

INTERACTION OF ADVANCED SCIENTIFIC IRRIGATION MANAGEMENT (ASIM) WITH I-SCADA SYSTEM FOR EFFICIENT AND SUSTAINABLE PRODUCTION OF FIBER ON 10,360 HECTARES

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ABSTRACT

Efficient drip irrigation of 10,000,000 fast-growing Pacific Albus trees in the water-challenged environment of Easter Oregon, US; requires not only a massive and complex computerized water distribution system but also an efficient and economical methodology to manage and deliver the water to the trees. The Greenwood Resources Boardman Tree Farm (GWR BTF) achieves this by interacting its Advanced Scientific Irrigation Management (ASIM) program with its state-of-art Irrigation Supervisory Control and Data Acquisition (I-SCADA) system to achieve high irrigation and economical efficiencies. Also within this ASIM / I-SCADA system combination is an elaborate automated soil moisture sensing operation and an original and innovative methodology incorporating a customized Advance Hydraulic Balanced Irrigation Scheduling (AHBIS) program, which enables smooth and steady hydraulic operation of 101 pumps at 23 major pump stations. Additionally, the BTF I-SCADA system operates pivot irrigation on 1,930 hectares (4,770 ac) of very high-value agriculture crops, including organic crops.

Boardman Tree Farm offers a show-case example where the latest technology and human ingenuity are utilized to drip irrigate vast areas of land, while at the same time minimizing the use of scarce water and energy resources and maintaining a sustainable and economical rate of fiber production for use in BioEnergy, Paper and Solid Wood production.

INTRODUCTION

In the semi-arid part of Easter Oregon, US, where less than 20 cm (8 in) of total annual precipitation occurs, exists the world's largest contiguous drip irrigated farm of 10,360 hectares (25,600 ac), managed by Greenwood Resources (GWR), and known as the Boardman Tree Farm (BTF) (Figure 1).

At BTF, 10,000,000 fast-growing Pacific Albus trees are irrigated by a massive and complex computerized water distribution system. Cost of pumping water is a major crop production cost, so a very aggressive and determined effort is made to operate the irrigation system efficiently and cost effectively. To achieve high irrigation efficiencies BTF uses Advanced Scientific Irrigation Management (ASIM) program, automated soil moisture sensing and one of the most advanced and sophisticated Irrigation Supervisory Control and Data Acquisition (I-SCADA) systems in the world. Additionally BTF

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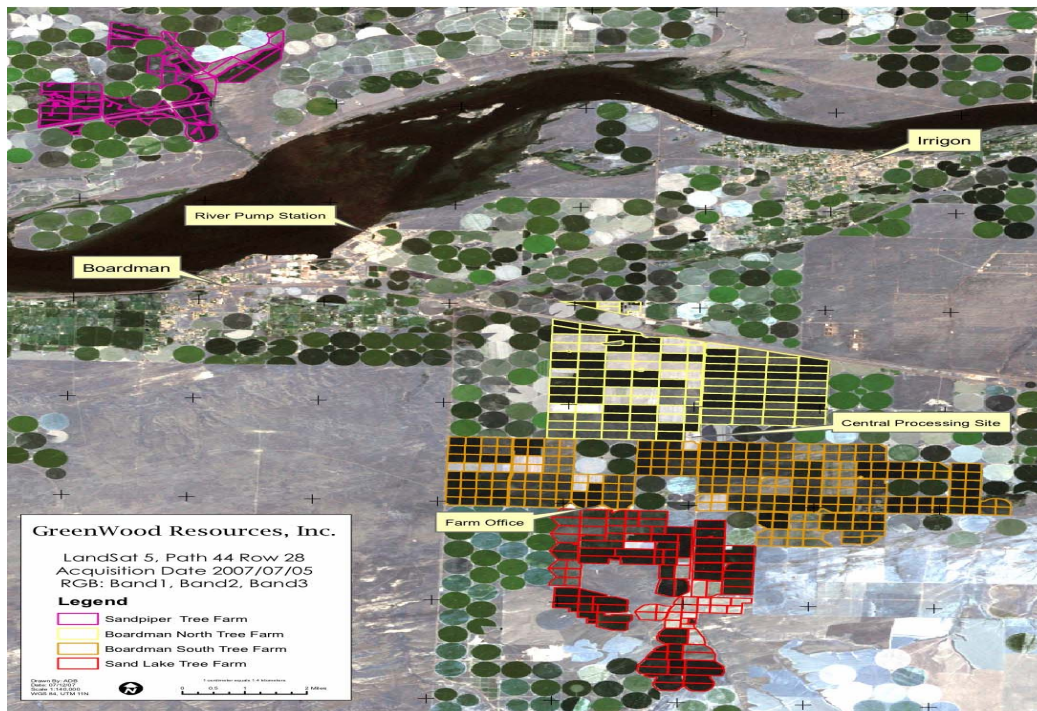


