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A review: Removal of sediment in water reservoir by using Siphon

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Abstract. Reservoir was the main sources in order to get basic needs in daily life but due to human activities the quality of water environment affected. A reservoir ordinarily formed by the construction of dam to store water. The most commonly purposed of this reservoir is to provide flood control, supply water for domestic purpose and to generate hydroelectric power. Reservoirs provide the most effective control for unexpected floods when reservoir waters levels are low, so that excess runoff can be storage. However, trapping sediments have been identify due to some of the environmental damages. Reservoir sedimentation is a very serious problem that will cause capacity reduction and water quality deterioration. This paper provides a framework to understand deeply the principles of siphon and to improve the design of the siphon to remove the sediment in reservoir.

1. Introduction

Reservoir is a place where water is collected or is a lake that is used for storing large amount of fresh water before it supplied to people. A barrier is construct across a river forming a pool of water where water can be stored on the upstream side of the barrier. It also known as dam reservoir or impounding reservoirs or storage reservoirs or river reservoirs. This reservoir produces several benefits including flood control, water supply, hydro power generation and others. As time passes, sediment continue to fill in the reservoir and reduce the surface area for recreation. In addition, all levels of the reservoir affected by reservoir sedimentation accumulation [1]. The deposited sediment in the reservoir is extremely problematic nowadays. Therefore, this study will focus on siphon to investigate the efficiency of reservoir sediment removal. Nevertheless, the flow velocity of stream flow decreases when the stream flow impounded in the reservoir. Thus, sediment was deposit in reservoir, which rapidly reduce the storage capacity also has an environment impact. This means that sedimentation deposition causes 20 larges reservoir has lost 8 billion m³ of storage capacity in China were described [2]. Figure 1 show that



a delta was form at the end of the upstream reservoir by coarse deposited sediment while finer particles deposited farther at the downstream of the reservoir. As shown in figure 1, presented delta was divide in two slopes, which is topset slope and front set slope. Topset slope at the upper slope of the delta and the steeper slope is known as front set slope [3].

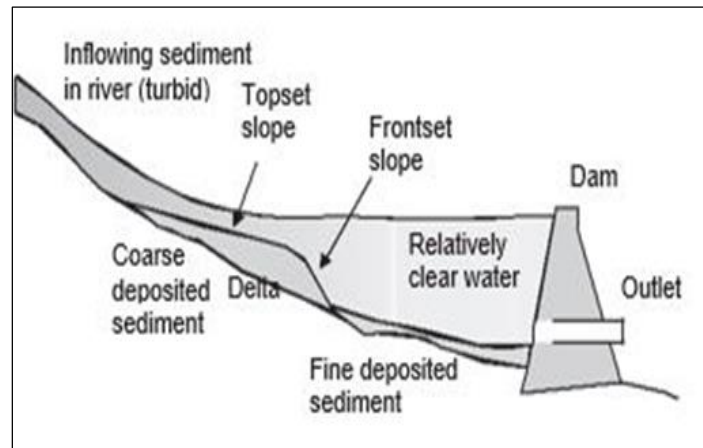


Figure 1. Delta formation from deposited [3].

Annually range between 0.5% and 1% of reservoir storage estimated to loss due to sedimentation deposited [4]. This means that to maintain the reservoir storage that already exist in this world further action must be carefully plan. It would give negative impact to all dams in the next 25-50 years if there were no strategies for reservoir sedimentation control [5].

1.1. Soil erosion

Soil erosion may occurred due to anthropogenic activities and it also a naturally occurring process. Some of the human activities causes environmental pollution such as land levelling, crop harvesting, and agricultural land. Besides, other researchers investigated one of the main causes of soil erosion was major land usage. Although there has been some of the research recognized anthropogenic activities as a major problem since 2007 that is more than 50% of land destroyed [6]. Generally, deforestation are the causes of soil erosion that mean cutting down the large area of forest as open area. As shown in figure 2, the large area will expose to heavy rain directly affected to the soil [7]. The soil is easier to lose and easier to erode without the roots of the tree which can cause flash flood or soil erosion. There is no doubt that human activities have resulted in large amounts of soil erosion in the world.

