TENTATIVE

ICE PROBLEMS IN WINTER OPERATION

RECOMMENDATIONS FOR RESEARCH

Engineering and Research Center
Bureau of Reclamation

APRIL 1971

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by

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PREFACE

On February 10, 1970, the Commissioner's Office requested the Chief Engineer's Office to review the major icing conditions that have occurred over the past 10 years on Reclamation projects and to furnish research recommendations related to alleviating or preventing adverse ice conditions. To achieve this goal an interdisciplinary study team was established at the Engineering and Research Center.

This report is a summary of the team's findings and recommendations. Inasmuch as the recommendations are subject to approval by the Commissioner's Office, the report, in its present form, will have limited distribution.

CONTENTS

ICE PROBLEMS IN WINTER OPERATION
RECOMMENDATIONS FOR RESEARCH

I. Purpose

Ice formation on reservoirs, rivers, canals, and associated structures hinders and, at times, prevents winter operation on a number of Reclamation projects. The resultant damage, curtailment of operations, and inconvenience led the Commissioner's Office to ask for a review of ice problems on Reclamation projects and recommendations as to further research needs related to alleviating or preventing ice problems. The Engineering and Research Center established an interdisciplinary study team to achieve this goal. This report is a summary of the team's findings and their recommendations.

II. Conclusions and Recommendations

The effects of cold weather on winter operations should be properly considered early in the planning and preliminary design stages of a project. In those areas subject to ice conditions, an assessment should be made of the existing problems and those which would occur after the project is constructed. The effects should be considered in the feasibility study and provisions for their alleviation included in the project plan. Not all problems may be readily determined in the planning phase. However, anticipated trouble spots should be properly considered in the design phase. It should be emphasized that a successful method of operation for one project may fail in another situation.

With the increasing need to effectively utilize our water resources, it is the consensus of this team that the Bureau of Reclamation needs to increase its capability to provide efficient winter operations with minimal adverse effects. To accomplish this objective we propose the following recommendations:

A. Natural Channels

1. Continue prototype - model research in the development of ice boom control structures in natural channels.

2. Investigate river channelization methods which are compatible with fish and wildlife requirements and will alleviate river ice problems upstream of reservoirs.

3. Investigate the possibility of keeping the backwater area of reservoirs free of surface ice by bubbler or pumped deep-reservoir water.

4. Reevaluate criteria for use in obtaining easements where potential ice jamming difficulties exist.

B. Water Conveyance Systems

1. Initiate prototype - model research in the development of ice control structures in water conveyance systems.

a. Ice booms for diversion of surface ice

b. Diversion of slush ice

c. Wasteway spillways for ice removal

2. Establish guidelines for design of concrete canal lining to avert rupture of lining due to frost heave.

C. Hydraulic Structures

1. Develop drain systems to collect and remove gate seal leakage prior to freezing.

2. Investigate techniques to keep trashracks in shallow forebays free of ice.

3. Investigate techniques to alleviate ice accumulation on outlet structures.

4. Develop an effective method for heating and insulating large tanks exposed to the atmosphere having capacities up to 50,000,000 gallons.

We also propose that an ice committee be established. The committee would:

1. Coordinate and direct the implementation of the aforementioned recommendations. (This would include establishment of specific objectives for each study and periodic evaluation of each study.)

2. Include personnel from Divisions of Planning Coordination, Design, General Research, and Water O&M. Contact personnel from Regions 1, 4, 6, and 7 would be assigned to relate pertinent information between the Regions and the Engineering and Research Center.

3. Be available for consultation in the review of new or existing projects where ice problems may prevail and recommend considerations pursuant to winter operation.

4. Implement a means of acquainting key Reclamation personnel with prevalent ice problems and current knowledge of alleviation techniques.

5. Establish criteria to be included in Reclamation Instructions for planning, design, and operation of Reclamation projects in cold regions.

III. Introduction

In conjunction with a report by Burgi and Johnson reviewing the literature and Reclamation experience related to ice formation, letters were sent from the Engineering and Research Center to the regional offices requesting the following information:

1. The location and extent of ice jams in natural channels upstream and downstream from reservoirs or other facilities that have been troublesome to the Bureau.

2. Extent and type of damage or inconvenience that has been caused by ice formations in canals, and at entrances to powerplants, spillways, outlet works, and other hydraulic structures.

3. Any corrective or preventive measures that have been undertaken to alleviate the problem.

The regional offices were very helpful in relating the ice formation problems confronting their winter operations. The problems ranged from extensive damages resulting from river ice jams to cumbersome problems such as clearing ice from trashracks. It is difficult to put a monetary value on the extent of damages or operational losses caused by ice formation. Much of the damage may be in the area of human relations, where it is impossible to arrive at a monetary value.

IV. Ice Problems

A. Natural Channels

Ice formation which results in the most extensive physical damage lies in the area of ice jams on rivers. The formation, growth, and decay or breakup of ice covers in many rivers may go through several stages during one winter depending on climatic conditions. Ice jams may occur in the formation, growth, or decay phase of a river ice cover but are usually more severe in the decay phase.

Ice cover in the formation phase is initiated by constrictions in the channel such as a sharp bend, debris, and bridge piers or by shallow stream depth, formation of sandbars, islands, and vegetative growth. As air temperatures dip well below freezing, the river produces ice which floats down the river. At constrictions, flat gradients in the channel, or the backwater of reservoirs, the float ice or frazil ice forms an ice cover. The cover may progress upstream while water flows underneath the cover.

However, in high velocity zones the cover thickens, some of the frazil ice goes under the cover, and an ice jam forms. In order for the riverflow to pass the obstruction, the water level upstream from the jam rises. The added pressure will either break the jam or the flow will go over and/or around the jam. If the banks are not sufficiently high to contain the rise in water level, flooding of adjacent areas will occur.

Ice jams in rivers in the decay phase of the ice cover are usually caused by an increase in discharge. The rise in stage breaks up the ice cover and large floes move down the river. Ice jams will form at constrictions in the same manner as described above.

