Ordinarily hydraulic developments with rock-earth dams include spillway structures whose discharge capacity must be sufficiently high to prevent the possibility of overflow across the rock-earth structures. In most cases these structures are built in dry pits protected by cofferdams. Dams with central cores can be constructed also in inundated pits from which the flows are diverted around the dam. Some examples of this method of carrying out the work are the following: the river-channel part of the 46-m high at the Irkutsk hydroelectric plant on the Angara River, and the Aswan High Dam, 111 m high, on the Nile River in the Arab Republic of Egypt. The flows of the Angara River were passed through toothed blocks in the powerhouse, and the Nile River flows were diverted through the hydroelectric plant canal.

In the USSR, several rock-earth dams are being constructed at the present time on rivers with large flood flows (Vilyui, 12,300; Ust'-Khantaika, 12,000; and Kolyma, 10,700 m³/sec). The diversion of such flows presents well-known difficulties requiring large capital investments on diversion structures and prolongs the dam construction period. In most cases, the diversion structures are partially or fully utilized for other purposes during the operation of the hydraulic development. During construction of rock-earth dams in dry pits protected by cofferdams, the rivers are diverted by any of the following methods: a) diversion tunnels (Nurek and Charvak dams) and bottom pipes (Mingechaur, Kolyma, and Serebryanka dams), which are subsequently used as water outlets or are closed; b) permanent open canals (Aswan High Dam) combined with the headrace or tailrace canals, or temporary canals closed off by the dam embankment (Vilyui dam); c) through a narrow passage in the dam or sectionally along a part of the river channel, with a tunnel or pipeline constructed to divert only the low-water flows (Akosombo dam in Ghana); d) the same, but with the dam submerged during passage of flood flows in the first or second year of the construction period (Ust'-Khantaika dam).

In many cases rock-earth dams are constructed without unwatering the pit and without using cofferdams. When this method is applied, for diversion of the river flows use is made of toothed blocks in the powerhouse (Irkutsk and Aswan High dams), or of previously constructed spillways (Arrow dam in Canada), or of openings temporarily left in the concrete structures (Ust'-Khantaika dam).

The cofferdams which protect the pit are usually of the rock-earth type and are included fully or partially into the dam profile. When these cofferdams are very high, their embankment volumes are considerable. Thus, the
Fig. 2. Overflow dam on Lake Kemi. 1) Moraine placed in water; 2) quarry-run rock; 3) selected stone, 1.5-3 tons in weight; 4) steel sheet piling; 5) moraine; 6) granite gneiss.

Fig. 3. Model investigations of different profiles of dam on Lake Kemi for discharge of 2000 m³/sec. The length of each test was 3 h. 1) Steel sheet piling; 2) scour surface.

Nurek upstream cofferdam is 65 m high and 1,620,000 m³ in volume; the Kolyma upstream cofferdam (63 m), 1,670,000 m³; the Akosombo downstream cofferdam (61 m), 2,060,000 m³; the Oroville upstream cofferdam in the USA (129 m), 1,448,000 m³; and the Charvak upstream cofferdam (38 m), 522,000 m³. Since these cofferdams are constructed during low-water periods of not over 6-7 months and including the winter months, the carrying out of this work, especially in mountainous regions, involves many difficulties.

For many cofferdams and dams constructed during the winter, the rate of progress of the fill-placing work has reached 210,000 m³/month (Krasnoyarsk cofferdam, 1963) and 300,000 m³/month (Kutusky dam, 1955, and Nurek cofferdam, 1967). During the construction of such cofferdams, the river channels are closed off. In order to extend the period of construction of cofferdams from one season to two, they are divided vertically into two stages. In this case the first-stage cofferdam should be of the overflow type (Toktogul and Oroville dam).

The diversion tunnels at several dams also reach impressive dimensions (the two tunnels at the Nurek dam, each 11.5 x 10 m; the two tunnels at the Charvak dam, 11 and 7.9 m, respectively; the tunnel at the Ust'-Khantaika dam, 10 x 10 m; the two tunnels at the Oroville dam, 5.5 m each; and the three tunnels at the Bennett dam, 16.5 m each). The construction cost of these tunnels is very high; the two downstream tunnels at the Nurek plant reaches 30%, and one downstream tunnel at the Charvak plant reaches 18% of the total cost of the dam. The length of the construction period for the first-level tunnel at the Nurek plant was 46 months and for the second-level tunnel, 38 months, for the downstream tunnel at the Charvak plant, 32 months, and for the tunnel at the Ust'-Khantaika plant, 12 months. Thus, the construction of diversion tunnels involves considerable outlays and substantial increases in the length of the preparatory period for dam construction. In the cases in which the diversion tunnels are not used subsequently in the dam operation, their construction may not be justified by the need for passing only the flood flows.

In the design of rock-earth dams it is necessary to examine the possibility of reducing the design discharge through the diversion structures by permitting temporary flooding of the dam during construction. Thus, for a design flood flow of 6900 m³/sec in the Khantaika River during construction, the diversion tunnel at the Ust'-Khantaika dam, 100 m² in cross-sectional area, was designed for a discharge of 500 m³/sec with a 12-m high cofferdam and, because of unforeseen circumstances, the Ust'-Khantaika dam was flooded twice (in 1968 and 1969) during its construction.

The flooding of part of a dam during construction by the passage of a flood flow can simplify substantially the construction of the diversion structures, reduce their volume, and consequently shorten the length of the preparatory period. In order not to suspend the fill-placing work during a flood's passage, it is necessary to endeavor to attain the condition that only a part of the dam is flooded, so that the work can continue at the nonflooded elevations in...