International Symposium on "Appropriate technology to ensure proper Development, Operation and Maintenance of Dams in Developing Countries", Johannesburg, South Africa, 18 May 2016
© SANCOLD, ISBN 978-0-620-71042-8

INSPECTION OF SUBMERGED AREA WITH THE USE OF AN UNDERWATER CAMERA SURVEY VEHICLE

Y Sakamoto[1], S Akimoto[1], and K Kera[1]
1. Numata Dams Integrated Operation and Maintenance Office, Japan Water Agency, Gunma- , Japan

ABSTRACT

Japan Water Agency (JWA) has the standard for the dams as river management facilities managed by the JWA. All the daily patrol, inspection, maintenance and repair work, etc. are being implemented based on this standard. But for the areas not exposed, there has been no measure of conducting the visual inspection.JWA therefore came up with an idea of using an underwater-camera to inspect the usually submerged part of the facilities and conducted the test at concrete arch dam and rockfill dam. As a result, it was proved that with both dams there were no damage or degradation.

1. INTRODUCTION

It is necessary to maintain the safety and functions of a dam for a long time in order to accomplish the purposes of the dam, including flood control, maintenance of normal functions of river water, and water supply. In view of this, appropriate maintenance of dam facilities and reservoirs is of prime importance. In this respect, the Dam Inspection and Maintenance Standard (the Standard) was established to keep dams, which are the river management facilities, in appropriate condition. Patrol, inspection, measurement, maintenance and repair are conducted as daily management operations of dam facilities according to the Standard. General patrol and inspection of a dam is performed mainly by visual check for apparent anomalies to grasp the condition of the dam facility. However, surfaces that are always underwater and therefore invisible are not generally covered by such an inspection. For dam facilities that were constructed many years ago, including the Yagisawa Dam and Naramata Dam, it is theoretically expected that the state of submerged parts which are not visible have changed because of the elapsed time after completion. The staff of these two dams performed by themselves inspections of some of the surfaces, that had always been underwater and therefore could not be visually checked, with an underwater camera (underwater camera survey vehicle). These two dams, which were subject to underwater inspection as reported in this paper, are multi-purpose dams constructed to perform flood control, maintenance of normal functions of river water, provide a new supply of water, and generate power. Their detailed data are shown, as follows:

Yagisawa Dam: This is an arch concrete dam located in Minakami Town, Tone-gun, Gunma prefecture (on the Tone River of the Tone River System), measuring 131 m of dam height and 204.3 million m^3 of total storage capacity. The dam started operation in 1967.

Naramata Dam: This is a rockfill dam located in Minakami Town, Tone-gun, Gunma prefecture (on the Naramata River of the Tone River System), measuring 158 m of dam height and 90 million m^3 of total storage capacity. The dam started operation in 1991.

2. INSPECTION METHOD

There are two reasonably conceivable ways to inspect submerged parts: one is through a visual check by a diver or images taken with a camera by a diver, and the other is through images taken by an underwater camera. The method of underwater camera by a diver faces several problems, including the limited depth of reach, the inability to film for a sufficient length of time because of diving time restriction, the difficulty of a diver's moving into a narrow space, and potential risk from diving in poorly visible underwater conditions. In view of these negative points, the inspection method with a mobile underwater camera was adopted.

2.1 Specifications of the underwater camera

The equipment used in underwater inspection is a survey vehicle equipped with an underwater camera. The vehicle comprises the underwater survey vehicle (Figure 1), a main cable (150 m), the main controller, the joystick controller, equipment connecting cables, and a monitor TV (Figure 3).

Size of the underwater camera survey vehicle is about 80 cm in length, about 55 cm in width, about 35 cm in height, and about 32 kg in weight, and is equipped with a total of four propellers, including two for forward motion (used also for rotation), one for vertical motion, and one for lateral motion, that allow the vehicle to freely move around in calm water at about 2.5 knots and dive to a maximum depth of 100 m. The underwater camera installed in the vehicle (Figure 2) has a resolution of 330 lines (horizontal), and is capable of flexibly moving 50 degrees up or down and 20 degrees left or right with a remote focus. The vehicle also has two 150 W underwater lights (Figure 2) and can take photos in close range even in a dark environment such as at the bottom of a dam reservoir. The staff used the joystick remote controller to move the vehicle in the water to a target object by remote control, and inspected the target while checking the real-time image shown on the TV monitor.

