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CONTROLLING SEDIMENT COLLECTION WITH DATA LOGGERS

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ABSTRACT

The proliferation of commercial non-programmable data loggers in the past five years has done little to increase sediment sampling efficiency in remote locations. Recent advances in microelectronics have encouraged the development of commercial, low-power, programmable data loggers at reasonable cost. Although some facets of hydrologic data collection may lend themselves to fixed-time sampling intervals, sampling efficiency in many applications can be improved using a programmable data logger. For example, controlling the collection of suspended sediment with a probability sampling program may involve generating and sorting random numbers, testing input parameters, and activating a pumping sampler.

Commercial single-board data loggers are now available with high-level programming languages, such as BASIC. Modified BASIC commands that provide easy access to the data lines can simplify the programming required to control data collection. Low-power requirements, ease of programming, and the increased flexibility of connecting multiple sensors can improve data collection in remote locations. In most cases, the user must provide signal conditioning hardware between the sensors and the data logger. Environmentally sealed hand-held computers transported to the site and connected to the data loggers allow field personnel to update programs, transfer data files, view and plot data, and add observer records.

INTRODUCTION

Development of low-power commercial data loggers in the past five years has resulted in a larger selection of equipment for hydrologic data collection. Unfortunately, in spite of significant improvements in data logger hardware, high-level language programs are almost non-existent. In fact, most data loggers are not programmable, and those that are often use proprietary "assembly-like" languages that are difficult to use and modify. Commercial low-power single-board data loggers now offer high-level languages and access to microprocessor I/0 (input/output) lines at considerable cost savings over non-programmable data loggers.

Early attempts to develop microprocessor-based systems demonstrated the potential of single-board data loggers to control sediment collection (Babbitt. 1987). Sampling algorithms provided a means to control the collection of samples in real-time, resulting in higher sampling rates during periods of interest. Technical limitations, such as assembly language programs and magnetic storage media, often discouraged potential users. By the mid- to late-1980s several commercial manufacturers of data loggers began to offer devices with a wide range of input sensor configurations, low-power requirements, and improved solid state memory. Most of these data loggers allowed only fixed-time sampling.

Another path of development utilized a programmable calculator interfaced to a pressure transducer and pumping sampler to control probability-based sampling for a study on cumulative effects in the Caspar Creek Experimental watersheds, near Ft. Bragg, California (Fads and Boolootian, 1985). Commercial products, such as the calculator used in the Caspar Creek study, often lack the robustness required in severe environmental conditions, and special precautions must be taken to protect the equipment.

Currently, four types of data loggers collect data from eight hydrologic studies in the Caspar Creek watersheds. Each study has unique requirements for interrogation intervals, sensor type, programmability, and data file structure. A large effort is expended in training field personnel to operate and maintain data loggers with dissimilar requirements. In addition to compatibility problems, the data loggers lack desirable and necessary features which would improve data collection. Replacement of existing data loggers with a single-board programmable data logger is under field evaluation. This paper describes the development of software and interface hardware for a single-board programmable data logger controlling the collection of suspended sediment samples and precipitation data.

SEDIMENT AND PRECIPITATION DATA COLLECTION

Sampling Methods

Suspended Sediment

Data for estimating suspended sediment loads are traditionally collected nonstatistically; that is, probabilities of collecting given samples are not known. This is partly why estimates made with these data give biased estimates of total load and variance (Walling and Webb, 1981). Algorithms that collect statistical samples to estimate sediment loads correct these deficiencies (Thomas, 1985; Thomas, personal communication, 1990). These methods use knowledge about sediment flux to improve sampling. One algorithm, called SALT (Selection At List Time), uses surrogate values calculated from discharge at 10-minute intervals that interact with preselected random numbers to enhance collecting sediment samples during high flow periods. Stratified sampling can also be used to obtain statistical samples with low variance by partitioning time into strata based on actual and expected changes in stage. Both schemes give unbiased estimates of total load and variance, but depend on sensing in-stream conditions to modify the sampling process.

