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REPAIR, EVALUATION, MAINTENANCE, AND REHABILITATION RESEARCH PROGRAM

TECHNICAL REPORT REMR-HY-3

ELEMENTS OF FLOATING-DEBRIS CONTROL SYSTEMS

by

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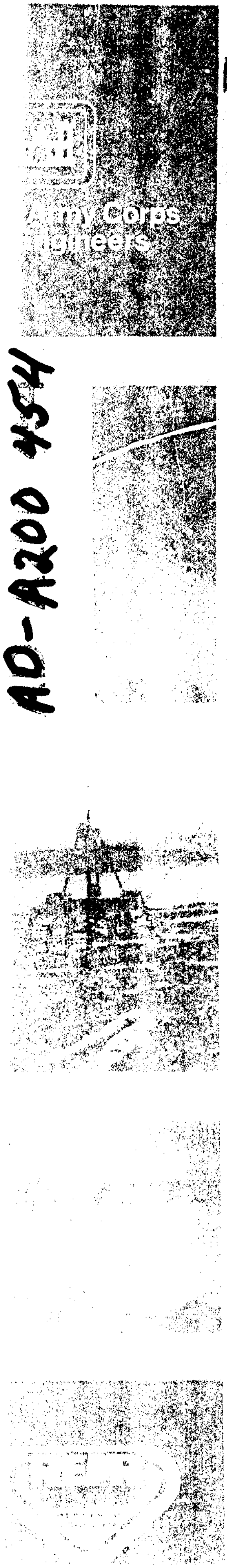

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Floating debris is a continual problem for all users of water bodies. It is destructive to locks, dams, bridges, electric plants, municipal water systems, and even recreational boaters. Wetlands, fish-spawning grounds, and streambanks can be disturbed by debris. This report contains a summary of the various methods for collecting, controlling, removing, and disposing of floating debris.

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PREFACE

This investigation was performed by the US Army Cold Regions Research and Engineering Laboratory (CRREL) for Headquarters, US Army Corps of Engineers (HQUSACE). The investigation was conducted under the Hydraulics problem area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program as part of Work Unit 32320, "Floating-Debris Control Systems."

The REMR Overview Committee of HQUSACE consists of Mr. James E. Crews and Dr. Tony C. Liu. REMR Coordinator for the Directorate of Research and Development, HQUSACE, is Mr. Jesse A. Pfeiffer, Jr., and the REMR Program Manager is Mr. William F. McCleese, Concrete Technology Division, Structures Laboratory, US Army Engineer Waterways Experiment Station (WES). Mr. Glenn Pickering, Hydraulic Structures Division, Hydraulics Laboratory, WES, is Problem Area Leader for the Hydraulics problem area, and Mr. Glenn Drummond is the Technical Monitor.

This report was prepared by Mr. Roscoe E. Perham, under the supervision of Mr. Guenther Frankenstein, Chief, Ice Engineering Research Branch, CRREL.

Commander and Director of CRREL during publication of this report was COL Morton F. Roth, CE. Technical Director was Dr. Lewis E. Link, Jr.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
acre feet	1,233.489	cubic metres
cubic feet	0.02831685	cubic metres
cubic yards	0.7645549	cubic metres
degrees (angles)	0.01745329	radians
Fahrenheit degrees	5/9	Celsius degrees or kelvins*
feet	0.3048	metres
horsepower (550 foot-pounds (force) per second)	745.6999	watts
inches	25.4	millimetres
miles (US statute)	1.609347	kilometres
pounds (mass)	0.4535924	kilograms
tons (2,000 pounds, mass)	907.1847	kilograms

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F-32)$. To obtain kelvin (K) readings, use: $K = (5/9)(F-32) + 273.15$.

ELEMENTS OF FLOATING-DEBRIS CONTROL SYSTEMS

PART I: INTRODUCTION

Background

1. Floating debris is found almost everywhere in the world in streams, rivers, lakes, and oceans. Floating debris can be composed of a variety of materials from plastic bottles to sage brush, but it is usually wood in some shape or form--from whole trees to lawn furniture. The material may be floating on the surface, or it may be a water-soaked length of hardwood suspended at some depth beneath the surface.

2. Floating debris affects recreational boaters by destroying propellers or making holes in boats. The propellers of commercial towboats can also be damaged by this debris. Floating debris can even cause difficulties for the average fisherman (Figure 1). Navigation lock operation is slowed by debris such as a stump caught on a gate sill. Bridges have been severely damaged and even destroyed by debris snagged on piers, and removing it from lock gates can be dangerous (The Waterways Journal 1986). Floating debris can have its greatest economic effect on users of large quantities of water such as hydroelectric and thermal-electric generating plants and municipal water systems. The users must provide equipment and methods (to be described later) to prevent floating debris from entering and damaging their turbines, valves, gates, and pumps. Debris protection devices generally cause a slight reduction in intake capacity and are also susceptible to impact damage from large debris. In the natural environment, wetlands, fish-spawning grounds, and streambanks can also be disturbed by debris, but the effects are usually not serious or long lasting (Harmon et al. 1986).

Objective

3. The objective of this report is to summarize and briefly describe the various elements found in floating-debris control systems. Functionally, the complete system collects and disposes of floating debris so that it ceases to be a detriment. Some debris, such as guard posts and soil stabilization

Figure 1. Fishermen and floating debris at a multipurpose, flood-control project on the Gyandotte River, Justice, WV (photo courtesy of US Army Engineer District (USAED), Huntington)

devices, is even put to good use. Not all installations have complete systems; e.g., a facility might collect floating debris, remove it from the river upstream of its dam intakes, and then dump it back into the river below the dam. At some dams, debris is merely passed through the control gates and sent downstream, although this practice can cause damage to the gates and gate seals, (USAED, Portland 1976). For shallow-draft waterways, consideration is given to the use of lock emergency gates for passing ice and debris (Headquarters, US Army Corps of Engineers (HQUSACE) 1980; Perham 1987).

Scope

4. The elements of floating-debris control in this report are described under the general headings: origins of floating debris, collecting floating debris, removing floating debris, and disposing of debris. Each group contains several elements, and the merits of having certain elements in one particular category rather than another are probably debatable. No hard and fast rules were applied except that all of the important factors of floating-debris control were to be included.

PART II: ORIGINS OF FLOATING DEBRIS

5. Living things need a certain amount of water in order to survive. In the presence of an abundant supply of water and a not-too-hostile climate, one can usually find a similarly abundant supply of plant and animal life, especially near bodies of water such as lakes, rivers, and streams. Trees and plants do not draw water directly from these water bodies but instead derive their moisture from the soil. The soil can absorb only a certain amount of rainfall during a particular period of time, and amounts in excess of this quantity become surface runoff. Also, if the soil is frozen when a rainfall occurs, very little absorption takes place.

Debris Transport

6. Surface water runoff is an important mechanism for bringing debris into the water bodies. Runoff can move some debris directly, but primarily it increases the stream velocities and water levels so that debris along the banks is swept into the stream. As water levels increase, the width of the affected land increases, and more debris can be carried. The intensity of water flow under some flood conditions is such that the direction and width of streams (rivers) are changed, and logs and stumps buried in sandbars can be washed loose (Cummins et al. 1983). Streambank erosion is the primary cause of whole trees' entering the watercourse (McFadden and Stallion 1976). The rapidly moving material is also a danger to many man-made structures such as harbor piers and bridge piers (Klingman 1973, Rowe 1974). High flows will also remove structures that are normally on land, as well as the loose debris that people dispose of in the watercourse.

