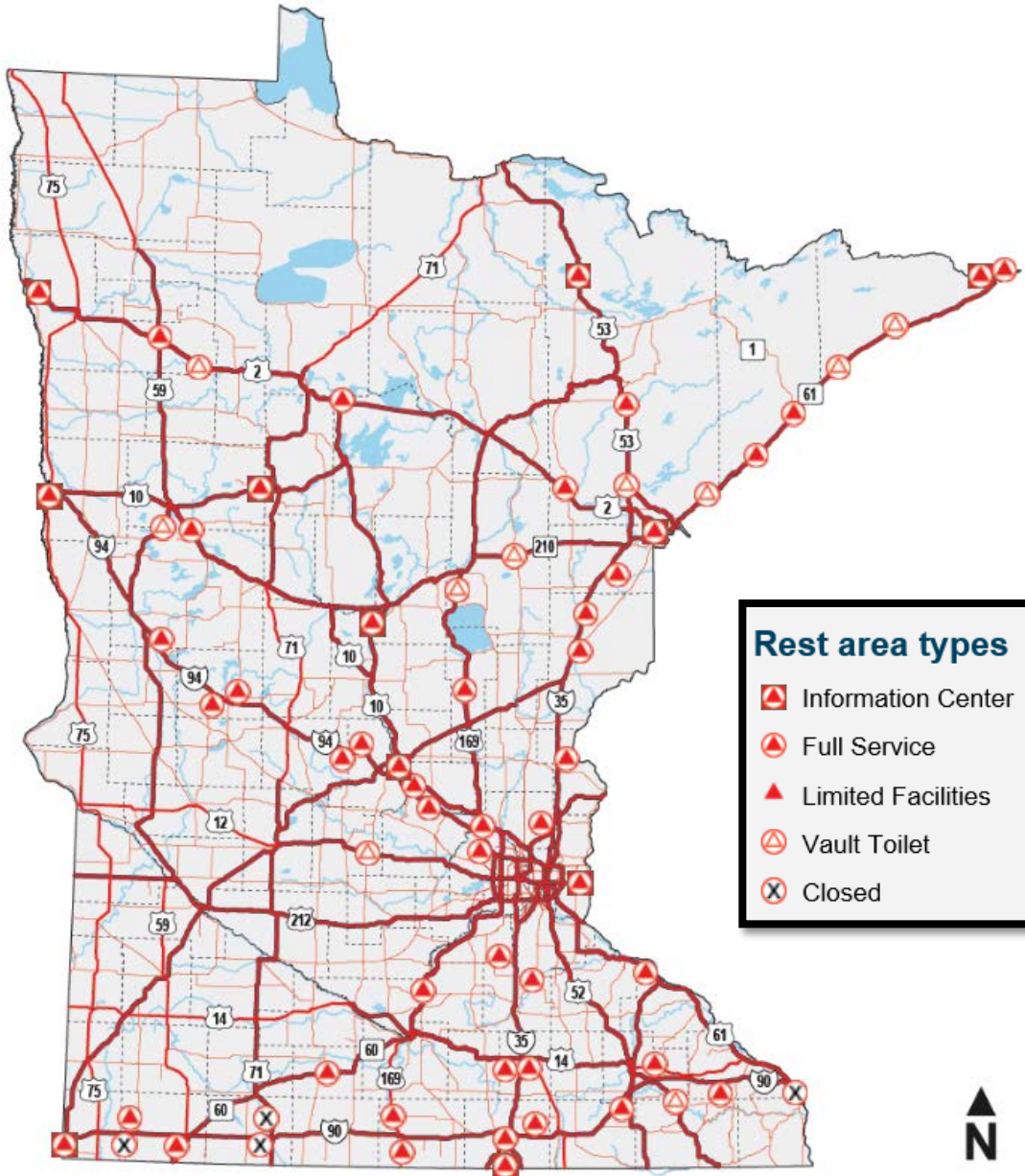


Figure 1.1: The Minnesota Department of Transportation Statewide Rest Area Program consists of a coordinated system of rest areas and waysides (MnDOT, n.d.).

This study includes three interstate rest areas, Culkin RA, Fuller Lake RA, and St. Croix TIC, and three non-interstate rest areas, Central Minnesota TIC, Frazee RA, and Lake Pepin RA. All six rest areas are open 24 hours a day, 7 days a week, and 365 days a year. TIC Explore Minnesota Tourism Counters are open and staffed from 9:00 a.m. to 5:00 p.m., all year, excluding holidays, at St. Croix TIC. The Central Minnesota TIC Explore Minnesota Tourism Counter is open 9:00 a.m. to 5:00 p.m. on weekends only in the winter and 7 days a week during the summer months. The findings will allow for current and future facility assessments and designs to be improved.

Chapter 2: Methods

One 15-day study period was originally planned for all six rest areas. However, a second study period was required when three rest areas were not prepared in time. The first study period occurred Monday, May 18, 2015 to Monday, June 1, 2015 at Culkin RA, Fuller Lake RA, and Central Minnesota TIC. The second study period occurred Monday, June 29, 2015 to Monday, July 13, 2015 at Frazee RA, Lake Pepin RA, and St. Croix TIC. These dates were chosen to include holiday weekends of Memorial Day and Independence Day due to increased travelers and subsequent visitors to rest areas.

2.1 People Counts

The University of Minnesota installed Traf-Sys Inc./Walker Wireless Omnicounter 418 and Compucount systems at the rest areas. The Omnicounter 418 device was battery powered and consisted of two parts (Figure 2.1); one unit transmitted an infrared beam and the second unit, the receiver, was placed parallel to the transmitter on the opposite door frame. The dimensions of the units are 3.5" x 1.75" x 1.0" (Walker Wireless, 2015.). Counts were recorded when the infrared beam between the two units was broken. As all six rest areas had two sets of front doors, all Omnicounters were mounted on the inside set of doors for better protection (see Figure 2.2). Omnicounters were installed so that the doors would not swing into the beam. The Compucount Data Controller contained an internal receiver, which collected counts from all Omnicounters within the building. The Compucount Data Controller used electrical power supply and was stored in the custodial offices at all sites. Data were downloaded from the Compucount Data Controller on site with an Ethernet cord. Following the connection between the Ethernet cord and computer, a web browser was opened and the IP address <http://192.169.1.55> was entered into the URL address bar. Counts were opened through the Export tab and copied into a blank Microsoft Office Excel Spreadsheet. Data were downloaded in the form of 30 minute counts and daily counts. Hourly counts were obtained through the summation of each hour's 00-minute and 30-minute counts.



Figure 2.1: Omnicounter transmission and receiver units.

The Omnicounters recorded counts anytime the infrared beam was broken, meaning visitors were counted both when entering and exiting the building. This required total counts to be divided by an error. Other factors contributing to miscounts include custodian cleaning and visitor re-entry to use the vending machine. The error was estimated at each site by manually counting the number of visitors that entered the rest stop with a hand-operated counter for one hour. The counts recorded by the Omnicounter during that same hour were divided by the manual count to give the error estimation. All site errors were averaged to give an error of 2.3, which was used for dividing total counts from all sites.

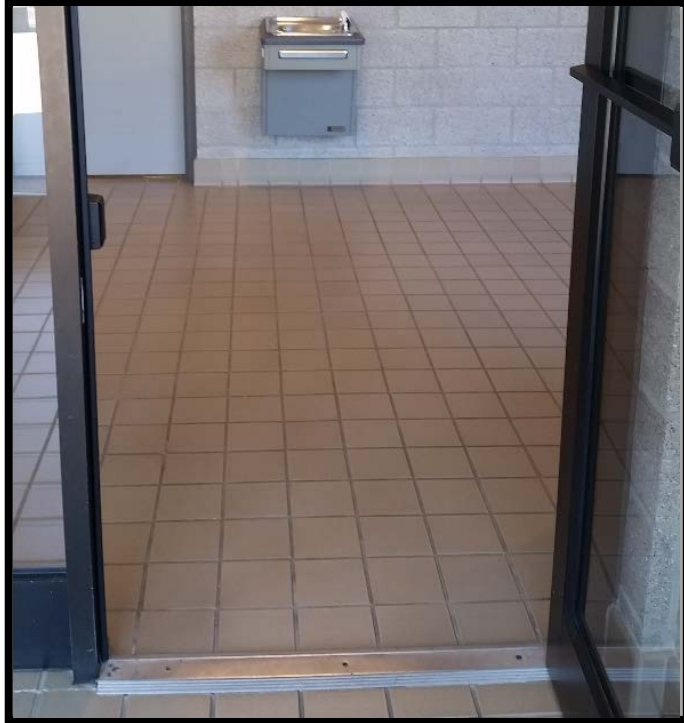


Figure 2.2: Omnicounters were mounted on the inside set of doors on the door frames.

The OmniCounter units were advantageous because they were battery powered and did not have to be in close proximity to an electrical outlet, unlike the Compucount Data Controllers. However, Omnicounter units could be limiting in that they require battery replacement after approximately one year. The Omnicounter units also had an indoor radio range limited to 110 feet, which limited the placement of the Compucount Data Controller.

2.2 Water-flow

Water-flow data were obtained from MnDOT in the format of cumulative daily water-flow in gallons. Cumulative water-flow was electronically recorded on the hour and automatically reset daily at 00:00.

The Meter-Master Model 20 Flow Sensor was used at Fuller Lake, St. Croix, and Central Minnesota. This flow sensor uses a magnetic sensor to digitize the water meter's magnetic wave. The flow sensor is connected to either Automated Logic Building Automation software or Niagara Building Automation software. Lake Pepin water-flow was obtained with a Badger Turbo Series meter that reads to the closest 100 gallons and was connected to a Recordall Transmitter Register flow sensor. Frazee used a Recordall Disc Series meter that read to the closest ten gallons and was connected to a Recordall Transmitter Register flow meter. All flow data were recorded by the flow sensor and stored on a MnDOT server, from which the data could be accessed and downloaded.

2.3 Traffic Counts

Traffic counts were obtained from MnDOT, who installed tubes that produced vehicle classification counts based on an algorithm that interprets axle hits. All ramps to rest areas were single lane, meaning there were no issues with simultaneous or occlusion axle hits.

Sensors at Frazee RA, Culkin RA, Fuller Lake RA, and Central Minnesota TIC had two tube sensors within each sensor unit. This resulted in two sets of traffic counts per sensor. The two sets of counts were averaged to get the final traffic estimation.

Traffic counts from Culkin RA had a 97% success rate of interpretation by the algorithm. In other words, 3% of the time the algorithm was unable to determine the type of vehicle from the axle hit pattern. To account for the 3% error, 1.03 (100/97) was added to each count. Data from machine 1 at Culkin RA had lower accuracy (tube A 90%, tube B 78%) as was not used in traffic estimation. The same process was used for Fuller Lake RA, which had 96% accuracy. Central

Minnesota TIC had poor accuracy (62%), so vehicle counts were obtained manually by dividing all axle hits by two.

2.4 Calculations

Hourly water-flow was obtained by calculating the difference between the desired hour and the following hour. A flaw with this design is that the water-flow for 23:00 could not be calculated, as the flow count reset to 0 gallons at 00:00. Daily water was calculated by the summation of hourly water-flow per day.

Water use per person and per car was calculated by dividing daily water-flow by daily visitors (adjusted for error) and daily traffic. Average water use per person and per car was calculated by first summing hourly visitors/traffic and hourly water based on date in a pivot table in Microsoft Office Excel 2013. Total daily water use was then divided by total daily visitors to give average water use. Confidence intervals were calculated using Excel's Descriptive Statistics in the Data Analysis Add-On. A Two-Sample t-Test assuming unequal variances was conducted to test water use averages between interstate and non-interstate sites, also using Excel's Data Analysis Add-On. An F-test was used to determine the equality of variances.

People counts corresponding to the 23:00 hour with no water-flow were omitted from daily summations to avoid underestimating water use averages. The pivot table was also to calculate averages, sums, as well as other functions across the entire two-week study period. These sums and averages could be sorted based on factors, such as day of the week or hour of the day.

People per vehicle estimations were calculated by dividing daily vehicle counts by corresponding daily people counts. This value represents the average number of people per vehicle that enter the rest stop, but cannot be considered an accurate estimation of amount of people per vehicle. Many times passengers do not enter the facility, but stay in the car or walk around the grounds of the rest area. For these reasons, the total number of people per vehicle would be larger than the calculated values.

Chapter 3: Culkin Rest Area Interstate

Two miles SE of Mahtowa, MN

NB Interstate 35

Carlton County



Rest Area Overview

Men's Restroom

Two toilets
Two urinals
Four sinks

Women's Restroom

Four toilets
Four sinks

Low-flow Fixtures

Other

Custodial mop sink
Water softener

Amenities

Pay phone
Vending machines
Drinking fountains
Play area
Pet exercise area
Picnic shelters & table

Study Overview

1st Study Period: Monday, May 18, 2015 to Monday, June 1, 2015

People Counts and Water-flow Data: May 18, 2015 to June 1, 2015

Traffic Counts: May 18, 2015 to 9:00 a.m. June 1, 2015

Water Use per Person

Average water use per person: 2.6 ± 0.2 gallons

Peak daily average water use per person: 3.4 gallons on Sunday, May 24, 2015

Range of average daily water use per person: 1.3 gallons

The **total daily water use** and the **total number of daily visitors** are displayed in Figure 3.1. The significant increase in visitor and water consumption occurred on what was the beginning of Memorial Day Weekend (Friday, May 22).

