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Improving Mission Readiness through Environmental Research

Evaluation of ECMI Instrumentation Deployed at Fort Benning

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BACKGROUND: The Strategic Environmental Research and Development Program (SERDP), Ecosystem Management Project (SEMP), Ecosystem Characterization and Monitoring Initiative (ECMI) is a long-term, multiagency program at Fort Benning, GA, to characterize the environment in and around Fort Benning and provide long-term databases documenting the environmental (meteorological, hydrological, biological, and geographical) conditions in the ecosystem. In 1999, as part of this program, the U.S. Army Engineer Research and Development Center (ERDC), Environmental Laboratory (EL) deployed 10 weather stations, 6 surface water stations, and 4 groundwater stations to support the SERDP, SEMP, ECMI long-term monitoring program.[1] This monitoring program is expected to continue for at least 10 years and be a prototype for long-term monitoring programs at other military installations.

Figure 1. Deployed meteorological station at the Natural Resources office

PURPOSE: The ECMI program includes an adaptation component. To ensure that an optimum monitoring capability is maintained, the current state of environmental instrumentation was evaluated. This technical note presents the results of the evaluation and provides recommendations on the acquisition of new sensors/field station/telemetry to enhance the long-term data collection activities at Ft. Benning.

METEOROLOGICAL STATIONS: The 1999 ECMI program requirement was to deploy several meteorological and surface water stations. Each of the meteorological stations was equipped to collect data on air temperature, relative humidity, barometric pressure, solar radiation, wind direction, wind speed, and precipitation. Additionally one station, near the Natural Resources office, was equipped to collect data on evaporation. All stations are powered by 12VDC batteries, maintained with solar panels. The stations were programmed to collect 1-minute samples and record 30-minute averages. Each station was also required to provide remote access

[1] Hahn, C. D., and Leese, D. L. (2002). "Automated Environmental Data Collection at Fort Benning, Georgia, from May 1999 to July 2001," ERDC TR-02-3, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

(telemetry) to the data as well as the recorder for both quality control and any program changes. These stations were to be reliable, flexible in the actual sensors to be deployed, and easy to maintain. In the three years since these stations were deployed, very few problems have been encountered during operation.

CURRENTLY DEPLOYED STATIONS: The meteorological stations (weather stations) initially deployed were procured from Campbell Scientific, Inc (CSI). This vendor was selected because of EL familiarity with their equipment and the wide range of available systems. The CSI data logger is very flexible in the variety of sensors that it can support as well as the programming of the data logger. It also supports a variety of telemetry options including cellular telephone, GOES satellite, and radio frequency. It can also support interconnected telemetry systems. The CR10X was selected as the primary data logger. The CR23X was selected for the station at the Fort Benning Natural Resources Office because it had more input channels than the CR10X. Table 1 presents the costs of the meteorological stations deployed at the time of purchase as well as the current prices.

Table 1
Costs of Meteorological Stations

Item	1999 Cost	Current (Sept 02) Cost
Data Logger		
CR10X	$1,090	$1,190
CR23X	$2,350	$2,500
Temp/humidity	$495*	$545*
Barometric pressure	$540	$575
Solar radiation	$245*	$275*
Wind speed/direction	$745*	$850*
Precipitation	$295*	$355*
Telemetry (cell phone)	$1,180	$1,205
Misc. (tripod, etc.)	$3,210	$3,181
Total	**$7,800**	**$8,176**

Note * Additional charges based on cable length.

Cellular telephones were selected as the telemetry option because of the remote access requirement and the lower cost versus GOES satellite. The current cost is approximately $27.00 per month for each telephone. Additionally cellular telephone allows for less restricted access than the GOES satellite. This technology has proven to be very reliable since deployment.

INSTRUMENTATION PROBLEMS AND SHORTCOMINGS: Very few problems have been encountered with the instrumented meteorological field stations since deployment. In two cases, lightning strikes resulted in some damage (requiring datalogger/sensor replacement) to the data loggers/sensors. In both cases the stations were quickly repaired (damaged equipment replaced) as soon as the damages were properly diagnosed.