Although both SALT and time-stratified sampling can be accomplished manually, remote study sites are well suited to automated data collection because of inherent problems of access and timing. In addition to controlling sediment collection, electronic data records reduce both labor and errors associated with keyboard entry and digitizing. Consider how an "intelligent" data, logger connected to a stage sensor and a pumping sampler would collect data on suspended sediment under time-stratified sampling. Several sampling. schedules with different sampling rates (i.e., bottles/hour) and stratum durations would be preselected for different in-stream conditions. In real-time at the start of each stratum, the data logger would determine in-stream conditions, choose the appropriate schedule, and randomly select the sampling times for the duration of the specified stratum. Then during the stratum period, the data logger would activate the pumping sampler at the selected times and store information needed for estimation. This process would be repeated for the period to be monitored and would require no human intervention until all of the bottles were filled.

Precipitation

Precipitation data are often collected at or near stream gauging stations. Programmable data loggers with multiple analog and digital I/0 lines can combine data collection from several instruments. In small mountain streams, precipitation information can be used in addition to stage to refine the sampling algorithm. Tipping bucket rain gauges provide a digital output based on the number of "tips" occurring during a defined period. Tips are counted in the "background" while the data logger is in a low-power mode. The data file can be compressed in real-time by retaining only those periods that contain precipitation.

Hardware

The gauging station equipment that is used to control time-stratified sampling and precipitation data collection includes a tipping bucket rain gauge, modified stilling well, pumping sampler and intake boom, interface circuit, single-board data logger, and hand-held computer (fig. 1).

Single-Board Data Logger/Controller

Controlling data collection of suspended sediment with probability sampling encompasses several steps that are most efficiently handled by a programmable data logger. A pressure transducer is periodically interrogated to obtain an analog voltage, which is converted to a digital representation and applied to a calibration equation to measure stage. Stage is subsequently used to determine the appropriate sampling schedule and is also retained as the hydrograph record. The data logger controls the collection of sediment samples by providing a short duration switch closure to the pumping sampler through an interface circuit. ,Finally, the data logger must have sufficient on-board memory to store all records of interest for a period spanning regular maintenance intervals.

In addition to these general requirements listed above, the data logger, should have low-power requirements, adequate A/D (analog-to-digital) resolution with multiple input channels, provide multiple digital I/0 lines, and support a high-level language. A limited number of commercially available data loggers meet these requirements. Onset Computer Corporation's Tattletale Model 4A[1] was chosen for its ease of hardware development, low-power requirements, moderate cost, and suitability for a wide range of hydrologic studies. Onset's products require that the user provide signal conditioning circuitry, sampling programs, and physical packaging. The Model 4A does not include a display or keyboard. A computer, connected to the data logger with a serial cable and running communications software, provides a means to write and list programs and transfer files. A low-power display interfaced to the data logger can provide information to field personnel in situations where they may visit the field site but do not have a hand-held computer.

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[1]Trade names are used for information only and do not constitute endorsement by the U.S. Department of Agriculture.

