Analysis on sediment transport processes around estuary and coastal shoreline area in the Sagami River Basin to promote reservoir sedimentation countermeasures and integrated sediment management

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ABSTRACT:

Sagami River Basin is a Class A River with the length of 113 km and basin area of 1,680 km^2, coming from the Mount Fuji and merged with the Nakatsu River into the Sagami Bay in Kanagawa Prefecture. Several dams (8 dams) and weirs have been constructed in the Sagami River Basin. While they have provided numerous benefits to society, they also have negative impacts such as on sediment regimes due to reservoir sedimentation. They have reduced the sediment supply to downstream reaches, resulting in coastal erosion of the Chigasaki Coast, riverbed degradation, fixed-river channels and intensive riparian encroachments, highlighting the need to adopt integrated sediment management at the river basin scale. Several measures have been implemented using removed-sediment from dam reservoirs, such as direct sediment augmentation on the shorelines eroded, and indirect one on the riverbed expecting the sediment to be transported to the coastal shoreline. However, sediment transport processes are yet to be revealed, particularly around the lower reaches, i.e. from the river mouth and estuary area to coastal shorelines, where sand terrace around the river mouth has been decreased and may not be much functional in transporting sediment from fluvial systems to coastal shorelines. The governmental committee composed of Ministry of Land, Infrastructure, Transport and Tourism of Japan (MLIT), Kanagawa prefectural governments, and Yamanashi prefectural government, issued the "Integrated Sediment Management Plan for the Sagami River Basin" in 2015, in close consultation and collaboration with the Committee on Integrated Sediment Management for the Sagami River Basin, in order to efficiently and effectively promote sediment management in an integrated and collaborative manner. This paper provides some results of quantitative evaluations of the sediment transport processes in order to develop the Plan and proposes a hypothesis of sediment transport processes in the Sagami River Basin, analyzing geographical survey data and numerical simulation results of fluvial and coastal systems, which is: "sand sediment transported from the Sagami River to the estuary area has been transported to the shoreline of the Chigasaki Coast by coastal waves though slowly". If this hypothesis is revealed, we can quantitatively evaluate the sediment volume, which is needed to come from the Sagami River to the estuary area, in order to decelerate the coastal erosion and sustain the coastal shoreline of the Chigasaki Coast. This quantitative evaluation enables to determine goals of sediment transport processes to be achieved for integrated sediment management involving various stakeholders.

1 INTRODUCTION AND OBJECTIVE

1.1 *Sagami River Basin*

Sagami River Basin is a Class A River with the length of 113 km and basin area of 1,680 km^2, coming from the Mount Fuji and merged with the Nakatsu River into the Sagami Bay in Kana-

gawa Prefecture (Fig.1). The Sagami River is a gravel-bed river and has been well known in *Plecoglossus altivelis altivelis* (called Ayu in Japan), which is anadromous fish, which has been important for Fisheries in Japan.

In order to meet the increasing water demand, Shiroyama dam and Miyagase dam have been constructed. These dams have been used for drinking, agriculture, and hydropower, supporting livelihood around the basin. On one hand, even though the Sagami River has been flooded by typhoons many times, flood management works such as dams, embankments, and dredging have contributed to reducing damages due to flooding. Further, gravel mining has been implemented in the river, leading to economic and social development of the basin.

