Feasibility Study

Final Report, June 24th 2013

Sediment Management of John Compton Dam

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Executive Summary

John Compton Dam and Roseau Reservoir in St. Lucia are affected by severe long term sedimentation, increased by recent sedimentation impacts of a hurricane induced flood. As the reservoir represents the major drinking water storage capacity for the northern part of the country, the effects on water supply are severe. If untreated, the sediment situation as well as drinking water provision in future will worsen, intensifying the countries water shortage. In addition the sediment body represents an additional load on the dam and thus a permanent risk. The concrete faced rockfill dam is not designed for taking this load, especially as some of its construction elements and foundation are already damaged by landslides and floods. Therefore short term action as well as a sustainable solution is urgently required on the sediment situation for security reasons. However, the conducted detailed survey revealed that the overall sediment situation is in some points different to what had been assumed before.

Additional repair on the dam, its constructional elements and its foundation are necessary, too. However, that is not part of this study which has been executed on short notice within a very tight time schedule.

The dam site and access road offer limited admission for heavy traffic in its present condition. Assembling and working space near the dam crest is hardly available, especially on the water side of the dam. This, too, limits applicable/available equipment and installation. Usual access to the reservoir is limited to a makeshift slip ramp which is capable for occasional watering of small and light boats. Taking this into account, no heavy equipment can be installed next to or within the reservoir rapidly.

Several approaches for technical solutions have been analyzed within this study. However, due to missing space next to the reservoir for sediment storage the only applicable method for sediment removal from the reservoir is a downstream passage of the sediment by light equipment using ConSedTrans-Method. The process offers near-nature sediment transfer, restoring sedimentation/erosion equilibrium in a near nature state if applied over sufficient time periods. In addition to the technical benefits the method is the only one which also provides ecological benefits by restoration effects.

In any case dredging measures in the headwater close to the dam can only take place in the dry season for security reasons, when the spillway is not in operation. The conducted sediment gauging showed that this part of the overall dredging work can wait until end of the rain season but should begin immediately after. Depending on hydrology the overall recovery measure will take approximately 4 years, followed by a sustainable sediment management. Project cost will be in the range of 3.0 M€ / 3.9 M US$ (thereof 1.7 M€ / 2.2 M US$ investment and 1.3 M€ / 1.7 M US$ operation).
for recovery project and 0.09 M€ / 0.12 M US$ per year for a sustainable sediment management, following the initial project.

The required water for sediment transfer could also be used for installation of a 250 kW hydropower plant which could be added to John Compton Dam. After full restoration of the reservoirs storage capacity the hydro plant would also provide additional economic benefit. To cope with any sediment load we recommend the installation of two Turgo-type hydropower units, each rated 125 kW and totaling 250 kW. The turbines can be connected to the existing bottom outlet, once the area around the bottom intake is cleared from sediment. Coated Turgo type turbines are mostly efficiency-resistant to sediment load in propulsion water and offer good efficiency over a wide range of water head. An alternative is the installation of two Francis units of the same size with coated turbine runners. The power station will allow renewable energy production as well as emergency power supply to the drinking water pumps at grid outage. Rehabilitation work on dam elements should already integrate preparations for a hydropower facility. The constructions cost of the power station is considered in the range of 0.75 M€ / 1.0 M US$.

In short, we recommend:

1. to use the current rain season for preparational works (0.5 M€ / 0.7 M US$)
2. to use the next season for equipment installation and critical dredging, starting before end of 2013 (1.6 M€ / 2.1 M US$)
3. to use ongoing wet and dry seasons for full sediment transfer until reservoir capacity is mostly restored by 2017 (1.3 M€ / 1.7 M US$)
4. to keep on ConSed-sediment transfer afterwards for sustainable reservoir operation (0.1 M€ / M US$ per year)

Possible options for phase 1 to 3 add up to 3.4 M€ / 4.5 M US$. An additional budget of 0.3 M€ / 0.4 M US$ should be taken into account for contingencies. A 250 kW hydropower station could be installed from phase 3 on.

Increasing the dam level - as suggested from other studies - is clearly not advisable for reservoir security reasons.
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1 Introduction

1.1 Contractual Background

The agreement for the feasibility study

Sediment Management of
John Compton Dam

was signed between Deutsche Gesellschaft für Internationale Zusammenarbeit (GiZ) and DB Sediments GmbH on March 28th, 2013. The objective of the contract is to carry out a comprehensive feasibility study and to compile all resultant data and information into a comprehensive and convincing feasibility study report.

1.2 Purpose of this Report

Within the partnership program “Adaptation of Rural Economies and Natural Resources to Climate Change” and “Management of Coastal Resources and Conservation of Marine Biodiversity”, GiZ jointly with its partner CEHI (Caribbean Environmental Health Institute) has offered the Water & Sewerage Company (WASCO) of St. Lucia to assist in identifying option to restore storage capacity of John Compton Dam. The reservoir of John Compton Dam, of which already 30% had been lost due to siltation before, forms St. Lucia’s main inland water source and thus is of paramount importance for the drinking water supply and well-being of its population.

In this respect the overall objective behind this report is to provide GiZ with a comprehensive report on technically sound, effective and cost-efficient sediment removal options as well as a sustainable sediment management plan.

1.3 Scope of Work

The Scope of Work is defined in the Terms of References (ToR) and can be summarized in short as follows:

- Data Research and Compilation on John Compton Dam and Roseau Reservoir
- Consultation with stakeholders and parties involved to assess the extent of the exposure (loss of storage volume, compromised drinking water supply)
- Site Reconnaissance and field work including required survey
- Set up of reservoir operation rules with regard to sediment management including measures of enforcement
- Elaboration of technical alternatives to restore reservoir capacity
- Advice on long-term sediment management plan ensuring sustainable and ecologically sound reservoir operation
- Time and cost estimate for both, reservoir restoration and long term operation and maintenance of the reservoir
- In addition to the contractually assigned tasks, DB Sediments conducted a pre-feasibility study on the hydropower potential of John Compton Dam.

1.4 Approach to the Assignment

For this assignment an early mobilization of the team to St. Lucia was essential to perform the required survey as well as data collection. Following this site reconnaissance employment, data analysis and subsequent planning work was performed at DB Sediments head office in Germany.

On April 10th Dietrich Bartelt, representative of DB Sediments, arrived in St. Lucia followed by the core Team April 16th 2013, consisting of Daniel Klose (Sediment Expert, Cologne, University of Applied Science) and the surveyors Jörg Bernhardt, Andreas Voss and Stefan Meyer. The Team returned to Germany on April 23rd, 2013.

1.5 Deliverables

The Feasibility Study Report is to be submitted as follows:
- draft version on April 26th
- final Version on May 17th.
2 Background

2.1 Project Location

The John Compton Dam Site located in northern municipality Roseau close to the village of Millet in the central highlands of St. Lucia/Caribbean Sea. Fig. 2.1 below provides an aerial view of John Compton Dam Site and the Roseau Reservoir. The site is located at approximate Lat/Long 13°54’0.3 N and 60°59’17.5 W.

Fig. 2.1 : Location of John Compton Dam Site (source: University of Texas)
2.2 Project Site Condition / Available Information

With respect to the actual condition and tight timeframe only very limited information was available to DB Sediments before starting the assessment. Hydrological information, topography of the reservoir and catchment area, sediment/siltation data and specifications of the main structures were not given before and thus had to be gained during the site reconnaissance. Documentation/planning on the civil structures or detailed maps were not available.
3 Project Reconnaissance and Consultation

3.1 Tasks and Findings

Task

The main task of the project reconnaissance conducted during April 11th – 23rd, 2013 by Dietrich Bartelt and Daniel Klose was to

a) gather and compile comprehensive data and information on John Compton Dam,

b) conduct an own independent site inspection, and

c) hold in-depth consultation with stakeholders and parties involved to gain a broader view and better understanding of the current situation and risks involved.

