Sediment Measurement for the Three Gorges Project

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Jingjiang Bureau of Hydrology and Water Resources Survey, China

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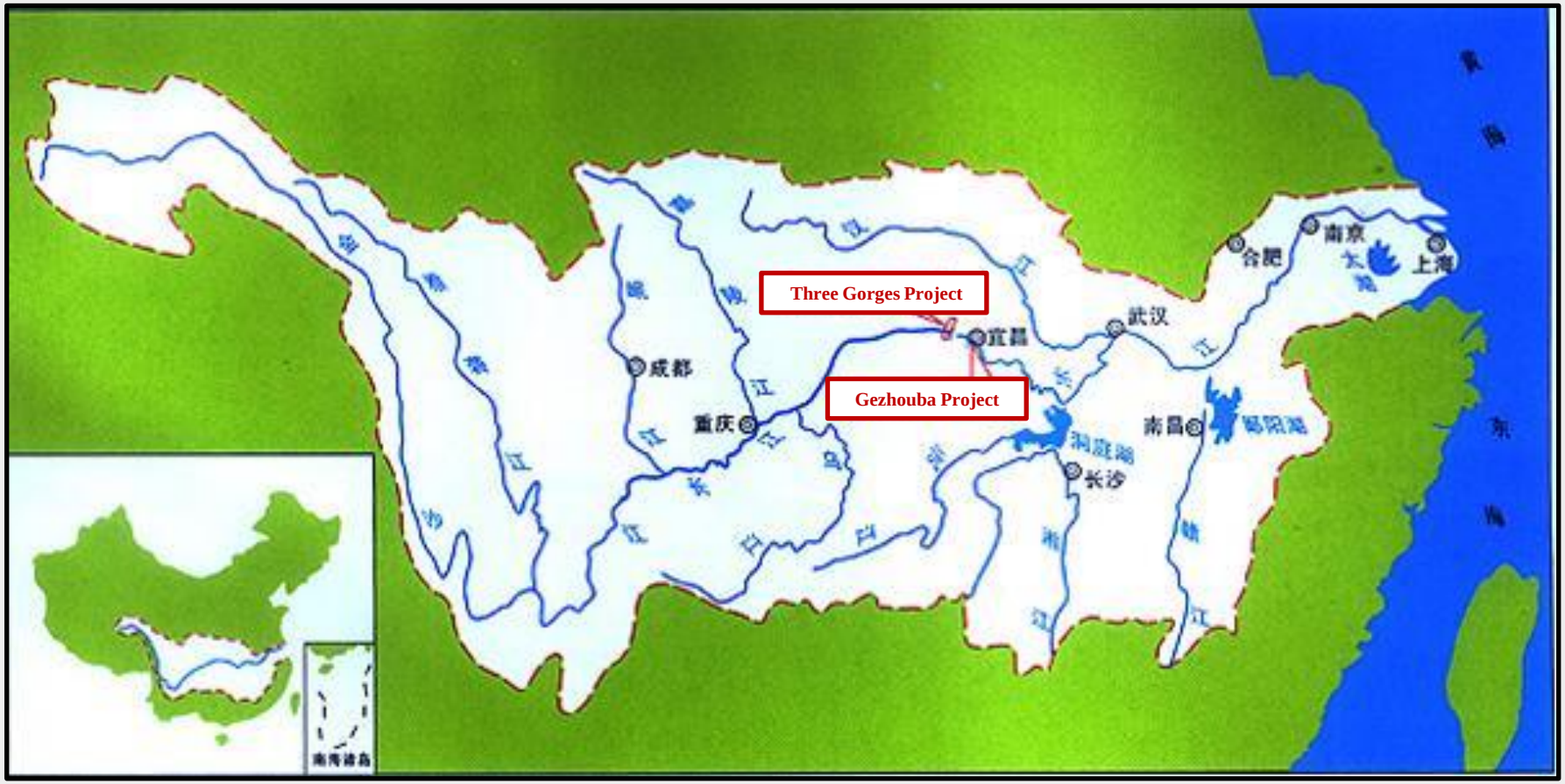
Content

1 Brief Introduction of the TGP



Location of the Three Gorges Project

1 Brief Introduction of the TGP

The Three Gorges Reservoir has retained an accumulative total of 153.3 billion cubic meters of flood water inflow from 2003 to 2019 and plays an indispensable role in mitigating the floods and in reducing the massive floods in the upper reaches of the Yangtze River.

The mainstream has always been called "Gold Waterway". The massive project has also played a significant role in improving navigation conditions and increasing shipping capacity in China's Yangtze River. Since the Three Gorges Reservoir started impounding in 2003, cargo transport condition has significantly improved. At the same time, the transportation costs have been greatly lowered as the average energy consumption of ships reduced to a third of what it was prior to the Three Gorges Project. The Three Gorges Dam commissioned a double-way five-step ship lock in 2003, which has since operated for 17 years consecutively by 2020

The Three Gorges Dam: a concrete gravity dam Length: 2335 m
Width: 115 m (bottom)
40 m (top)
Height: 185m
Normal impounded water level: 175 m

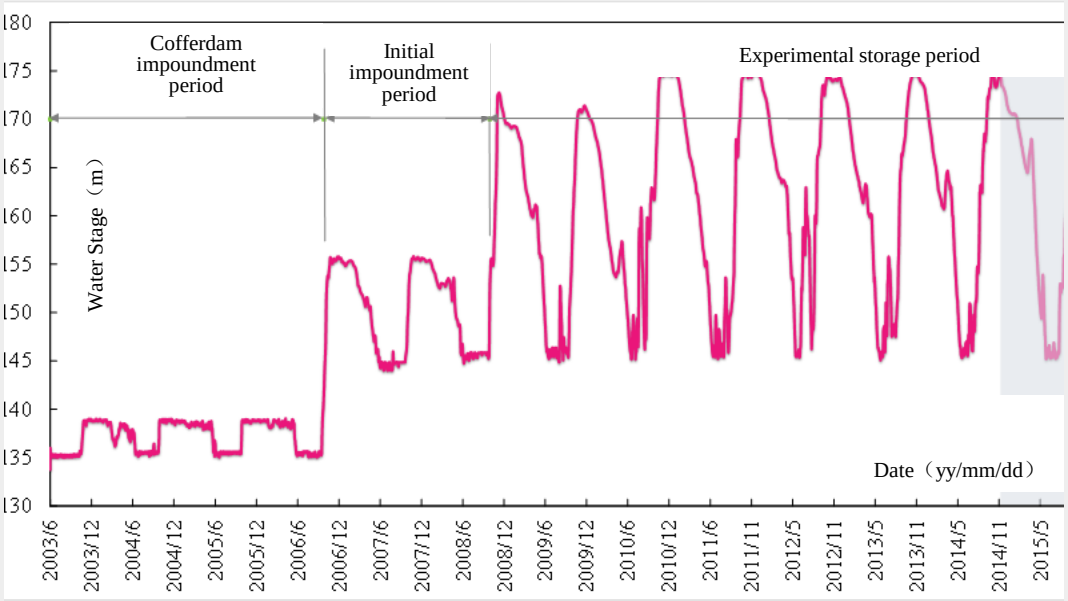
Total storage capacity: 39.3 billion m^3
Flood control capacity: 22.15 billion m^3
Adjustment capacity: seasonally adjusted

Hydropower Stations
32 700000-kw-generating units
14 （left bank）
12 （right bank）
6 （underground）
In addition, there are two 50,000-kw power generating units.

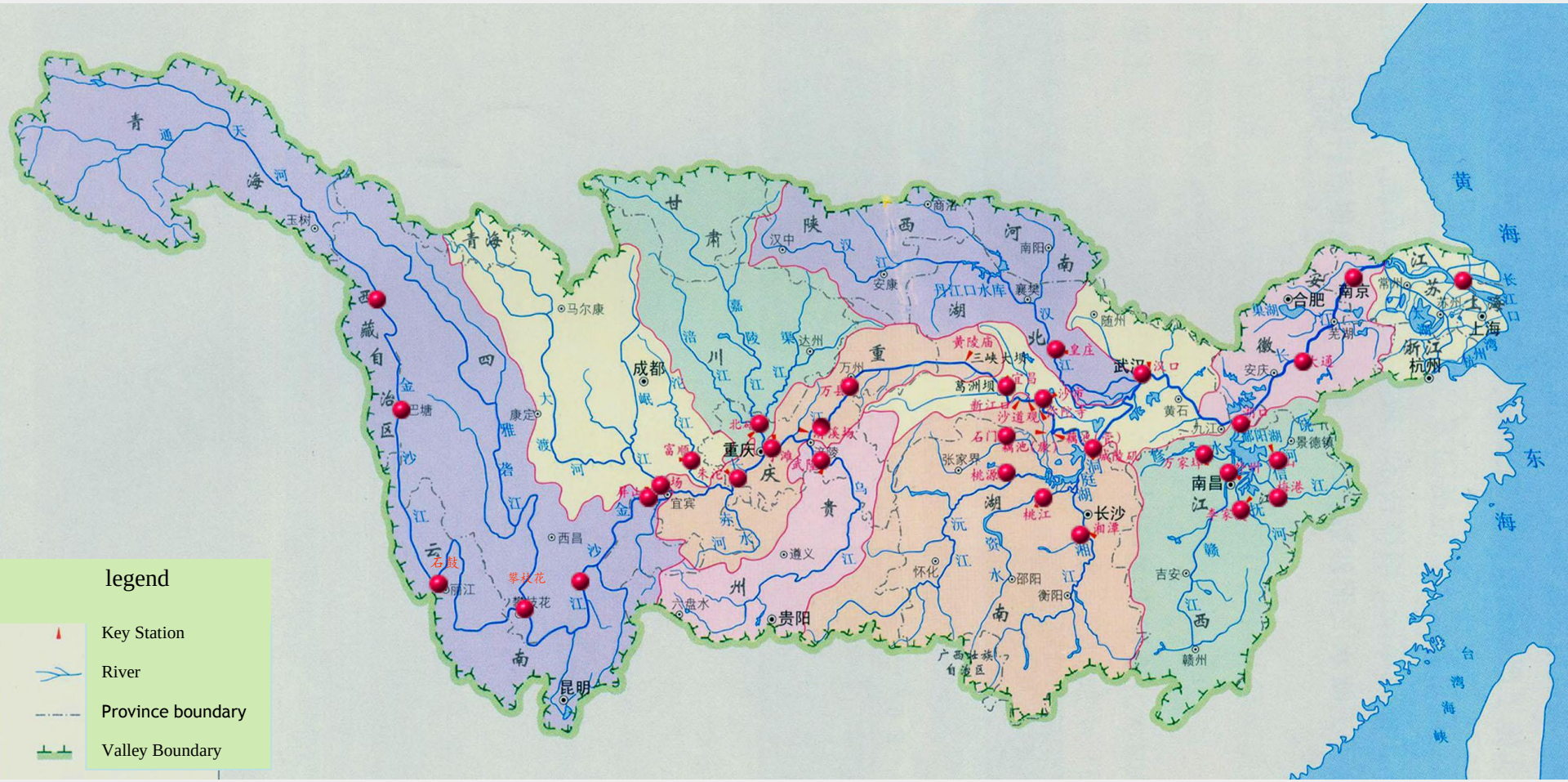
1 Brief Introduction of the TGP

On April 3,1992, the Fifth Session of the Seventh National People's Congress Adopted the Resolution on the Construction of the Three Gorges Project on the Yangtze River.
In December 14, 1994, Premier Li Peng of the State Council announced at the commencement ceremony of the Three Gorges Project held in Sandouping, Yichang that the Three Gorges Project was officially started.
On November 8, 1997, the Three Gorges Project realized the closure of the main river, marking the successful completion of the five-year first phase of the project and the transfer of the project to the second phase.
On June 1, 2003, the Three Gorges Project officially impoundment. In June 16, 2003, the Three Gorges Ship Lock began its trial operation.

The Three Gorges Project has three main benefits, namely, flood control, power generation, navigation and water resources utilization, among which flood control is considered to be the most core benefit of the Three Gorges Project.