7. A study of streambank erosion along 141 miles* of the Connecticut River that contained four hydroelectric dams was made by Simons et al. (1979), and the important variables which caused bank erosion there were identified. An analysis of the causes of bank erosion showed that these causes can be subdivided into those that cause general bank erosion and those that cause upper bank erosion, i.e. near the normal water elevation. The most important are

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

the tractive (shear) forces exerted by flowing water, which cause general bank erosion, with their maximum effect occurring approximately two-thirds of the depth below the water surface. Other forces such as pool fluctuations of various types, seepage, waves from boats and wind, gravitational forces, and ice are the most common causes of upper bank erosion. But, even if the upper bank is stable, water flow can erode the lower bank and thereby cause failure of the upper bank as well. Sometimes the weight of the trees on the bank can contribute to failures, but vegetation almost always provides protection to the streambanks.

Erosion

Wind and wave action

8. On lakes and large rivers, wind causes wave action which damages shorelines and causes some natural materials to fall or slide into the water. Of primary concern is the effect of wave action on man-made structures. Boat docks, boats, and small buildings can be smashed by waves, and much of the flotsam can remain in the water. A severe occurrence is the destruction of a log-storage boom. Logs under wave action can displace hand-placed riprap from reservoir boundaries (Sherard et al. 1963). Wind and wave action can also damage the natural locations of debris storage such as coves and peninsulas. In forest areas, wind damage is a major source of debris input to streams (Harmon et al. 1986). Wind has been known to carry appreciable quantities of sagebrush and tumbleweed into western rivers. In some areas construction and agricultural materials are blown into the water; the most troublesome of these perhaps is the plastic film or sheets that eventually become draped over trash racks and screens.

Ice breakup

9. The power of moving ice during spring ice breakup is very great. If it were not for the layer of border ice that usually protects the riverbanks, more damage would occur. Ice can increase the undercutting of streambanks, and ice jams may result in large quantities of water and debris-entrained ice flowing into fields and woods where debris has accumulated. Some trees are also damaged and broken by the force of the moving ice. Large rivers such as the Liard and MacKenzie in Canada have very powerful ice runs in the spring,

and the broken ice is sprinkled at times with what appears to be the remains of small forests (Figure 2).

Figure 2. Large numbers of trees entrained in broken ice during spring on the Liard River in western Canada. Photo courtesy of T. Prowse, Environment Canada

10. In many shallow riverine areas, substantial amounts of grass and weeds are frozen into the ice cover in winter. In spring, the ice cover is lifted by rising water levels, and the plants are uprooted. The ice melts on the way downstream or while stopped in front of an intake. The released grass can deposit on the intake in sufficient quantities to cause severe blockage.* Some material will pass through the openings, but much of it will remain draped over the intake grating.

Forests

Forest litter

11. In forests, trees sprout from seeds or from roots of other trees and grow as their life cycle dictates. Deciduous trees and some conifers lose all their leaves every year, but most conifers lose only a portion of the

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* Personal Communication, 1977, T. K. Coffman, Project Manager, Albeni Falls Project, Newport, WA, USAED, Seattle, Seattle, WA.

older ones annually. Some tree branches die long before the main tree trunk and, in time, fall to the forest floor. The forest litter is usually protected by the tree canopy during the summer and by a snow layer in the winter. In early spring the deciduous trees are without leaves, and as heavy rains descend, much of the litter is washed away.

12. In mountainous regions the streams are narrow, and the adjacent banks and flood lands are steeply inclined. Fallen trees can bridge the stream and remain in place for long periods of time. These trees can arrest the downstream movement of bushes, branches, small trees, and leaves and hold much of this material in place. The retained material will decompose in these storage sites, which also act to reduce the speed and erosion potential of the streamflow (Cummins et al. 1983). Subsequent flood flows from heavy rains and snow-melted water will try to dislodge these large trees. Eventually a flow large enough to carry almost any debris jam along will develop.

13. As an example, the debris-control facility on the Clark Fork River in Idaho usually receives fewer than 4 acres of debris per year, although in years past the quantities were greater. A flash flood on one of its tributaries, Lightning Creek, brought down approximately 15 acres of debris (Coyle 1982). Undoubtedly much of this debris had been stored in and along the creek bed for some time. Figure 3 shows the Clark Fork Drift Yard.

14. US Forest Service researchers have selected several stream sites in the Northwest and are studying the mass balance of the woody debris along, and in, the streams (Lienkemper and Swanson 1985). Many major factors contribute to this mass balance, such as tree population, wind effects, flood stages, and decomposition; these factors vary widely in values. Also, it generally takes a long time for natural processes to dispose of a dead tree in the forest. The periods of study have continued for only 7 to 9 years, and, therefore, researchers are hesitant to make any estimates based upon it. However, it would be helpful to know how much debris to expect from one tributary or another.

Forestry practices

15. Forestry is the scientific management of forests for the continuous production of goods and services (Sisam 1956). There are some aspects of the subject which should be pointed out as important in minimizing the production of floating debris. The most important function of the forests is protection of the water sheds. Forest lands soak up great quantities of water and reduce

Figure 3. Clark Fork Drift Yard, ID, a floating-debris storage-removal area on the edge of the Pend Oreille Lake

the floods and erosion that bring floating debris to the streams and rivers. If a generous ground cover is maintained during tree harvesting and roads are made erosion resistant, the forest land can still protect the watershed. The forest must be protected against fires, also, because a severe fire will consume layers of litter and humus on the forest floor, exposing the soil beneath and leaving it susceptible to erosion. The harvesting of trees on a reasonable schedule will reduce the number of dead trees that may fall into the streams and rivers. The decomposition of dead trees and their products--leaves, branches, and twigs--is valuable, however, because it provides nutrition for the soil.

16. In the early days of logging, but after the most easily harvested timber stands near large rivers were gone, smaller rivers and streams were used for the water transport of logs. Often these streams were substantially modified by such practices as removing fallen trees and riverbank growth, blasting large boulders and pool sills, and blocking off sloughs and side channels. These measures were taken to avoid log jams when the logs were sent downstream during the spring runoff of rain and snow melt. Also used were many streams that were literally too small and had insufficient water flow to carry logs. Splash dams were built to make these streams useful. These

structures stored water in an upstream pool that also held the logs. The water, which was periodically dumped, carried the logs downstream. The rush of water could also pick up and carry timber that had been dumped earlier at other points in the streambed (Sedell and Duval 1985). The significance of these logging techniques is that the hydraulic capacity of nearly every stream in forest lands from coast to coast was substantially increased over that which existed during its primeval state. It is partly for this reason that it is difficult for water and debris to remain in the forest lands.

17. The loss of logs from storage and handling areas can be reduced by certain changes in methods. For instance, the loss of logs from sinkage will not generally occur during storage if bundles are used (Pease 1974). Bundles are logs held together loosely with wire or metal bands. This approach is somewhat different from the older, flat-raft method, which is still in common use and consists of loose logs stored and towed inside a series of boomsticks. A log in a flat raft that becomes waterlogged will sink and move with the water currents away from the raft.

