

# **THE FLORIDA SUGAR INDUSTRY - TECHNOLOGIES AND TRENDS**

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## **ABSTRACT**

The Florida Sugar Industry has consistently been improving the operation and efficiency of several sugar mills. The trends in operation and efficiency are discussed followed by a survey of technologies and applications that cumulatively have contributed to these improvements in operation. No attempt is made to formulate cause and effect of the technologies, but general comments are made on the experience of some of the technologies and the possible trends that these technologies may lead the industry to, in the future. The technologies covered are in the areas of milling, processing and the power plant, as well as the technologies applied in quality control.

## **INTRODUCTION**

The process of extracting sugar from sugarcane and crystallizing it has not changed significantly over several hundred years. The basic unit operations of pH control, heating, clarification, evaporation and crystallization still comprise the basic process. The technology of the extraction process changed when the cane diffuser was developed, but the conventional mills are still needed to dewater the bagasse leaving the diffuser. Although the basic process is the same, every sugar mill in the world differs, primarily by two factors: the incorporation of new ideas into the design of the unit operations, and the implementation of new technologies. The Florida Sugar Industry is no exception to this trend.

In the early 1990's, the Florida sugar industry had begun to implement new technologies by following the example of the Brazilian, Australian and South African sugar industries. These include shredders, fourth roll mills, hard surfacing of mill rolls, rotary juice screens, Donnelly chutes, and chokeless pumps. Throughout the 1990's, the implementation of new technologies continued which resulted in the trend illustrated in Figure 1: an improvement in the processing rate. This graph shows that for several of Florida sugar mills, collectively, the processing rate on an hourly basis improved by approximately 20 %. Concurrently, the overall recovery for sucrose for the same mills, also increased by approximately 8 %. This is illustrated in Figure 2. Although we cannot credit any one technology with these improvements, we believe that collectively, new technologies implemented over the decade of the nineties are the basis for these improvements.

The scope of this paper is not to discuss every technology in detail, but rather to highlight the technologies that have had an impact in the extraction of sucrose, in the fabrication of sugar, and in quality control and information technology.

### **Cane harvesting and transport**

The end of harvesting cane by the hand-cut method came to an end in 1992. The Florida Sugar Industry had anticipated that the hand-cut method of harvesting was coming to an end so that by 1992, a significant percentage of the sugarcane was being harvested with mechanical harvesters. The transition was planned and executed over several years. The transition from hand-cut cane to mechanical harvesting forced the industry to change its habits of harvesting sugarcane. This new technology created problems, but it also created flexibility that was not available with the previous method. This flexibility was translated into several advantages: the time it took to burn and harvest the fields could be reduced as the time of burning could now be scheduled closer to the time of harvesting, reducing the overall burn to crush time. Another advantage became evident as the time of harvesting could be extended into the night time hours. These two factors resulted in improving the efficiency of cane delivery.

Other changes include the self-dumping wagon, the use of global positioning system to guide and direct the cane hauling tractors and the use of radio frequency transmitters to track and identify transportation equipment.

### **Extraction of sucrose**

In the late 1980's, the most important technological change in the milling tandems was the introduction of the Donnelly chute and the fourth roll. Although not all the sugar mills in Florida have fully converted the milling tandems to this technology, the transition will eventually take place. The advantages of this technology were well proven in other sugar mills around the world before Florida adopted the technology. The combination of the Donnelly chute providing positive feed to the fourth-roll and the top roll increases the grinding rate with a corresponding improvement in extraction. The experience at Sugar Cane Growers Cooperative, where one of the two milling tandems has been fully converted to the Donnelly system, shows that the converted tandem is able to grind 30 % more cane, and the extraction is better by more than one percentage point. The experience at other Florida mills has been similar. The low fiber of the Florida cane varieties does not justify the heavy-duty shredders usually found in other mills where the fiber percent cane is much higher. Florida has been able to improve cane preparation by the use of swing-back knives. These sets of knives combine the principal of the shredder without the high power consumption of heavy-duty shredders. At Sugar Cane Growers Cooperative, the preparation index with swing-back knives has consistently tested in the low to mid 80's. The better preparation has had a positive effect on the milling operation.