Figure 1. Satellite image of Boardman Tree Farm (BTF) in Eastern Oregon showing both the drip and pivot irrigated lands. Included also is the GreenWood Resources Sand Piper Tree farm located in Washington state and north of Boardman.

utilizes original and innovative methodology incorporating customized Advance Hydraulic Balanced Irrigation Scheduling (AHBIS) program, to create individual block irrigation schedule regimes. These irrigation schedule regimes provide precise irrigation together with a smooth and steady pump stations hydraulic operation.

One of the success stories of BTF's excellent water management practices is the demonstrated ability to irrigate with such accuracy (± 1 minute) and precision that the central 60 cm (2 ft) wide soil strip between the three meter (10 ft) wide tree rows always remains dry. This level of water application efficiency is unparalleled on such a grand scale anywhere else in the world!

The BTF overall tree management strategy emphasizes the use of the most efficient water delivery methods via drip irrigation and automation. Together with the use of the highest quality tree clonal material and the continuous monitoring of crop vigor and health, BTF aims to become the lowest cost producer of high quality sustainable wood fiber products. The Pacific Albus trees at BTF are grown on an eleven to fourteen-year rotation. For disease control and other reasons, multiple clones of Pacific Albus trees are used to add genetic diversity. Each clone has its own characteristic needs for water and fertilizer and unique production quality and quantity. Pacific Albus trees are known to grow more than five centimeters (2 in) a day during peak growth and have growth rings more than three and a half centimeters wide (1.5 in). The trees are harvested at an average sustainable rate of one tree every 16 seconds. For BioEnergy fiber production the trees are harvested

every two years, for paper chip production the trees are grown for six to seven years and for solid wood the trees are harvested at twelve to fourteen years of age. It is a dynamic harvest plan which adjusts to market needs in order to maximize economical returns and production efficiencies at the Saw Mill located within BTF.

PROJECT FACTS

Boardman Tree Farm (BTF)

The BTF consists of two main units - North/South Boardman Tree Farm and the Sand Lake Tree Farm. In the North/South BTF, 7,500,000 fast-growing Pacific Albus trees are irrigated by a massive and very technically complex automated water distribution system. The large tree acreage is operationally divided into 369 individual irrigated blocks, each ranging in size from 16 to 28 ha (40 to 70 ac), which are fed by 13 different pumping stations from two independent farm water supply distributions; which also supplies water to other various crops on 1,930 ha (4,770 ac) under pivot irrigation. The extensive irrigation pipe network consists of 805 km (500 ml) of buried pipe 4 to 183 cm (1.5 to 72 in) in diameter and 23,100 km (14,330 ml) of drip tube with nearly 20,000,000 emitters. The 13 pumping stations have 70 irrigation pumps with a total of 22,640 kW (30,350 HP), producing peak flow capacities of 689,000 lpm (182,000 gpm) and a capacity to produce 992,000,000 lpd (262,000,000 gpd). Single pump capacities range from 1,900 lpm to 121,000 lpm (500 to 32,000 gpm) with pump motors ranging in size from 22 to 746 kW (30 to 1,000 HP).

North/South Tree Farm together with the Sand Lake Tree Farm, collectively form the BTF and cover 104 square km (40 sq ml) planted with 10,000,000 Pacific Albus trees on 10,360 ha (25,600 ac). Additionally there are a combined total of 2,225 ha (5,500 ac) of various high value crops including organic crops under pivot irrigation but on a non-GWR ownership. Both the trees and the pivot crops are irrigated by 23 major pump stations through 101 pumps. BTF peak pumping capability of 28,420 kW (38,100 HP) can deliver in excess of 852,000 lpm (225,000 gpm) with a capacity to produce 1,226,000,000 lpd (324,000 gpd). This very large volume of water is feed via nearly 27,000,000 emitters to the trees through an astounding 30,622 km (19,028 ml) of drip line, which is about $\frac{3}{4}$ the circumference of the earth. The 250 sand media filters in the irrigation system gives BTF the largest concentration of operational sand media filters in the world (Figure 2). Even though it is one of the largest rural water distribution systems in the state of Oregon, GreenWood Resources Drip irrigation System (GWRDIS) has the capacity to pump enough water per day to serve three cities the size of Portland, the largest city in the state of Oregon. The BTF with its present size of 10,360 ha (25,600 ac) is the world's largest irrigated fiber farm and the North/South BTF is one of the largest contiguous drip irrigated farms in the world. BTF is also a world leader in large-scale drip irrigation efficiency.