Meetings and Discussions

In addition to talks and discussion on a face-to-face basis the following main meetings were held during the visit:

a) Kick-off meeting with WASCO, WASCO headquarters, Castries, April 12th, 2013.
   Participants:
   Dr. Horst Vogel, GiZ
   Dr. Christopher Cox, CEHI
   Mr. Treverne Yorke, WASCO
   Dr. Dietrich Bartelt, DB Sediments

   Main topics:
   - Background to dam construction (Initial dam construction in 1994, flood damages in 1994 and construction in 1995)
   - Halcrow study in 2005
   - Hurricane Tomas in October 2010
   - Halcrow study in 2011

   As a follow-up to the meeting, pictures, data and reports on the above mentioned points were handed over by a set of CDs.

b) Meeting at CEHI, April 16th, 2013
   Participants:
   Dr. Horst Vogel, GiZ
Dr. Christopher Cox, CEHI
Mrs. Patricia Aquing, CEHI
Dr. Dietrich Bartelt, DB Sediments

Presentation of the team members to CEHI management at Castries

c) Debriefing meeting, WASCO headquarters, Castries, April 19th, 2013

Participants:
Dr. Horst Vogel, GiZ
Dr. Christopher Cox, CEHI
Mr. Treverne Yorke, Mr. Antonio Toussiant, WASCO
Mr. Andreas Voss, Mr. Stefan Meyer, and Mr. Jörg Bernhard (GEO DV)
Dr. Dietrich Bartelt, DB Sediments, (via Telco)
Mr. Daniel Klose (Cologne University of Applied Science )

Main Data and Information gathered

The following main data, information and reports have been collected and compiled:

a) "Assessment of the Hydropower Potential of the John Compton Dam St. Lucia", Update; December 2008; Caricom/GTZ;


c) "POST HURRICANE TOMAS ASSESSMENT OF THE ROSEAU/MILLET WATER SUPPLY SYSTEM AND THE JOHN COMPTON DAM"., May 2011, Halcrow Group Limited

d) Pictures of John Compton Dam construction in 1994 and 1995 and Hurricane Tomas October 2010

Site Inspection and Consultation

On April 16th, 2013 a detailed site inspection of John Compton Dam and the Roseau Reservoir from the dam structure up to the intake area of the reservoir was performed by the engineering team of DB Sediments (Dr. Dietrich Bartelt; Daniel Klose, MSc) jointly with Mr. Cletus Alfred, a team member of WASCO. The team shipped along the whole reservoir shoreline for visual inspection and deboarded at significant locations with regard to siltation features. Photographs taken during the site inspection of the reservoir, its intake areas and specifics are given in Annex B.

Prior to this site inspection a consultation meeting was held jointly with Mr. Amatus Hamilton, Mr. Cletus Alfred und Mr. Antonio Toussiant (WASCO) supporting the field reconnaissance.
A second site inspection focused on the downstream river reach from the dam structure to the estuary mouth which was performed by Mr. Daniel Klose on April 17th, 2013 and April 18th, 2013 jointly with Mr. Antonio Toussiant to get a clear understanding of the river morphology and flow conditions and also to locate sediment traps.

Furthermore the following four representative sediment samples were taken and transported to Germany for analysis:

a) Sample 1: taken at Roseau River at the beginning of backwater in the south of the reservoir; sample scraped from under the water

b) Sample 2: taken from the 2nd feeder river (direction from dam to backwater) on the west coast of the reservoir

c) Sample 3: taken from the 1st feeder river (direction from dam to backwater) on the west coast of the reservoir

d) Sample 4: sampling point next to the boat slip landing in the vicinity of the dam structure

All four samples were taken on April 20th, 2013 by scraping sediment from under the water surface. The locations of the samplings and photographs are given in Annex D. Photographs taken during the downstream river reach reconnaissance are given in Annex C. Photographs of the dam structure are given in Annex A. The bathymetric and topographic survey performed and the results gained are described in Chapter 4.

3.2 Consolidated Findings / The Problem

Dam Structure

Although the focus of this study is on the sediment management and restoration of storage capacity to secure long-term operation and water supply, we need to point out several safety concerns with respect to the dam structure itself:

a) The base outlet is covered by silt and thus not working. Furthermore, the outlet valve is not operable.

b) The dam has two intakes for drinking water extraction at the levels of -18.90 m and -6.40 m below FSL, out of which only the upper one is working, as the lower one is covered by a layer of silt of approx. 6.0 m thickness. The intake at level -6.40 m (95.10 m ASL) will only be operable with the support of divers as a classic manual suction dredge may damage the installation upon dredging.
c) There is a severe mudslide at the right abutment on the east side of the dam structure (see photographs Annex A) which need closed inspection with regard to stability.

d) The lower wall of the spillway chute is destroyed (see photographs Annex A) which in addition endangers dam stability on the right abutment in case of spillage.

e) On April 20th, 2013 water level raised to 101.9 m ASL activating the spillway. It was observed that the flip bucket (energy dissipation) is not properly working. Instead the discharge runs along both sides which leads to erosion at the dam toe (see photographs Annex A).

f) According to our information and site inspection there is no functioning monitoring instrumentation installed with regard to water levels, seepage, settlement/movement, which allow survey and monitoring of the dam safety.

As there is no outlet operable except for the drinking water intakes the majority of the storage capacity has to be regarded as dead storage volume and is not accountable for flood retention. Considering that the one remaining functioning outlet can be operated by divers only, we have to state that in respect of flood control the dam is inoperable and water levels in the reservoir cannot be sufficiently controlled. This was experienced on April 20th, 2013 during the site inspection, when at the beginning of the rainy season the water level raised from 99.4 m ASL (326 ft ASL) to 101.9 m ASL (334.4 ft ASL; FSL = 333 ft ASL) within three days (see photographs Annex A).

These are serious safety concerns with regard to the stability of the dam, especially considering, that John Compton Dam is a rockfill embankment dam not designed for any spillage over the dam structure. We therefore strongly recommend to perform safety inspections of the dam on a regular basis and to take near-term countermeasures with regard to the safety aspects listed above. Reference is also made to the dam safety inspection performed by Halcrow in 2011 and the respective report.

**Reservoir and Siltation**

With regard to the siltation and restoration of the reservoir capacity the main findings of the site inspection are:

a) The sedimentation of suspended sediments in the reservoir has grown up to the dam structure. The base outlet as well as the lower outlet for the drinking water supply is already blocked (although this is partly due to the Hurricane Tomas).

b) The sediment masses next to the dam also produce a significant extra load on the dam body. This had most likely not been considered during the design phase and respective stability calculations. Therefore the sediment at
the dam also causes an additional security issue which should be dissolved as soon as possible.

c) At the backwater of the reservoir a prominent sediment delta has been developed already. This delta has a length of approx. 500 m shortening the original reservoir length (see photographs in Annex B).

d) Roseau Reservoirs acts very typical with respect to sediment trapping and the distributed sediment fractions in longitudinal direction. We find mainly coarse material forming sand banks at the reservoir backwater (inflow Roseau River) and at the feeder river inflow – although there to a lesser extent. Moving closer to the dam structure the suspended material is much finer and can be characterized as clayey silt (see photographs in Annex B and Annex D).

e) Four characteristics samplings have been taken and subsequently analyzed in Germany. The respective grain-size distribution curves are given in Annex H.

f) When inspecting the reservoir shoreline several landslides were detected, mainly on the eastern shore (see photographs in Annex B). This underpins the visual impression that the reservoir slopes are not stable and that e.g. heavy rainfalls lead to further slope erosion and slope failures. It shall be mentioned that major landslides might not only lead to an additional significant loss of reservoir capacity but could also induce wave action across the reservoir with in turn endangers opposite slope stability and/or the dam structure.

g) Considering the item above it is obvious that raising the existing dam height to increase the reservoir capacity is not a preferred option as the additional impoundment would further degrade slope stability.

h) Site investigation of the downstream river reach proves that most of the suspended material is deposited in the Roseau Reservoir. Turbidity is very low and the river bed contains only very limited fraction of fine material. This could be observed even up to location D (see also photographs Annex C). The content of fine material continuously increases in flow direction as the river reinstates his original conditions according to his tractive force. The particle grain size development along the river floor shows clearly that in difference to a natural state Roseau Reservoir traps significant amounts of sediment which usually would be part of the complete river stretch. Thus downstream Roseau River actually faces a sediment deficit.

