WATER INTAKE STRUCTURES FOR SURFACE AND SUBSURFACE WATERS

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Contents

Summary

In this chapter, the withdrawal of water from a reservoir is described and the relations between the withdrawal, the reservoir environment, and the function of the intake work aee examined. Storage of running water affects both the water quality of the reservoir and the flow rate and water quality of the downstream river channel.

1. Introduction

A reservoir is constructed in order to store water while it is required. Stored water is withdrawn from the reservoir in order to utilize the energy of the water or water itself. In this chapter, the withdrawal of water from a reservoir is described and the relation between the withdrawal, the reservoir environment, and the function of the intake structure is described.

Most water stored in reservoirs is utilized for irrigation, and a smaller volume is supplied to urban water supply systems. Hydraulic power generation utilizes the energy of the stored water without consuming it. The running water may be stored for future use and for pumped storage generation, smoothing the seasonal variation of flow rate in

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order to improve the annual utilization efficiency, even at hydraulic power generation reservoirs. Water may be supplied to the downstream river, using water stored in the reservoir, in order to provide ecological benefits during dry periods.

There is a difference between withdrawal from a reservoir and direct withdrawal from a river or from underground. Storage of running water affects the water quality of reservoirs as well as the flow rate and quality of the downstream river channel.

When water is directly taken from a river, the water retention phenomenon does not occur, because it fundamentally does not accumulate. Since environmental problems, land subsidence, etc., may arise, when balance between supply and demand of groundwater is not maintained, it is necessary to control withdrawal of groundwater. This slows the flow of groundwater, and it is necessary to consider the effect on a very long time scale.

Water from a reservoir may be discharged direct to the river downstream of the dam, or directly transported through a water channel and/or tunnel to the place where it is utilized. The required water quality is dependent on the proposed water-use, e.g. drinking water, industrial water, irrigation, environmental enhancement. Intake works must be planned with regard to reducing the negative effect on the environment in the reservoir.

Spillway and outlet works for flood control must be incorporated, in order to allow discharge from the reservoir during periods of flood or prolonged high inflow. Nitrogen and oxygen become supersaturated by aeration caused by discharge from these outlet facilities, and fish survival may be threatened in the downstream river. Nitrogen is dangerous to fish as a supersaturated gas, as it is absorbed in the blood, and can form intravenous bubbles.

In addition, a sediment flushing facility and a facility for drawdown must be included within the structure of the dam, in order to ensure their appropriate function and safety. Though the use of these facilities is limited, their operating method must be considered, because it may cause significant impact to the downstream ecosystem.

2. Types

In temperate and subtropical regions, low-temperature river water which flows in autumn and winter is stored in the bottom layer of the reservoir. Solar radiation to the reservoir surface is intensified in the early spring, and the surface water is warmed. The temperature of the water stored in the reservoir’s upper layer is further increased by inflow, because its temperature also rises at this time. Thermal stratification, stabilizing the upper and lower layers, therefore occurs in summertime. The water quality, dissolved oxygen and nutrients, and distribution of suspended matter, depends on this stratification.

In cold climates, however, the surface water is cooled, and a different form of thermal

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stratification develops, in which the bottom layer is at a higher temperature. This occurs when the surface layer is 4 ^{o}C. or less.

Mixing of the top and bottom layer is inhibited when a thermocline is created with a strong density difference between the top and bottom, and the oxygen supply to the bottom layer may become inadequate. Intake structures are generally designed and operated to suppress the development of a thermocline. The flow in the reservoir is fundamentally a density current, because density stratification is formed. Though the density current mainly originates from thermal stratification, it is necessary to take account of the variation in density as a consequence of turbidity, when there inflow of turbid, high-density water at times of flood. The structures described below are being tried in order to ensure provision of water with a quality appropriate to the intended use.

1) Surface Intake

A surface intake is used in order to take water from the reservoir surface when is comparatively clear. Obviously, the withdrawal must follow the fluctuations of the reservoir level. It is necessary to prevent contamination of the lower layers in order to efficiently take the surface water. Hydraulic examination is conducted to determine the approach velocity distribution and withdrawal water depth.

2) Subsurface Intake (Submerged Intake)

Regardless of the reservoir water level, a subsurface intake takes water from a low level in the reservoir. The intake will have a simple shape, because this system can fix the intake level. The water temperature of the water is often low, and it contains little phytoplankton.

3) Multi-Level Intake (Selective Withdrawal)

Selective withdrawal is done at an optional position in order to take water of the desired quality. The form of the density stratification is positively controlled by this system in order to effectively utilize the stratification in the reservoir. The shape of the facility is similar to that of a surface intake, but there is some difference in the top of the facility. Sometimes the intake is in the middle layer, when the upper and lower layers are prone to contamination

3. Water Quality Control

Water quality problems related to water temperature, muddy water, eutrophication, etc. are particularly likely to occur in reservoirs that include natural lakes. Water quality control is a very important consideration in withdrawal from reservoirs, and the various facilities described in this section are used to provide this control.