18. The construction of man-made dams is followed by raising a pool behind the dam and inundating land up to the level of the pool. This flooding kills trees and most other vegetation below the pool level, which then becomes floating debris. Also, wooden structures, fence posts, and similar material can become debris. To avoid the problems that may arise because of the presence of these materials, the land is cleared below a specified elevation (US Bureau of Reclamation 1977).

Debris jams

19. Debris jams are composed of whole and partial trees, stumps, branches, and brush. They are an entangled mass that was moving with the currents and became grounded on a sandbar or a bend in a river or formed a dam across a tributary. A larger flood flow may remove the debris jam, or it may be broken down over a long period of time by natural effects such as decomposition (Cummins et al. 1983) or a series of partial removals by flood-propelled ice floes and logs.

Beaver dams

20. The quantity of debris brought into streams by beavers is unknown, but beavers are well known for their industriousness in building dams and their moundlike houses. After selecting a site for a dam on a small river or brook, beavers cut down saplings and small trees which they embed in the

stream bottom along with stones to make the dam base. Additional sticks, twigs, grass, leaves, and sod form the bulk of the dam.

21. In addition to the trees cut down by beavers, the trees flooded by the pool will die. Flood conditions, especially those coupled with ice action, can wipe out a beaver dam and bring this mass of wood downstream. A large beaver dam in Wyoming was 1,046 ft long and contained about 1/4 acre-ft of potential debris (Bartlett and Bartlett 1974). One near Berlin, NH, was 4,000 ft long and contained no fewer than 40 beaver lodges, but these sizes are exceptions (Tanner 1977). Careful research indicates, however, that the work of the beaver is by far a net benefit to the ecosystem through increased retention of sediments and organic matter and other important habitat modifications (Naiman, Meliello, and Hobbie 1986).

Man-Made Materials

Shore structures

22. Structures built along the banks of rivers and streams are often subject to flooding. A particular example is the band concert stand on the Youghiogheny River in McKeesport, PA. The platform is part of a public park built under an urban renewal program. As seen in Figure 4, the platform has the river as a backdrop. At the upstream edge of the structure are several two-pile dolphins which protect it from damage and possibly destruction by floodwaters and waterborne debris.

23. Another protective structure on the Ohio River at Huntington, WV, is shown in Figure 5; trees are growing on it. It is a debris and ice deflector made from steel barges loaded with stone and sunk upstream on the loading dock and cell which it protects. The long axis of the deflector is inclined to the river flow; its top is 10 to 12 ft above pool stage. A line of steel pilings helps keep it in position.* Harbor piers and wharves can be damaged by debris that gets between pilings and interconnecting framework, especially the walers, i.e. horizontal members. The debris, which may be a log, timber, or derelict "camel" (a floating fender), moves up and down with wave and tidal action, abrading the structure. Sometimes service pipes and conduits are

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* Personal Communication, 1984, R. M. Templeton, Manager, Huntington Terminal, The Ohio River Company, Huntington, WV.

Figure 4. Pile clusters protecting a band stand on the bank of the Youghiogheny River at McKeesport, PA, against possible damage by moving ice and floating debris

Figure 5. Debris deflector (structure to the right of the cell) on the Ohio River above Huntington, WV, deflects floating debris and ice around this fleeting area. (Water flow is right to the left)

damaged instead of the structure. The source of much of this debris in a large bay is often another old wharf or pier in need of repair. Examples of these are prevalent along the coast; the deck is usually gone but the old pilings and dolphins remain, as shown in Figure 6, rotting and under constant action by wind and wave and marine borers. Over time, pilings will break loose and become a hazard.

Figure 6. Old pilings of an abandoned pier, potential floating debris, Oakland, CA, 1986

Dumps

24. Dumps improperly located along water bodies can become sources of floating debris. During flooding, trash is washed from these areas that are normally dry into streams and rivers.

PART III: COLLECTING FLOATING DEBRIS

Permanent Structures

Natural features

25. There are many natural features that collect debris, and some of them may be convenient points for the removal of this material. A large tree that falls across a stream or small river can serve as a collection point for quantities of debris. Also, large rocks, sandbars, and shallow sloping beaches collect debris. It also accumulates in small bays and sloughs when the water currents and winds are directed favorably. These features or other natural effects such as water currents may be incorporated in several ways into debris-collection systems. Natural flow conditions can be used to collect a certain amount of debris behind a simple streaming structure as shown in Figure 7.

Figure 7. Debris collected by a thin, floating structure anchored at one end and streaming part way out into small turbulent river

Shear wall

26. A shear wall is a flat, vertical structure usually of reinforced concrete that is aligned parallel with or at an acute angle to the direction of water flow. The structure reaches from above the water surface to some

depth below the surface; 12-ft and 17-ft depths have been used. The shear wall is pier mounted and usually supports a bridge or walkway that acts as a stiffener and increases the strength of the structure. When used in conjunction with a gate at one end, the shear wall may function as a baffle wall (see below) for flow into an intake and as a shear wall when the gate is open.

Baffle wall

27. A baffle wall, or curtain wall, (Figure 8) is a vertical wall placed in front of an intake structure to intercept floating debris and ice floes and thereby reduce impact loads and ice pressures on the intake debris rack. The wall, made of reinforced concrete, extends several feet below the water surface. Trash rack cleaning and removal is done in a space between the baffle wall and the intake structure.

Figure 8. A battle wall forming the edge of the forebay of the Vernon Hydroelectric Station, Vermont. (Behind the 8-ft-deep wall are access openings for the trash rake; the trash rack is inclined 20 deg from the vertical)

Dikes

28. A dike, a long, low embankment with sloping sides, is made of fill material, usually earth or rock. Dikes are often used as river training structures, of which there are several types: spur, longitudinal, L-head, and vane. The latter type is used to form one side of a debris-collection facility at China Bend (Figure 9) on the Columbia River 110 miles upstream of

Figure 9. Man-made dike (long strip of land in upper left) at China Bend on the Columbia River, about 30 miles from Canada, forming part of a debris-collection facility for Grand Coulee Dam (photo courtesy of the US Bureau of Reclamation)

Grand Coulee Dam. Two vane dikes are set nearly parallel with the water currents in relatively shallow water to guide debris into a holding boom at their downstream end. The debris has a natural tendency to move into the holding boom because of the river bend location, but any strays are deflected in that direction by a shear boom at the upstream end of the dikes.*

Trash struts

29. Trash struts are structural beams placed in front of an intake in an open framework so that large debris, such as whole trees, will not enter water conduits (Perham 1987). The struts are usually streamlined to reduce hydraulic drag.

Trash racks

30. Trash racks are probably the single most important debris-control device. In some countries they are called trash screens. They are designed to remove debris too large to pass through the turbines and control valves without blocking passageways or damaging the mechanism.

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* Personal Communication, 1985, R. Bute (deceased), General Engineer, Grand Coulee Project Office, US Bureau of Reclamation, Grand Coulee, WA.