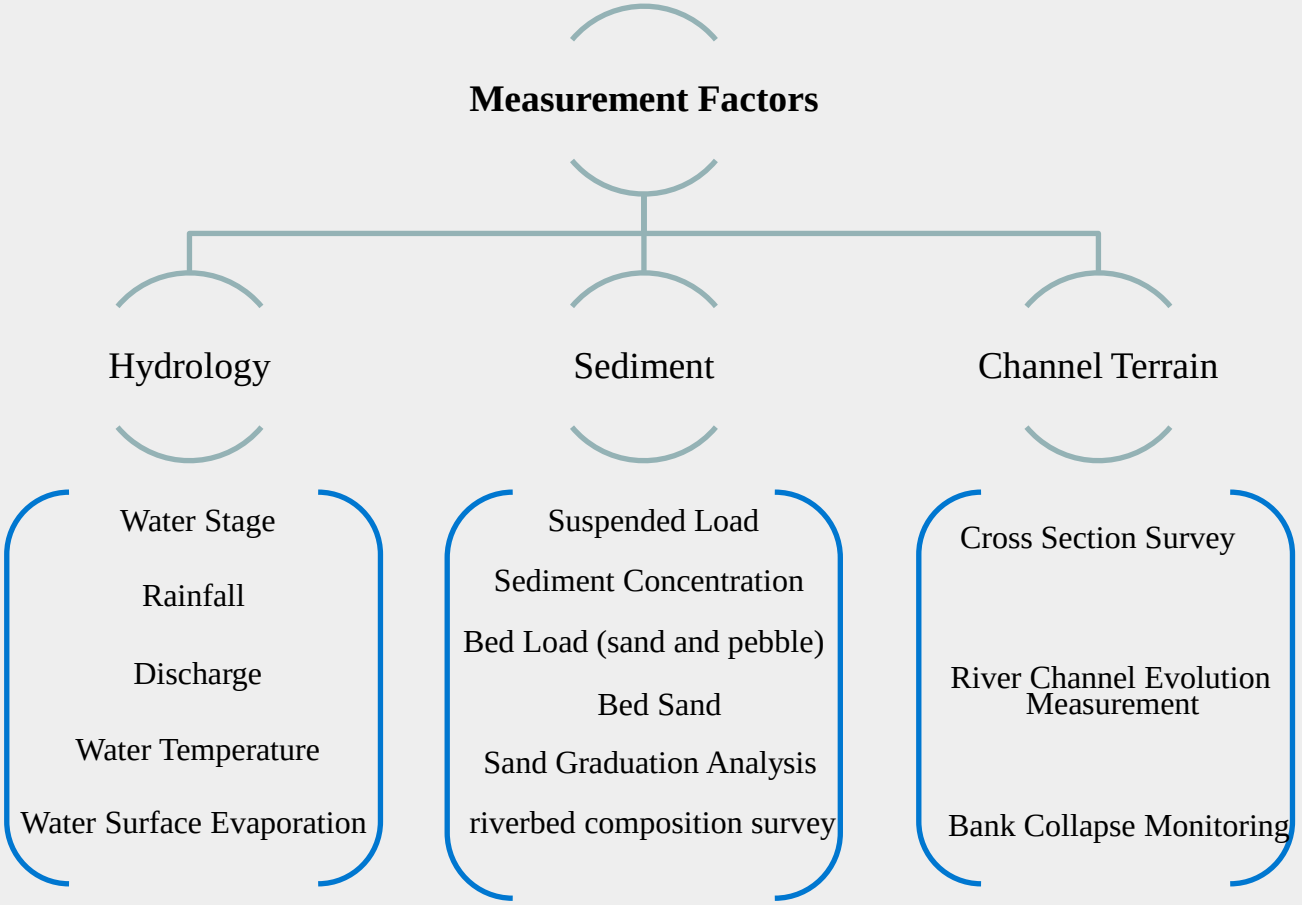


长江流域主要水文站



Distribution of key hydrological stations along main stream and tributary

2 Distribution of Hydrology Stations and Measurement System



（1）Water Stage

Preventive maintenance of water gauges

（1）Water Stage

Radar type

Bubble type

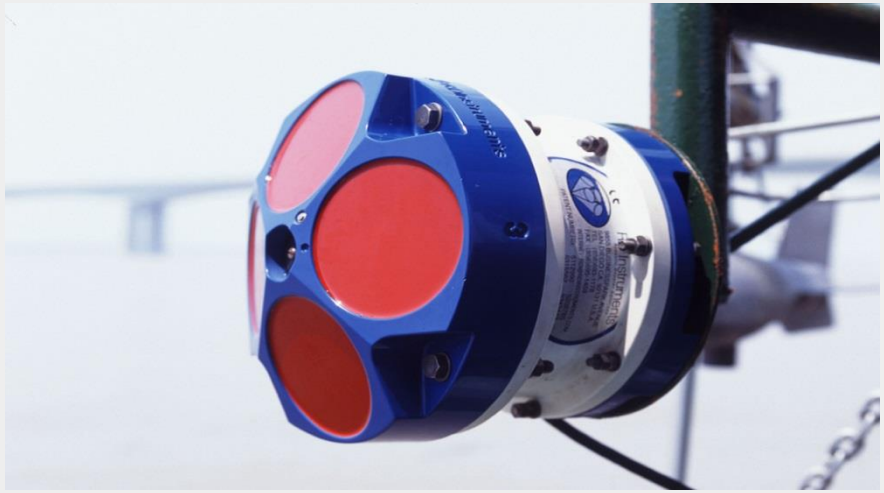
（1）Water Stage

Pressure type

（2）Rainfall

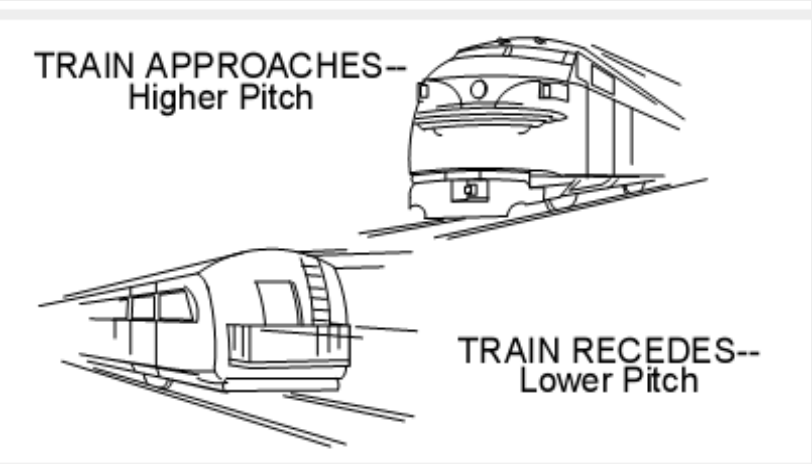
Automatic pluviometer

（3）Discharge- Acoustic Doppler Current Profilers Carried by ships

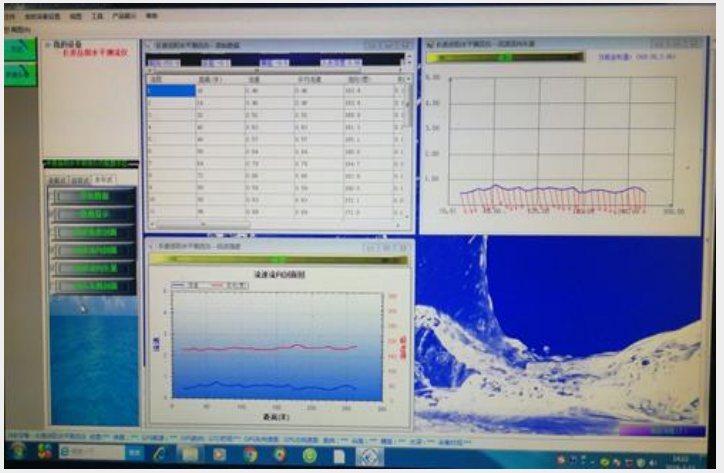


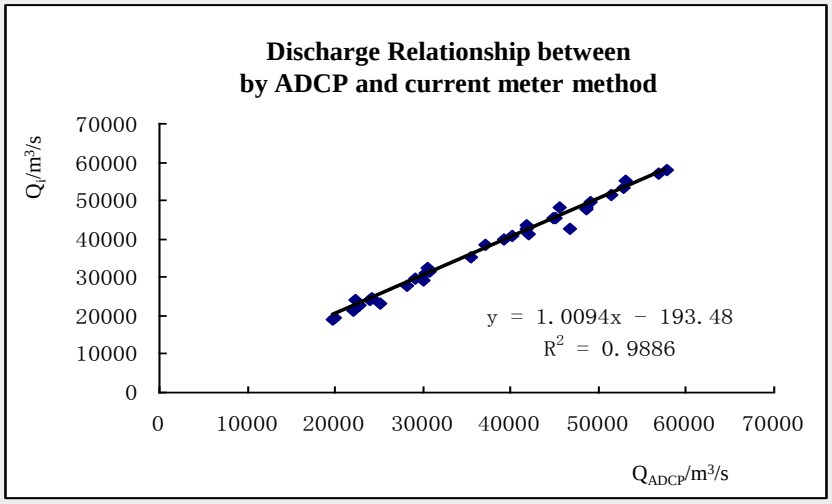
ADCP- Acoustic Doppler Current Profilers Carried by boat

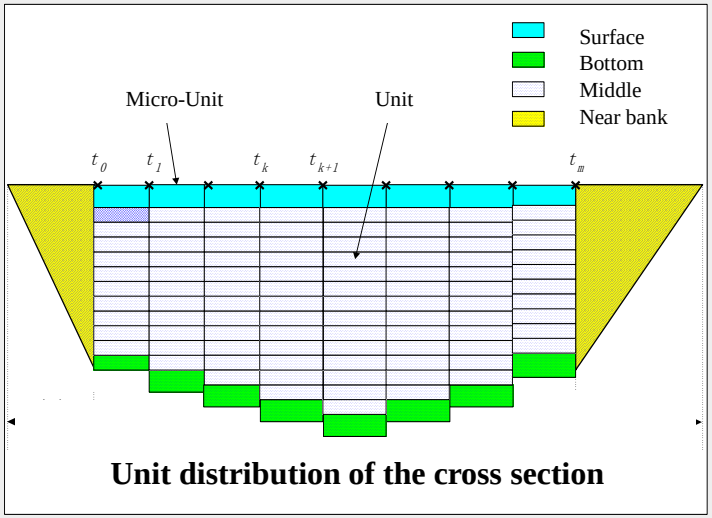
（3）Discharge



Principle of Doppler effect



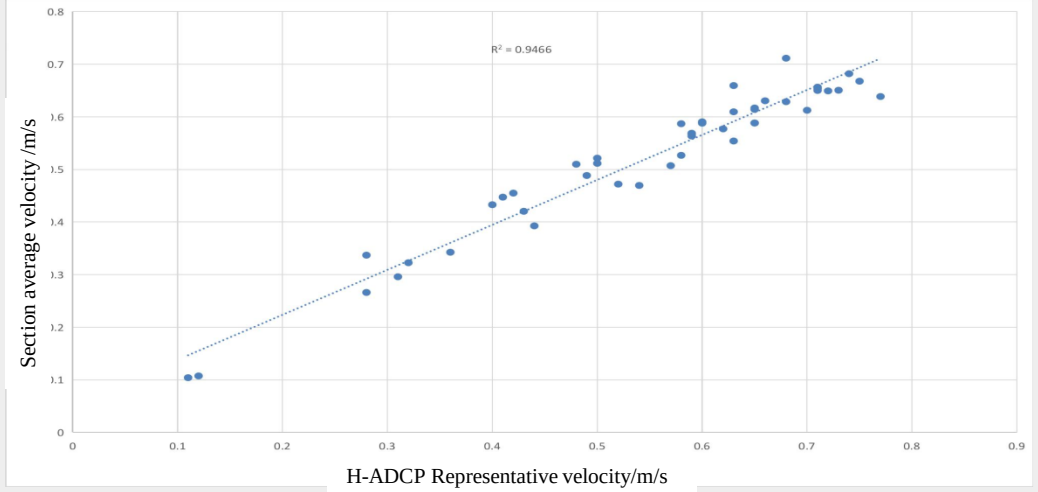


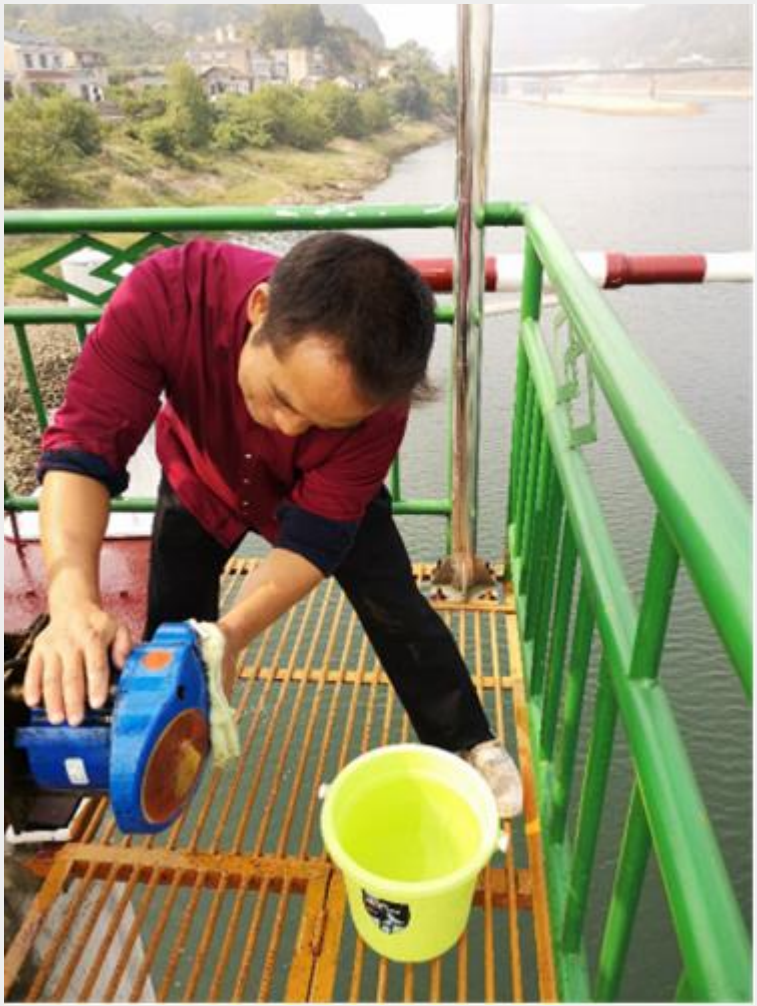


Unit distribution of the cross section

3 Measurement Technologies of Flow and Sediment

（3）Discharge-Horizontal ADCP





Clean Horizontal ADCP

（3）Discharge-Current meter carried by cableway and ship

3 Measurement Technologies of Flow and Sediment

（3）Discharge- Water Surface velocity

Side-scan Radar

Airborne radio current meter

Digital Particle Image Velocimetry (DPIV)

（3）Discharge- Water Surface velocity Electronic buoy

THE ELECTRONIC BUOY uses GNSS technology to track the trajectory, velocity and direction of water. By analyzing these data, the river flow pattern can be obtained. The electronic buoy has been successfully used in Taihu Lake, Yangtze River, Hanjiang River and other rivers and lakes.

MODEL Porpoise V2V RTK

PRODUCT FEATURES

- Follow the structural design of fluid mechanics to weaken the influence of wind-induced flow
- Excellent flow following performance
- Lightweight design, can be operated by one person independently or thrown by UAV
- Centimeter level high precision RTK Positioning
- Timing positioning and tracking function
- Real time data display and data analysis module
- IP68 waterproof
- It is suitable for river, lake, sea and other scenes

（3）Discharge- Water Surface velocity　Visual flow velocimetry/Digital Particle Image Velocimetry

VISUAL FLOW VELOCEMETRY is a new measurement technology in the field of hydrology. The advanced image processing technology is applied to analyze the river surface texture image to obtain the surface texture features and the movement data and distribution of the tracer.

MODEL HK-VFV

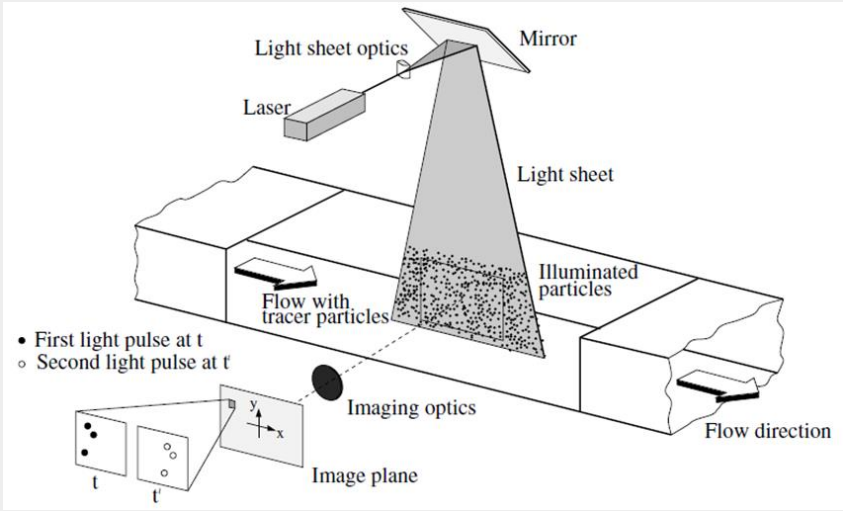
PRODUCT FEATURES

- Based on intelligent image processing and machine learning
- Remote contactless real time flow measurement
- Automatic timing flow measurement
- Unattended monitoring station
- It has the characteristics of green environmental protection and energy saving
- It is suitable for rivers, lakes, open channels, sewage outlets and other scenes

（3）Discharge- Water Surface velocity　Visual flow velocimetry/Digital Particle Image Velocimetry

Particle Image Velocimetry (PIV) is recognized as the most powerful and practical diagnostic tools for flow field analysis in fluid dynamics applications. Instantaneous 2D and 3D flow images are measured with high spatial and temporal resolution.

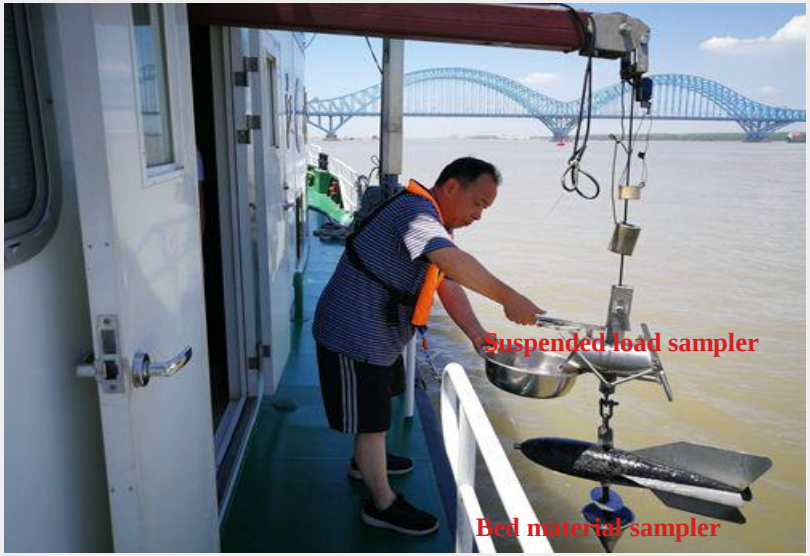
The experimental setup of a PIV system typically consists of several subsystems. In most applications tracer particles have to be added to the flow. These particles have to be illuminated in a plane of the flow at least twice within a short time interval. The light scattered by the particles has to be recorded either on a single frame or on a sequence of frames. The displacement of the particle images between the light pulses has to be determined through evaluation of the PIV recordings. In order to be able to handle the great amount of data which can be collected employing the PIV technique, sophisticated post-processing is required.



（3）Discharge- Water Surface velocity

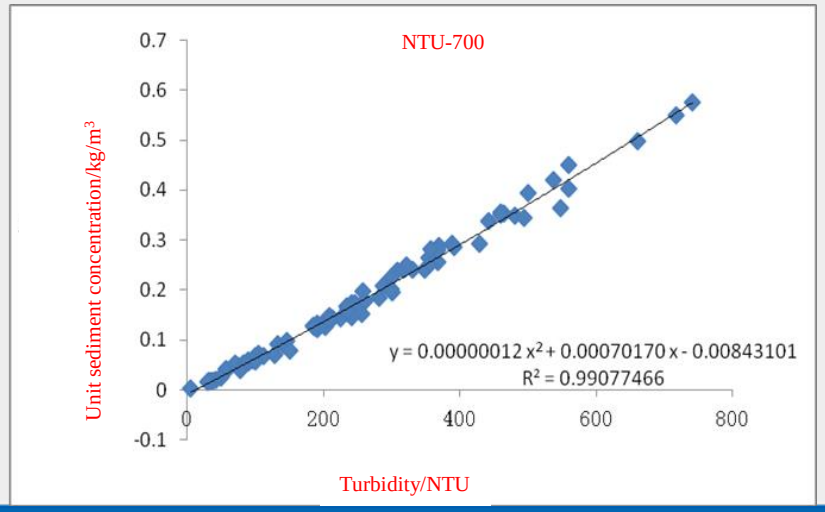
Automatic cable flow measuring robot system in hydrologic station