As the underwater camera survey vehicle requires a power source of 100V, power was supplied to the vehicle from an engine power generator (1.6 kVA).

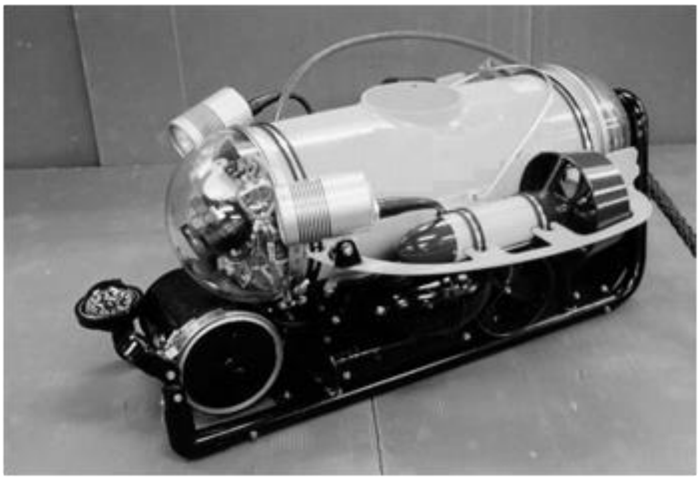

Figure 1. Entire view of the underwater camera survey vehicle

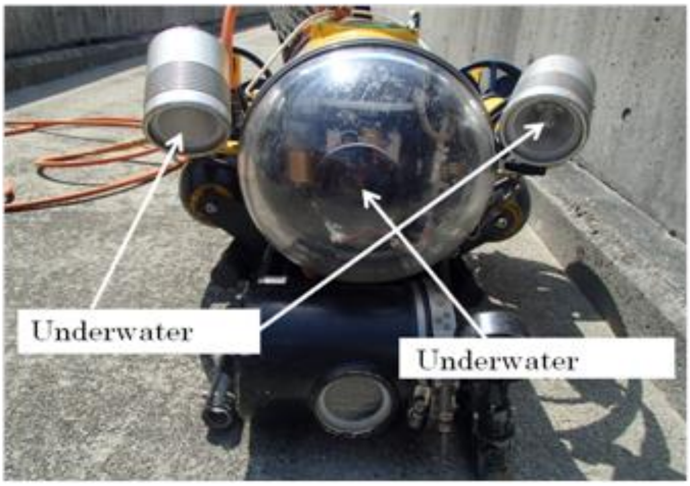

Figure 2. Underwater camera and underwater lights (150w×2)

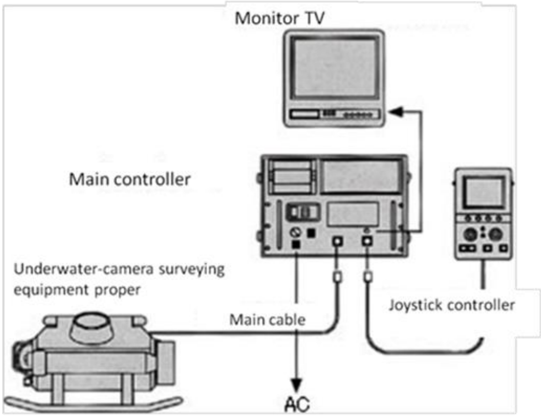

Figure 3. Composition of the underwater camera survey vehicle

2.2 Inspection system

2.2.1 Numbers of crew necessary for inspection

A minimum number of five persons is necessary to conduct an underwater inspection, including one inspector watching the image on the TV monitor, one operator of the vehicle, one inspection result recorder, and two cable men winding and unwinding the main cable.

Figure 5. shows an example of equipment and personnel arrangement, while Figure 4 shows a scene of inspection.