Figure 2. BTF I-SCADA Remote Terminal Unit (RTU) with sand media secondary filters.

Irrigation Supervisory Control and Data Acquisition (I-SCADA) System

BTF irrigation practices cover a huge area and are very complex and demanding, thereby requiring a very sophisticated control and monitoring system. BTF state-of-art I-SCADA system controls and monitors 250 pumps, 369 irrigation blocks, 1254 automated valves and 46 center pivots. BTF's I-SCADA system consists of two master processors and a single computer installed with Human Machine Interface (HMI) software, all interacting together with the 153 Remote Terminal Units (RTU) (Figure 2). All communications to the RTU's is done by Spread Spectrum radio telemetry on two totally independent licensed radio frequencies. This I-SCADA system is designed to remotely control valve(s) or pump(s) within a radius of 24 km (15 ml) from the Operator Interface Terminal (OIT) at the office. All I-SCADA system remote field actions occur within two seconds of operator command, with full control acknowledgement within 5 seconds of command initialization from the OIT. Irrigation system operations can be remotely, or manually, programmed and stored at multiple locations on the I-SCADA system such as the OIT, master processors and the RTU's. I-SCADA system real time data is stored on a sequential database. Some data is stored every minute, and is then plotted for trends and also analyzed to improve BTF irrigation performance and methodologies.

IRRIGATION

Survival of Pacific Albus trees at BTF is largely dependent on irrigation water. In the semiarid environment during peak evapotranspiration rates, the project's irrigation system cannot adequately provide the trees high daily water consumption. Additionally for some tree clones the timing of irrigation is also important, therefore requiring random daily irrigation start times. Growing trees under these conditions and in sandy soils is a challenge in itself, further compounded with the fact that any cessation of irrigation for

more than 15 hours causes a detrimental reduction in yield or even death of trees! Therefore reliability of the BTF irrigation system is very crucial.

BTF's pumping energy cost of nearly \$4,000,000 for an irrigation season of less than eight months is a major operational cost for tree production; so achieving a high pumping efficiency is crucial task of the BTF I-SCADA system.

With all these tough environmental and tree demands, has forced BTF to implement very sophisticated and reliable water management practices. With 369 individual blocks, that cycle irrigation as much as four times a day, irrigation scheduling is also a hydraulic nightmare.

There are basically two major irrigation challenges facing the BTF:

1) Water deliverance from the source to the trees.

Every irrigation project has its challenges and the challenges faced by BTF, especially in water deliverance are not unique except for its very large scale of operation. BTF met these challenges by spending adequate resources to ensure the delivery of water is not an issue in tree production. Senior water rights, upgrading/changing of existing water deliverance facilities by using the latest and appropriate technology with "good" engineering were the keys. Once the deliverance system was installed, a state-of-art I-SCADA system was installed to control and monitor the whole BTF irrigation system. This I-SCADA system provided the ability to "spoon feed" the trees with specific amounts of water and fertilizer.

2) Water management and irrigation scheduling.

In the areas of water management and irrigation scheduling, BTF faces challenges that are huge, ongoing and very complex that require unique solutions involving collectively the I-SCADA system and the use of multiple customized and in-house software. Additionally these challenges are made even more demanding as they affect the whole economics of the BTF operation.

The I-SCADA system tackles these daunting challenges of water management and irrigation scheduling by interacting together with sophisticated and customized Advanced Hydraulic Balanced Irrigation Scheduling (AHBIS) software. This AHBIS program generates an I-SCADA operational code file with nearly 12,000 individual block irrigation schedules with random daily irrigation start times and hydraulically balanced. The I-SCADA / AHBIS program interaction allows BTF to micromanage irrigation scheduling at the individual 16 to 28 ha (40 to 70 ac) block level.