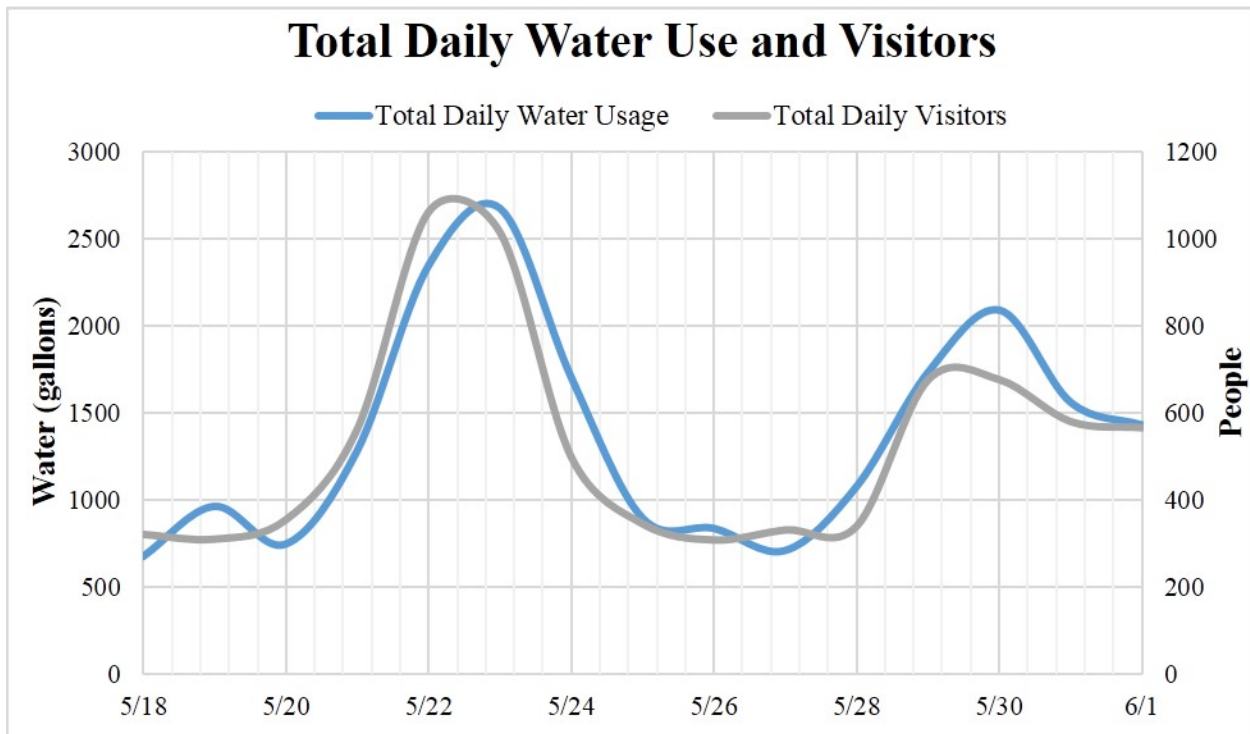


Figure 3.1: Total daily water use and total daily visitors at Culkin RA from May 18, 2015 to June 1, 2015.

The **average hourly water use** and **average hourly visitors** are displayed in Figure 3.2. The early morning spikes that do not correlate with visitors can be attributed to the function of the water softener.

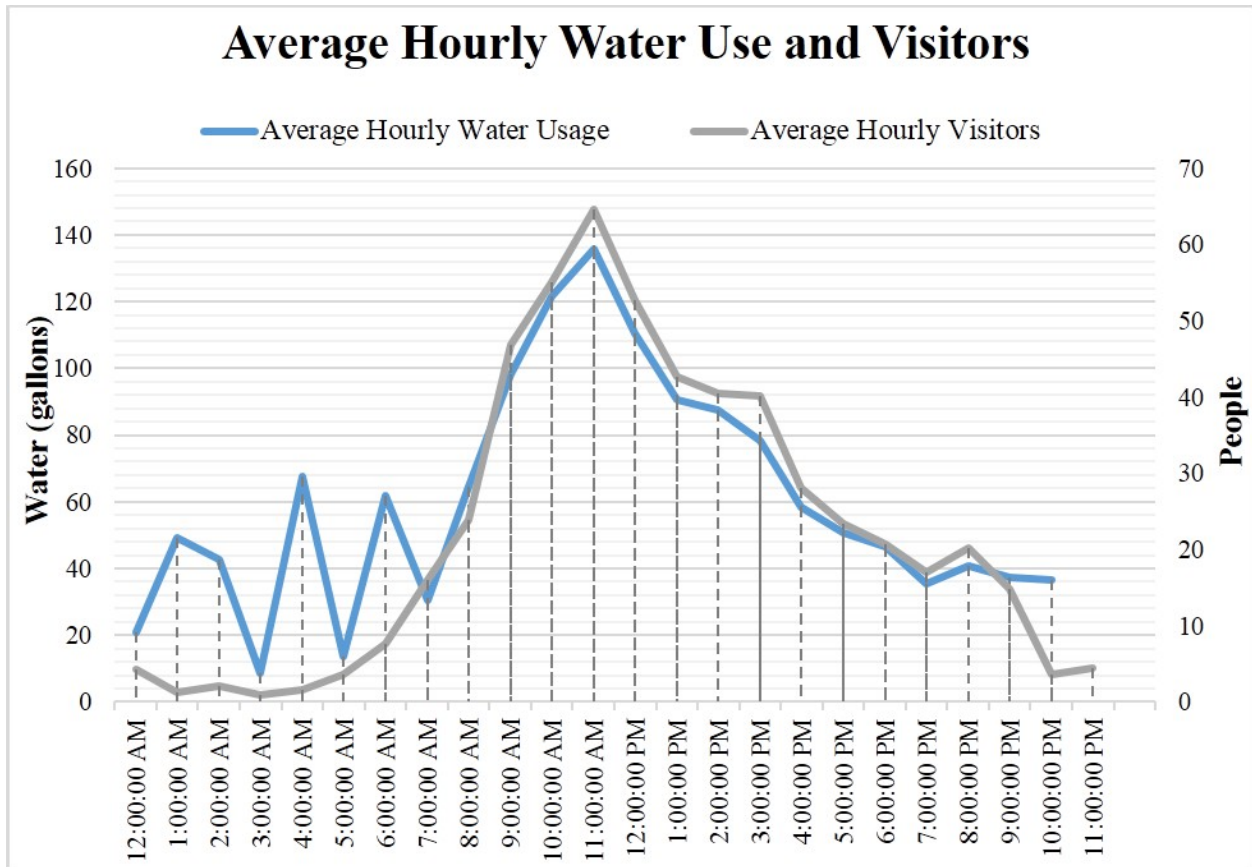


Figure 3.2: Average hourly water use and average hourly visitors at Culkin RA from May 18, 2015 to June 1, 2015.

Water Use per Vehicle

Average water use per vehicle: 3.1 ± 0.5 gallons

Peak daily average water use per vehicle: 5.1 gallons on Sunday, May 24, 2015

Range of average daily water use per vehicle: 3.2 gallons

Average number of people per vehicle: 1.2

The average water use per vehicle is displayed in Figure 3.3.

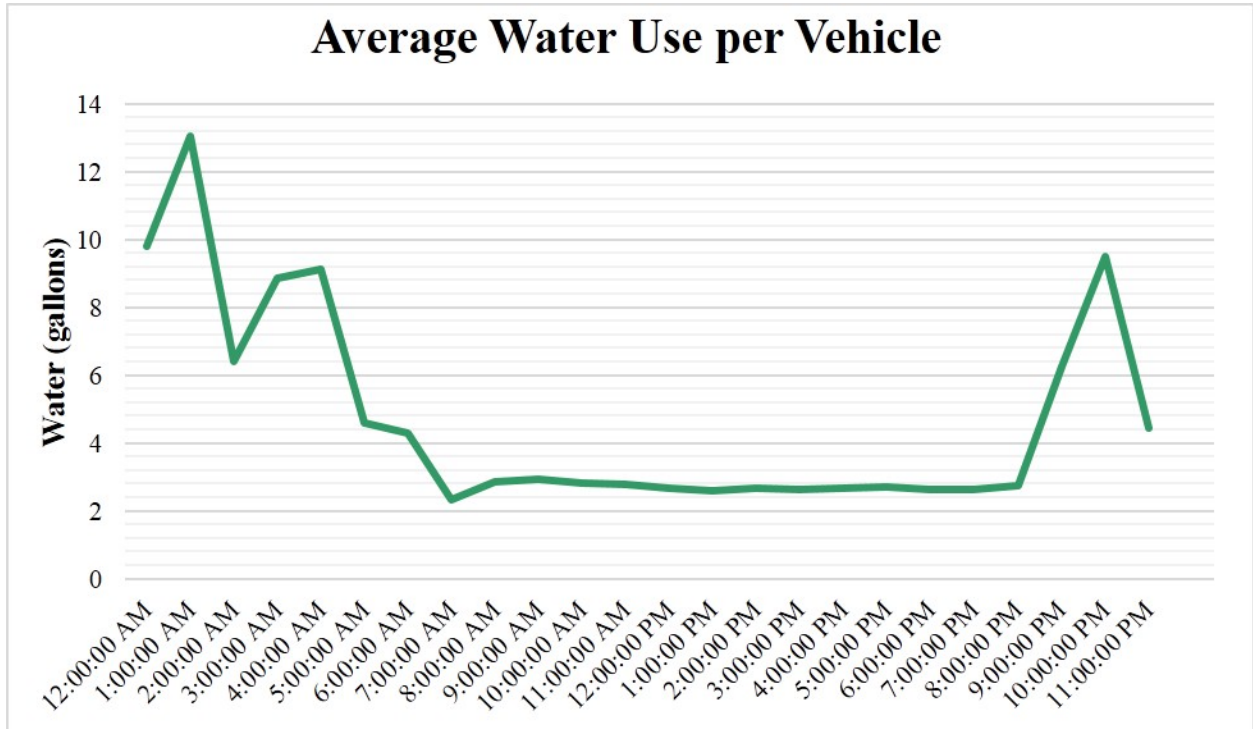


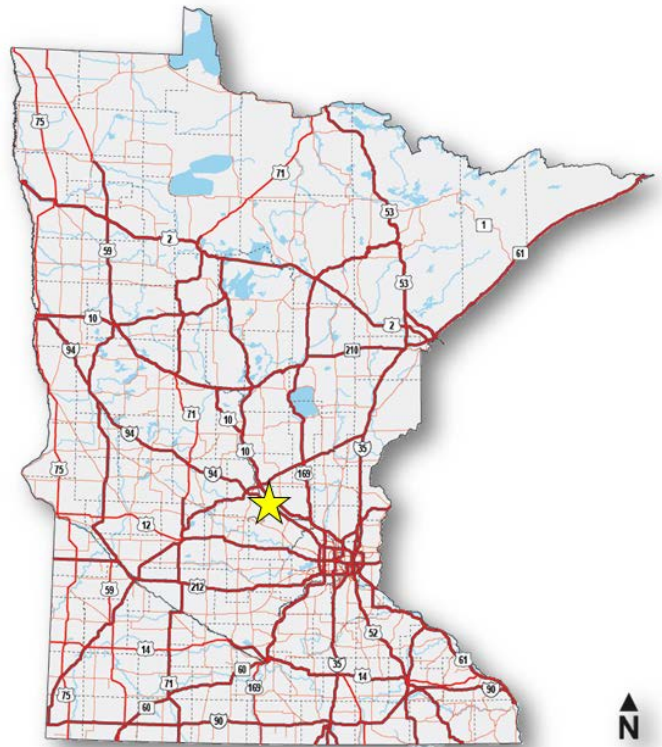
Figure 3.3: Average water use per vehicle at Culkin RA from May 18, 2015 to June 1, 2015.

Chapter 4: Fuller Lake Rest Area Interstate

0.8 miles NW of Clearwater, MN

WB Interstate 94

Stearns County



Rest Area Overview

Men's Restroom

- Two toilets
- Three urinals
- Four sinks

Women's Restroom

- Five toilets
- Four sinks

Low-flow Fixtures

Amenities

- Pay phone
- Vending machines
- Drinking fountains
(inside & outside)
- Play area
- Pet exercise area
- Picnic shelters and tables

Study Overview

1st Study Period: Monday, May 18, 2015 to Monday, June 1, 2015d

People Counts and Water-flow Data: May 18, 2015 to June 1, 2015

Traffic Counts: May 18, 2015 to 10:00 a.m. June 1, 2015

Complications:

Fuller Lake was the only rest area in this study that lacked a divider between the two front doors, which likely resulted in more erroneous people counts. Given counts occurred when the infrared beam was broken, two people passing simultaneously through the door would result in a single count, instead of two.

Water Use per Person

Average water use per person: 3.8 ± 0.3 gallons

Peak daily average water use per person: 4.6 gallons on Thursday, May 28, 2015

Range of average daily water use per person: 1.6 gallons

The **total daily water use** and the **total number of daily visitors** are displayed in Figure 4.1. The significant increase in visitor and water consumption occurred on what was the beginning of Memorial Day Weekend (Friday, May 22).