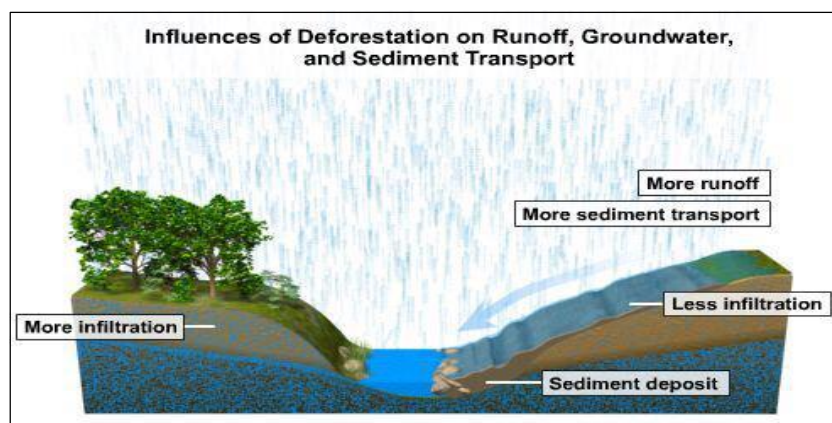


Figure 2. Influences of deforestation and sediment transport [7].

Other than that, sediments yield was form depending on soil erosion in the catchment. It is important to reduce this problem, as the sediments will go through into the reservoir and affected water supply. Reported that human activities give drastic impacts on topography and soil erosion by land levelling activities like terracing for expand the cropland areas.

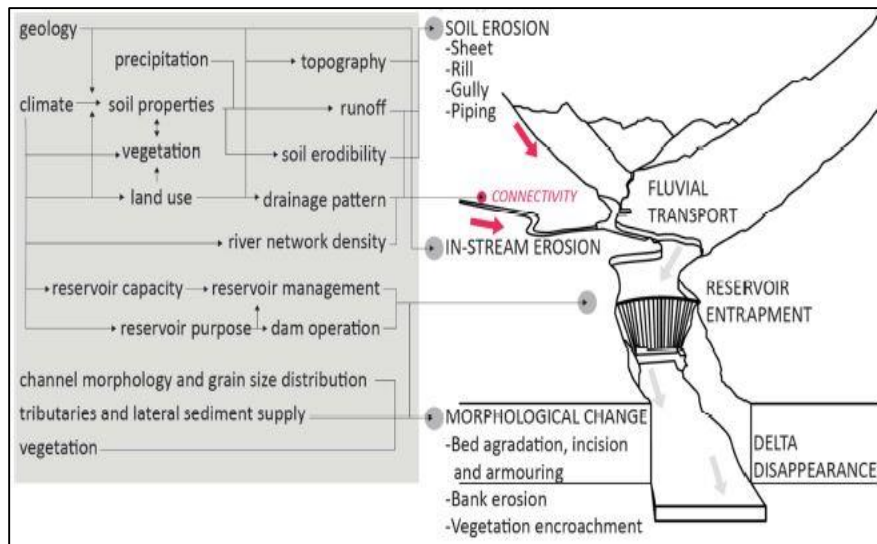


Figure 3. Conceptual figure between soil erosion and sediment entrapment and their factors [8].

The arrows, bold red and grey as shown in figure 3 above signalize sediment mobilization and fluxes. Hence, in order to identify subsequent sediment fluxes and potential erosion site both topography and morphological in the catchment play an important rule. Water flow downwards on the catchment towards the steepest slope. The flow network of the catchment define flow direction for each point of the catchment area.

2. Sedimentation

Sedimentation is an unavoidable phenomenon occurred in all reservoir. Sedimentation is a process of allowing suspended materials or particles such as silts or clay in water by gravity. The sedimentation in reservoir causes several major problem mostly in water supply. However, there is a wide range of sediment management techniques or mitigation around the world but some regions are use different technique due to geographical and climatic area that was studied by some researcher [9]. It was mentioned poorly design intake structure is one of the causes South Africa facing sedimentation problem [10]. In this case, to ensure the continuous water supply from the reservoir some mitigation was apply to remove the sediment. To achieve long-term sustainability, there have several strategies to manage reservoir sedimentation. The reservoir sediment management classified in three categories as methods as to reduce sediment delivery from watershed, to minimize amount of sediment and removal of deposited sediment. These three categories have several sub-techniques are illustrated as figure 4 [11].