Figure 4. Inspection staff on the boat

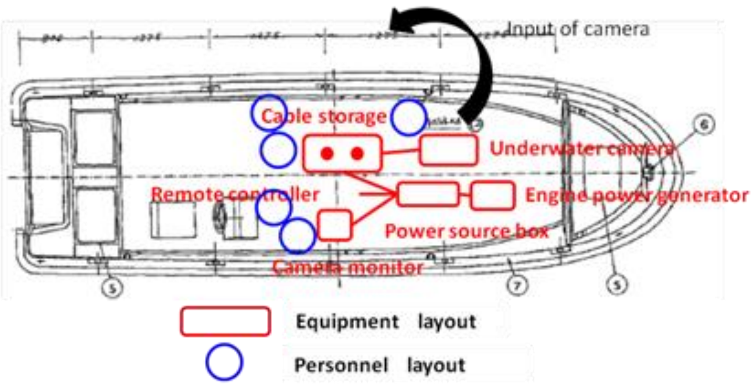

Figure 5. Equipment and personnel arrangement(Example)

2.2.2 Safety management

The water intake facilities of the Naramata Dam (surface intake gate, bottom intake gate, and sluice-gate-sills), to be discussed later, were inspected from the ground, and other areas, were inspected with an underwater camera survey vehicle operated from aboard a vessel.

Since it was necessary to transport some of the heavy inspection equipment onto the vessel and to carry out some onboard work, including cable winding, we prepared a work procedure as a guide to ensure work was executed appropriately, including who-does-what, inspection work procedure, expected risk factors, and accident prevention measures, distributed the procedure to all workers (Japan Water Agency staff), made sure that they understood it, and conducted the inspection.

2.2.3 Coordination with relevant organizations

The types of operations frequently conducted by dam staff for the facilities owned by the power producer include retention of the reservoir water level, and supply of irrigation water. If the underwater camera survey vehicle were damaged due to an unexpected situation and were washed away downstream during an inspection, the vehicle could damage the power generation facilities. Such a risk is considered particularly high for inspection of the upstream side of the dam body of the Yagisawa Dam near the water intake for power generation, and the sills of the surface intake gate and bottom intake gate of the Naramata Dam. In view of this risk, the power producers and river administrator had preliminary consultations about the inspection plan. It was mutually agreed that power generation and water discharge were suspended during the underwater inspection, and the inspection was conducted. Furthermore, it was fortunate that no irrigation water was supplied at both dams in June 2014 when the inspection was conducted. As a result, power generation and water discharge were only temporarily suspended during the inspection, which did not adversely affect dam operation.

3. INSPECTED LOCATIONS

3.1 Yagisawa Dam

At the Yagisawa Dam, inspection points included (a) the sills of the guard gate of the discharge duct of the outlet works, (b) inlet screen, (c) check of the inlet of the water filling pipe for anomalies such as deformation, damage or corrosion, and confirmation of the condition, and (d) the condition of concrete on the upstream side of the dam body (arch dam and wing dam). The areas of inspection are shown in Figures 6, 7 and 8.

For (d) the areas of inspection, if all these areas were inspected, it would be impossible to complete inspection in the limited number of days as the area to cover would be too wide. In addition, since it was also an important purpose of inspection to compare the inspection results between the first inspection and any future inspection, the inspection locations should be easily recognizable in the submerged environment. In view of these conditions, it was decided that the joint of the blocks (boundary between 11BL and 12BL as a representative joint) for the arch dam and one center measuring line at 26BL in contact with the right bank thrust blocks for the wing dam be selected as inspection locations.

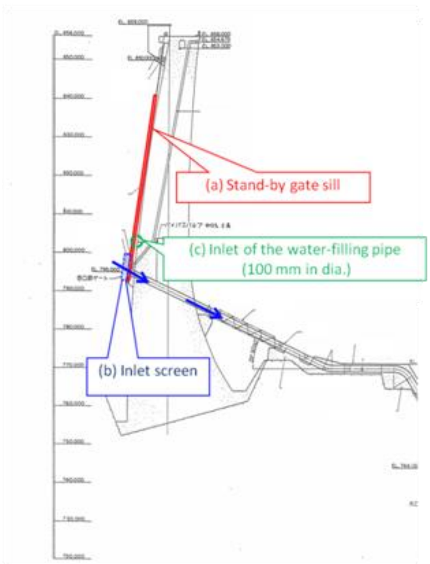

Figure 6. Inspection Point at the Yagisawa Dam (1)： (a) Stand-by gate sill of the outlet conduit of the Yagisawa Dam, (b) Inlet screen, (c) Inlet of the water-filling pipe