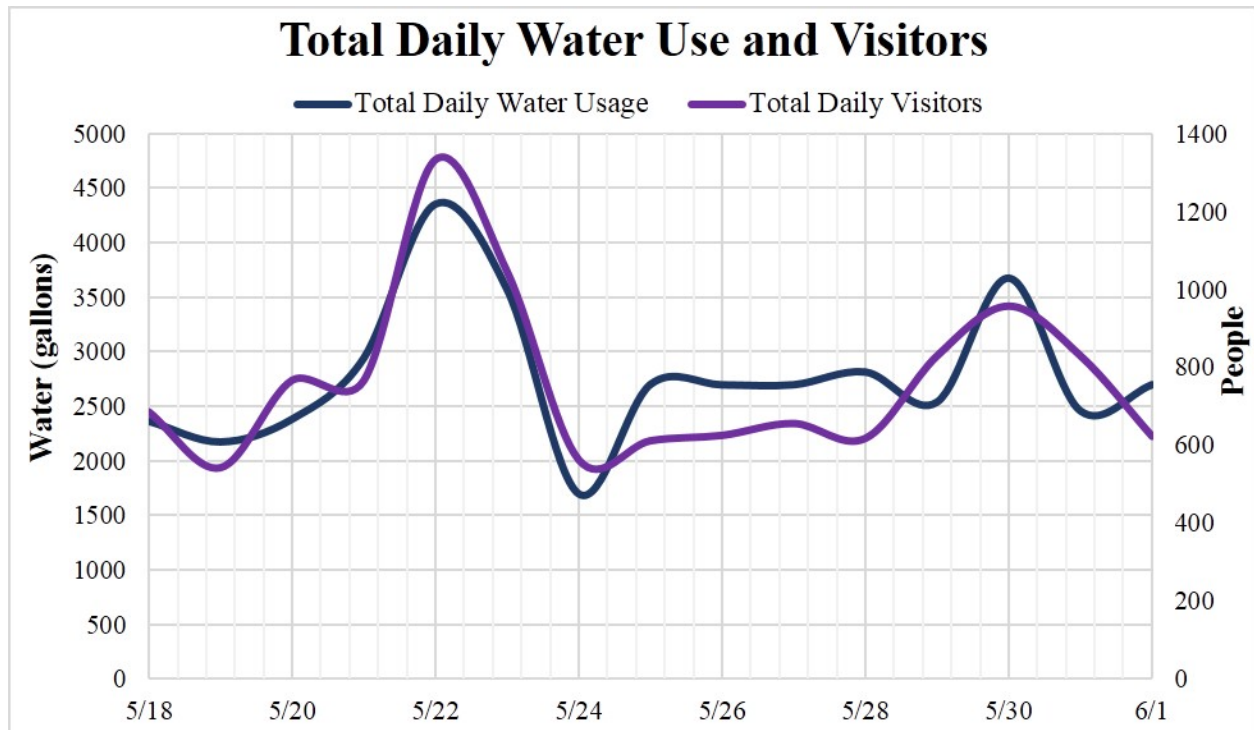


Figure 4.1: Total daily water use and total daily visitors at Fuller Lake RA from May 18, 2015 to June 1, 2015.

The **average hourly water use** and **average hourly visitors** are displayed in Figure 4.2. The early morning spike that does not correlate with visitors can be attributed to the function of the water softener.

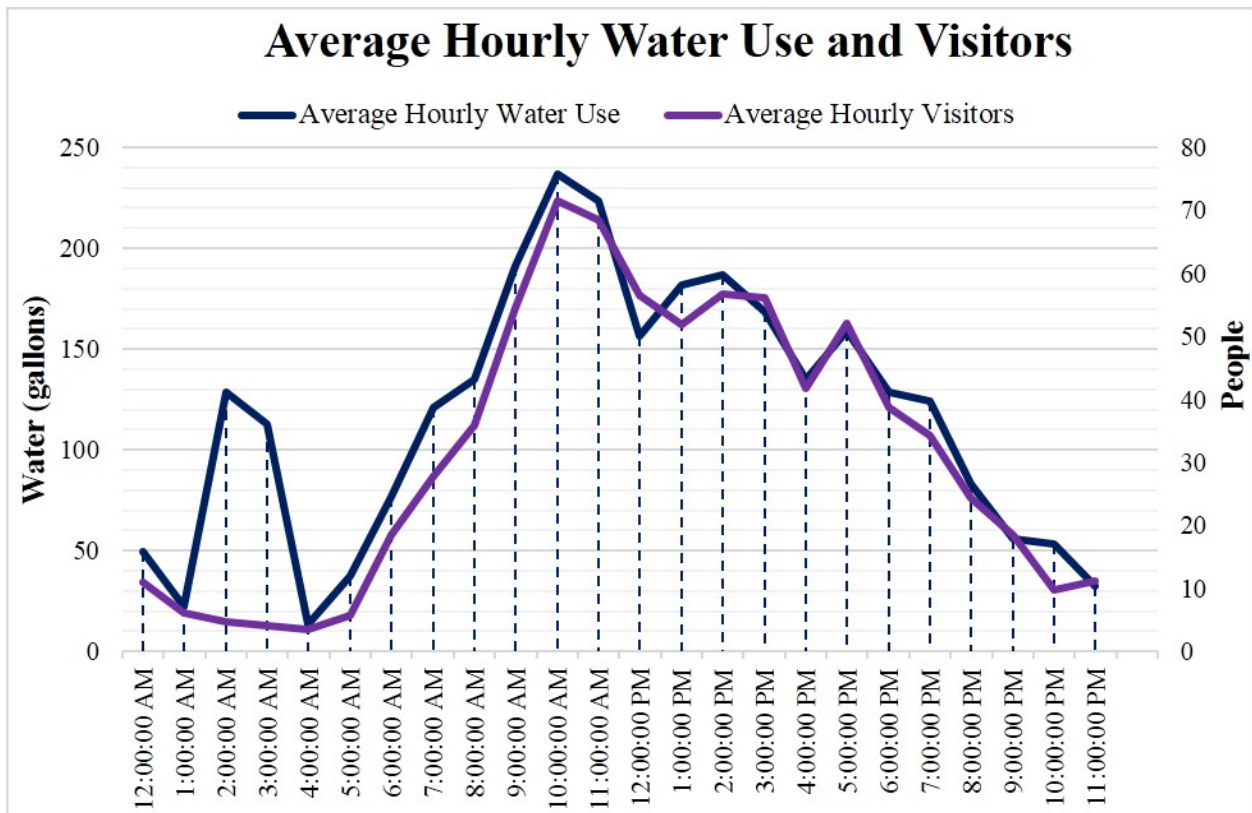


Figure 4.2: Average hourly water use and average hourly visitors at Fuller Lake RA from May 18, 2015 to June 1, 2015.

Water Use per Vehicle

Average water use per vehicle: 2.7 ± 0.3 gallons

Peak daily average water use per vehicle: 3.6 gallons on Monday, May 25, 2015

Range of average daily water use per vehicle: 1.8 gallons

Average number of people per vehicle: 0.7

The **average amount of water used per vehicle** is displayed in Figure 4.3.

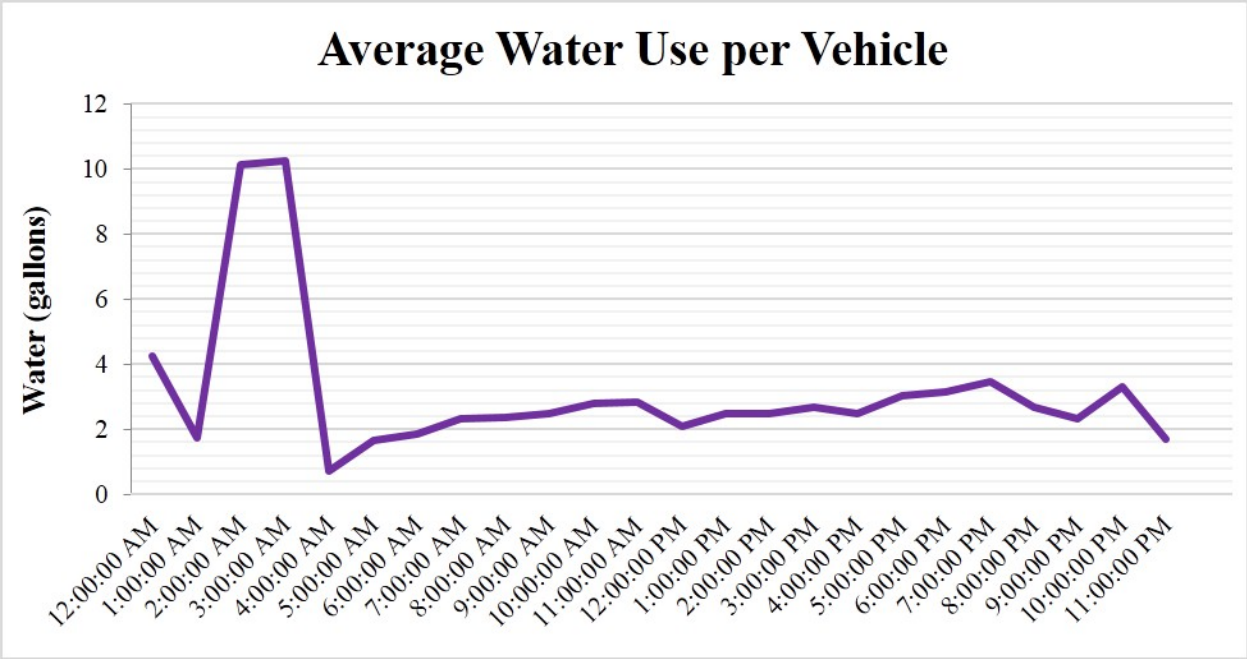


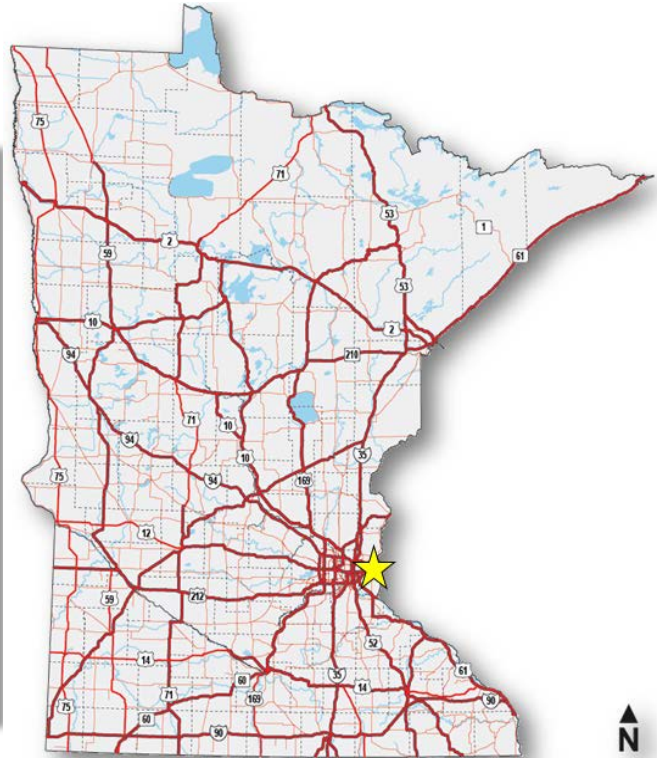
Figure 4.3: Average water use per vehicle at Fuller Lake RA from May 18, 2015 to June 1, 2015.

Chapter 5: St. Croix Travel Information Center Interstate

2.8 miles W of St. Croix River

WB Interstate 94

Washington County



Rest Area Overview

Men's Restroom

Six toilets
Four urinals
Four sinks

Women's Restroom

Eight Toilets
Six Sinks

Family Restroom

Two Toilets
One Sink

Designated Assisted Restroom

Low-flow Fixtures

Other

Custodial mop sink
Water softener

Amenities

Staffed Explore MN Tourism
Pay phone
Vending machines
Drinking fountain
Play area
Pet exercise area
Picnic shelters & tables
Bicycle racks
Located on recreational trail system

Study Overview

2nd Study Period: Monday, June 29, 2015 to Monday, July 13, 2015

People Counts: May 18, 2015 to June 1, 2015

Water-flow Data: 10:30 a.m. June 30, 2015 to July 13, 2015

Traffic Counts: 11:00 a.m. June 30, 2015 to July 13, 2015

Complications

Traffic counters were not installed in time for the 1st study period, which in conjunction with other site complications resulted in a 2nd study period.

Water Use per Person

Average water use per person: 2.6 ± 0.1 gallons

Peak daily average water use per person: 2.9 gal on Wednesday, July 8, 2015

Range of average daily water use per person: 0.5 gallons

The **total daily water use** and the **total number of daily visitors** are displayed in Figure 5.1. The increase in visitors and water consumption on Friday, July 3 and Sunday, July 5 can be attributed to Independence Day Holiday Weekend.

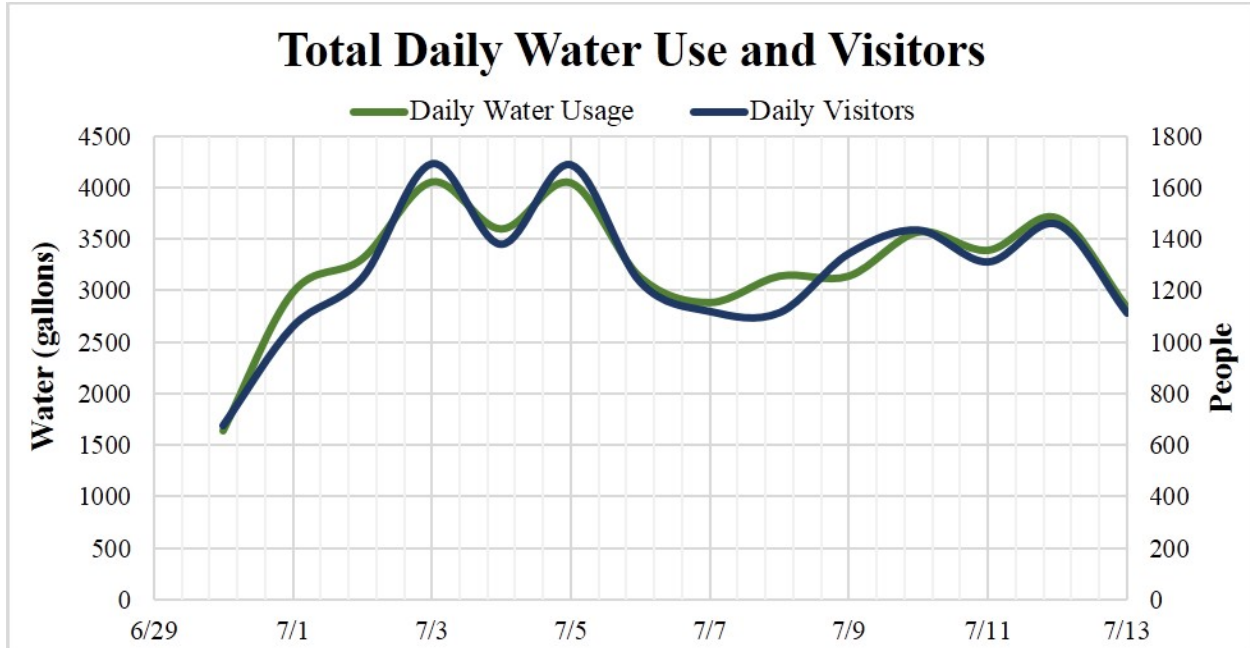


Figure 5.1: Total daily water use and total daily visitors at St. Croix TIC from June 29, 2015 to July 13, 2015.