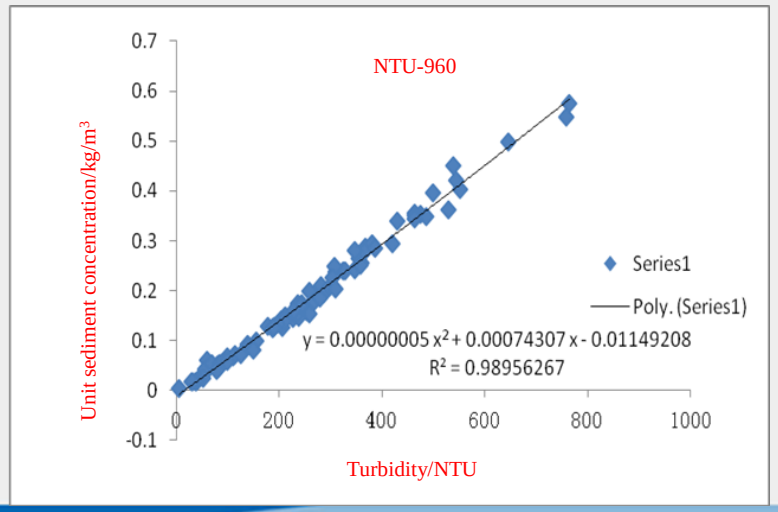
（4）Sediment-Sampler



$$Cs = 0.0000012 \times T_b^2 + 0.0007017 \times T_b - 0.00843101$$

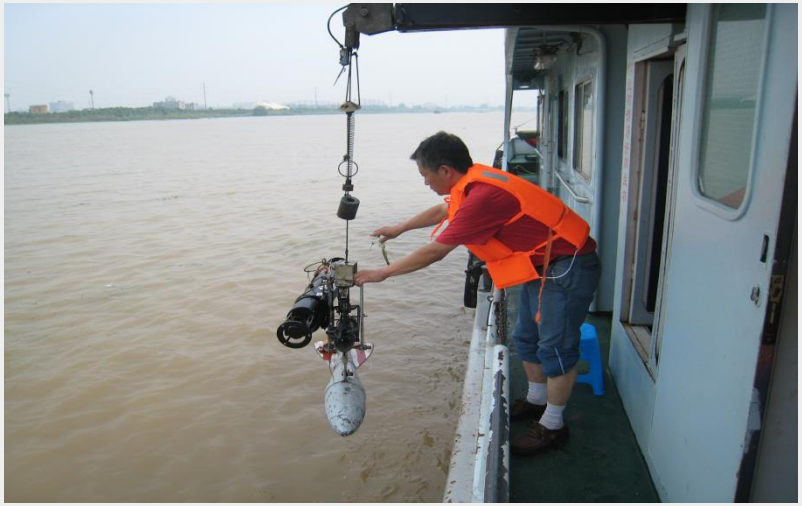
Turbidimeter



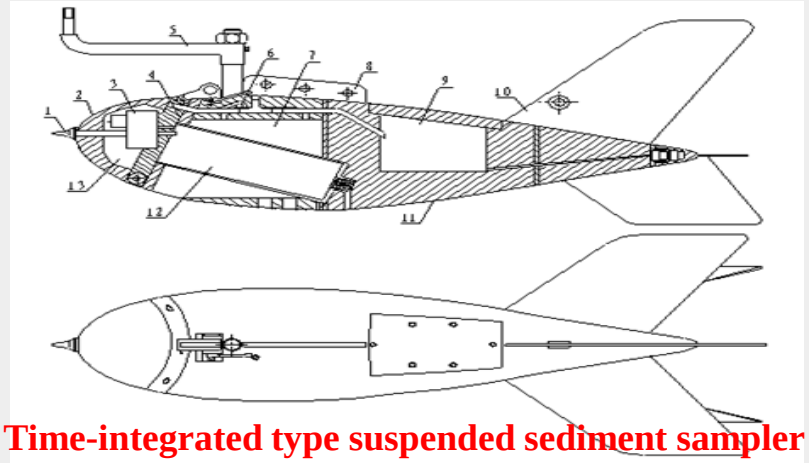


3 Measurement Technologies of Flow and Sediment

（4）Sediment-Sampler Instrument comparison - Lisst 100x



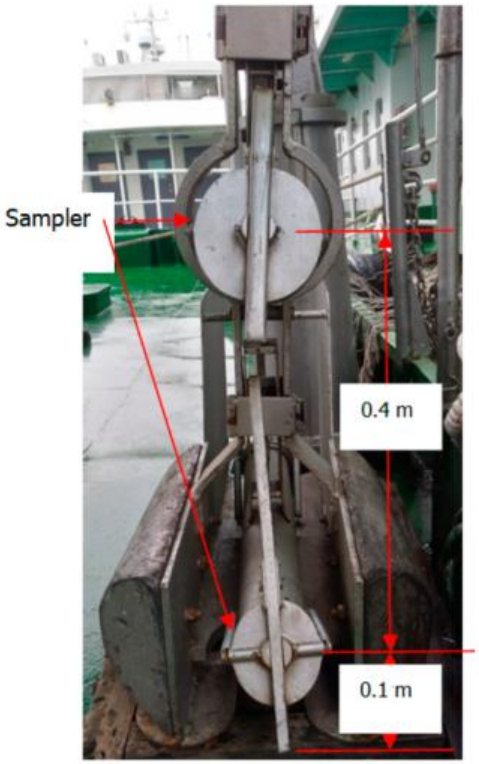
（4）Sediment-Sampler



Time-integrated type suspended sediment sampler

（4）Sediment-Sampler

(b)



(c)

Figure 2. Samplers for suspended sediment in the field survey; (**a**) is the sampler with fish lead, and (**b**,**c**) are the samplers for sampling suspended sediment at the two near-bed points (different camera angles).

Suspended sediment sampler at the two near-bed point

（4）Sediment-Sampler

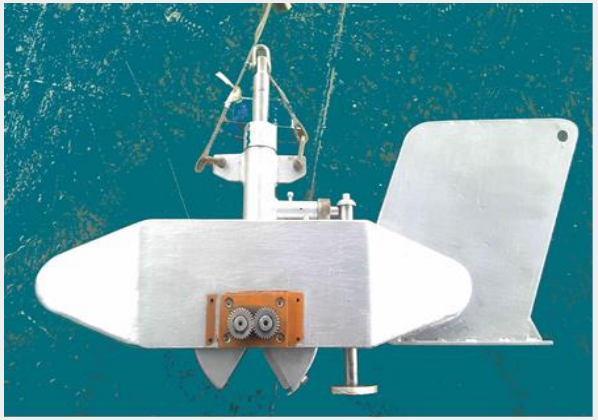
Bed load sampler: sand

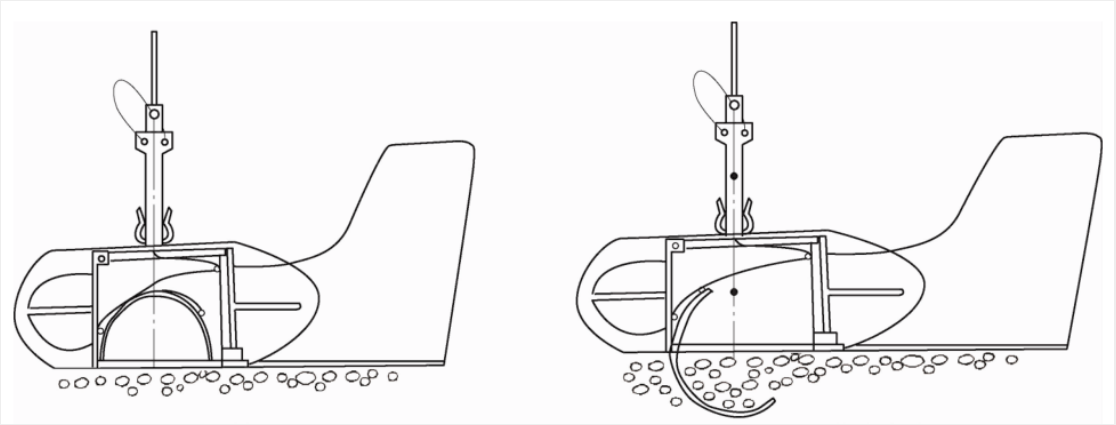
（4）Sediment-Sampler

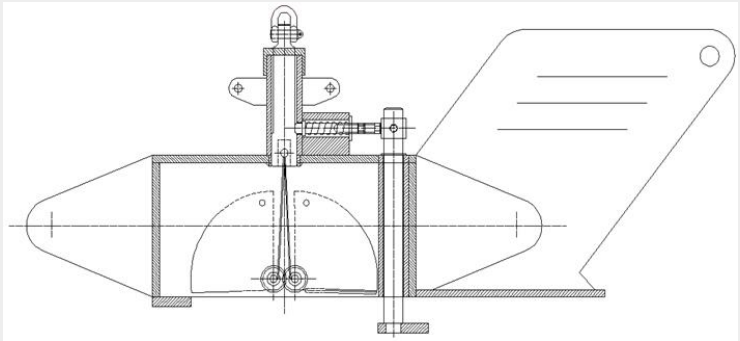
Bed load sampler: pebble

3 Measurement Technologies of Flow and Sediment

（4）Sediment-Bed material sampler digging bucket type





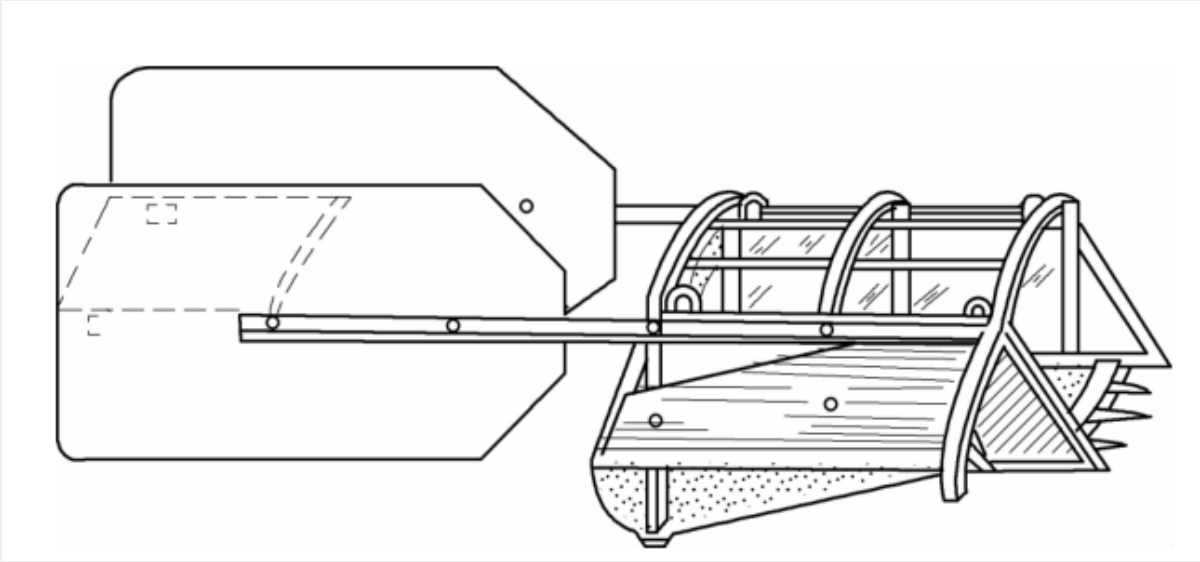


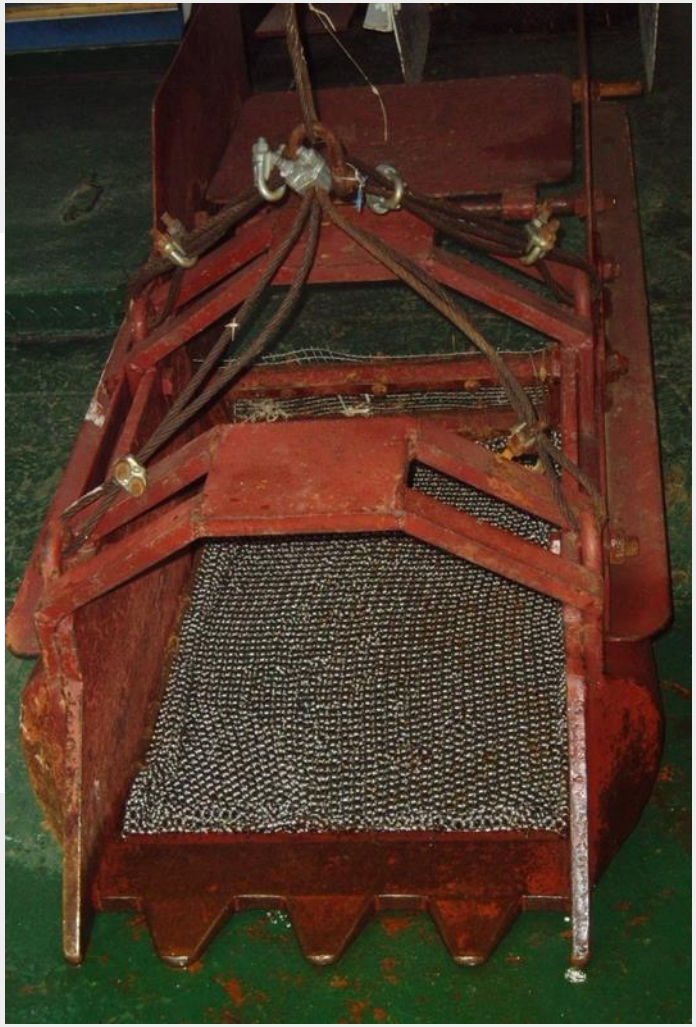
Touch riverbed

Dig sand/pebble

Double door

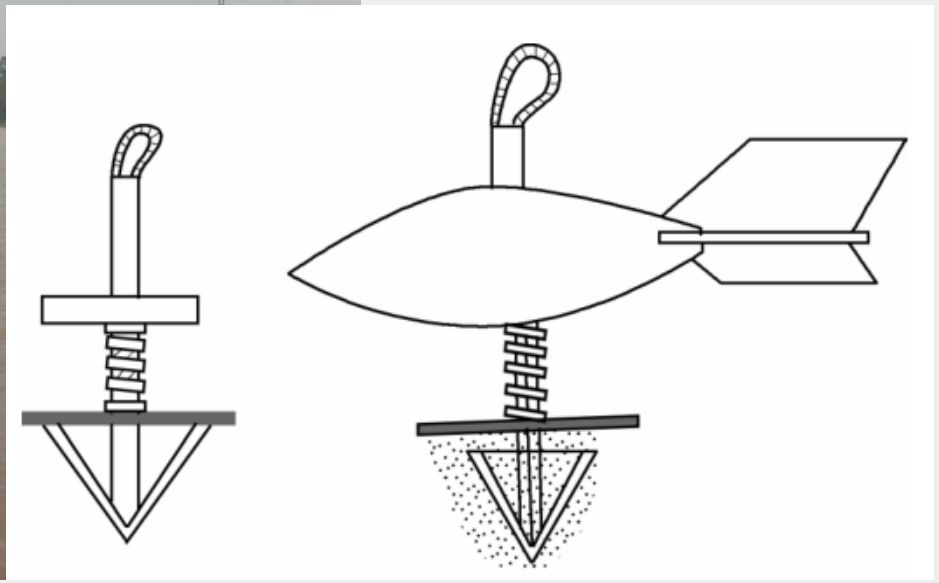
（4）Sediment-Bed material sampler





Plough type

（4）Sediment-Bed material sampler bevel-type



No working Working

（4）Sediment-Dry bulk density sampler　　Roller type

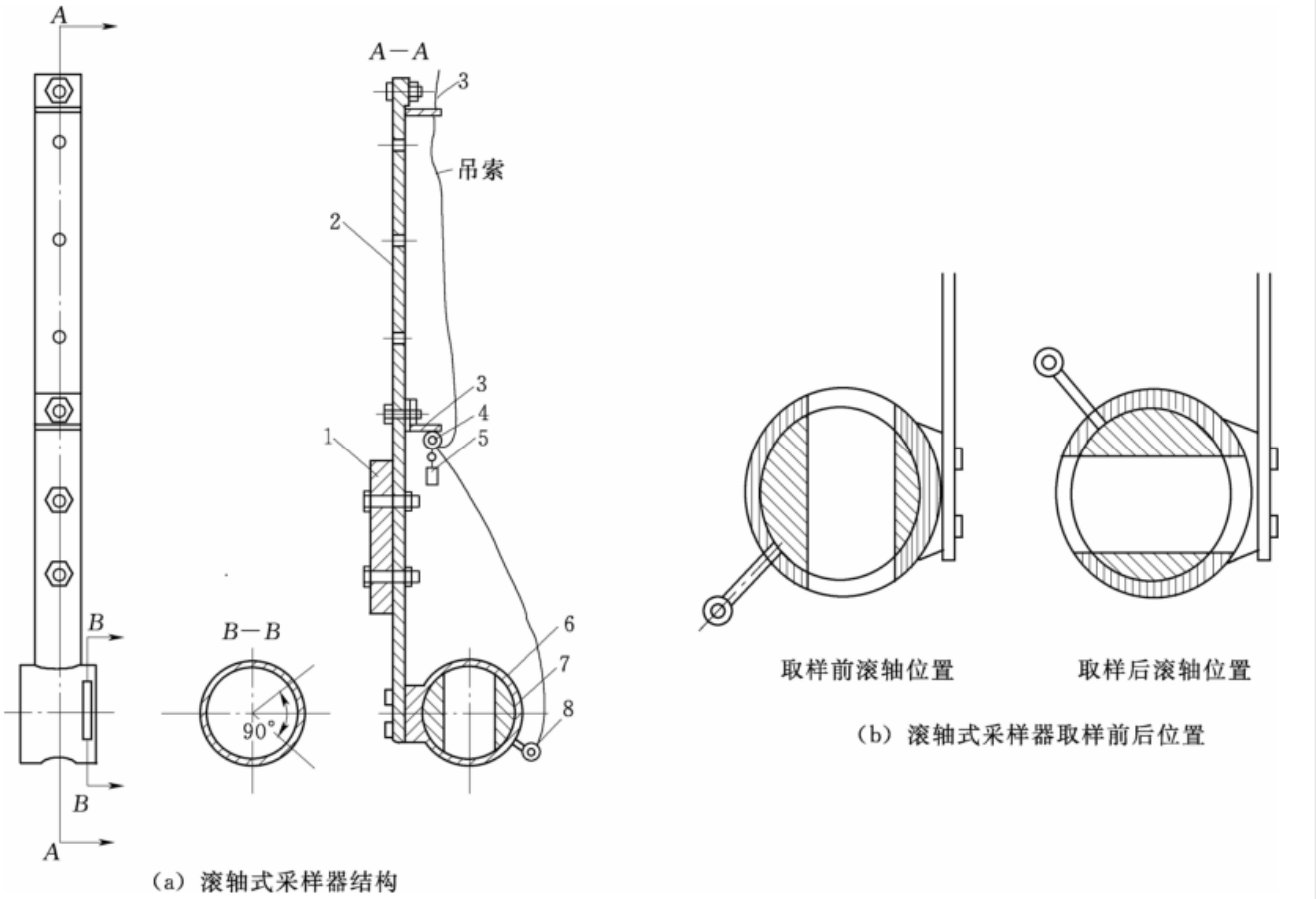
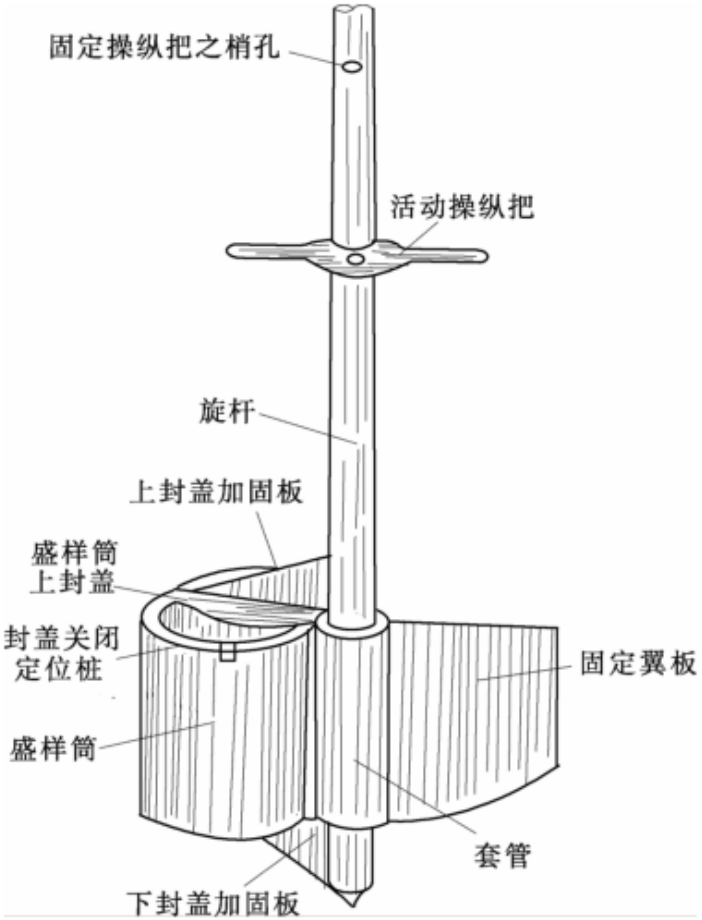


