Flow Monitoring in Landscape Irrigation Systems

Author

Patrick Halahan. Vice President of Engineering. ET Water Systems, Inc.

Novato California. phalahan@etwater.com

Abstract. The increased use of smart irrigation controllers - along with incorporation of weather data and soil moisture sensors among other tools - are indicators of an industry trend toward greater use of technology to drive water conservation and overall system performance. As a key element of this trend, flow sensors are becoming more prevalent to measure water usage and to help manage irrigation systems. ET Water Systems, Inc. has deployed many smart irrigation products and tools which incorporate flow sensors, with customers using flow sensors to:

- Measure water usage during scheduled irrigation, manual watering, and other water usage events;
- Identify high flow conditions (e.g. main line break);
- Identify slow leaks;
- Compare current flow on a station to historical flow data to investigate for issues such as broken heads or blocked drippers; and
- Collect data for water budgeting and compliance purposes.

This paper will use real world field data to demonstrate how to get the most out of flow monitoring. Different flow sensor techniques will be reviewed with a discussion of their accuracy, limitations, and how to use them to enhance irrigation management and water conservation programs.

Keywords. Flow sensing. Flow measurement. Flow management. Flow in irrigation. HermitCrab.Hermit Crab HermitCrab flow monitoring. ETwater flow monitoring.ETwater smart. ETwater SmartWorks panel, smart controller, flow monitoring.

Why have flow sensing?

The use of flow sensing systems falls broadly into two categories:

- To monitor water usage: This would be in some form of volumetric measurement such as gallons or acre feet.
- To check the irrigation system for problems such as broken heads or pipe breaks: These types of readings would be in gallons per minute or similar.

Adding a flow sensing system to an older conventional or “clock” type of irrigation controller generally does not make a lot of sense because the flow data and alerts are not sent anywhere in real-time; they have to be viewed and reacted to at the controller. Managers, owners and contractors typically prefer that flow data be delivered digitally to a computer so it can be graphed and manipulated, in addition to responding to alerts or other issues. With the advent of two-way communications systems built into the latest generation of smart controllers, water usage data and potential issues with flow rates can be transmitted in real time to a remote location.

One of the challenges with smart controller technology is that achieving significant water usage reductions - and attaining the related cost savings- are often elusive unless actual water usage at a site is benchmarked and monitored, often incorporating normalizing factors such as relative evapotranspiration rates from one period to the next. A“Smart Controller” is typically meant to reduce water usage and save money, but if users don’t measure the before and after water usage they cannot know the full extent of savings. This is where the value of flow sensing and monitoring can be appreciated.

Typical properties of flow in an irrigation system

A typical irrigation system frequently includes a Master valve and numerous station valves. When an irrigation valve is turned on, water flow through the sensor builds to a high value while the air is being expunged from the system and then decreases to a steady state once the pipes of the irrigation system are full and water is being applied to the landscape. Many measurement systems or irrigation controllers require the input of a “fill time” which is the time required to fill the pipes and achieve a steady flow through the system. It is important to note that fill times may vary from station to station depending on the irrigation system design. The fill time is related to the pipe volume between the station valve and the irrigation method (sprinklers, rotors, drip line, etc.) The more sophisticated and easier-to-use controllers use algorithms in the flow measurement system, but such approaches need to be carefully designed and crafted to ensure that consistent measurements are taken every time a station is turned on. The diagram in Figure 1 below illustrates how flow rates can vary over time, especially immediately after water is turned on.

