# CHAPTER 2

## FLUVIAL EROSION PROCESS AND FIELD MEASUREMENT TECHNIQUES: AN OVERVIEW

*Muhammad Nda[1,2], Mohd Shalahuddin Adnan[1*], Mohd Azlan Mohd Yusoff[1],*
*Onemayin David Jimoh[3] and Mohammed Saidu[3]*

[1]Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia,
Parit Raja, Batu Pahat, 86400 Johor, Malaysia.
[2]Civil Engineering Department, School of Engineering Technology,
The Federal Polytechnic Bida, Niger State – Nigeria.
[3]Civil Engineering Department, School of Engineering and Engineering Technology,
Federal University of Technology Minna, Niger State, Nigeria.
*Corresponding author email: shalahudin@uthm.edu.my

**Abstract**

Fluvial erosion is the detachment of soil particles from the riverbank or bed by the action of numerous factors including land use, vegetation geomorphology, soil properties and climate change. There are various techniques currently available for measuring riverbank erosion at broad range spatial and temporal scales. Riverbank erosion measurements are vital in the documentation of riverbank erosion and deposition. Measurement of riverbank erosion could provide several important information that could be used for various functions, especially in river corridor management. Various measuring techniques have been implemented with varying degrees of success. This paper highlights and discusses different methods, emphasising on their operating principle, merits, and demerits as well as their field application. The measuring techniques include erosion pin, survey, erosion painting, photo electronic erosion pin (PEEP), photogrammetry, and lidar technology. The selected methods discussed in this chapter could help researchers and or practitioners in predicting or evaluating riverbank erosion of a given study area.

***Keywords—; Fluvial system, riverbank erosion, erosion measurement, sediment contribution***

## 2.1 Introduction

Fluvial is a common term used in defining the processes regarding sediment conveyance or transfer from one location to another within a system in rivers and streams, as well as erosion and deposition within the system [1]. Similarly, riverbank degradation is a process resulting from the combination of erosive water power (stream power) as well as the effects of gravity. The dynamic nature of the river system is prone to changes due to prevailing conditions of geology, topography, vegetation, water level, and climatic change [2]. These result to changes in the river channel modifications such as; geometry, channel slope, and the river morphology [3]. The occurrence can be during a flash flood event or over a sequence of many years. Also, geomorphic reactions such as; channel widening, bank instability, physical habitat degradation, and other geomorphic reactions can enhance riverbank erosion process. Bank erosion constitutes a significant problem in the fluvial system, as about 90% of the total amount of a catchment sediment yield is generated from it [4]. Erosion due to water action is experienced when the stream power is at its all high during peak flows. Sediment erodibility is dependent on the opposing frictional force [5]. Friction resistance to particle movement in non – cohesive sediment is influenced by particle size, shape, and density [6].

On the other hand, the resistance to erosion in cohesive sediment is primarily influenced by the strength of the cohesive bond of the particles [7]. The formation of riverbank can be described as a composition of bedrock with low erodibility during a particular period, or of sediment that is extremely erodible and could result in severe engineering and environmental problems [8-9]. This calls for increasing concern in the world today as usable land is loss to riverbank erosion. According to Curran and McTeague [10], private properties including a major regional highway and farmland in Alaska were eroded by Matanuska River. The next property and landowners are left with the financial and physical burden of either repairing or replacing the damaged properties.

Erosion prevention cost can also be enormous, recently $116 million was budgeted for erosion and flood control by the Alberta regional government to provide a means of repairing damages from 2013 floods and prevention of future reoccurrence [11]. The huge expense involved in putting up erosion prevention and or mitigation measures necessitate coming up with viable techniques and strategies to prevent or stop activities identified to cause or accelerate erosion. Therefore, many management concepts and measuring techniques using conventional methods and new techniques have been developed to ascertain riverbank erosion rates, to mitigate soil loss and sediment transport within the river channels.

