



Soil retention capability of *Deschampsia caespitosa*, *Phalaris arundinacea*, and *Poa pratensis* upon exposure to flowing water  
by Curt Calvin Strobel

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Land Rehabilitation  
Montana State University  
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**Abstract:**

The health of riparian systems and establishment and development of riparian vegetation depends on streambank stability. Streambank stability refers to a bank's resistance to change and its resilience after change. It is a function of the soil composition of the bank itself and the type, amount, and vigor of vegetative cover. Streambank rehabilitation is best accomplished by planting vegetation to stabilize and protect the soil, rather than using rigid lifeless materials. Because many species of grasses establish more rapidly than woody vegetation, they may play an integral role in stabilizing streambanks.

The goal of this study was to determine the potential of tufted hairgrass (*Deschampsia caespitosa* (L.) Beauv.) (DECA), reed canarygrass (*Phalaris arundinacea* L.) (PHAR), and Kentucky bluegrass (*Poa pratensis* L.) (POPR) to stabilize degraded streambanks.

A stream flow simulator (SFS) was constructed to evaluate the ability of DECA, PHAR, POPR to retain soil in the root mass while exposed to moving water.

Forty-eight samples of each species were grown in a greenhouse for 120 days after which they were tested for soil retention capability. Each species was tested at bankfull and 65% below bankfull levels.

There was no significant difference in mean soil loss between DECA and PHAR or between PHAR and POPR, however, there was a significant difference in mean soil loss between DECA and POPR. There was no significant difference in mean soil loss between samples tested at bankfull flow compared to samples tested at below bankfull flow. Complete soil loss was observed in all unvegetated controls at both water levels which occurred within five minutes after exposure to moving water.

Rapid growing rhizomatous grasses seeded immediately after peak runoff subsidence are capable of stabilizing degraded streambanks so that slower growing woody vegetation can establish. Further testing may provide a basis for selection of grass species for use in streambank rehabilitation projects.

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APPROVAL

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Curt Calvin Strobel

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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## ABSTRACT

The health of riparian systems and establishment and development of riparian vegetation depends on streambank stability. Streambank stability refers to a bank's resistance to change and its resilience after change. It is a function of the soil composition of the bank itself and the type, amount, and vigor of vegetative cover. Streambank rehabilitation is best accomplished by planting vegetation to stabilize and protect the soil, rather than using rigid lifeless materials. Because many species of grasses establish more rapidly than woody vegetation, they may play an integral role in stabilizing streambanks.

The goal of this study was to determine the potential of tufted hairgrass (Deschampsia caespitosa (L.) Beauv.) (DECA), reed canarygrass (Phalaris arundinacea L.) (PHAR), and Kentucky bluegrass (Poa pratensis L.) (POPR) to stabilize degraded streambanks.

A stream flow simulator (SFS) was constructed to evaluate the ability of DECA, PHAR, POPR to retain soil in the root mass while exposed to moving water.

Forty-eight samples of each species were grown in a greenhouse for 120 days after which they were tested for soil retention capability. Each species was tested at bankfull and 65% below bankfull levels.

There was no significant difference in mean soil loss between DECA and PHAR or between PHAR and POPR, however, there was a significant difference in mean soil loss between DECA and POPR. There was no significant difference in mean soil loss between samples tested at bankfull flow compared to samples tested at below bankfull flow. Complete soil loss was observed in all unvegetated controls at both water levels which occurred within five minutes after exposure to moving water.

Rapid growing rhizomatous grasses seeded immediately after peak runoff subsidence are capable of stabilizing degraded streambanks so that slower growing woody vegetation can establish. Further testing may provide a basis for selection of grass species for use in streambank rehabilitation projects.

## INTRODUCTION

It is estimated that 70 to 90 percent of riparian ecosystems that were once present in the United States have disappeared (Council on Environmental Quality 1978). By 1988 the U.S. General Accounting Office's study of streamside management on public rangelands showed that in some states as much as 90 percent of federally managed streams were in a degraded condition. Continuing degradation has been attributed to industrial waste pollution, livestock grazing, farming, logging, mining, and urban development (Hunter 1991). As a result of disturbances to natural riparian ecosystems, an interest in conservation and rehabilitation of existing riparian zones has developed.

