Hsieh, Kuo-Chang; Liao, Che-Min; Chen, Yi-Liang

Impact of Dams on River Sediment Transport and the Countermeasures Using Dajia River Basin as an Example

12th International Conference on Hydroscience & Engineering
Hydro-Science & Engineering for Environmental Resilience
November 6-10, 2016, Tainan, Taiwan.

Impact of Dams on River Sediment Transport and the Countermeasures —Using Dajia River Basin as an Example

*Kuo-Chang Hsieh, Che-Min Liao, Yi-Liang Chen**
Department of Water Resources and Hydraulic Engineering, Sinotech Engineering Consultants. Ltd.
Taipei, Taiwan

ABSTRACT

Dajia river basin environment have adjusted since 921 Earthquake with large scale landslides. Environmental disaster and man-made facility will interact with each other, then induce compound disaster. For example, dams make the unbalance of sediment transport and then induce river bed change that affect the cross-river bridge and diversion works. This study evaluates the impact of dams on Dajia river sediment transportation, and suggests that the countermeasures should focus on maintaining the continuum of sediment transportation to promote the resilience of river bed evolution.

KEY WORDS: Continuum of sediment transportation; Dajia river; Environmental disaster

INTRODUCTION

The Dajia River watershed with vulnerable geology, since the occurrence of 921 Earthquake in 1999, has made its geology even more vulnerable and caused the loosening of debris in watershed. In 2001, the incursion of Typhoon Tora-Ji caused the massive downgrading of debris within watershed and also caused several new landslides. In 2004, the incursion of Typhoon Min-Dulle (also called Chi-Ur Flood) induced a large-scale rainstorm colluvial deposit and river sediment which slid downward from upper river reach to middle river reach. The severe sediment caused the compound disasters as the inundation of three hydro power plants, several landslides along the Taiwan Route No 8, and scouring of dikes. The compound disasters recurred from 2005 to 2012.

After 921 Earthquake, Dajia River basin environment was still firmly situated as adjustment status for post disaster. The environmental disasters and the man-made facilities have affected each other and thus causing a chain of interrelated disasters. To sustain the quality of the environment and maintain the stability of the river bed, the focus of the countermeasures should be on how to resolve the problem of sediment-related disasters.

THE RIVER CHANNEL ENVIRONMENT AND AN OVERVIEW OF IT'S PROBLEMS

River Channel Environment

The Dajia River is located in the mid-west of Taiwan. With a drainage area of 1,244 square kilometers, a total length of 124 kilometers, and an average gradient of 1/60, it is considered a torrential river. Based on its geological characteristics, the Dajia river can be categorized into 5 sections as figure 1 which are divided by Te-Chi Reservoir, Ma-An Dam, Shi-Gang Dam and the bridge for national highway no. 3. In addition, most rainfall occurs in the Dajia River's upstream watershed, with an average rainfall of 2,400 to 2,800 millimeters per year.

Environmental Disasters

Following the 921 Earthquake, the Total Area of Landslide Increased.

After 2004, the total area of landslide was 4,147 hectares. The ratio of landslide in the watershed reached 3.3%, which was four times greater than that before the earthquake,

The Dam and River Narrow-Section Hindered the River Sediment Transporting

After 2004, from Tien-Lung Dam to Ma-An Dam, the sediment deposition in the river bed reached 15.47 million cubic meters. From 2005 to 2014, the government had strengthened river dredging for approximately 5.00 million cubic meters. After the large cross section investigation, the river drainage could wash away approximately 3.53 million cubic meters less than volume of dredging.

This study estimates that two reasons for that river channel cannot have the natural sediment transport capacity. The first reason is the narrow-section canyon near the Li-Lun Bridge limiting the sediment transportation. The second reason is the backwater and the increase of water storage levels in the Ma-An Dam during the flooding season have caused the decrease of the river sediment transport capacity at upstream.

The Reservoir Trap Sediment and the Earthquake Uplift Ground Surface Enhanced Erosion Force, Which Then Induced A Sediment Shortage River.