Other technologies that are gaining acceptance are the use of chokeless pump for mill maceration and rotary screens to screen the bagacillo from the juice. The use of duplex stainless steels on the maceration and juice pumps provides corrosion and erosion resistance so that the rubber lining which was customary in these applications is no longer needed. The use of other new technology materials is being used in places where corrosion has been a problem. The high chrome steel referred to as 3CR12 is finding its way into conveyors, chutes, covers, and could

eventually begin to replace piping around the milling tandems where corrosion and erosion continue to be a problem.

Computerized control systems are being used to monitor and control the milling operation. We expect this system to continue to become more sophisticated and become more integrated with the rest of the factory.

In the future, hydraulic mill drives, currently in use in several countries, may find use in Florida as a way to increase mill horsepower without replacing the entire motive force by leaving the original mill drive and installing the hydraulic drive directly on one of the mill rolls.

### **Fabrication**

The processing of sucrose into crystallized sugar also has been improved by the introduction of new technologies. This is evident by the fact that over the decade of the 1990's, the overall recovery for several Florida sugar mills has been improving, as shown in Figure 2. The trend is going to flatten out, since we believe that the overall recovery with current process technology has an upper limit of 90 percent. To achieve overall recoveries above this limit, the losses in final molasses need to be reduced to levels below six percent. To achieve this goal, new technologies would be needed, as we believe that losses in final molasses in some of the Florida sugar mills are at the lowest level they can be with current technologies. However, some research and development on new technologies conducted at Sugar Cane Growers Cooperative may hold promise for this endeavor.

The fabrication of sugar begins with the addition of lime to raise the pH of the juice. Most Florida mills do cold liming, which is followed by heating the juice to 220°F. Two new types of heaters have found their way into this process. Spiral heaters are being used to heat the juice by cooling condensate. Plate heaters are being use in the heating of limed juice using vapor 3 from the second vessel of the triple-effect evaporator.

The clarification process is being studied using computational fluid analyses in other countries to find better ways to improve existing clarifiers. Florida is currently analyzing improvements to existing clarifiers by implementing some of the findings. Computer controls have been implemented at Sugar Cane Growers Cooperative to control mud levels using variable frequency drive to control speed of mud pumps.

Vacuum rotary filters have been the technology of choice to recover sucrose from the clarifier mud. With the coming of mechanical harvesting, several mills had to improve their mud filtering capacity by adding more filters. Sugar Cane Growers Cooperative recently installed a new large mud filter with a total filtering area of 1,750 sq. ft. This is consistent with another trend that is beginning to take place: adding large capacity equipment to reduce installation, maintenance, and labor costs.

The Robert evaporators are the predominant technology used in most Florida mills. Falling film evaporators have been tried but with limited success. However, two new types of evaporators have been tried in other countries, as well as in Louisiana. The falling-film plate evaporator has been implemented successfully in Guatemala, Mexico, and the plate evaporator has been also successfully used in Louisiana. Most of the Florida mills have applied computer control systems to existing effects. The automation has claimed little if any gains in capacity but has had some reduction in labor costs. In the case of the Sugar Cane Growers Cooperative, bleeding vapors to heat limed juice has moderately improved the evaporation capacity of its triple effects. We believe that the plate evaporator and the falling-film plate evaporator will eventually find applications in the Florida sugar industry.

Sugar Cane Growers Cooperative has fully automated the vacuum pan station. The automation has increased the throughput of the pans and labor costs have been reduced. Other mills have automated this station with similar results. Most of the mills have gone to the double magma system. To improve the recovery of "C" massecuite, the retention time has been increased by the addition of vertical crystallizers and by conventional crystallizers installed in a tower configuration.

Large capacity batch centrifugals have been installed to replace smaller batch centrifugals. Most mills have continuous centrifugals installed in "B" or in "C" sugar. Sugar Cane Growers Cooperative, in 1996, changed its process to the double magma system and installed large capacity centrifugals in its "B" station and more recently converted all "C" continuous centrifugals to center feed design. The center feed design in conjunction with an improvement to the massecuite feeding system improved the capacity of the "C" station. The trend in centrifugals is large capacity machines with automatic controls.

### **Power production**

The strict emissions required by EPA to install new steam generators has discouraged some Florida mills from installing additional steam generating capacity. One steam boiler that was installed to burn bagasse in the second half of the 90's had to be installed with electrostatic precipitators to meet environmental emission standards.