Following are some of the rivers on Reclamation projects that experience ice jams:

*1. Gunnison River - upstream of Blue Mesa Reservoir

*2. Payette River - upstream of Black Canyon Reservoir

*3. Missouri River - upstream of Canyon Ferry Reservoir

*4. Wind River - upstream of Wind River Diversion Dam

*5. North Platte River - upstream of Glendo Reservoir

*6. James River - downstream of Jamestown Reservoir

*7. Milk River - downstream of Fresno Dam

*8. Fryingpan River - downstream of Ruedi Dam

9. Bighorn River - downstream of Boysen Dam.

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* References in Appendix.

*10. Heart River - confluence of Heart River and Missouri River

*11. Yellowstone River - several areas below the confluence with the Bighorn

*12. North Platte River - several areas between Alcova and Glendo

*13. Yakima River

B. Water Conveyance Systems

Winter operation of water conveyance systems in cold regions has been accompanied by problems of such magnitude and complexity to preclude year-round operation in some areas. Some projects, however, due to years of experience and persistent efforts of their personnel have been able to maintain winter operation. Indeed, the feasibility of some projects is contingent upon a 12-month operation period.

Some canals have experienced complete blockage of flow. This has been the result of any of several conditions:

1. A canal operating with an ice cover may become plugged as large volumes of frazil ice are taken into the canal from a river diversion (Riverton Project, A-17; Newlands Project, A-5).**

* References in Appendix.
** A- indicates Appendix.

2. A canal operating without an ice cover may become plugged as large volumes of frazil or anchor ice are produced in the canal itself (Grand Valley Project, A-9; Sierra Pacific Power Company, A-6).

3. Many canals have had similar problems when, after a winter shutdown, the canal was reopened in the spring. With an accumulation of snow and ice in the canal prism, and a demand for water as early as possible, the operator, in an attempt to flush out the canal, may produce an ice jam of major proportions (Ralston Chute, Shoshone Project, A-18).

Such plugging may result in a washout of the canal with accompanying flooding, or in the case of a power canal the shutdown of a powerplant with loss of power revenues.

Wasteways have become plugged as ground-water seepage enters the wasteway and freezes. Gate leakage has also resulted in large ice formations in wasteways (Newlands Project, A-5; Shoshone Project, A-18).

Pipe systems are somewhat free of the usual ice problems. However the need for excluding ice at the headworks may be even greater. Once ice-free water enters the pipeline, there should be no further tendency to freeze, except at locations where the pipe or appurtenant structures are exposed. Valves, blowoffs, vents, and tanks are vulnerable to freezing.

C. Hydraulic Structures

Hydraulic structures operated during periods of extended cold weather conditions are subject to operational difficulties. These difficulties affect intakes, outlets, and spillways by choking or restricting normal operation and by limiting or preventing emergency operations.

Intake trashracks may be clogged shut with collections of frazil ice on the bars or choked off with chunks of floating surface ice (Central Utah Project, A-7). In either situation delivery of water or production of power or both may be interrupted. Clearing ice from trashracks is not easy. Many man-hours and dollars may result in only minimal relief.

Ice formation on outlet works or spillways is usually a direct result of leakage or spray. It will not normally interrupt water delivery or power production. It may collect and cause damage to structures (Morrow Point Dam, Colorado River Storage, A-8; Navajo Project, A-10). Also emergency operation of outlet gates and valves may be prevented by frozen seals or ice accumulations on exposed control mechanisms (Grand Valley, A-9).

Forebay tanks, regulating tanks, and surge tanks located at intervals along aqueducts are usually exposed to the atmosphere and may require heating or insulating.

Gate seal leakage, trickle or spray, will freeze and accumulate into large blocks of ice. Such accumulations may prevent emergency usage of gates and delay or interfere with early spring water deliveries. Surface thaw conditions or spring water releases may dislodge this type of ice block and send it downstream where it may plug siphons, canals, or other structures. The large ice blocks may cause ice jams, destroy embankments, or rip out conduits (Shoshone Project, A-18).

Siphons, penstocks, and discharge lines are subject to freezing unless proper design and operational considerations are satisfied. One unique problem is the result of regelative ice formation. This occurs in the inlet sections of a pipeline, and is due to pressure changes. This formation is characterized by very rapid buildup, and blockage of flow.

Ice formation resulting from spray or leakage provides serious safety hazards to operating personnel and maintenance crews. Maintenance scheduled during winter months may be delayed or prevented (Grand Coulee Dam, Columbia Basin Project, A-2; Navajo Project, A-10; Shoshone Project, A-18).

Any combination of these problems may occur on a given hydraulic structure depending on its type, location, climatic conditions, mode of operation, and the need for winter operation.

V. Planning, Design, and Operational Considerations

Although the ice conditions previously mentioned do not have simple solutions, there are some general practices to consider in the planning, design, and operational phases of projects in cold regions to reduce ice problems.

A. Natural Channels

There are no specific solutions for ice jams in natural channels. Some general observations can be stated about natural channels which effectively carry water when ice conditions prevail.

A channel with an ice cover will pass the flow more efficiently if it has a uniform cross section. An ice cover insulates the water from subfreezing air temperatures and eliminates the formation of frazil ice. A channel having a small width-to-depth ratio will pass the flow with less resistance than one with a large width-to-depth ratio. A channel without bars, islands, debris, bridge piers, or sharp bends is less susceptible to ice jams. Ice jams in natural channels can be alleviated by:

1. Improvement of the channel by dredging, removing debris and eliminating sharp bends.
2. Constructing levees to contain the flow and/or ice.
3. Constructing ice boom control structures where feasible to retain ice above areas susceptible to damage.
4. Maintain river discharge as constant as possible to eliminate the possibility of ice cover breakup.

5. Maintain releases from reservoirs close to the native flow whenever possible during winter operation.

6. Releases from outlet works and/or powerplants are warmer than winter spillway releases and should be given consideration when releasing water from reservoirs during winter operation.

When property adjacent to the channel is involved and is subject to damage, the obtaining of flood easements is an alternative to modification of the channel. Although a flood easement may relieve the operating agency from liability, the adverse public relations resulting from damages must be given some consideration.

The modification of natural channels may affect the fish or game habitat. A smooth, uniform channel may not afford as much fish habitat as a channel with pools, riffles, and snags. However, some compromise here may provide a satisfactory solution.

In some areas the modification of a channel or construction of levees may be objectionable from the standpoint of appearance. This may be the case on natural channels adjacent to recreation areas or subdivisions. Special considerations to make the constructed features less objectionable may be required.

