

## AN IMPROVED BEDLOAD SAMPLER

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### ABSTRACT

Improvements upon the Birkbeck bedload sampler (Reid et al., 1980) were implemented in the North Fork of Caspar Creek, a gravel-bedded stream draining 383 ha in northern coastal California. Bedload sediment falls through a slotted plate covering a .125-m<sup>3</sup> steel box set within a formed concrete pit in the streambed. In the original Birkbeck design, a water-filled pressure pillow beneath the box responded to the weight of accumulating sediment and the overlying water column. The hydraulic pressure was communicated via tubing to a pressure-bulb transducer, which was in turn connected via a set of mechanical linkages to a chart recorder. In two seasons of experimentation at Caspar Creek, the pillow and hydraulic and mechanical linkages of a Birkbeck-like sampler were replaced with an electronic load cell and an electronic data logger, resulting in more trouble-free operation, greater precision, and reduced background noise. Low-profile fences were erected along the cover plate slots to prevent material from entering traps across the lateral slot boundaries. Data were collected at 2-minute or 5-minute intervals from four bedload pits and recorded on non-volatile memory chips. Because of rapid filling of the boxes, a suction dredge was used to empty sediment from boxes during storms.

### INTRODUCTION

The tremendous temporal and spatial variability of bedload transport rates (Carey, 1985; Hubbell, 1987) in streams gives rise to large sampling errors. To lessen these errors, pit or trough samplers have been designed to provide a continuous or nearly continuous record of bedload transport.

The earliest documented apparatus was used in Mountain Creek, South Carolina (Einstein, 1944). Modifications proposed by Hubbell (1964) would have made it portable and easy to install in low-velocity streams. However, because it is difficult to lift coarse sediment with a pump, and the apparatus requires continuous pumping from a hopper located in the streambed to a weighing tank on the bank, its application is limited to sand-bed streams.

The most elaborate sampler design (Emmett, 1980) consisted of a concrete trough constructed across the riverbed, covered by a series of eight hydraulically actuated gates which could be opened or closed individually. A conveyor belt beneath the trough carried the trapped sediment laterally to a weighing hopper where the weights were recorded once each minute. Such a system would be impractical to implement on a limited budget.

A vortex-tube bedload trap (Klingeman and Milhous, 1970; Hayward and Sutherland, 1974) caught sediment in a diagonal trough in which a streamflow-induced vortex evacuates the sediment to the bank. This system, however, does not allow separate measurements of transport rate at different locations along a cross-section.

The Birkbeck pit sampler (Reid, Layman, and Frostick, 1980) allows continuous measurement of bedload at several locations within a cross-section. It is not suitable for measuring the entire cross-section, but it is the only sampler that does not require removal of the material from the channel for weighing. Bedload sediment falls through a slotted plate covering a box which rests within a formed concrete pit in the streambed. A water-filled pressure pillow beneath the box responds to the weight of accumulating sediment and the overlying water column. The hydraulic pressure is communicated via tubing to a pressure-bulb transducer, which is in turn connected by a set of mechanical linkages to a chart recorder. A continuous record of stage is needed to correct for varying pressure head due to the overlying water column. Like most other trap samplers, the Birkbeck sampler is not portable, but it is less expensive to install and operate. This paper reports modifications of the Birkbeck sampler which increase its resolution, accuracy, dependability, and usefulness.

## FIELD INSTALLATIONS

### First Year Setup

The sampler was placed in the North Fork of Caspar Creek, a gravel-bedded stream draining 383 ha in northern coastal California. Our design (Fig. 1a) was similar to the original Birkbeck design except that an additional water-filled pressure pillow was placed in a stilling well and was connected to each of 4 differential pressure transducers (Model P305D, Validyne Engineering Corp., Northridge, California<sup>1</sup>) that were connected to the pillows in the pits. Thus the effect of water pressure was removed, and deflection of the transducer diaphragm produced a voltage proportional to the submerged weight of the sediment-filled box. The volume of the collecting box was 0.125 m<sup>3</sup>, and the slot in the pit cover was 20 cm by 40 cm with the short side transverse to the flow. The analog signal from the transducer was converted by an electronic data logger (Easy Logger, Omnidata International, Inc., Logan, Utah<sup>1</sup>) to digital values which were encoded onto an EPROM (erasable programmable read-only memory) module at 2-minute or 5-minute intervals. Time resolution was thus much improved while eliminating the labor of manually extracting chart data. (At Birkbeck College, transport rates were manually integrated over 30-minute periods.) The EPROM modules were later read onto magnetic disk and erased for reuse. The boxes were winched from the pits after storms by a system of cables suspended from two towers on opposite banks of the creek.

