Measurement of currents in Lake Mead with the deep water isotopic current analyzer (DWICA)

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MEASUREMENT OF CURRENTS IN LAKE MEAD WITH THE DEEP WATER ISOTOPIC CURRENT ANALYZER (DWICA)

by

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Applied Sciences Branch
Division of General Research
Engineering and Research Center
Denver, Colorado
In Nov 1967, a Deep Water Isotopic Current Analyzer (DWICA) was used to study current patterns in the Boulder Basin of Lake Mead to determine if low-quality water from Las Vegas Bay might enter the Southern Nevada Water Project intake on Saddle Island. Secondary objectives were to study the general current patterns in Boulder Basin and the effect of power discharges at Hoover Dam on these currents. Results of current measurements at 3 stations in Boulder Basin are given. Observations indicate a definite possibility that low-quality water from Las Vegas Bay might enter the water intake on Saddle Island. Current measurements off Promontory Point show a correlation between power discharges at Hoover Dam and current velocities in this area, with peak current velocity lagging the discharge peak by about 2 hr. Because data obtained in the study cover a short time period, suggestions for further study of general current patterns in Boulder Basin are included.
ACKNOWLEDGMENT

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The assistance of Rex A. Elder, Director, Engineering Laboratories, Tennessee Valley Authority, in making the DWICA available for the Bureau's use at Lake Mead is greatly appreciated.

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INTRODUCTION

The Southern Nevada Water Project will divert water from Lake Mead for municipal use in Southern Nevada. The intake for this project is on Saddle Island in Boulder Basin. (See Figure 1.) Immediately north of Saddle Island, Las Vegas Bay opens into Boulder Basin. Treated sewage enters Las Vegas Bay from Las Vegas Wash.

In November 1967, the Bureau carried out a program of current measurements in Boulder Basin to determine if low-quality water from Las Vegas Bay might enter the intake on Saddle Island. The current patterns in Boulder Basin and the effect of power discharges at Hoover Dam on these currents were also studied.

Because deep lake currents have very low velocities, conventional flow metering devices were not applicable in this study. The only instrument capable of accurately measuring these ultra-low velocities was the Deep Water Isotopic Current Analyzer (DWICA).

Since the Bureau did not have one of these instruments, the Tennessee Valley Authority (TVA) was contracted to provide the DWICA and perform the current measurements in Boulder Basin under Bureau direction.

CONCLUSIONS

The current data obtained at Station 2 indicate a definite possibility that low-quality water from Las Vegas Bay might enter the water intakes on Saddle Island.

Current profiles at Station 1 indicate a correlation with power discharges at Hoover Dam, with a peak in the main current velocity lagging the discharge peak by about 2 hours.

It should be noted that the current information obtained in this study is limited in time to 1 week in November of 1967. In order to draw more definite conclusions about current patterns in Boulder Basin, further studies over a longer period of time would be required.

During the field study the need for a more stable work platform for the DWICA was noted. In the TVA reservoirs it has been possible to stabilize the instrument barge by mooring it with four lines secured on the shores. Hydraulic mooring winches on the barge pull the lines taut and the barge remains stationary “even in relatively rough water” (Elder and Vigander, 1966). In Lake Mead no such arrangement was possible and the instrument barge had to be secured by anchoring in deep water. It was often necessary to delay or recheck measurements because of the barge’s rocking. The DWICA itself may be supported on the bottom of a lake on tripod legs (Figure 2). However, this type of arrangement would limit study to bottom measurements in lakes where deep, unconsolidated sediments were not a problem.

DESCRIPTION OF DWICA

The Deep Water Isotopic Current Analyzer was invented and developed by William H. Johnston Laboratories, Incorporated, for the U.S. Atomic Energy Commission (AEC). The model used in this study was the DWICA-1B designed for use by the TVA in its southeastern reservoirs. (See Figure 2.)

The DWICA operates on the time of travel principle using iodine-131 as the tracer. The DWICA is suspended at the desired depth from the instrument barge (see Figure 3) and when it has stabilized in the water, a small slug of the radioactive tracer is injected from the isotope discharge. Twelve photo-multiplier detectors are arranged around the isotope discharge and as the tracer passes beneath one of the detectors its time of travel and position are recorded on the instrument barge. The compass aboard the DWICA gives the magnetic bearing of the activated detector and thus the direction of flow is determined.

Characteristics of the DWICA-1B are listed in Table 1. In the Lake Mead Study, measurements of temperature, depth, and electrical conductivity were also recorded.