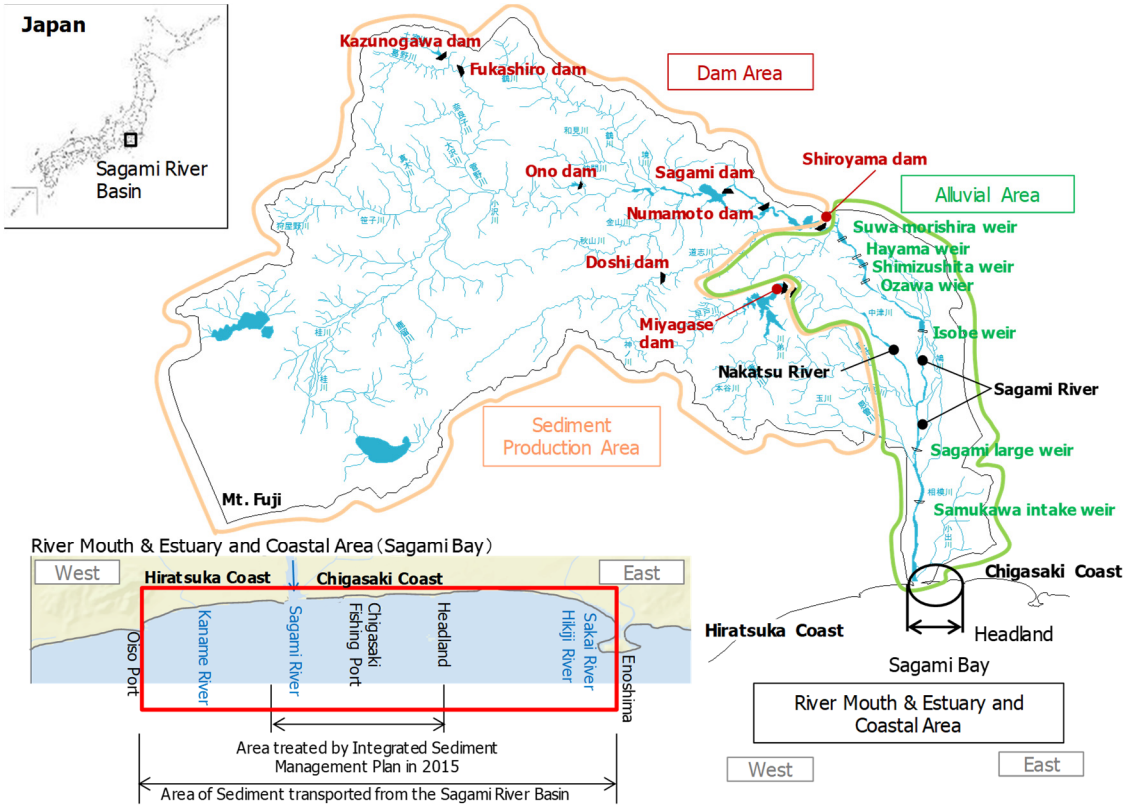

Figure 1. Sagami River Basin.

1.2 *Positive and negative aspects of water resources development*

Several dams (8 dams including Shiroyama dam and Miyagase dam) and weirs have been constructed in the Sagami River Basin. While they have provided numerous benefits to society, they also have negative impacts such as on sediment regimes due to reservoir sedimentation. They have reduced the sediment supply to downstream reaches, resulting in coastal erosion of the Chigasaki Coast, riverbed degradation, fixed-river channels and intensive riparian encroachments, highlighting the need to adopt integrated sediment management at the river basin scale.

Several measures have been implemented using removed-sediment from dam reservoirs, such as direct sediment augmentation on the shorelines eroded, and indirect one on the riverbed expecting the sediment to be transported to the coastal zone. However, sediment transport processes are yet to be revealed, particularly around the lower reaches, i.e. from estuary area to coastal shorelines, where a sand terrace around the river mouth has been decreased and may not be much functional in transporting sediment from fluvial systems to coastal shorelines.

1.3 *Objective*

This paper proposes a hypothesis of sediment transport processes in the Sagami River Basin, analyzing geographical survey data and numerical simulation results of fluvial and coastal systems. It also discusses challenges in further promoting countermeasures for reservoir sedimentation and integrated sediment management in the basin.

2 INTEGRATED SEDIMENT MANAGEMENT PLAN FOR THE SAGAMI RIVER BASIN

2.1 *Activities implemented*

In the Sagami River Basin, negative impacts of flood and water resource development works have been relevant such as reservoir sedimentation, coastal erosion of the Chigasaki Coast, riverbed degradation, fixed-river channels and intensive riparian encroachments. Even though several measures have been implemented, the effectiveness would be limited when these measures are solely implemented. For example, one measure implemented at an upstream reach may negatively affect the sediment regime at the lower reach. Therefore, an integrated approach to sediment management at the basin scale is important involving various stakeholders, in order to balance sediment regimes that support morphological and ecological processes of the basin, and balance among water use, flood management, and the river environment.