### 2.1.1 Riverbank Erosion Process

Sediment load and watershed hydrology can be influenced by human activities, which results in rapid adjustments of the river channel, as well as enhanced bank erosion rates and lateral channel migration in the river dynamics There are three central bank erosion processes classified as follows;

slumping, mass failure and Direct hydraulic action [12–15].

- Mass failure; is a critical factor that occurs whenever a large slab of material detaches from the riverbank and slides to a lower position (Figure 2.1). This occurs primarily when the critical height and angle of the bank is surpassed. The vulnerability of a riverbank to mass failure depends on the structure, geometry and properties of the riverbank soil.

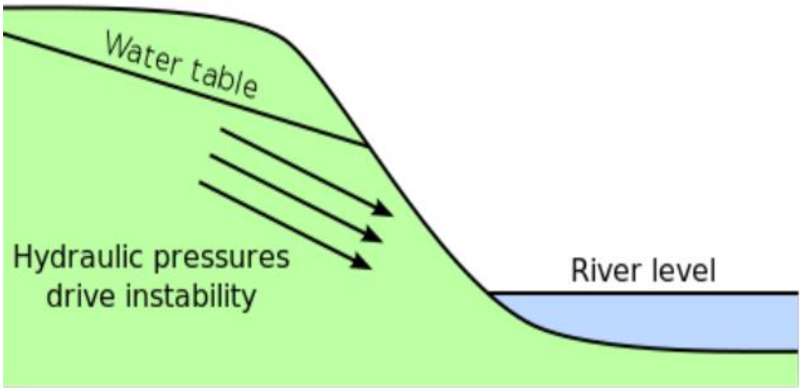

Figure 2.1: Mass wasting resulting from rising river stage [16]

- Slumping; Riverbank collapse due to the gravity-driven movement of sediment blocks down slope. Soil moisture condition of riverbanks is link to slumps and the undercutting of the toe or the lower bank due to direct hydraulic action (Figure 2.2). Clay saturation reduces cohesion, which can lead to slumping. Seeping, piping, and sapping of water through a cohesive bank decrease the internal resistance of the particles, which can cause bank failure. Saturation of riverbanks after peak flows, leading to high pore pressure can be responsible for bank failure or collapse. A significant amount of sediment is deposited to a river at a time due to slumping.

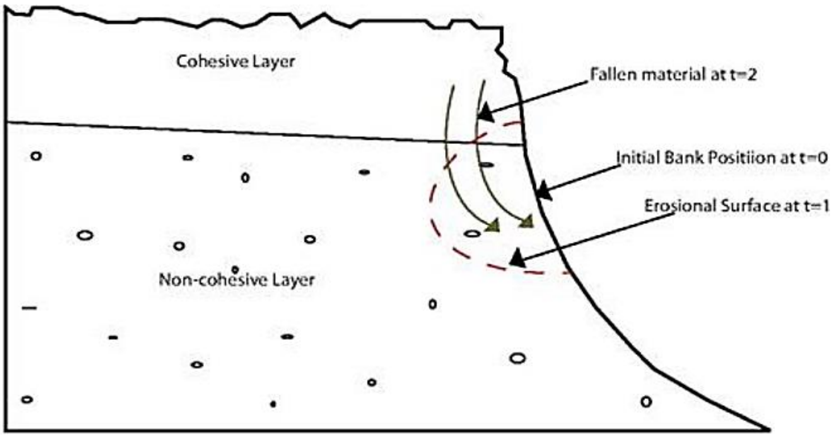

Figure 2.2: Slumping resulting from undercutting of riverbank [16]

- Direct hydraulic action; This is the process by which erosion of the riverbank is caused by the direct impact of flowing water on the bank. Hydraulic action is a function of stream power or shear strength. Though, because of frost action and slumping work concurrently in tandem with hydraulic action. The riverbank erosion amount will no longer be a simple function of stream power. These three processes efficiency all depends on the level of sediment saturation, repeated rainfall, and peak flow events can have a severe effect on the bank, causing more erosion than one off-peak flow of high magnitude. Classically, hydraulic action cut banks in the lower region. Upper bank region is removed by slumping because of lower bank region undercutting. Slumping of the upper bank that falls in front of the lower bank will serve as a blockage for the lower bank region and may for some time prevent the section from further eroding until such a time the blocks themselves are eroded. The riverbank retreat due to hydraulic action is illustrated in Figure 2.3.