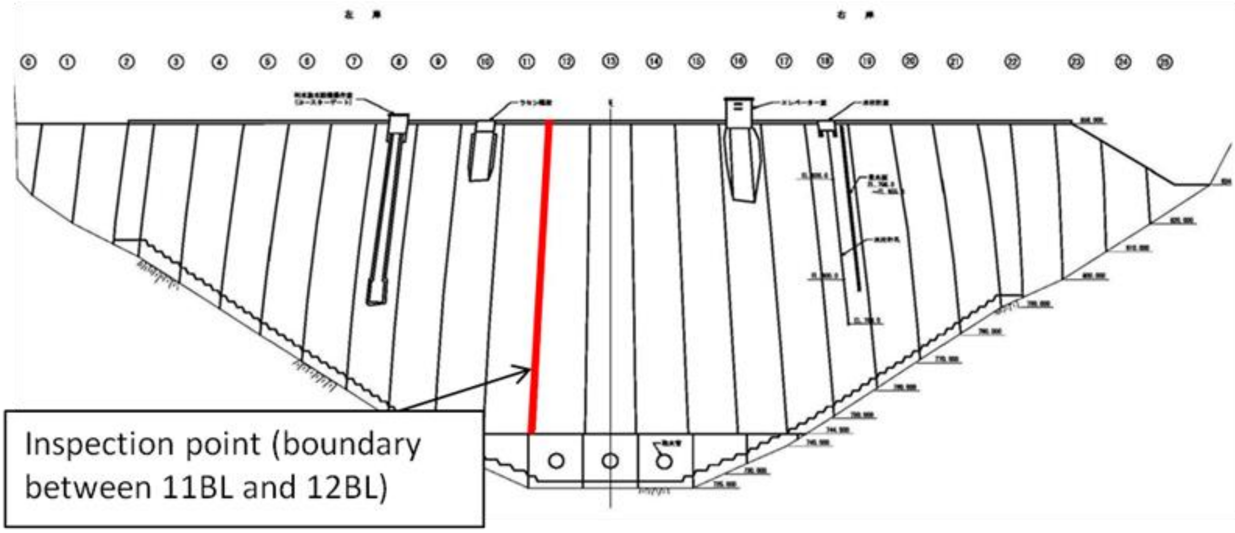

Figure 7. Inspection Point at the Yagisawa Dam (2)：(d) Inspection point on the upstream side of the Yagisawa Dam body (arch dam)