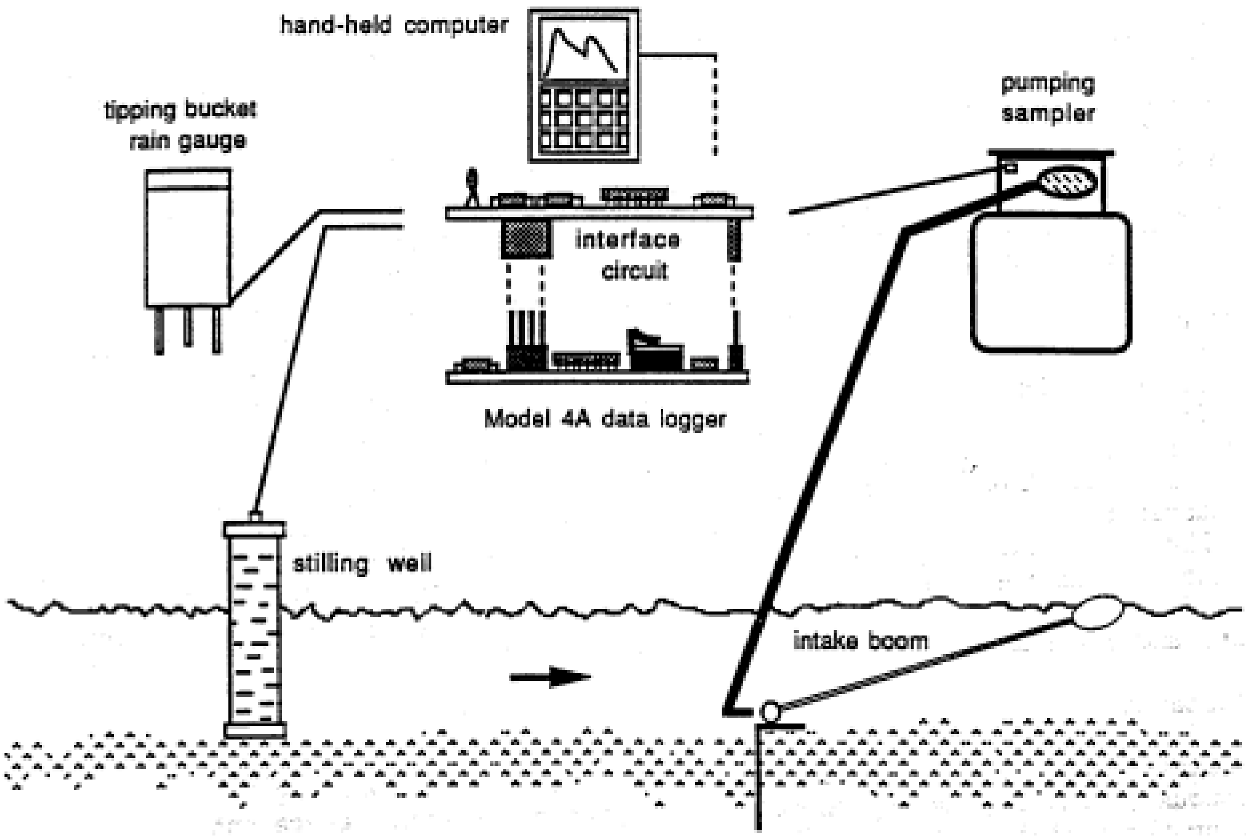

Figure 1. Gauging station equipment.

Stage Sensing

Solid state differential pressure transducers sense changing water depth. by converting the mechanical flex of a silicon diaphragm to a proportional electrical signal while compensating for atmospheric pressure changes by venting the dry side of the diaphragm to the atmosphere. Because -changes in voltage across the silicon piezoresistive bridge are small, the output signal must be amplified to the range of 0 to 5 volts. Amplification can take place within the sensor assembly or on an interface circuit board. Onset manufactures an interface circuit board, suitable for prototyping or for limited production, that provides connections to power, analog inputs, and digital I/0 lines. To conserve power the data logger's A/D converter is active only during a small time window, and input devices must either have a fast settling time or invoke an assembly language subroutine to stabilize the signal before conversion is started. Input signals are converted ratiometrically to a 12-bit result and shifted left four bits, producing a 16-bit result in the range of 0 to 65,520 A/D units. Combined accuracy of most transducers is between 10 and 12 bits, so the additional bits of "precision" should be treated appropriately. The A/D value is applied to the pressure transducer's calibration equation to obtain a stage value in they appropriate units.

A modified stilling well, constructed of PVC pipe and geotextile filter fabric, can be anchored to the streambed. This design dampens wave pressure, blocks sediment entry, and maintains the pressure transducer in a fixed location. This simple installation greatly reduces the logistics associated with using traditional large-diameter stilling wells.