The average hourly water use and average hourly visitors are displayed in Figure 5.2.

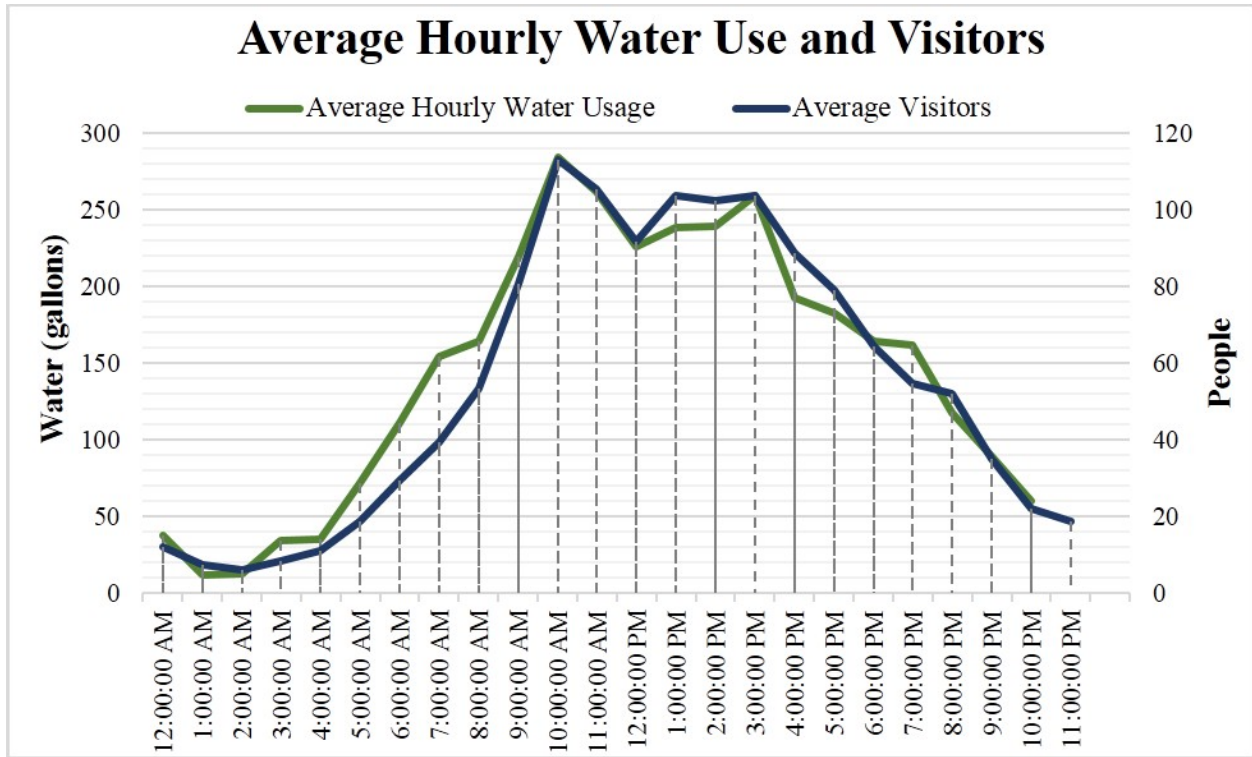


Figure 5.2: Average hourly water use and average hourly visitors at St. Croix TIC from June 29, 2015 to July 13, 2015.

Water Use per Vehicle

Average water use per vehicle: 2.7 ± 0.4 gallons

Peak daily average water use per vehicle: 4.1 gallons on Saturday, July 4, 2015

Range of average daily water use per vehicle: 2.6 gallons

Average number of people per vehicle: 1.1

The average amount of water used per vehicle is displayed in Figure 5.3.

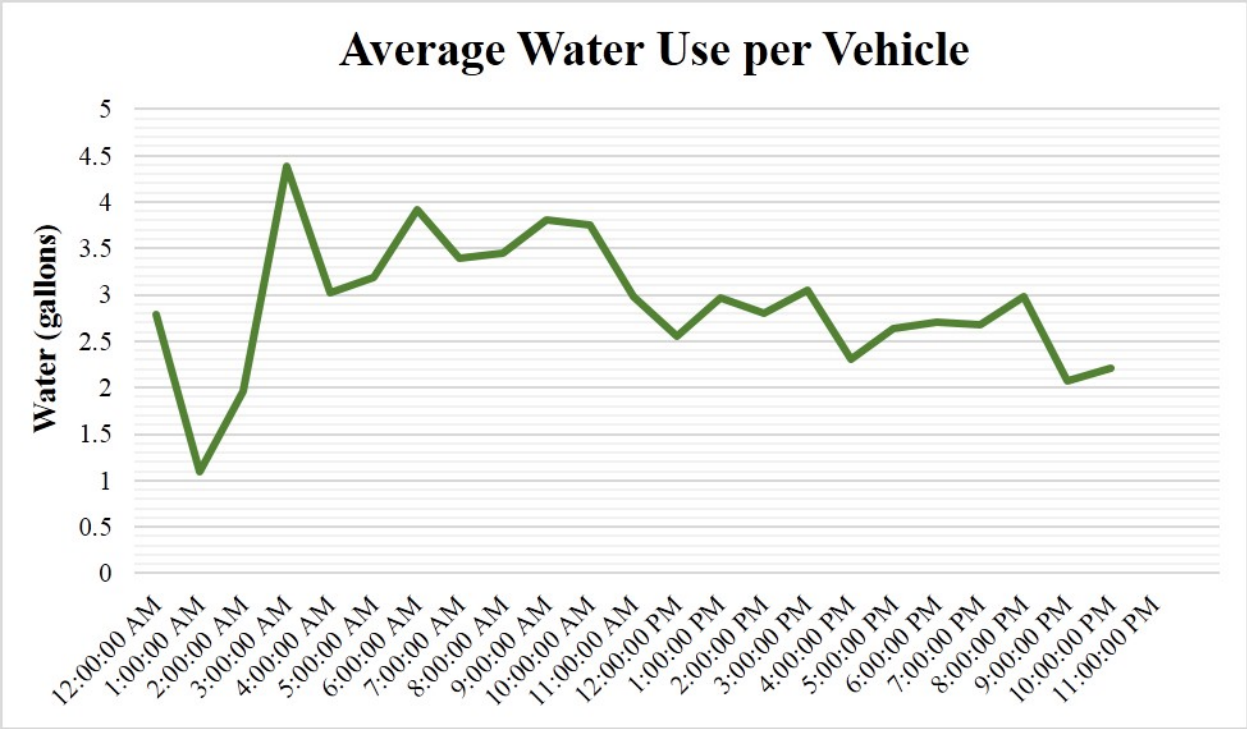


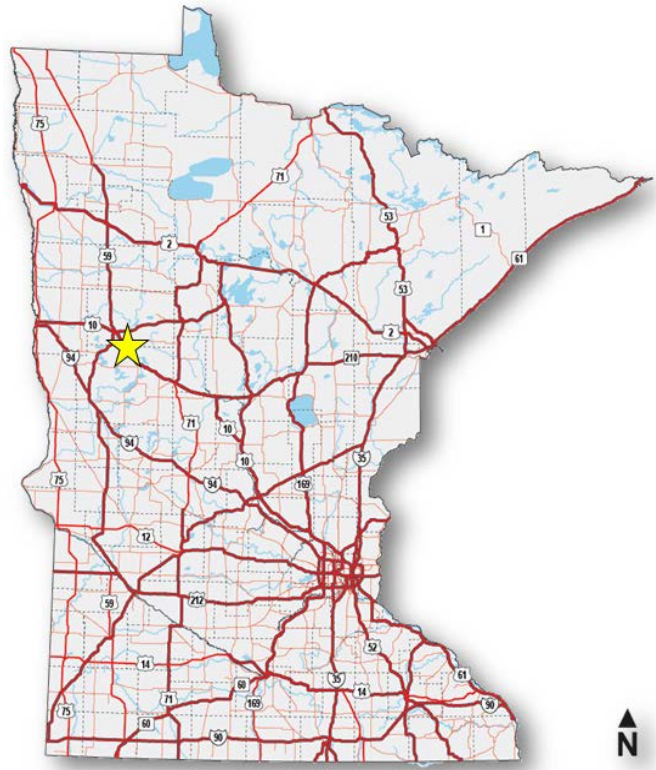
Figure 5.3: Average water use per vehicle at St. Croix TIC from June 29, 2015 to July 13, 2015.

Chapter 6: Frazee Rest Area Non-Interstate

One mile S of Frazee, MN

WB Highway 10

Otter Tail County



Rest Area Overview

Men's Restroom

Two toilets
Two urinals
Two sinks

Women's Restroom

Four toilets
Three sinks

Family Restroom

One toilet
One sink

Designated Assisted Restroom

Low-flow Fixtures

Other

Water softener
Water fountains (inside & outside)
Custodial sink

Amenities

Pay phone
Vending machines
Pet exercise area
Picnic shelters & tables
Mosaic artwork
Accessible for both directions of traffic

Study Overview

2nd Study Period: Monday, June 29, 2015 to Monday, July 13, 2015

People Counts: June 29, 2015 to July 13, 2015

Water-flow Data: 2:00 p.m. June 29, 2015 to July 13, 2015

Traffic Counts: 10:00 a.m. June 29, 2015 to 11:00 a.m. July 13, 2015

Complications:

Automated water meter was backordered and unable to be installed for 1st study period.

Water Use per Person

Average water use per person: 2.1 ± 0.1 gallons

Peak daily average water use per person: 2.5 gallons on Saturday, July 4, 2015

Range of average daily water use per person: 0.7 gallons

The **total daily water use** and the **total number of daily visitors** are displayed in Figure 6.1. The increase in visitors and water consumption on Friday, July 3 and Sunday, July 5 can be attributed to Independence Day Holiday Weekend.

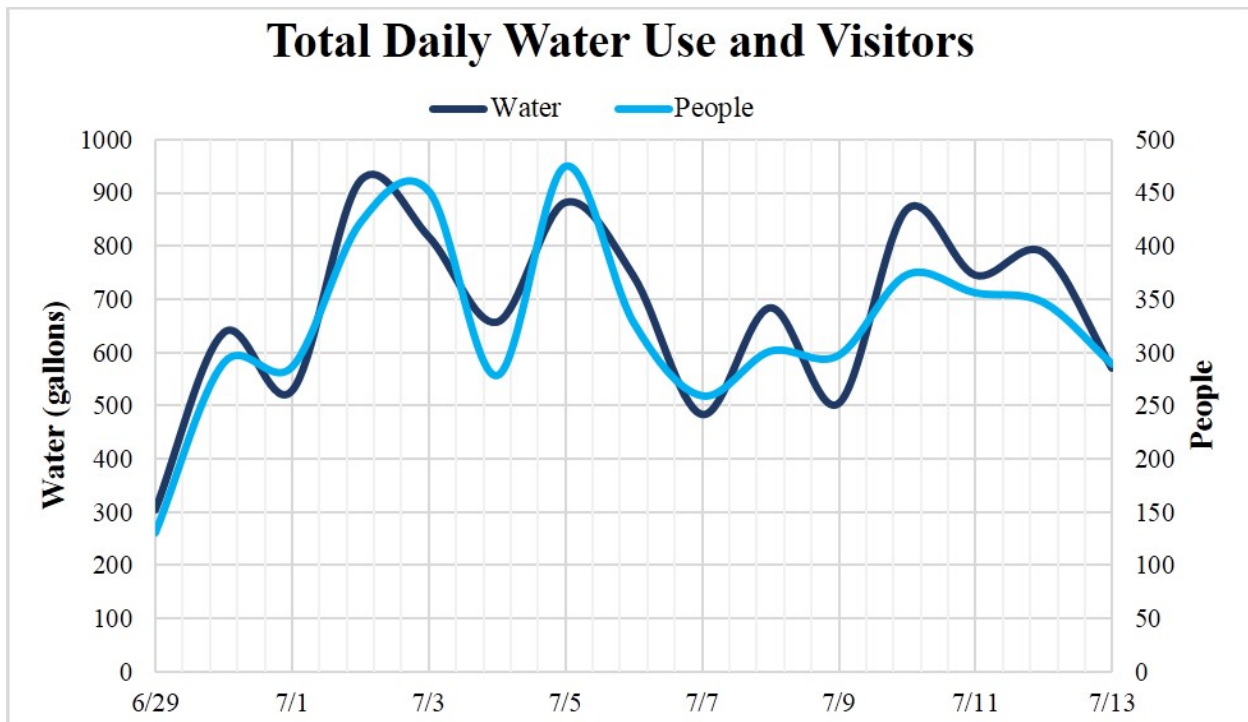


Figure 6.1: Total daily water use and total daily visitors at Frazee RA from June 29, 2015 to July 13, 2015.

The **average hourly water use** and **average hourly visitors** are displayed in Figure 6.2. The early morning spike that does not correlate with visitors can be attributed to the function of the water softener.