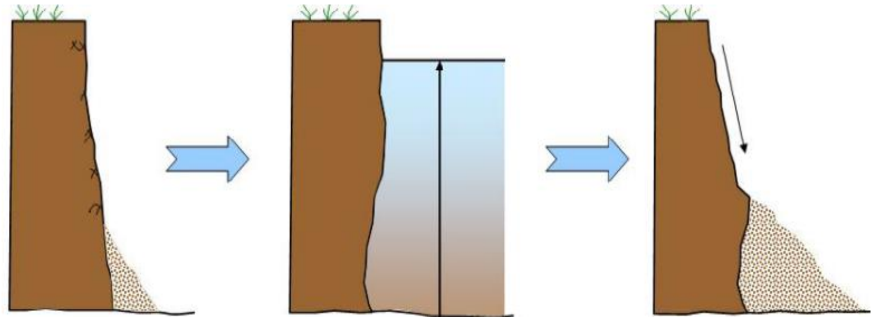

Figure 2.3: Riverbank failure resulting from mass failure and hydraulic action [16]

### 2.1.2 Factors Influencing Riverbank Erosion

Riverbank vulnerability to erosion can be influenced by the type of riverbank material, shapes, sizes and stratigraphy [17]. Riverbank with sand and gravel as its major components are more susceptible to erosion whereas riverbanks composed of more cohesive particles like silt and clay are less susceptible. The bond between clay-size and other fine-grained particles is strong and are referred to as cohesion. The particle geometry and electrostatic attraction between the particles determine the degree of cohesion [18]. Cohesive materials detached as bulk and often referred to as a mass failure of many individual particles, in contrast, non-cohesive materials is detached as entrainment of the individual particle [17]. However, many alluvial riverbanks are characterised by different components of cohesive and non-cohesive materials. The horizontal arrangement of their layers can influence the erosion rate of a riverbank. For instance, riverbanks with low layer composition of non-cohesive materials, which commonly erodes faster than the cohesive materials, this often leads to an undercutting of the riverbank that is more vulnerable to erosion than a riverbank with a moderate slope [19]. Asides riverbank material composition the moisture content of the riverbank material also plays a vital role in the rate of erosion. Other factors that influence riverbank erosion are:

1) **Catchment urbanisation**; this increases the total runoff rates and erosive energy in the channel resulting in river channel complexity decrease and river channel depth and width enhancement [20]. Uncontrolled livestock grazing can enhance riverbank erosion [21]. Besides, livestock in-stream trampling can cause the instability of the riverbank resulting in an incision. Also, trapping ability of sediment by channel and riverbank vegetation is reduced by livestock grazing in-stream. Peak flows can be increased by soil compacted during livestock grazing and trampling leading erosion in downstream reaches of a river. Channelisation and removal of riparian areas in rivers lead to excess transport capacity and riverbank instability [22-23]. River channelisation also decreases sinuosity and in turn, enhance the velocity of water, which provides higher power to erode the riverbank and bed deposits [24].

2) **Land clearing and tree logging**; are also factors which influences the stream stability and enhances riverbank erosion rates. Mean temperature of a catchment can be altered downward by tree logging, thereby increasing frost and needle ice occurrence on the riverbank substrate resulting in a loss of inter-ped cohesion [25-26].

