Experiences with Lake Sedimentation in Assabol Reservoir Three Years after Completion of Dam

This document shall help to share our experiences in struggling for an optimised water management and sediment flushing with other people of the world, and especially with Ethiopian engineers and Ethiopian scholars/students. This paper complements the findings of the thesis of my son Andres Strebel (summer rains 2006, refer attached document). Based on intensive observations of lake behaviour (including photo monitoring) and in comparison to land shaping processes observed in the rivers of the upper watershed, I take the (scientific) risk of making forecasts, based on very little data available.

The lake is created by a concrete arch dam of 42 m height and stores a volume of approx. 1 million cubic meters between the gate at level 1822.50 m and the crown of the dam 1842 m above sea level. The reservoir is small in relation the annual inflow (5% in average). Without regular flushing, the live storage would be as low as 8 years only.

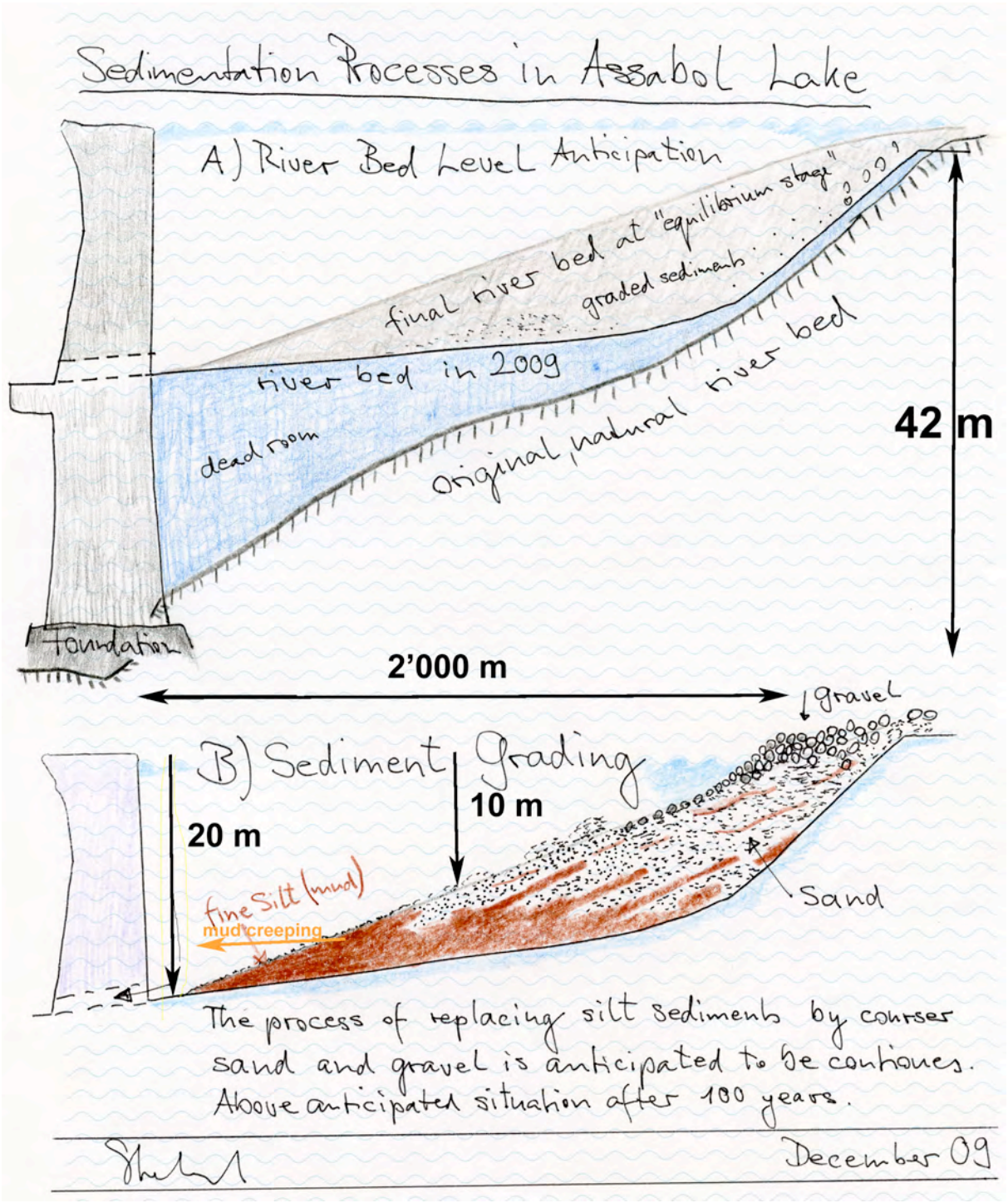
The lake is equipped with a sluice gate and a diversion tunnel, i.e. with a 1x1.25 m door in the dam at 20 meters lower than the crown, what allows to fast empty the lake and to let pass surplus flow without longer retention. By keeping open the gate for several weeks during first half of summer rains, 60% of hydraulic flow passes the reservoir under mostly drawdown conditions and washes out sediments by forming a retrogressive incised channel (gully in the sediments). This has washed out during the past three years 50% of the sediments. As steeper the valley becomes due to ongoing accumulation of the other 50% of the sediments, the ratio of out-washing will further increase. Finally, after twenty or so years, an equilibrium between sediment accumulation and sediment erosion will occur in the reservoir.