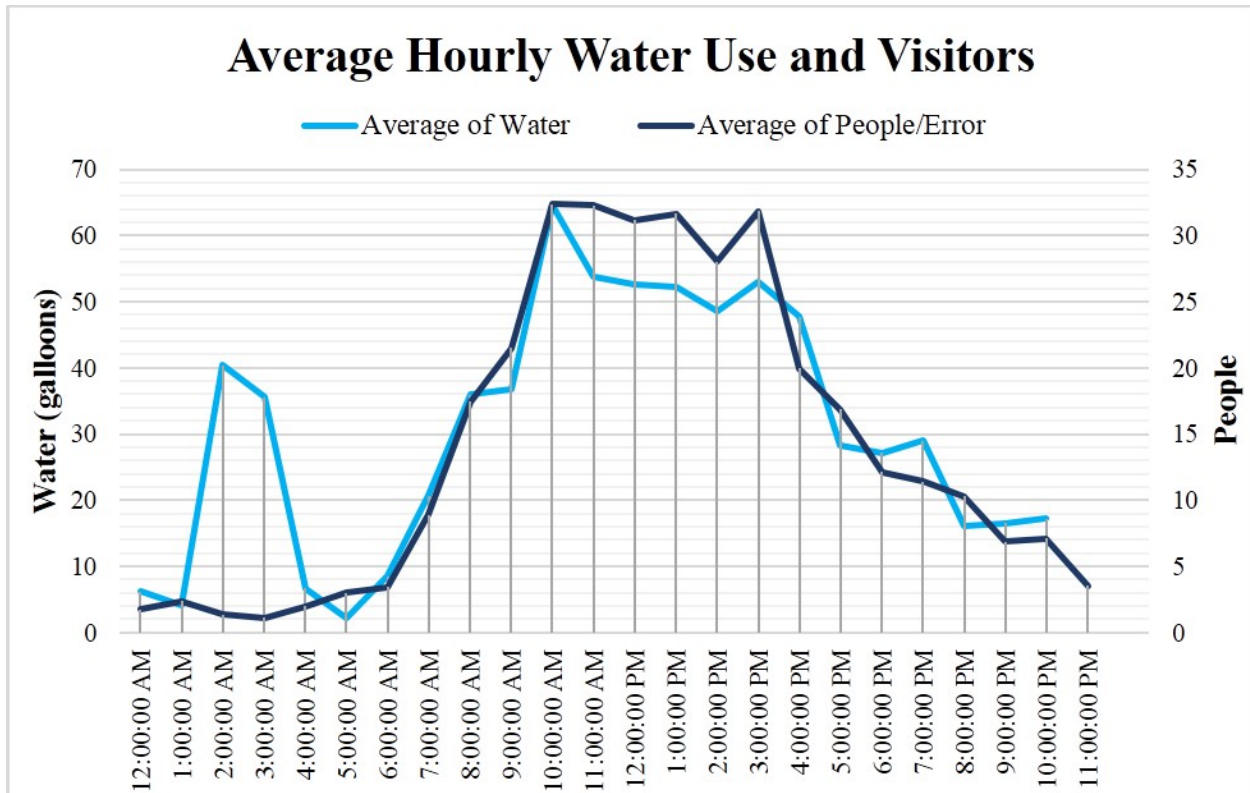


Figure 6.2: Average hourly water use and average hourly visitors at Frazee RA from June 29, 2015 to July 13, 2015.

Water Use per Vehicle

Average water use per vehicle: 2.3 ± 0.3 gallons

Peak daily average water use per vehicle: 3.4 gallons on Saturday, July 4, 2015

Range of average daily water use per vehicle: 1.9 gallons

Average number of people per vehicle: 1.2

The **average amount of water used per vehicle** is displayed in Figure 6.3.

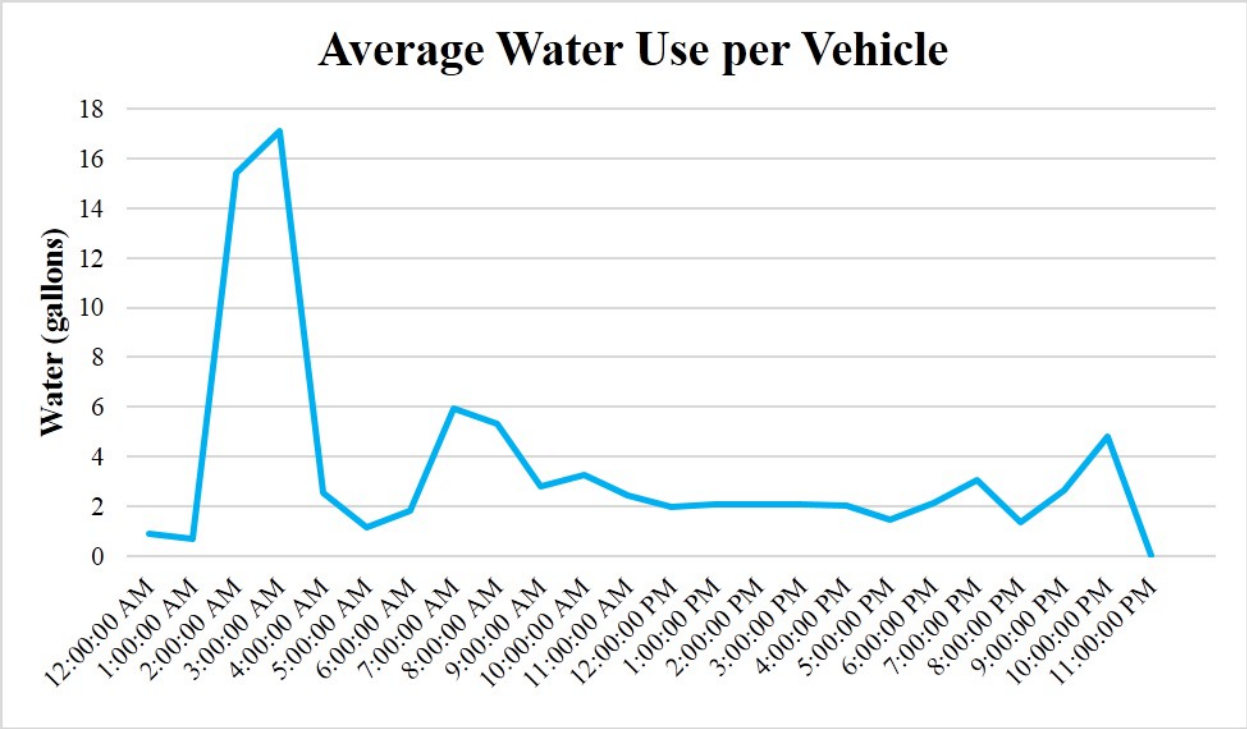


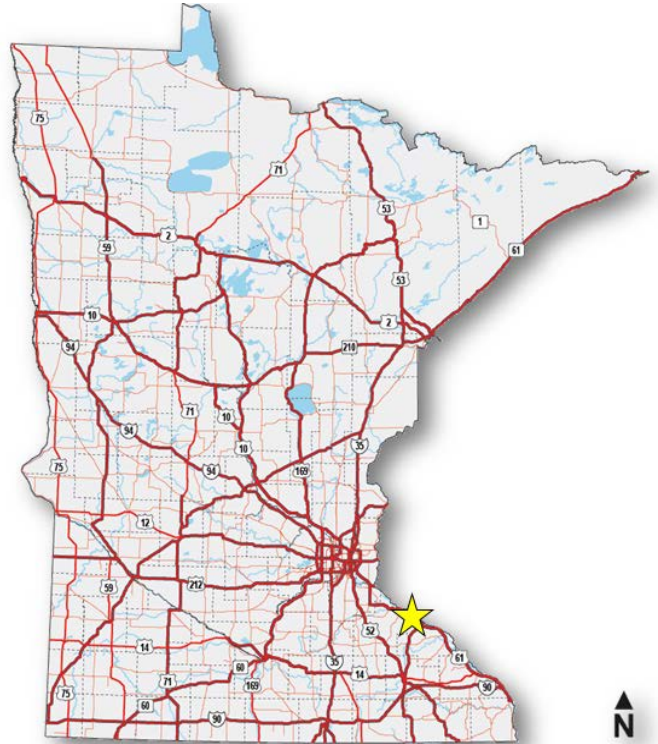
Figure 6.3: Average water use per vehicle at Frazee RA from June 29, 2015 to July 13, 2015.

Chapter 7: Lake Pepin Rest Area Non-Interstate

Two miles N of Lake City, MN

NB Highway 61

Goodhue County



Rest Area Overview

Men's Restroom

- Two toilets
- Two urinals
- Three sinks

Women's Restroom

- Four toilets
- Three sinks

Low-flow Fixtures

Other

- Water fountains

Amenities

- Pay phone
- Vending machines
- Pet exercise area
- Picnic shelters & tables
- Bicycle rack
- Views of Lake Pepin
- On the Great River Road
- Accessible for both directions of traffic

Study Overview

2nd Study Period: Monday, June 29, 2015 to Monday, July 13, 2015

People Counts and Water-flow Data: June 29, 2015 to July 13, 2015

Traffic Counts: 10:00 a.m. June 29, 2015 to 11:00 a.m. July 13, 2015

Complications:

Traffic counters were not installed in time for the 1st study period, which in conjunction with other site complications resulted in a 2nd study period.

Water Use per Person

Average water use per person: 0.70 ± 0.06 gallons

Peak daily average water use per person: 0.96 gallons on Monday, July 6, 2015

Range of average daily water use per person: 0.38 gallons

The **total daily water use** and the **total number of daily visitors** are displayed in Figure 7.1. The increase in visitors and water consumption from Friday, July 3 to Sunday, July 5 can be attributed to Independence Day Holiday Weekend.

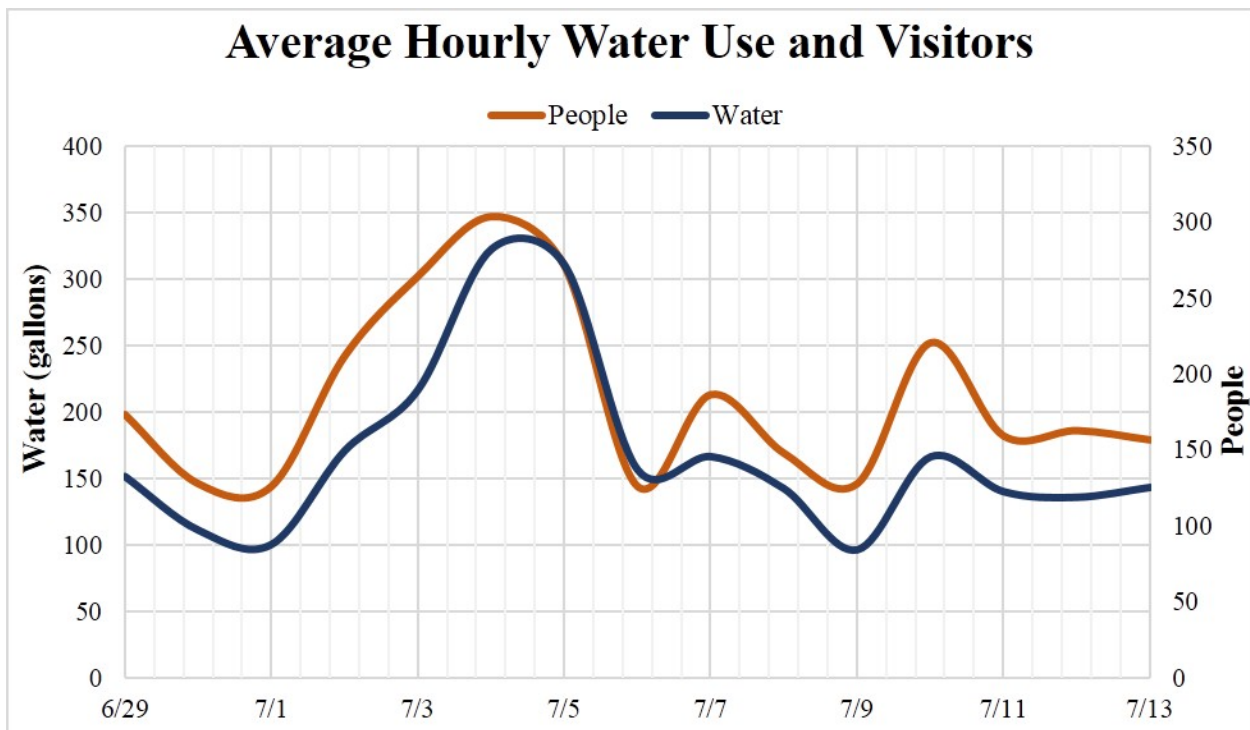


Figure 7.1: Average hourly water use and average hourly visitors at Lake Pepin RA from June 29, 2015 to July 13, 2015.

The average hourly water use and average hourly visitors are displayed in Figure 7.2.

