RICE WATER TEMPERATURE

FRANKLIN RANEY

LOW IRRIGATION WATER TEMPERATURES have already begun to reach problem proportions in the production of certain crops in northern California and may become far more common, especially in the northern parts of the State, as our water storage program progresses.

Early agriculture was along the rivers where limited volumes of water were drawn from warm zones along shorelines or from shallow wells. As agriculture moved farther from the water courses into still more arid climates, crop irrigation was not only essential but became more frequent. Larger volumes of water per season were required. Cooler river water was drawn upon. Wells went deeper. Finally, water needs required stream control. Impoundment structures were built. Today, on several watersheds in California, water is being stored in reservoirs not far from the snow fields. From these deep reservoirs, cold water is being discharged in large volumes and taken rapidly into irrigation canals for immediate application to cropped areas.

When Shasta Dam was completed in 1945, the temperature of the Sacramento River below the dam changed suddenly from 61° to 45°F., a fall of 16 degrees. During the same year river water temperatures fell 5 degrees at Sacramento, 260 river miles below the dam. Immediately, rice growers found that often as much as five percent of their planted acreage did not mature in time for harvesting at the end of the available crop season of 160 days. Irrigation water taken from the river more than 100 miles below the dam had become too cold for satisfactory rice growth. Growers farthest from the river water diversion point and those using well waters or warmer surface waters, were seldom affected.

About 325,000 acres of rice are now being raised under flood conditions in California, a practice which tends to accentuate the physiological effect of low water temperature since the buds and flowers are subjected to low temperatures during their entire formative period. Experience from the Shasta service area shows that a water temperature of below 69 degrees may result in severe rice yield reductions and uneconomic delays in the maturity date.

Rice farmers report that the colder water seriously retards rice germination and emergence from water; prevents or delays heading; prevents filling of the grains; and delays maturity. California rice growers with years of experience say that California varieties of short-grain, glutinous rice cannot be matured in the required 160-day season at water temperatures of 60 degrees. No damage appears to occur in the field between 69° and 77°F.

Low water temperature is considered an important limiting factor in Japanese rice production and considerable attention has been given to development of water-warming techniques to combat it. However, this literature is largely in the Japanese language and has not yet been translated. In Italy rice yields are reported to be depressed by the cold water drawn from short, fast streams draining the Alps toward the Po River Valley. Since similar situations exist in Chile, Turkey, and India, it can be expected that low water temperature effects will eventually be reported from these areas, as well as from other rice growing regions bordering high mountains and steep watersheds in both temperate and tropical regions.

Future problems

The effect of Shasta Dam upon the temperature of surface water being used for irrigation in California will not be unique. More dams are being built as the State develops its outlined water plan. A growing proportion of our surface irrigation water will be drawn from cold water impounded in reservoirs not far from the high watersheds.

The California Water Plan gives consideration to the multiple use of water for agricultural, domestic, and industrial purposes, hydroelectric power development, flood control, protection of the quality of fresh water, and the interests of fish, wildlife and recreation. Its completion involves the construction of some 200 new reservoirs throughout the State, with a total storage capacity of about 51 million acre-feet in addition to the 20 million acre-feet of storage capacity in existing reservoirs.

The largest unit of the California Water Plan to be built by the State is the Feather River Project. The key to the project is a dam costing about $390 million to be constructed on the Feather River five miles above the city of Oroville. The reservoir will store 3.5 million acre-feet of water from the 3,610-square-mile watershed. It is expected to smooth out the Oroville hydrograph of the Feather River which has ranged uncontrolled from an annual maximum runoff of 9,750,000 acre-feet (1906–1907) to a minimum of 1,200,000 acre-feet (1925-1926).

Oroville reservoir

The Oroville reservoir will have a maximum area of 15,500 acres and a shoreline of 167 miles. Preliminary designs of the dam called for a maximum surface elevation of 900 feet and a minimum of 550 with the tailwater outfall at 204 feet. The power head used to develop the projected 2 million kilowatt hours of energy would vary from 696 feet to 246 feet. Therefore, the water intakes would always be at least 300 feet from the reservoir surface and would draw from cold bottom water. Under these conditions the estimated tailwater temperature at the dam would be nearly constant at 42°F—several degrees colder than that pouring from the Shasta penstocks into the Sacramento River. Outlet temperatures for the planned afterbay of 23,000 acres with a depth maximum of 30 feet are estimated to be 3°F warmer (45°) in April and 8°F (50°) in August. At present the water temperature of the Feather River increases gradually during the growing season from 48° in April to 78° in August and drops back to 60°F in October.

The distance from the dam to the mouth of the river is about 70 miles, and from the damsite to the major irrigation water intakes is less than 25 miles. Experience on the Sacramento River below the Shasta Dam shows that water does not warm up much more than one degree for each 25 miles in the bed of a controlled river, nor more than one degree per ten miles in major canals. This means the temperature of water in the Feather River would not exceed 55° during the growing season after the dam was completed.