This additional cost to control particulate emissions and other emissions requirements has encouraged some mills to become more energy efficient. The strategy at Sugar Cane Growers Cooperative to balance the production of high-pressure steam and low-pressure steam was to install a 12 MW condensing turbo-generator set. The turbo-generator has been programmed to switch loads with other non-condensing turbo-generators units to balance the low-pressure steam requirements. This makes feasible improving the usage of vapor 2 and vapor 3 to reduce exhaust steam demand. The results are reflected in a reduction of the steam consumption on a per unit basis.

In the electrical power plant, a power management system is being implemented to improve power distribution and management. The controls for the electrical power plant and the

## Johnson: The Florida Sugar Industry – Technologies and Trends

steam boilers have been upgraded to replace obsolete controls and to improve the control with an automated system.

### **FUTURE:**

The recent acquisition of Tate & Lyle of North America by the Florida Crystal Group and Sugar Cane Growers Cooperative of Florida made the Florida industry a fully vertically integrated industry. The vertical integration may change the implementation of new technologies at the sugar mill level.

We see the following trends for Florida:

In the extraction of sucrose, we foresee improved cane preparation without paying a big price in energy consumption.

In fabrication, we will see more applications of plate heaters for limed juice and clarified juice, the replacement of old Robert evaporators by falling film evaporators and plate evaporators to gain evaporation efficiency, the use of continuous vacuum pans to improve grain size, steam balance and reduce final molasses losses.

In the factory as a whole, the trend is the application of new materials to reduce maintenance costs, the integration of automated systems and the creation of computer supervisory controls to improve production and reduce energy requirements.

For the long range, juice softening technology which was partially developed at Sugar Cane Growers Cooperative could provide several advantages: eliminating chemical cleaning of the evaporators, a reduction in the ash content of the raw sugar, and an improvement in sugar recovery. Another technology that was researched at the Cooperative was the ultra-filtration of clarified juice. This technology may also play a role in the future as part of the softening system or to achieve other improvements in the process.

### **QUALITY CONTROL AND INFORMATION TECHNOLOGY:**

The goals of factory quality control include:

- a) To increase efficiency and productivity while reducing process losses and costs,
- b) To provide accurate and precise feedback in reporting, analyses and measurements, and
- c) To apply the principles of green chemistry.

With the revolution in electronic technology, we have seen the development over the years of more sophisticated instrumentation. Due to increased productivity throughout the industry, advances in automation and instrumentation have become a trend. These trends and technologies include:

**Green Chemistry**

**Near Infra Red Technology**

**Addition of Enzymes, and Biocide**

**On-line Nephelometers**

**Fluorescence Technology**

**Radio Frequency Probes**

## **Global Positioning System Geographical Information Systems**

In order to comply with the EPA's **Green Chemistry** mission ([www.epa.gov](http://www.epa.gov)) that develops and promotes chemical technologies that reduce or eliminate the use or generation of hazardous substances and chemical products, and to help achieve the goals stated above, the Florida Sugar Industry has adopted new technologies that eliminate the use of chemicals or hazardous materials to monitor and control factory processes.

**Near Infra Red (NIR) Technology** can be seen operating in different areas of sugar and cane juice analysis in the Florida mills. It was first used for on-line determination of moisture in bagasse in the reflectance mode. Reflectance NIR has also been applied on-line to determine moisture in raw sugar. This has been evolving to include on-line raw sugar pol and color measurements. With the superior results obtained with trials performed on cane juice in the transmittance mode, NIR technology has been used for several crop seasons for the analysis of incoming cane juice for grower payment (Johnson 2000). For the 2001-2002 crop season, one of the Florida mills has implemented an on-line NIR system for cane quality determination. For this application of cane juice analysis, an on-line fine screening system is necessary to remove bagacillo particles from the sample. NIR is proving to be a low maintenance, non-invasive, rapid, accurate and reliable method of analysis, which eliminates the use of chemicals for clarification.

For the future, the Cane Analysis System currently operating in Australian mills will be implemented here in Florida. This reflectance NIR system will perform on-line analysis of the prepared cane for the growers' individual consignments for parameters such as pol, Brix, fiber, ash, invert, preparation index, trash, and phosphate. With the amount of information collected from this on-line NIR instrument, the opportunity exists to re-evaluate, and improve the system of payment for Florida farmers.