B. Water Conveyance Systems

Every project has problems peculiar to its own geographic situation and the configuration of its related features. The method that proves successful for one project may not be successful for another.

Some canals are operated successfully under an ice cover. This method requires that the water diverted into the canal be fairly free of ice. Some ice-covered canals have been plugged by the entrance of ice at the headworks. Care should be taken to maintain a uniform flow so that the ice cover is not broken.

Some canal operators use ice removal equipment to maintain a canal free of an ice cover. This practice is used in canals where the entrance of ice cannot be satisfactorily controlled. The ice cover is broken off as it begins to project from the canal banks. It is important to break off the shore ice before it becomes too thick (Grand Valley Project, A-9; Sierra Pacific Power, A-6).

There are several methods used to divert relatively ice-free water from a river. All of these methods require excess water which is not always available. Most schemes utilize ice-shearing booms to divert floating ice over the spillway and allow water more or less ice free to flow through the headgates (Sierra Pacific Power Company, A-6).

The same result can be accomplished without the floating ice booms by cutting a channel through the surface ice. Using outboard motors or electric motor-driven propellers increases the flow through the narrow ice channel and slush ice can be diverted into a wasteway (Riverton Project, A-17).

To minimize turbulence and therefore frazil ice production, the canal alinement and profile should be uniform. Transitions at checks, siphons, tunnels, turnouts, etc., should be streamlined. Where practicable they should be covered to eliminate the formation of anchor ice.

Canal sections should be as deep and narrow as possible, consistent with good hydraulic and structural design.

Wasteways should be provided for the purpose of ice removal. An in-line overflow section is best, where feasible, to facilitate flow of ice over the spillway without a change in direction of flow. A log boom is usually effective in channeling the flow of ice over the spillway.

Selective withdrawal from storage reservoirs should be considered for canal headworks where practicable. This will enable the operator to form an ice cover on the canal earlier by discharging cold water, or to prolong the ice-free flow as long as possible, by discharging warmer water. The winter temperature profile in a reservoir is characterized by a water temperature near 32° F at the surface, and warmer temperatures approaching 39.2° F at the bottom.

As in the open channel system, the pipe system requires special attention at the headworks to exclude ice from the pipeline. While the ice can cause problems in the open channel system, it can be intolerable to the pipe system.

Where a pipeline need not be operated during the winter, it should be drained to prevent damage from internal freezing and ice plugs the following spring. Where winter operation is required, drains should be provided for emergencies. Valves, blowoffs, and vents should be insulated where exposed to the weather. Of prime importance, the forebay, or inlet to the pipeline should utilize heated trashracks.

C. Hydraulic Structures

Air-bubbler systems have been very effective in eliminating intake structure ice problems at dams with deep reservoirs. Air injected into the reservoir below the water surface rises to the surface and creates convection currents that circulate warmer water from the lower levels of the reservoir to the surface. This eliminates ice accumulation on trashracks and inlet pipes. The bubbler system is effective only where water is available at a temperature significantly above the freezing point.

The problem of trashrack plugging can be solved in most instances by proper design. Trashracks should have good submergence when possible to prevent surface ice accumulation. If trashracks cannot be adequately submerged, a flat slope (for example 30°) of the racks will minimize jamming of ice against the racks. Racks should be heated if there is a possibility of frazil ice accumulation on the bars. The racks should be heated before ice accumulation starts.

Gate structures where winter operation is normal or where emergency operation may be required should be enclosed and provided with heat. Heat tapes should be installed in drains, in air vents, around control piping, behind wallplates and under sillplates of gates to insure emergency operation of outlets and spillways.

Powerplant and pumping plant forebays should be deep and the water should have a velocity of about 2 ft/sec or less. They may require an overflow wasteway with ice boom facilities for ice removal. The forebay design should anticipate the need for a bubbler system. Provision should be made for its future addition if adequate warm water is available and the need exists.

Enclosure of gates on diversion dams may provide adequate protection to aid winter operation (Newlands Project, A-5).

Wind spray over the top of spillway gates which results in ice accumulation can be reduced if operational considerations will permit lowering the reservoir water surface below maximum level prior to cold weather (Angostura Dam, A-14; Grand Coulee Dam, Columbia Basin Project, A-2).

Heated troughs properly oriented across outlets and spillways may be used to collect gate seal leakage, thus preventing ice accumulation. The leakage flow could be disposed of by external or internal heated drains or may be pumped back into the reservoir or forebay.

Hazardous ice accumulations that can result in potential injury to project personnel may be reduced or eliminated by proper planning or design. Heating or enclosing sidewalks and access routes will avoid injury to operating personnel. Safety during maintenance will be enhanced by providing weather doors, heat, and special equipment to overcome the effects of cold and ice (Hungry Horse Dam, A-3; Grand Coulee Dam, Columbia Basin Project, A-2; Shoshone Project, A-18).

Forebay tanks, regulating tanks, and surge tanks of the size and number being planned for the Hardin-Gillette Aqueduct (Montana and Wyoming) will require considerable study to determine the optimum balance and best methods of heating and insulating. The reconnaissance study indicated that there may be 20 or 30 such tanks ranging in diameter from 50 to 400 feet and in height to 150 feet.

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GLOSSARY

Anchor Ice - ground ice - needle ice - Ice formed below the surface of a stream or other body of water, on the streambed, or upon a submerged body or structure

Floe Ice - float ice - Ice formed on the surface of a body of water, usually of a thickness of several feet, which has been broken up into pieces and floats about in this form

Frazil Ice - Fine spirules of ice found in water too turbulent for the formation of sheet ice. Frazil ice forms in supercooled water when the air temperature is far below freezing. Frazil ice may extend to the bottom of the stream and dam its flow

Ice Gorge - ice jam - The choking of a stream channel due to piling up of ice against some obstruction forming a temporary dam

Heat of Fusion - The quantity of heat necessary to change a solid to a liquid with no temperature change (for water, 80 cal/gram, 144 Btu/pound)

Regelation - A double phenomenon consisting of, first, the melting of contiguous surfaces of ice under pressure, and second, their refreezing when the pressure is reduced. Due to the fact that substances which expand on freezing also melt when pressure is applied, ice melts under pressure and refreezes when the pressure is removed