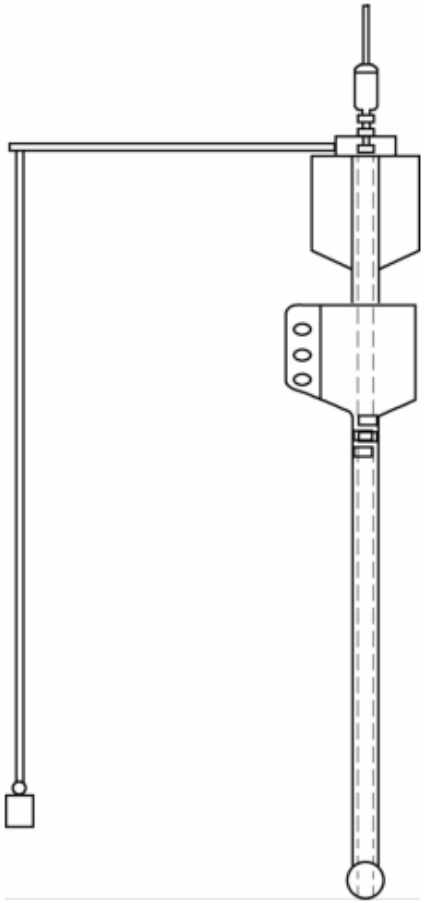
图 3－11　滚轴式采样器示意图

1—铅块；2—采样器把体；3—绳索支撑铁；4—挂钩；5—铅锤；6—采样器滚轴体；7—采样器滚轴；8—销钉

（4）Sediment-Dry bulk density sampler



Spinner handle type



Piston drill pipe type

（4）Sediment-Dry bulk density sampler

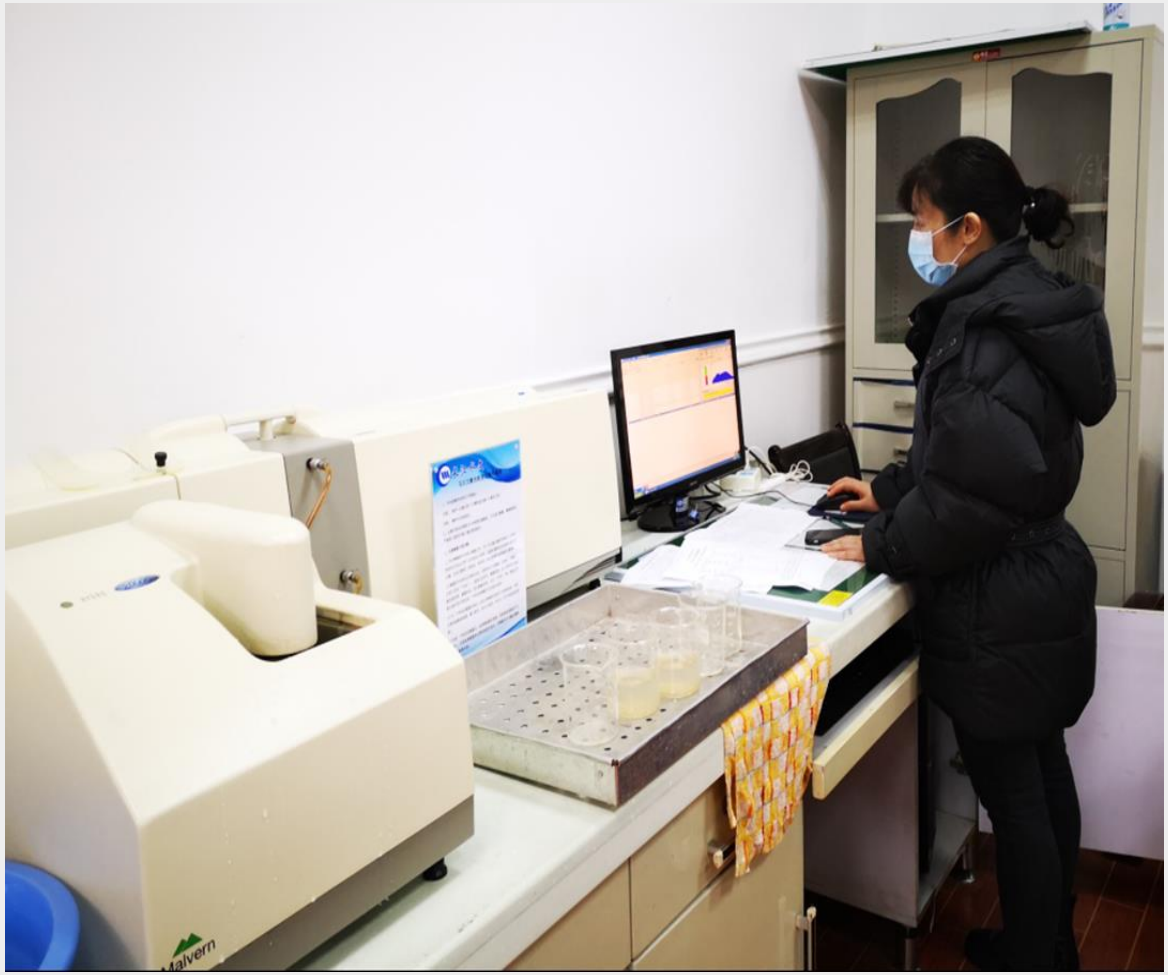
AZC-1 rotary type

Plank type

Sediment sample

3 Measurement Technologies of Flow and Sediment

（4）Sediment-Particle gradation analysis



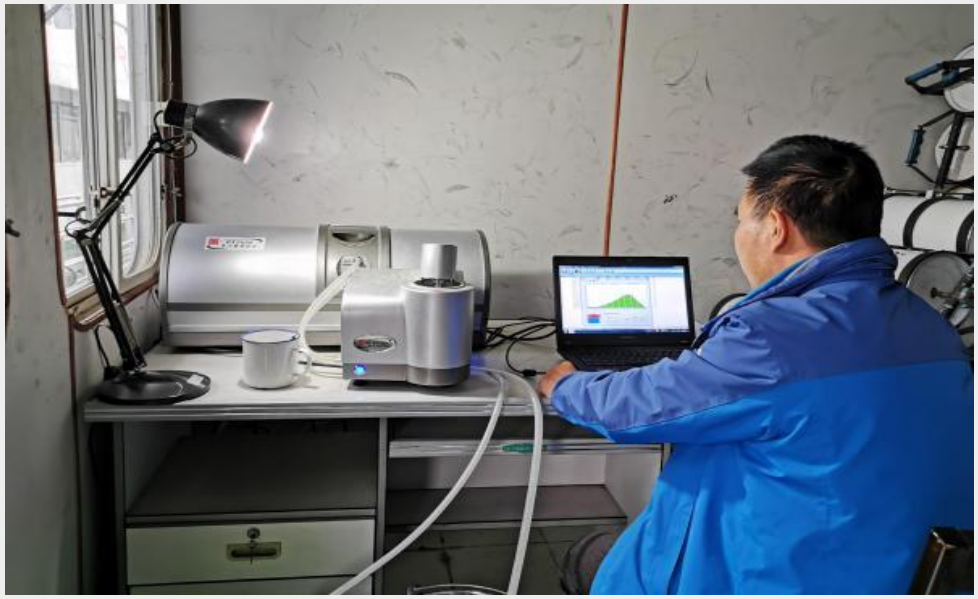
Malvern laser particle size analyzer

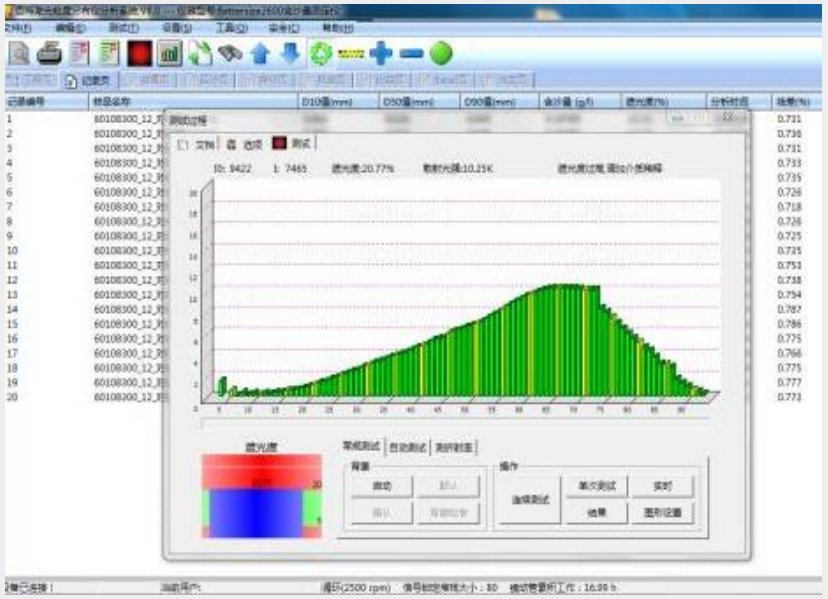
Sedimentation velocity method

Photoelectric particle analyzer

3 Measurement Technologies of Flow and Sediment

（5）Sediment-Suspended sediment concentration analysis





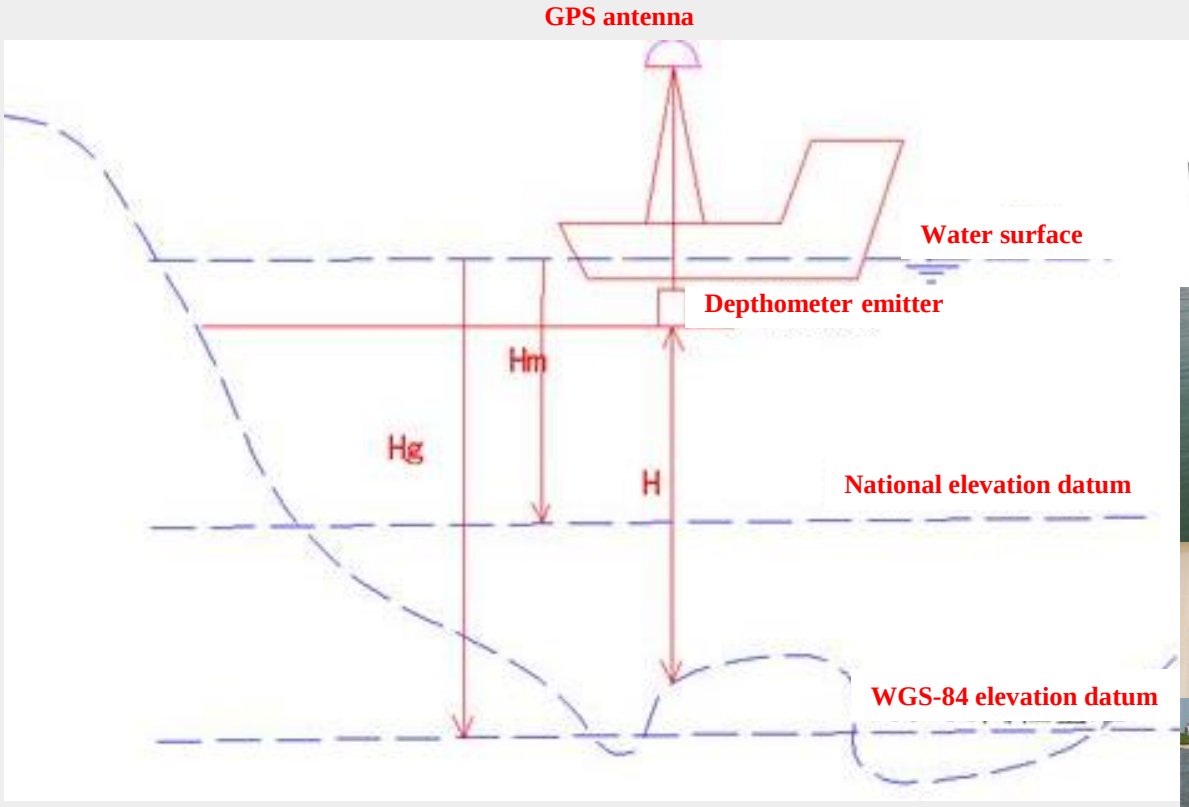
Baite 2600 laser particle size analyzer

The traditional method of drying and weighting after collecting water sample cannot meet the timeliness requirements today. Based on Mie scattering principle, a method of measuring sediment concentration by laser particle size analyzer was proposed in practice. The volume concentration of suspended sediment particle size distribution in water samples with certain suspended sediment content was analyzed by laser particle size analyzer. The conversion relationship between volume concentration and weight concentration was calibrated. The suspended sediment content can be converted rapidly when the distribution of suspended sediment particle size was analyzed.