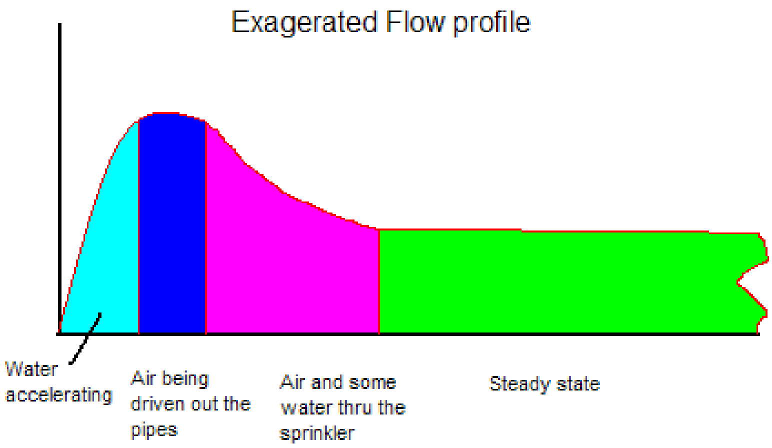


Figure 1

Achieving consistent and accurate flow measurements is important in order to benchmark proper flow rates for a site, with those benchmarks serving as references for accurate and effective high or low flow alerting. False flow alarms are a nuisance that can be avoided once a system is properly benchmarked.

Flow ranges

The amount of flow can vary widely based on several factors. The size of the property and hence the related size of the main irrigation line will make a large difference. Similarly the type of emitter can vary from small low-flow-drip emitters to large-volume rotors.

For this discussion we will review a large residential or small commercial installation capable of 40 gallons per minute (gpm) on a 1 ½ inch mainline. With today's focus on water conservation, drip emitters are used as much as possible. The inherent challenge is the low flow rate of a drip station. In order to determine that a drip emitter is blocked or the restrictive ¼ inch pipe is broken, the flow monitoring system needs to deliver repeatable and consistent readings at low flow volumes. Accuracy would also be desirable, but in this instance repeatability and consistency are the most important factors. The following table indicates some of the flow conditions one might encounter at this site:

	Output	Flow	Comments about requirements
1	Drip emitter	1.2 gpm	Need a consistent low flow measurement capability
2	Large rotors	32 gpm	Largest normal flow on the property
3	Sprays	12 gpm	Small reduction indicates filter clogging. Large increase indicates a head is broken
4	Main line break	Nearly 40 gpm	Need immediate shut down of the master valve

Sensor types

There are many brands and types of flow sensors on the market for measuring the flow of water through pipes. As we focus on the landscape irrigation sector, cost and performance considerations have resulted in two types of flow sensors being used most commonly. They are:

- Paddle type flow sensors.
- Impeller or turbine flow sensors

Other sensor types that are used in the irrigation sector include Ultrasonic, Magnetic and Thermal Mass. In particular, Magnetic type flow sensors are used in very large installations and in some agriculture irrigation systems.

Paddle type flow sensors
A paddle type flow sensor operates when water flowing through the pipe strikes the lower half of the paddle wheel. The upper half is protected from the water flow so the paddle wheel will rotate.
The paddle sensors typically fit into a “T”fitting in the main line as shown in Figure 2 below.

Figure 2

This picture Figure 3 shows the paddle that rotates due to the water flow

Figure 3

The paddle rotation is converted to electrical pulses which are measured or counted to compute the flow reading. Due to stiction (static friction) and other effects, the paddle requires a certain amount of flow before it starts to rotate. Paddle sensors are frequently poor at reading low to very low flows.

Additionally, these types of sensors need a certain length of straight pipe upstream and downstream of their location to minimize turbulence and erroneous readings. The manufacturers typically suggest at least 10 pipe diameters upstream and 5 diameters downstream with no flow disturbances such as valves or bends.

Impeller or turbine flow sensors

There are several manufacturers that market impeller type flow sensors. Typically, these types of flow sensors are integrated into a water meter. Some vendors call these products hydrometers, although a hydrometer is actually a device that measures liquid density and is used in the making of wine or beer. These impeller or turbine flow sensors are incorporated in water meters whose design includes a register that displays water usage. See the following illustration Figure 4.