The health of riparian systems and establishment and development of riparian vegetation depends on streambank stability (DeBano and Heede 1987). Streambank stability refers to a bank's resistance to change and its resilience after change. It is a function of the soil composition of the bank itself and the type, amount, and vigor of vegetative cover (Bohn 1986). Rehabilitation of degraded stream channels has traditionally addressed bank stabilization through civil engineering methods and techniques. This may be due to the lack of understanding by many civil engineers of the benefits provided by established plants.

The application and effectiveness of conventional engineering structures such as gabions, revetment, riprap,

flow deflectors, and flow dividers are well known. However, Kohnke and Boller (1989) noted that these static structures are inflexible when stressed, cost prohibitive, and aesthetically displeasing. In addition, they fail to remove excess streambank soil moisture and cannot heal themselves when damaged. The most important fact to consider is that the use of static structures results in an unnatural stationary stream channel. Streambank erosion, channel meandering, bank sloughing, and flooding are natural processes (Lines et al. 1978) that produce a dynamic equilibrium within the stream ecosystem.

Schiechl (1980) suggested that we must learn to protect our environment by using nature as a working partner. Natural means of stabilization or bioengineering, places minimum reliance on mechanical or structural techniques, and maximum reliance on nature, aided by mankind (Lines et al. 1978). From this perspective, streambank rehabilitation is best accomplished by planting grasses, forbs, shrubs, and trees to stabilize and protect the soil, rather than using rigid lifeless materials. Furthermore, it is often less costly and easier to obtain immediate benefits through revegetation than through channel changes using artificial stream structures (Platts 1983). Vegetation protects streambanks by reducing the erosive energy of water, by trapping sediment that aids in maintaining the streambank, and by protecting the bank from damage by ice or debris flows and animal trampling (Platts

1983; Jackson and VanHaveren 1984). Large shrubs and trees with their extensive root systems provide bank stability. However, because many species of grasses establish more rapidly than woody vegetation, grasses may play an integral role in stabilizing streambanks. Grasses not only filter out sediment, reduce overland flow, and trap nutrients, but they also reduce the erosive effect of water long enough to allow woody vegetative species to become established.

The goal of this study was to evaluate the ability of tufted hairgrass (Deschampsia caespitosa (L.) Beauv.), reed canarygrass (Phalaris arundinacea L.), and Kentucky bluegrass (Poa pratensis L.) to retain soil in the root mass while exposed to moving water.

## LITERATURE REVIEW

Riparian Degradation

Accelerated erosion in stream systems can often be attributed to removal of vegetation (Lines et al. 1978; Monsen 1983; VanHaveren and Jackson 1986) through a variety of actions including concentrated livestock grazing, timber harvesting, and road construction (VanHaveren and Jackson 1986; DeBano and Heede 1987; Clifton 1989). Further degradation occurs from ice scouring, floods, rodent tunneling, gullying (Altpeter 1944), channelization, burning or spraying, urban development, and/or upper watershed modification (Lines et al. 1978). Such disturbances result in changes in vegetative composition and reductions in vegetative cover that can directly alter the structural integrity of streambanks and floodplains (VanHaveren and Jackson 1986).

Effects of Riparian Vegetation on Streambank Stability

Riparian vegetation is critical for reducing bank erosion and lateral channel migration (Clifton 1989). Vegetation is also essential for building and maintaining stream structure conducive to productive aquatic habitat (Platts 1983). Reclaiming degraded streams to support mature riparian communities composed of woody and herbaceous plants depends on rapid vegetative stabilization of deposited sediment (Skinner et al. 1985). Riparian vegetation supplies the floodplain with this protective stabilizing blanket (Altpeter 1944;

Platts 1983; Elmore 1985). Willows, grasses, sedges, and rushes reduce streamflow velocity causing sediment deposition (Platts 1983; Elmore 1985) into the vegetative blanket thereby contributing nutrients to streambank soil and increasing plant production and vigor as well as floodplain fertility. Vegetation overhanging the streambank also helps reduce flow velocity during floods. This leads to further sediment deposition and retention in the floodplain (Hunter 1991).