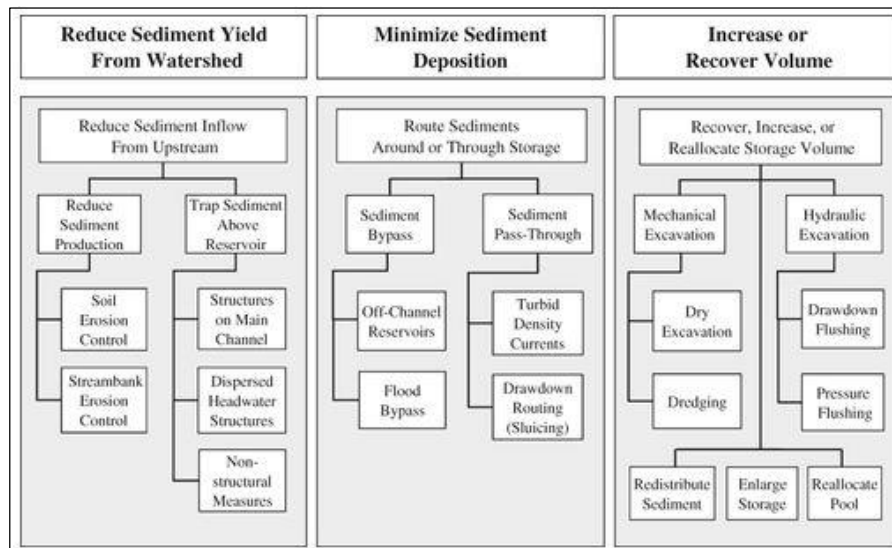


Figure 4. Classification of strategies to manage reservoir sedimentation [11].

Therefore, an appropriate design of the intake structures minimized the problem of sedimentation in reservoir. Various strategies have been studied and applied for reservoir sedimentation control.

2.1. Sedimentation process and reliability concept

Sedimentation process in all water bodies occurred naturally. All river contain sediment and deposit the sediment loads in the water of reservoir where sediment accumulation may give negative impact. Researcher observed that suspended particles begin to settle out with a wide range of particles in the form of bed or suspended load when flowing into the reservoir [12]. In the reservoir, the heavier sediment particles will deposited first in the upstream of the reservoir whereas fine sediments is carried farther into the reservoir downstream of the reservoir in the form of suspended load. River usually carries the sediment particles depends on some factors, which are the flow and volume of water and size of the sediment particles.

Between precipitation in the mountain and flooding in the floodplains there have hydrological link forming by the catchment of water from the catchment [13]. River system can be defined as a continuous process of energy conversion. Water is transport to the catchment outlet when kinetic energy was convert from potential energy at the top of the catchment. Therefore, sediment deposition processes occur during the altered hydraulic geometry reduces energy for the sediment transport. From figure 5, the large sediment will be deposited first at the beginning of the reservoir known as delta while the smaller sediments depositing at the bottom of the reservoir or as the reservoir continues to deepen.

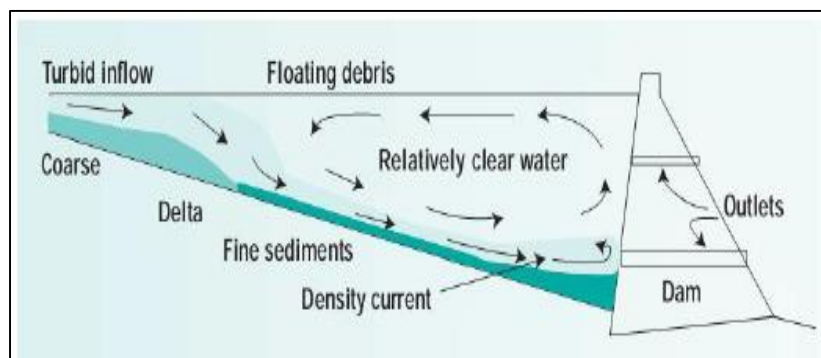


Figure 5. Reservoir sedimentation process [13].