As a consequence for the reservoir, there was a great introduction of silt and sediments to the reservoir. The bottom outlet was blocked with stones and trees and later on covered with sediments and silt. Furthermore, it was pointed out that aggressive water had corroded the steel construction of the gate. Mr. Yorke stated concerns
that if opening the gate, the outflow could not be stopped again. Under actual conditions, this is absolutely reasonable.
4 Bathymetric and Topographic Survey

4.1 Preliminary remarks

The conducted topographic survey also takes reference on surveys which were performed in 2005 and 2011. However, no information was given on equipment that was used for these precedent measurements. It has to be assumed that standard depths measurement equipment (sonar) had been applied. A sonar measures medium/material density. Standard equipment usually takes the first major density change as depths signal for the sea floor which is appropriate for many applications, especially for navigation.

In reservoirs, the original valley floor is usually covered with consolidated sediments of a certain density. If fine sediments are present, the compact sediment usually is covered by a layer of light sediment, dispersed by density currents. This layer is not consolidated, but possesses properties more similar to a fluid then a solid matter. Therefore this layer is called "fluid mud".

Standard measurement equipment sometimes takes the upper edge of the fluid mud layer as the sediment range which may be right from the perspective of drinking water storage, but not from a sedimentological standpoint. To really find the sediment edge, in these cases a more sophisticated sonar technology has to be used.

4.2 Applied Equipment

For the given measurement task a SONOBOT-device was selected (see Fig. 4.1). The device is equipped with a high precision differential GPS for high accuracy cartography (GPS, GLONASS and ASCOS) and as core component a S2C ultra-broadband echosounder (depth measurement accuracy ± 1.5 cm, minimum depth 0.5 m, maximum depth of 40 m).
In its standard configuration the device is able to operate remote controlled. The multi-frequency detector allows for a direct measurement of sediment thickness. However, due to customs restrictions and a very tight time frame not all of the power supply could be transferred to St. Lucia in time. Therefore the device had to be fixed to a boat for cruising and the measuring equipment could only detect the consolidated sediment / fluid mud border firmly. Nevertheless, measuring accuracy and positioning information were not affected. Therefore a sufficient database for sediment assessment could be gained.

4.3 Measurements

The executed measurement with the above described equipment delivered cartography of the whole accessible reservoir (excluding the silted backwater area that could not be reached safely due to rising water level) in a 10 x 10 m pattern. In addition sediment probes were taken from several locations along the reservoir (see Annex D).

![Water depths illustration according to 2013 measurement](image)
4.4 Findings

The overall sediment situation is typical for a reservoir affected by fine sediment intrusion through inflow from the upper backwater region. Maximum sediment grain sizes range from 25 mm at the upper reservoir end to 0.2 mm near the dam (see Annex H). Also the sediment mass allocation is typical within the reservoir. The coarse particles at the upper end form a silted delta while fine particles being spilled into the lower regions are spread rather equally by density streams, forming a smooth sediment surface.

Fig. 4.3: Reservoir ground shape/sediment surface in 2013 survey

Sediment thickness allocation is given in Fig. 4.4. Annex F comprises more details. As expected most sediment is situated in the regions closer to the dam, see Fig. 4.5.

Fig. 4.4: Sediment coverage of Roseau Reservoir in 2013 survey
Later dredging work will have to be appropriate to relevant sediment distribution. For operational planning detailed map information is given in Annexes E-G.

The performed measurements identified the overall sediment volume in Roseau Reservoir in 2013 to 804,000 m³, compared to 2005 situation (see Annex H). Sediment deposition from 1995 to 2005 is assessed to 200,000 m³. As Roseau Reservoir already faces restrictions on drinking water extraction, the annual inflow of additional approximately 20,000 tons of sediment will further worsen siltation situation and respective limitations on water provision.
5 Hydrology

St. Lucia is divided into 37 major watershed areas out of which 10 are major basins with an area greater than 15 km². The Roseau catchment is the largest basin in St. Lucia covering an area of 48.3 km² (Cox, 2003) and one of the most important with regard to water supply. The Roseau River has an approximate length of 19 km.

Rainfall is spatial unevenly distributed over the island with mean annual precipitation ranging from 1,500 mm at the coast up to 3,800 mm in the interior. Most precipitation occurs between June and November while the period between December and May is drier. This is depicted in the annual precipitation distribution as given below:
Fig. 5.2: Annual precipitation distribution at Roseau Station

The catchment area draining into Roseau Reservoir has a size of 15 km². The mean annual flow at John Compton Dam site is recorded to be 0.776 m³/s, the annual rainfall amounts to approximately 3,500 mm. This relates to a run-off ratio of approximately 47 %.

The average daily outtake from the reservoir for drinking water supply is 7.5 million gallons per day (28.390 Mm³/d), which equals a constant water extraction of 0.33 m³/s.

To calculate the annual sediment volumes which can be continuously transferred downstream based on the ConSedTrans-Method (see Chapter 7.3), inflow curves into Roseau Reservoir are required. Those were taken from the report “Water Resources Study of the John Compton Dam, 2005” with gives inflow series for the years 1996 - 2004. As an example the inflow series for the year 1998 is given in Fig. 6.3:
Fig. 5.3: Inflow Series to Roseau Reservoir in 1998

On the basis of the given flow series and the daily drinking water supply of 7.5 million gallons per day (28.390 Mio. m³/d) the inflow, the storage extraction and the remaining excess water (outflow of the reservoir), which can be used for sediment transport downstream or hydropower production, has been calculated. It shall be mentioned that highest priority was given to the drinking water supply, i.e. first the drinking water demand has to be fulfilled before any excess water is available for any other uses.

According to available data for 1998 and 2000 the total inflow is 8.861 MG (33.54 Mio. m³) and 8489 MG (32.13 Mio. m³) respectively. Approximately 1/3 of the inflow is used for drinking water supply, which leaves 6.129 MG (23.2 Mio m³) and 5750 MG (21.76 Mio. m³) as excess water for other uses in 1998 and 2000 respectively.

In both years the annual average inflow amounts to approximately 1.0 m³/s (1.1 m³/s in 1998; 1.05 m³/s in 2000). As this is not in line with the figure of 0.776 m³/s (see “Water Resources Study of the John Compton Dam, 2005”) it is recommended to re-check inflow series and the annual average inflow of 0.776 m³/s as given by Halcrow. For the time being, this deviation was dealt with by applying an adjustment factor of 0.776/1.1 and 0.776/1.05 for the years 1998 and 2000 respectively.

Fig. 6.4 depicts the storage extraction during the dry season, when drinking water demand exceeds the inflow to the reservoir. In 1998 the maximum storage extraction amounts to nearly 1.2 Mm³ in the month of May. On the basis of a total remaining nominal storage volume of 2.0 Mm³ this amounts to 60 %.