ALTERNATIVE METEOROLOGICAL STATIONS: Several lower cost meteorological systems are currently available. Many of these systems incorporate monitoring consoles where the data are displayed graphically. Data logging capability is limited and in most cases requires a computer to be connected to the monitoring console to record the data. Telemetry, if available, is not a turn-key option, requiring the end user to acquire and assemble the telemetry system. Also some of the systems require AC power, which is not available at most of the station locations on Fort Benning. Table 2 details the systems evaluated.

Table 2
Details for Alternative Meteorological Stations

System	Telemetry Available	Logging Capability	Power Requirements	Cost
Weather Monitor II	No	No	110 VAC	$395.00
Vantage Pro	User implementation	24 records	5 VDC	$502.00
Capricorn 2000	User implementation	511 records	12 VDC	$1,475.00
WS-2000	User implementation	Requires computer for logging	12 VDC	$1,483.00
WLS-8000	NO	Requires computer for logging		$3,999.00

The Weather Monitor II system is a simple inexpensive weather reporting system designed for the home or office with the data displayed on a small console. It has no telemetry or logging capability and has a 110VAC power requirement. The Vantage Pro system is another console system; however, the console has limited logging capabilities. It does have a serial port to interface to a computer and that could be used as a telemetry link; however, the manufacturer does not offer that option. The Capricorn 2000 system is again a console-based system with more logging capability than the Vantage Pro. Like the Vantage Pro, it has a serial port to interface with a computer. The manufacturer also offers a short- range radio link, but the range is limited to under 1600 ft. The WS-2000 system is a wireless system that transmits the data from the remote station to a display console. It has no logging capability unless connected to a dedicated computer. The WLS-8000 system again is a console type system. It also requires a dedicated computer for data logging.

EVALUATION OF NEW METEOROLOGICAL SENSOR TECHNOLOGY: Two new sensors were evaluated that could have some impact on the long-term monitoring program. The first is the ultra-sonic wind sensor available from R.M. Young, CSI, Met One, and several other vendors. This sensor has no moving parts to wear or freeze and is capable of measuring extremely low wind speeds (<0.25 m/s) and also three-dimensional wind speeds, which could be important to some applications. Because of the electronics involved in this technology, these sensors have a high power consumption rate (4 watts versus ≈ 0 watts for existing sensor), and could adversely impact the power requirements of the weather station. Also these sensors cost over $2,100 each (the current wind sensors cost approximately $850) and the advantages of this sensor do not outweigh the high cost and power consumption. The second new sensor is a fuel moisture/ temperature sensor (fire stick). This sensor consists of a wooden dowel rod instrumented to measure the temperature and moisture content of the dowel and provides data to compute National Fire Danger Rating System (NFDRS) indices. These probes have been used (until recently) by the U.S. Forest Service to predict fire danger. The forest service no longer uses these sensors, favoring a developing computer model that uses air temperature, relative humidity, and solar radiation to compute the indices. A software program (Fire Weather 2000 with NFDRS module, $1,234.00) is available from Forest Technology Systems, Inc. to compute the NFDRS indices. A new computer model under development by the

U.S. Forest Service should be available in 4QFY03; however, it is being developed for the UNIX platform, but could be ported to the PC/Windows platform. EL will evaluate this in the future and acquire the code for the ECMI long-term effort.

RECOMMENDATIONS FOR METEOROLOGICAL FIELD STATIONS: EL currently recommends no change to the existing meteorological instrumentation. The lower cost systems noted above have too many operational limitations to be remotely deployed as the CSI stations are.

SURFACE WATER STATIONS: Surface water stations were deployed to collect water data on selected watersheds at Fort Benning. Two surface water stations were initially deployed at Sally Branch and Bonham Creeks (August 1999). A third station was deployed on the Upatoi Creek in May 2000. In August 2000, three additional stations (collecting only water stage, velocity, and temperature data) were deployed on Little Pine Knot, Oswichee, and Randall Creeks.