Hydraulic Balanced Irrigation Scheduling (HBIS) is an original and innovative methodology of creating individual block schedule regimes that leads to a smooth and steady pump station hydraulic operation. This methodology is incorporated into a customized highly sophisticated Advance Hydraulic Balanced Irrigation Scheduling (AHBIS) program that optimizes irrigation schedule regimes, such that no pump changes

are necessary during a period of a particular irrigation schedule regime. This also leads to steady canal withdrawal rates at the pump stations thereby assisting the irrigation district to have an efficient canal operation. It also allows the operation of a very large complex irrigation system without the use of expensive and very complex pump automation programs. The AHBIS methodology improves pumping energy efficiency with tangible pump energy savings, decreases irrigation system wear and greatly improves human resource allocations. This “smooth” operation of the irrigation system is “easy” on the irrigation hardware of the system and lessens the work load of the irrigation team members as their interaction with the I-SCADA system is normally only limited to reacting to its remote pager alarm message(s). This hydraulically smooth operation is what enables the I-SCADA system to become a “stand alone” system.

ADVANCED SCIENTIFIC IRRIGATION MANAGEMENT (ASIM) PROGRAM

1. The BTF water management goal, for economical and environmental reasons, is to ensure that the water pumped by the irrigation system is the right amount for the trees – “no more no less”.
2. The goal of applying only the absolute minimal amount of water that the trees need, lead to the development in-house of sophisticated and comprehensive Advanced Scientific Irrigation Management (ASIM) program. This ASIM program is operated on weekly basis throughout the irrigation season.
3. The weekly ASIM program starts from weather data collected from the local AgriMet station(s) (Figure 3). AgriMet stations are a satellite-based network of nearly 75 automated agricultural weather stations located mainly in the Pacific Northwest and are operated and maintained by the Bureau of Reclamation. The AgriMet weather data is analyzed together with weather forecasts from three independent sources, including a customized weather forecast provider. Further computation and analysis with a 22 year historical local weather database, leads to a prediction of Evapotranspiration (ET) and Growing Degree-day (TG) rates for the coming 10 days. The ET and TG information is then input into in-house Pacific Albus crop models, which result in an accurate and repeatable scientific approach to predicating water demands for each age group of trees. Collectively this *predicated water demand* is the accumulated amount of water to be pumped by the BTF irrigation system and is the right amount of water that the trees actually need for the coming week.
4. Nearly 375 automated soil moisture sensors provide real time soil moisture readings at various locations and depths around BTF. The soil moisture data is collected by I-SCADA and stored in a sequential database. Analysis of the soil moisture data provides information if any adjustment to the soil moisture reservoir in the soil is required. The goal of BTF, for optimum economical growth of the trees, is to maintain greater than 80% available soil moisture in the root zone. The automated soil moisture sensors also monitor the irrigation water encroachment to the central 60 cm (2 ft) wide soil strip between the three meter (10 ft) tree rows; which according to state water right rules has to always remain dry. A detailed soil moisture evaluation status (increase/decrease) at each

field, including other analysis, is done at this stage of the ASIM program and a *soil moisture* report is created.



Figure 3. "HERO" AgriMet station located North boundary of BTF.

5. The *predicated water demand* per tree age group is converted to *hours of irrigation* operation and is presented to the Water Group of BTF team for acceptance and modifications. The present and extended weather forecast, extended and historical ET and TG graphs and the *soil moisture* report are also presented at the same time. This is a major decision of the week and one that impacts greatly on the economics of BTF. Debate is done on issues such as; if water demands for a particular age group of tree need any adjustment, date and time for the start of the next irrigation schedule, pump availability and water quality issues such as system flushes. Water Group members provide input on irrigation hour's adjustments per age group and clone, special irrigation requests, single or multiple block runs, daily to every third day schedules, number of cycles per day, system flushes and special water regimes for experimental testing and harvesting. A report with the final decision on the *hours of irrigation* for each age group and other irrigation parameters is then prepared and forwarded onto the next stage of ASIM program.

6. The information from the *hours of irrigation* report is then input into an in-house software program and hours adjusted due to higher or lower emitter flows in comparison to design flows. Additional adjustment to the hours is made due to the BTF Deficit Irrigation program. After computation a determination of the expected water demand at each pump station and the expected withdrawal rates from the irrigation canal is made. Pump selection per pump station for efficient water delivery is also computed and relayed to the irrigation team for confirmation on availability of the selected pump(s) to the I-SCADA system. The expected water withdrawal demand from each of the irrigation canal pump stations is then relayed to the irrigation canal company 24 hours before the new schedule goes into place. The final output of this stage of ASIM program is an

irrigation demand file that is forwarded to the next step of the ASIM program for encoding into the I-SCADA system.