31. In screening the debris, the trash racks become blocked and must be cleaned. Otherwise, the excessive pressure drop through the trash rack and diminished water flow rates cause inefficient operation of the turbine; they also affect pumps in the same manner. In many locations the normal day-to-day cleaning operations are not enough, and in time more drastic steps must be taken (Perham 1987).

32. A framework of structural beams supports the trash racks against loads from debris impacts and pressure differentials. Some but not all structures are designed to withstand the force of complete blockage. The trash rack is faced with a series of vertical, parallel bars to facilitate cleaning (Figure 10); bars with a flat, rectangular cross section are usually the most economical. The trash rack face usually has a slope to facilitate raking, although a flat, vertical face will use the least amount of material. Most trash racks are made in sections that may be removed for further cleaning and repair. Several dams, however, such as Black Eagle on the Missouri and Chatillon on the Ottawa River in Canada have permanent trash racks. Some trash racks or screens are curved outwardly around an intake (Figure 11) to reduce the water velocities through the openings.

Drift deflector

33. The drift-deflector barge on the left bank of the Ohio River at Huntington, WV, is a permanent structure, although its parts were once mobile. The structure, inclined at a 45-deg angle to shore, was made from two large steel barges filled with rock and sunk in place, one on top of the other. Its vertical, smooth steel sides do not catch or hold debris. A line of steel pilings was installed at the downstream side to keep it from moving.

Moveable Structures

Boom or log boom

34. The Technical Dictionary on Dams (International Commission on Large Dams (ICOLD) 1978) defines the boom or log boom as "a chain of logs, drums, or pontoons secured end to end and floating on a reservoir so as to divert floating debris, trash and logs." This definition, though good, is rather narrow and applies to the type of boom that is referred to in this report as a diversion or a shear boom. The function of some log booms is to collect and to

Figure 10. Trash racks at the Racine hydroelectric plant on the Ohio River extend well above the normal water levels, which it does not control because it is an adjunct to a Corps of Engineers' lock and dam

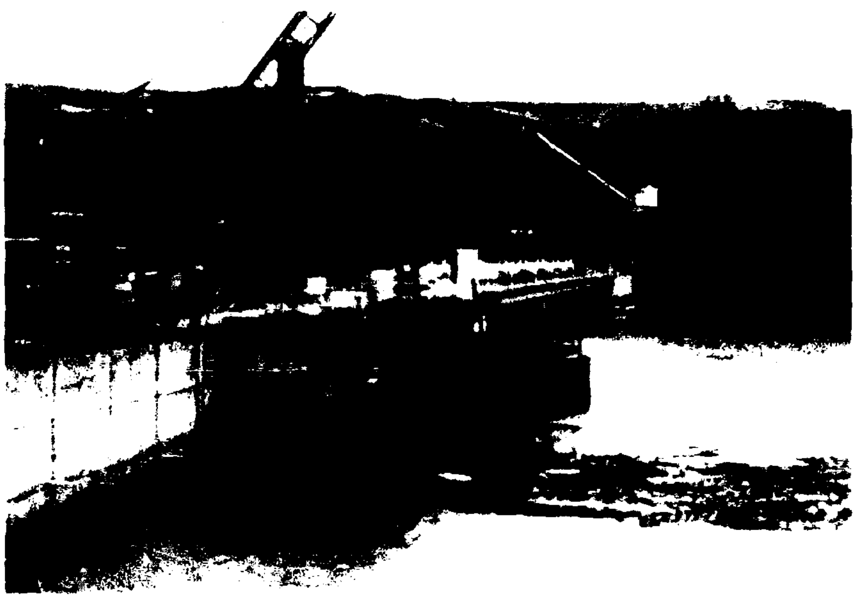

Figure 11. Trash screen built out from the dam face in a semicircle to gain rack area to maintain low velocities at at Rainbow Dam, Missouri River, Great Falls, MT (photo courtesy of Montana Power Company)

hold the floating debris, without diverting it, and these are referred to herein as retention or holding booms.

35. When the construction of booms is considered, one can find designs in which the boom units, i.e. logs, timbers, or pontoons, are connected end to end, as the above definition implies. There are other designs, however, in which the boom units are connected individually to a wire rope that provides the structural strength. A broken timber in this latter type of boom will usually have little effect on the boom, whereas in the first type of boom, the result would be a complete failure. Some booms are also held in place by pilings, dolphins, or piers. The boom units are arranged end to end, and they may have certain end connections, but their structural strength is solely a function of the holding devices. Each boom is designed to follow water level changes so that it will not be easier at any normal condition for debris to go over or under the boom.

36. Water velocity, flow direction, and water depth are very important considerations in boom design. A boom that functions as expected in one location may not work at another site if these factors are appreciably different between the two locations.

Retention boom

37. Retention booms, or holding booms, are located and sized to hold debris inside or outside of an area. The rather large boom (Figure 12) at Vernon Station on the Connecticut River keeps nearly all of the incoming debris away from its intake trash racks and fish ladder. Each 80-ft-long boom unit is built like a timber truss and extends down 4-2/3 ft below the water surface. The units are held in place by concrete piers that have standard steel rails affixed to the upstream face of the piers. Occasionally the spring ice forces will turn a boom unit over.*

38. A second type of retention boom is shown in Figure 9. It is a single line, or string, of booms used to hold debris in the holding grounds at China Bend after the debris has been deflected into the area. One version of this type is a double-string boom composed of logs chained end to end and held in place by a series of pilings. It forms the downstream edge of a

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* Personal Communication, 1985, C. Schmitt, Assistant Superintendent, Vernon Station New England Power Company, Vernon, VT.

Figure 12. Large, concrete pier restrained boom units at Vernon (VT) Station on the Connecticut River, holding most of the floating debris away from the intakes; the booms contact steel rails on the piers

debris-control system and prevents floating debris from entering a large lake that is a very popular recreation area.

39. This second type is also used as an active device called a roundup boom or a bag boom. The single string of boom sticks is drawn around a quantity of loose debris usually for the purpose of condensing it and moving it from one place to another (Figure 13). It is also used as a temporary holding boom while debris is being raked from the shoreline.*

40. A third type of boom, at Mt. Morris, NY (Figure 14), is made from sawed timbers and is used to restrain debris that collects behind a flood-control dam. Its main function is to prevent debris from going over the spillway and downstream where it might jam against bridge piers. During most of the year, the boom is draped down the reservoir banks and across the valley floor.

Deflector boom

41. The deflector, shear, or glance boom is a line of floating elements

* Personal Communication, 1985, R. Bute (deceased), Grand Coulee Project Office, US Bureau of Reclamation, Grand Coulee, WA.