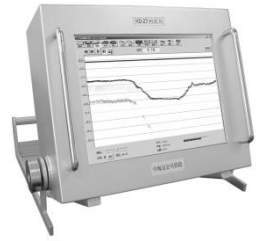
3 Measurement Technologies of Flow and Sediment

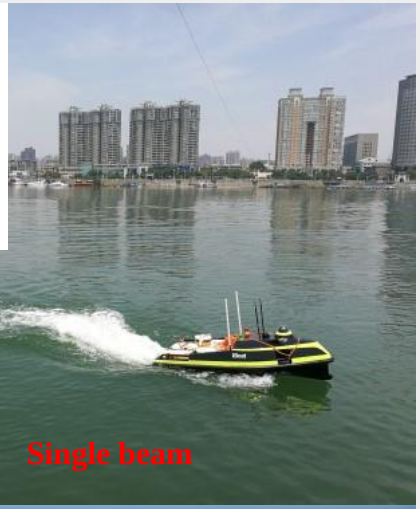
（5）Water surface evaporation

（6）Topographic survey-Underwater topographic survey



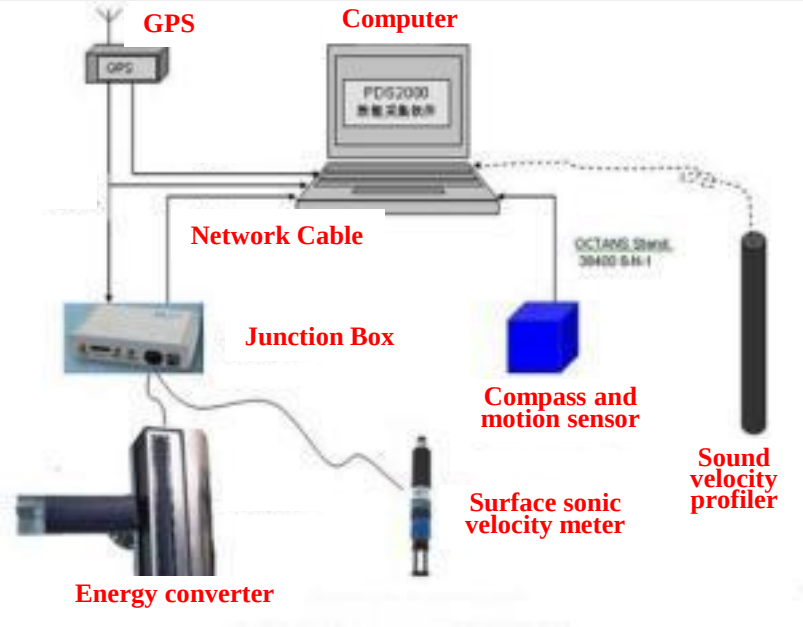
Principle of underwater topographic survey



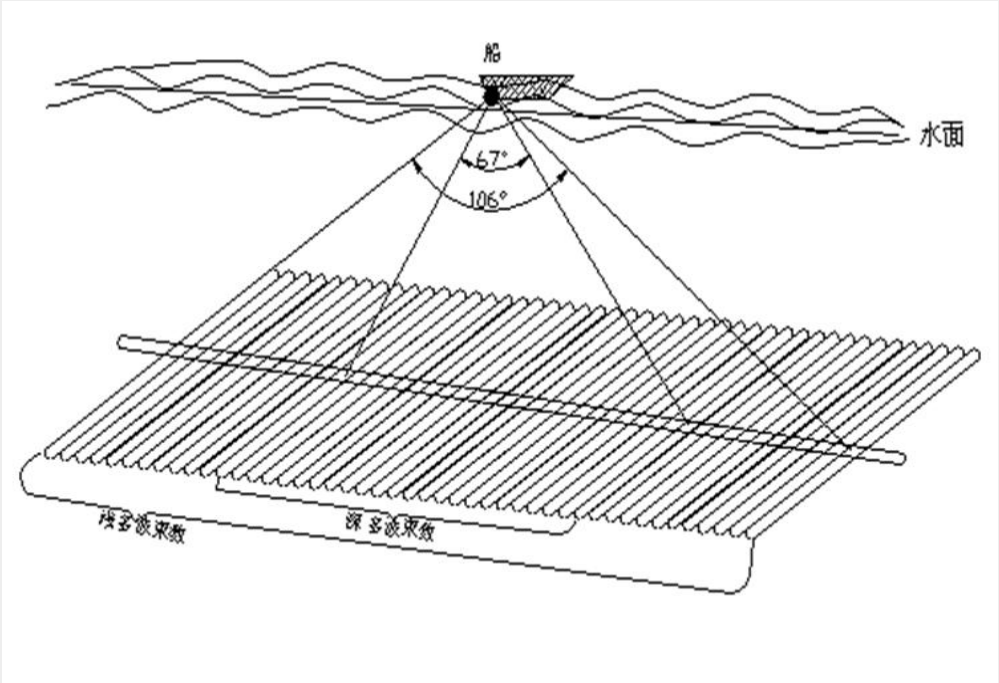


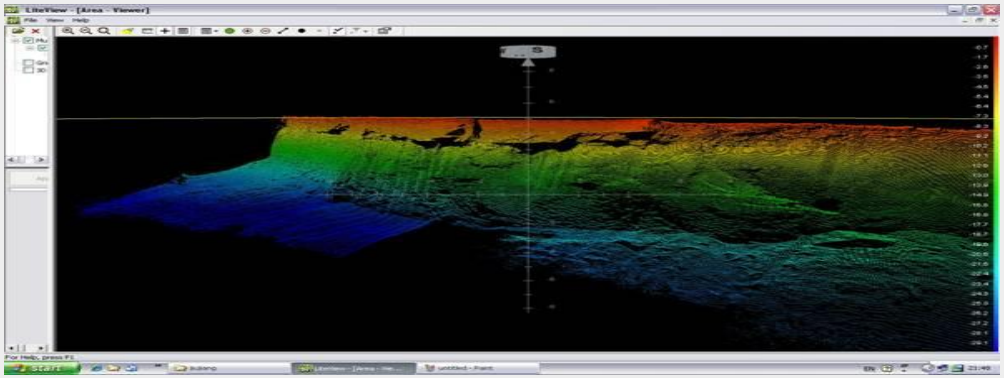
3 Measurement Technologies of Flow and Sediment

（6）Topographic survey-Underwater topographic survey



Multi-beam sounding system





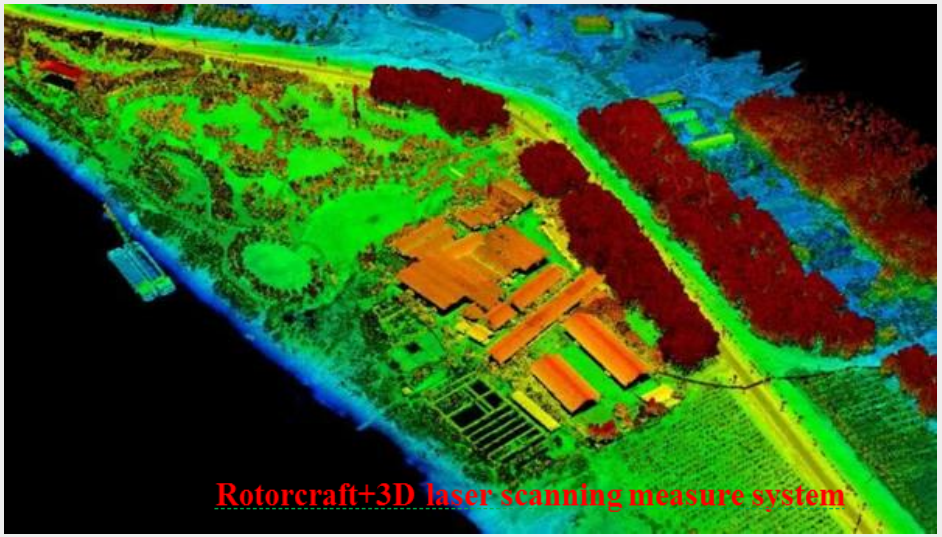
（6）Topographic survey-Land topography

Rotorcraft+3D laser scanning measure system

3 Measurement Technologies of Flow and Sediment

（6）Topographic survey-Land topography

Fixed-wing aircraft+3D laser scanning measure system

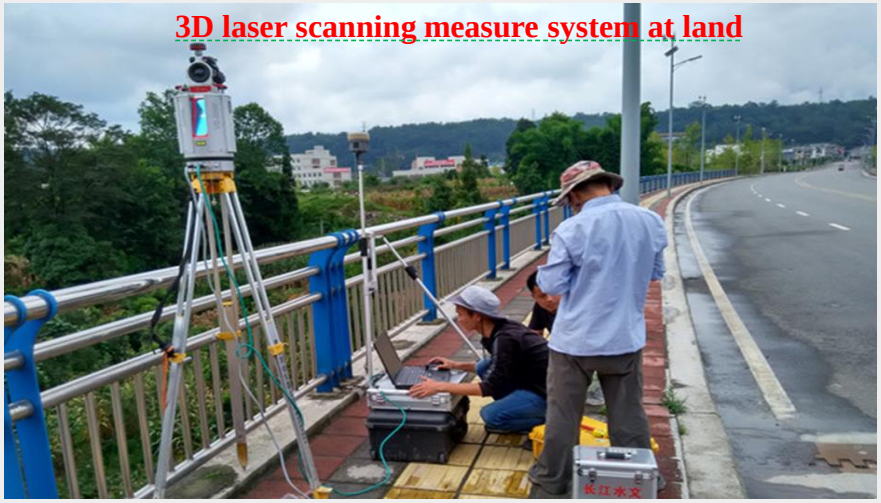


Rotorcraft+3D laser scanning measure system

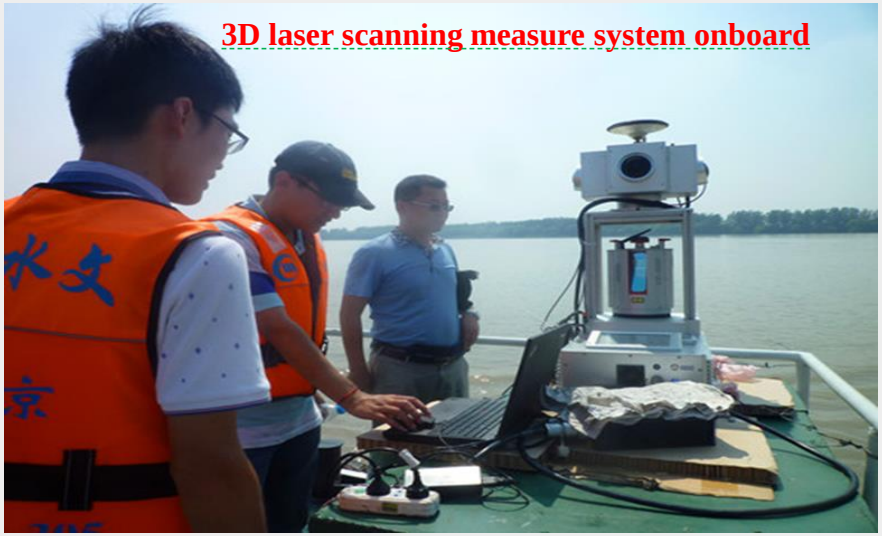
3 Measurement Technologies of Flow and Sediment

（6）Topographic survey-Land topography

3D laser scanning measure system at land

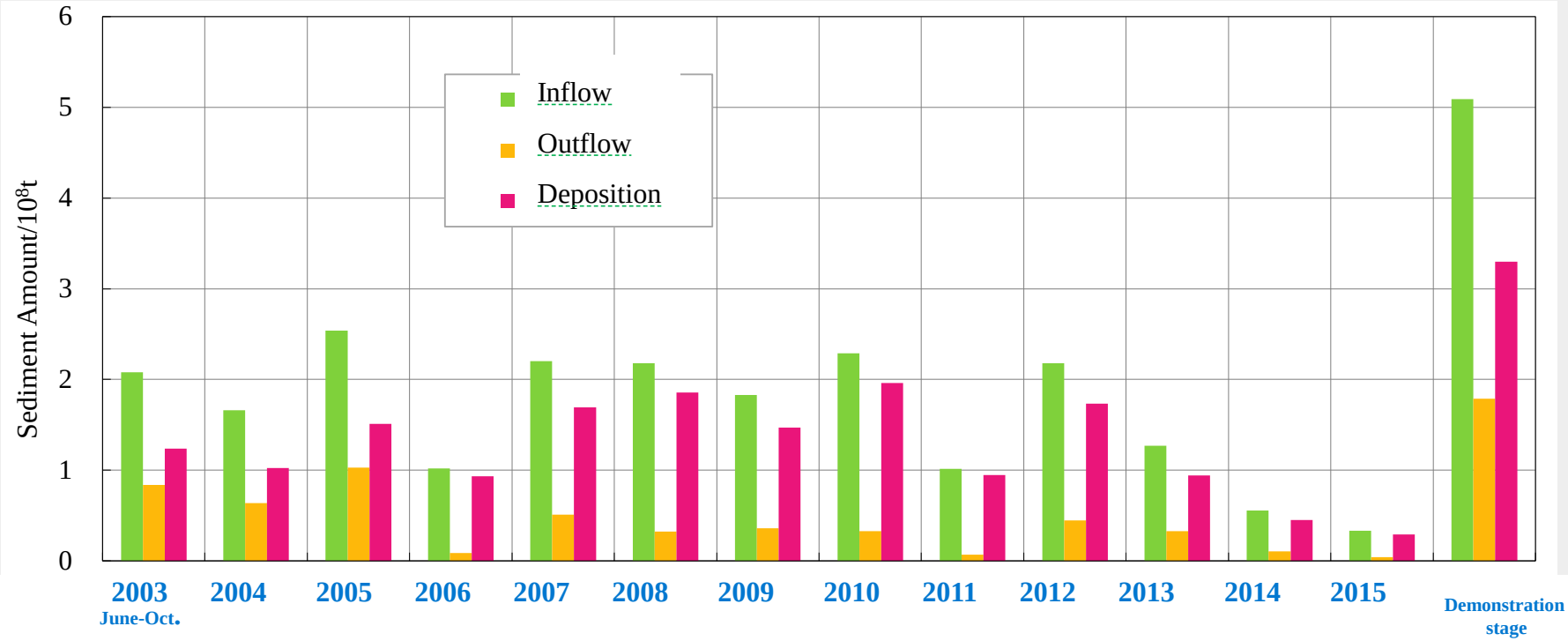


3D laser scanning measure system onboard



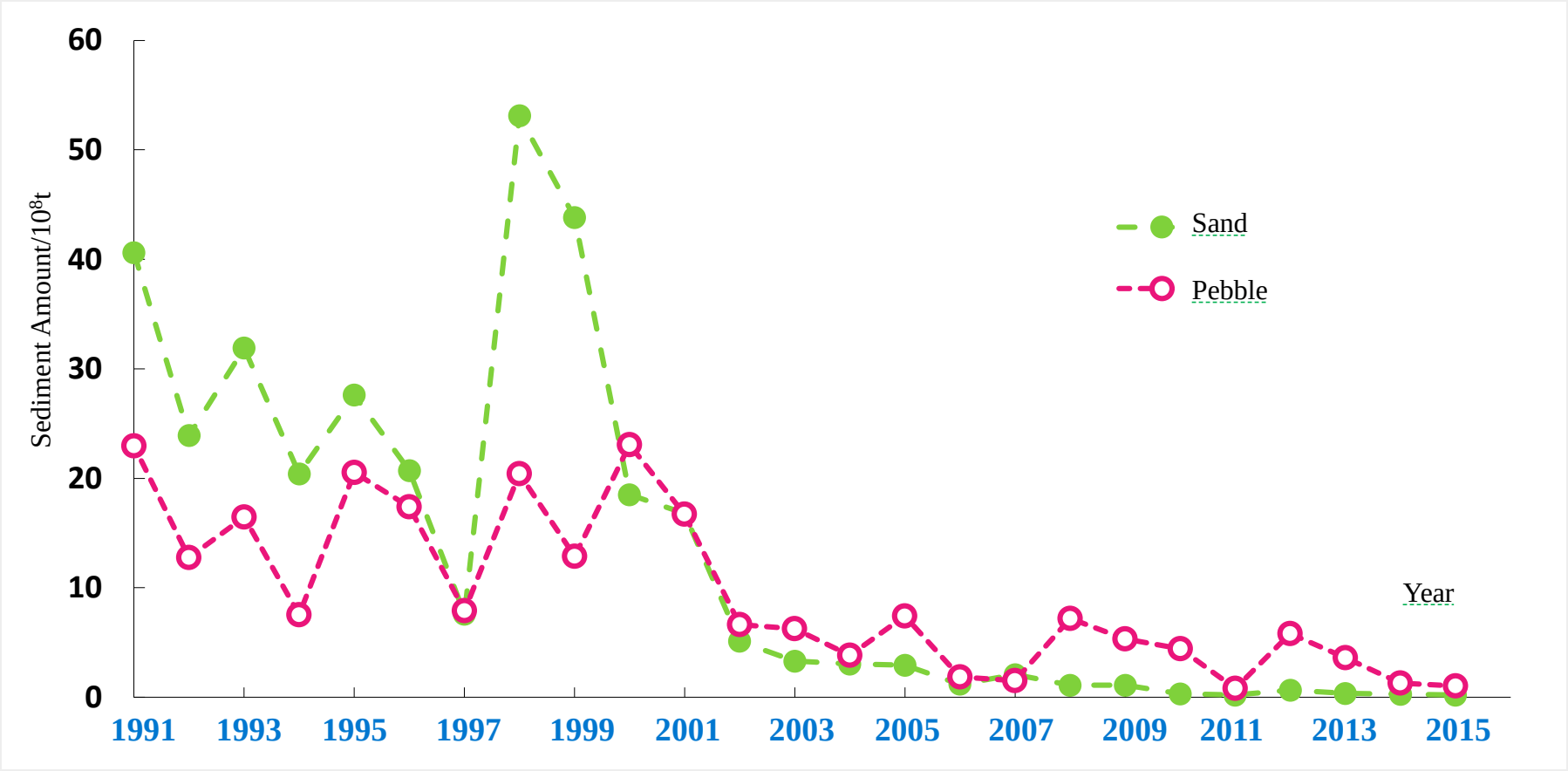
4 Sediment Measurement Results

（1）Changes of inflow and outflow of the Three Gorges Reservoir



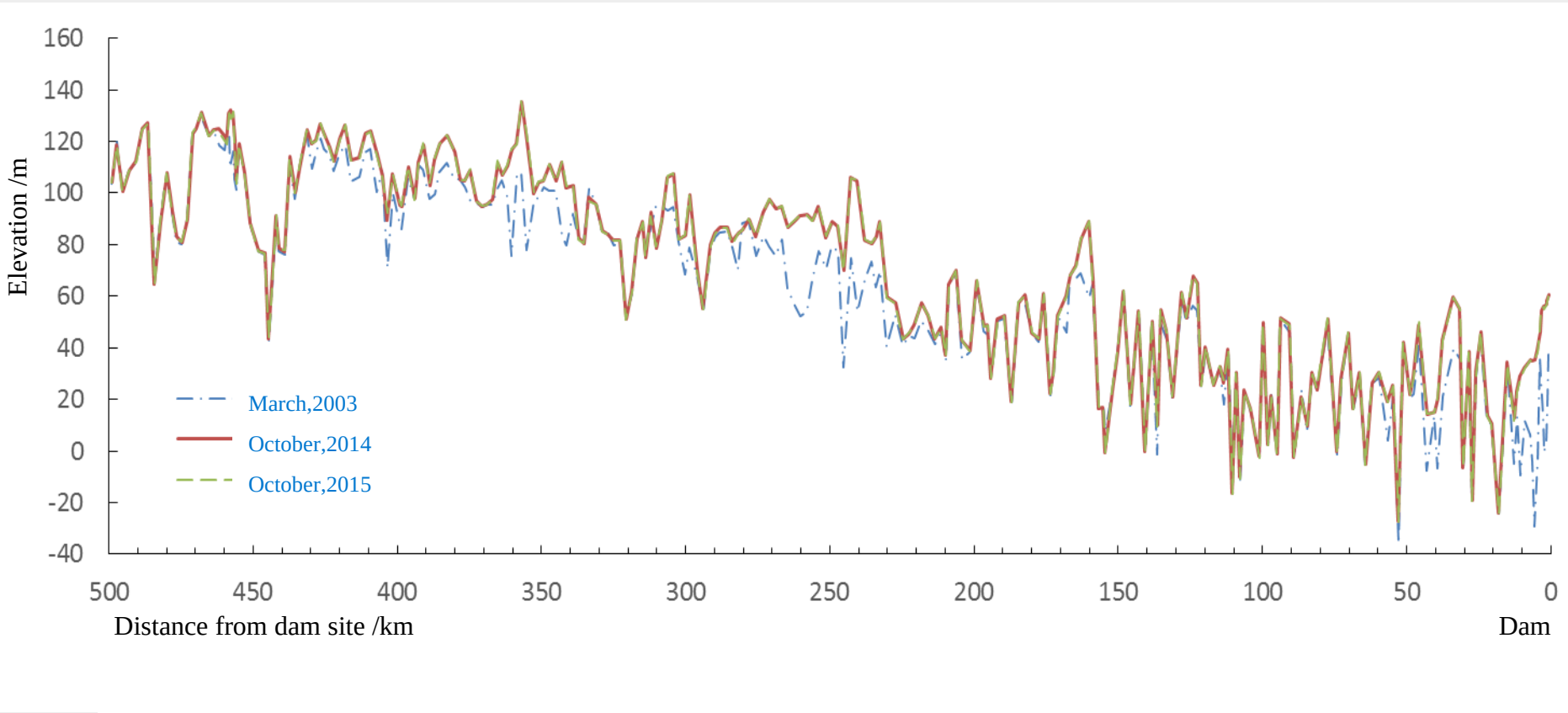
Sediment deposition amount in the Tree Gorges Reservoir