7. For actual I-SCADA implementation of the planned hours of irrigation, a six-day irrigation schedule regime for each of the 369 individual blocks is created from the *irrigation demand* file by the AHBIS program. It is a tedious and complex process of laying out an irrigation schedule that provides not only the irrigation needs of each block precisely but also covers the block flush requirements, has random daily irrigation start times and maintains a steady hydraulic demand at all times at each pump station during the duration of the irrigation schedule. The output of the AHBIS program is the *BTF irrigation schedule code* file, consisting of nearly 12,000 individual block irrigation and/or flush schedules over a six day period. This irrigation schedule regime allows the BTF irrigation team to micromanage irrigation at each block level to within +/- of a minute, for a high precision and accurate irrigation of the Pacific Albus trees.
8. The *BTF irrigation schedule code* file is then transferred, via Ethernet, to I-SCADA master processor which in turn remotely transfers, via radio, to the 93 RTU's for implementation at field level. The I-SCADA OIT displays the new irrigation schedule and system flushes of each block, keeps track of its real time operation as it progresses and stores the data in the database every minute. An 18-page report on the new daily irrigation schedule for the next six day run is the final output of the weekly ASIM program at BTF. This irrigation schedule report is then disseminated to the BTF irrigation team.
9. When the weather conditions change enough to affect the trees predicted water demand, the ASIM program is run again and a new *BTF irrigation schedule code* file created. Major structural failures with the BTF irrigation system can also cause a change in the water regime and thereby initiate a new partial, or full, ASIM program run.
10. If the water demand for the trees does not change over a six-day period, the I-SCADA system will automatically repeat the previous week's irrigation schedule.

OTHER IRRIGATION EFFICIENCY PRACTICES

Beside the use of ASIM and AHBIS programs together with the I-SCADA system, BTF utilizes other important practices for achieving high overall irrigation efficiencies. These practices include:

- 1) Use of an award winning design for closed-loop drip irrigation system together with pressure compensated emitters to achieve the highest possible irrigation application efficiencies.
- 2) Use of Variable Frequency Drive (VFD) motors, Real-Time innovated pump selection guides at the I-SCADA OIT for single and multiple pumps operations, Real-Time data of energy usage per unit of water pumped and combined with on-line pump testing; all collectively help improve irrigation pumping energy efficiencies.
- 3) Use of extensive Real-Time flow and pressure monitoring at pump station and block levels, enables high irrigation uniformity efficiencies.

- 4) Complex localized RTU programming at each block level to enable hydraulic Self Recovery of the irrigation system in case of partial lose of pumps or pumps stations. This Self Recovery allows partial irrigation to occur minimizing the downtime effects of an irrigation system failure.
- 5) Use of sophisticated “auto-pump shut-off” RTU programs for maintaining system integrity when irrigation system fails. This is combined together with extensive Real-Time alarm/pager system to alert operators of an irrigation situation that would affect irrigation performance or efficiency.
- 6) Use of satellite multi-band imagery and aerial Infra Red (IR) information to assist in improving irrigation uniformity efficiencies.

CONCLUSION

With the use of innovative irrigation water management ideas and methodologies, together with precise and accurate application of irrigation amounts, BTF farm achieves high overall on-farm irrigation efficiencies in excess of 95%. The BTF offers a show-case example where latest technology and human ingenuity are utilized to drip irrigate vast areas of land, while minimizing the use of scare water and energy resources while maintaining a sustainable and economical rate of fiber production for use in BioEnergy, Paper and Solid Wood production. At BTF the use of Advanced Scientific Irrigation Management (ASIM) program, State-of-Art I-SCADA system, extensive automated soil moisture monitoring, multiple weather sources, Pacific Albus crop curves and the use of complex customized and in-house software, allows BTF to adequately irrigate its trees very efficiently and so maintain its position as a world leader in large scale drip irrigation efficiency.

With its innovative and sophisticated drip irrigation technology, BTF can help lead the world in advancing the spread of large-scale drip irrigation projects. Implementation of drip irrigation technology is ever so much important in today’s times, where some countries social and economical survival may very well depend on migrating from less water efficient irrigation systems to more water efficient drip irrigation systems, allowing optimum use of their scarce and diminishing water resources.

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