Rime Ice - Ice crystals on solid objects, in fog with temperature below the freezing point, caused by solidification of supercooled particles on coming into contact with a solid object

Sheet Ice - Ice formed on the surface of the water in lakes, ponds, and streams where the velocity is low. It starts forming near the banks and then gradually extends toward the center

Slush Ice - Unfrozen mixture of water and ice

Supercooled Water - Water when its temperature has been reduced below the freezing point without solidification. Supercooled water can produce ice at -0.01° C

APPENDIX

A-1

Region: 1

Project: Boise

Feature: Payette River - Idaho

Pertinent Communication: Letter from Project Superintendent to Regional Director, Boise, Idaho dated May 13, 1970

Telephone conversation: Central Snake Projects Office, January 12, 1971

There is a very troublesome and reoccurring ice jam problem at Montour, Idaho, where the Payette River enters the backwaters of the Black Canyon Reservoir. Over the years silting has decreased the channel capacity at the backwaters of the reservoir. During extremely cold weather the reservoir freezes completely over and float ice coming down the river starts to pile up, forcing the river over the banks. Flooding in this area is also experienced during many spring runoffs when the inflow to Black Canyon Reservoir approaches 10,000 cfs. Methods of alleviation tried by the project include drawing the Black Canyon Reservoir down 2 to 10 feet, reducing the inflow, and fluctuation of the inflow from Cascade Dam. None of these practices has proved effective in all cases and all have an adverse effect on power production at the Black Canyon Reservoir.

The latest flooding occurred the first week of January 1971. Approximately 300 acres of land were flooded and the Union Pacific Railroad track was washed out. Flood easements cover only one-half of the flooded area.

A-1

An ice jam occurred on the north fork of the Payette River some 17 miles downstream from Cascade Dam several years ago. The release at Cascade Dam was changed from over the spillway to the high-pressure gates. Within a week's time the warmer water had cut a channel through the jam and the riverflow returned to within its channel.

Aerial view of Montour, Idaho area flooding January 10, 1971. Photo P3-162-908NA

Water flowing through washed-out railroad right-of-way behind the McConnell Ranch January 9, 1971.
Photo P3-102-903NA

Region: 1

Project: Columbia Basin

Feature: Grand Coulee Dam - Washington

Pertinent Communication: Letter from Operations Manager, Coulee Dam to Regional Director Boise, Idaho, May 21, 1970

Letter from Project Manager, Ephrata, Washington to Regional Director Boise, Idaho, November 18, 1969.

Letter from Regional Director, Boise, Idaho, to Chief Engineer dated June 10, 1970

Ice formation on the 0.8 to 1.0 downstream face of Grand Coulee Dam during the operation of discharge facilities has not caused any major problem to date but is a potential safety hazard to both men and equipment.

Sources of ice formation are:

(a) Spray over top of drum gates due to wind

(b) Spray from drum gate leakage

(c) Spray from drum gate discharge

(d) Discharge over drum gates

(e) Discharge from lower elevation outlets (1150, 1050)

(f) Snow on downstream face of dam

Areas of difficulty encountered due to ice buildup:

1. Winter removal of temporary flashboards (drum gate elevation extensions) is a hazard to equipment and personnel.

2. Hazard to personnel and equipment on main unit transformer decks.

3. Potential line or insulator damage due to ice buildup on transformers adjacent to spillway.

4. Repairs to the concrete exit troughs of the elevation 1036 and 1136 outlet tubes.

5. Spillway bucket inspection or repairs.

A deicing system (air-bubbler type) has worked very well in keeping ice from forming on the trashracks and faces of both the dam and pumping plant wing dam.

A-3

Region: 1

Project: Hungry Horse

Feature: Hungry Horse Dam - Montana

Pertinent Communication: Letter from Project Superintendent, Hungry Horse, Montana, to Regional Director, Boise, Idaho, dated April 24, 1970

Telephone conversation: Hungry Horse Dam January 19, 1971

Ice conditions occur on the outlet tube structure, the hollow jet valves, and associated piping if they are used for discharge during the winter. No major problems have developed. However, it could be of considerable inconvenience if maintenance were required during this period.

The initial design provided for deicing systems at the entrances to the outlet works, glory hole spillway, and intake structures. These deicing systems have been very effective in preventing the formation of ice sheets.

Closeup view of Hungry Horse outlet works showing ice buildup resulting from operation of the three 96-inch hollow-jet valves - No. 3 jet valve is still operating. March 23, 1965. Photo P447-105-6750NA

Region: 1

Project: Yakima

Feature: Yakima River - Washington

Pertinent Communication: Letter from Project Superintendent, Yakima, Washington, to Regional Director, Boise, Idaho, dated May 28, 1970

Telephone conversation: Yakima Project, December 29, 1970

There are two areas on the Yakima River where ice jams are a major concern:

1. Ice jams start near the Yakima Cement Products plant at Selah, causing flooding of the lowlands upstream of the jam.

2. Ice jam starts about 1 mile upstream of Roza Diversion Dam and continues for some 10-20 miles up the river. There is a problem in deciding when to open Roza Dam gates to relieve inundation upstream. This has to be at a time when power production is not necessary. There is no power generation at the Roza Plant when the gates are open.

Ice formation in the power canals has caused several outages for the Roza and Chandler generators. The project has some deicing equipment at the Roza and Chandler Powerplant forebays and at Roza Diversion Dam, but this is not adequate. The anchor ice and floating ice problems are generally severe enough that the powerplants and canals are shut down until the temperatures rise and the water temperature is above freezing.

Covering over canal headworks radial gates at Prosser Dam has reduced icing problems.

Trashracks are used with three single-phase transformers which vibrate the racks to remove anchor ice.

Roza I. D. breaking ice in Roza Canal at Mile 8, preparatory to starting Roza powerplant generator. Dragline can reach only half width of canal. January 11, 1965. Photo P33-109-6966NA

Lower end of ice jam in Roza Canal Mile 8.3, unlined to lined canal transition; flow 300 ± cfs. January 7, 1965. Photo P33-109-6960NA

Flood caused by Yakima River ice jam, about 1 mile long, below railroad bridge, East Selah area. Hammon cattle ranch at right. January 7, 1965. Photo P33-109-7618NA

Region: 2

Project: Newlands

Feature: Tahoe Dam, Truckee Canal - Nevada

Pertinent Communication: Letter from Acting Assistant Regional Director, Sacramento, California, to Chief Engineer dated June 1, 1970

Telephone conversation: Newlands Project January 26, 1971

Lake Tahoe Dam

The reservoir rarely freezes over although the winters can be quite severe. Adequate protection to aid winter operation is provided by a wooden structure over the 17 outlet gates.