A recommendation for "Sustainable Sediment Regime and Environment for the Sagami River Basin" was published in 2001, which had been discussed at the "Committee on Integrated Sediment Management for the Sagami River Basin", composed of various stakeholders such as academic experts, NGOs, fisherman's cooperative association, governmental organizations, etc. A concept of this recommendation was embedded in the Basic River Management Policy for the Sagami River Basin in 2007.

Further, the governmental committee composed of MLIT, Kanagawa prefectural governments, and Yamanashi prefectural government, issued the "Integrated Sediment Management Plan for the Sagami River Basin" in 2015, in close consultation and collaboration with the Committee, in order to efficiently and effectively promote sediment management in an integrated and collaborative manner (MLIT, 2015).

2.2 *Scope of the plan*

This Plan addresses the issues on spatial and temporal discontinuity of sediment transport processes caused due to human-induced activities such as dam construction and gravel mining, which became currently apparent and will continuously become serious in the future. This Plan specifies challenges against such issues by implementing counter-measures in a collaborative manner among stakeholders. It also addresses sediment transport processes, which are yet to be revealed, in order to determine effective counter-measures by implementing pilot projects such as sediment augmentation, and to understand processes by conducting monitoring projects.

This paper provides some results of quantitative evaluations of the sediment transport processes in order to develop the Plan. Area of Sagami River Basin around the coastal shoreline is defined between Oiso port in the West and Enoshima Island in the East, where have been consisted of sediment transported from the Sagami River Basin through the river mouth (Fig.1). Of which, this paper and the Plan treat the area between the Hiratsuka New Port and the head land at the Chigasaki Coast.

3 METHODOROGY

3.1 *Geographical survey and numerical simulation in the Sagami River Basin*

A numerical simulation model was developed in order to analyze sediment transport process in the whole Sagami River Basin. The model we adopt was conceptually developed by Yamamoto

et al. (2004) for the Hino River in Japan. This model combines the distributed runoff model and one-dimensional riverbed variation model, in which the rain-fall data is an input, and it is verified by discharge hydrographs and sediment budget balance at dams and river channels since 1990 to 2013. We developed a sediment-budget map during this period as the current condition.

In order to analyze change in sediment-budged balance between the current and old conditions, the result of 1950s was used for comparison, which was developed by Umino et al. (2004) when preparing the recommendation for "Sustainable Sediment Regime and Environment for the Sagami River Basin".

3.2 *Geomorphological changing patterns of the lower reach of the Sagami River Basin*

Morphological change of the river mouth and coastal shorelines was analyzed, using several aerial photo data since 1961 to 2015.

3.3 *Geographical survey and numerical simulation in the coastal shoreline of the Sagami River Basin*

It is important to understand sediment transport processes, i.e., sediment coming from the river channel in the middle reach to estuary area through the river mouth, and transported from the river mouth to the Chigasaki Coast.

A large flood occurred in 2007, which exceeded the mean annual maximum discharge. Geographical survey has been conducted before and after the flood in 2007. Therefore, change in sediment transport processes during the 2007 flood was analyzed, particularly addressing the lower reach where fluvial and coastal systems are interacted. As for sediment volume coming from the river system, the result obtained by the numerical simulation model in section 3.1 was used.

4 RESULTS AND DISCUSSION

4.1 *Sediment-budget balance of the whole river basin between current and old conditions*

As for the sediment composed of middle reach of the river (i.e., d_{60} = 1 to 70mm), in 1950s, sediment volume transported was 40,000 m^3/year at the Shiroyama dam and 20,000 m^3/year at the Miyagase dam, then merged and 50,000 m^3/year at the Sagami bridge (Fig.2). The current sediment volume at the Sagami bridge is around 20 % as compared with the one in 1950s.