3) **Riverbank vegetation;** riverbank failure can result from removal or lack of vegetative cover of a riverbank leading to higher evaporation which results to high moisture contents and excess pore pressure causing the failure of the riverbank [25]. Complimentary to this, riverbank materials cohesion can be enhanced by vegetation. Vegetation provides the necessary roughness, which reduces the flow turbulence and affects bank stability, thereby reducing the turbulence and velocity near the riverbank, and these ultimately reduce the erosion. Riverbank material cohesion is also improved by vegetation leading to a reduction in riverbank vulnerability to erosion. Equally important is the ability of vegetation to provide a means of drainage, thereby protecting the riverbanks from erosion due to wetting or moisture content of the riverbank [27]. It is also important to note that some vegetative covers do not serve as a means of stabilising a riverbank. A study by Trimble [28] suggests that forested riverbanks can distort river channels form, and that grassed channel riverbanks stored between 2,100 $m^3$ to 8,800 $m^3$ more bank sediment than forested segments. Despite this, vegetation can cause riverbank instability due to additional weight from mature trees, which increase the creeping of soil from the riverbank into the river channels [29].

### 2.1.3 Riverbank Erosion Contribution to Sediment Load

The relationship between riverbank erosion and sediment load in a fluvial system can be estimated by knowing the amount of eroded riverbank materials and sediment load [30-31]. Several techniques can be used to evaluate annual riverbank erosion rates. The conventional techniques used in measuring riverbank erosion include; erosion pins, survey and photogrammetry, photo electric erosion pin, painting, which involves taking a repeated measurement of erosion over a period. The sediment (particles) detached by erosion and deposited into the river channel amounts to a contribution to both suspended and bedload sediments [18].

Russell *et al*. [31] suggests that riverbank erosion is a leading contributor of suspended sediment concentration in specific catchments. There is a high percentage variation in suspended sediment contribution due to riverbank erosion from one river to another (Table 2.1). The rate of riverbank erosion is different from one segment of the river reach to another and are characterised by spatial variability based on features of a catchment. Stream power, which is a product of discharge and slope is a vital parameter that affects the spatial variability of riverbank erosion rate. It is arguably to say, the rate of riverbank erosion is expected to accelerate where stream power is high with an erodible substrate [32-33]. Earlier studies also opined that lower segments of alluvial rivers with lower gradient are prone to highest rates of riverbank erosion due to mass failure events [34]. Catchment local geology can influence rates of riverbank erosion, i.e., rock outcrop and presence of natural gravel armouring in the river channel can reduce erosion rates in segments where they are available [35-36].

Table 2.1: Contribution of riverbank erosion to some rivers

| **River** | **Catchment area ($Km^2$)** | **Type of land use** | **Riverbank sediment contribution (%)** | **Reference** |
|---|---|---|---|---|
| San Diego Creek, California | 288 | Urban | 66 | [28] |
| River Seven,England | 380 | Urban | 17 | [37] |
| Gelbaek Stream | 1200 | Urban | 92 | [38] |
| St. Lawrence River, North America | 1000 | Urban | 65 | [39] |
| Blue Earth River, Minnesota | 9028 | Agricultural | 31-44 | [40] |
| River Aire, England | 1,004 | Urban | 43-84 | [41] |
| River Torridge, England | - | Agricultural | 23 | [42] |
| River Frome, England | 437 | Agricultural | 7-19 | [43] |
| River Piddle, England | 183 | Agricultural | 7-21 | [43] |
| Forth corb, Oklahoma | 800 | Urban | 46 | [44] |
| Valley Creek, Pennsylvania | 60.6 | Urban | 43 | [45] |
| River Kennet, England | 214 | Agricultural | 31 | [46] |