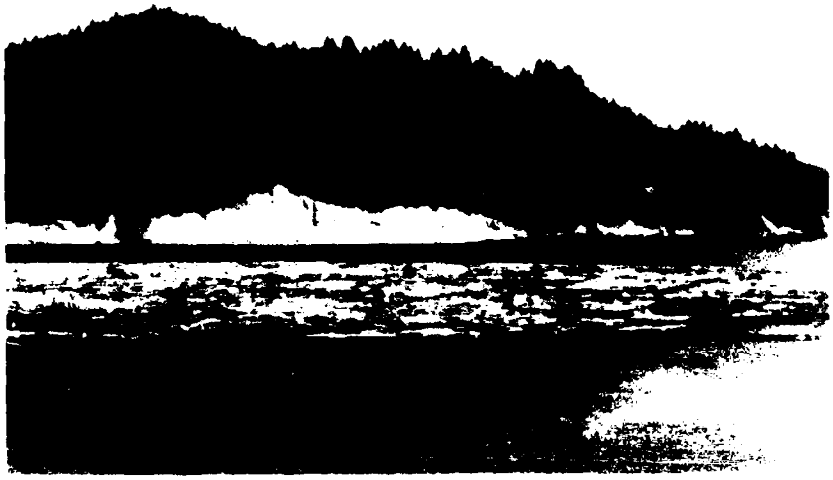

Figure 13. An accumulation of floating debris condensed and confined by a roundup boom and workboat now awaiting removal and disposal

Figure 14. Holding boom at the Mt. Morris (NY) flood-control dam on the Genesee River; each timber unit is connected individually to the boom rope and is made from two parallel timbers with a space between for stability

set at a steep angle to the river currents. The debris is moved along the smooth face of the boom by the hydraulic drag of the current. The debris is then moved laterally to a holding pond or holding boom where it is eventually removed from the water or routed downstream. The shear boom is used to route floating debris around a structure, such as a dock, and to keep it away from intakes and out of certain lakes and waterways. Several examples of shear booms are listed in Appendix A; the one at Chief Joseph Dam is shown in Figure 15. At Chief Joseph Dam the debris moves down to the left end of the boom and into a small bay where it is restrained from leaving by a holding boom.

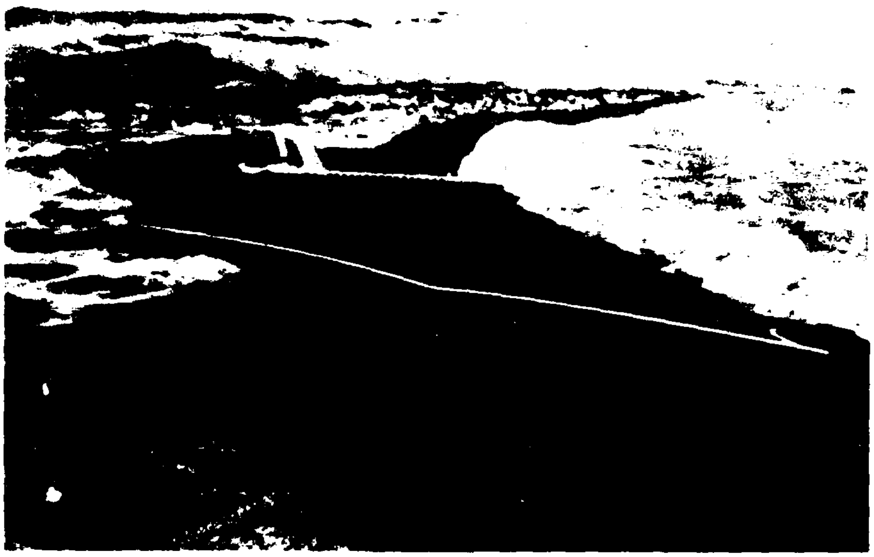

Figure 15. Aerial view, looking downstream at the 3,000-ft-long debris boom upstream of Chief Joseph Dam on the Columbia River, Washington

42. A boom on the Clark River in Idaho, shown in Figure 16, has been in operation since the mid-1950's to the best of the manager's knowledge (Coyle 1982). The 100-ft-long boom units, built from large logs and planks, are held in placed by pile dolphins. The boom has been found to work best in deflecting the incoming forest debris when the angle of inclination to streamflow is 20 deg or less (HQUSACE 1983). When the angle-to-stream flow of the boom becomes too large, the debris has to be helped along the boom face by a workboat or some other means, as seen in Figure 17.

Nets

43. Nets are used to collect and hold debris. They may be suspended

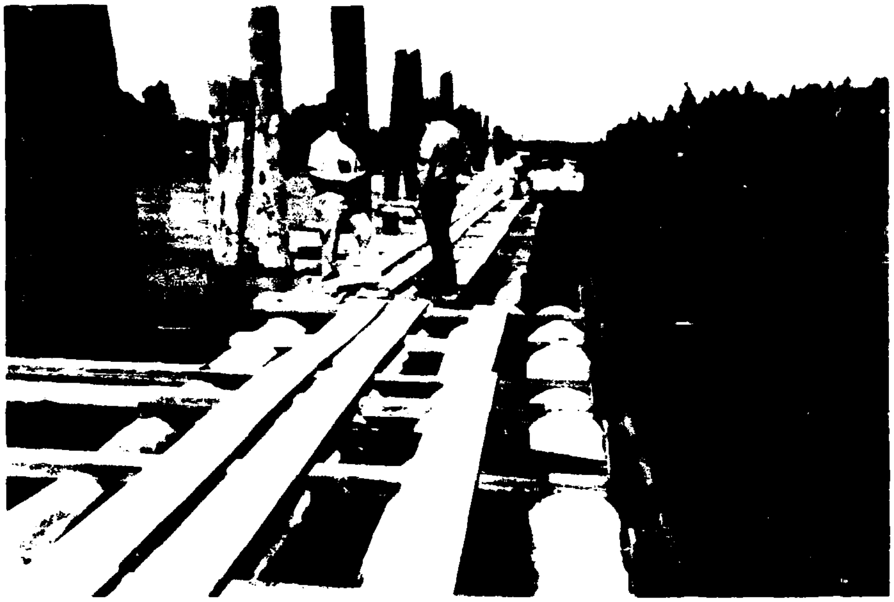

Figure 16. View looking downstream along Section A of the debris-deflector booms on Clark Fork River, Idaho, used to collect debris upstream of Pend Oreille Lake; the offset in boom alignment keeps debris from collecting in section joints

Figure 17. Workman loosening floating debris at a deflection boom on the Missouri River upstream of Black Eagle Dam, Great Falls, MT (photo courtesy of Montana Power Company)

from a log boom and actually be a structural part of the boom. Nets are also used with a crane boat to retrieve debris from harbors (Figure 18).

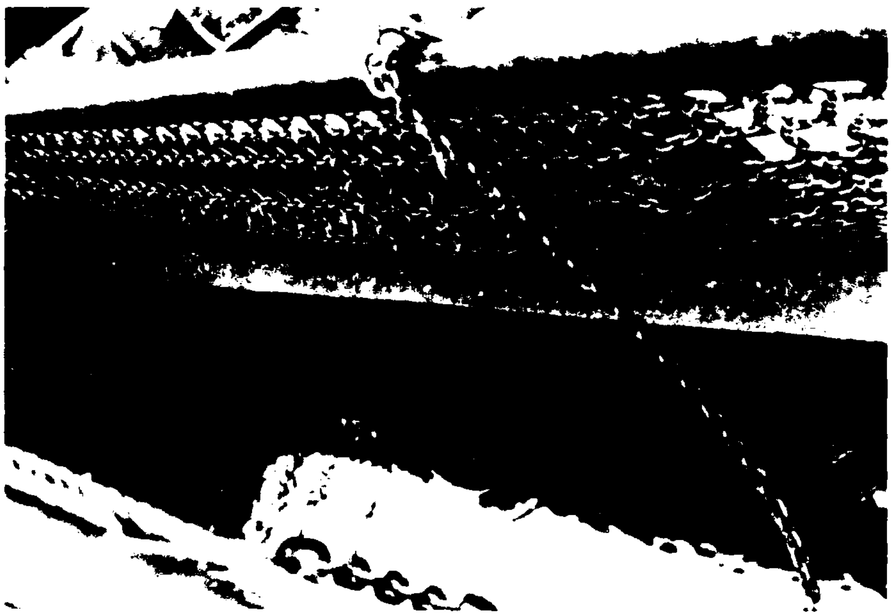

Figure 18. Part of the chain net on the Corps' debris boat Coyote used to sieve fl ating debris from San Francisco Bay

Barges

44. A barge makes a good debris deflector when set at an angle to the water current. Its vertical, smooth sides are made of steel and do not catch and hold any material.