### First Year Performance

In the first year of operation, a number of difficulties were encountered.

1. **Punctured and collapsed pillows.** It is possible that the pillows may have been punctured by sediment entering the pits through inadequate seals beneath the pit covers. The seals were eventually improved by gluing neoprene to the underside of the pit covers.

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<sup>1</sup>Trade names are used for information only and do not constitute endorsement by the U.S. Department of Agriculture

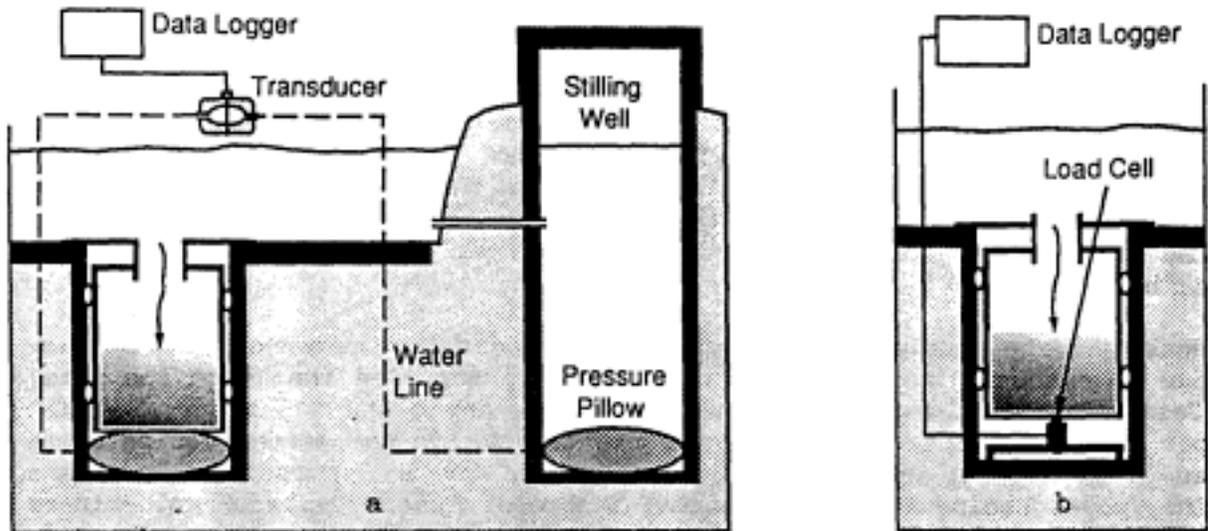


Figure 1. Bedload sampler. (a) First year design employed water-filled pressure pillows and differential pressure transducer. (b) Simplified design used load cell in place of transducer and eliminated hydraulic system.

2. **Air entering fluid lines through faulty connections and pillow valves.** In order to obtain valid data, air had to be bled regularly from the fluid lines. Experimentation with different types of connectors yielded some improvement, but the leakage problem is inherent to any system with numerous hydraulic linkages. This is particularly true where fluid is under tension, as in this application, because the transducers are at a higher elevation than the pillows.
3. **Transducer diaphragms overstressed.** Bleeding air from the system involves applying a suction to fluid lines to withdraw air and water. If done carelessly, excessive pressure can warp transducer diaphragms.
4. **Pillow calibrations unstable.** For a given change in weight, transducer output was found to change from storm to storm. Thus it was necessary to calibrate each pit after every storm.
5. **Boxes filling with sediment early in storms.** In the only two significant storms, all the boxes filled with sediment. In the first storm of the year, one box was filled within 30 minutes of the initiation of bedload movement, and all boxes had filled within an hour. Thus no bedload data were collected for most of the storm.
6. **Cable system failure.** Because of improper design, one of the towers supporting the cable system became unstable and could not be used.