Riparian zones altered by widened channels, frequent channel realignments, and poorly vegetated banks and floodplains can be rehabilitated by reestablishing plants in the streamside zone (VanHaveren and Jackson 1986). Such vegetation protects streambanks (Monsen 1983; Jackson and VanHaveren 1984; Beschta and Platts 1986) by reducing the erosive energy of water (Li and Shen 1973; Platts 1983) and by trapping sediment (Schumm 1963; Andrews 1982; Platts and Rinne 1985).

#### Importance of Sedimentation in Streambank Formation

During floods streamside vegetation reduces water velocity and allows bank building through deposition of sediment (Elmore and Beschta 1987, 1988). Because sediment deposition is normally greater on the convex (inside) sections of banks than on the concave ones, revegetation of the convex bank (usually a point bar) causes sediment deposition which builds the bank to a height closely matching that of the eroding concave bank (Altpeter 1944; Platts and Rinne 1985).



In order for the banks of a stream channel to be maintained at a constant width over time, the rate of bank material erosion must be balanced by the rate of deposition (Andrews 1982).

While rapid deposition of sediment is usually associated with low growing forms of woody vegetation, a cover of grasses often serves the same purpose (Altpeter 1944). The filtering effect of riparian vegetation is partly responsible for deposits of fertile soils on many floodplains such as mountain meadows (Swanson 1989). Sediment filtration results in aggradation of the stream bed and banks (Clifton 1989). Once riparian vegetation becomes established, it not only traps nutrient-rich sediment but also acts as a "sink" for nutrients and sediment discharged from the surrounding ecosystem (DeBano and Heede 1987). Uptake of nutrients and stabilization of the stream channel by riparian vegetation improves the quality of water leaving riparian zones (Schumm 1963; Andrews 1982; DeBano and Heede 1987).

#### Soils and Streambank Stability

Streambank stability is further controlled by the composition of bank material, including both vegetation and sediment (Smith 1976). Differences in soil type are likely to account for differences in inherent bank stability. Streambanks with xeric soil types, composed typically of cohesionless sand and gravel, are much less stable than banks comprised of mesic or hydric types. Hydric types, mainly composed of silt and clay, are associated with the most stable

banks (Hackley 1989). Soil profiles on streambanks vary greatly. In some cases the soil material is homogeneous from the top of the bank to the bed of the stream channel. However, there can be considerable variation within the profile, representing changes in behavior and deposition by the stream throughout long periods of time. This will result in various degrees of bank stability. Heterogeneous streambank deposits may result in unstable bank conditions due to differing degrees of substrate cohesiveness. Planting vegetation on streambanks consisting of non-cohesive bank materials can provide stability and prevent bank collapse (Altpeter 1944).

#### Role of Roots in Stabilization

Severe bank erosion along impacted streams can be explained in part by the lack or absence of root systems which aid in soil stabilization (Groeneveld and Griepentrog 1985). The diversity of vegetative growth forms provided by trees, shrubs, sedges, forbs, and grasses, produces a variety of root networks capable of stabilizing deposited sediment. These root networks are especially important on unconsolidated alluvium (Elmore 1985; Elmore and Beschta 1987,1988). Large root masses reinforce deposited sediment by increasing tensile and shear strength of the bank soil mass (Groeneveld and Griepentrog 1985). Erosion rates drop with increases in root mass. Bank sediment deposits with 16 to 18 percent by volume of roots with a 5 cm root mat for bank protection had 20,000

times more resistance to erosion than comparable bank sediment without vegetation (Smith 1976). Dense bank vegetation reduces undercutting and helps build banks so channels typically become narrower and deeper where once they were wide and shallow (Elmore 1985; Elmore and Beschta 1987, 1988; Clifton 1989; Hunter 1991).

#### Establishment and Survival of Woody Species

Establishment of woody plants is critical in rehabilitating riparian areas (Volny 1984). Woody species often provide local channel stability and resistance to channel erosion allowing sedges, rushes, grasses, and forbs to establish (Elmore and Beschta 1987, 1988). Willows continue to be the woody plant of choice because they are usually readily available, easily established, grow rapidly, and provide more stability to the site than other woody plants (Monsen 1983; Schultze and Wilcox 1985). Thousands of cuttings have been established in Oregon, Washington, and California and are proving effective for bank stabilization (Lines et al. 1978; Schultze and Wilcox 1985); however, there have been failures or poor success with willow plantings. In California during 1978-80 and 1982, the leading cause of willow failure was heavy rainfall and runoff which uprooted cuttings before the plants became established. Additional causes of failure during this period resulted from subsequent drowning of cuttings planted too low in the streambed, breakage of cuttings due to high flow velocities, planting too