**Enzyme** addition as cooling tower water treatment controls foam and reduces evaporator scaling. Enzymes are biodegradable liquid concentrates of vegetable origin produced by bacteria that work to break down solids. The result of the enzyme addition is cleaner surfaces of the louvres and drift eliminators in the cooling tower. They also help prevent corrosion by regulating pH and lowering dissolved solids and conductivity.

**Biocide** addition to the milling tandems has been improved by simple modification of the dosing system. Studies at SCGC have shown that the use of FDA approved biocides decreases bacterial decomposition of sucrose in juice, increasing sugar recovery. Some Florida mills have modified their dosing systems to increase efficiency and to reduce costs by purchasing the bactericide in bulk, and have designed a more sophisticated pumping system for more accurate and reliable dosing.

Turbidity in clarified juice is currently monitored for clarification quality. For the future, **on-line nephelometers** for automated control of juice clarification will include monitoring of

individual clarifier compartments to improve overall juice quality. The results will be incorporated in the computerized Process Control Network to generate 24-hour performance graphs to evaluate trends, and to automate and control the clarifier mud pumps.

**Duotrac Radio Frequency Probes** are used to monitor and control Brix in massecuites, mother liquor and syrups. They can be used in either continuous or batch vacuum pans. The Duotrac radio frequency probe provides two 4-20 milliamp output signals. One is series resistance, which correlates to massecuite Brix, while the other is series capacitance, which correlates to the mother liquor Brix. For improved control of continuous pans, crystal content can be derived by the linear combination of the two signals in a predetermined ratio (Radford and Cox 1986). The radio frequency probes are found to be less susceptible to encrustation. They are low maintenance and easy to clean while providing accurate and reliable Brix control.

**Fluorescence Technology** can be found in the boiler laboratories detecting sucrose in boiler feedwater. Reclaimed condensate returned to the boilers as makeup water can contain small quantities of sugar from evaporator carryover. In the past, this was monitored by either grab samples and alpha-naphthol testing, or online analysis using a sodium analyzer. Frequently the caustic cleaning would result in false alarms with the sodium analyzer, while grab samples did not tell the entire story. The on-line detection system using fluorescence technology optimizes accuracy and timely analyses without the frequent false alarms, and can be calibrated to detect low levels of sugar in the feedwater (Herrera 2001). Figure 3 shows a typical makeup water graph.

Using the fluorescence detection system, condensate is typically analyzed before delivering the water to the boilers. The water is held in pre-storage tanks, and depending on the results of the analysis, the water will be either sent to the boilers, or diverted to the recovery system for reprocessing. Since sugar itself does not have fluorescent properties, the analyzer detects the non-sugar components in the juice. This system has resulted in better quality feedwater to the boilers. Automation of the delivery valves is planned for the future.

**Global Positioning System (GPS)** is a multibillion-dollar U.S Department of Defense Project that includes a network of 24 satellites orbiting the earth continuously broadcasting position information. This information is gathered by GPS receivers designed to determine an exact location anywhere on earth using latitude, longitude, and altitude.

Automatic Vehicle Locator (AVL) incorporates GPS technology along with network communications, vehicle management software, and real time map display software to provide vehicle tracking. GPS/AVL can detect the speed, the direction, the odometer reading, if the ignition and lights are on, and the exact location of a vehicle. This tracking system has greatly enhanced truck distribution to harvested fields. It has improved delivery efficiency 13 % by guiding and directing the cane hauling trucks to avoid gaps at the harvesting units.

**Geographical Information System (GIS)** is a visual reporting tool made up of software and hardware that can be used to network and share data among departments, growers, or even

among companies. A field map is generated by tracing features from Digital Ortho Quarter Quadrangles by the US Geological Service.

GIS is used for locating varieties by field, crop age, number of rows in a given field, number of acres, yield data, and other attributes defined in a relational database. After the data is collected for each field, it is displayed as a map. Instead of assessments being made from text-based reports, decisions can be made after visualizing the entire picture of events and collective data for each field. For example, temperature-logging stations are located and monitored throughout the industry. GIS affords us the ability to exchange data with other mills to determine freeze-affected areas, along with temperatures and duration of freeze. Figure 4 shows an example of a GIS map showing duration of low temperatures during a freeze event. For the future, GIS will be used to determine field acreage using only the four corners of a field. It can also be used for variable rate application technology for precision agriculture.