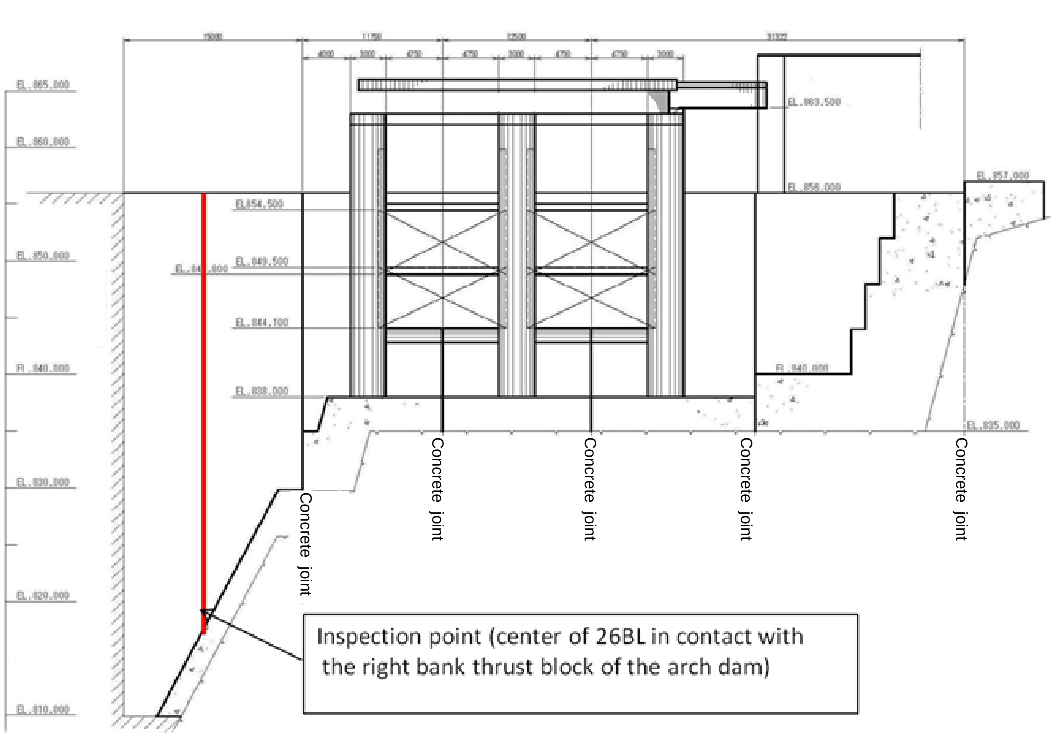

Figure 8. Inspection Point at the Yagisawa Dam (3)：(d) Inspection point on the upstream side of the Yagisawa Dam body (wing dam)

3.2 Naramata Dam

Inspection points of the Naramata Dam included (e) the sills of the surface intake gate, bottom intake gate, and sluice gate of the Naramata Dam, (f) surface intake, intermediate section, and bottom intake screens, (g) concrete surface of the apron of the energy dissipator, (h) concrete surface of the intake tower of the surface intake facility, and (i) the sedimentation at the sediment retaining wall (on the bottom intake side). The areas of inspection are shown in Figures 9, 10 and 11.

For the inspection area (h), the focus was put on the center measuring line on the reservoir side plane of intake tower of the surface intake facility based on the same viewpoint as that of the inspection area (d).

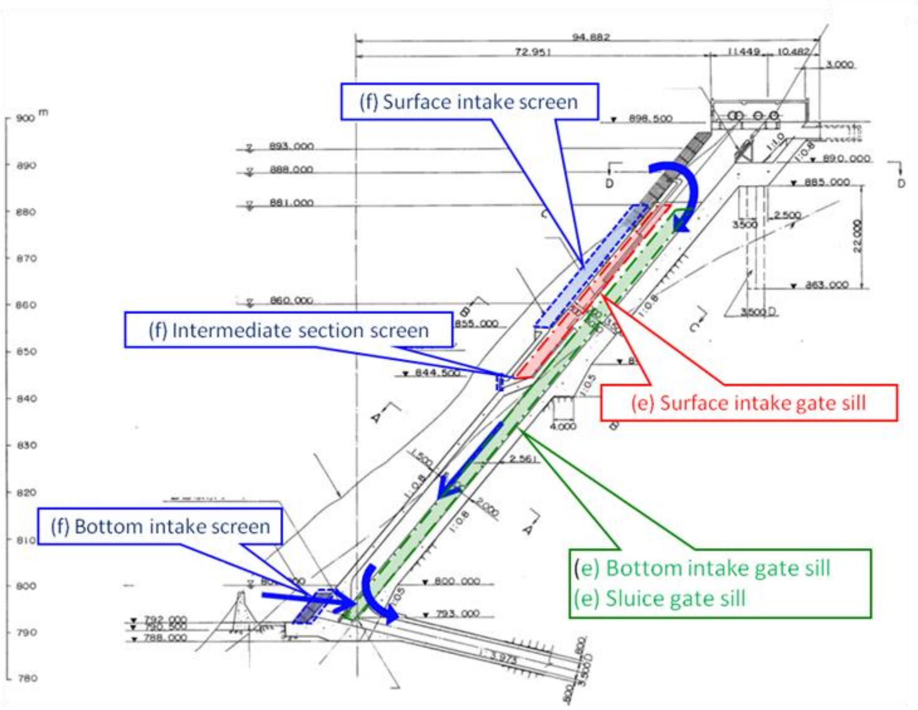

Figure 9. Inspection Point at the Naramata Dam (1)： (e) Sills of the surface intake gate, bottom intake gate, and sluice gate of the Naramata Dam and (f) surface intake, intermediate section, and bottom intake screens