Figure 4

The picture below Figure 5 shows the internal mechanism of an impeller type flow sensor

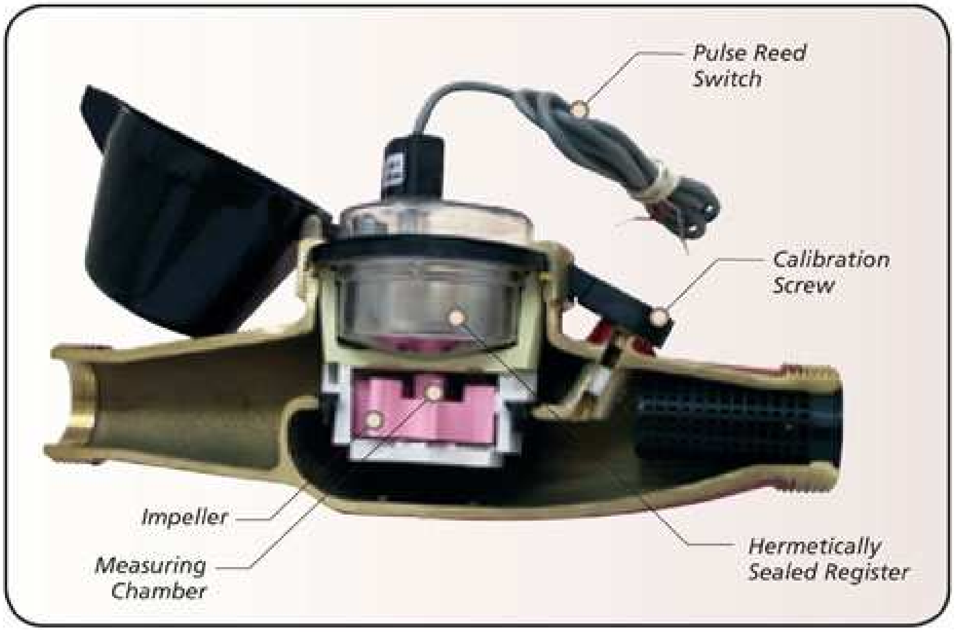


Figure 5

The electrical output from impeller or turbine type flow sensors comes in two varieties: a reed switch with two wires and an optical type sensor with 3 wires. The impellers typically start turning at very low flow rates so flows near 0 can be recorded.

Impeller sensors can also be incorporated into a master valve. Impeller or turbine type flow sensors do not require a straight section of the pipe either upstream or downstream that is clear of flow disturbances.

Which sensor should I use?

The choice of the sensor type depends on a number of factors:

- How is the flow data going to be used by the irrigation contractor or property manager? If, for example, the water usage is going to be compared to water usage reports from utilities or other water purveyors then high accuracy is required;
- Dynamic range of flow that is being measured;
- Cost;
- Ease of installation; and
- User friendliness.

Accuracy and dynamic range

ETwater has tested and worked with a number of flow sensors and found that the specifications provided by manufacturers are often misleading and not always accurate. For example one paddle wheel sensor manufacturer quotes an accuracy of +/- 1% but our tests determined that the accuracy was closer to +/- 3%. Furthermore, the accuracy of the paddle wheel drops off even more dramatically at low flow rates.

The Table 1 below shows the manufacturer-stated performance data for an impeller sensor:

Performance Data

Size	Lowest Flow *within ± 5% Accuracy*	Lowest Flow *within ± 2% Accuracy*	Nominal Flow *within ± 2% Accuracy*	Maximum Flow *within ± 2% Accuracy*
¾"	0.2 GPM	0.9 GPM	11 GPM	14 GPM
1"	0.3 GPM	1.2 GPM	15.4 GPM	20 GPM
1 ½"	0.9 GPM	3.5 GPM	44 GPM	55 GPM

Table 1

This Table 2 below shows the manufacturer-stated performance data for a paddle wheel flow sensor:

FLOW SENSOR MODEL				
NOMINAL SIZE		1 "	1 1/2"	2"
	Feet per Sec	GPM	GPM	GPM
Minimum Flow	0.25	0.86	1.8	2.8
	1	3.5	7.24	11.3
	2	7	14.5	23
	3	10.4	22	34
	5	17	36	57
	7	24	51	79
	10	35	72	113
	12	42	87	136
Maximum Flow	15	52	108	170

Table 2

Note the numbers are a bit misleading and that they are different between the different types of flow sensors. The “Lowest flow” of the impeller type is with a +/- 5% accuracy whereas the “Minimum flow” for the paddle wheel is the minimum it can record. Our tests showed that for a paddle wheel flow sensor the “Minimum flows” indicated in the table were “best case scenarios” of the lowest flow the paddle wheel sensor could register. The impeller type flow sensors, on the other hand, were able to obtain readings well below the “lowest flow” amounts indicated in that table, and in many cases were able to obtain readings all the way down to very nearly 0 flow rates. Based on our test we recommend an impeller type flow sensor when drip systems are used. The paddle wheels often register no flow on a drip system even when there is flow.

Cost

A direct cost comparison is difficult to undertake between paddle wheel flow sensors and impeller flow sensors as the costs, components and specifications can vary widely across type of sensor and type of installation. Much depends on how one specifies and purchases the sensor system. For example, most impeller systems come with a register whereas the paddle wheel sensors do not.

Ease of installation

Some of the differences between types of sensors become particularly clear when it comes to installation. For example, paddle wheel flow sensors require lengths of straight pipe both upstream and downstream of the sensor to eliminate turbulence. This results in many paddle wheel type sensors being installed below grade. Alternatively, the impeller sensor does not have the "straight pipe" requirement and lends itself to installations such as shown in Figure 6, which incorporates an impeller sensor along with a valve and a bend in the pipe in close proximity.

Figure 6

Here the sensor and valve are installed after the back flow preventer. This particular installation is for a transit authority in California. For this user the accuracy of the flow signal was quite important and their choice of flow sensor and type of installation reflected this requirement.

User friendliness

Impeller sensors feature a register which displays the flow that has occurred or is occurring. This provides the user with real-time information that the flow sensor is operating properly, and also allows the local operator to record water usage. An operator can view the register panel which will indicate the level of flow that is occurring. Paddle type sensors operate differently and do not indicate when the paddle is rotating.

ETwater smart irrigation controllers are compatible with many paddle type and impeller type flow sensors. To address the "real-time visibility" issue with many paddle type sensors, all ETwater controllers include an indicator that demonstrates when the flow sensor is pulsing. ETwater controllers also have indicators for solenoid current which provide troubleshooting and diagnostic tools when installing and managing flow sensors of various types. When the user sees a pulsing LED on an ETwater controller, it indicates the sensor is sending flow pulses and the user is then informed that the flow sensor is connected and transmitting flow data.

The picture below, Figure 7 shows some of the LED indicators that ETwater has incorporated in our controllers. This particular unit is an ETwater SmartWorks 50-pin Rain

Bird replacement panel, designed to convert Rain Bird Maxi Com units to ETwater smart irrigation controllers and systems.