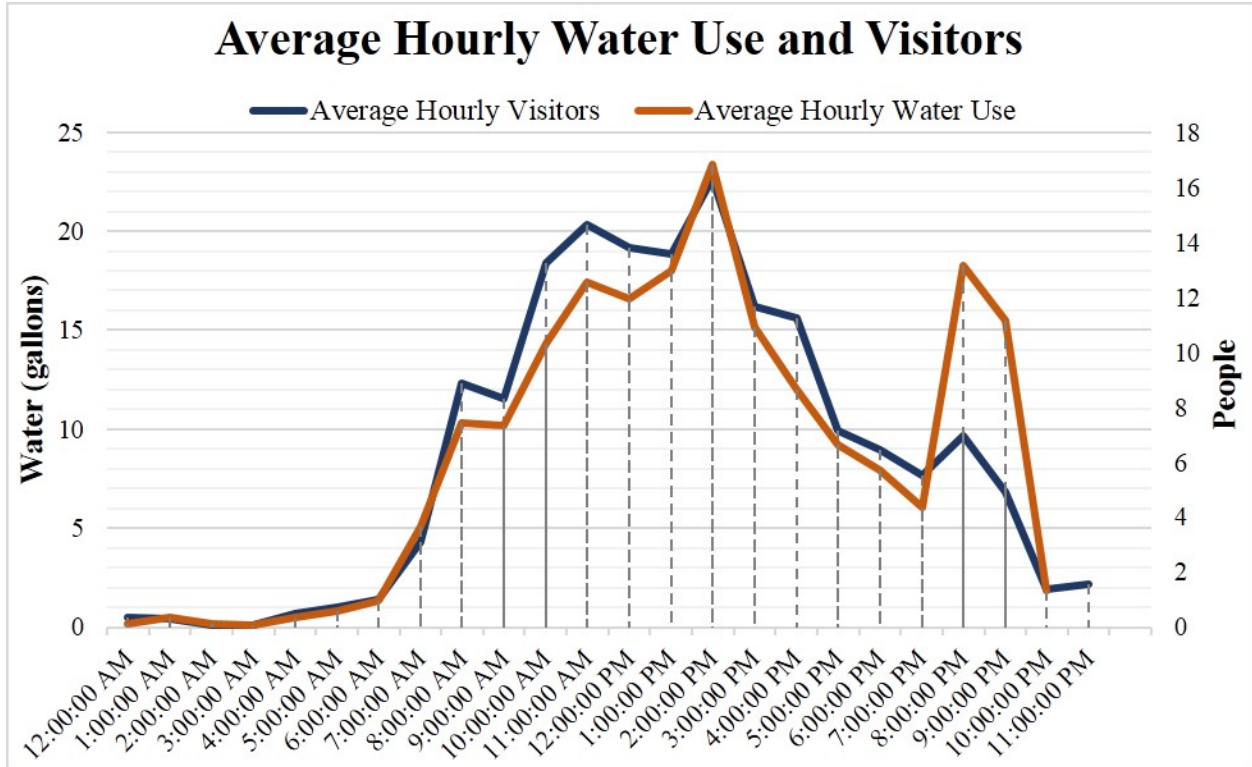


Figure 7.2: Average hourly water use and average hourly visitors at Lake Pepin RA from June 29, 2015 to July 13, 2015.

Water Use per Vehicle

Average water use per vehicle: 0.59 ± 0.07 gallons

Peak daily average water use per vehicle: 0.82 gallons on Sunday, July 5, 2015

Range of average daily water use per vehicle: 0.47 gallons

Average number of people per vehicle: 0.9

The average amount of water used per vehicle is displayed in Figure 7.3.

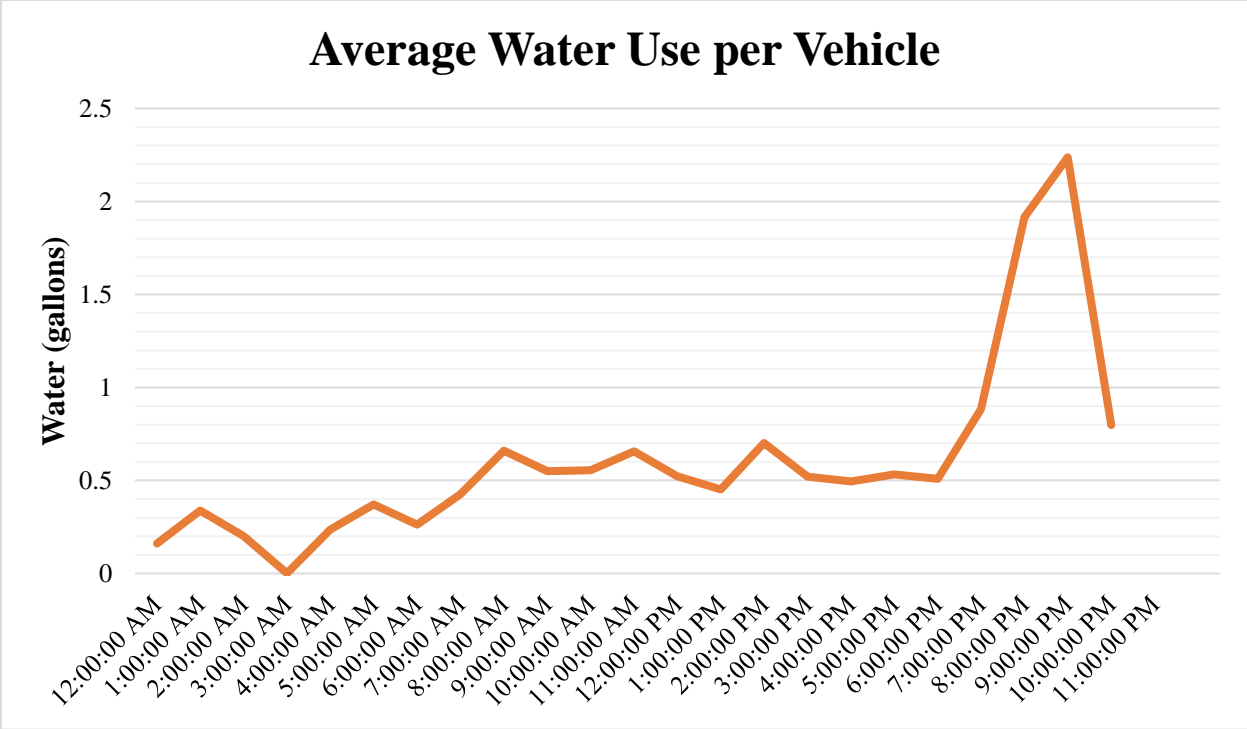


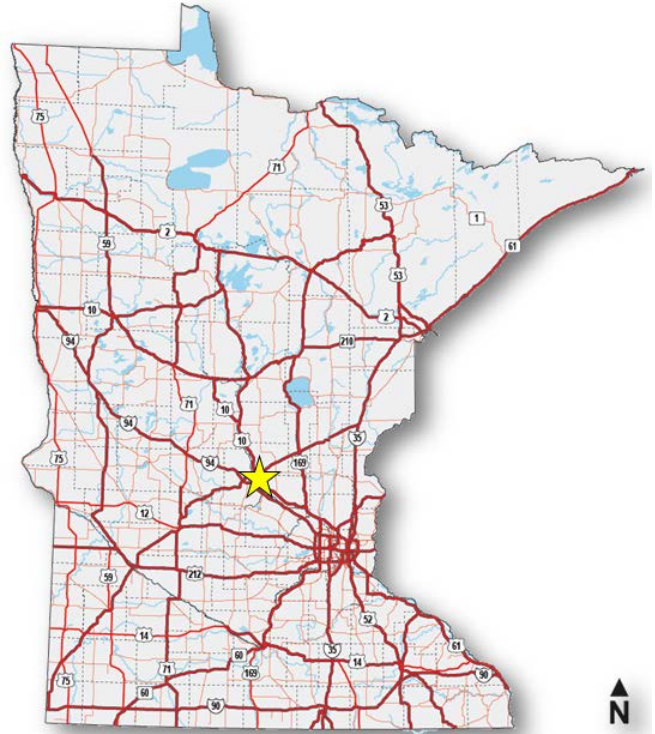
Figure 7.3: Average water use per vehicle at Lake Pepin RA from June 29, 2015 to July 13, 2015.

Chapter 8: Central Minnesota Travel Information Center Non-Interstate

Two miles SE of St. Cloud, MN

WB Highway 10

Sherburne County



Rest Area Overview

Men's Restroom

- Three toilets
- Two urinals
- Four sinks

Women's Restroom

- Six toilets
- Four sinks

Other

- Water fountains
- Water softener

Low-flow Fixtures

Amenities

- Staffed Explore MN Tourism
- Pay phone
- Vending machines
- Pet exercise area
- Picnic tables
- Bicycle rack
- Play Area
- Located on Great River Road
- Accessible for both directions of traffic

Study Overview

1st Study Period: Monday, May 18, 2015 to Monday, June 1, 2015

People Counts: May 18, 2015 to June 1, 2015

Water-flow Data: None - substituted with Greenview Water Records.

Traffic Counts: 11:00 a.m. May 18, 2015 to 9:00 a.m. June, 1, 2015

Complications:

The automated water meter at Central Minnesota TIC malfunctioned until June 6, 2015, five days following the end of the study period. As a result of the malfunction, no water-flow data could be obtained. Traffic counters were unavailable for reinstallation for the 2nd study period.

Custodial duties include manually recording total daily water use by observing the water-flow meter (Figure 8.1). This estimation of water-flow was utilized for this site, but is not as accurate as readings from the automated water meter.

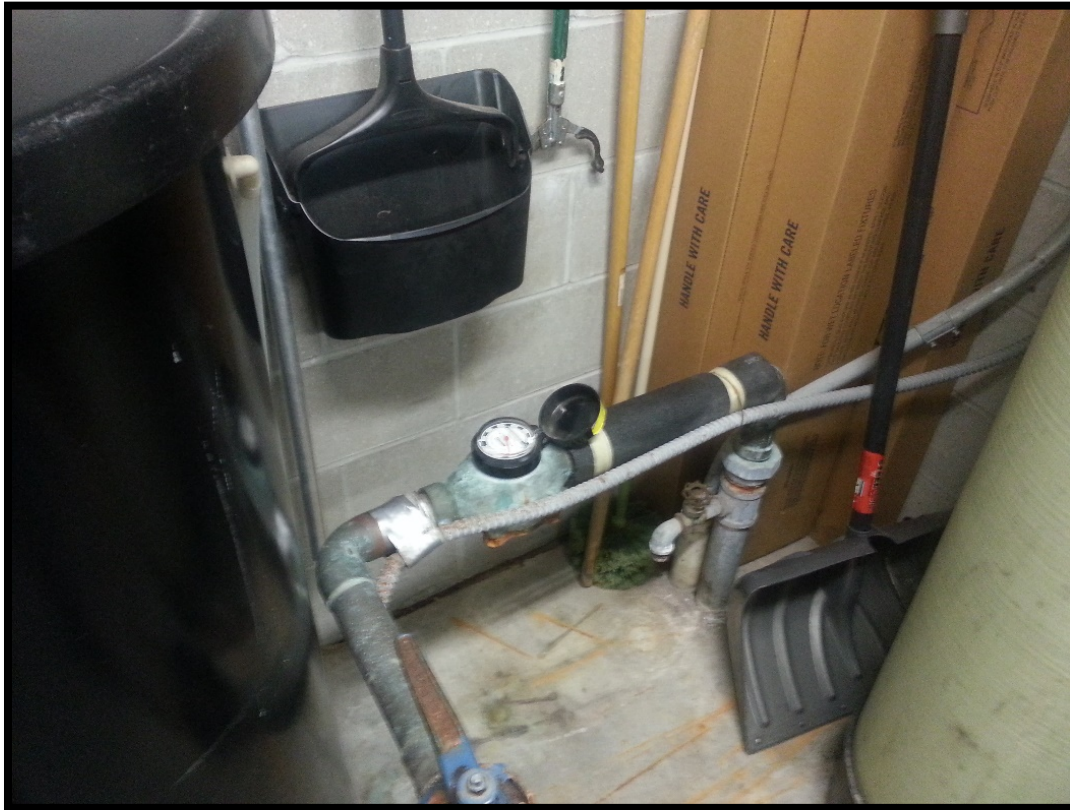


Figure 8.1: Water-flow meter at Central Minnesota TIC used to visually estimate daily cumulative water use to the nearest 100 gallons.

Water Use per Person

Average water use per person: 1.8 ± 0.3 gallons

Peak daily average water use per person: 3.0 gallons on Sunday, May 24, 2015

Range of average daily water use per person: 2.0

The total daily water use and total daily number of visitors are displayed in Figure 8.2.

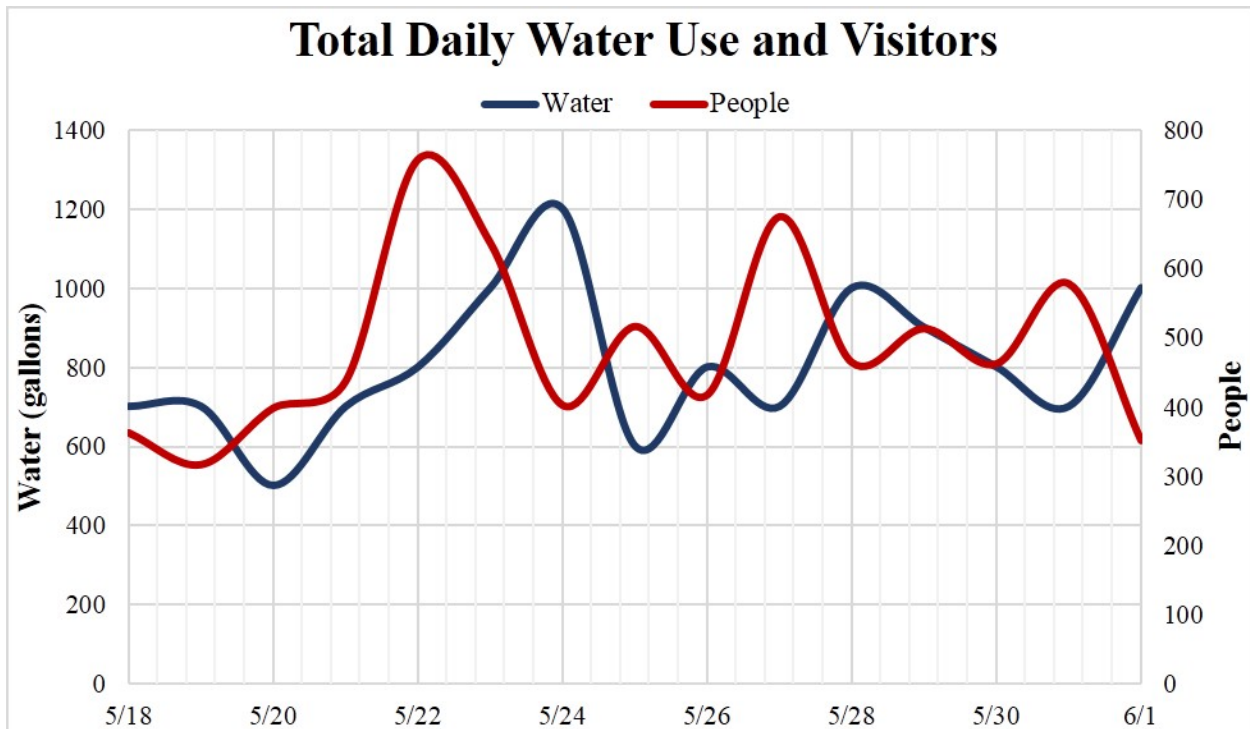


Figure 8.2: Total daily water use and total daily visitors at Central Minnesota TIC from May 18, 2015 to June 1, 2015.