### CONCLUSIONS

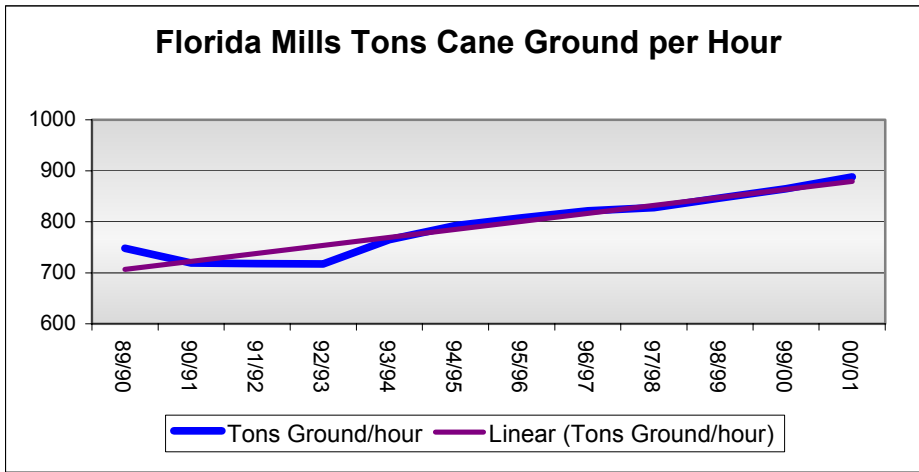
Although the process of milling cane to produce raw sugar has not changed considerably over the past several hundred years, advances in the last decade can only reveal a sliver of the rapidly developing innovations that will be available in the future. Advances in automation and instrumentation will likely continue for factory quality control. This will include an increase in on-line measurement and control of factory processes, along with networking information databases.