### 2.2 Riverbank Erosion Field Measurement

Rivers are known to perform these three sediment related activities; transportation, erosion, and deposition. Landform deposition and erosion is caused by aforementioned activities [47]. Erosion is a phenomenon that continuously occurs naturally without warning and indicators; it has been recognised as a genuine issue for decades. It is projected that erosion will pose even more severe challenges in the future because of uncontrolled development. The natural evolution of erosion and sedimentation have been in existence all through geological time and have been responsible for the shape of the present landscape of the earth [48]. Water bodies do receive particles and sediments from degraded riverbed due to riverbank erosion. The river channel particle combined with the riverbank materials would cause their interconnection separated by the action of water flow. The materials (particles) transportable will start moving and deposited in the downstream section of the river [49]. This process could result in severe engineering and environmental problems. Therefore, many management concepts and measuring techniques using conventional and new methods have been developed to ascertain riverbank erosion rates, to reduce soil loss and sediment transport within the river channels. The sections below describe methods of measuring riverbank erosion, operating principle, and studies that employed the use of the technique. Table 2.2 presents an overview of each technique, operating principle, merits, and demerits.

Table 2.2: Summary of riverbank erosion field measuring techniques

| **Technique** | **Operating principle** | **Merits** | **Demerits** |
|---|---|---|---|
| Erosion pins | Installed pins exposure or deposition are measured | Low cost, sensitivity and simple set up | Spatial sampling difficulties, error due to pin movement and pin loss |
| Survey | Repetitive cross-sectional measurements | Easily set up and inexpensive. | Established benchmark stability issues, requires on-site personnel |
| Erosion painting | Monitoring painted surface after erosive events are analysed | Erosive events are easily noticed, easy setup. | Unreliable and requires on site personnel. |
| Photogrammetry | Captured pictures are converted to DEMs and analysed | Multiple angles capturing possible, availability of image processing software. | Capturing clear images is very challenging and expensive. |
| Photo electronic erosion pin (PEEP) | Sensor cells exposure to light are measured | Continues quasi-time series change measurement, automatic measurement system | Relatively expensive as more than one unit is required for measurements |
| Lidar Technology | Short light pulses released by laser scanners reproduced by earth surface are analysed | Wide range of coverage from multiple angles | Areas with dense vegetation are prone to have voids. |

## 2.3 Erosion Pins

The fundamental principle of erosion pin technique remained mostly the same since the early studies by Ireland and Wolman in 1939 and 1959 respectively. A measured rod length (galvanised iron) is firmly introduced into the riverbank (areas prone to erosion) leaving out a visible small measured portion. As the riverbank erodes, more rod protrudes out. Measurements are taken from the end of the pin (probably from painted calibrations on it or from some suitable engravement) to the bank surface using Vernier calliper. Measurements are taken at close intermissions and or during high flow to record riverbank particle removal. Increased pin exposure is registered as an indication of erosion, while the decrease of pin exposure is assumed to indicate accumulation [50-53].

The erosion pin technique is mainly limited to measurement of riverbank retreat, rather than overland erosion measurement. The technique's acceptance was rapid all through the '70s. Most earlier users were geomorphologists working on British sites even though the initiative was from the United States of America, i.e. [54–56]. The technique as the following merits: (i) suitable for a wide range of fluvial environments; applied in an extensive fluvial climate and geomorphological works, (ii) Simplicity; A single person can install, maintain and record measurement of a network of erosion pins there is no need for a specialized equipment, (iii) Low cost; Setting up an array of erosion pins is not expensive, (iv) Sensitivity; Small amounts of bank retreat can be detected (as small as a millimetre). Thus, pins are particularly appropriate for the measurement of retreat for the small river where bank retreat rates are likely to be low. Temporal and spatial bank retreat patterns may be of crucial importance to process inference and can be measured with a closer – knit pin arrangement, which can be measured more often [57].

Similarly, the technique is characterised by the following demerits: (i) Difficulties in Spatial sampling; Proper care must be taken in deriving volumetric, or gravimetric bank retreat estimates as the technique is point specific, (ii) reading interpretations; measurement errors may arise if the river bank surface contract or swell relative to rod stability, (iii) Pin movement; Movement of pins during measurement may lead to errors in values of bank retreat,(iv) Pins loss; In the cause measurement period, sometimes pins are entirely eroded out or wholly covered by sediment deposits. In this event, no reading is possible [57].