As for the sediment composed of lower reach of the river (i.e., d_{60} = 0.2 to 1mm), in 1950s, sediment volume transported was 65,000 m^3/year at the river mouth. The current sediment volume at the river mouth is 10,000 m^3/year, which is around 15 % as compared with the one in 1950s. These results show that sediment volume transported were drastically reduced both at middle and lower reaches of the river.

4.2 *Geomorphological changing patterns of the lower reach of the Sagami River Basin*

Figure 3 shows Geomorphological changing patterns of the lower reach of the Sagami River Basin from 1961 to 2015. The coastal shoreline has been kept stable in 1960s to 1970s, but then coastal erosion has occurred particularly in the east coast, namely Chigasaki Coast. Particularly, Yanagishima district of the Chigasaki Coast has lost the coastal shoreline with the width of approximately 60 m. Even though coastal protection works such as wave-absorbing dykes and headland in the Chigasaki Coast have been constructed, coastal erosion has not been decelerated. The Kanagawa prefectural government has decided to implement sediment augmentation on the Chigasaki Coast using the removed-sediment form the Sagami dam. The volume of the sediment augmentation was 300,000 m^3 in ten years from 2006 to 2015 (i.e., 30,000 m^3/year). As for the sandbar at the river mouth, the position has been kept almost stable along with the coastal shoreline until 1972 (expect some local changes), and then has been set back to the upstream river.

Sediment composed	Location	1950s	Current
Alluvial area (d_{60} =1 to 70mm)	Sagami bridge	50,000 m³/yr	10,000 m³/yr
River mouth & estuary and coastal area (d_{60} = 0.2 to 1 mm)	River mouth	65,000 m³/yr	10,000 m³/yr

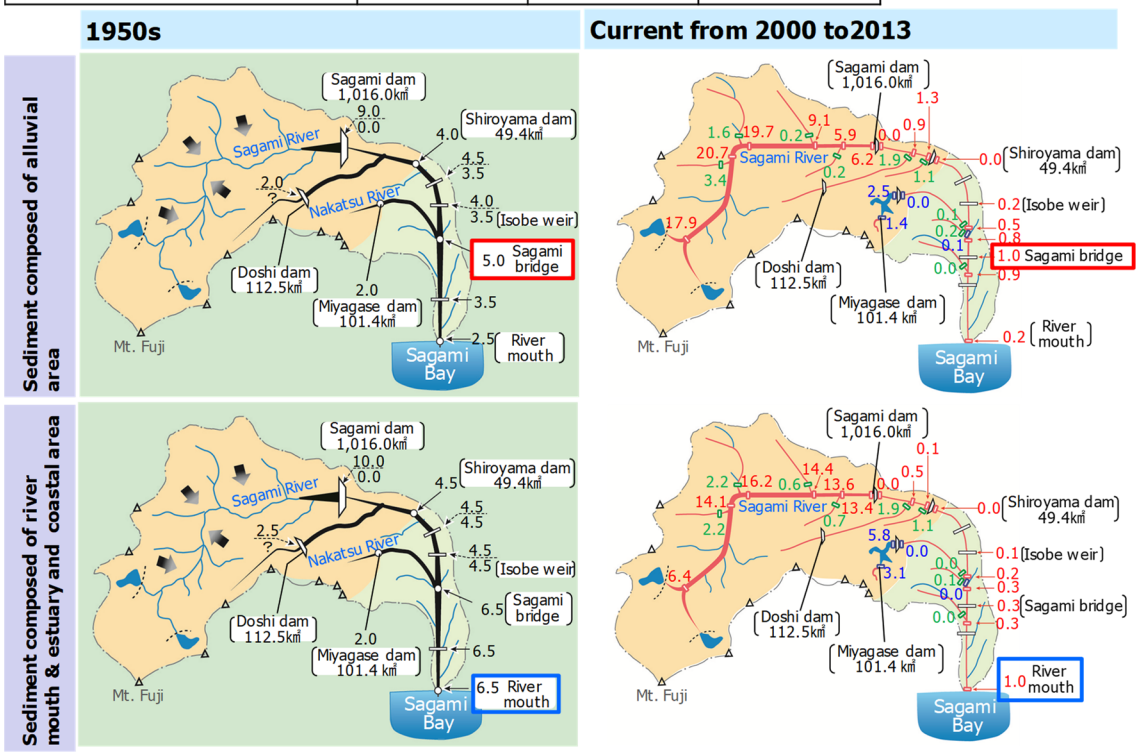

Figure 2. Illustration of sediment budget of the Sagami River Basin in 1950s and 2013.