4 Sediment Measurement Results



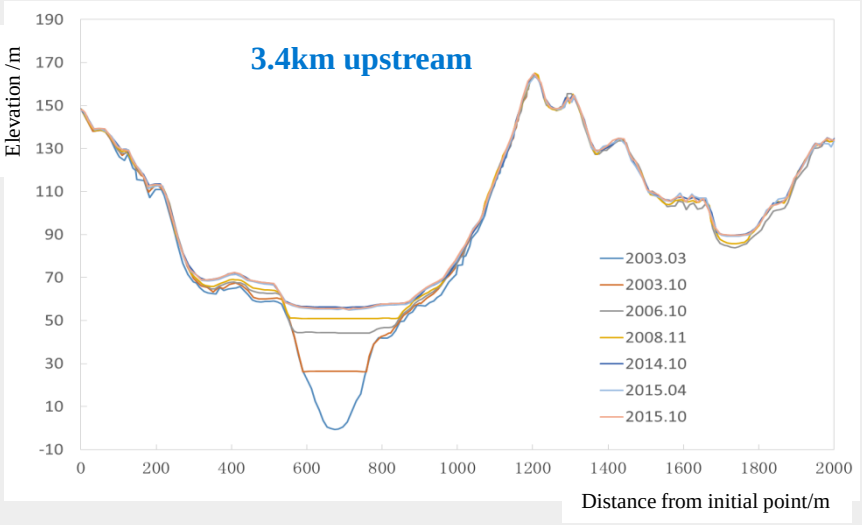
Bed load (Sand and pebble) transport amount in Cuntan Station

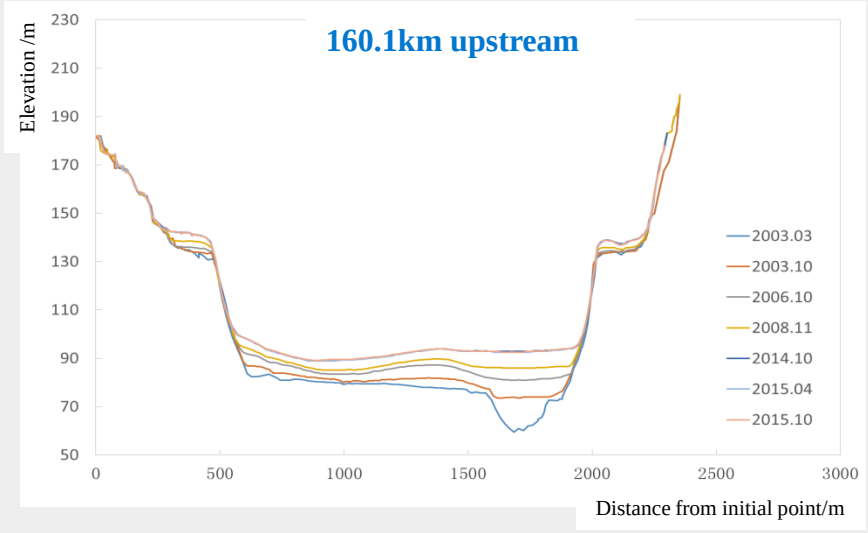
4 Sediment Measurement Results

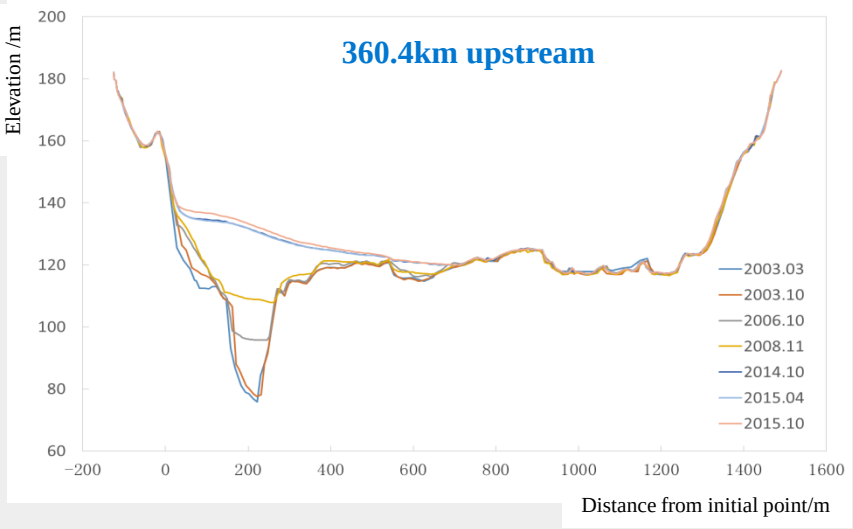


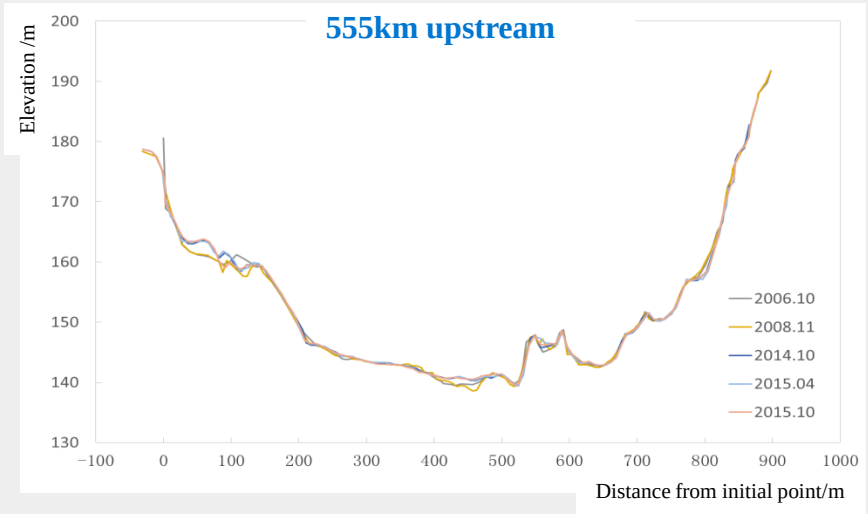
Changes of bed longitudinal section in the Three Gorges Reservoir

4 Sediment Measurement Results









Variation of typical cross section reservoir of the Three Gorges Reservoir

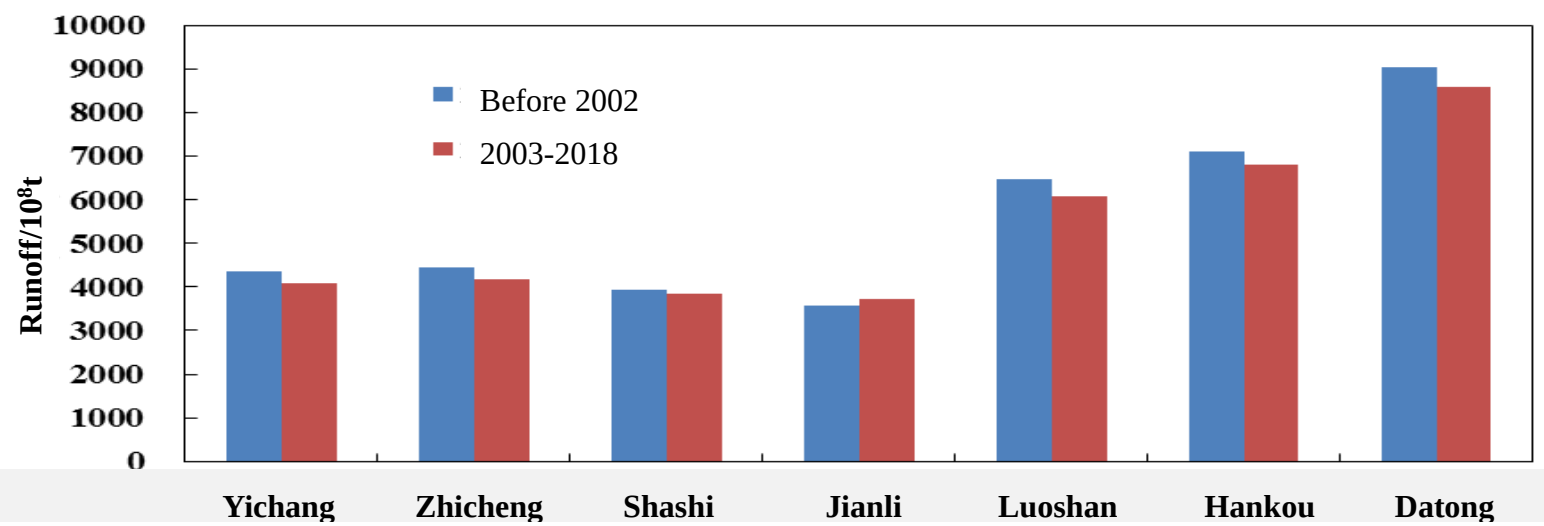
4 Sediment Measurement Results

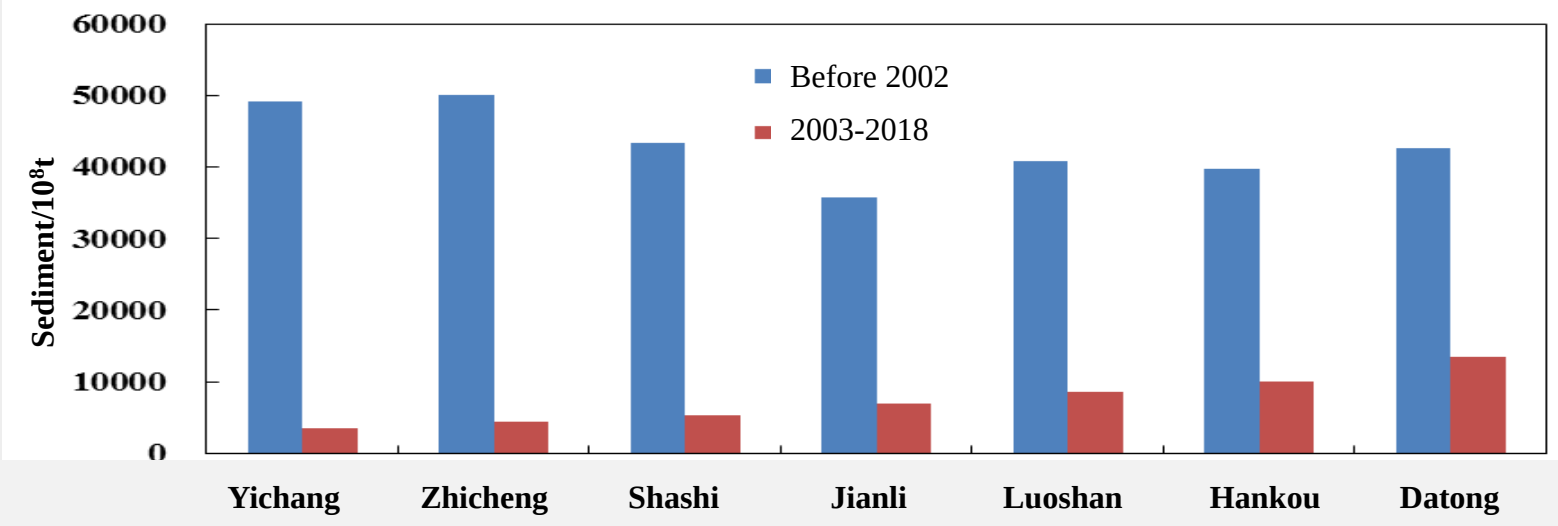
（2）Variation of runoff and sediment along the downstream reach of TGP

Distribution of the main stations along the downstream of TGP

4 Sediment Measurement Results

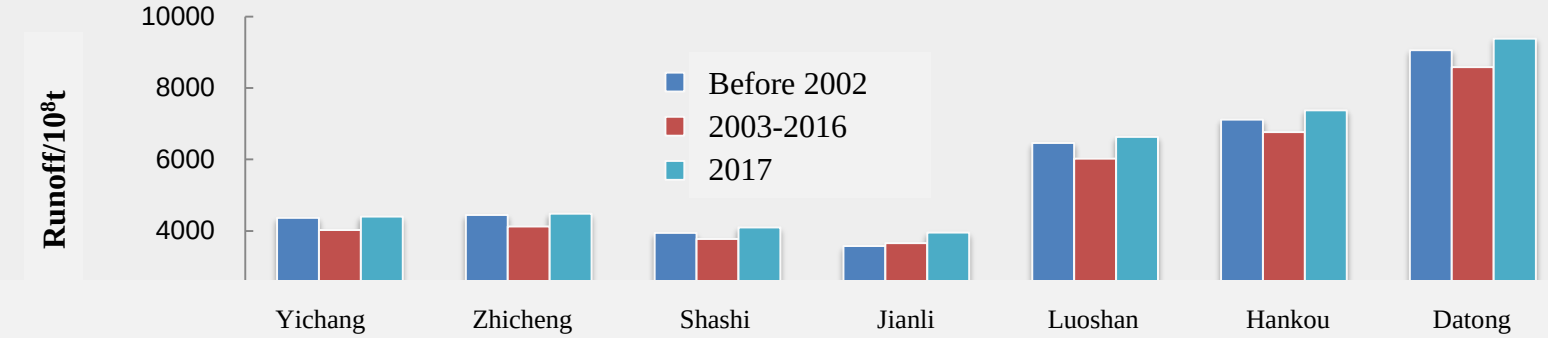
（2）Variation of runoff and sediment along the downstream reach of TGP