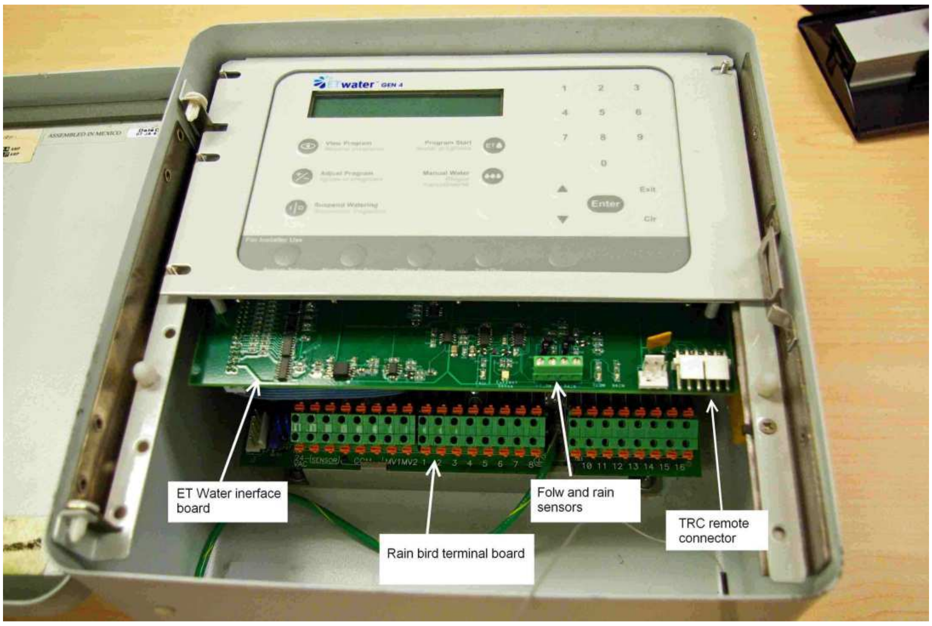


Figure 7

A close up of the LED is shown below in Figure 8

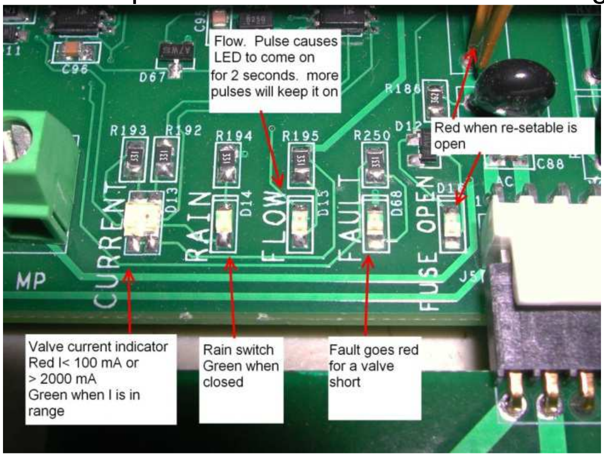


Figure 8

ETwater has recently introduced a flow sensor adapter for its HermitCrab line of retrofit products. The "flow sensor adapter" in the photo below, Figure 9 incorporates easy-to-see LEDs that confirm when the flow sensor is connected and transmitting flow data.

Figure 9

Wired or wireless connections

There has been a lot of industry discussion about and interest in wireless flow sensors. These are particularly attractive for retrofit situations which are already established; as such wireless sensors may alleviate the need to dig a trench for the sensor cable. Several companies are actively marketing wireless sensors. We are intrigued by the possibilities presented by wireless flow sensors, but in our experience their performance has been uneven so far. This may be technology whose time is coming, but has not yet arrived. Examples of issues that we have encountered or about which we have received reports include false readings caused by electrical interference such as from garage doors.

Other efforts to avoid new trenching include work by several companies to put the flow signal on the master valve solenoid control wires or in some sort of 2 wire form.

Sensor wiring

The electrical connections to the flow sensor are amongst the most sensitive on an irrigation controller. Most sensor manufacturers recommend shielded wire of around 18 gauge conductors. Here are a few recommendations based on our experiences with flow sensors:

- Do not use solenoid wires as the sensor wire. They will not be shielded or a twisted pair.