Truckee Canal

The operation of Truckee Canal for transporting water the year around is changing. Before 1967, winter operation of the canal was more extensive than at present. At that time, the main problem came as a result of the slush ice diverted from the river into the canal causing ice jams at the checks. Their operational procedure consisted of keeping the canal ice covered when at all possible. The earth canal has four checks which permitted operating at the full water depth during winter operation.

The Derby and Gilpin Wasteways both have a major operational problem resulting from gate leakage and subsequent freezing downstream from the gates. Under emergency conditions it may take several hours to free the gates using propane burners to melt the ice.

Region: 2

Project: Truckee Storage - California-Nevada

Feature: Boca Dam, Sierra Pacific Power Company, Reno, Nevada

Pertinent Communication: Letter from Acting Assistant Regional Director, Sacramento, California, to Chief Engineer dated June 1, 1970

Telephone conversation: Sierra Pacific Power Company, January 27, 1971

Boca Dam

To protect service pipes and valves from freezing, a tarp cover is always placed over the valve chamber in winter. An insulated cover with burning electric lights protects the manometer gage from freezing during subzero weather.

Power Company

The power company has four hydroplants on the Truckee River west of Reno, Nevada. At each plant there is a 3- to 4-mile flume used to deliver water from the river to the plant. The flumes are operated without an ice cover. This requires four diversion dams. A shearing boom is used at each diversion dam to divert the float ice away from the flume intake. The operation of the shearing booms requires excess water. The trashracks at the powerplants are inclined 30° to the horizontal. The float ice tends to move up the racks with the help of the water current where as many as three men are required to rake the ice up and off onto a chute where it returns to the river.

The bubbler system does not perform the normal function of circulating warm water from the bottom to the surface, because the shallow depth of the forebay precludes the necessary heat reserve. However, the system does keep the water surface agitated and retards block ice formation. When the forebays of the powerplants fill with ice, a variable level intake is used to find relatively ice-free water. The intake consists of a 5- by 2-foot opening in a larger gate which can be moved up and down.

The personnel mentioned that at times the bars of the trashracks accumulate ice very rapidly. This usually occurs when the air temperatures are quite cold. The ice actually precipitates out onto the bars when the water is supercooled.

The warmer water at the bottom of Boca Reservoir is sometimes used by the power company to flush ice from their flumes.

Region: 4

Project: Central Utah

Feature: Knight Diversion Dam - Utah

Pertinent Communication: Letter from Construction Engineer, Duchesne, Utah, to Chief Engineer dated March 23, 1970

Letter from Regional Director, Salt Lake City, Utah, to Chief Engineer dated June 2, 1970

Telephone conversation: Duchesne, Utah, January 8, 1971

Letter from Construction Engineer, Duchesne, Utah, to Director of Design and Construction, E&R Center, February 12, 1971

On this new diversion dam of the Central Utah Project ice buildup resulted in major difficulty to the operation of the trashracks on the intake structure. The trashracks extend above the waterline, thus allowing subfreezing air to enter the gate chamber behind the trash-racks. This has resulted in ice formation on the gate guides above the present heating elements resulting from spray and prevents proper gate movement. The heating elements presently on the guides will have to be extended to eliminate ice formation on the guides.

The project personnel replaced a section of steel trashrack with a wooden trashrack last winter to determine if this would improve the problem of clogging trashracks with debris and ice. The wooden section had a 6-inch spacing instead of the 3-inch spacing of the steel racks. There has been an improvement in operation but project personnel feel it is more related to the large spacing than the wooden racks.

Region: 4

Project: Central Utah

Feature: Knight Diversion Dam - Utah

Pertinent Communication: Letter from Construction Engineer, Duchesne, Utah, to Chief Engineer dated March 23, 1970

Letter from Regional Director, Salt Lake City, Utah, to Chief Engineer dated June 2, 1970

Telephone conversation: Duchesne, Utah, January 8, 1971

Letter from Construction Engineer, Duchesne, Utah, to Director of Design and Construction, E&R Center, February 12, 1971

On this new diversion dam of the Central Utah Project ice buildup resulted in major difficulty to the operation of the trashracks on the intake structure. The trashracks extend above the waterline, thus allowing subfreezing air to enter the gate chamber behind the trash-racks. This has resulted in ice formation on the gate guides above the present heating elements resulting from spray and prevents proper gate movement. The heating elements presently on the guides will have to be extended to eliminate ice formation on the guides.

The project personnel replaced a section of steel trashrack with a wooden trashrack last winter to determine if this would improve the problem of clogging trashracks with debris and ice. The wooden section had a 6-inch spacing instead of the 3-inch spacing of the steel racks. There has been an improvement in operation but project personnel feel it is more related to the large spacing than the wooden racks.

They have found that by maintaining the water surface as high as possible they can develop an ice cover high enough that the effective flow area of the trashrack is much improved over that at a lower water-surface elevation.

Floating ice against the trashracks. Note how the ice slabs have turned and flattened against the rack, greatly reducing the intake cross section. February 4, 1970.
Photo CN66-436-828NA

Region: 4

Project: Colorado River Storage

Feature: Curecanti Unit - Colorado

Pertinent Communication: Letter from Regional Director, Salt Lake City, Utah, to Chief Engineer dated June 2, 1970

Letter from Project Construction Engineer, Montrose, Colorado, to Chief Engineer dated April 24, 1970

Travel Report dated February 9, 1971, from P. H. Burgi, K. J. Greene, and B. J. Peter to Acting Chief, Division of General Research, Director of Design and Construction, Chief, Division of Water O&M

Ice Jams on the Gunnison River

The major ice problem for the Curecanti Unit is at the head of Blue Mesa Reservoir. With each period of subzero temperatures floating ice has backed up against the ice cover at the head of the reservoir and has gradually built an ice cover progressing upstream. In some locations ice jams have formed and some low areas adjacent to the river have been flooded. There are reports in the Gunnison, Colorado, newspaper of ice cover and jams on the river before the construction of Blue Mesa Dam. Although major river channel work could be a solution to the problem, it may not be acceptable for environmental or aesthetic reasons.