The sediments eroded, transported and deposited consist to 90% or more of very fine sand and silt. The rest consists of organic particles, sand and gravel. The silt stems mostly from surface dust covering the entire watershed. Flood water contains approximately 50 grams of suspended sediments per litre, thereby this average amount varies drastically (for details refer attached thesis of Andreas Strebel).

Acting forces for the transport of sediments are mostly streaming water mobilised by gravity, and to a much lesser extend density currents under water. In addition, surface wind waves and their washing effect play also their small role. Finally, it is assumed that bubbles of bio-gas (Methane gas) are promoting the mud creeping and the forming of a flat mud cake in front of the dam, besides the low consolidation properties of the water saturated silt.

The size of the gate is limited, because of financial and transport limitations. The gate can only discharge a small proportion (5 to 10%) of a bigger flash flood, what leads to the creation of temporary back water, lasting several hours. This reduces the flood level downstream and promotes water saturation of the sediments, what increases erodability and bank slumping. Negative is the reduced flushing and sluicing effect.

The construction of a second diversion tunnel remains an option in case the loss of storage would be much higher than anticipated.



Schematic, longitudinal profiles with anticipated sedimentation of lake Assabol

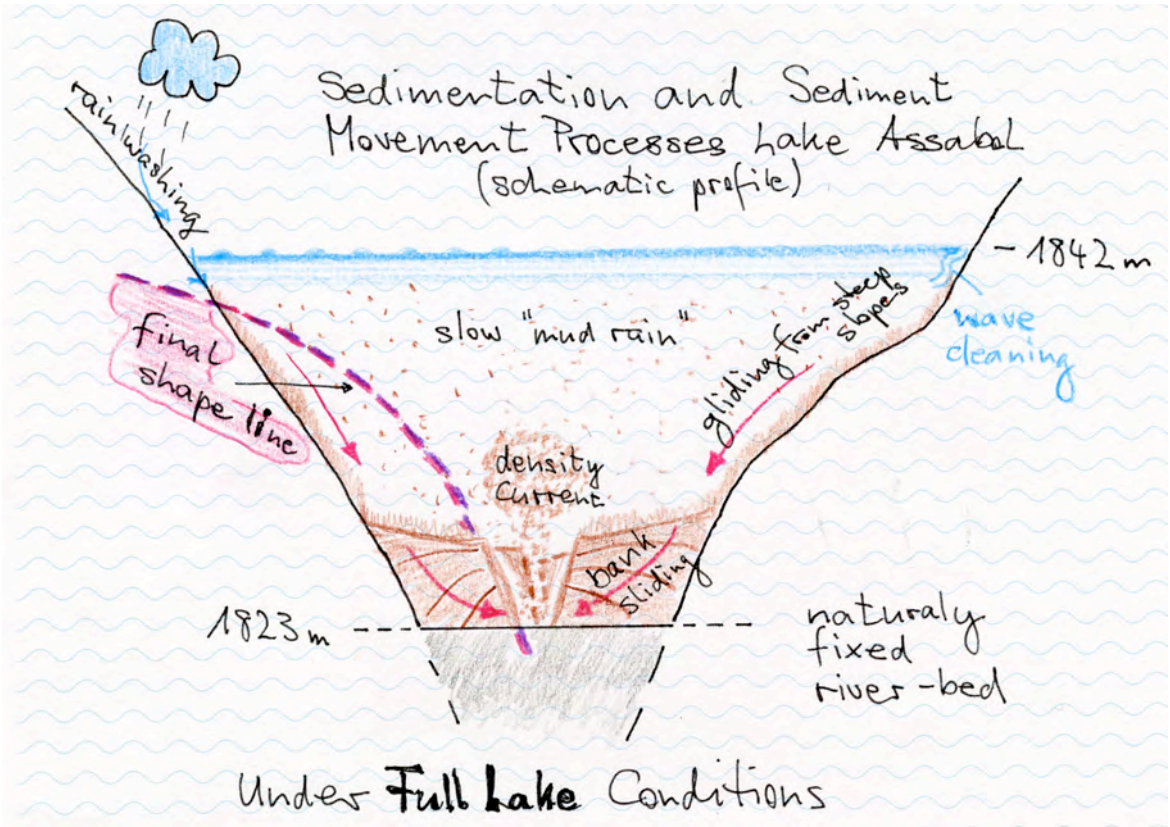
The present sedimentation processes can be described as follows:

1. At the mouth of the lake (upper part), dynamic flood events happen occasionally. Today, the former cascading gorge has a constant riverbed lifted by two to three meters by new gravel and sand accumulation. The hillsides

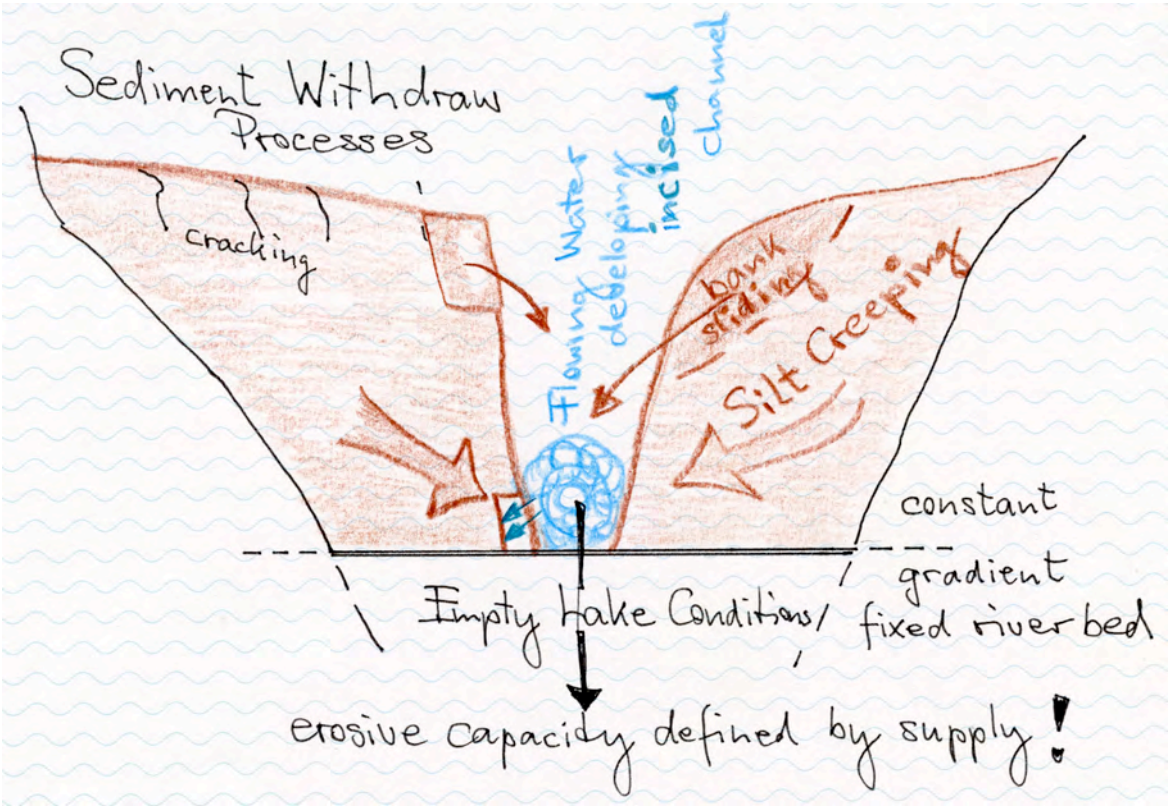
(slopes) remain free of sediments. It is anticipated, that this shape can be maintained under regular flushing operation. During the past three years, two bigger deltas have developed, however, both have been again washed down into the middle part of the reservoir. The relative narrow channel is best exposed to flushing with flood water, and always free of backwater during periods of open gate.