Average water use per vehicle: 2.1 ± 0.8 gallons

Peak daily average water use per vehicle: 7.0 gallons on Monday, June 1, 2015

Range of average daily water use per vehicle: 5.9 gallons

Average number of people per vehicle: 1.1

The average amount of water used per vehicle is displayed in Figure 8.3.

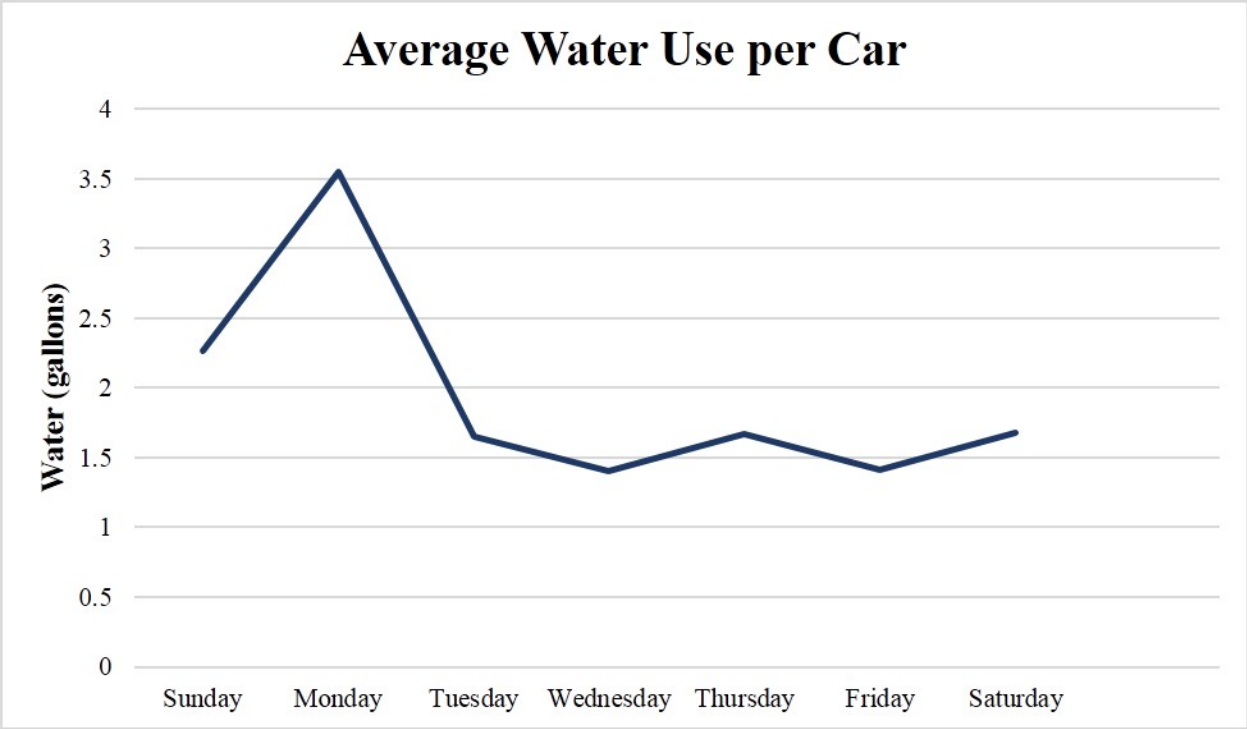


Figure 8.3: Average water use per vehicle at Central Minnesota TIC from May 18, 2015 to June 1, 2015.

Chapter 9: Rest Area Comparison

Figure 9.1 displays average water use by day of the week at all sites, where Monday is 1 and 7 is Sunday. Figure 9.2 displays total daily water use at all sites.

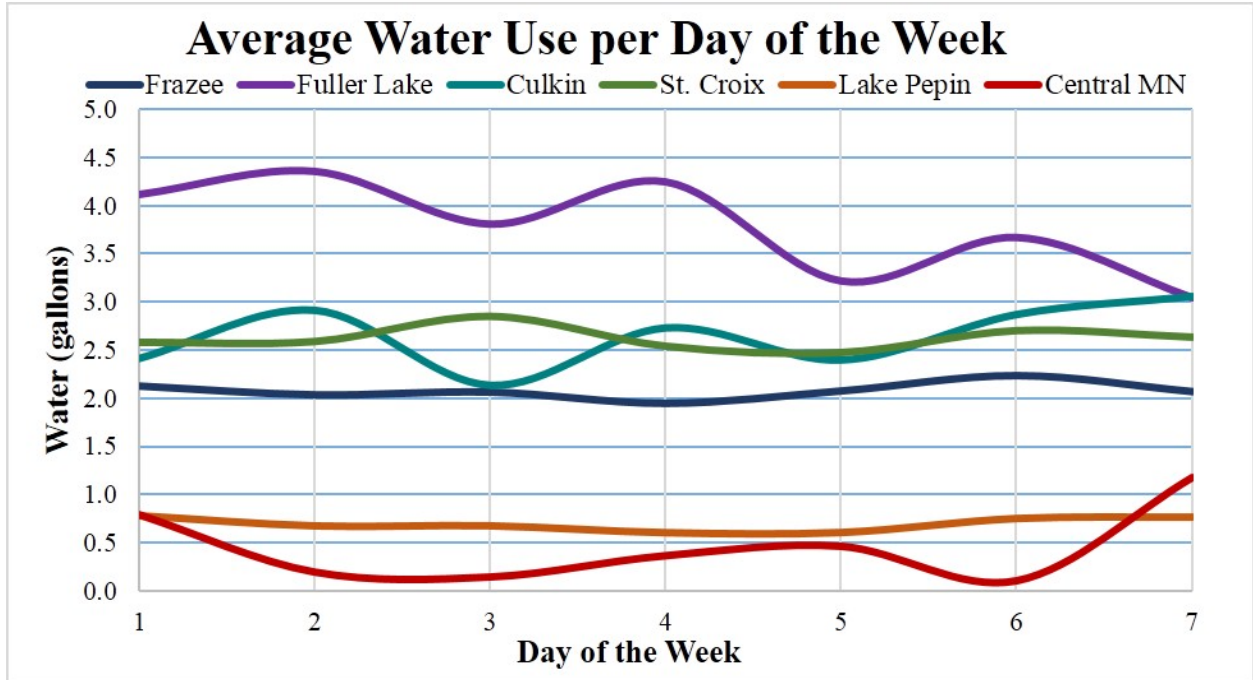


Figure 9.1: Average water usage as averaged by day of the week.

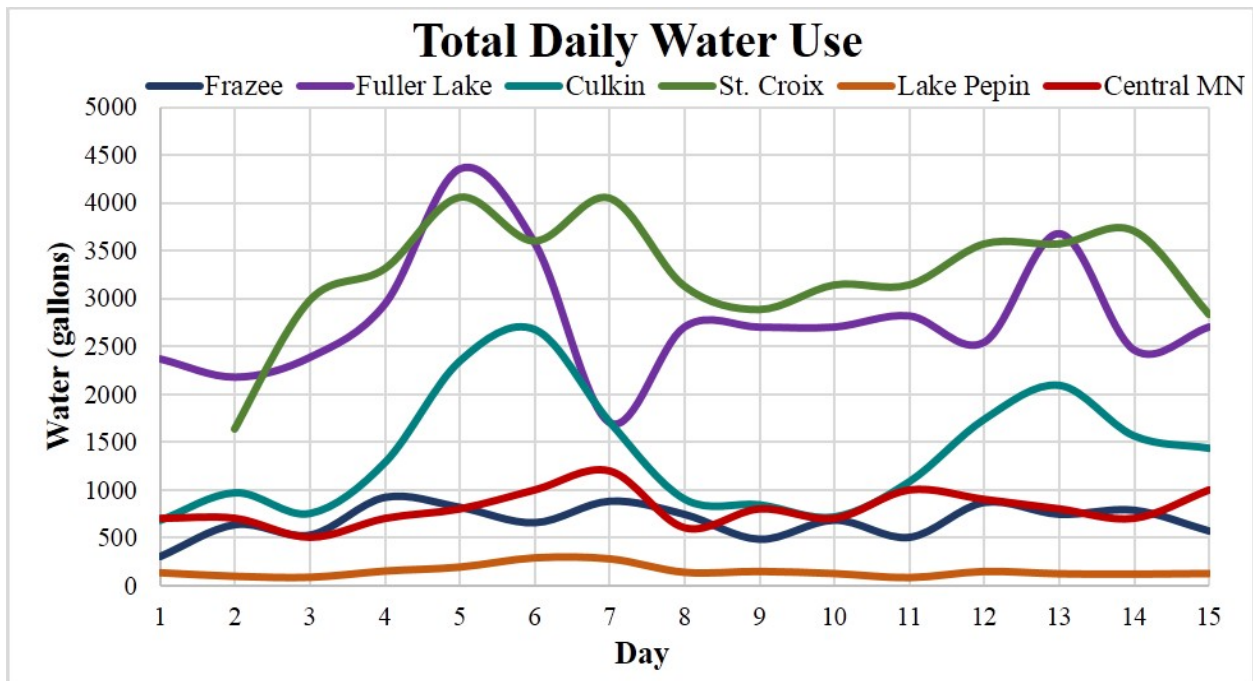


Figure 9.2: Total daily water use for all six study sites for the 15-day study periods.

Figure 9.3 displays total daily visitors for first study period sites. The increase in visitors on day four occurred on what was the beginning of Memorial Day Weekend (Friday, May 22). Another smaller but still noticeable increase in visitors occurred on the second weekend (days 12 to 14) at Fuller Lake and Culkin.

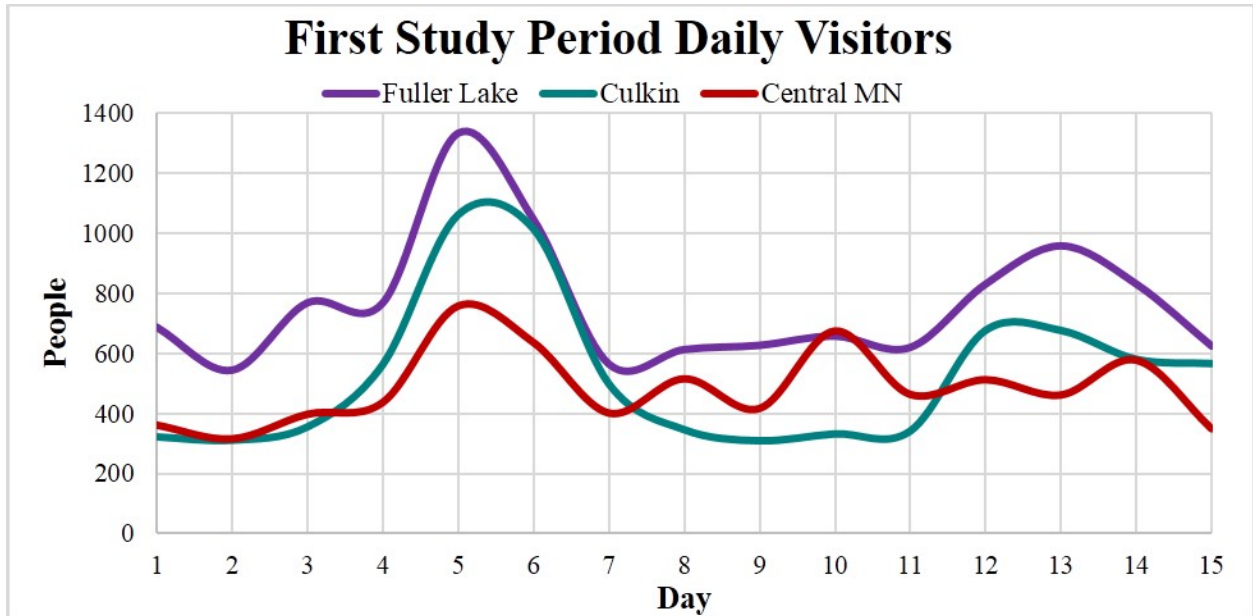


Figure 9.3: Total daily visitors at Culkin RA, Central Minnesota TIC, and Fuller Lake RA from May 18, 2015 to June 1, 2015.

Figure 9.4 displays total daily visitors for second study period sites. The increase in visitors from day four to day seven occurred over what was the July 4 holiday weekend.