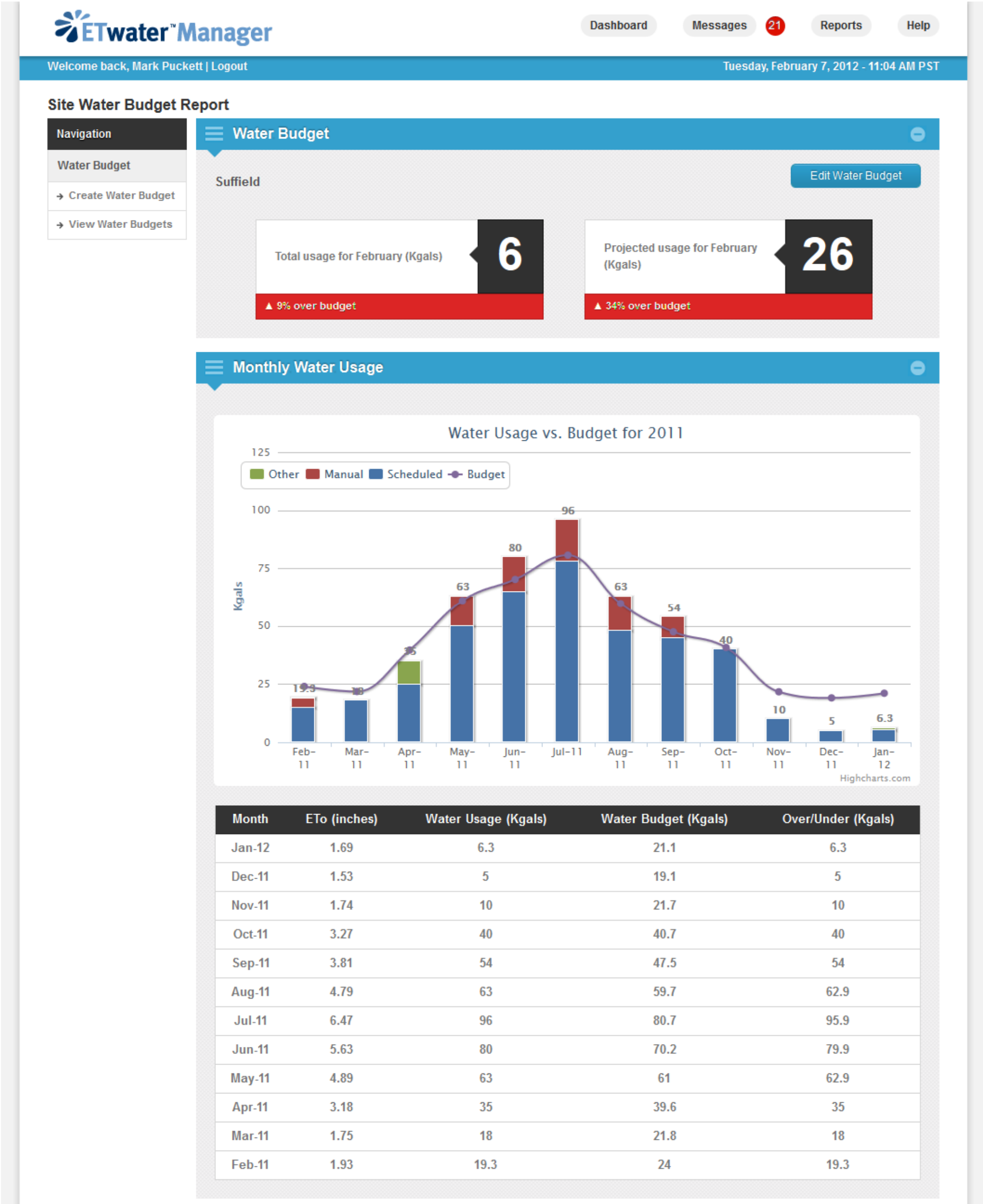
- Avoid running the sensor wires with solenoid wiring if possible. The solenoid wiring can inject noise into the sensor wiring.
- Keep the wiring connections dry. Wet connections will stop the sensor from operating properly.

What to do with the data?

Once the flow sensor data has been collected, it needs to be presented to users in a way that helps identify problems and manage water usage. There are many ways to present data and this topic alone could be the subject of an entire paper. But we will not go into such detail here.