According to the surveying data from 2005 to 2014, river channels

from the Ma-An Dan to Shi-Gang Dam have accumulated siltation of 1.35 million cubic meters. The increased sediment was considered a reasonable result after Chi-Ur Flood. However, at the same time, the river incised from Shi-Gang Dam to the HSR Bridge upstream of national highway no. 3, with accumulated erosion of 3.37 million cubic meters, which is considered unreasonable. The river reach downstream the Shi-Gang Dam become sediment shortage river.

The study estimates that major cause of the continuous erosion from the Shi-Kun Dam to the HSR Bridge was derived from the dredging volume of 3.9 million cubic meters from the Shi-Kun Dam between 2005 and 2014. The other cause was that the earthquake uplift ground surface downstream of Shi-Kun Dam by 6 to 10 meters and this has led to the stronger flushing force.

COUNTERMEASURES

The environmental disasters in Dajia River were classified as the upstream reach deposition by massive debris supply and downstream reach scouring by lack of sediment supply. The countermeasures are thus to sustain the continuum of sediment transport. Water Resources Planning Institute, Water Resources Agency, has proposed the *Master Plan for Integrated Regulation of the Dajia River Basin in 2015*, with the primary principle of comprehensive erosion and sediment control as below.

Segmented Planning for the Management of the Dajia River

The application of river reach zoning allows the efficient of river management. The segmented planning for the management of the Dajia River can be divided into the sediment supply zone and sediment transportation zone, as shown in figure 1.

Aims and Principles for the Management of Sediment

Upstream Zone of Sediment Supply—the Conservation of Water and Land Resources and Sustainability of Storage Volume in Reservoir
The cumulative deposition volume of the Te-Chi Reservoir has reached 29.1%. To maintain the reservoir storage volume, the management principles are thus restricting land usage, removing sediment using turbid current venting at dam site, and sediment dredging at ponding area.

The Mid to Upstream Zone of Sediment Supply—Maintaining the Safety of Villages and Hydropower Facilities

The management principle is to maintain flood-carrying capacity. The periodic monitoring and the dredging of deposited river sections prevent the river channel bed deposition from going up and dams with the hydraulic sediment releasing by spillway.

The Middle Stream Zone of Sediment Transportation—Sustaining the Normal Function of the Shi-Gang Dam Without Affecting the Continuum of Sediment Transportation

The management principle is utilizing sediment dredging to prevent the deposit in the ponding area of Shi-Gang Dan and the coarse material of dredging material will leave at downstream reach as the source of the armoring layer for river bed.

The Mid to Downstream Zone of Sediment Transportation—Maintaining River Channel Steadiness

The management principles are considering the reduction of discharge per unit width in the eroded river section, supplementing the armor layers, and protecting flood-plain to maintain main channel at river center.

The Downstream Zone of Sediment Transportation—Maintaining River Channel Flooding Capacity and Stabilizing the Coastal Environment.

The management principles are periodically surveying river channel, and executing the dredging of deposited channel sections, and monitoring coastal line regression.

OVERVIEW OF CURRENT EXECUTION

The authorities responsible for the Dajia River in recent years have adopted the principle of respecting the continuum of sediment transportation in order to achieve the comprehensive erosion and sediment control. A example of current execution between the Mountain Line Railway Bridge and the Ho-Fong Bridge as follows:

The river training works include such as the excavation of the flood plain on siltation bank to maintain the mainstream, widening the mainstream for the reduction of the discharge per unit width and the supplementing armor layers to prevent incised channel.

The excavation of left bank flood plain from 2012 to 2015 by excavating the siltation bank bed and filling the scouring bank, the mainstream was channeled to the river center, which thus has a widened mainstream and reduced the discharge unit width.

In 2012, the implementation of armor layers from dredging material was postponed and lifted the bed elevation. The implementation of armor layers suspend from 2013 for the sakes of the expensive cost, and public opinion.

CONCLUSION

The 921 Earthquake and Chi-Ur Flood had caused the increase of debris and sediment in watershed of the Dajia River. The current investigation has indicated that the river deposition has not been decreased for the Ma-An Dam and upwards,, however, the river scouring in the Shi-Gang Dam downwards is noticeable. The Dajia River's environmental disasters classified as the upstream reach deposition by massive debris supply and downstream reach scouring by lack of sediment supply. The principles for the countermeasures are to respect continuum of sediment transportation, to apply the comprehensive erosion and sediment control such as the implementation of armor layers from dredging materials, widening the mainstream for the reduction of the discharge per unit.