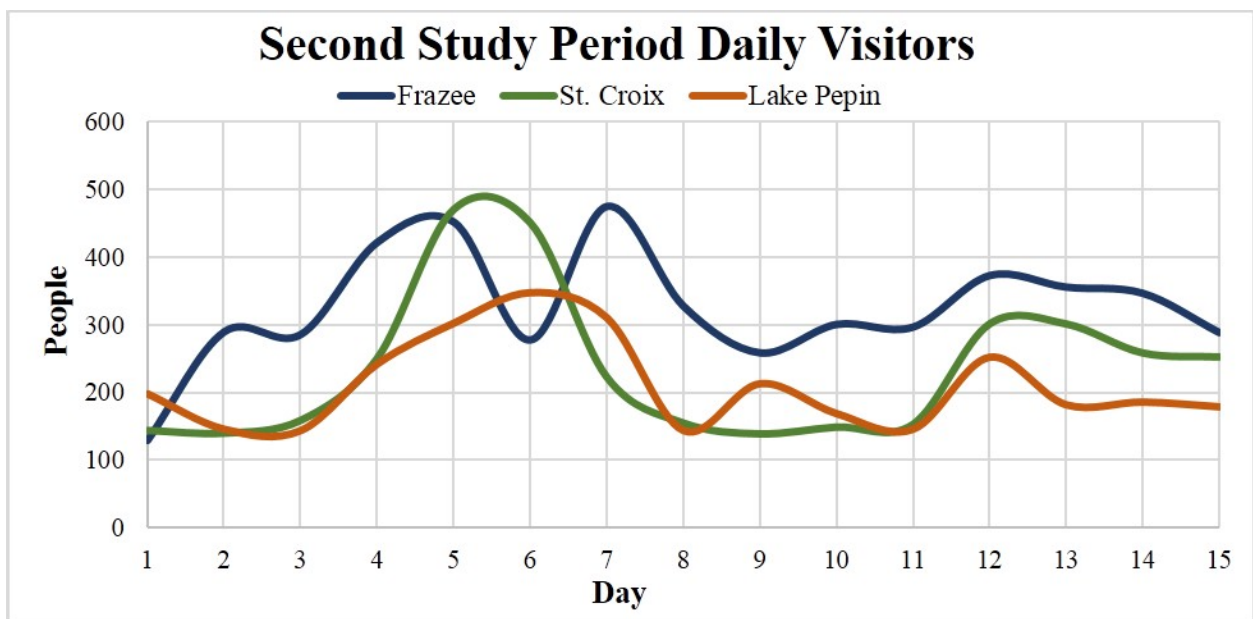


Figure 9.4: Total daily visitors at Frazee RA, Lake Pepin RA, and St. Croix TIC from June 29, 2015 to July 13, 2015.

Figure 9.5 displays average hourly water use per person. The early morning spike that does not correlate with visitors can be attributed to the function of the water softener.

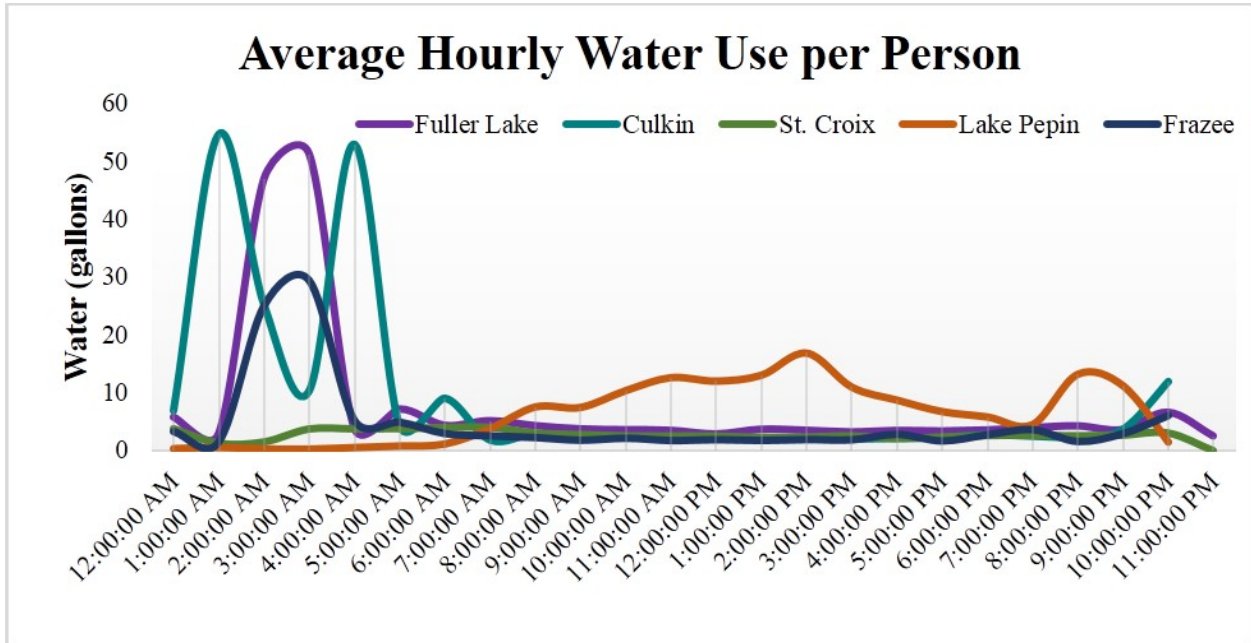


Figure 9.5: Average hourly water use per person for Fuller Lake RA, Culkin RA, St. Croix TIC, Lake Pepin RA, and Frazee RA.

The heaviest average hourly water-flow occurs roughly from 8:00 a.m. to 7:00 p.m. at Fuller Lake R.A. and St. Croix TIC from 9:00 a.m. to 4:00 p.m. at Culkin R.A. and Frazee R.A. (Figure 9.6). Lake Pepin R.A. average hourly flow increases slightly during the daytime hours, but as a whole remains quite steady throughout the entire day.

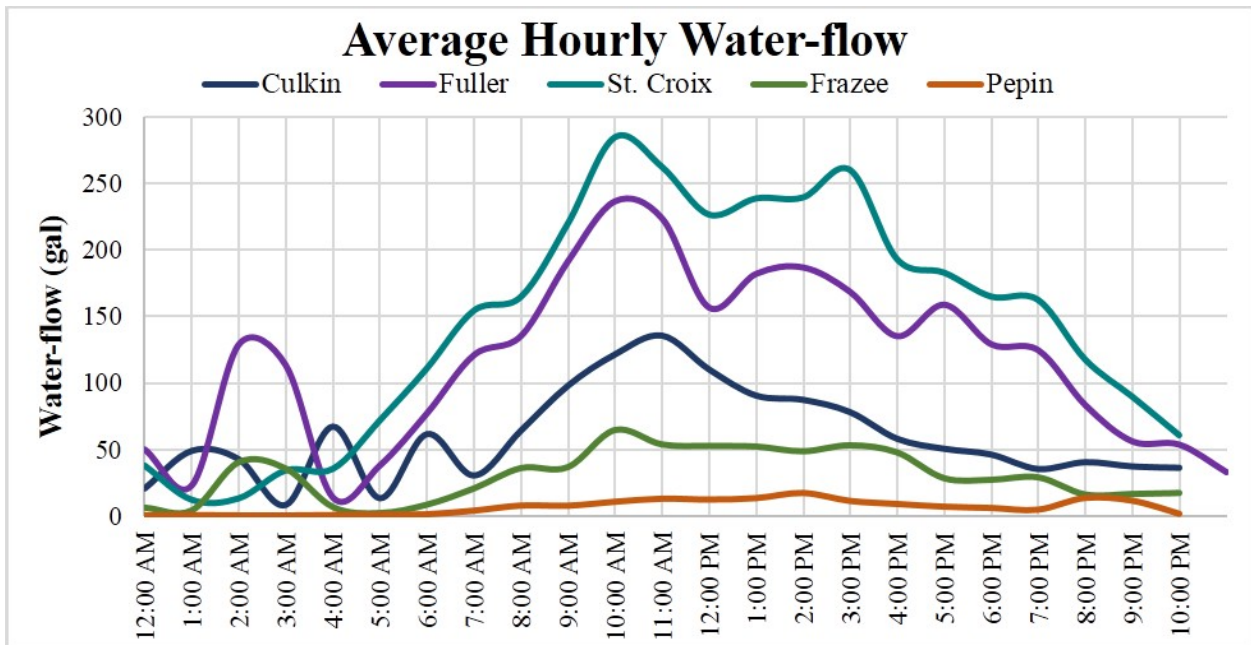


Figure 9.6: Average hourly water-flow for all sites.

A comparison of interstate and non-interstate locations is shown in Table 9.1. Visitors at the Interstate sites Culkin and Fuller Lake use considerably larger amounts of water than Interstate site St. Croix and Non-Interstate sites Central Minnesota, Frazee, and Lake Pepin. A significant difference was found between interstate and non-interstate sites, $t(44) = 9.16, p < 0.05$, with an average water use of 3.2 ± 0.3 gallons at Interstate sites and 1.8 ± 0.2 gallons at non-interstate sites (Table 9.2). There is no immediate explanation for the differences observed.

Table 9.1: Average water use per person at interstate study sites and non-interstate study sites.

Interstate	Average Water per Person (gal)	Non-Interstate	Average Water per Person (gal)
Culkin	2.6 ± 0.2	Central MN	1.8 ± 0.3
Fuller Lake	3.8 ± 0.3	Frazee	2.1 ± 0.1
St. Croix	2.6 ± 0.1	Lake Pepin	0.70 ± 0.06
Average	3.2 ± 0.3	Average	1.8 ± 0.2

Table 9.2 displays average water use per vehicle for each site, as well as the average between interstate and non-interstate. Average water use per vehicle was found to be significantly different ($t(77) = 5.53, p < 0.05$).

Table 9.2: Average water use per car at interstate study sites and non-interstate study sites.

Interstate	Average Water per Car (gal)	Non-Interstate	Average Water per Car (gal)
Culkin	3.1 ± 0.5	Central MN	2.1 ± 0.8
Fuller Lake	2.7 ± 0.4	Frazee	2.3 ± 0.3
St. Croix	2.7 ± 0.4	Lake Pepin	0.59 ± 0.07
Average	2.8 ± 0.2	Average	1.6 ± 0.4

Average people per car for interstate and non-interstate are displayed in Table 9.3. A t-test assuming unequal variances was conducted ($t(82) = -1.37, p > 0.05$) and found no significant difference in average person per car between interstate and non-interstate sites. The site averages are low, with some even below one person per car due to visitors not entering the facility. In particular, Lake Pepin averages less than one person per vehicle, which can be attributed to the rest area entrance also serving as an entrance to a separate parking lot for a shoreline park area. Vehicles entering may not have visited the rest area, but only the park area.

Table 9.3: Average people per vehicle at interstate study sites and non-interstate study sites.

Interstate	Average People per Car (gal)
Culkin	1.1 ± 0.1
Fuller Lake	0.72 ± 0.1
St. Croix	1.1 ± 0.2
Average	0.95 ± 0.1

Non-Interstate	Average People per Car (gal)
Central MN	1.1 ± 0.2
Frazees	1.1 ± 0.1
Lake Pepin	0.96 ± 0.3
Average	1.1 ± 0.1

Chapter 10: Discussion and Conclusions

The 1979 MnDOT design charts determined water-conserving devices used on average 2.8 gpcd (gallons per capita per day), while non-water-conserving devices used 4.5 gpcd. The results of this study found similar water use averages for low-flow fixtures (all sites have low-flow fixtures), with averages ranging from 0.7 gpcd to 3.8 gpcd and an overall average of 2.3 gpcd. Interstate rest areas average 3.0 gallons per person and non-interstate average 1.5 gallons per person. The average water use per person at the Central Minnesota TIC is 1.7 gallons; however, this value cannot be considered accurate due to the previously mentioned technical difficulties experienced during the study. When including a safety margin to account for variation and error, a water usage per person of five gallons is recommended.

Interstate and non-interstate sites were found to have significantly different water use averages for people and vehicles. However, at this time, there is no simple explanation for the differences. It could be due to these facilities being smaller with less volume of water being used for water treatment and cleaning.

It is important to note that average water usage reflects water use required for one person to use a rest area facility, which includes direct use of toilets, urinals, and sinks, as well as water required for cleaning and maintenance of the rest area, including water softeners. Facilities are cleaned by Greenview custodial staff as needed throughout the day and water used for cleaning cannot be specifically accounted for based on water-flow data. Greenview custodial staff are present at all rest areas from 8:00 a.m. to 12:00 a.m., with a shift change occurring at 4:00 p.m.

Culkin, Fuller Lake, and Frazee all have substantial increases in water use during the morning hours due to the operation of water softeners, which are programmed to run on demand specifically during off peak usage hours (early morning). This data confirms the lowest water demand occurs in early morning hours and would be useful for future water softener programming.

Peak daily average water use per person is valuable for the design of septic systems. Systems must be designed to handle maximum usage and the peak usage for daily averages gives a good estimation as to the magnitude of wastewater demand a system must be capable of handling. In the future, the University of Minnesota (UMN) recommended MnDOT conduct water usage studies similar to this prior to the design and installation of new rest area septic systems, but over longer time periods. This study highlighted variation between sites, regardless of categories such as interstate or non-interstate, which suggests it is inadequate to design a rest area septic system based on categorical labels alone. Knowing maximum demands and usage trends would allow for the most suitable septic systems to be installed, which would subsequently save money and resources on necessary, but preventable, alterations.

While this report intended to validate or redefine the design charts and formulas for rest area septic systems, the two-week study period did not provide sufficient data from which to calculate values that fully explain per person and per vehicle water consumption values. It is recommended to use five gallons per person as a conservative estimate of peak water consumption for septic system design. A similar value for potable water consumption is warranted.

10.1 Study Limitations and Future Research

This study was limited to a two-week period focusing on Memorial Day and the Fourth of July. This early season holiday along with a limited two weeks of data might not have provided peak usage for most sites. Future research should involve a longer study period that examines additional factors, such as seasonal differences in water use. The UMN suggests this research could be continued at these sites for three years to determine seasonal variations and to further vet the design information. A longer study period will result in more accurate water use estimations and defensible values that could be used to update design charts and formulas.

References

Minnesota Department of Transportation. "Types of Rest Areas". *Safety Rest Areas & Waysides*. Internet. Accessed August 20, 2015. <http://www.dot.state.mn.us/restareas/types.html>

Minnesota Department of Transportation. "Find a Rest Area in Minnesota". *Safety Rest Areas & Waysides*. Internet. Accessed August 20, 2015. <http://www.dot.state.mn.us/restareas/find.html>

Walker Wireless. (2015). "OmniCounter People Counting System". *Traf-Sys People Counting Systems*.