#### Modifications After the First Year

In the second year of operation, solutions to all the above problems were found. First, one pillow was replaced with an electronic load cell. (In the third year, all the pillows were replaced with load cells.) A load cell is essentially an electronic strain gauge, which incorporates a Wheatstone Bridge circuit across which a fixed excitation voltage is applied. Minute deflections of a strain member result in the generation of a millivolt output proportional to an applied force. Net deflection due to hydrostatic forces is zero; hence output does not need to be corrected for stage. The load cell, placed beneath a sampler box (Fig. 1b), is wired directly to the data

logger, thus eliminating all problems associated with hydraulic systems and pressure transducers. The cell we chose (Model BSP-0.5A, Hardy Instrument Co., San Diego, California) is stainless steel and hermetically sealed for underwater applications. Its performance seems unaffected by two years of immersion. According to the manufacturer, when the load is applied in the correct manner, it is accurate to 0.23 kg without calibration; and with careful calibration, errors may be reduced by as much as a factor of 10. Unless the maximum load is exceeded, a load cell should never have to be recalibrated.

To deal with the problem of inadequate box capacity, we began using a suction dredge to evacuate boxes during storms without removing them from the pits. In Caspar Creek, flows rarely exceed 0.5 m in depth and 1.5 m/sec, so with proper safety precautions, it is possible to work in the stream during storm flows (Fig. 2). A centrifugal pump, powered by a 5-horsepower gasoline engine, moves sediment in an arrangement commonly used by placer gold-miners (Fig. 3)..-The gravelly bedload material never enters the pump. Instead, water is pumped through the jet, creating a venturi effect which draws a slurry from the suction hose and discharges it downstream.

To reduce the need for frequent pumping and concomitant instream disturbances, the slot width was narrowed from 20 cm to 10 cm. Only about 1% of the bedload, by weight, is coarser than 10 cm, based on pebble counts of material deposited in a delta just downstream of the bedload sampling station. The refitted slot is thus still capable of capturing nearly all particles transported across it.

Another modification which reduced the amount of material entering the pits was construction of low-profile fences along the cover plate slots to reduce the potential for lateral entry of material into the pits. Emmett (1980) compared transport rates from summing individual gates to determinations with all gates open and discovered that the gates, when opened individually, consistently overestimated transport rates by a factor of 1.3, because of lateral entry of sediment. His slots were 1.83 m by 0.25 m, oriented transverse to the flow, compared with our 0.10 m by 0.40 m, oriented parallel to the flow. Therefore, our oversampling would probably be greater than 1:3 without some sort of barrier. A fence height of 5 cm was estimated to be tall enough to block most bedload while minimizing hydraulic disturbance. The upstream edge was cut back at a 45° angle in order to reduce the potential for material lodging against it and blocking the slot.

The overhead cables and tripods were replaced by an I-beam bolted to two steel columns on opposite streambanks. After a storm, the boxes are now easily and safely removed from the pits using a chain hoist suspended from a carriage that rolls along the I-beam on two wheels (Fig 4). After each storm, the boxes are removed from the pits, weighed with a dynamometer, and dumped into a basin on the streambank where the sediment is mixed and subsampled for particle size analysis.

#### Performance After the First Year

In the second and third years of operation we were able to obtain nearly complete records from all pits in six of seven bedload-moving storms. One or more pits had to be pumped out in five of the seven storms, and one pit was pumped out twice in a storm. In the biggest storm, however, large particles