### ACKNOWLEDGEMENTS

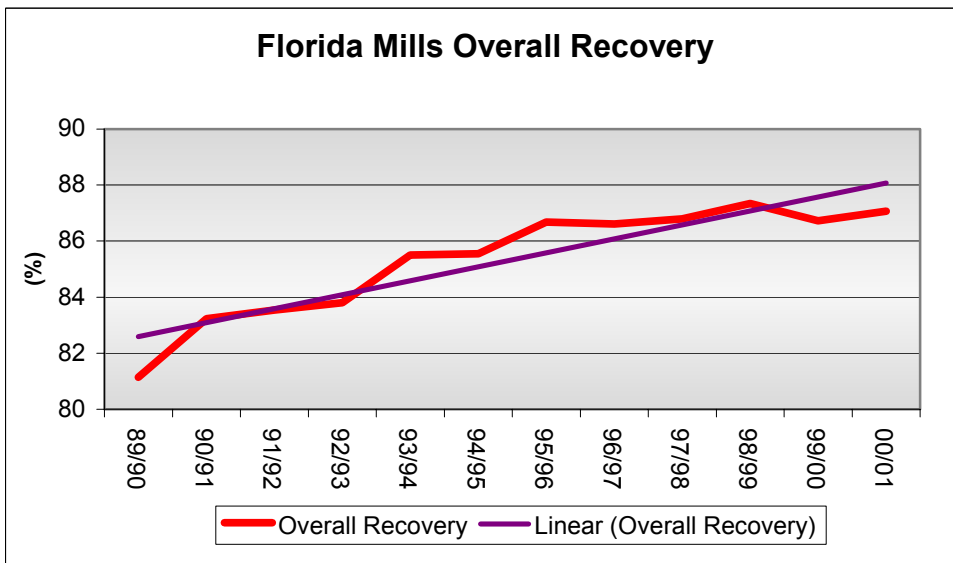
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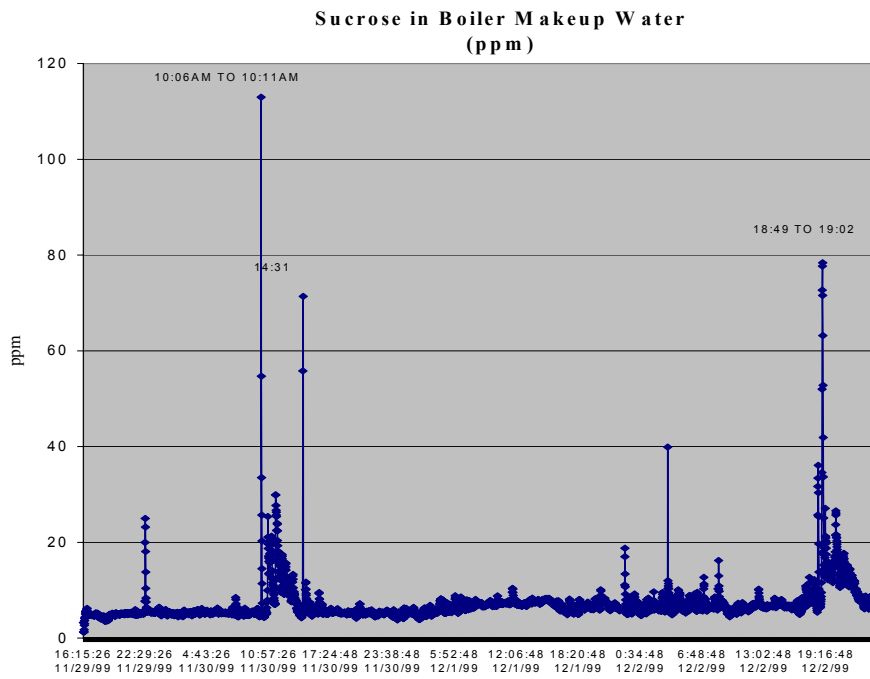
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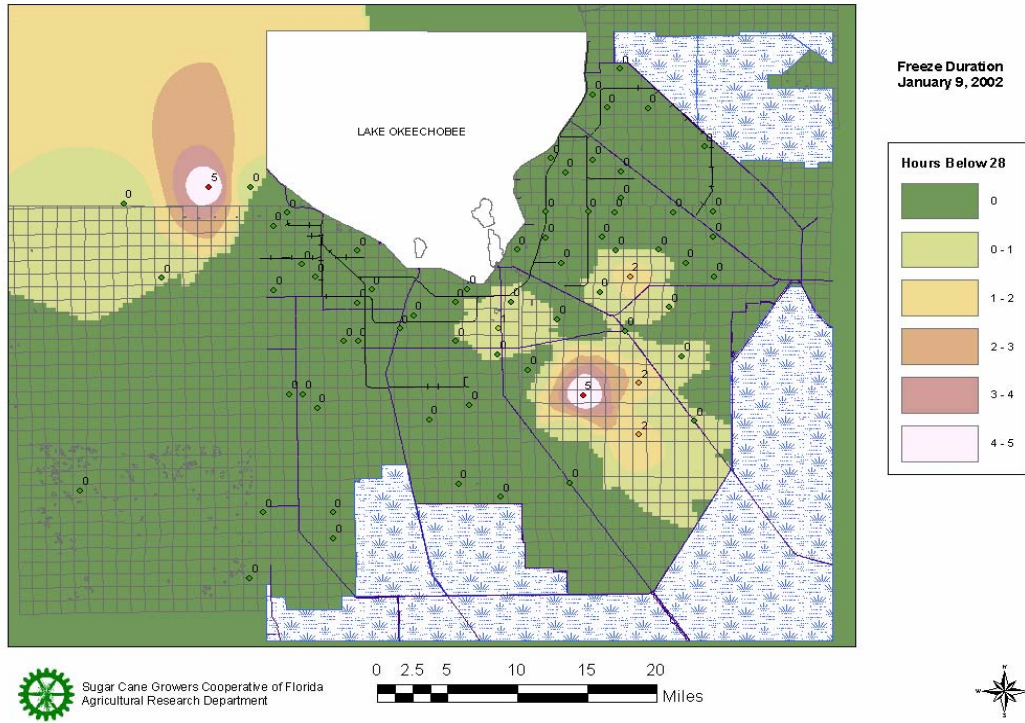
**Figure 1.** Florida mills tons cane ground per hour showing a 20 % improvement over twelve seasons.



**Figure 2.** Florida mills overall recovery showing an 8 % increase over twelve seasons.



**Figure 3.** Graph of boiler makeup water using fluorescence technology on-line detection system.



**Figure 4.** Geographical Information System map showing duration of low temperatures during a freeze event.