Table 1

<table>
<thead>
<tr>
<th>CHARACTERISTICS OF DWICA-1B</th>
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<tbody>
<tr>
<td>Diameter</td>
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<tr>
<td>Height</td>
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<tr>
<td>Weight in air</td>
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<tr>
<td>Reservoir capacity</td>
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<tr>
<td>Injection volume</td>
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<td>Injection pressure</td>
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<td>Maximum velocity</td>
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<tr>
<td>Practical minimum velocity</td>
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<tr>
<td>Direction resolution</td>
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<tr>
<td>Compass resolution</td>
</tr>
<tr>
<td>Drift distance</td>
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<tr>
<td>External power</td>
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</tbody>
</table>

From Elder and Vigander, 1966
Elder and Vigander (1966) summarize the capabilities and limitations of the DWICA-1B as follows: "...the DWICA-1B current-meter system is uniquely capable of accurately measuring steady or unsteady flow velocities and 0 to 0.2 foot per second at depths up to at least 350 feet. The instrument is sufficiently rugged to withstand routine use in the field. However, relatively heavy auxiliary equipment is needed to handle the relatively large and bulky underwater instrument."

LAKE MEAD STUDY

Current measurements with the DWICA-1B were carried out in Lake Mead's Boulder Basin from November 10 through 17, 1967. The DWICA-1B, the instrument barge, and operating personnel were provided by TVA on a reimbursable basis.

Three stations were selected for the study (see Figure 1). Station 1 was off Promontory Point, about a mile above Hoover Dam. The water depth at this site was 410 feet. Station 2 was about a mile north of Saddle Island where Las Vegas Bay joins Boulder Basin. Water depth here was 280 feet. Station 3 was in Boulder Basin, about 0.6 mile southwest of Sentinel Island. The water depth at this point was 358 feet.

Station 1:

Current profiles were obtained at Station 1 on November 10, 11, 12, and 16. The measurements on the 11th and 16th included temperature and conductivity determinations. The data obtained on these 4 days are summarized in Figures 4 through 7.

During the night of November 16 and 17, current measurements were performed at Station 1 while the turbine peaking cycle was being carried out at Hoover Dam. The results are presented in Figures 8 and 9.

A comparison of the current profiles obtained at Station 1 indicates a strong current in the direction of Hoover Dam and approximately centered on the elevation of the outlet. Measurements obtained during the peaking cycle indicate that this current is closely related to discharges through the dam, with a peak in the current velocity at Station 1 lagging the discharge peak by about 2 hours. (See Figure 9.)

On November 11, 12, and 16, current measurements were carried below the 300-foot depth. Strong bottom currents in the direction of the dam were observed on the 11th and 16th. These may be density currents and could be caused by sediment load, salinity, or cold inflow.

Density currents caused by sediment load are not uncommon in Lake Mead; however, project personnel say that no such currents have been noted near the dam since the reservoir reached its full length.

An increase in conductivity at the 400-foot depth was observed on the 16th (Figure 7), indicating a higher degree of salinity at this level. However, since no such increase was observed on the 11th (Figure 5), the evidence for a density current caused by salinity remains inconclusive.

Finally, it is impossible with the available data to decide either for or against a density current caused by cold inflow, since all that is required for such a current to flow at this depth is that its density be equivalent to that of the surrounding water. Therefore, the inflow would not necessarily have to be colder than the reservoir at this depth and need not cause a discontinuity in the temperature profile.

Station 2:

Current measurements were carried out at Station 2 on November 13 and 14, with temperature and conductivity also being measured on the 13th. Data for Station 2 are presented in Figures 10 and 11.

The current profiles at this station agree rather closely in indicating a strong current at the surface flowing into Las Vegas Bay out of Boulder Basin. Below this current and centered at about the 100-foot depth is a slightly stronger current flowing in the opposite direction. This current, flowing out of Las Vegas Bay into Boulder Basin, coincides with the top of the thermocline. The conductivity profile at this point exhibits a very prominent peak, indicating an increase in salinity.

These current profiles also compare quite closely with those obtained by Slotta et al. (1969) in their study of entering streamflow effects on currents of a density stratified model reservoir. In this study it was noted that at the lowest streamflow velocities little mixing took place between the entering flow and the reservoir water. The major part of the streamflow "proceeded down the reservoir slope until reaching a reservoir depth having equivalent..."
density” and then “flowed horizontally across the reservoir.”

“At the higher streamflow velocities more mixing occurred creating a large mixing current, and at the highest streamflow velocities mixing was so extensive that very little of the entering streamflow discharged down the reservoir slope. As the mixing current increased a reverse current at the surface caused by entrainment to the mixing current occurred.” (Slotta et al., 1969)

From the study cited above, it would appear that the saline main current noted at Station 2 represents the inflow from Las Vegas Wash, while the surface current may be a reverse current caused by entrainment to the main inflow.