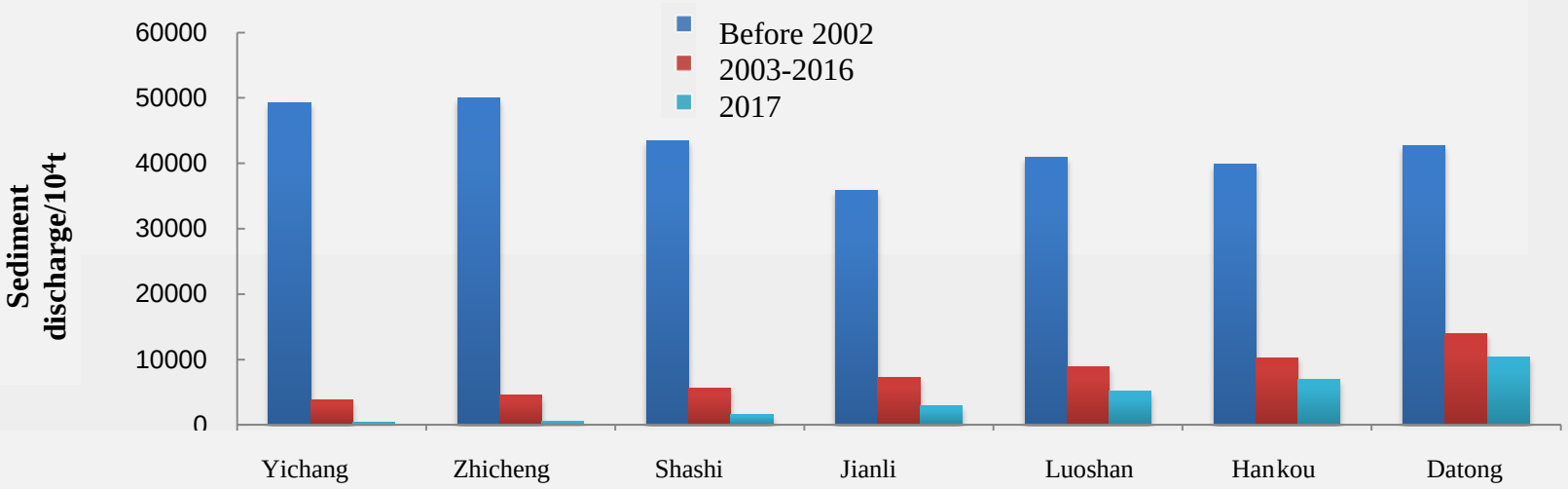




4 Sediment Measurement Results

（3）Variation of runoff and sediment along the downstream reach of TGP

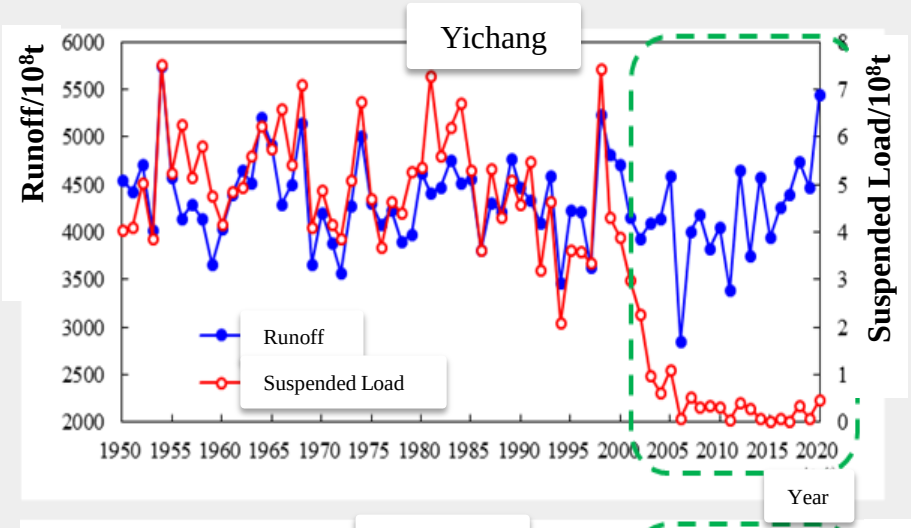


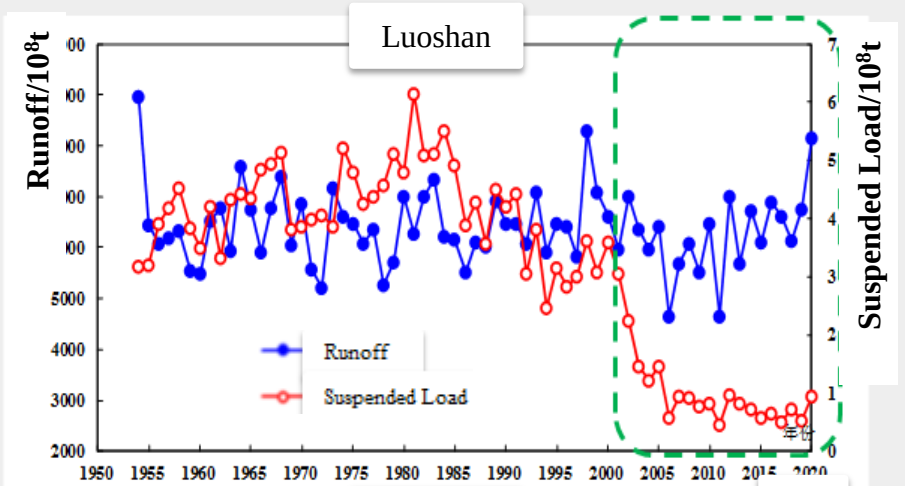


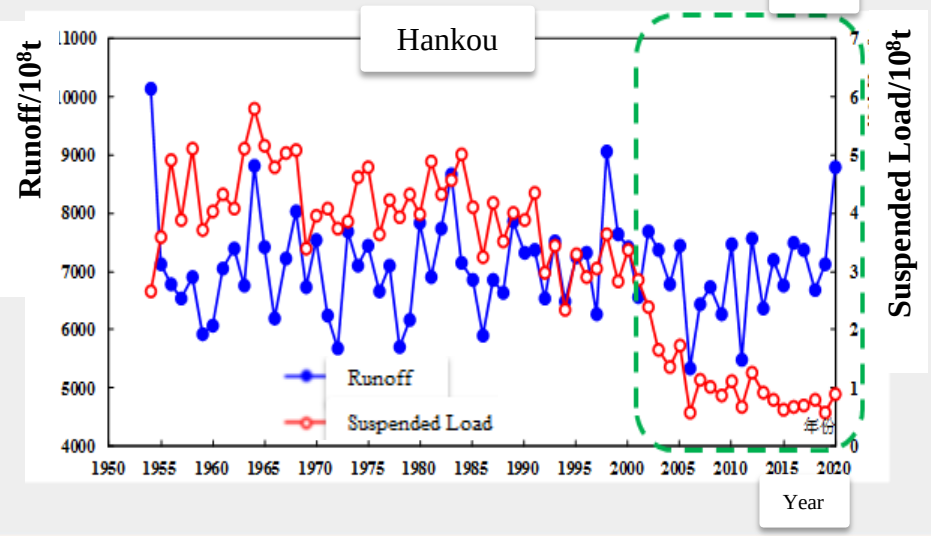
- The runoff upstream changed slightly, and the sediment discharge decreased obviously since impoundment.

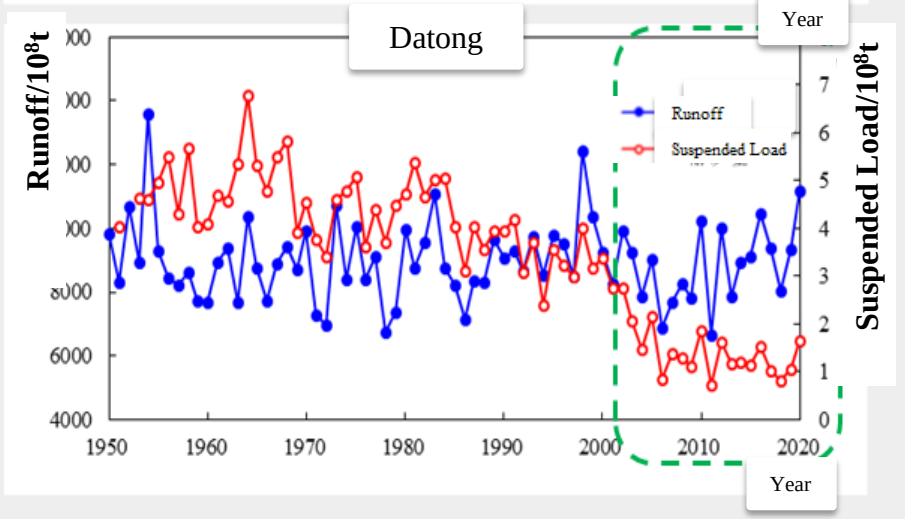
4 Sediment Measurement Results

（3）Variation of runoff and sediment along the downstream reach of TGP



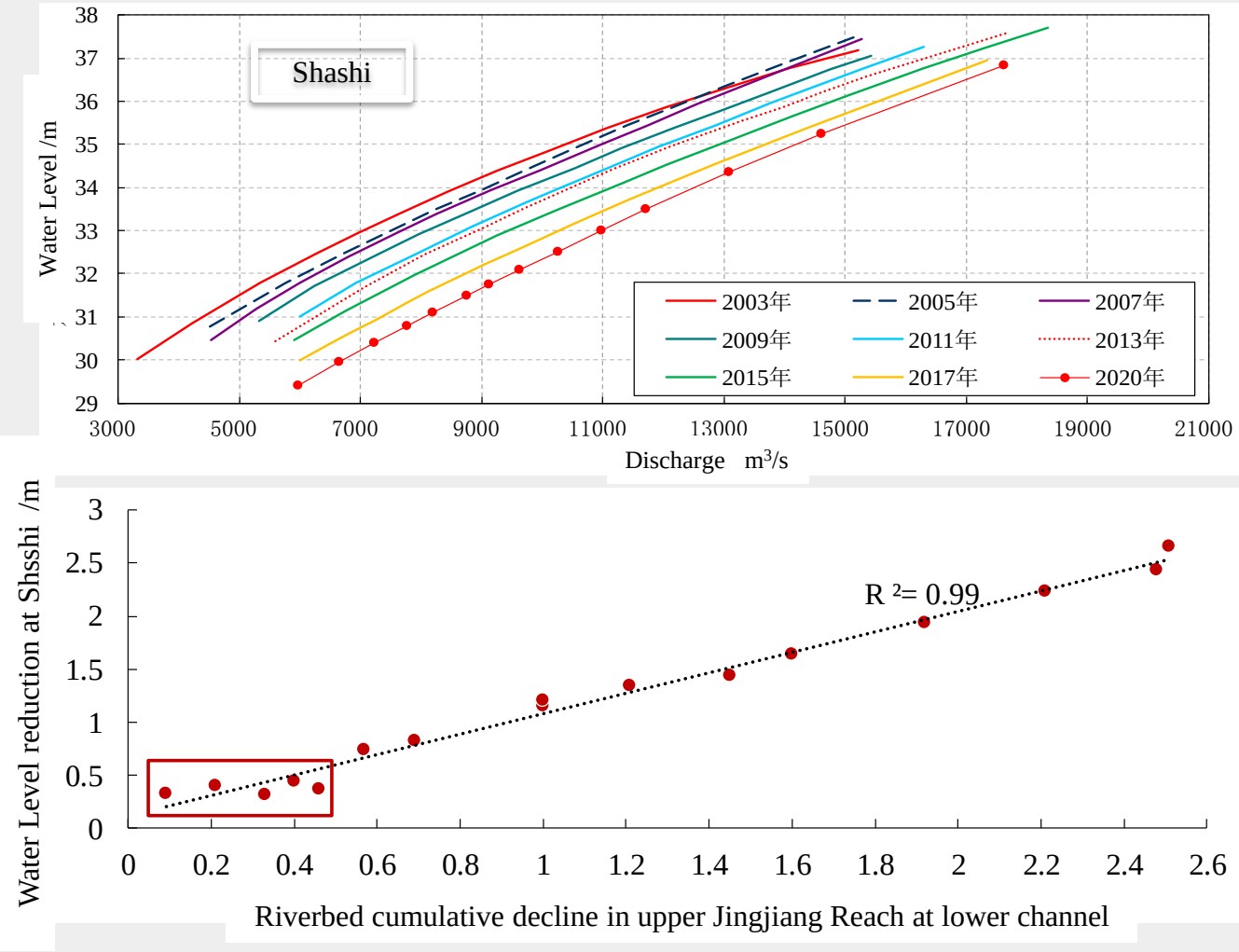






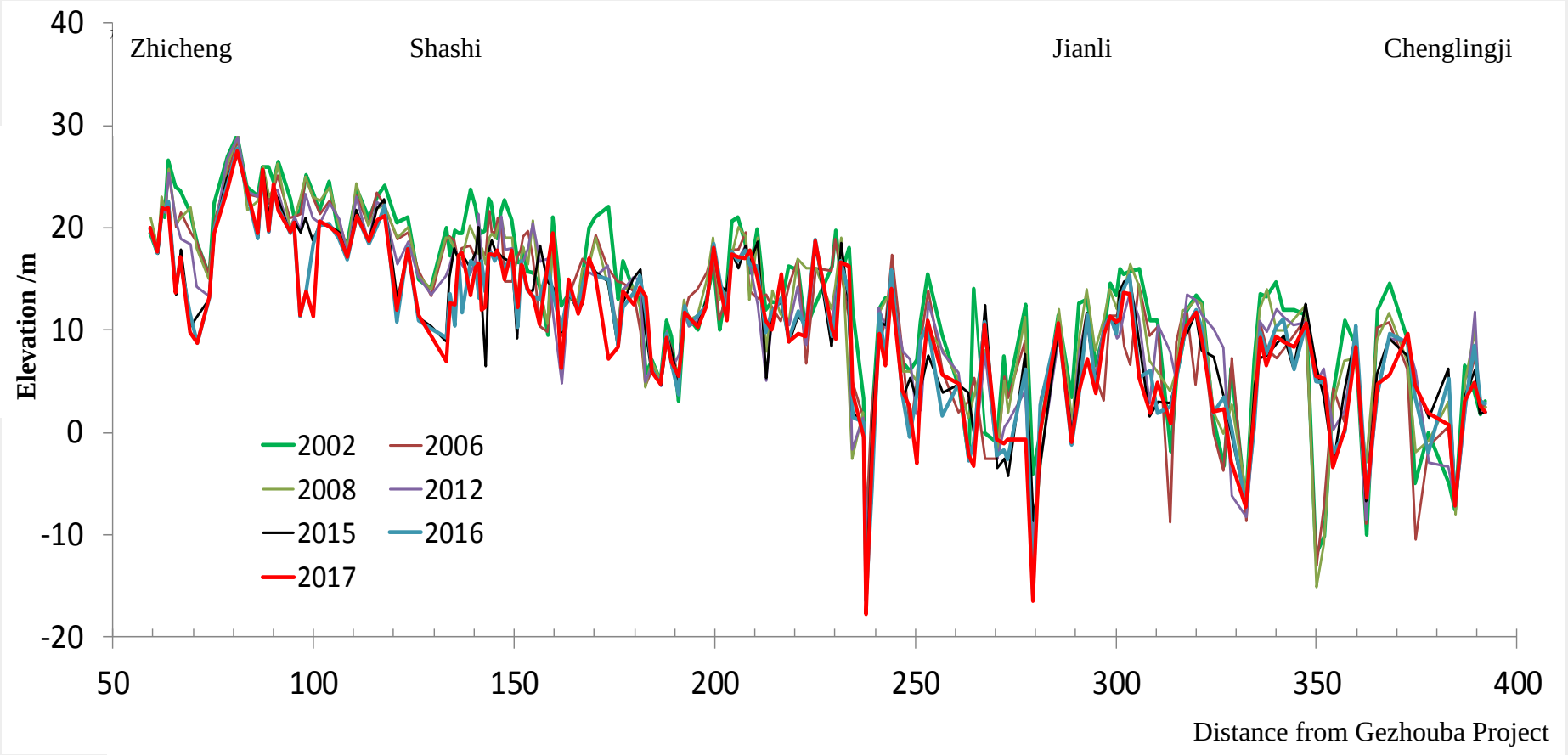
4 Sediment Measurement Results

（3）Variation of runoff and sediment along the downstream reach of TGP



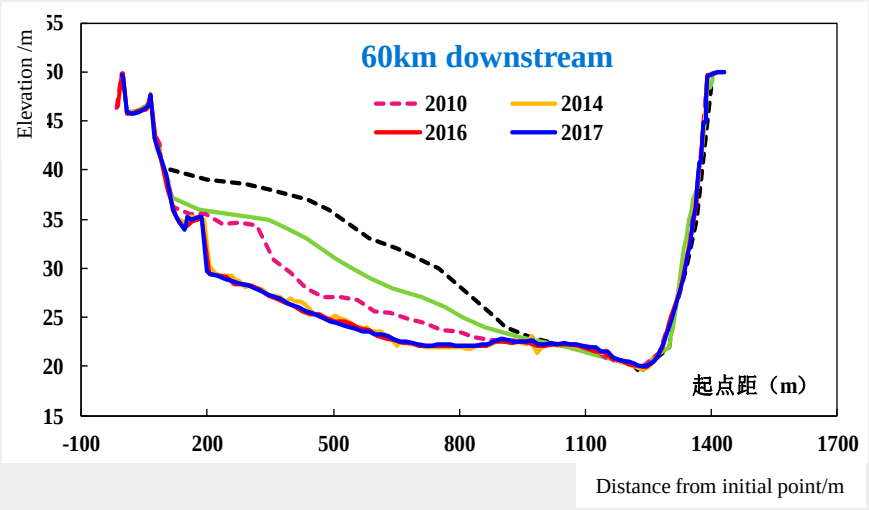
Relationship between water level reduction and erosion amount in up jingjiang reach at low channel