Everybody should be aware, that not the complete Reservoir volume can be used for drinking water supply. The high degree of permanent sediment intrusion into the
reservoir causes density streams of fine particles in the lower water regions, forming fluid mud and dull water. To avoid compromising the drinking water supply it is recommended not to exceed the storage extraction to an extraction volume of more than 1.5 Mm³.

![Reservoir Water Use 1998](image1)

![Reservoir Water Use 2000](image2)

Fig. 5.4: Adjusted Inflow, Storage Extraction and Outflow for the years 1998 and 2000
The details of the calculations are given in Annex I.
6 Present Reservoir and Sediment Management

6.1 Present Reservoir Management

The initial volume of Roseau Reservoir is assumed to be 3.0 Mio. m³. Due to the silting process the nominal volume has been reduced to approximately 1.9 Mio. m³.

Reservoir Operation Management is governed by the drinking water extraction of 7.5 MGD (28.390 m³/d), required to fulfill the demand which has highest priority in respect of water usage. Besides the drinking water supply there is currently no further water extraction for other uses or for riparian flows.

As the base outlet is not functioning and the spillway is ungated the drinking water extraction is the only controllable outflow. Thus, reservoir water levels as well as spillage are – except for the 7.5 MGD drinking water extraction - purely a function of the inflow. In this respect an active reservoir management with regard to water supply or flood control is not in place.

Basically most time of the year the reservoir is filled up to the Full Supply Level (FSL) and spillage takes place as inflow exceeds the drinking water extraction. During the dry season drinking water extraction exceeds the inflow with leads to a drawdown of the water level which is subsequently refilled. This is depicted in Fig. 5.4 above (see Chapter 5) as well as in Fig. 6.1 below:
6.2 Present Sediment Management

Currently no active sediment management takes place at Roseau Reservoir.

Fig. 6.1: Reservoir Water Levels (Dam Levels) and Drinking Water Extraction (Pumped Flows) 1996 – 2005 (Source: Halcrow)
7 Options to Restore Reservoir Capacity

7.1 Conventional Solutions Approaches

Opening the Base Outlet

Sedimentation processes usually start at the up-stream entrance into the reservoir which typically is the most distant point from the dam axis. As sedimentation increases the settled sediments eventually reach the dam. To prevent the dams discharge elements from plugging, the operator is now forced to flush the base outlets periodically (e.g. every six months). If neglected, the equipment will become inoperable within short term, because the sediment will cover the gear. The tremendous runoff generated by opening the outlets erodes the sediment right upstream of the intake. The eroded sediment is transported downstream in short time and at a high rate (Figure 7.1).

Performing this method is quite simple and besides a working base outlet structure, requires no further physical facilities. However, with this technique a tremendous quantity of water for power generation or water supply is lost. Furthermore, significant amounts of sediment are moved into the downstream river section in a very short time period. This can lead to negative morphological and ecological effects. Anyway, the method is applicable only when sedimentation already reached the dam line. Opening the base outlet then only leads to a dissipation of sediments in close vicinity of the outlets and within a narrow channel (see Fig. 7.5). The overall operative range of the reservoir is not restored.

Manual Dredging

Another procedure is manual removal of sediments. Here the sediment is excavated by suction dredgers, hydraulic excavators or - after lowering the reservoirs water level
and initial draining - wheel loaders (Fig. 7.3). After the often expensive removal and transport the sediment has to be stored on separate drainage fields for years or decades in order to reduce the water content. Thereafter it may be used as covering material for simple ground work applications. The relatively high percentage of organic ingredients (usually 2 … 30 %) prevents a use as a ground construction material even after dredging. In many cases, landfill is required.

The procedure allows for a thorough cleaning of reservoirs, but at exorbitant costs. Expenses consist of sediment dredging activities, plant/reservoir shutdown of several months as well as transport and dump expenditures which are in a million dollar range even at small reservoirs. Worst of all: The sediment is extracted from the river system, leading to permanent erosion damages downstream.

Some extraction measures are combined with mechanical dewatering equipment to reduce the need of land use for natural sediment dewatering. In practice the use of mechanical dewatering usually is restricted to applications where sediment amount is not too large (e.g. 20,000 m³) and road infrastructure is in good condition. Furthermore next to the used centrifugal dewatering systems (filter screen presses do not have a sufficient capacity) enough space has to be available for product material loading and traffic. Settings for centrifugal operation and effective capacity usually are found only during site operation as sediment properties vary. At recent measures mechanical dewatering frequently led to significant cost overruns.

In case of Roseau Reservoir even reducing excavation and dewatering to the smaller amount ‘A’ from Halcrow report would lead to approximately 200,000 t of dewatered sediment mass. With optimal handling, loading and use of 36 ton 8 wheel dump trucks this requires about 8,000 transports or 16,000 heavy traffic transfers. We do not consider the access road even after some reinforcement capable of handling this size of traffic volume safely.
**Sludge Dredging and Disposal downstream**

This method involves suction dredging campaigns where sediment is dug in large quantities, transferred over the barrage and dumped downstream (Figure 7.3). For good reason this is not allowed in many countries. The loss of great amounts of flushing water for power production or irrigation may be even acceptable. The short-time transfer of large sediment quantities into the downstream river section however causes a massive intrusion into the river morphology and ecology.

![Fig. 7.4: Disposing campaign](image)

**Impacts and Constrains of Conventional Approaches**

It is apparent that all the conventional approaches to restore reservoir capacity as described above have severe negative impacts on river morphology and the whole ecosystem. Even when disregarding the environmental damages caused, these approaches

a) require in general legal permission by local/regional authorities which – if granted at all – is often linked to time consuming application procedures and environmental compensation measures,

b) are cost intensive (direct construction costs) and – in addition - often induce high secondary costs in consequence of (i) sediment transport and sediment disposal, (ii) monetary losses due to plant/reservoir shut down, (iii) environmental compensation payments and (iii) high losses of water for energy production and

c) often cause extensive restrictions to reservoir operation up to long-term plant shut down.

For the reasons given above, none of the conventional approaches to restore reservoir operation can be recommended from our point of view. With regard to John Compton Dam these approaches are anyhow no realistic option, considering that water is a scarce and invaluable resource and the operation of Roseau Reservoir is
crucial for the drinking water supply of central and north St. Lucia. Thus, significant losses of generation water, restrictions to plant operation or even a plant shut down are not acceptable and have to be avoided.

### 7.2 Examples of Conventional Approaches

**Langmann Dam / Austria**

In 2008/2009 the base outlets of the Langmann Dam in Austria were opened with the aim to flush the sediments of the reservoir downstream through the outlet of the dam. As can be seen from the picture below, flushing a reservoir creates a groove-like depression where sediments are eroded and transported downstream. The majority of the sediment however will remain in the reservoir. In addition the flushing lead to enormous ecological damages downstream, destroying the interstitial and thus the aquatic and riparian habitat. A further negative impact was a high mortality rate of fish in the downstream river reach.


**Glen Canyon Dam / USA**

Approximately 500 Mio. kilotons of sediment are trapped at Glen Canyon Dam (completed in 1966) at the Colorado River, USA. On a 4-year basis the outlet gates of Glen Canyon Dam are opened to flush down the sediments with a peak flow of 1,290 m³/s over a 24 h period. This flushing is not only environmentally questionable; the financial costs due to the loss of energy production are estimated to approximately 3 Mio. US$. 