Figure 2. Surface water station on Sally Branch Creek

Current Surface Water Instrumentation: The instrumentation at these water stations consisted of a Druck pressure type stage sensor, a Rocky Mountain Instrument Doppler velocity sensor, and a Hydrolab multi-probe to measure water temperature, pH, turbidity, dissolved oxygen (DO), specific conductivity, and nitrate ions concentration, all connected to a CSI CR10X data logger. The CR10X logged data from the Hydrolab using the SDI-12 industry standard interface and consolidated that data with the water stage and velocity data, and provided a telemetry interface. A decision was made in July 2000 to remove the Hydrolab instruments due to costly instrument and sensor maintenance requirements (approximately 14 days) and due to insufficient stream flow for proper monitoring. A thermistor was added to each station to measure water temperature. Water chemistry (DO, specific conductivity, pH, water temperature, and nitrate ion) would be manually sampled on a biweekly basis using the Hyrdolab instrument. Table 3 lists the datalogger and sensors and the costs.

Table 3
Surface Water Instrumentation

Datalogger/Sensor	1999 Cost	Current Cost
Data Logger (CR10X)	$1,090	$1,1190
Druck PDCR 1830 (Stage)	$612.50	$712.50
Rocky Mountain VMT (Velocity)	$1,095	$1,520
HydroLab Datasonde	$10,107	$5,720*
CSI Model 107 Thermistor	$77	$81
Total		
As initially deployed	**$12,904.50**	**$9,142.50**
As now deployed	**$2,875**	**$3,503.50**

Instrumentation Problems: The Hydrolab datasondes initially presented problems with heavy power requirements, which were not presented in the system documentation. This was primarily due to heavy power requirements of the datasonde. The turbidity sensors also developed problems. These sensors were equipped with a shutter to protect the lens from damage caused by debris in the water. In operation, the shutter would trap suspended sediment behind the shutter and scratch the lens during operation. The nitrate ion probes also caused several problems because these probes have a short useful working life, and constant immersion in water only accelerated their demise. The datasondes were removed in July 2000 due to poor performance and low stream flow. Currently the Hydrolab is used to manually sample each stream at two-week intervals. Two stations (Oswichee Creek and Little Pine Knot Creek) were damaged during unexpected high water conditions. The station on Oswichee Creek was located approximately 4 meters above the stream bed, but still flooded.

Alternative Instrumentation: Three companies have since developed multi-probe packages similar to the Hydrolab previously used. YSI and In-Situ each manufacture a multi-probe sensor and Hydrolab now manufactures two multi-probe sensors. Each of these packages has maintenance schedules requiring service on a weekly to biweekly basis. A search did reveal single-parameter probes with much longer maintenance intervals, which can provide some of the water chemistry data (DO, pH, conductivity, and turbidity) at a higher resolution than currently being obtained. Some of these sensors have been procured and are being evaluated for long-term deployment at Fort Benning.

Recommendations for Surface Water Stations: Several of the single-parameter probes (DO, pH, conductivity, and turbidity) are currently being evaluated as to accuracy, dependability, and maintenance cycles. However, manual sampling with the Hydrolab will be continued to collect the nitrate data as well as comparison data for the single parameter probes.

GROUNDWATER STATIONS: In June 2001, four groundwater wells were drilled at Little Pine Knot Creek, Oswichee Creek, Randall Creek, and Sally Branch Creek. These wells were instrumented with In-Situ Mini-Trolls, to measure groundwater temperature and level. The Mini-Trolls have been very dependable since deployment. The only problems encountered have involved the connector between the probe and computer interface cable. Longer interface cables were procured and remain attached to each Mini-Troll. At the time of deployment, no telemetry options were considered for these probes. Since deployment, In-Situ has developed the Troll 9000, which measures DO, pH, salinity, turbidity, conductivity, and nitrates in addition to depth and temperature. They have also developed several telemetry options including radio frequency systems and cellular telephone.