Sample Collection

The ISCO model 2700 sampler is a portable device designed to collect 24 discrete samples by pumping the water/sediment mixture from the stream to the sample bottles. Several sampling modes are possible with the model 2700. When the control unit is set to Flow Mode, as in the case of time-stratified sampling, the sampler waits for a short duration switch closure from an external controller before collecting each sample. The data logger provides the switch closure by setting a digital output line high and then low. An optical isolation circuit provides microprocessor protection end the required switch closure. The ISCO collects a preselected sample volume by counting the rotations of a peristaltic pump according to the settings made on the controller. The sampler intake is mounted on a depth-proportional. intake boom anchored in the thalweg of the channel (Eads and Thomas, 1983). After each sample collection, the sampler's distributor arm is advanced to the next bottle, and the sampler then waits for the next signal.

Precipitation

Precipitation data are collected in the "background" by supplying a continuous 5 volt regulated source to a tipping bucket rain gauge and counting the number of tips as they occur. Background measurements are made with a BASIC "count" function that increments a variable for each square wave cycle appearing on a digital input during the measurement interval. Measurements are made while the program is in a "sleep" state.

Data Retrieval

Two methods are available for retrieving data files from the field: files can be transferred to a environmentally sealed hand-held computer, or a replacement data logger can. be exchanged with the field data logger. Computer file transfer permits field personnel to enter observer records directly into the electronic file in real-time and to examine the data file on site. Plotting software permits a quick visual inspection of the data to determine whether plot traces look abnormal or values are out of range. This provides an opportunity to quickly replace defective sensors before additional data are lost. Onset offers communications software that simplifies data and program transfer with pop-up windows and limited selections that reduce training requirements for field personnel. Program updates are loaded to the data logger in the same manner that data are transferred.

Software

The Model 4A uses a version of BASIC that has been modified for the requirements of a low-power data logger and provides unique I/0 commands that simplify interfacing requirements. Two methods of writing programs are available. TTBASIC provides an interactive environment where programs are developed on the data logger using a computer or terminal. TTBASIC supports 26 integer variables and one data array. Program editing is restricted to line replacement. Assembly language subroutines can be developed for unique applications that require special functions or increased speed.

Program logic for time-stratified sampling (fig. 2) demonstrates the flexibility of using a programmable data logger. Observer records provide additional information about site conditions that may affect the electronic record. For instance, differences between pressure transducer and staff plate readings may be used to adjust the electronic record. To determine the time to the first interrogation, or wake-up, a timer is set to check the real-time clock for the correct start time. Once a stratum is selected and started, sampling will continue until that stratum has been completed. When the stage drops below a minimum threshold, a new sampling schedule will not be initiated until the stage rises above the threshold. If the program selects a new sampling schedule that requires more bottles than are available in the sampler, the rate remains the same but the stratum-length is shortened. At least two samples per stratum are required to compute variance. The data file contains all of the necessary information for analysis. Precipitation is stored as a separate record in the file to simplify data reduction. Finally, the display is refreshed and the timer is set for the next wake-up. The program is ended by pressing a switch on the interface circuit board that is connected to a port of the microprocessor. When the microprocessor detects an interrupt the program writes an ending record and halts.

The lack of floating point software can increase the complexity of programming when real numbers are needed, as in the case of time-stratified sampling. Generating random numbers between 0 and 1 in real-time and converting the result into integers in multiples of ten minutes is not a trivial task. An alternate solution is to generate random numbers on a computer and down-load the file to the data logger, but this does not make the most efficient use of the data logger.

SUMMARY

Low-cost single-board data loggers supporting high-level languages, such as BASIC, provide the flexibility to use sampling algorithms that range from, simple applications, such as collecting precipitation data, to the more complex requirements that are needed for probability sampling. Onset's, Model 4A requires two skills not normally needed when using data loggers: a basic understanding of analog and digital electronics and programming skills in BASIC. The expertise required in these two areas depends on the complexity of the intended application. For some sensors, such as non-amplified pressure transducers, the user must provide signal conditioning circuitry. But for single-ended sensors, the user may be required to only solder a few wires. The user must also provide a protective enclosure and the physical connections for the sensors and battery.

Currently, the only limitation of this technology is that Onset's data. loggers do not support floating-point mathematics. In simple applications, this is not a problem. But, in cases requiring mathematical equations, programming expertise and code complexity are increased.