### 2.4 Survey Technique and Erosion Painting

Survey technique relies on the repeated measurement of a riverbank cross-sectional surface for a minimum of two separate times. The difference in the measurements taken is compared, and erosion or deposition is evaluated from it. Survey technique is characterised with some errors, the two primary sources of error are; (i) The technique itself is accompanied with specific precision and accuracy, (ii) Identification of established stable benchmark point over time which will not affect measurements outcome is sometimes challenging. The overall accuracy of the result obtained using this technique relies on the availability of established, high-quality benchmarks. The technique is easy and inexpensive to set up, many early researchers who focused on river bank erosion [51], [58-61] have deployed survey method to measure erosion with acceptable satisfactory results.

On the other hand, erosion painting as the name implies is painting a surface and monitoring it after every erosive event, in a bid to acquire records of spatial erosion distribution of the study site. Recently, studies, including those by Surian *et al.* [62] and Dietrich *et al*. [63] used paint on sediment patches in streams to see whether floods will move them. Similarly, Gill and Lang [64] used paint applied in a dotted manner on a rock to detect an appropriate location for a more detailed study. More importantly, Beer *et al.* [65] in their study compared erosion patterns shown from paint removal to those obtained from repeated topographic measurements and resolved that erosion painting technique is cheaper, quicker, and can provide quantifiable necessary information on erosion patterns over possibly large areas.

### 2.5 Photogrammetry

The advent of several technologies over the last two decades has given rise to quick high-resolution field topographic measurements. Laser scanners can obtain so many data points within the possible shortest time. There are many photogrammetry techniques available to use a hand-held camera to capture a picture and convert same to excellent quality topographic data by free available software's [66]. Besides, many drones that serve as carriers for cameras are now largely available, for example [67-68]. The use of photogrammetry to produce digital elevation models (DEMS) out of satellite and aerial images have been on for a while now.

Nevertheless, despite great heights achieved by photogrammetry in a wide range of areas, it has limitations in erosion measurements. Only substantial amounts of failure, i.e. mass wasting, could be constrained due to relatively low resolutions of the DEMS and their accuracy. Also, obtaining excellent quality cloud-free images covering the erosion-prone areas at the right time could be difficult and expensive. However, comparison of DEMS obtained before and after an erosion event form the bases for calculating erosion or deposition that occurred in an area [69–71].

### 2.6 Photo Electronic Erosion Pin (PEEP)

Photo – Electronic Erosion Pin (PEEP) sensor is an automatic erosion monitoring technique initially developed by Lawler [72-73] to assist in reducing measurement difficulties. PEEP is a waterproof transparent rod consisting, a vertical row of photosensitive cells connected in series all enclosed within the 16 mm acrylic waterproof tube with 2 mm wall thickness as illustrated in Figure 2.4. The device is self-powering containing an array of 10 visible – light photovoltaic cells. The voltage generated by sensors is proportional to the length of the PEEP array exposed to light. Light variations are normalised by a single reference cell [74]. The PEEP sensor is partly inserted vertically on erosion-prone sites and connected to a data logger for automatic recordings. Eroding of surface exposes more cells to light, thereby causing the device voltage output to increase, while deposition reduces outputs [75-77]. The magnitude, frequency, and timing of an erosive or deposition event are revealed in the logged data [78].