2. The middle part of the lake will gradually fill, until the riverbed will reach level 1931 m asl. In addition, the northern bay tends to build up stable banks, reducing gradually lakes' surface and volume. In addition, gravel and sand deposits will replace fine silt deposits. This place will become the meeting place between the retrogressive incised channel and the delta formation. Forecasts on land changes are difficult, and sudden mass gliding will also play its role. In addition, human land reclamation efforts have to be anticipated and will also play its shaping role.

3. In the part of the lake up to approx 300 m in front of the dam the mud cake tends to creep or flow, and will fill the lowests parts of the lake by a cake of semi-liquid mud. The erosion of the incised channel will maintain a relatively constant amount of mud deposits in this part of the lake.



Schematic Cross Profile with Silt Sediment Processes in the middle and lower part of the reservoir ***during filled lake***



Schematic Cross Profile with Silt Sediment Processes in the middle and lower part of the reservoir ***during drawdown of lake: incised channel development***

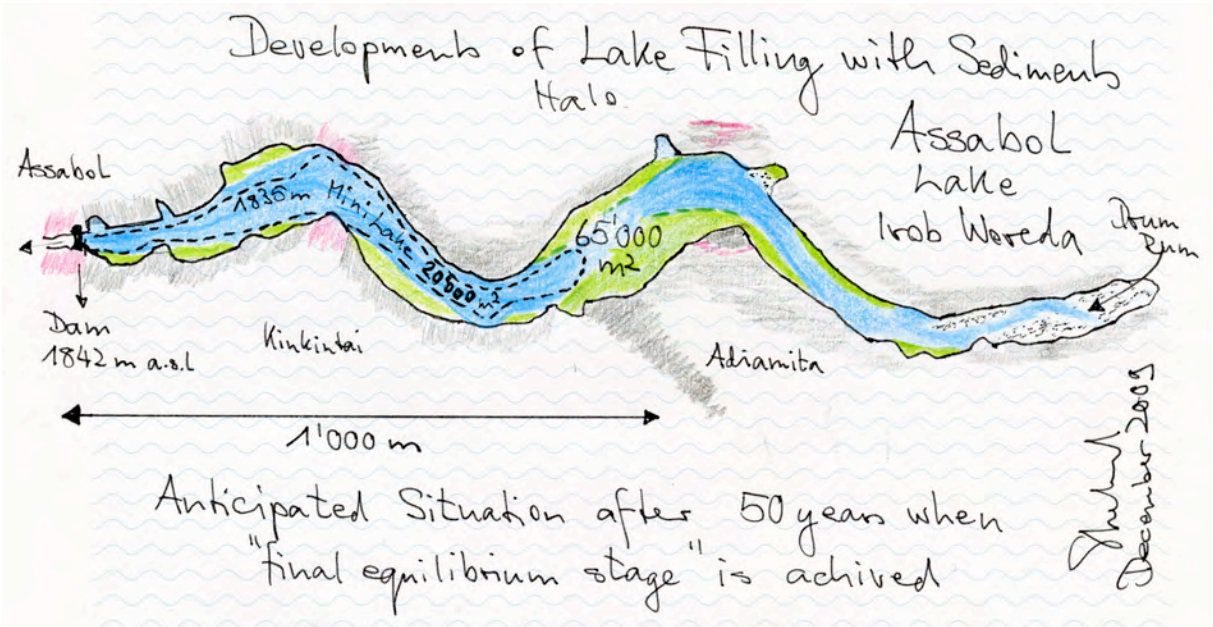
Estimated and Anticipated Sediment Balances