REFERENCES

Water Resources Planning Institute, Water Resources Agency. (2015). Review of Master Plan for Integrated Regulation of the Dajia River Basin(2012~2015).

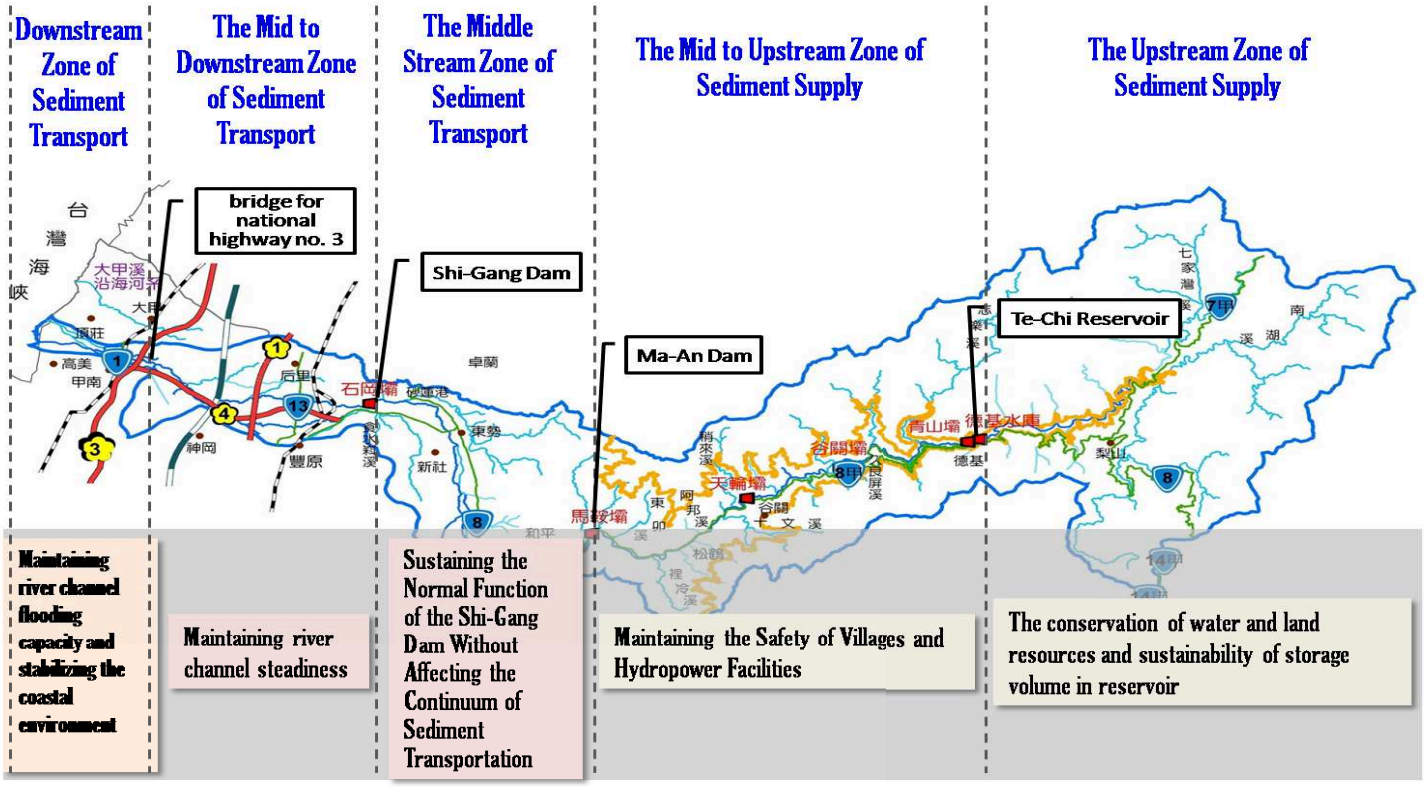

Fig. 1 River Reach Zoning and the Aims and Principles for the Management of Sediment for Every Zone