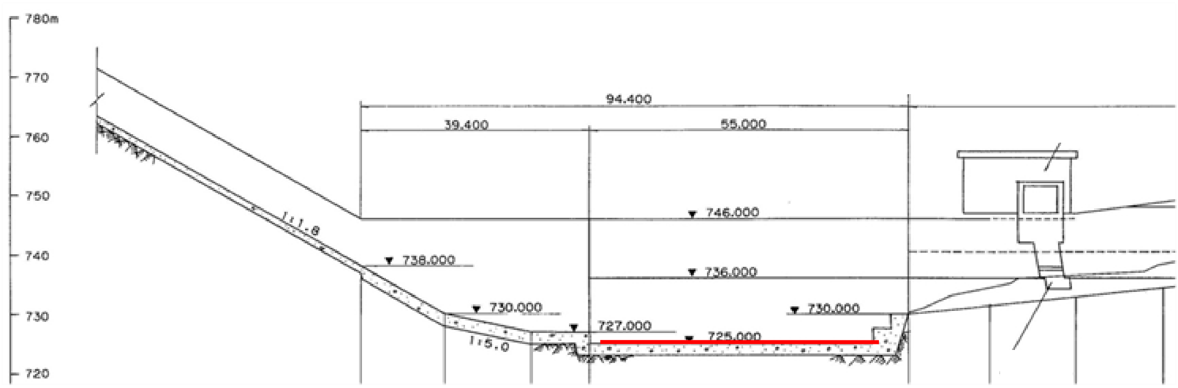

Figure 10. Inspection Point at the Naramata Dam (2)： (g) Inspection area for the concrete surface of the apron of the energy dissipator