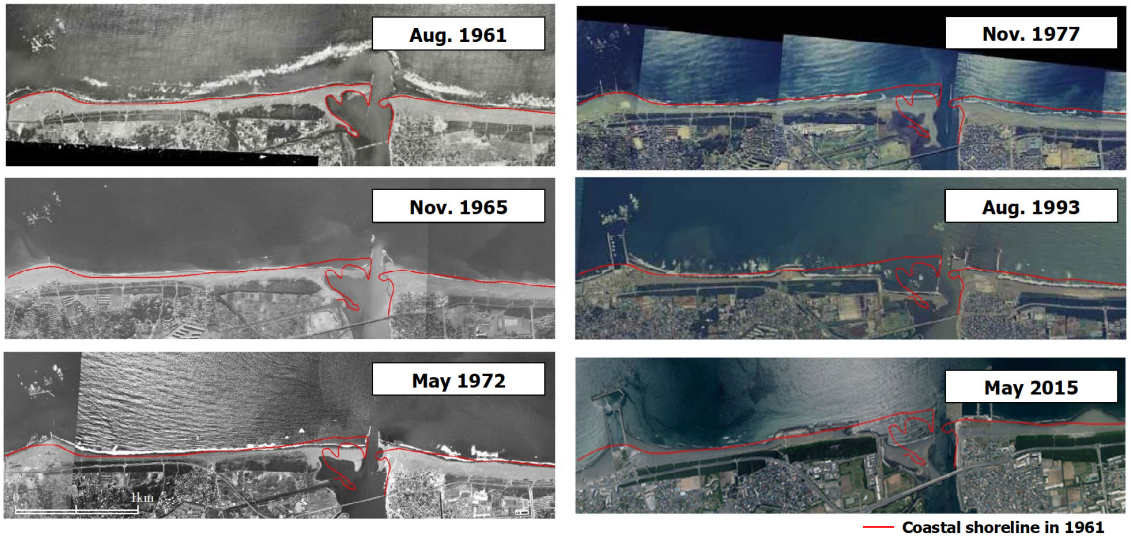

Figure 3. Geomorphological changing patterns of the lower reach of the Sagami River Basin.

4.3 *Geographical survey and numerical simulation in the lower reach*

The river mouth and Chigasaki Coast is composed of sand sediment, which have been transported from the Sagami River during floods and has been deposited on the sandbar of the river mouth and estuary area where fluvial and coastal systems are merged. The deposited-sediment on the estuary area seems to be transported and reached to the coastal shoreline of the Chigasaki Coast by coastal waves coming from the South to East. However, sediment transport processes

around the lower reach have yet to be revealed. Therefore, change in sediment transport processes during the 2007 flood was analyzed.

Figure 4 shows sediment transport processes of the lower reach of the Sagami River Basin during the 2007 flood. Sand sediment (i.e., d_{60} = 0.2 to 1 mm) with the volume of 20,000 m^3 was transported from the Sagami River to the river mouth and deposited on the estuary area with 21,000 m^3. We assume that sand sediment with 20,000 m^3 provided from the Sagami River to the estuary area would be all set back to the sandbar in its reformation processes by coastal waves. In the Chigasaki Coast, sand sediment with 60,000 m^3 was deposited in five years. It is understood that temporal processes are different, i.e., sand sediment moves fast by floods in the fluvial system but moves slowly by waves in the coastal system. Despite the understanding of the difference in temporal scales of sand sediment transport processes, it is revealed that sand sediment transported from the Sagami River to the estuary area has been transported to the Chigasaki Coast by coastal waves though slowly.