Morrow Point Dam

There have been heavy accumulations of ice buildup on the outlet works gatehouse. The icing results from spray, and from leakage past the spillway gate seals. When the ice breaks off or melts it falls on the walkway and has damaged the handrail on the walkway. The ice formation will prevent operation of the weather doors and is a hazard to personnel.

Blue Mesa Dam

Problems were experienced during the winter of 1967-68 and, to a lesser degree, during the winters of 1968-69 and 1969-70 with operation of the intake structure deicing system (bubbler system) at Blue Mesa. Corrective and preventive measures taken include:

(a) Changing automatic control thermostat settings so that the deicing system becomes operative at a higher ambient temperature

(b) Eliminating the intentional time delay between operation of the "system on" thermostat and actual start of the deicing system compressors

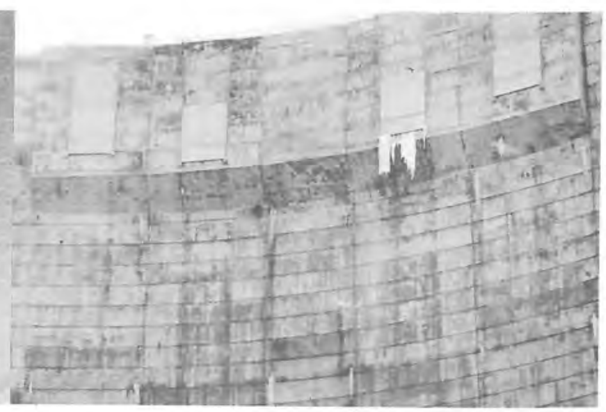
(c) Applying heat to the air compressor discharge manifold by wrapping the manifold pipe with heat tape

(d) Changing the source of compressor intake air from inside the gate structure to the outdoors

There was also a problem with ice plugging of the vent pipes for the outlet works tube. Heat cables are being installed to prevent ice accumulation in the vent pipes.

The winter of 1970-71 the bubbler systems at the intake structure and around the spillway gates functioned properly.

View looking upstream on the Gunnison River adjacent to the Dos Rios Homesites. Note the emergency dikes being placed to contain water forced out of channel by ice. January 8, 1971. Photo P622-D-68761NA



View of ice accumulation on downstream face of Morrow Point Dam due to spillway gate leakage. January 8, 1971. Photo P622-D-68763

View of ice accumulation on Morrow Point Dam outlet gate house due to spray and spillway gate leakage. January 8, 1971. Photo P622-D-68762NA

Region: 4

Project: Grand Valley

Feature: Grand Valley Diversion Dam - Colorado

Pertinent Communication: Letter from Regional Director, Salt Lake City, Utah, to Chief Engineer dated June 2, 1970

Telephone conversation: Grand Valley Project, January 13, 1971

This project operates its main canal for diversion of approximately 800 cfs to the Orchard Mesa Powerplant. In recent years the Public Service Company installed a thermal powerplant along the canal about 4 miles upstream from the Orchard Mesa Powerplant. They take water from the canal for cooling purposes and return it warmed enough to prevent the formation of ice in the canal.

During winter operation, the canal transports a mixture of slush ice and water. Before the thermal powerplant was constructed, the forebay of the Orchard Mesa Plant would sometimes fill with ice, reducing the flow. The personnel would stop operating and flood the forebay in an attempt to float the ice over the wasteway. This could take a day or two. When alternate warming and cooling trends occur in the winter, the ice condition is aggravated.

The present operating procedure is to keep the ice-laden flow free of an ice cover. A service road was constructed along the length of the canal and a truck-mounted hydraulically operated excavating machine with a wrist-action bucket is used to remove any shore ice protruding from the banks of the canal. The truck moves along the canal at a moderate speed while an operator on the truck maneuvers the buckets of the machine so as to break off any shore ice. The object is to keep the ice moving. If it stops it would soon jam the whole channel cross section. At times they use light charges of explosives (1/4 sticks) to keep ice moving.

Typical truck-mounted, hydraulically operated excavating machine. Photo P257-D-47911

A-10

Region: 4

Project: Navajo

Feature: Navajo Dam - New Mexico

Pertinent Communication: Letter from Regional Director, Salt Lake City to Chief Engineer dated June 2, 1970

Travel Report dated May 26, 1970, from D. L. King to the Chief Engineer

The No. 2 hollow jet valve when discharging during freezing temperatures causes ice to form and accumulate on the west side of the control house to such depth as to make entry extremely difficult if not hazardous. A portion of the chain link fence atop the right stilling basin was destroyed by ice.

At Buff, Utah, on the San Juan River, which is about 160 miles downstream from Navajo Dam, a severe ice jam in January 1969 caused some damage to a footbridge and endangered a few oil or gas wells by flooding some of the low-lying lands adjacent to the river channel. Adjustments of the releases at Navajo Dam, dependent on conditions, might assist in relieving the problems, if the timing was correct. The distance downstream might nullify any initially positive effect.

Region: 6

Project: Buffalo Rapids, Lower Yellowstone and Buford-Trenton

Feature: Yellowstone River - Montana

Pertinent Communication: Letter from Acting Regional Director, Billings, Montana, to Chief Engineer dated June 12, 1970

Telephone conversation: Billings, Montana February 19, 1971

Ice jams have created bank cutting and the loss of irrigable lands and laterals on the Buford-Trenton and Lower Yellowstone Projects. Almost every spring the intakes at Glendive, Fallon, Terry, and Shirley Pumping Plants are jammed with cakes of ice. At Shirley and Terry the stems to the river gates are removed, and at these two plants and also at Fallon, the intakes are sealed with stoplogs and earth at a cost of $1,000 to $2,000 annually. The Yellowstone River flows northeast to its confluence with the Missouri River. It is not uncommon for the upper reaches of the Yellowstone River to experience a warming trend before the lower reaches. If a Chinook wind sets in, it is possible to greatly increase the runoff resulting in severe ice jamming in the lower reaches of the river. In February of 1971 an ice jam occurred just downstream of the Glendive Pumping Plant; this raised the Lower Yellowstone River some 25 feet above normal flow resulting in flooding of the motors and control equipment at the pumping plant.