The possible effect of this inflow on the water intakes on Saddle Island was studied by resolving the current vectors at Station 2 into their components along a straight line drawn from the station to the Henderson waterpipe intake on Saddle Island (Figure 12). The resolved profiles for both days at Station 2 are shown in Figure 13.

These profiles indicate a major component current in the direction of the waterpipe intake between the depths of 50 and 110 feet. If the original current vectors are indeed the inflow from Las Vegas Wash, the resolved profiles indicate a definite possibility of this flow reaching the intakes on Saddle Island.

Station 3:

On November 15, one set of current measurements was made at Station 3. Temperature and conductivity measurements had been performed the previous day. Figure 14 summarizes the information obtained at Station 3.

It is difficult to make any general interpretation of the data at Station 3, because more than one current profile is needed to indicate patterns or trends. At this point, the data are inconclusive.

RECOMMENDED RESEARCH

To draw more definite conclusions about the current patterns in Boulder Basin, the following minimum studies should be done.

(1) **Between Las Vegas Bay and Boulder Basin.**—Current profiles should be obtained at three stations (including the present Station 2) in the channel between Saddle Island and Black Island in order to define the general current pattern between Las Vegas Bay and Boulder Basin. Water samples should be collected at depth intervals and analyzed for major cations, anions, nutrients such as nitrates and phosphates, and other parameters indicative of movement of water from Las Vegas Wash into Boulder Basin.

(2) **At Station 3.**—Several profiles should be obtained here to permit the detection of any trend or pattern in the currents. A series of current measurements during the turbine peaking cycle at Hoover Dam may be useful to determine what, if any, relationship the currents in this part of Boulder Basin have to the currents noted at Station 1. Water samples could be analyzed to compare with those taken between Las Vegas Bay and Boulder Basin.

In order to improve the effectiveness of the DWICA in future studies, some thought should be given to improving the stability of the instrument barge in wide reservoirs where shore mooring is not possible.

REFERENCES


RECOMMENDED RESEARCH

To draw more definite conclusions about the current patterns in Boulder Basin, the following minimum studies should be done.
Figure 1. Location of stations in Lake Mead.
Figure 2. Deep water isotopic current analyzer DWICA-1B.

(From Elder and Vigander, 1966)
Figure 3. Instrument barge. The DWICA-1B is visible at the right end of the deck, under the hoist. Photo P45-D-69650.
Figure 4. Station 1 — Current profile on 11-10-67.
(11:30 A.M. - 4:00 P.M.)
Figure 5. Station 1 – Current profile on 11-11-67.
(8:47 A.M. - 3:20 P.M.)
Figure 6. Station 1 — Current profile on 11-12-67.
(10:30 A.M. – 1:00 P.M.)
Figure 7. Station 1 – Current profile on 11-16-67.
(12:15 P.M. – 4:10 P.M.)
Figure 8. Station 1 — Current measurements at various depths during turbine peaking cycle, 11-16 to 11-17-67.
Figure 9. Station 1 - Power discharge and current velocity at 210 ft. depth vs. time, 11/16 to 11/17/67.

Total Power Discharge, in thousands of c.f.s.

Current Velocity (feet/sec.)

Note:
- Current direction during entire cycle varied from Mag. Bearing 190° to 200°
- Mag. Bearing of Hoover Dam = 210°
- Barge rocking, data questionable
Figure 10. Station 2 — Current profile on 11-13-67.
(11:46 A.M. – 5:32 P.M.)
Figure 11. Station 2 — Current profile on 11-14-67.
(9:55 A.M. – 11:47 A.M.)
Where:

\( V_i \) = Component of current along Station 2-Intake axis.
\( V \) = Observed current vector at Station 2.
\( \alpha \) = Difference between observed current bearing and bearing to intake (0-360°).

Figure 12. Method of resolving current vectors.
Figure 13. Station 2 - Resolved current profiles.
Figure 14. Station 3 — Current profile on 11-15-67. (12:18 P.M. – 5:00 P.M.) Note: Temperature and conductivity measured on 11-14-67.
ABSTRACT

In Nov 1967, a Deep Water Isotopic Current Analyzer (DWICA) was used to study current patterns in the Boulder Basin of Lake Mead to determine if low-quality water from Las Vegas Bay might enter the Southern Nevada Water Project intake on Saddle Island. Secondary objectives were to study the general current patterns in Boulder Basin and the effect of power discharges at Hoover Dam on these currents. Results of current measurements at 3 stations in Boulder Basin are given. Observations indicate a definite possibility that low-quality water from Las Vegas Bay might enter the water intake on Saddle Island. Current measurements off Promontory Point show a correlation between power discharges at Hoover Dam and current velocities in this area, with peak current velocity lagging the discharge peak by about 2 hr. Because data obtained in the study cover a short time period, suggestions for further study of general current patterns in Boulder Basin are included.

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