Figure 3. Typical groundwater station with Mini-Troll

Recommendations for Groundwater Stations: The author recommends no changes to the groundwater instrumentation at this time. As mentioned above, In-Situ, Hydrolab, and YSI manufacture multiprobe systems capable of sampling the groundwater wells, should water chemistry data become required from the groundwater stations. Cellular telephone telemetry is also available, but at this time, no need for telemetry has been demonstrated.

Telemetry Systems: During the initial planning and deployment on the long-term monitoring program, it was determined that remote access to the sensor data was essential. Several options were available for telemetry of the sensor data and were evaluated. For local area access, radio modems provide the optimal solution. Each station is equipped with a radio modem, and another radio modem is attached to the computer processing the data. Repeater radio modems would be deployed as necessary to provide reliable communications. Another approach was to use cellular telephones and modems. This approach allows for access from multiple sites. However, this technology consumes a good deal of power, even when on standby and the phone must be switched off and on at specified times during the day. A third option is GOES satellite up/downlink. This option is suitable for very large networks; however, the hardware costs are quite expensive ($3K per station). Table 4 illustrates the advantages and disadvantages of each telemetry system.

Table 4
Comparison of Telemetry Systems

Telemetry System	Advantages	Disadvantages
RF modem	Low power usage Full-time access	Limited user access Limited network size Local access only
Cell phone	Multiple user access Large network	Power hungry Monthly fee
Satellite	Large network Low power usage	High hardware cost Monthly fee Requires open sky view Limited data access

Current Telemetry System: Cellular telephone telemetry was selected because of the accessibility and lower cost than satellite ($27.00/month). This technology has worked very well in most cases. Occasionally, problems have been encountered at the water stations, due to terrain (topography and forested vegetation) around the water stations or weather/solar conditions. Redundant data are stored at the station and can be manually retrieved, if needed.

Additional Telemetry Issues: Many manufacturers (Campbell Scientific included) also offer hardwired systems. While these are not practical for the deployments over large areas such as at Fort Benning, they may be suitable for small deployments or temporary installations. Also some manufacturers allow the various telemetry systems to be combined, using RF technology for a local site network with the base station linked to telephone for multiple or offsite user access. Wired technology is also considered useful to link several stations located in close proximity (<1000 ft) to each other, with that network linked to other technologies for remote access.