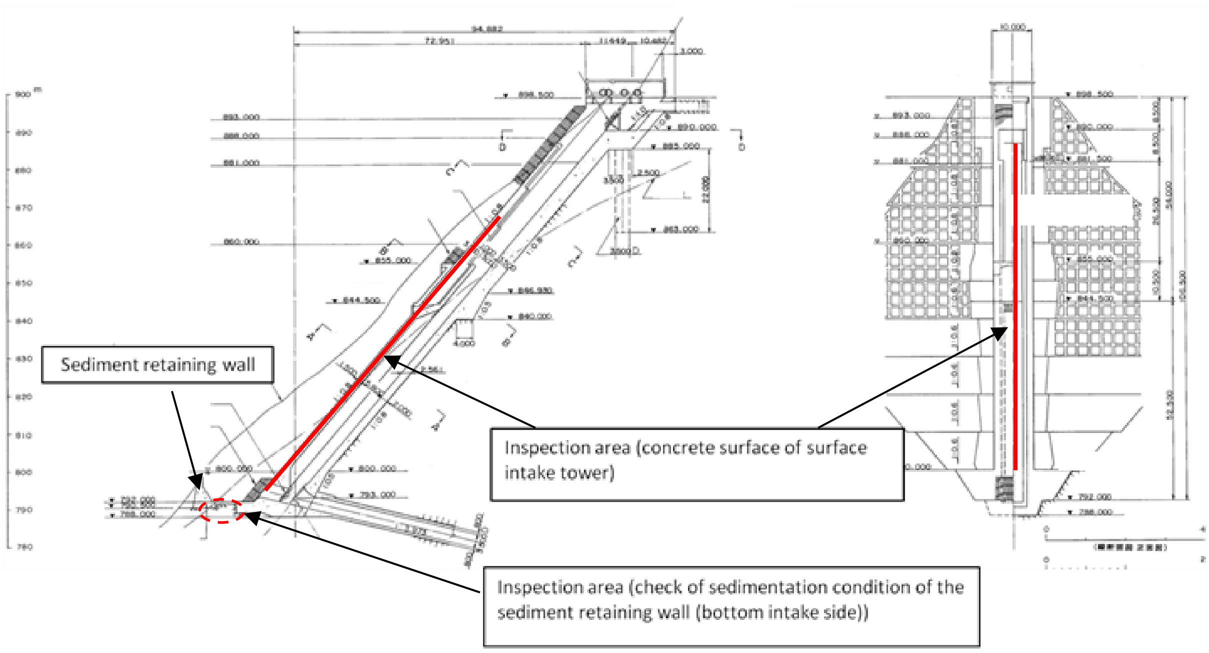

Figure 11. Inspection Point at the Naramata Dam (3)： (h) Inspection area for the concrete surface of the intake tower of the surface intake facility, and (i) the sedimentation at the sediment retaining wall

4. INSPECTION RESULTS

Underwater camera inspection of some of the non-visible parts submerged in the water of the Yagisawa and Naramata dams revealed that there were no areas which required immediate repair and/or maintenance works. The inspection results for each check point are described as follows:

4.1 Yagisawa Dam

Ordinary steel was used at (a) the guard gate sills of the outlet duct of the outlet works, (b) the water filling pipe screen, and (c) the inlet. Although tubercles were partly seen on the surface, no deformation or damage that would disturb gate operation was observed.

Figure 12. Screen for the stand-by gate of the outlet works of the Yagisawa Dam

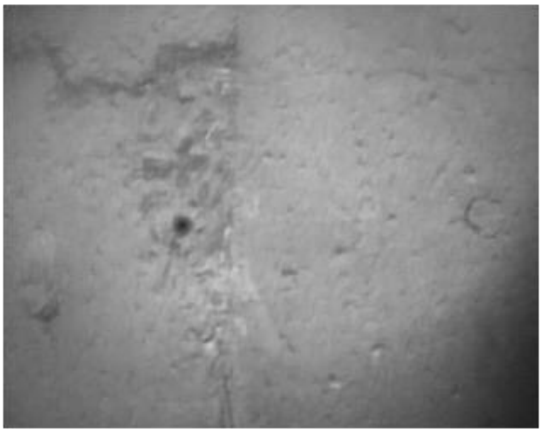

Figure 13. Condition of the upstream site of the arch dam body of the Yagisawa Dam(819m in elevation ; boundary between 11BL and 12BL)

The inspection of (d) the concrete of the upstream side of the dam body found cracks estimated to be minute and closed, minor flakes and rock pockets, slight peeling and leaching of surface cement paste, and exposure of rebars (not structural rebars) in the arch dam, as well as minor rock pockets and light peeling and leaching of surface cement paste in the wing dam. It is presumed that these deteriorations do not affect stability of the dam body at this moment and undergo very slow deterioration.

4.2 Naramata Dam

For (e) the sills of the surface intake gate, bottom intake gate, and sluice gate of the Naramata Dam, and (f) surface intake, intermediate section, and bottom intake screens, although sinkers were found above the bottom screen, both the sills and screens were made of stainless steel and thus suffered no corrosion. No deformation or damage that would affect their intake function was found either. For (h) the concrete surface of the intake tower of the surface intake facility, no damage was found. For (i) the bottom intake side of the sediment retaining wall, sediments were deposited on the bottom plates of the retaining wall. However, since the majority of the retaining wall itself (from near the bottom plate to the top) could be checked, it was confirmed that the bottom intake was not buried by the sediments.

For (g) the concrete surface of the dissipator apron, it was impossible to check the condition because of sediment deposition. We therefore changed the schedule and checked the retaining wall surface of the nearby discharge carrier (dissipating element). The inspection found minor flaking, and slight peeling and leaching of surface cement at part of the concrete surface. These deteriorations of concrete, however, are not serious enough to affect the dissipation capability, and their deteriorations are considered to be very slow.