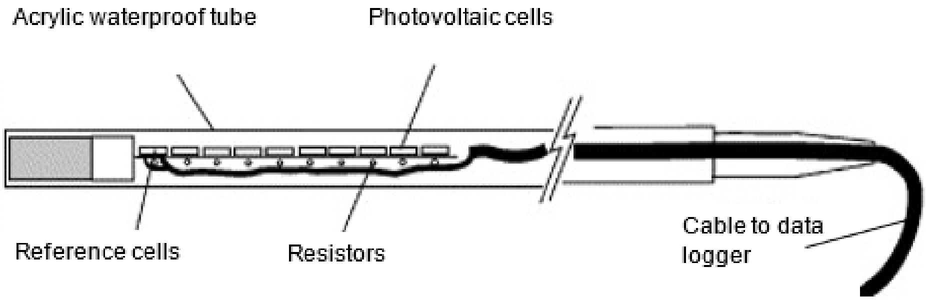

Figure 2.4: Photo Electronic Erosion Pin Sensor (PEEP) [75]

Photo Electronic Erosion Pin (PEEP) among its equal a lead, in providing quasi-continuous time series changes and the first to offer bases for elevation change comparison on a time scale between minutes to hours. The technique also has some drawbacks; (i) non-satisfactory resolution for small-scale measurements and observed scouring around the instrument due to hydrodynamics disturbance, (ii) fouling over sensors may occur over long deployments and (iii) relatively high cost of the device as more than one unit may be deployed [79].

## 2.7 Lidar Technology

Light detection and ranging (Lidar) technique is relatively new for a digital model generation with high spatial accuracy and resolution. The technique employs the use of laser carriers which could be ground-based (tripod) or airborne (aircraft) to quantify erosion [80]. Aircraft serve as carriers of laser scanners that releases light pulses reproduced by the earth surface. The range between the earth surface and the aircraft are measured using the flight time between pulse release and detection, putting into consideration the high speed of light. The inertial measurement unit (IMU) and a differential global positioning system (GPS) is used in ascertaining the aircraft position and orientation. A scanning device covers a strip on the ground. The 3D coordinates of the laser scanner points on the ground are determined by the combination of GPS, IMU, range and beam deflection measurements. Laser scanners are typically characterised with 100,000 KHz pulse rate, outputting a 3D point cloud. Most of the instruments used in Lidar allows registration of multiple reflections of one emitted pulse if different objects are hit. Digital terrain models (DTM) are generated from the last return, while forest canopy models may be generated from the first return. Removal of vegetation and artificial objects from data are achieved through filtering during DTM generation. Processing Lidar data is characterised by a high degree of automation and reliability in DTM generation when compared to other stereo or multi-image matching [81–83].

Lidar technique also presents a few constraints and disadvantages; features been surveyed may have data voids created from vegetation roughness, which is called shadows. Shadows are eliminated by scanning the feature from various angles. However, in study areas with dense vegetation, other techniques that may be more effective should be used. Large datasets to be processed pose a significant challenge and most times require unique software that requires high earn computer formations. Software packages used are numerous (e.g., Cyclone, RiScan Pro, Poly works) without a standard format. Data transfer between software packages are not easy because of compatibility issues [84].

## 2.8 Studies on Riverbank Erosion

This chapter aims to put forward valuable information regarding selected techniques used in measuring riverbank erosion to serve as a guide for researchers and practitioners in choosing suitable field measurement technique. Several measurement techniques are described in previous sections, highlighting their mode of operations, merits and demerits. This section presents an overview of previous research work carried out using the different measurement technique as presented in Table 2.3.

As presented in Table 2.3, Boardman *et al.* [85] monitored ten study sites subjected to overgrazing for at least one century (1850 – 1950) and still grazed by sheep in the Sneeuberg upland of the eastern Karoo in South Africa. Using an array of 25 metal erosion pins, taking measurements for approximately one year between March and December. The erosion rates result for the study sites range from 3.1 to 8.5 mm $yr^{-1}$ and extrapolate to 53 to 145 t ha $yr^{-1}$. The result obtained from the sites is considered quite high compared to other erosion rates around the world. However, direct comparison of erosion rates results with other sites [86–88] is difficult because of variations in measuring techniques, climate and lithology.