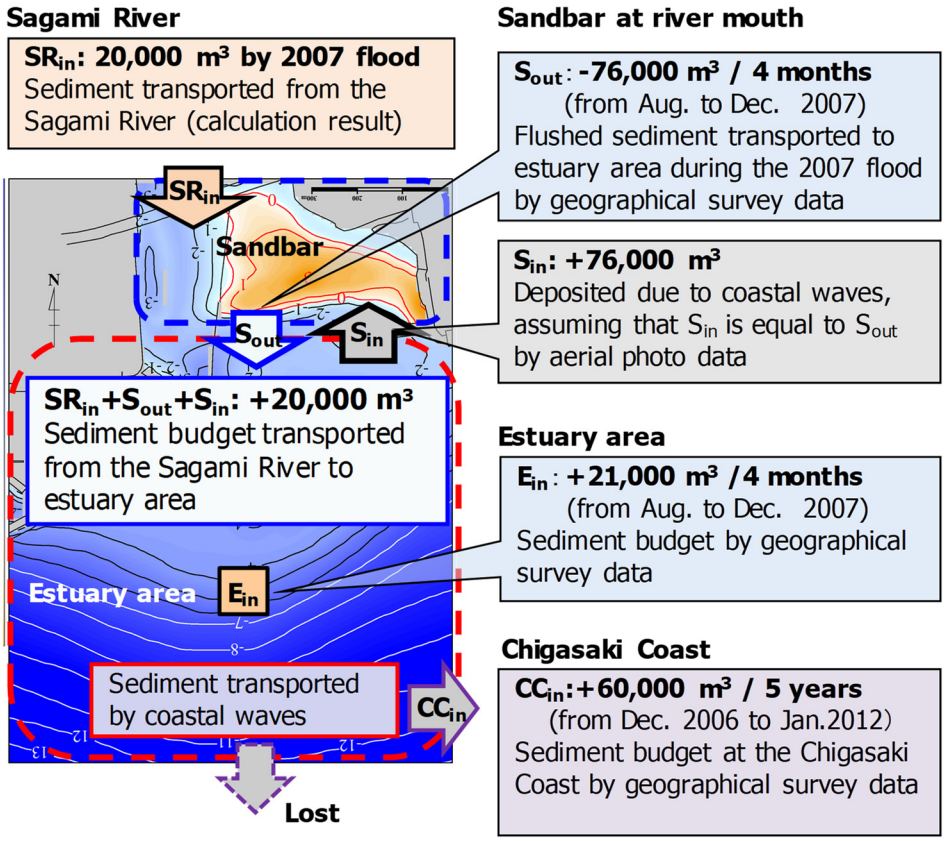

Figure 4. Sediment transport processes of the lower reach of the Sagami River Basin during the 2007 flood.

4.4 *Discussion*

We analyzed the sediment transport processes around the lower reach of the Sagami River Basin in section 4.3 and proposed the hypothesis that "sand sediment transported from the Sagami River to the estuary area has been transported to the Chigasaki Coast by coastal waves though slowly". Figure 5 shows the hypothesis on sediment transport processes of the lower reach of the Sagami River Basin. If this hypothesis is revealed, we can quantitatively evaluate the sediment volume, which is needed to come from the Sagami River to the estuary area, in order to decelerate the coastal erosion and sustain the coastal shoreline of the Chigasaki Coast. This quantitative evaluation enables to determine goals of sediment transport processes to be achieved for integrated sediment management involving various stakeholders.