Yellowstone River, Montana - Aerial view looking upstream at an ice jam 8 miles west of Miles City, Montana. Note flooding on both sides of the river channel. February 16, 1971. Photo AX-600-36NA

Yellowstone River, Montana - Aerial view looking upstream at flooded farmland and buildings in the Yellowstone Valley near Hysham, Montana. Note ice jam upper right corner of photo. February 16, 1971. Photo AX-600-31NA

Aerial view looking upstream at the Glendive Pumping Plant on the Yellowstone River near Fallon, Montana. Note ice on the left riverbank and ice plug in the intake channel. Water reached elevation 2159.25 and entered pumping plant windows and door. This elevation was 4.25 feet higher than the record of 2155.0 set in February 1943. February 16, 1971. Photo A243-600-8NA

Large chunk of ice that floated into the pumping plant area during flood. Pumping plant building is at the man's right. High water elevation was approximately at the top of the man's head. March 1, 1971. Photo P243-D-68759

Floodwaters move swiftly down the Yellowstone River following release of an ice jam downstream from the Lower Yellowstone Diversion Dam. Note turbulent flow. February 16, 1971. Photo A14-600-34NA

Looking at intake side of pumping plant showing large chunks of ice that were left after flood that occurred February 15, 1971. Note trashracks. March 1, 1971. Photo P243-D-68760

A-12

Region: 6

Project: Canyon Ferry

Feature: Missouri River - Montana

Pertinent Communication: Letter from Acting Regional Director, Billings, Montana, to Chief Engineer dated June 12, 1970

Ice jams forming on the Missouri River in the Townsend area have been a serious problem for many years. This problem has allegedly resulted from the impoundment of water in Canyon Ferry Reservoir. The winter of 1959-1960 seemed to be particularly severe with ice jams and resulting flooding in November and December. In November several head of cattle were lost and flooding of property adjacent to the river resulted in bitter feelings between residents of Townsend, Montana, and the Bureau of Reclamation.

Missouri River flooding condition - Head of Canyon Ferry Reservoir near Townsend, Montana. November 18, 1959. Photo P296-600-803

A-13

Region: 6

Project: Milk River

Feature: Milk River - Montana

Pertinent Communication: Letter from Acting Regional Director, Billings, Montana, to Chief Engineer dated June 12, 1970

Ice jams forming in natural channels present a problem many years during periods of high spring flows on the Milk River below Fresno Dam. These jams have not seriously damaged Bureau on-stream facilities, but the resulting flooding of the valley area has damaged canals, laterals, farmlands, and cities.

A-14

Region: 6

Project: Pick-Sloan Missouri Basin Program, Angostura Unit

Feature: Angostura Dam - South Dakota

Pertinent Communication: Letter from Acting Regional Director, Billings, Montana, to Chief Engineer dated June 12, 1970

Spray from reservoir wave action has caused extensive ice accumulation on the underside of the gate hoists associated with the operation of the radial gates. However, the ice accumulation has not yet affected operations.

Water leakage past the rubber seals of the radial gates has caused extensive ice accumulation and has prevented normal operation of one of the gates on one occasion. Operation personnel believe there is the possibility of an ice pileup on the radial gates caused by high winds whenever the reservoir water level is near the top of the radial gates. Releases have been made to maintain a reservoir water level at approximately 1 foot below the top of the radial gates during periods of ice cover and substantial inflows to minimize possible ice damage and/or inoperative gates.

Region: 6

Project: Pick-Sloan Missouri Basin Program, Heart Butte Unit

Feature: Heart River - North Dakota

Pertinent Communication: Letter from Acting Regional Director, Billings, Montana, to Chief Engineer dated June 12, 1970

The spring thaw on the Heart River generally precedes that of the Missouri River by about 2 weeks. The floating ice from the Heart River is prevented from entering the Missouri River by the cover ice of the Missouri. This results in an ice jam on the Heart River at its confluence with the Missouri.

View looking west along old U.S. Highway No. 10 west of Mandan, North Dakota. The water had receded about 1 foot at the time photo was taken. Note the ice blocks. April 4, 1969. Photo P1112-603-76NA

Region: 6

Project: Pick-Sloan Missouri Basin Program, Jamestown Unit

Feature: James River - North Dakota

Pertinent Communication: Letter from Acting Regional Director, Billings, Montana, to Chief Engineer dated June 12, 1970

In 1969 serious flooding occurred in Jamestown, North Dakota, because of heavy runoff of Pipestem Creek, which joins the James River in Jamestown.

At one time prior to 1960 an ice cover formed on Jamestown Reservoir at an elevation close to the top trashracks at the inlet structure. One rack apparently lifted slightly with the ice, tilted, and dropped into the inlet structure.

Region: 6

Project: Riverton

Feature: Wind River - Wyoming

Pertinent Communication: Letter from Acting Regional Director, Billings, Montana, to Chief Engineer dated June 12, 1970

Telephone conversation: Riverton Project, January 14, 1971

River Ice Jam

The most serious ice jamming and flooding on the Riverton Project has occurred upstream of Wind River Diversion Dam. Approximately 1 mile upstream from the dam the river gradient is very flat resulting from sediment aggrading the channel bed.