In order to improve the sedimentation problem, there have some methods or techniques that need to understand. In design of a reservoir, the most important factors that must be considered is the distribution and the density of the sediments also the mean annual sediment. The texture and size of deposited sediment has significant effect on the density of sediment in reservoir. Sediment deposit such as silt and sand have higher density compare to clay. For information, it is interesting to know sediment classification that was propose as shown below [14].

Table 1. Classification of sediment according to size.

Sediment type	Size range (mm)
clay	<0.004
silt	0.004 to 0.062
sand	0.062 to 2.000

Observation from previous study shows that active storage is the portion of the reservoir can be used to control natural inflows and as a water storage to prevent flooding or can be described as reservoir reliability, which perform all the required function. Some factors of reliable reservoir is storage (S_t) also known as active storage that collect or store a volume of water at time (t) above the minimum level. The range of active storage (S_t) are between zero to maximum value c depends on reservoir size. Excess water will flow through the spillway during flood that will reach the above normal limit c . This is more preciously known as flood control storage. Besides, two situations are called as dead storage or inactive storage when water storage below the minimum level. These situations provide volume sediment accumulation and to protect habitat of the reservoir in the dry period. Other than that, net inflow X_t is sum of cumulative inflows, from $t-1$ to time t , minus losses at the same time. Inflows to the reservoir is mostly from rainfall and other sources. Losses occurred from evaporation, seepage and leakage under dam. Water demand δt is sum of the water requirement for different uses provided by the reservoir ($t-1$, t). Water demand may depend on seasonal agriculture and quantity of water. Meanwhile, release R_t is an actual amount water from reservoir to fulfil water demand during time period ($t-1$, t). The release, R_t equal to water demand, δt ($R_t < \delta t$) when the reservoir has sufficient amount of water. Another factor is spill, W_t , which is excess water during flood, cannot be stored in the reservoir due to above the limit c of reservoir size [15].

3. Basic of siphon

Siphon have been used in industry for many years and quite important or useful for variety applications. There are several definitions of a siphon. The word siphon is come from Ancient Greek, which known as pipe or tube. A siphon or also called as syphon is a device that liquid will flow through the tubes or generally is a tube which water can be moved from a reservoir to another level point. Other than that, a siphon as a tube or a pipe allowed liquid or water to move from higher level to lower level by atmospheric pressure. It also capable in raising water over the barrier, which make siphon interesting and highly useful in reservoir system, [16]. In classical word, a siphon is an inverted tube, which bent into “U” shape causes liquid to flow upward. Once siphon have been inserted into the reservoir it will carry the liquid from higher level of reservoir with no pump and fall down maintained by gravity and atmospheric pressure when the level is lower than surface reservoir level. From another theory, the gravity will pull down the liquid from reservoir to the exit of siphon causes low pressure at the top of the siphon. The pressure in liquid system is due to weight of the liquid [17].

Siphon is a very important in waterworks and industry, transferring water and evacuate water. Generally, a siphon work occurred due to differences between liquid in upper reservoir and lower reservoir by gravitational potential energy. Figure 6 below shows some of the siphon characteristics that can be figured out easily by considering mathematical relationship. The atmospheric pressure at A and

B are same with both the top container and the bottom container open to the atmospheric. Liquid from container A was forcing by atmospheric pressure to container B and decrease in the conduit by the pressure, ρgh . The density of the liquid known as ρ where h is the height of the conduit above the liquid level of A and g is the acceleration due to gravity. While the atmospheric pressure will forcing the liquid from B to A and decreases by pressure of the conduit, ρgh where h is the height of the conduit above liquid B, [18].