![Glen Canyon Dam](source: Wikimedia Commons)
7.3 Continuous Sediment Transfer

As an intelligent alternative to the previous discussed conventional methods a new “ConSedTrans-Method” has been developed and already successfully applied in other projects. This approach does not only avoid the negative impacts summarized in chapter 7.1, but does also restore the overall sedimentation process in a river to a near to natural state by making reservoirs permeable for sediment. Thus, the approach brings the balance of sedimentation and erosion in a river system back to a natural or close to natural sustainable state, fulfilling the requirements of the Water Framework Directive 2000/60 of the European Community as well as the US Sediment Acts. Moreover, as the standard equipment is fully automated, it is also economically very competitive, even without considering the costs of the secondary effects as discussed before.

In contrast to the conventional approaches the ConSedTrans-Solution is based on devices allowing continuous and controlled transfer of sediment within the reservoir in a relatively small scale but permanent mode. Key element is an automatically working vessel with a suction dredging system installed that can be diesel or preferably electric driven. To allow for an exact positioning the vessel is directed by tractor cables. Sediments are loosened by a suction head, pumped towards the reservoir’s
outlet and dumped in front of the outflow elements. The vessel gradually strikes the reservoir floor until the surplus sediment is removed (see Fig. 7.7).

Fig. 7.7: Continuous Sediment Transfer

- Step 1: Sediments are dredged by a suction head, pumped across the reservoir and dumped in front of the power stations/hydro facilities water intake.

- Step 2: The dumped sediments in their smoothed condition are eroded by the reservoirs outflow.

The newly dumped sediments are eroded by the hydraulic discharge and therefore carried out of the reservoir, passing outflow organs (turbines or outlet valves, weirs, spillways). These outflow elements are able to handle water flow with some degree of sediment load. Wear on the discharge elements (e.g. turbine blades, valves) remains within normal range unless sediment content is increased to a considerably high degree. Even then coating of turbine components or wear on equipment is much less costly than technical dredging alternatives. The sediment transfer rate can be adapted to the outflow rate and parameters to guarantee a compatible process speed.

Fig. 7.8: SediMover – Sediment transfer vessel
With a maximum element weight of 3 tons, the equipment (Fig. 7.8) can be installed with a small mobile crane or even slipped into the reservoir once a suitable slip ramp will be available.

### 7.4 Customized Approach

Since Roseau Reservoir suffers from severe sedimentation which limits essential water storage and supply a fast recovery is strongly recommended. This has to take into account several obligations. Main aim should be to:

- restore access to lower intake at 82 m ASL
- restore a maximum economically feasible storage capacity which should be in the range of 50 % sediment removal, reducing reservoir sedimentation from \( \frac{2}{3} \) to \( \frac{1}{3} \) of original storage volume
- restore access to bottom outlet for emergency and hydropower use

Major restrictions and conditions for de-sedimentation are:

- no use of bottom outlet until renewal of this component which requires significant lowering of water level and thus largely emptying the reservoir
- no dredging work in vicinity of the spillway during rain season for security reasons
- no land storage capacity within reservoir valley available
- maximum water exploitation for drinking water supply/irrigation during dry period
- fine sediment intruded into the lower part of the reservoir will disperse smoothly due to density currents, so within a certain time the active reservoir floor will always form a more or less even lower plain, ranging towards the dam site
- In contrary to the assumption of the Halcrow Report 2011, that the more or less even sediment surface structure is caused by a flood, we clearly assess that due to the particle sizes the actually surface structure is a result of existing density currents. These are not directly depending on floods, so whenever there is fine sediment in motion within the reservoir, the lower regions close to the dam structure will face sedimentation of fine sediments, filling any dredged space.
- limited access to the dam site and reservoir
reservoir use for drinking water supply which limits application of diesel driven equipment

Fortunately, some aims and conditions suitably fit together in good manner:

- sediment grain size across the reservoir allows for good dredging characteristics; however equipment has to be properly selected to cope with trees and debris which will complicate work in some areas
- due to limited heavy traffic access and required/possible capacity for initial dredging, the operative equipment for all project phases can be of similar size, allowing for synergies.

There may be a chance to find additional ways to transport equipment to Roseau Reservoir, e. g. using heavy lift helicopters. The most powerful helicopter in St. Lucia is able to lift net loads of 900 kg which is by far not sufficient. Up to date it was not clear weather other helicopters, e. g. equipment from the UN as part of disaster recovery missions, will be available in the region. Therefore such transports were not taken into account.

Due to the restrictions and aims described above, a combination of measures on short and long term will offer the best solution. Aims on short term notice are:

- re-establishing as much operational range of Roseau Reservoir as possible
- taking additional pressure from the dam by reducing/removing the sediment body in dam vicinity
- restore function of all buried dam outlets for security reasons

As there is no storage space available all dredged sediment has to be transferred downstream. This however is in general accordance with natural river condition, as sediments have been transported downstream prior to the erection of the dam. Therefore sediment transfer capacity has to be assessed for the downstream river stretch (Chapter 8.1).

Recommended short term action will be dealt with in detail in chapter 8.4. On the long run the following issues will get into focus:

- sustainable sediment management
- use of surplus/drainage water for hydropower production
These issues will be dealt with in chapter 7.5 and 9. For reaching these targets some serious restrictions on technical solutions have to be taken into account:

- limited access to the dam site concerning heavy traffic
- limited space at the dam site for construction/assembly
- ongoing drinking water extraction from the reservoir
- general use of the reservoir for drinking water supply which sets strict limits for use of harmful substances within the reservoir, especially diesel driven dredging equipment

Recommended short term measures on John Compton Dam / Roseau Reservoir are:

- renewal of the access way and ladder to the drinking water intake
- renewal and extension of boat slip installation
- installation of a swimming pier for regular personnel and material access to the reservoir
- creating space for on-site land installations for storage and auxiliary equipment, delivery of according equipment
- power supply
- installation of manual dredging equipment
- preparations for automatic dredging equipment

Due to restrictions on heavy traffic all equipment needs to be limited to a comparably low weight. This is also valid for mobile cranes, limiting weight of assembled equipment before lowered to the reservoir. Facing the actually given infrastructure it will not be possible to lower single massive dredgers into the reservoir. This is both impossible by equipment transportation weight and weight of the required mobile cranes. Another problem of massive dredgers is that these are usually diesel powered and equipped with a large gasoil fuel tank. It is not advisable to operate such a potential danger for drinking water supply inside a reservoir if alternatives are at hand.

In current reservoir configuration dredged sediment of both sustainable sediment transfer and short term sediment removal should be pumped to the downward stretch of the spillway to allow for transport in the river flow or for erosion and
transport at floods. Once a hydropower facility will be installed, the sediment can and should be transferred through the hydropower plant.

To guarantee for an ongoing sufficient quality of drinking water extraction, a turbidity measurement close to the drinking water extraction as well as additional wells for substitution use may be installed.

### 7.5 Alternatives

In an alternative to the above described approaches a combination of continuous sediment transfer and temporary land deposition could be performed. This temporary landfill will require additional installations. However, the extra sediment storage capacity will provide additional flexibility for sediment removal in case the downstream river transport capacity will be exceeded.

For environmental as well as cost reasons for sediment dewatering and deposition we strongly suggest the usage of settling basins instead of mechanical dewatering devices. Though requiring a significantly larger area, settling basins in the Roseau Reservoir case provide the following advantages:

- lower fuel consumption since no energy intensive mechanical dewatering equipment is required,
- no chemicals required for dewatering in contrary to polymer injection as coagulation aid in mechanical dewatering which is essential for this process; chemicals in this case would be contained in treated sediment whereas settling basin ‘product’ will be free of other ingredients and unrestricted for later other use or return in Roseau River or other harm concerning pollution,
- wet sediment transfer can be done by sludge pumping instead of truck transportation.

In case dredging process will show a surplus of sediment for downstream Roseau River, the gained solid fraction could also be used for other purposes on land instead of returning it into the river at wet times with high Roseau River discharge. Such purposes could be fertilizing, construction material or land coverage. The usage however will be subject to probing and materials properties assessment.