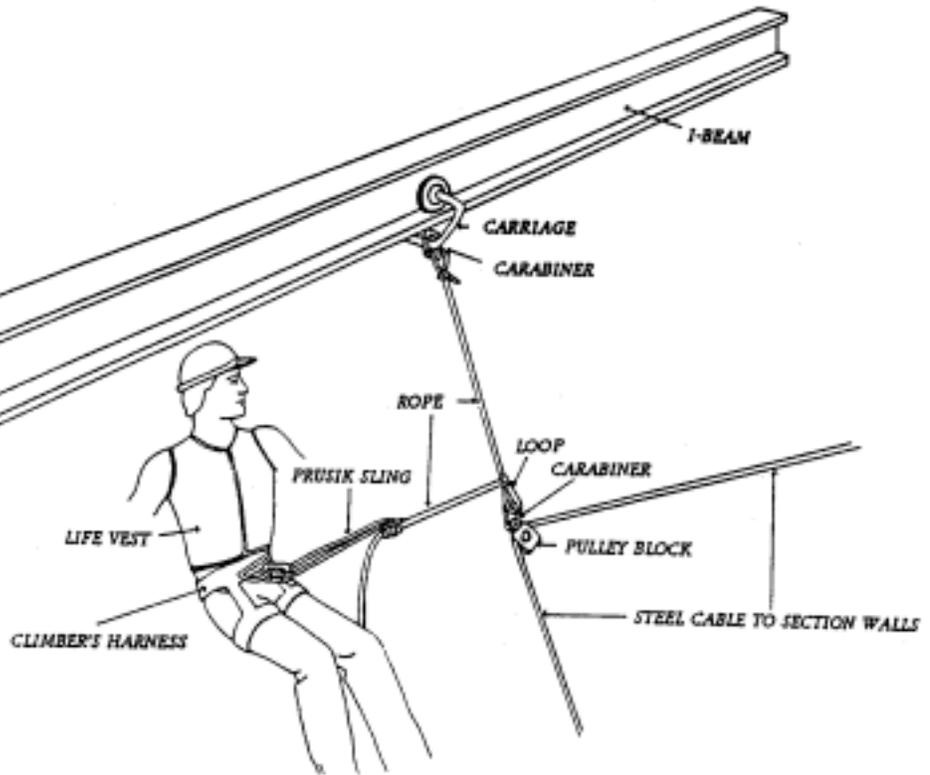


Figure 2. Harness system increases range of flows in which a person can safely work in the stream channel to pump sediment from pits. Pulley block and carriage allow lateral movement. Prusik sling holds weight in tension, but can be slid along rope to adjust distance from cable.

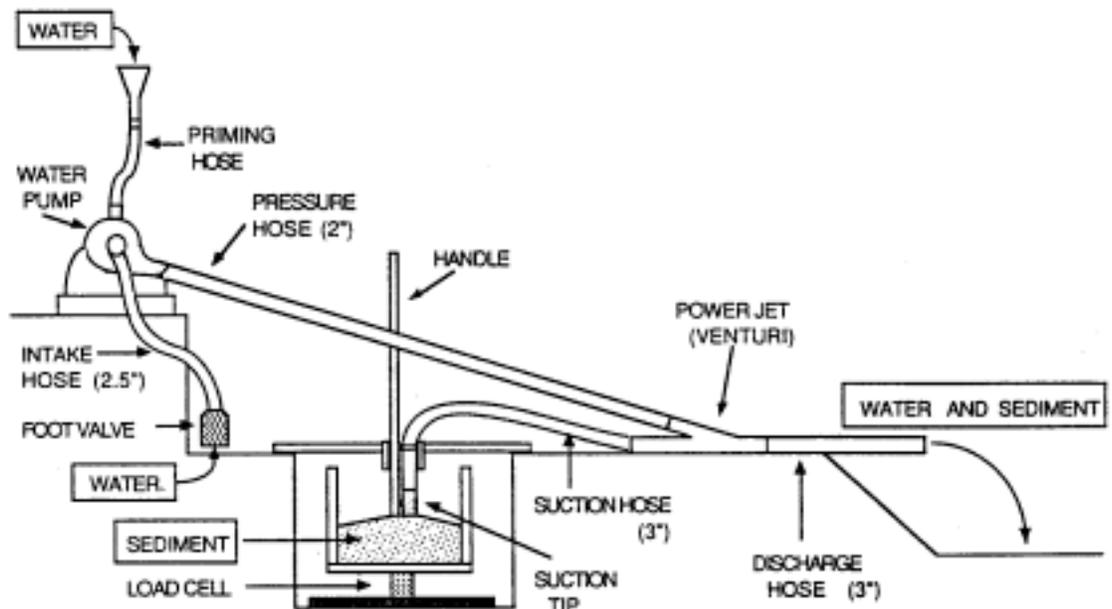


Figure 3. Centrifugal pump and power jet use venturi effect to extract sediment from bedload trap.