Water Conveyance Systems

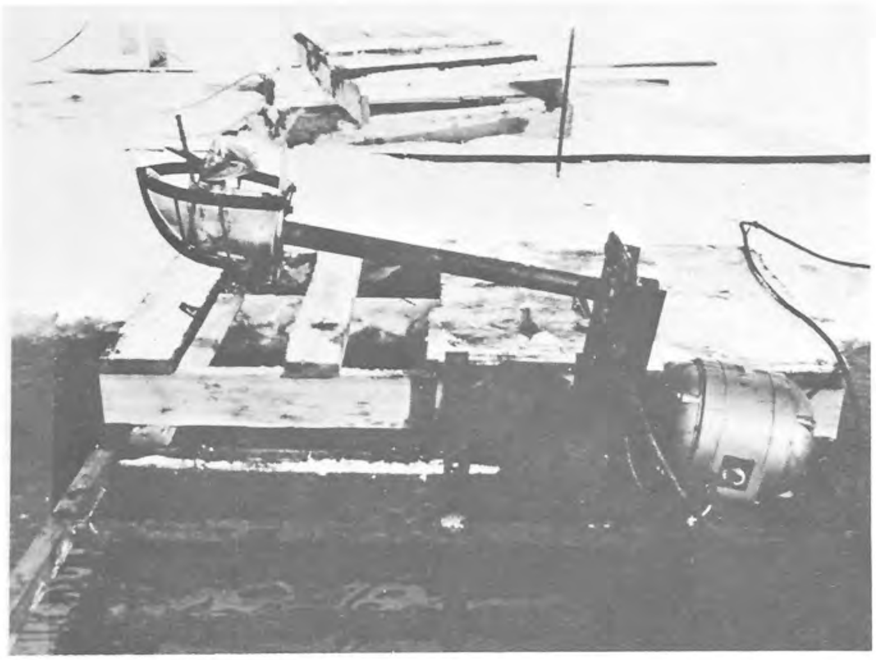
Operation of the First Division for power during the winter months has always been a problem, primarily at the diversion dam, the siphons on the Wyoming Canal, and the forebay of the Pilot Butte Powerplant.

Personnel at the Wind River Diversion Dam have developed a unique procedure for diverting slush ice from the canal headworks. A channel 3 to 4 feet wide is cut in the ice cover on the Wind River just upstream of the dam, and outboard motors and propellers are placed in the channel to divert slush ice over the diversion dam, thus preventing entry of the ice into the Wyoming Canal which feeds Pilot Butte Powerplant.

Approximately 300 cfs is diverted into the canal and another 50-60 cfs is used to divert the slush ice over the dam into the river.

The Wyoming Canal is kept checked-up to form an ice cover. The problems arise when a Chinook wind warms the air temperature, thus breaking up the ice cover. When this occurs, the canal siphons can become ice choked.

View looking upstream at channel cut in ice at the Wind River Diversion Dam. Four outboard motors and propellers have been placed in the channel to divert slush ice over the dam, thus preventing entry of ice into power canal. December 14, 1967.
Photo P36-703-23NA



View showing one of the electric ice machines over the slush ice channel above diversion dam with the propeller out of the water. January 14, 1950. Photo A-580

Ice condition, intake Midwest Siphon. December 27, 1948. Photo A-232

Ice in Pilot Butte Wasteway. January 26, 1949.
Photo A-191

Region: 6

Project: Shoshone

Feature: Shoshone-Heart Mountain Irrigation District, Buffalo Bill Dam, Montana

Pertinent Communication: Letter from Acting Regional Director, Billings, Montana, to Chief Engineer dated June 12, 1970

Telephone conversation: Shoshone-Heart Mountain Irrigation District, January 29, 1971

Ralston Chute

The Ralston Chute, an open rectangular concrete structure that runs due east from Heart Mountain main canal, is a very effective trap for snow and ice produced by the late April or early May blizzards. When the chute plugs with snow and ice, the delivery of irrigation water to the thousands of acres beyond it comes to a halt. Dipping the mixture of snow and ice out of the chute with a dragline bucket is expensive and damages the lining. The district has decided to cover approximately 3 miles of the chute at a cost of $50,000 over a 3-year period.

Headgate to Siphon

At the headgate to the siphon used to cross the Shoshone River the radial gate seal leaks. The leakage results in ice accumulation at the entrance to the siphon. In the spring of 1950, a 50-ton piece of ice broke loose and tore out part of the metal siphon.

To solve the leakage problem a clay seal is formed between the gate and stoplogs. This is an expensive and cumbersome operation ($1,000/year). The clay also causes difficulties when some of it gets into the powerplant.

Seepage Problems

The project personnel also mentioned a safety problem as a result of ice accumulations on the Buffalo Bill Dam abutments resulting from seepage through the abutments.

Ralston Chute plugged with snow and ice. Photo SP394

Ralston Chute plugged with snow and ice.
Photo PX-D-68694

Region: 7

Project: Fryingpan-Arkansas

Feature: Fryingpan River - Colorado

Pertinent Communication: Letter from Acting Project Manager, Pueblo, Colorado, to Regional Director dated May 25, 1970

Letter from Regional Director, Denver, Colorado, to Chief Engineer dated June 2, 1970

In January of 1970 ice jamming developed along the Fryingpan River from Ruedi Dam to its confluence with the Roaring Fork River at Basalt, Colorado. When the ice jams developed, causing the backwaters to build up, the releases from Ruedi Dam were reduced from 95 cfs to a native flow of about 45 cfs. Although there was no physical damage from the ice jams and resulting backwaters, it is worth noting that flows larger than the native flows of rivers can result in an ice-jamming situation more severe than normally experienced.

Ice buildup on Fryingpan River in Basalt, Colorado.
January 13, 1970. Photo C382-706-401NA

Region: 7

Project: North Platte

Feature: North Platte River - Wyoming

Pertinent Communication: Letter from Project Manager to Regional Director dated May 18, 1970

Letter from Regional Director, Denver, Colorado, to Chief Engineer dated June 2, 1970

Travel Report dated January 6, 1971, from P. H. Burgi to Acting Chief, Division of General Research

There are several areas along the North Platte River from Alcova Dam to the state line where ice jams occur every winter season. In the North Platte River downstream from Glendo Dam, three reaches of riverbank were riprapped and an irrigation pump lowered, because of river degradation, at a cost of $70,000. Wintertime powerplant releases which break up existing river ice cover and/or cause ice jams downstream from Glendo Dam have been discontinued. Controlled uniform flows of reduced quantity are released from Gray Reef Dam downstream to Glendo Reservoir during the winter icing season. An experimental log boom to trap slush ice and trigger a stable ice cover at an earlier date has been constructed about 10 miles above Casper, Wyoming, to reduce the volume of slush and solid ice in the improved areas above and at Casper.

Log boom - North Platte River - North Platte Project - Wyoming. Panoramic view of log boom. January 4, 1971. Photo C20-703-1207

View showing stringers of Ervine Bridge on North Platte River, some broken by the ice. Upstream side of bridge. January 4, 1967. Photo P20-703-5715NA

GPO 835-095