Figure 14. Sinkers above the bottom intake gate

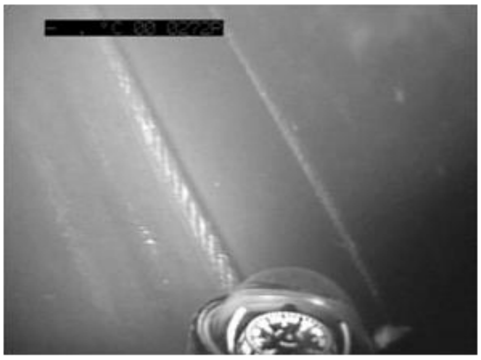

Figure 15. Sill of the bottom intake gate of the Naramata Dam

Figure 16. Sedimentation at the bottom intake side of the sediment retaining wall

5. FUTURE POINTS TO NOTE AND TASKS TO SOLVE

The underwater inspection conducted as reported in this paper revealed the following findings:

- The underwater camera survey vehicle is capable of freely moving around in calm water and diving to a maximum depth of 100 m with its propulsion units. It allows us to efficiently and quickly conduct visual inspection of dam facilities constantly submerged under water. In particular, the more experienced the operator, the quicker he can move the vehicle around, and the more efficiently he can conduct inspection.
- The underwater camera survey vehicle can repeatedly dive, float and conduct inspection for a long time at great depths, which cannot be generally done by human divers. In addition, dam management staff do not need to go to the trouble of arranging divers, and can conduct an inspection at any time.
- When a concrete surface with no markers such as vertical construction joints was inspected (specifically the upstream side of the wing dam of the Yagisawa Dam) during the underwater inspection of parts of the dam facilities always under water, a rope with a plumb bob as a marker (hereinafter a marker rope) was installed along the surface subject to inspection (Figure 17).

Figure 17. Installing a marker rope

Without a marker rope, it is impossible to judge if the underwater camera survey vehicle is moving vertically down or not. With a marker rope, the operator can lower the vehicle along the rope and operate it while checking the motion direction. This therefore allows the inspector to conduct efficient and accurate inspection in a short time.

When the marker rope is marked with a tick mark at a certain interval, the inspector can roughly tell the depth or elevation of the inspection point. This arrangement allows us to monitor changes of condition over time by comparing the results with a future inspection when the same point is inspected years later. Meanwhile, when the inspection area is not a vertical surface, as in the case of (h) the intake tower of the surface intake facility of the Naramata Dam, it is impossible to set a marker rope. It would therefore be difficult to determine the current location of the underwater camera survey vehicle. In this case, the inspector would have to estimate the present position only by checking the design drawing of the facility in question. In this case, if any damage is found at such a check point, it is difficult to identify its location, which poses problems to implementation of necessary corrective actions.

- It is difficult to evaluate the concrete condition based only on the observation of the image. If a final evaluator experienced in concrete directly checks the inspected part on the monitor and repeatedly focuses on the portion that needs attention or seems to need repair during inspection, more accurate evaluation will be possible.
- When sediments are deposited over the surface to inspect, the condition of that part cannot be checked. During the inspection, there occurred a situation where the present position of the underwater camera survey vehicle was lost because the vehicle stirred up deposited sediments and worsened visibility.

Secular changes have been observed for the Yagisawa Dam and Naramata Dam that have been operated for 48 years and 24 years, respectively, since their operations started. According to the Dam General Inspection Procedure and Commentaries, analysis of the repair records for dams under direct management of the Ministry of Land, Infrastructure, Transport and Tourism and dams of the Japan Water Agency confirmed that repairs were required more often for dams roughly 30 years in use after their operation started. It is therefore necessary to continue appropriate maintenance of dam facilities to enable them to achieve their original purposes and functions. For inspection of non-visible parts of facilities, it is more important to conduct systematic inspection, constantly understand the prevailing conditions, and take timely corrective actions.

Despite some incompleteness earlier mentioned, inspection of non-visible parts with an underwater camera allows us to conduct inspection efficiently, quickly and at any time once an underwater camera is made ready. The Numata Dams Integrated Operation and Management Office intends to clarify the problems, improve those incompleteness, and continue periodic inspections of submerged parts with an underwater camera.

6. ACKNOWLEDGEMENTS

Authors obtained permission to publish from their organisation and clients.

7. REFERENCES

Japan Water Agency (2008).*Dam Inspection and Maintenance Standard* in Japanese,

Ministry of Land, Infrastructure and Transport(2013),*the Dam General Inspection Procedure and Commentaries* in Japanese,pp34-115.

oOOo