At ETwater we have learned that many users want current flow data to help them manage water usage. To meet these needs ETwater has developed a number of online dashboards and presentation graphics that incorporate flow data, demonstrating historical and budgeted water consumption, along with current readings. ETwater also sends users e-mails in real time based on alerts that are generated by high and low flows.

A representative ETwater display regarding flow is shown in Figure 10 below:



Month	ETo (inches)	Water Usage (Kgals)	Water Budget (Kgals)	Over/Under (Kgals)
Jan-12	1.69	6.3	21.1	6.3
Dec-11	1.53	5	19.1	5
Nov-11	1.74	10	21.7	10
Oct-11	3.27	40	40.7	40
Sep-11	3.81	54	47.5	54
Aug-11	4.79	63	59.7	62.9
Jul-11	6.47	96	80.7	95.9
Jun-11	5.63	80	70.2	79.9
May-11	4.89	63	61	62.9
Apr-11	3.18	35	39.6	35
Mar-11	1.75	18	21.8	18
Feb-11	1.93	19.3	24	19.3

Figure 10

This screen shot shows the current water usage on site versus a water budget. The water budget is developed by the ETwater online tools based on the needs of the landscape, weather, irrigation system, and location.

The user can "drill" into these reports and obtain more detailed information, all the way down to the individual station level. These reports can be run for variable times such as the last 30 days or between dates specified by the user. Below, Figure 11 is part of such a report:

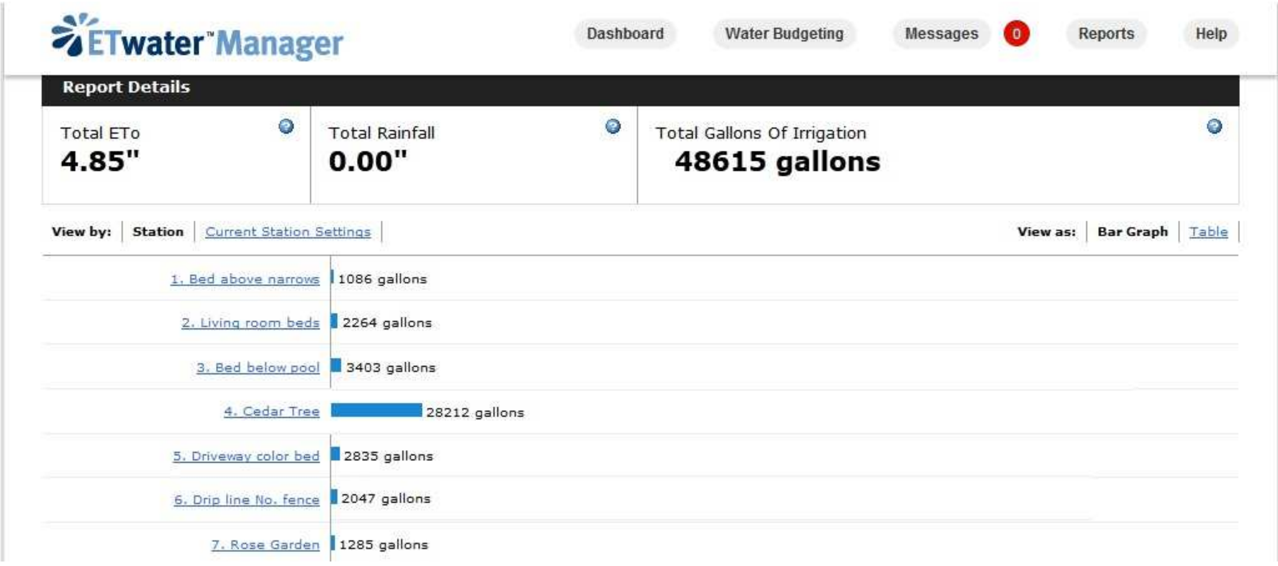


Figure 11

ET Water also provides alert reports showing stations which have generated High or Low Flow alerts. These alerts can be viewed online and are also automatically sent to an email account. Figure 12 is an example email of a high flow alert:

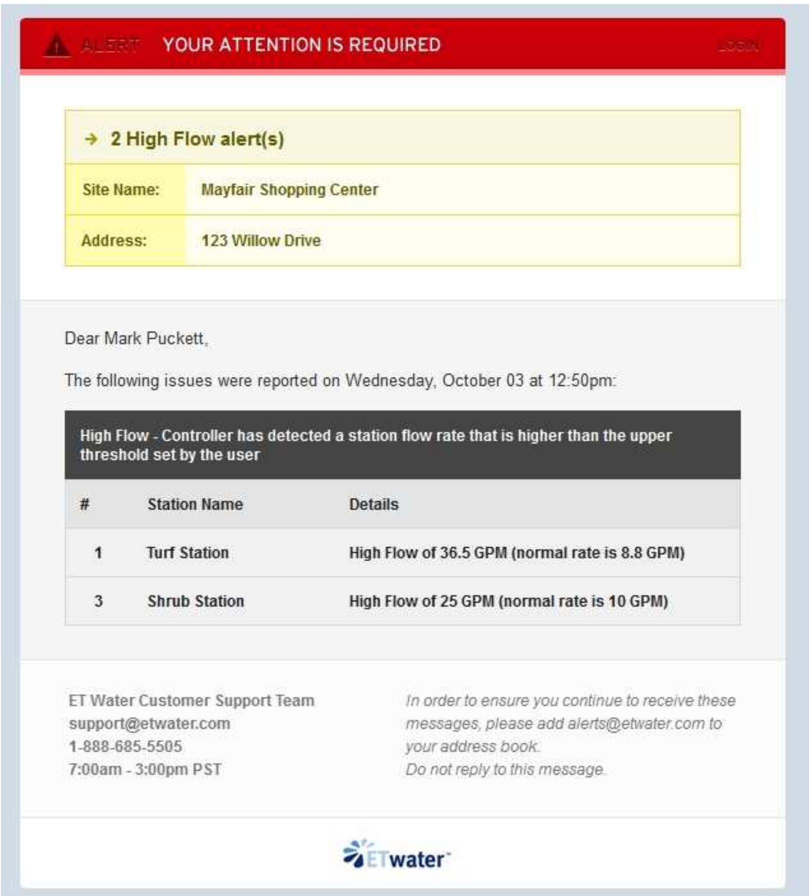


Figure 12

Conclusion

With the push for a reduction in water consumption, along with the costs of water and delivery rising, ETwater is seeing increased demand for flow measurement and the incorporation of flow measurement in managing overall landscape irrigation solutions. Most users of ETwater Smart Irrigation solutionshave installed ETwater systems to save water among other benefits. With that as a backdrop it is natural that many users wish to incorporate flow monitoring to provide greater visibility into system operation and efficiency and greater control and automation in the event of a line break or other system malfunction. The technologies are highly complementary.

In this paper we have identified many of the different technologies that are used for sensing flow. We have discussed the pros and cons of the different leading technologies. And we have demonstrated that flow sensing and smart irrigation solutions can be effectively integrated, as we at ETwater do with all of our solutions now that HermitCrab has been updated to accept flow data.

Flow sensing can help a great deal with the management of the irrigation system and obviously is key to the measurement of water usage. Many flow systems and technologies are relatively new and best practices regarding usage and system integration are not well understood and, in many cases, are still in development. We at ETwater pride ourselves in being able to help and guide our customers in this new area of flow sensing.

Acknowledgements

We would like to acknowledge the following.

Mr. BillBolton in Marin CA for letting us test flow on his site and helping us with copious amounts of data about flow collected over several years.

Manufacturers, Bermad and Netafimand CST for providing samples for us to use in tests.

2Core for providing their latest technology for testing.

References

Internet

Types of flow sensors

http://en.wikipedia.org/wiki/Flow_measurement