deep, and desiccation caused by planting on sites too far from the channel (Schultze and Wilcox 1985). Douglas (1987) noted that probable factors preventing seedling establishment of Setchell willow (Salix setchelliana Ball) adjacent to the channel of a Canadian river were water level recession after seed dispersal, inundation, and physical removal of fine substrate by strong currents. Inundation is harmful primarily when it occurs during the growing season. Maximum tolerance of willows to inundation is forty to fifty percent of the growing season, at least for initial establishment (Gill 1970; Kozlowski 1984).

The failure of woody plant establishment could be reduced by utilizing proven planting procedures. However, methods for interplanting woody species into established grass stands or recent seedings have not been fully developed and need further study (Platts et al. 1987; Skovlin 1984).

#### Effects of Grasses on Streambank Stability

Grasses form vegetative mats on streambanks which aid in reducing bank erosion and sloughing. Grasses, like woody species, cause sediment to settle out and build up banks during overbank flow events (Platts 1983; Platts and Rinne 1985). Grasses have traditionally been used to control sheet and rill erosion on bare soil during the establishment of woody plants (Lines et al. 1978). In terms of streambank stabilization, sodforming grasses may adequately protect the banks of low gradient streams (e.g. those flowing through

meadows) or ephemeral channels, but for many small streams this type of vegetation alone is inadequate to resist the erosional forces of flowing water. The fibrous root systems of grasses, once exposed to running water, can easily be washed clean of soil particles leading to rapid bank erosion. For many stream channels, root systems of woody vegetation in combination with grasses and forbs provide a better physical barrier to the effects of high velocities and turbulence by creating banks with considerable surface roughness and relative stability compared to the effects of grasses and forbs alone. The result is that channel widening and erosion at bends can be significantly reduced or eliminated (Beschta and Platts 1986) when a combination of grasses, forbs, and woody vegetation are established (Platts and Rinne 1985).

#### Artificial Bank Protection Structures

Artificial channel and bank protection structures can also enhance riparian development. Bank protection structures are used for armoring banks, and for deflecting or separating flows. Armors are designed to keep banks in their present location; flow deflectors are used for eliminating erosional impacts on critical banks; and separators divide streamflow into high and low energy sections with the low energy flow moving adjacent to the bank (DeBano and Heede 1987). These structures can impact riparian zones both beneficially and adversely (Altpeter 1944; Beschta and Platts 1986; DeBano and Heede 1987; Elmore and Beschta 1987, 1988).

Altpeter (1944) noted that on extreme curves it was necessary to dispense with vegetation on the outside bank and resort to rock placement to stabilize the bank. Permanent protection of the toe of the bank by rock riprap was often necessary along straight channel reaches, as well as on outside banks.

Where bank protection structures are installed, lateral incremental stream adjustments cannot occur (Beschta and Platts 1986; DeBano and Heede 1987). This locks the stream channel into a fixed location resulting in a static stream channel (Elmore and Beschta 1987, 1988). However, many biological systems are dependent on normal channel and floodplain adjustments associated with systems in dynamic equilibrium (VanHaveren and Jackson 1986). Because stream systems are dynamic (Beschta and Platts 1986), natural channel function involves a mobile bed and localized fluctuations in channel geometry about a long-term stable average (Andrews 1982; Jackson and Beschta 1982). Only after a new stream equilibrium has been reached, can new riparian plant communities establish on sediment deposits (DeBano and Heede 1987).

Artificial bank protection structures do not directly obstruct the channel, but by deflecting or separating streamflow may affect nearby riparian sites. Channel aggradation induced by structures may be of such magnitude that existing riparian areas become buried (DeBano and Heede

1987) due to a wide range of flow and sediment transport conditions (Beschta and Platts 1986). Therefore, if an in-stream structure is large enough to cause deposition of most of a stream's sediment load, erosion in downstream riparian zones may result because the sediment-free water has sufficient energy to pick up new sediment (Beschta and Platts 1986; DeBano and Heede 1987). Beschta and Platts (1986) noted that since bank protection structures are not dynamic, major rock works such as spur-dikes, revetment, and riprap, which are relatively permanent features, are undesirable for enhancing fish and wildlife habitat.