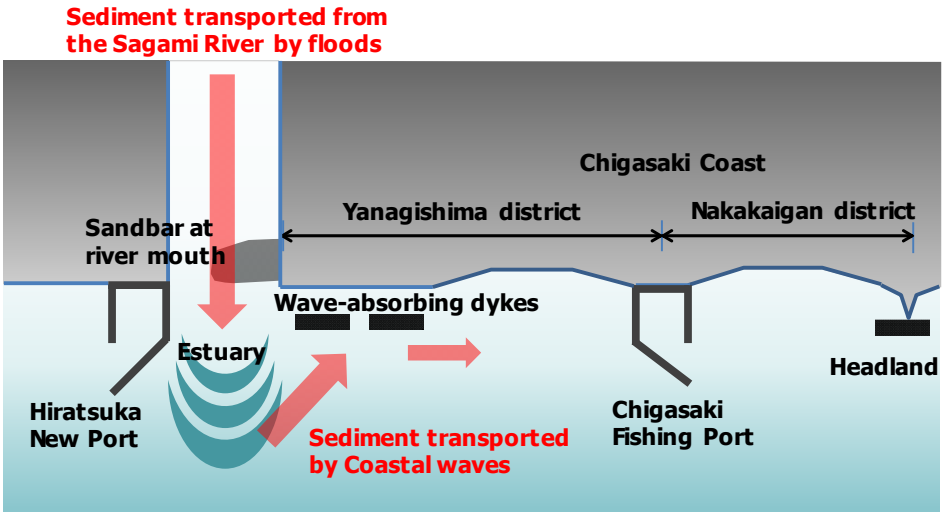

Figure 5. Hypothesis on Sediment transport processes of the lower reach of the Sagami River Basin.

Currently, several measures have been implemented using removed-sediment from the dam reservoir (i.e, Sagami dam and Doshi dam), such as direct sediment augmentation on the Chigasaki Coast, and indirect one on the riverbed expecting the sediment to be transported to the coastal zone. The direct sediment augmentation transporting sand for long distance by dump tracks from dams to coastal area is costly and not sustainable from a long term perspective. If the sand can be transported for short distance by dump trucks from the dams to rivers below dams, then can be transported for long distance by floods to the river mouth and estuary area, and finally can be transported to the Coastal Area, this measure would be considered more effective and cost-friendly in an integrated and sustainable manner. Thus, it is important that reservoir sedimentation countermeasures not be solely addressed by one authority, but be addressed involving various stakeholders in the river basin, in order to promote integrated sediment management.

However, the hypothesis we propose is based only on sediment transport processes during the 2007 flood. Much data for a longer period is needed to verify the hypothesis. This hypothesis has been neither addressing the dynamic sediment transport processes currently, since the result is almost based on the geographical survey data at the estuary area and coastal shoreline. Therefore, it is important that wave, current, and turbidity measurements be conducted in the estuary area as well as geographical surveys during floods and high tidal waves. Numerical simulations for coastal shoreline-change due to waves should also be conducted to predict impacts and effectiveness of measures to be adopted.

5 CONCLUSIONS

A numerical simulation model was developed in order to analyze sediment transport process in the whole Sagami River Basin. The results showed that sediment volume transported were drastically reduced both at middle and lower reaches of the river.

Change in sediment transport processes during the 2007 flood was analyzed, particularly addressing the lower reach where fluvial and coastal systems are interacted. Dispite the understanding of the difference in temporal scales of sand sediment transport processes, it is revealed that sand sediment transported from the Sagami River to the estuary area has been transported to the Chigasaki Coast by coastal waves though slowly.

We proposed the hypothesis that “sand sediment transported from the Sagami River to the estuary area has been transported to the Chigasaki Coast by coastal waves though slowly”. However, the hypothesis we propose is based only on sediment transport processes during the 2007 flood. Much data for a longer period is needed to verify the hypothesis. It is important that wave, current, and turbidity measurements be conducted in the estuary area as well as geographical surveys during floods and high tidal waves.

REFERENCES

Ministry of Land, Infrastructure, Transport and Tourism of Japan (MLIT). 2015. Integrated Sediment Management Plan for the Sagami River Basin. MLIT [in Japanese with English synopsis].

Umino, S., Tatsuno, T., Yamamoto, K., Watariguchi, S. & Honda, S. 2004. Study on relations between sediment management in the Sagami River Basin and river environment. Advances in River Engineering, Japan Civil Engineering Society, vol. 10: 185-190 [in Japanese with English synopsis].

Yamamoto, S., Inuyama, K., Yoshizumi, M. & Nishimoto, N. 2004. Evaluation of sediment regime in the Hino River Basin. Advances in River Engineering, Japan Civil Engineering Society, vol. 10: 173-178 [in Japanese with English synopsis].