Nearly 229,000 acres (54%) of the Feather River service area were irrigated in 1958. Almost none of the grain-producing area was irrigated. One-quarter each of the vegetable crops (2,200 acres), field crops (6,700 acres), and mixed crops (6,800 acres) was irrigated from the Feather River source. About half of the rice (48,000 acres), pasture (16,200 acres), and nearly all of the deciduous fruit tree crops (48,500 acres) were irrigated with water diverted from the Feather River.

Irrigated agriculture in the Feather River service area is expected to rise from 225,600 to 368,200 acres by the year 2020. If agriculture does well in this region, it will have to become still more intensive than at present. Water temperature effects on crops may become more important, and in some cases critical, to the agriculturist. As cost-price gaps narrow still further, all factors of production will be considered carefully.

Construction of Oroville Dam on the Feather River was authorized in 1960. Water purchase contracts are to be signed by the end of 1963 and the delivery of water is projected to begin in 1968. In 1962 the State Department of Water Resources funded a program of research by the University of California at Davis for the purpose of investigating the effects which construction of Oroville Dam would have upon irrigation water temperature and crop growth.

The program consists of the following three phases:

1. Water temperature measurements on the tributaries of the Feather River above the reservoir. These data will be used as water temperature bench marks.

2. Water temperature measurements in the Feather River and distribution canals of the service area before, during, and after construction of the dam. Measurements of the gradient of water temperature from the Feather River to the irrigated fields will properly assess temperature conditions at cropside.

3. A field and controlled-soil temperature investigation relating plant behavior to low values of root temperature on "bench mark" fields selected in the irrigated area for representative conditions of soil management and crop rotation.

Irrigation trials are being made on selected crops using a number of irrigation water temperatures in order to assess the effect of various root temperatures on crop growth and yield with the weather prevailing during the cropping season.

Crops are also being grown at controlled root and irrigation water temperatures under greenhouse conditions to determine: effects upon crop plants of sudden changes in water temperature from a given mean temperature; relationships between root temperatures and developmental stages; relationship between temperature effects and plant-soil-moisture history; and effects of high transpiration rates upon plant performance under various soil temperature conditions. Cross-correlation will be made between plant responses under greenhouse and field conditions, especially with regard to stand establishment, crop growth, and yield of marketable parts.

In July, 1963, the State Department of Water Resources, after urgent discussion with Sacramento Valley rice growers and other farmers, and with irrigation scientists of the University of California, Davis, agreed to build a surface water skimming tower in the Oroville reservoir. With this single bold stroke river temperatures below the dam are forecast to be increased 15°F. The hazard of low water temperature effects in agriculture and in rice growing especially will be greatly reduced. From a study of experience with Shasta Reservoir, it is likely that the skimming tower in the Oroville Reservoir will permit the power plant at the dam to operate normally and still prevent the temperature of the Feather River at the dam discharge from falling much below 55°F. Conservative estimates of warming in the forebay and afterbay could result in water temperatures at major canal headgates of about 62° in April and 66° in August.

Despite this great possible reduction in the threat of low root temperatures to crops of the Feather River service area, investigation of crop response to irrigation water temperature as a production factor is continuing. All foregoing estimates of temperatures produced by the construction of Oroville Dam are based on the best available analogs and judgment. Measurements and experimental data relating crop performance to irrigation water temperatures will be especially important if the forecast temperature gains are too optimistic.

General knowledge of how the construction of dams lowers the temperature of river waters will be valuable in anticipating detrimental effects to agricultural crops and assist in developing measures to minimize these effects. The prospect of recurring compensation for cold water damage is certainly cheerless. If irrigation water temperatures can be held at desirable levels, a maximum crop area can be irrigated; the best plant growing conditions can be maintained; the spectrum of crops that can be grown profitably may be broadened; and the water temperature needs of fish, wildlife, and recreation may be given consideration.

Franklin Raney is Assistant Research Irrigationist, Department of Irrigation, University of California, Davis.

CONTROLLING WATER TEMPERATURES

Some of the partial solutions proposed for the problem of maintaining irrigation water temperatures for rice above critical minimum thresholds include:

1. Skimming warmer surface water from the reservoir for release into stream channels is one possible approach, although this is still not a common practice. The U. S. Bureau of Reclamation is incorporating a surface water skimming tower in the design of Whiskeytown Dam on Clear Creek near Redding in response to the needs of wildlife downstream. In building new reservoirs, Japanese engineers are considering this approach as a partial solution to low-temperature damage to rice which is so common in Japan. An intake tower is being added to Folsom Dam on the American River to permit use of warmer surface water during the spring and use of cooler bottom water during the summer in order to improve conditions for fish.

2. Providing an afterbay with sufficient area to permit the water to warm before use may be feasible in some cases. (The proposed Oroville afterbay of 23,000 acres will warm the water only 3 to 8 degrees at the required flow rates.)

3. Broad, shallow canals as a joint water conveyance and water-warming facility are being used in Japan. (Empirically designed water-warming basins are now used by rice farmers in the Glenn-Colusa Irrigation District.)

4. In certain instances other sources of energy such as electricity, waste heat from atomic fission reactors, or heat from deep-earth hydrogen fusion reactors may be available.

Both economic and engineering considerations will dictate the feasibility of each of these solutions to water warming.