It is important to avoid excessive rigidity in rehabilitating stream-riparian systems in order to allow the biological processes associated with dynamic equilibrium to proceed (VanHaveren and Jackson 1986). Structures are often installed in streams where they are not needed because we rarely allow several years of vegetation recovery before identifying where in-stream structures will provide the greatest value. Installing permanent instream structures in rangeland riparian areas without changing vegetation management is counterproductive in the long run. Therefore, spending large amounts of money to build instream structures will seldom solve riparian problems and may only allow managers to sidestep difficult decisions (Elmore and Beschta 1987, 1988).

Maintenance of instream structures is necessary to insure that they continue to function properly. Frequently, once instream structures are funded and built, additional funding for annual or periodic maintenance is lacking (Beschta and Platts 1986). Therefore, it is usually easier and less costly to rehabilitate streambanks using vegetation than by using artificial stream structures (Platts 1983, 1985).

#### Riparian Research Needs

Little research has been initiated to reclaim streams and riparian zones to promote subsurface water storage, control non-point source pollution, and answer questions related to water rights and demand for new supplies downstream (Skinner et al. 1985). Methods and techniques for revegetating to achieve high establishment rates and reduced plant mortality have not been adequately evaluated (Platts et al. 1987; Skovlin 1984). In addition, evaluation of individual plant species to provide optimal streambank stability requires further study (Lines et al. 1978). There are adequate investigations and reports in the literature that demonstrate the importance of maintaining quality riparian habitats, but, these investigations fail to address the methods necessary to rehabilitate riparian environments. Future study should be directed toward determining how to rehabilitate these habitats once they are degraded (Platts and Rinne 1985).

The goal of this study was to evaluate the ability of tufted hairgrass, reed canarygrass, and Kentucky bluegrass to



retain soil in the root mass while exposed to moving water. This research will begin to address the question of which grasses are adequate for the needs of the riparian rehabilitation scientist.

## MATERIALS AND METHODS

Controlled Environment

This investigation was carried out in a controlled environment in the Montana State University Plant Growth Center. Daytime temperatures were held relatively constant at 21°C while night time temperatures were maintained at 13°C. These temperatures fall within the minimum and maximum temperature range for sustained shoot (16°C to 24°C) and root (10°C to 16°C) growth (Beard 1973). Supplemental lighting was used to insure a constant day length of fourteen hours, the average day length for Bozeman, Montana from April through September (Caprio et al. 1990).

Species Description

Deschampsia caespitosa (L.) Beauv. (Hitchcock 1971) (Appendix A) is a native species better adapted to high elevations typically ranging from 1900 to 3000 meters (Youngblood et al. 1985). It is a densely tufted, shallow rooted perennial reproducing primarily from seed (Best et al. 1971). Stands are common on poorly drained soils and in areas that are seasonally flooded (Hansen et al. 1988). Some researchers believe that many tufted hairgrass community types at high elevations have been replaced by Kentucky bluegrass (Franklin and Dyrness 1973; Hansen et al. 1988; Padgett 1981). The change in community dominance type from tufted hairgrass

to Kentucky bluegrass has been attributed to poor grazing practices (Franklin and Dyrness 1973).

Phalaris arundinacea L. (Hitchcock 1971) (Appendix A) is a robust, native, deep-rooted species (Evans 1946; Booth and Rumely 1989) that spreads by short vigorous rhizomes. Stands typically occur on wet or poorly drained soils (Alberta Agriculture 1981). It tolerates more water during the growing season than any other cultivated grass yet withstands short summer droughts. New seedlings are successfully established in early spring. This species is also easily established by pressing sod or stems with "joints" into wet soil (Hafenrichter et al. 1968).

Poa pratensis L. (Hitchcock 1971) (Appendix A) is an introduced, shallow-rooted, rhizomatous species (Weaver 1920; Evans 1946; Youngblood et al. 1985) that is a major community type at low to mid-elevations throughout the Rocky Mountain region. It is a common component of the driest riparian communities (Hansen et al. 1988) typically found on well drained, fine textured soils (Youngblood et al. 1985).

These species were selected for testing in this study based on their different rooting forms. They are also common components of riparian communities in southwestern Montana.