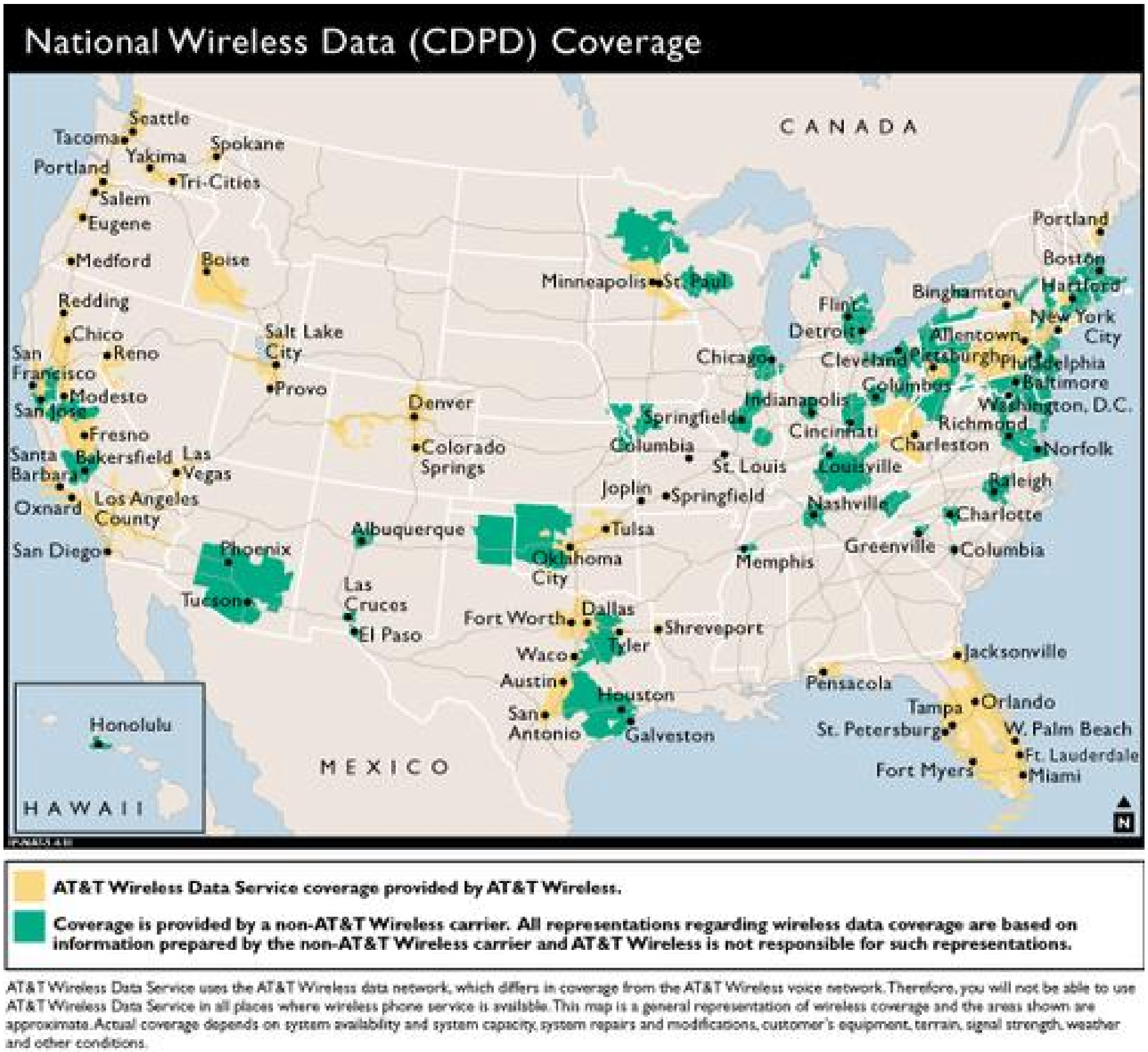

Figure 4. National wireless data (CDPD) coverage

New Telemetry Technology: Following the trends in digital cellular telephones, some manufacturers have developed interfaces using similar digital cellular technology. Campbell Scientific is offering a system developed by Airlink, which provides access via an IP address (assigned by the provider). This is important to consider for the future, as many cellular companies are phasing out analog networks, converting the bandwidth to digital. At this time cellular digital packet data (CDPD) service is limited (see Figure 4) and is not available at Fort Benning (monthly cost not available at this time).

Another new technology that is an extension of the RF modem technology is the spread spectrum technology. Spread spectrum technology involves frequency agile radios, which alter the Transmit/Receive (TX/RX) frequency when it encounters interference in the signal. Typically this technology is limited to short-range applications; however, with the proper antenna technology and clear line of sight, the transmit path can approach 10 miles. Table 5 shows the cost of these technologies.

Table 5
Cost of Spread Spectrum Technology

System	First Station	Additional Stations
RF (VHF/UHF)	$1,950.00	$725.00
Spread spectrum	$1,266.00	$631.00
Analog cellular	$1,205.00*	N/A
Digital cellular	$932.00*	N/A
Satellite	$3,193.00*	N/A

* Monthly/annual service fee not included.

SUMMARY: As of September 2002, there are no better, more reliable, lower cost (disposable) systems for long-term monitoring of meteorological and groundwater conditions than those currently installed at Fort Benning. There are a few surface water sensors that warrant evaluation and potential deployment at Fort Benning and evaluation of these sensors is under way. ERDC will continue to review the market for new and more cost-effective sensors for long-term monitoring.

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At the time of publication of this technical note, the Director of EL was Dr. Edwin A. Theriot and Chief of EE was Dr. David J. Tazik. Dr. James R. Houston was Director of ERDC, and COL John W. Morris III, EN was Commander.