Similarly, the erosion pins were also used by Hart *et al.* [88] to measure erosion rates in residual limestone soils in two sites for ten years and four years, respectively. The average erosion rate measured over ten years was 20 mm $yr^{-1}$ at one site (convex divides) and 5 mm $yr^{-1}$ at another site with chert gravel surface (gullies) over four years. Comparing the average erosion rate reveals that of the convex divides to be significantly higher than the gullies, implying control by different processes, some of which may be periodic. The authors observed that the frost action during winter formed a thin layer of loose soil on the surface of the convex divides and in summer transported to the gullies either by rain splash or dry gravel.

Table 2.3: Summary of previous studies on riverbank erosion measurement

| Title | Study Location | Technique used | Author |
|---|---|---|---|
| A 13-year record of erosion on badland sites in the Karoo, South Africa. | Sneeuberg upland of the eastern Karoo, South Africa | Erosion pin | [85] |
| Measuring erosion rates on exposed limestone residuum using erosion pins: a 10-year record, | Highland rim, middle Tennessee, USA. | Erosion pin | [88] |
| The measurement of riverbank erosion and lateral | Review Paper | Survey technique | [51] |

| | | | |
|---|---|---|---|
| channel change: A review | | | |
| Graffiti for science-erosion painting reveals spatially variable erosivity of sediment-laden flows | Swiss Alps, Switzerland | Erosion painting | [65] |
| Volumetric measurement of riverbank erosion from sequential historical aerial photography | Kaipara catchment, New Zealand | Photogrammetry & Lidar Technology | [89] |
| Bank erosion of an incised upland channel by subaerial processes: Tasmania, Australia. | Tasmania, Australia | Photo Electronic Erosion pin (PEEP) | [90] |

A review of riverbank erosion and lateral channel change by Lawler [51] suggests that the use of survey technique in riverbank measurements yield acceptable results. Likewise, comparison studies by Beer *at al*. [65] between erosion paint and repeated topographic measurements confirmed the ability of erosion paint technique to provide visible quantifiable erosion pattern over a large area. Spikermann *et al.* [89] measured bank erosion rates using photogrammetry techniques side by side with light detection and ranging (Lidar) to collect data at five river reaches. Historical aerial photographs between 1950 and 2015 are used, and results show that the erosion rates within that time frame for the five rivers is between 0.14 m yr$^{-1}$ and 0.21 m yr$^{-1}$ and are within the same level with previous measurements in New Zealand.

Prosser *et al.* [90] studied riverbank erosion process in an incised channel for two years. Detailed bank erosion measurements were carried out using photo electronic erosion pins. The result reveals the bare bank eroded at 13 ± 2 mma$^{-1}$, meaning subaerial processes that loosen bank controls erosion. Thus, river flow is unable to detach cohesive clays from river banks, and erosion is largely confined to the accessibility of loose materials. Moderate grass cover can prevent bank erosion to a large extent by reducing the subaerial erosion processes. Based on previous studies, it is clear that each measuring technique has its comparative advantage and limitation in assessing riverbank erosion.

## 3 Conclusions

Human and anthropogenic activities are identified as significant causes to changes in watershed hydrology and sediment load, which enhances geomorphic adjustments of river channels. This adjustments within a river system accelerate riverbank erosion, thereby increasing the sediment load due downstream. Therefore riverbank erosion process is considered a significant contributor to sediment load in a river system. The need for accessible and reliable riverbank erosion data is essential in ensuring proper and adequate management of the river system. There are many techniques in the measurement of riverbank erosion available for researchers and practitioners to choose from. The choice of a technique to be used will be based on suitability of application, availability of the equipment, budget considerations, human resource, result quality and others.

Erosion pins appear to have widespread usage because of its comparative advantage in terms of easy setup and cost even though it has its drawbacks. However, further research and refinements are necessary to reduce major technique drawback. Most practitioners and researchers believe simultaneous use of more than one technique may yield better results.

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