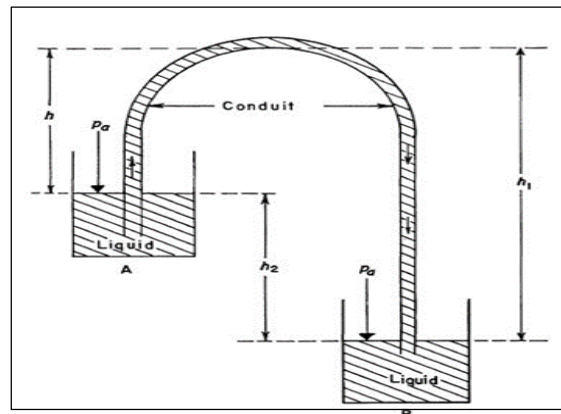


Figure 6. Principles of siphon [18].

3.1. Siphon components

Some features need to consider during design process which it will affect the discharge of the siphon [19]. Siphon pipe material is one of the important things in design process to ensure the operation is going well. Each material can be found in wide range of size and some of the basic information for siphon pipe materials shown in table 2.

Table 2. Siphon materials option.

Pipe Material	Considerations
HDPE	Very flexible, which can eliminate the need for bend fittings. May not be readily available in some locations. Pipe is buoyant and will float if measures are not taken to weight the pipe down.
PVC	Bend radius of pipe can be used to eliminate fittings. Can be bell/spigot jointed for good seal.
STEEL	Very common, most pipe suppliers will have a quantity in stock. Usually the least expensive option due to availability. Weld joints would be best for air tightness but time consuming and may be expensive.
CMP	Pipe is capable of withstanding large pressure differentials. Relatively heavy creating difficulty in transport and set up. Relatively expensive. Typically not a good choice because of difficulty obtaining an air tight seal, hydraulic capacity and more difficult to set up.
ALUMINIUM PIPE	Could be a good choice to transport outlet water to better downstream location to reduce erosion and effect of dam embankment. Often readily available. Pipe collapsing strength is minimal and should only be used if lift is minimal.

Most of the materials option are cost effective, economical and easily built. To ensure the siphon function well, the inlet of the siphon must be properly construct to prevent air entering the siphon while the outlet should be submerged in the water to avoid air entrapment in the siphon.

3.2. Types of siphon and its applications

Usually there are many types of siphon with different shapes and materials used. The design criteria of siphon need to understand either the siphon is appropriate for the specific site. Siphon have some types that commonly used which are 'N' shape and 'M' shape. As shown in Figure 6, the entire 'N' shape of siphon has same diameter compared to 'M' shape of siphon, as the liquid will flow from the higher level of the tube to the lower level.

Figure 7 below show 'M' shape of siphon. The size is longer than 'N' shape of siphon, which is very effective to carry the sediment. As increasing the inlet diameter, the velocity inside the siphon will increase to remove the sediment easily through the siphon.



Figure 7. 'M' shape of siphon [20].

Other researcher has conducted an experiment with different types of suction head to compare sediment removal efficiency with different suction head. Plain-type suction head and wedge-type suction head was use in the experiment. According to the result, wedge-type suction head was chosen, as it is the best efficiency option. The diameter of the float tank was doubled than the suction head diameter directly gave the best effect of suction head. In a case presented, the discharge and sediment removal efficiency of siphon suction increased due to the increasing of suction head diameter [20]

Referring to other study, a self-siphon pipe are used in the experiment and is divided into seven segments in order to study the influence of length for each segment which has straight segment and bent segment. This study was using molecular dynamic (MD) method implementing Euler method to predict whether fluid can flow to each segment. Water velocity decreases when fluid flow through the self-siphon mostly into the semi-circle bend pipe where there is a friction force, [21]

Siphon system invented with different scale and its using square edge and rounded inlets. It consists inner siphon pipe and sliding outer pipe with flange and keep the distance between flanges and sediments properly to remove the sediments effectively and continuously. The sediments will suck by the siphon when the negative pressure arisen between the flange [22].

4. Conclusions

As a conclusion, this study attempted to understand the technique and to improve the design of the siphon in order to remove the sediment in reservoir. This method has potential to remove sediments and it does not pose any significant impact especially regarding safety. The relatively low cost and its constant removing sediments operating without fuel, electricity or pump. Compared to other methods such as hydraulic dredging, dry excavation and flushing method it was the most effective method to remove sedimentation. The method could be used to analyse a wide variety of problems with much more positive implications for sustainability of water supply.

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