#### Procedures

A stream flow simulator (SFS) shown in Figure 1, was constructed to evaluate the ability of tufted hairgrass, reed

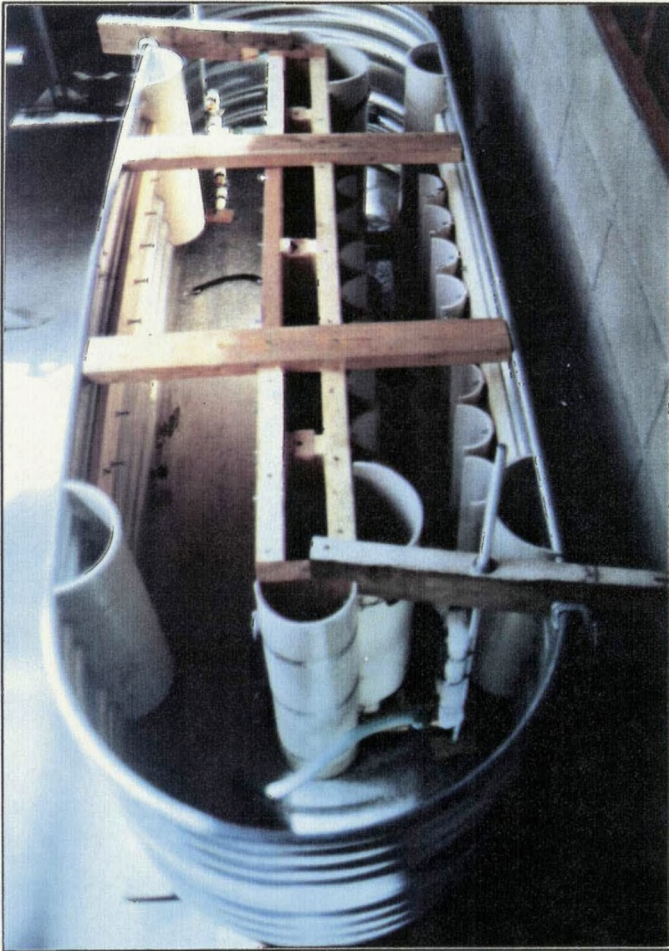


Figure 1. Streamflow simulator.

canarygrass, and Kentucky bluegrass to retain soil in the root mass while exposed to moving water. Artificial streamflow was created by attaching two 0.5 horsepower submersible pumps to a jet system (Figure 2). The system was calibrated to achieve a maximum flow rate of 0.97 m/sec which is the magnitude of flushing flow recommended by Wesche et al. (1986).

Flow velocity was measured with a Montedoro-Whitney Corporation PVM-2 portable velocity meter. Velocities in the SFS ranged from 0.43 m/sec measured at the slowest end of the channel to 0.98 m/sec measured at the fastest end of the channel.

Each species was tested at bankfull and at 35% of bankfull levels. These flow levels were chosen because bankfull flow is the discharge stage that is the dominant control for changes in stream channel morphology (Petts and

Foster 1985), and below bankfull is the discharge stage which appears to have little influence on bank stability (Andrews 1982).

#### Trial Streamflow Simulator Run

Ten soil/root cores (10 x 38 cm) of each species were collected from representative stands found at three field locations. Tufted hairgrass samples were gathered from the bank of the Taylor Fork of the Gallatin River, 22.5 km south of Big Sky, Montana, reed canarygrass from the bank of Rocky Creek 1.6 km north of Bozeman, Montana, and Kentucky bluegrass from the bank of Cottonwood Creek 24.1 km north of Ennis, Montana.

Nine samples of each field collected species were weighed and then placed in 10 x 38 cm PVC containers (Figure 3), loaded into the SFS (Figure 4), and tested at the bankfull level. Samples were exposed to moving water in the SFS for twenty-four hours. Observations were made hourly by carefully feeling the soil column of each sample to detect soil loss. Visual examination was impossible due to the turbidity of the water. After twenty-four hours the cores were cautiously removed and allowed to drain for one hour before being oven dried at 75°C for twenty-four hours. Soil loss from each core was calculated as:

$$\text{soil loss} = \text{initial dry wt.} - \text{final dry wt.}$$

expressed in grams.

The data collected from the trial run were used for a



































































