### Dewatering site

A suitable area for establishing settling basins could be identified on the upper western slope in Roseau Valley downstream of John Compton dam. The site is located 950 m air range / 1,300 m transport distance from the dam axis (see Annex N). Its
former use was as a quarry for construction of the dam. The area surface is mostly flat. Before usage as a settling basing the area will require a surface treatment concerning deforestation and ground stability preparation. This can be done by standard lumber equipment, bulldozers, wheel loaders etc.

**Dimensioning**

Taking into account a planned initial sediment extraction rate of 120,000 t/a, we suggest a sediment dewatering site capacity of 30,000 m³ with some reserves concerning site modifications, rest periods and loading/unloading. For determining of general dewatering properties, tests on sediment material will be required. Exact dewatering properties will only be available during later operation as properties can vary within overall bulk of reservoir sediment. To give a few core dimensions, 30,000 t of sediment will mean

- an equivalent of ca. 45,000 m³ sediment/water in original condition within the reservoir with a typical solid ratio of 50 mass-%.
- a pumping volume of 135,000 m³ solids/water mixture with a solid ratio of 20 mass-%.
- a residual volume of 30,000 m³ at a proposed dewatered solid ratio of 2/3 solids and 1/3 water.

As ground conditions are not clear yet, for further planning we assume a possible average storage height of 2 m and an effective site area of 15,000 m². The setup of the dewatering basins can be altered upon area availability also during conduction of the overall measure.

**Site Makeup**

Dewatering basins on plain ground require damming. Standard earth fill dams require proper construction material and a surface or core sealing. For practical reason we recommend to use sediment as dam material. Of course this will not be possible with sediment only. Instead GeoTubes (Fig. 7.9) or similar material should be used to form dams with sediment. GeoTubes consist of permeable textiles which allow dewatering of pumped in sediment. A standard approach would consist of GeoTubes only. For economic reasons we suggest to use GeoTubes as dam body and form a drainage area consisting of three basins. After dewatering, the filled tubes represent a dam body of sufficient stability. The tubes can also be stapled to several layers, allowing for several meters of dam height.
**Operational Aspects**

To cope for appropriate cooperation of settling basin operation and dredging, the later could be performed with one dredger as proposed in 8.4 or two mini dredgers with each of half capacity compared to the large one. Operation of two mini dredgers will provide a good operational combination when working with three dewatering basins as then up to two basins will be in operation for parallel filling and one basin will allow for settling and if required sediment removal for land usage. Operation of two mini dredgers plus management of settling basin will require 6-7 staff per shift for operation.
8 Dredging Dimensioning and Equipment

Dimensioning of equipment is divided into seizing of

- initial dredging and
- sustainable sediment transfer.

Before technical dimensioning can be done, the sediment inflow into the reservoir, the hydromorphologic transport capacity of the river reach as well as medium sediment inflow into the reservoir has to be assessed.

8.1 Ongoing Sediment Intrusion

Sediment mass within Roseau Reservoir currently sums up to 803,000 m³, compared to 2005 conditions and approximately 1,000,000 m³, compared to natural valley. An average sediment density in comparable geology / topography is 2,000 kg/m³. Water content within the sediment strongly varies, depending on age and depths of the according layer as well as the grain size. Organic components within Roseau Reservoir sediments are of minor importance. Since the deeper sediment layers are not accessible for probing, we consider average water content of 50 % a technical approximation.

Taking into account the reservoir age of 18 years, the medium sediment intrusion is about 50,000 m³ (wet) / 50,000 tons (dry) per year. Hurricane Thomas and its rainfall surely are not a regular effect. 600 mm of rain within a period of 26 hours were an extreme event, followed by an exceptional corresponding sediment intrusion. Therefore we assess the usual average sediment intrusion into the reservoir in the range of 20,000 m³ (wet) / 20,000 tons (dry) per year, corresponding to 1995 - 2005 development.

8.2 Sediment Transfer Capacity of Downstream River Reach

Since there is no storage capacity directly near the reservoir available to landfill sediments, natural limiting factor of sediment transfer is the downstream river transport capacity. However, this does not necessarily mean that a permanent and complete sediment transport in every river segment is guaranteed. This means that depending on actual flow transferred sediment may deposit directly downstream of John Compton dam and be eroded later when higher flow allows for sufficient erosion capacity. This is from technical and ecological point of view generally acceptable since sediment transfer in nature is usually not constant, too. However, not to exceed environmentally tolerable sediment ratios, a technical monitoring for sediment transport should be established.
After the surplus sediment has been distributed by the flow, the affected river reach will be shortly and fully recolonized by benthos and fish again forming a sound ecological habitat without any ecological damage. Sediment effects will not be as severe as in a reservoir flushing described in chapter 7.1.

For the possible natural sediment storage we consider a 3 km long reach as appropriate, beginning downstream of the dam and ending before the river passes the first settlements at (717600 E, 1540000 N). Taking into account the locally found sediment grain sizes, for transportation and even re-erosion a river flow velocity of 3 m/s is considered as a safe basis according to Hjulström diagram (see Annex J). This velocity occurs several times during flood season, so a safe passage of sediments further downstream generally is assured. Due to physical scale effects a detailed calculation of sediment transport is not possible, even in case parallel model tests in hydraulic research facilities are added. However, sediment transport has to be monitored in regard of sediment in water ratio, deposition range and deposition volume. If necessary, sediment transfer from dredging could be adjusted by different equipment operation.

In the case that contrary to current state of science and gained experience downstream sediment transport will not meet hydromorphological criteria for short term sediment transport capacity in Roseau River, for a fast recovery during the initial project surplus sediment could be stored in a temporary sediment basin, which could be installed further downstream to the site, where sufficient area is available. This sediment will then also be given back to the river in future rain seasons to restore the temporary storage site. However, currently we do not deem such a measure to be required.

Assumed that the legal situation/ground provision is granted, from a technical standpoint storage could easily be created by using surrounding geotubes, filled with water/sediment mixture. The gained additional storage would be filled from the dredging installations directly, requiring a 4 km long sediment pipeline from the reservoir to the next available land space. The sediment would be stored as dredged and fed back to the river whenever river flow allows for sufficient transport capacity.

### 8.3 Recommended Equipment for Sustainable Sediment Management

Dimensioning of long term sediment transfer equipment for a fully automated and robust operation should be in line with regular sediment intrusion into the reservoir. Potential additional intrusion as well as special dredging at sensitive areas like intakes or civil structures should be done by using manual dredging equipment.
The equipment should be remotely supervised. Due to limited accessibility of the reservoir banks the installation of booster pumps within a drinking water reservoir is environmentally complex. However, sufficient pump capacity will be required for the transfer line with a maximum length of 2 km. The equipment should be electric driven to avoid any large quantity of harmful substances within the reservoir, such as fuel for diesel engine fueling.

According to regular sediment intrusion the medium transfer capacity of the equipment should be in the range of 20,000 tons (dry) per year. On a 5,000 h/year\(^1\) operative basis this requires a 4 tons / h (dry) or 40 m³/h pump capacity with a sediment content of 10 mass-%.

Restrictions on access traffic to the reservoir limit the equipment to a maximum element weight of approximately 3 tons. Vessels like the SediMover (see Fig. 7.8) fulfill these requirements, including a sufficient transfer capacity. The equipment will be able to handle the present sediment grain fractions. However, special attention has to be given to trees and debris within the reservoir.

### 8.4 Equipment for Short Term Sediment Removal

According to downstream hydromorphological sediment transfer/absorption capacity the short term sediment removal should be done over a timeframe of four years. The required equipment will be manually operated during daytime (10 h/day, 6 days/week). Presumably it will be required to interrupt dredging during floods, as it is too risky to have mooring cables in place under fast currents drifting debris.