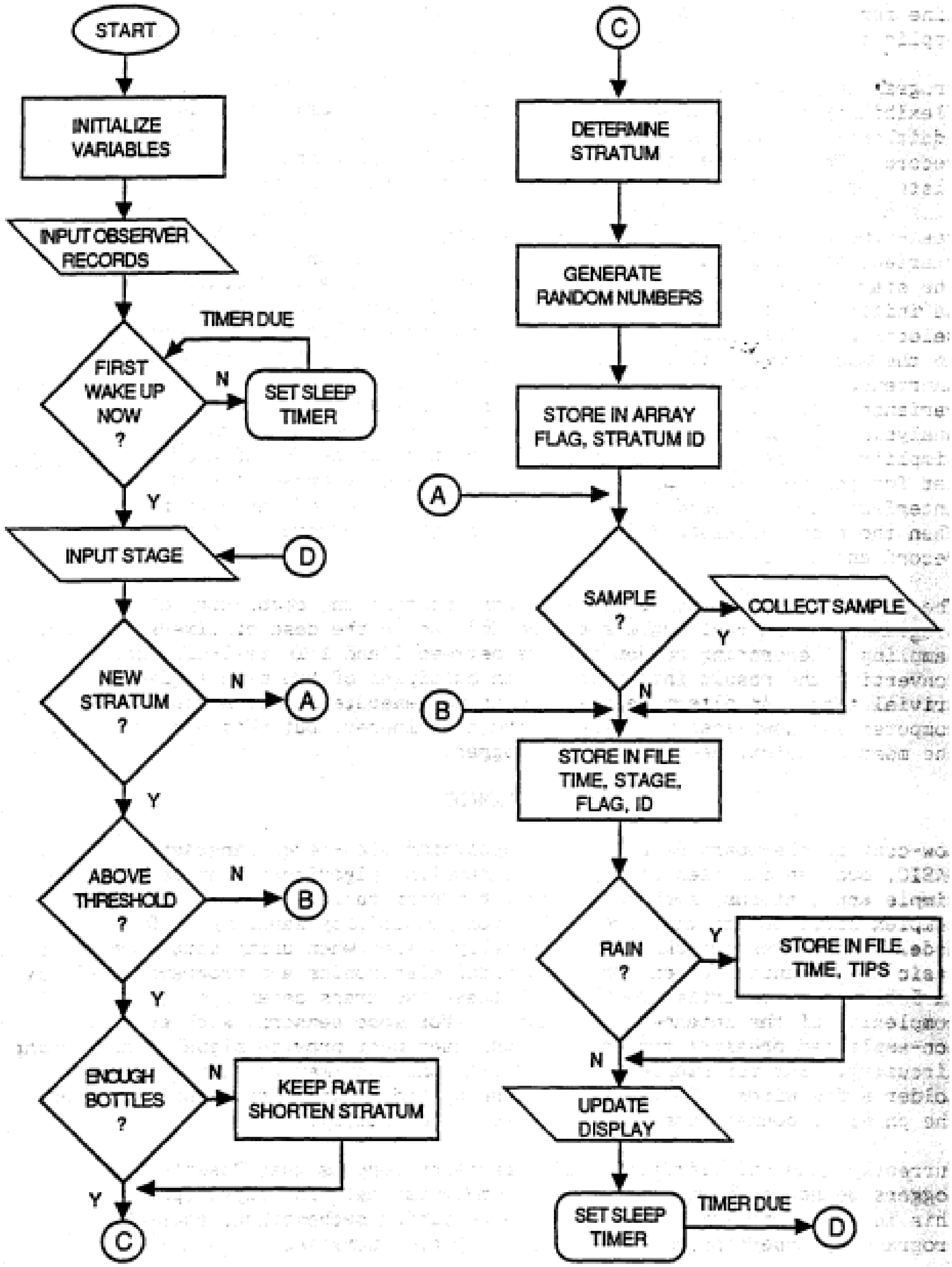

Figure 2. Program logic for time-stratified sampling. Letters inside circles indicate a continuation of the flow chart.

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