Fences

45. Fencing may be located where runoff tends to carry material into the river. Fencing is used most frequently to protect road culverts in mountainous areas. The material can be easily removed by road crews. Often, fencing in flood-prone land beside a river will catch appreciable quantities of debris.

PART IV: REMOVING FLOATING DEBRIS

46. Floating debris is removed from water bodies by machines, equipment, and manually operated tools. The removal process in some locations uses two or more pieces of equipment and sometimes includes supplemental steps, such as having a workboat and a string boom tow collect debris to the removal point. The more important features or characteristics of equipment used to remove floating debris are given in this section. The equipment, unless it is extremely specialized, will have a general name, but often the name will refer to an existing machine that has been modified in some manner so that it can handle debris better. An example modification is the welding of teeth onto a clamshell bucket to give it a better grasp of debris.* An example of specialized equipment is a log bronco, or small workboat designed to move logs from a log holding area to a mill landing (Figure 19).

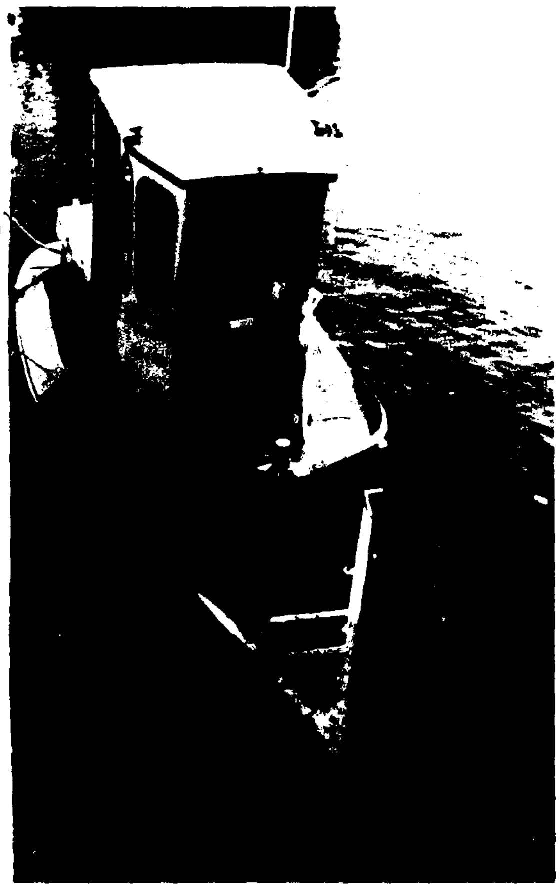

Figure 19. Small, maneuverable workboat called a log bronco used to push logs around a pool or to tow a string boom, Lower Granite Lock and Dam, Snake River, Pomeroy, WA

* Personal Communication, 1985, J. Woolford, Superintendent, Racine Hydroelectric Plant, Racine Lock and Dam, OH.

47. In addition to equipment modifications, techniques have been developed that make the removal process more efficient or less troublesome. When a trash rack is being raked, the flow through the unit that it protects is reduced and, in some installations, stopped completely. The debris is then easier to remove from the bars. Conversely, there are other places where the racks can be raked under full load, depending on the intake design, the type of debris received, and the raking system.

48. Many techniques have been developed for site-specific reasons, such as the continuous removal of debris as it is carried to the dam by the high spring flows (provided additional personnel and overtime funding are available), because when the flow slackens, the prevailing wind can blow the debris all over the pool (Blefgen 1964). In another area, Lower Granite Lock and Dam, Pomeroy, WA, the forces of the wind are combatted by a supplemental boom installed upstream of the debris accumulation. On the Columbia River there are at least two sites where debris is deflected into shallow-water areas and held until the water levels can be dropped. The debris is then handled by ground-based equipment such as bulldozers. One dam on the Connecticut River has an air bubbler system and sluiceway for frequent removal of small material such as leaves, grass, twigs, and brush. The large material is removed by a truck crane only once a year.

49. Other techniques include: monitoring head losses across each trash rack to determine the need for cleaning; sending divers down to observe the effectiveness of intake cleaning methods*; removing silt, debris, and large sinkers from in front of the trash racks; and removing floating debris from tributaries far upstream of the dam. The list of techniques is greater than that given here, but the most important technique is to take a careful look at the debris-removal equipment and methods to determine whether there are any changes in the process or perhaps the structure that would make either more efficient. At Bonneville Dam the operators found that making a gated hole to the sluiceway from the fish screen cavity immediately disposed of a difficult and expensive debris-removal procedure.**

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* Personal Communication, 1985, L. Barbeau, Chief Operator, Carillon Powerhouse, Carillon, Quebec, Canada.

** Personal Communication, 1985, Q. O'Brien, Chief of Maintenance, Corps of Engineers, Bonneville Lock and Dam, Cascade Locks, OR.

Trash Rakes

Hand rakes

50. The hand rake (Figure 20) is an implement with projecting tongs used to remove small debris from trash racks of small hydroelectric plants and other relatively small water intakes. The rake itself is a good tool, but the process is labor intensive. Trash racks must be hand raked continually when the debris is coming down with the spring floods. The cumbersome 25-lb rakes have long handles; consequently, they rotate easily, causing the worker to inadvertently rake with the back of the rake.*

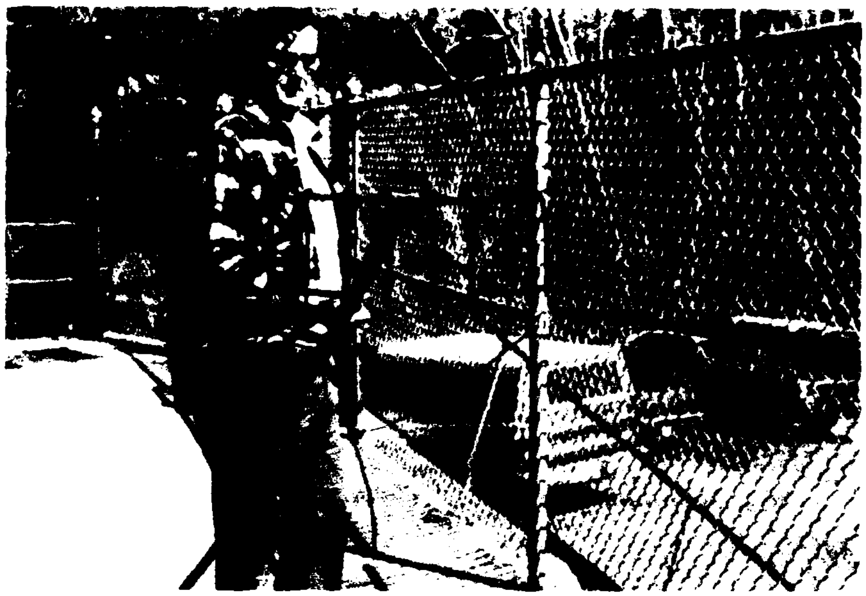

Figure 20. Hand rake for cleaning the trash racks at a small hydroelectric plant on the Deerfield River, Shelburne Falls, MA

Shoreline rakes

51. Floating debris stranded along the shoreline may be collected with some efficiency with a special rake on a crane-operated dragline (Figure 21). The rake is operated in the manner of a dragline excavator by a crane with a long boom. The rake may be cast out beyond the end of the crane boom 10 or more ft. The debris is collected from around the anchor site into one spot.