Required effective transfer capacity is 600 tons/day within season. Taking into account effective daily working time and keeping reserves for unforeseen difficulties, the effective pump transfer capacity should be rated at 300 m³ (fluid) per hour, at a solid content of 20 mass-% this resumes to 60 tons per hour. The nominal pump capacity should be rated higher to cope with contingencies. The sediment grain sizes will be no problem for the equipment. The equipment will have to be robust enough to cope with debris and sunken trees within the reservoir. Regular work on the swimming equipment will be required to unblock hydraulic cutting tools.

Maximum operating depth should be up to 30 m below water level, pumping distance up to 2 km. The nominal transfer capacity should be achieved at a transfer distance of at least 1 km.

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\(^1\) full load equivalent, real operation time is higher
Given the restrictions on access roads, only equipment is applicable which can be split into modular elements with a maximum of 3 tons each which can be lowered to the reservoir separately and assembled within the water. A sample on suitable equipment is given in Fig. 8.1 and Fig. 8.2.

Fig. 8.1 Sample of deep dredger
Besides selection and dimensioning of the core components, also auxiliary tasks are of elementary importance:

- Renewal and extension of boat slip installation
- Installation of a swimming pier for regular personnel and material access to the reservoir
- Creating space for on-site land installations for storage and auxiliary equipment, delivery of appropriate equipment
- Power supply
- Installation of manual dredging equipment
- Preparations for automatic dredging equipment

**8.5 Operational and Environmental Aspects**

**Operational Aspects**

Most special equipment will be manufactured outside St. Lucia and shipped to the site. Nevertheless, work with the equipment and maintenance will largely be done by
local employees who will be trained for experienced operation. Existing site knowledge, environmental topics and technical issues will form a good combination among the skills of estimated 4-5 FTE\textsuperscript{2} staff during initial dredging and 2 FTE staff for sustainable operation on the proposed customized approach, 6-8 FTE at further alternatives. All these approaches can be integrated in overall reservoir management.

The practical dredging work will be combined with a precursory field survey, identifying possible obstacles in the actual dredging workspace. The survey can be performed by standard sonar with a sufficient optical resolution. Possible obstacles could be mainly deadwood like trees/branches and rock. Depending on obstacle size and properties the dredging equipment will process/destruct the obstacle, slip over or evade it. In case of persistent obstacles that cannot be let within the reservoir a diver mission and/or local mechanical excavation may be required. However, comparable sites did show no major problem on underwater obstacles.

Besides the initial transport and installation of special equipment, a considerable amount of work and other equipment manufacturing will be necessary, prior to operation. Whenever possible this should be done in joined cooperation with local companies and facilities.

**Environmental Aspects**

As outlined in the previous sections, sediment transfer further downstream is guaranteed over the seasons. Indeed, with sediment transfer in place, the overall sediment flow is restored to a state similar to the situation before erection of Roseau Dam. This natural flow had not been constant, too, as sediment transport seldom is. Overall sediment transfer will not have a negative effect on the situation, compared to the unaffected state.

To allow for adjusting the dredging and sediment transport processes, both technical solutions described in 7.4 (customized approach) as well as 7.5 (alternatives) include flexibility in all relevant technical elements. If sediment transport capacity of Roseau River should not be sufficient in some parts of the year, dredging rate could be lowered or sediment flow could be increased towards the proposed dewatering site.

To ensure environmental compliance of the measure, we suggest a technical monitoring of sediment flow and deposition, consisting of water/sediment probing and frequent level surveys. In case an extensive environmental and social implication monitoring is desired, we strongly recommend applying the *IHA Sustainability Assessment Protocol*, which is the only overall framework for hydro infrastructure assessments so far. An assessment then would include overall Roseau Reservoir effects in

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\textsuperscript{2} Full Time Equivalent
both benefits and environmental/social implications. The protocol is available at http://www.hydrosustainability.org. It has been developed in close cooperation with several major environmental organizations such as the World Wide Fund for Nature (WWF) and The Nature Conservancy (TNC).

Concerning the reservoir, a sustainable sediment management will prevent the reservoir from further or repeated siltation and becoming marshy, massively changing the character of the ecosystem. In addition, rising temperatures within the reservoir will affect drinking water quality and also lead to increased downstream water temperatures reducing dissolved oxygen content and increasing the risk of eutrophication. These negative impacts will be avoided when applying a sustainable sediment management.
9 Future Reservoir Management

The current solely use of Roseau Reservoir is drinking water supply. Therefore all other utilizations have to subordinate under drinking water provision which is 7.5 MG per day more or less constant all year, summing up to 10.4 Mm³ per year. This water extraction is equivalent to 42.3 % of the average annual reservoir inflow. The core goal is to keep this primary use unaffected from any other application.

Other applications in this case are sediment transfer and possibly hydropower production. Both will require additional water use from the reservoir. On the given layout, water use for sediment transfer is 0.73 Mm³ per year during initial phase and 0.2 Mm³ per year for later sustainable ConSedTrans-Method, corresponding to 3 % and 0.8 % respectively of annual water inflow. Thus, the minor additional water use requires also additional storage volume during dry season. This additional water provision can be accomplished by two effects:

- upon installation sediment transfer will gradually recover “its own” storage capacity
- in case of dry years / very dry seasons sediment transfer could always be interrupted

The implications of sediment transfer on reservoir use are shown in Fig. 4.4 and Fig. 9.2 for both, the initial phase and the subsequent sustainable transfer.
Reservoir Water Use 1998

Fig. 9.1: Reservoir use with sediment transfer during initial phase

Fig. 9.2: Reservoir use with sediment transfer during sustainable transfer
A possible water use for hydropower will have to be taken from surplus water during wet season. During hydropower operation the sediment transfer can be executed via the hydropower facility, making use of the transfer water. Once the storage capacity of the reservoir will be partly re-established, hydropower use and sediment transfer can be further optimized.

In summary, drinking water supply will only marginally be affected by sediment transfer and/or hydropower production.
10 Hydropower

From a hydrological standpoint the inflows into Roseau Reservoir, the storage capacity once it has been regained and the water extraction for drinking water supply allow for a hydropower plant (HPP) at John Compton dam. A hydropower use indeed is especially recommended at this site as

- energy required for drinking water supply pumps as well as continuous sediment transfer could be produced on site; excessive energy could be feed into a grid upon grid connection,

- recovered storage capacity will allow not only for energy production during wet season,

- recommended sediment transfer is combined with a regular water disposal which can be used for an additional fraction of hydropower production.

For water provision, in principle an intake is available in form of the existing reservoir base outlet. Currently the outlet is blocked by sediment and debris. Before the base outlet can be used again, the area has to be dredged, the structures inspected and party renewed. For hydropower use, also a trash rack installation in front of the intake is required. Due to a currently missing operational bottom outlet and the permanent reservoir use for drinking water provision a significant part of the work will have to be done by divers.

The piping within the former diversion tunnel must be checked and repaired/ replaced if necessary, especially because the use as a penstock can be affected with other pressure requirements than a pure outlet use. The power plant could then be connected to this penstock with a new outlet valve downstream to turbine water extraction to provide the base outlet function for the reservoir. The current outlet valve would be removed to create place for construction of the power house.