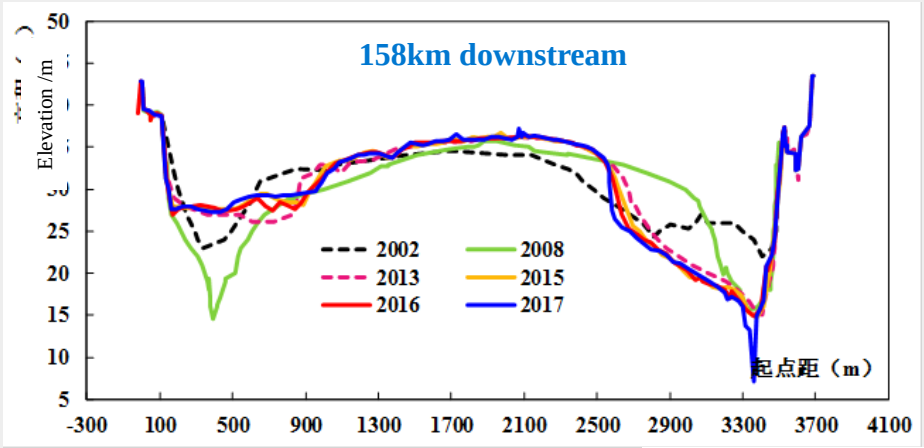
4 Sediment Measurement Results

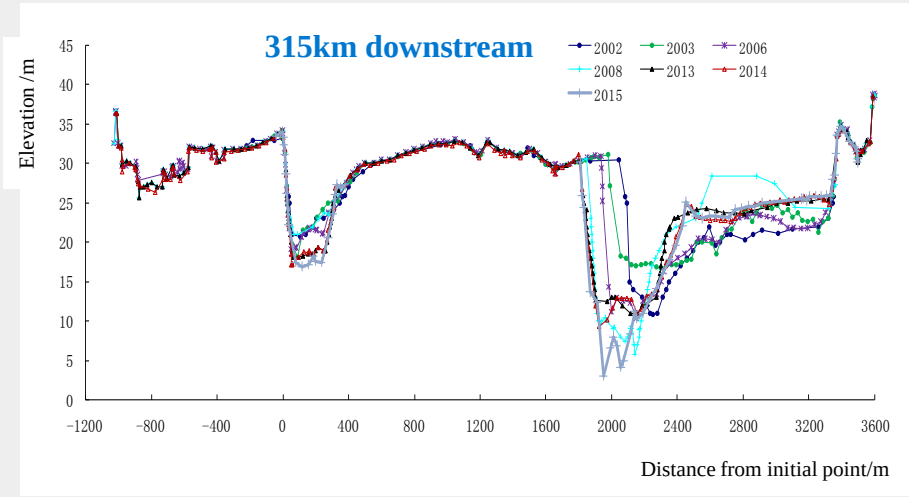


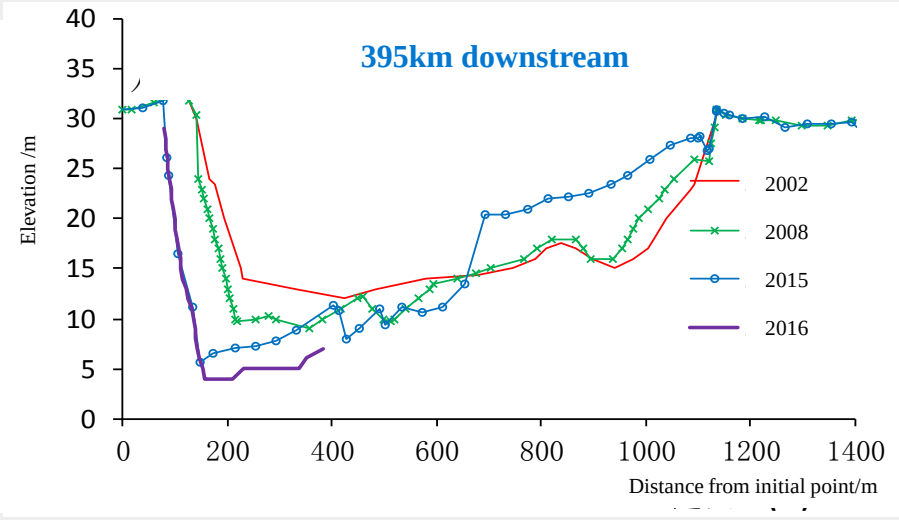
Variation of bed longitudinal section in the downstream reach of the Three Gorges Project

4 Sediment Measurement Results





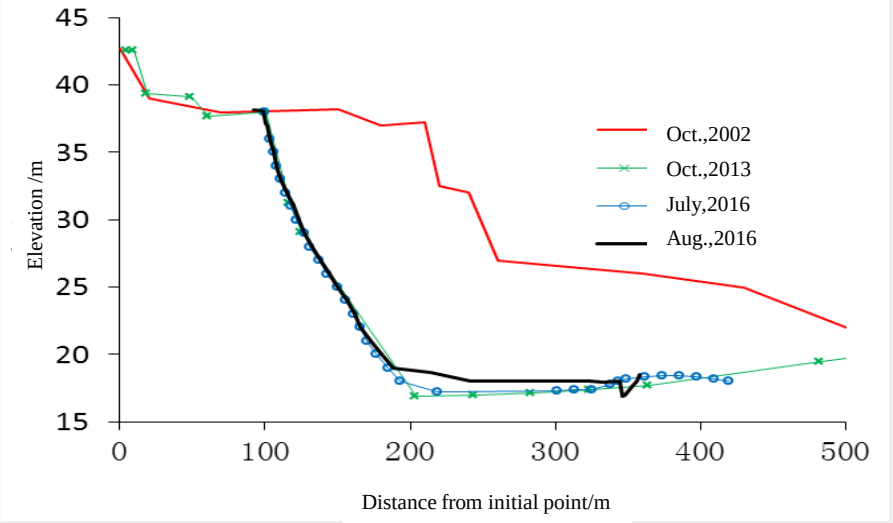


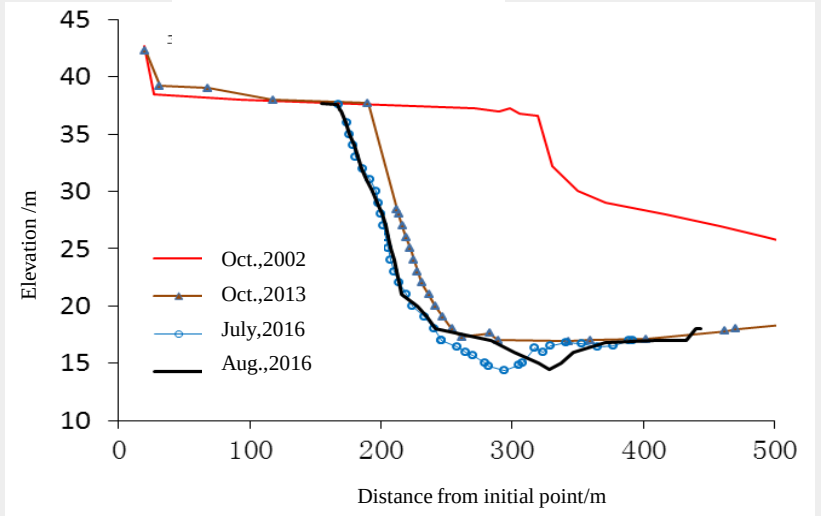


Variation of typical cross section in the downstream reach of the Three Gorges Project

4 Sediment Measurement Results

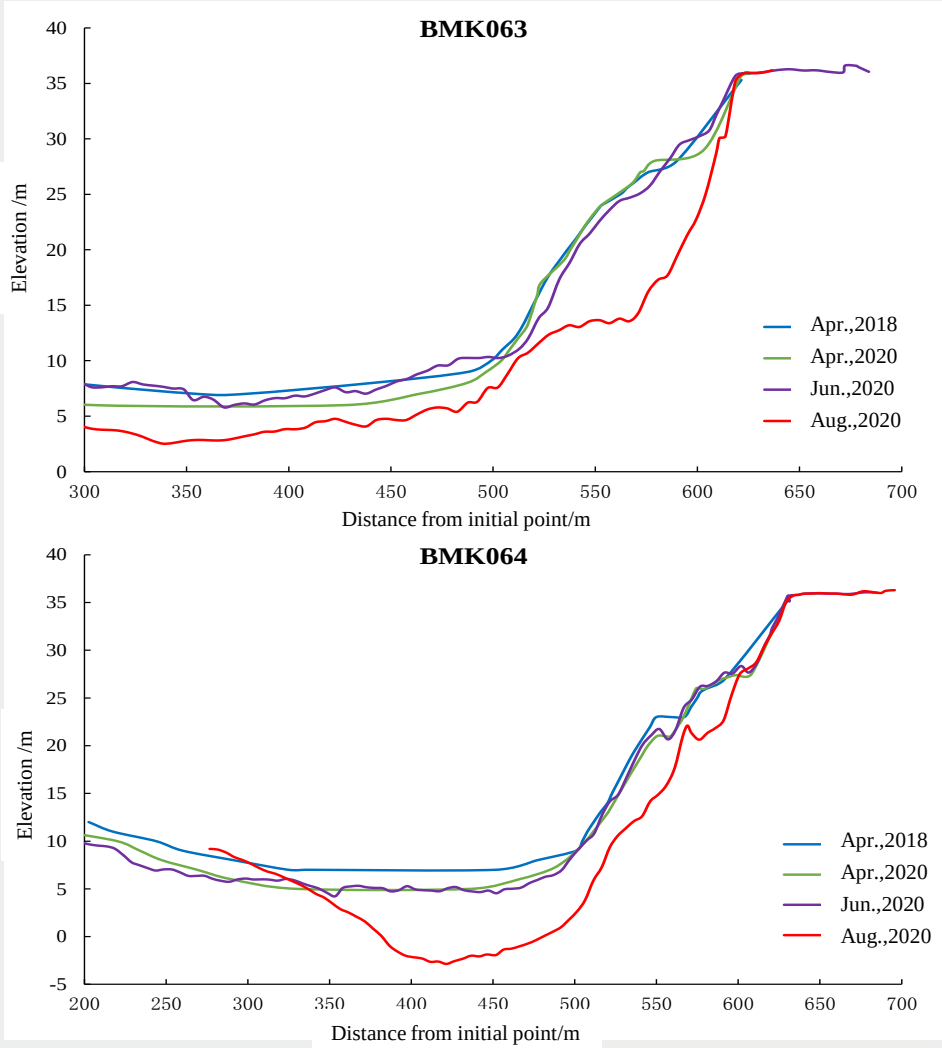
（4） Typical bank collapse along the downstream reach of TGP





4 Sediment Measurement Results

（4） Typical bank collapse along the downstream reach of TGP



4 Sediment Measurement Results

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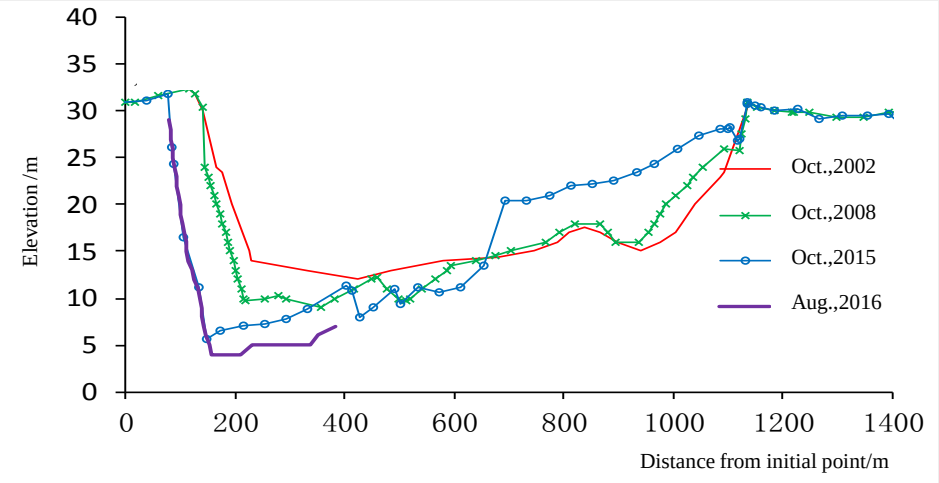

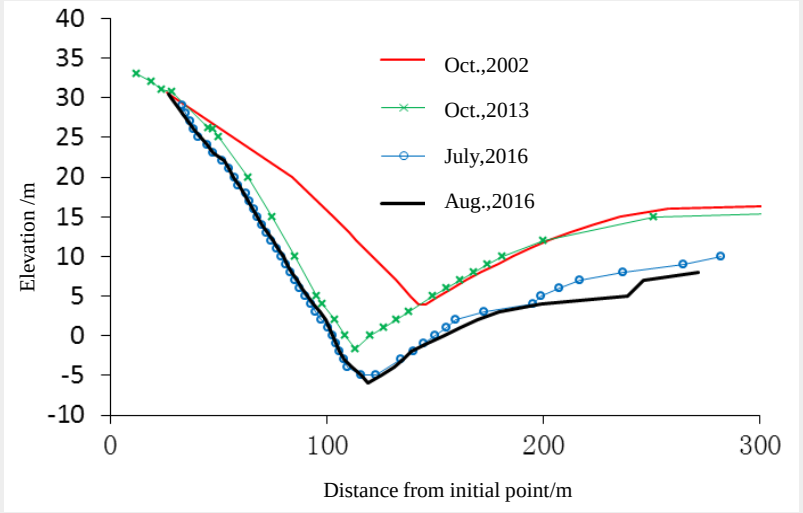

4 Sediment Measurement Results

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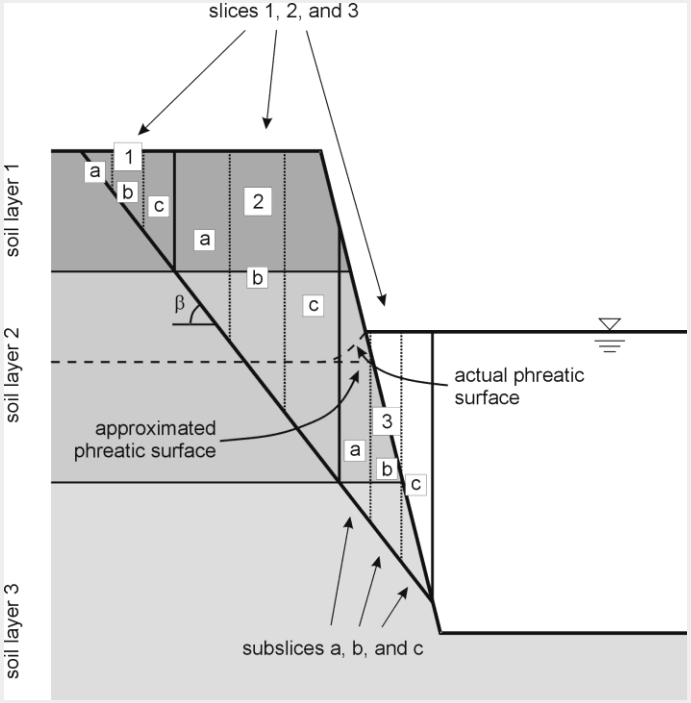
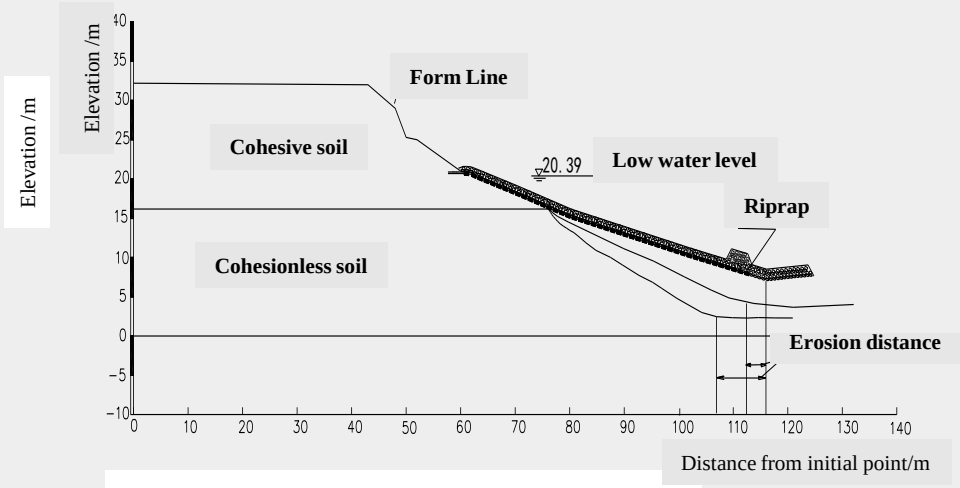
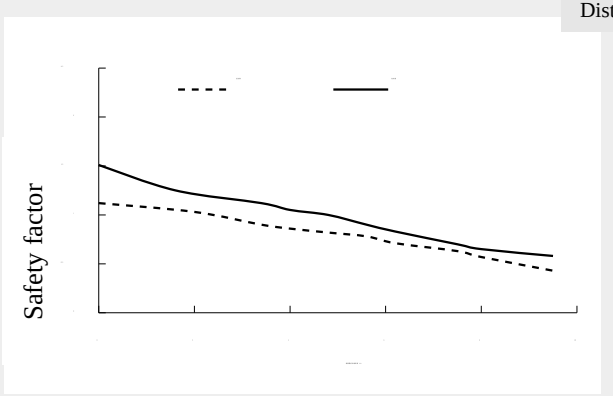






Erosion distance of bank toe

BSTEM（Bank Stability and Toe Erosion Model）Model

4 Sediment Measurement Results

（5） Bank revetment

Wire mesh

Ecological slope protection

Facing brick of low water platform

Ecological slope protection

Mold pebble row

Silting cage

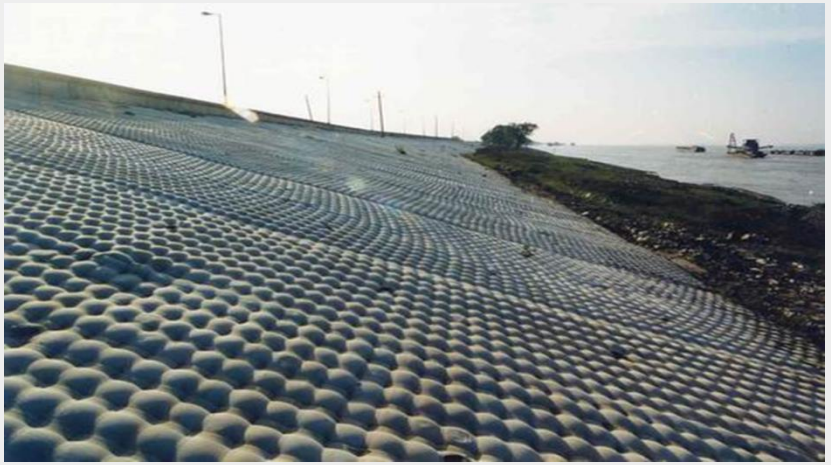
4 Sediment Measurement Results

（5） Bank revetment

Rock riprap

Concrete hinge row

Wire basket of pebble



Mould-package concrete

Thank you very much !