Water quality problems include those caused by the quality of the discharged water on the downstream river. This effect can be mitigated by choosing the most appropriate

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intake level. Changes in water quality attributable to the storage of running water may affect or limit the water-use. This can be reduced by controlling the change in water quality in the reservoir.

Such water quality problems are a result of processes operating in the reservoir environment, such as stratification of the waters. Efforts are, therefore, made to maintain water quality by reducing the stratification. The methods available for controlling stratification include lowering the thermocline by selective withdrawal, and destroying the thermocline by circulating the water.

1) Outlet Work

The level of the thermocline in the reservoir is dependent on the elevation of the spillway, if the discharge from the spillway is large. The discharge capacity of the spillway is fixed in relation to the original function of the spillway, but there is some capacity for choice in the level of the spillway. A part of the overflow crest may be substituted in the orifice spillway in order to control the water quality of the reservoir. As the spillway discharges fresh water from the surface of the reservoir, turbid water accumulates in the reservoir. However, abnormal growth of plankton may be prevented by discharging the plankton-rich surface layer.

2) Selective Withdrawal Facility

It is possible to optionally set the intake water level of the selective withdrawal facility. One of the main functions of this facility is to control the level of the thermocline. As a result, the thickness of the surface layer and the level where the river water flows are regulated. Another function is to take the water selectively from a level that offers the required water quality. The former is used as a countermeasure to prevent muddy water and eutrophication, and the latter is used as a means of to maintaining water temperature and reducing muddy water.

3) Water Quality Control Curtain

This is a method of controlling the flow from a reservoir by installing a curtain transversely in the surface layer of the reservoir. The curtain is a pollution control membrane hung from a float resembling a log boom on the surface of the water. The water in the bottom layer can be taken efficiently when this is hung near the intake at a level lower than the intake level. Precipitation of flowing suspended matter is promoted when this is installed in the upper reach of the reservoir.

The curtain should also be installed in the upper reach of the reservoir as a eutrophication countermeasure,. The curtain must be about 5m deep considering the photic region. The retention time is short in the reservoir upstream from this curtain. As the concentration of nutrients is high in this area, it is an environment where phytoplankton can readily proliferate. It is therefore necessary to examine the effect on landscapes, etc. beforehand.

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4) Circulator

The circulation equipment vertically mixes the storage water and controls the density distribution of the reservoir. An example of this kind of equipment is one that continuously releases bubbles supplied by a compressor. A lot of water is moved upward by the rising bubbles. Either just the surface layer is mixed, or all the layers; these methods are called surface layer circulation and all layer circulation respectively.

Both techniques include a process that lowers the thermocline. The cold water from the bottom layer mixes with surface water, its temperature rises to an intermediate temperature, and it expands to the thermocline as a density current. Through this process, the phytoplankton existing mainly in the surface layer is carried to the deeper layers in the reservoir. As a result, the proliferation is suppressed. Though this is a very effective process, it is not for long term application.

The surface layer circulation technique, which mixes the surface layer, destroys the surface thermocline formed by insolation, creating a surface layer of uniform temperature. As a result, the thickness of the mixed surface layer increases to below the depth reached by the light. The phytoplankton is then dispersed in an environment of limited light where it does not proliferate so readily. The algae dispersal effect is limited to the vicinity of the circulation equipment after the mixed layer is formed. However, the wind can be counted on to guarantee sufficient mixing, because there is no density difference in the mixing layer. It becomes difficult for cyanobacteria to proliferate, because the sedimentation of large phytoplankton is prevented.

There are two bubble release techniques. In one type, the bubble release mouth is installed in a tower or floating body fixed in the water. In the other, the release mouth is hung from a body floating on the water surface.

The all-layers circulation technique destroys the thermocline, and it mixes the whole reservoir. When this occurs, the bottom layer is supplied with the oxygen, and mixes the bottom cold water layer with the surface water. This avoids the cold water problem, and in addition, it disperses the phytoplankton. Flow control using the density current phenomenon is also an effective way of solving various water quality problems in reservoirs. In this case, the thermocline is maintained, and the all layer circulation method is thus not adequate.

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Biographical Sketches

Shuji Takasu is director at the Hydraulic Engineering Research Group, Public Works Research Institute, Independent Administrative Institution, Japan, where he is responsible for research into dam structural engineering, hydraulics related dams and reservoirs, hydrology and watershed management. He has maintained an active interest in the design of hydraulic structures, i.e. spillways, outlet works and gates, and in hydraulics related to sedimentation and water quality in reservoirs.

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