Available construction space is very limited within the valley with additional design restrictions. The western slope of the downstream valley section is used for drinking water installations. The center part of the valley should not be blocked for flood drainage reasons. The eastern valley slope had been affected by a landslide. However, the eastern slope bears the location of the outlet valve and possible penstock. Due to the existing spillway and flood drainage restrictions there is no easy way of leading the penstock towards the western valley side. Therefore the HPP should be located on the eastern slope at the end of the existing outlet pipe. Also due to Hurricane Thomas experience the HPP has to be provided with a flood safe powerhouse.
General site conditions in the aspects of hydropower are similar to the ones outlined under sedimentation issues, especially concerning overall site access. Currently heavy road traffic is restricted. In addition currently there is no traffic access to the other valley side but just a foot path.

A first evaluation of the site suggests that the former landslides affected only top layers of soil. Therefore it should be possible to secure side walls and power house by rock anchors. For direct site access a cable crane may be the initial method, followed by a bridge construction on a flood save level. A first sketch of the proposed installation is given in Annex M.

The hydrological assessment as given in Annex M too, results in a HPP in the range of 250 kW which fits to former calculations of other studies. For reasons of reliability, for efficiency in part load and foremost for reasons of limiting the required bridge capacity and costs, we recommend to split the plant capacity into two engine sets.

A standard setup for this plant size would be a Francis turbine type. However, considering construction cost, efficiency robustness on sediment wear and easy to change runner wheel, we suggest selecting Turgo type turbines. We also recommend a TC-HVOF coating for sediment resistance. Appropriate sets are available from several manufacturers.

Fig. 10.1: Turgo type turbine (source: Gilkes Hydropower)

For times when minimum water provision for turbine operation is not available, an additional small centrifugal pump in reverse operation, working as a small turbine, could be integrated in the installations.

A financial assessment of overall HPP construction cost at this project stage is always affected with a significant degree of uncertainty. However, taking into account the sketched layout, infrastructure and installations, we consider the project cost in a range of 4,000 $/kW or 3,000 €/kW, summing up to 1 M US$ or 0.75 M€. This does not include major work on massive new intake construction.
The above given first layout of a hydropower facility at John Compton Dam has been done on best guess without detailed survey as hydropower has not been the core question of this study. For a profound planning more detailed information (e.g. on hydrology, topography, geology, etc.) is required.

In any case, in the long run, the electricity bill of WASCO could be reduced with the installation of sustainable hydro power generation.
11 Timeframe and Cost Estimate

The situation of endangered drinking water provision requires urgent action. On the other hand, major work within the reservoir should only be done with appropriate equipment and under acceptable safety conditions including access to the reservoir.

Considering the technical information, constraints, and dimensions, a profound schedule for preparation, installation, and operation is given as follows:

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<td>Organizational issues</td>
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<td><em>Short term Sediment removal</em></td>
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<td>Equipment inkl. auxiliaries</td>
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<td><em>Sustainable sediment management</em></td>
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<td>Equipment inkl. auxiliaries</td>
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<td>Options</td>
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<td>Aux. power supply (land based)*</td>
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<td>According fuel estimate</td>
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*Fig. 11.1: Project schedule for sediment management implementation and conduction*

Design, final component selection, and construction will take several months, followed by transportation time of the required components to St. Lucia. During final design and preparatory works in Germany, the local land equipment assembly can already take place. The swimming gear requires reliable landing installation as a reinforced boat/equipment slip and a swimming pier and power installation.

If the project starts in due course, the first dredging work will be possible before end of 2013 and just before end of the wet season. Depending on according equipment availability, the initial dredging may also start earlier. This would also implicate that the weather conditions would enable safe operation. In any case, first storage volume rehabilitation will be achievable before the next dry season begins. The first dry season will be used to further restore a part of the overall storage volume and especially to dredge sediment close to dam and water outtakes to ensure water provision and base outlet function.
The according cost for each task and additive/option positions can be rated as follows:

<table>
<thead>
<tr>
<th>Measure</th>
<th>Cost estimate</th>
<th>Implementation</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planning and Preparations</strong></td>
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<tr>
<td>final design and components</td>
<td>150,000 €</td>
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<tr>
<td>slip ramp, swimming pier, etc.</td>
<td>60,000 €</td>
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<tr>
<td>land installations</td>
<td>100,000 €</td>
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<tr>
<td>power connection</td>
<td>10,000 €</td>
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<tr>
<td>general equipment</td>
<td>150,000 €</td>
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<tr>
<td>organizational issues</td>
<td>20,000 €</td>
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<tr>
<td><strong>Short term Sediment removal</strong></td>
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<tr>
<td>equipment incl. auxiliaries</td>
<td>650,000 €</td>
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<tr>
<td>Transport</td>
<td>50,000 €</td>
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<tr>
<td>Installation</td>
<td>50,000 €</td>
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<tr>
<td>Operation</td>
<td>250,000 €/a</td>
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<td><strong>Sustainable sediment management</strong></td>
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<td>equipment incl. auxiliaries</td>
<td>300,000 €</td>
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<td>Transport</td>
<td>30,000 €</td>
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<tr>
<td>Installation</td>
<td>30,000 €</td>
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<tr>
<td>Operation</td>
<td>80,000 €/a</td>
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<td><strong>Others</strong></td>
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<tr>
<td>Miscellaneous</td>
<td>100,000 €</td>
<td>10,000 €/a</td>
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<tr>
<td><strong>Options</strong></td>
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<tr>
<td>aux. power supply (land based, without fuel)</td>
<td>60,000 €</td>
<td>15,000 €/a</td>
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<tr>
<td>according fuel estimate</td>
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| Sum without options                               | 1,700,000 €   | 340,000 €/a    |           |
| Sum incl. options                                 | 1,760,000 €   | 435,000 €/a    |           |

Fig. 11.2: Cost table

This cost estimate is based on experience, price indications of adequate vendors and assessment of local conditions at initial site visit. Contractually reliable numbers will be available after a quotation. Due to always existing risks during performance of such projects, we recommend to budget additional 300,000 € as contingency.
12 Conclusions

Roseau Reservoir features all characteristics of typical advanced reservoir sedimentation, increased by the effects of a hurricane induced flood based sediment intrusion. Complicating conditions on this reservoir are missing available land space, restricted heavy load access, restricted reservoir access and the ongoing need for drinking water extraction.

Within this study several approaches for reservoir recovery have been discussed. Taking into account limits and conditions of the different alternatives the only reasonable solution is to transfer the respective sediment downstream of the dam structure and using the natural transport capacity of Roseau River to further disperse the sediment in the downstream river reach up to its mouth in accordance to natural transport behavior. A short term sediment removal campaign to safeguard the required drinking water extraction should be accompanied and followed by a sustainable long-term sediment management. Other considered standard technical approaches are not recommended for technical or security reasons.

Limited access to the reservoir also sets restrictions to equipment that can be transported to or lowered into the reservoir. The same is valid for installations within the narrow land space near the dam crest. Even considering the urgent need for measures, proper equipment preparation and installations to access the reservoir such as a sufficient boat slip and a swimming pier require time for preparations. Local conditions require modular equipment that can be securely transported to the reservoir and mounted within the water.

The initial reservoir recovery measures as well as sustainable sediment transfer can be done without interruption of drinking water supply. Safety reasons will require some pausing of sediment transfer during each season for dredging near the dam.

Following these recommendations, a profound reservoir recovery could start before End of 2013 and would last approximately four years.

Duisburg/Germany, May 14th, 2013
13 Annexes

A) Photographs of Dam Structure

B) Photographs of Reservoir, Backwater Areas of the Reservoir, Sedimentation and Siltation

C) Photographs of Downstream River Reach

D) Location of Samplings


F) Sediment Allocation and Thickness within Reservoir

G) Cross Sections within Reservoir

H) Sediment findings

I) Hydrology

J) Sediment Transfer Calculations

K) Sediment Transfer Installations

L) Cost Estimates

M) Hydropower Assessment

N) Dewatering Site Location

O) Dewatering Site Sample