Year Western Calen-dar	Sedimen-tation	Outwashes	Balance-Trapped materials	% of reservoir volume losses	Remarks **Estimation based on simple measurements**
2006	125000	70'000	55'000	7%	Results ob Master Thesis Andres Strebel
2007	12000	0	120'000	22%	Gate blocked
2008	12000	80'000	40'000	27%	Proper flushing, little rain
2009	12000	70'000	50'000	33%	Wood Blockage, reduced flushing
2010	110000	100'000	10'000	34%	**Anticipated** Impact of road construction on gravel transport reduced.
2011	110000	100'000	10'000	36%	Upper catchment check dams extended.
2012	130000	120'000	10'000	37%	Intensified incise channel building (due to gradient growth)
2013	140000	130'000	10'000	38%	Mere anticipation
2014	110'000	120'000	-10'000	37%	
2015	130'000	90'000	40'000	42%	
2016	110'000	120'000	- 10'000	41%	
2017	110'000	130'000	- 20'000	38%	Near to equilibrium.

The washing-out or **flushing effect** is mostly determined by the erosive forces building the incised channel (flushing channel). This retrogressive acting gully digging of the river occurs mostly in the lower half of the reservoir, where sediments are fine (mostly fine sand and silt) and soil bank gliding occurs. This washing out leads to density flows with a ration of 2 water to 1 mud, and one single flood event can easily flush out 20'000 m3 by a 1'000 meter long new channel, as observed several times. As higher the banks will grow, as more sediments will be provided to the flushing water, both finally reaching a first stage of equilibrium.

Until now, the sluice gate operation was limited to opening at beginning of Summer Rains and closing towards the end. This creates downstream a new river-eco-system: Floods are reduced in size and prolongated in duration, the sediment content is reduced, what washes out the river bed. During the aftermath of the flood low water carries a lot of sediments, what is completely different to former years when clean river flow occured 24 hours after the flood has passed. Today, the flushing water under open gate conditions creates soil banks in the river bed, what offers new opportunities for land creation (e.g. by using pipes to transport saturated water to fields).

In the longer run trials have to be made, to open the gate only during limited time of the flood, and to permit flows with very high sediment contains. This could make soil collection for downstream lands even more attractive.



Situation with anticipated shape and volume of reservoir after 50 years

Photo Sequence with view from Dam towards Reservoir

2005, dam body (under construction) at the level of the sluice gate

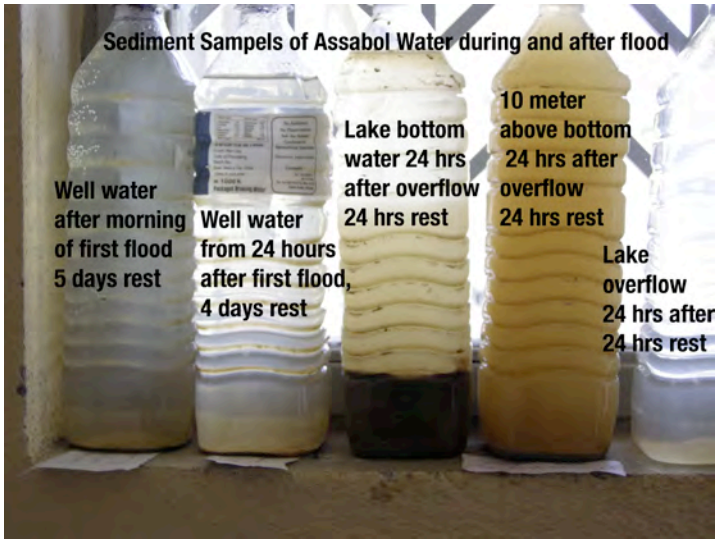
August 2006, Gate always open, dam height 33 meters

Mud Cake after Gate Blockage during Summer Rains 2007

Dried sediments from summer 2007, in November 2007

August 2008, shortly before closing of sluice gate

August, 2009 (observe reduced amount of sediments when compared with 2008)



Various water samples revealed a high stratification of lake water, changing within few hours and that the intake water is good enough for pipe flow.

Delta sediments from year 2007 washed completely out during only one medium flood in early July 2008

exfiltrating water 800m upstream from dam Bruno Strebel January 2010