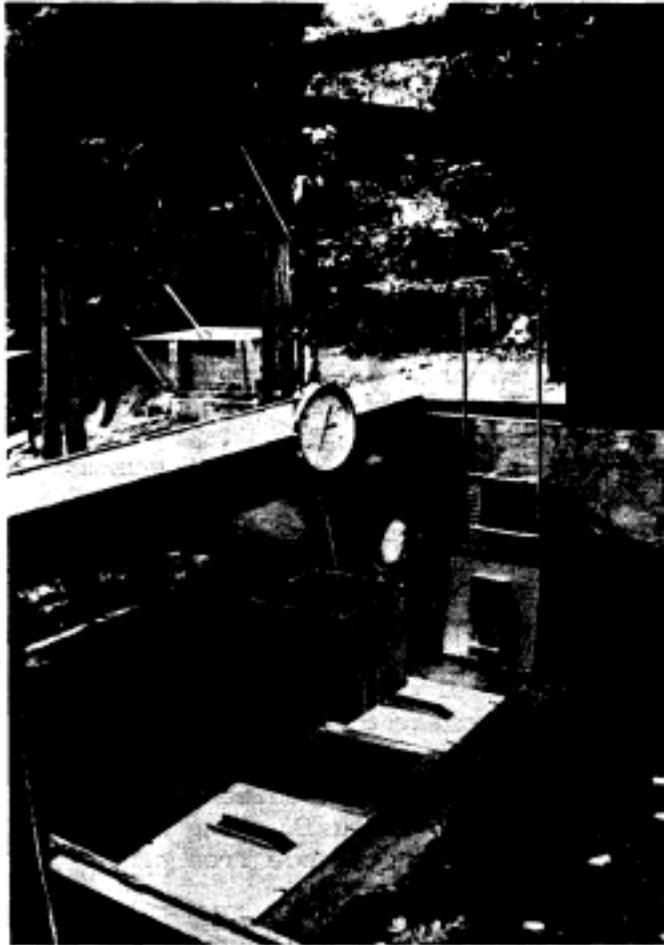


Figure 4. Sediment-filled box is removed from pit with chain hoist and weighed with dynamometer suspended from I-beam.

plugged the intake nozzle of the suction hose and the strong current made it too difficult to repeatedly clear the nozzle.

An examination of a storm trace (Fig. 5) shows the load cell output to be less noisy than the pillow/transducer output, even though the most sediment was collected in the pit with the load cell. The point is further illustrated by comparing the traces when there is a disturbance in the channel. Between hours 10 and 11 the author was working in the stream channel, and caused hydraulic changes that produced spiking in the stage and pillow traces without affecting the load cell output. Disturbances from pit pumping, Helley-Smith sampling and discharge measurements, and from debris lodging in the vicinity of the pits cause similar spiking.

An additional advantage of using load cells is that they are not as subject to temperature effects as pressure transducers. Besides being less sensitive to temperature, they are subjected to smaller temperature changes by being submerged in water. The contrast is evident on traces showing diurnal