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* Personal Communication, 1985, A. Mooney, Superintendent, New England Power Company Stations, Shelburne Falls, MA.

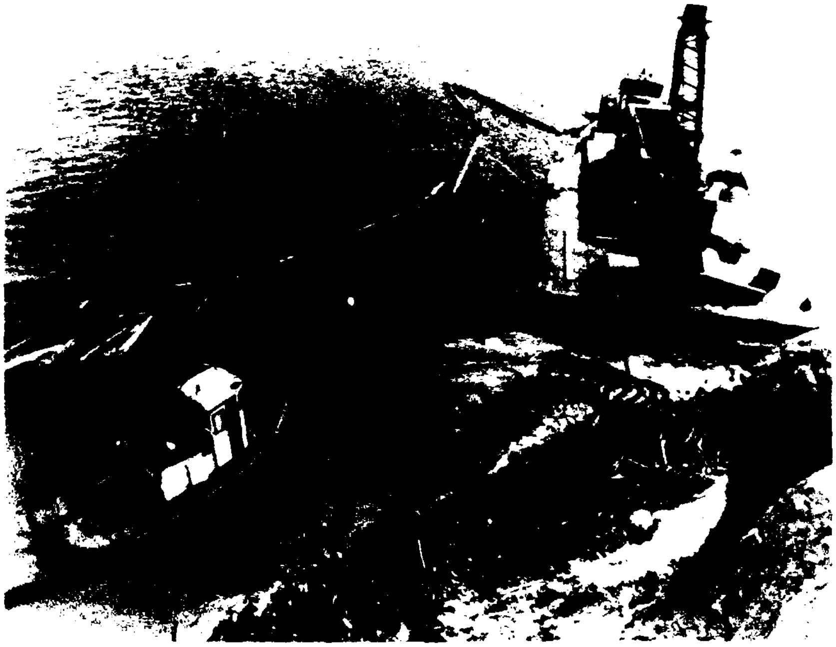


Figure 21. Barge-mounted crane, on right, using a special rake to clean debris from the shoreline upstream of Grand Coulee Dam; assistance is provided by workboats and a holding boom (photo courtesy of the US Bureau of Reclamation)

A set of log tongs or a clamshell is used to lift the debris into a container.*

Self-powered trash rake

52. A variety of self-powered trash rakes are used to clean the debris from trash racks. Two common types are the Newport News trash rake and the Leonard trash rake (Creager and Justin 1950). These systems of cables, winches, motors, controllers, and a hinged rake are mounted from a traveling gantry crane. A small version of this type of rake is shown in Figure 22. The gantry crane is driven to a specific trash rack, the rake is lowered by drum hoist down through the debris accumulation, and the raking bottom shelf of the trash rake is opened automatically. At or near the bottom of the trash rack, the raking shelf rotates back to the horizontal raking position, and its individual fingers reach between the trash rack bars. The rake, raised by cable along the face of the trash rack, scrapes off the accumulated debris which collects in the body of the rake. At the gantry the debris is dumped

* Personal Communication, 1985, R. Bute (deceased), Grand Coulee Project Office, US Bureau of Reclamation, Grand Coulee, WA.

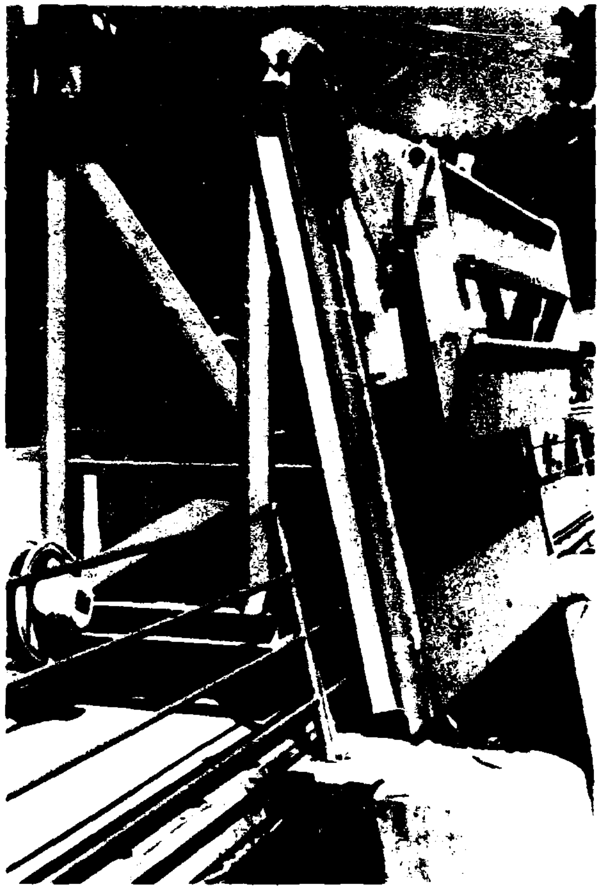


Figure 22. Trash rake at the Upriver Dam Powerhouse, Spokane River, City of Spokane, WA; the machine has two rakes and a hopper

onto the deck, into a hopper car, or into a sluiceway. Some manual labor is involved at this point.

53. A trash rake of more recent origin is the Berry Trash Rake, which has a self-powered gantry and a hydromechanical rake plus associated electric motors, pumps, and reservoirs (Berry 1984). The rake, much narrower than a trash rack, is a telescoping arm with a rake head that is a combination of scraper and bucket; the operating handles are like those of a bulldozer. The rake head moves parallel with the trash rack face and has no teeth to engage the bars. It can force its way down through the debris and some ice, if necessary. Versions of the rake use a plain deck, a dumping hopper, or a conveyor system. A model of the rake (Figure 23) in use at New England Power Company Plant No. 3 on the Deerfield River in Massachusetts shows the