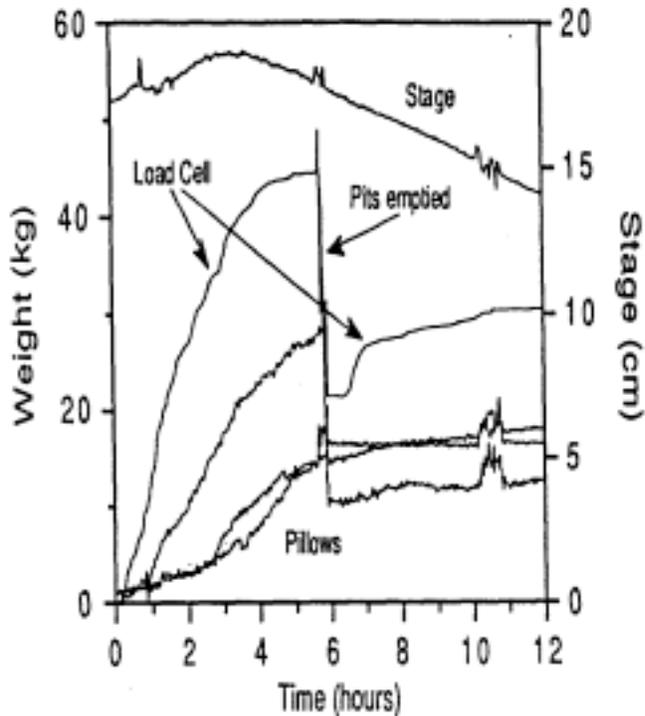


Figure 5. Storm plot of accumulating sediment. One pit was instrumented with a load cell and 3 with pressure pillows.

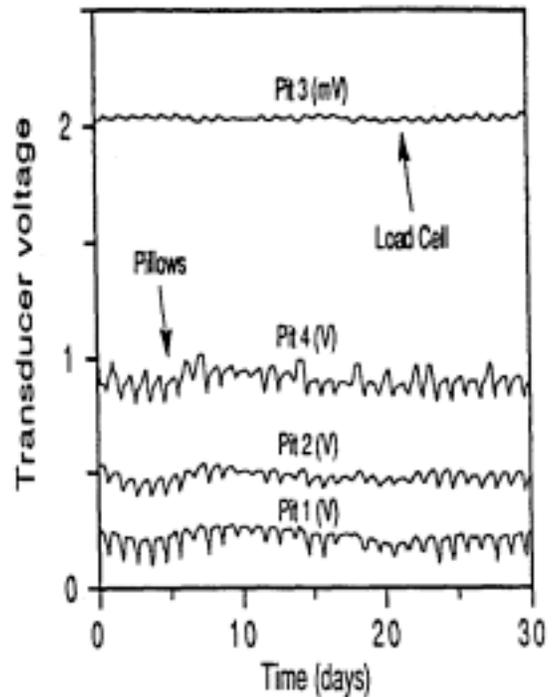


Figure 6. Diurnal temperature effects on load cells and pillow-transducers.

fluctuations (Fig. 6). Such temperature effects may, however, be unimportant when considering transport rates over small time periods, because the error from a significant temperature change will be distributed over many time intervals.

All pits were calibrated five times during the second year and the stability of the load cell was compared with that of the pillow arrangements. The coefficients of variation for calibration slopes were 1.8, 2.1, and 3.4% for the pillows, compared to 0.6% for the load cell. The median standard errors of estimate were 0.50 kg for pillows and 0.40 kg for the load cell, but the calibration accuracy was limited by the fact that our calibration weights were known only to the nearest 0.25 kg. In the third year of operation, we used load cells in all the pits, and the median standard error of estimate from 8 load cell calibrations was reduced to 0.22 kg by simply standardizing the calibration procedure. More precise calibration should be possible, but may not be warranted for this application.

#### SUMMARY

Continuous measurements of bedload are needed to overcome large sampling errors associated with highly variable transport rates. Because it automatically weighs sediment in the stream, the Birkbeck bedload sampler is perhaps the most practical method in use today for obtaining continuous records of bedload transport and its variation across a stream channel. At Caspar Creek, the water-filled pressure pillows, pressure transducers, and chart recorders of the original design (Reid, Layman, and Frostick, 1980)

were replaced with electronic load cells and data loggers. The electronic system requires less effort to operate and maintain, and produces very high-quality data with excellent time resolution. A centrifugal pump was used to empty boxes when they filled during storms, and an overhead I-beam was installed to facilitate weighing and subsampling of box contents after storms. Oversampling due to lateral entry of material into slot samplers should be recognized and avoided by experimenters measuring bedload transport rates. Our solution was to erect low-profile lateral fences along the slots, but their effect on hydraulics and sampling efficiency has not been tested.

#### ACKNOWLEDGEMENTS

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