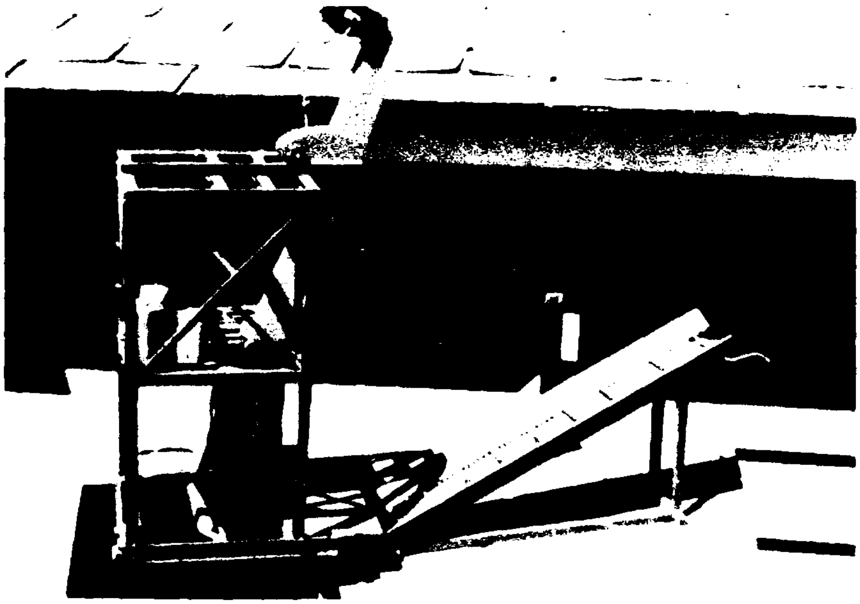


Figure 23. Model of the Berry trash rake used at NEPCO No. 3 on the Deerfield River at Shelburne Falls, MA

mechanical arrangement more clearly than do photos of the actual installation (Perham 1986).

54. Small intakes usually have small trash rakes, but unless the rakes are powered in the downward direction, it may be extremely difficult for them to penetrate the floating-debris concentration at the trash rack (Perham 1986).

Gantry crane-operated trash rakes

55. Hydroelectric plants have an intake gantry crane that moves along rails on the forebay deck from one end of the plant to the other. It supports many essential functions such as handling intake gates, bulkheads, deck gratings, trash rack sections, and sometimes trash raking. The gantry will have a cantilever crane reaching out over the trash racks for that purpose. The type of trash rake at Bonneville 2 (Figure 24) will often force trash to the bottom instead of grasping it (USAED, Portland 1983).

56. The trash rake used at Albeni Falls Dam, Pend Oreille River, Idaho (Figure 25a), is shown between the gantry legs in Figure 25b. Its work is aided by a log grapple (lifting tongs at the lower left of the figure) which picks up large logs and surface debris. The 10-ft-long trash rake, which can lift 3,000 lb, rakes from the bottom up at a speed of 20 ft/min. The debris

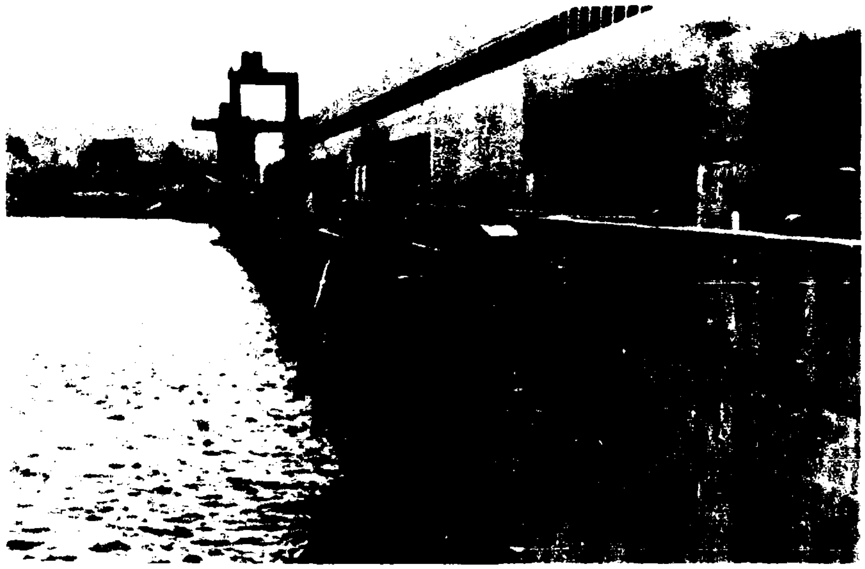


Figure 24. Trash rake at Bonneville 2 on the Columbia River; the rake is operated by the gantry crane in the background

collected by this equipment is put in a sluiceway and flushed downstream after a sufficient quantity has accumulated.

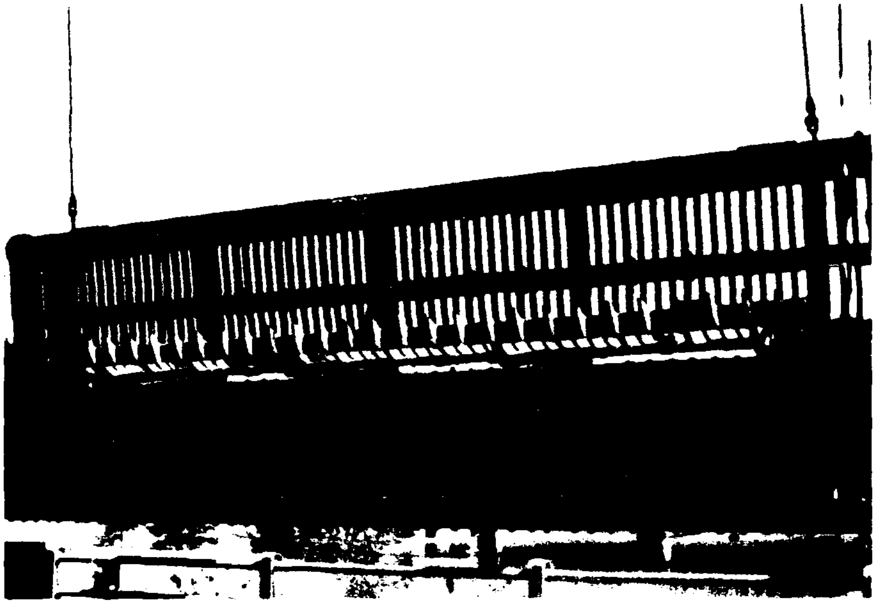
57. A different type of gantry crane-operated rake is located at Chief Joseph Dam on the Columbia River. It is a heavy structure (Figure 26) that slides down the trash rack, removing debris as it travels downward. The set of curved fingers on the bottom of the rake are rotated down and out during raking. At the bottom of the trash rack, the curved fingers are rotated back into the position shown, enclosing the debris in the triangular space. The rake is then lifted, and the debris is dumped into a truck.

58. The trash rakes are set in position by the crane, but they may be aligned vertically or horizontally by rollers or skids. The teeth on some rakes reach between the trash rack bars a small distance, but on other rakes they move flush with the surface.

Cranes and Hoists

Background

59. The crane is a machine for raising, shifting, and lowering heavy weights by means of a projecting, swinging arm or with a hoisting apparatus supported on an overhead track. Several types of cranes are used to lift,



a. Gantry-operated trash rake

b. Gantry crane

Figure 25. Gantry-operated trash rake and gantry crane at the Albeni Falls Dam, Pend Oreille River, Idaho

Figure 26. Trash rake at Chief Joseph Dam, Bridgeport, WA, operated by a gantry crane; it scrapes debris from the trash rack while moving down the rack face

move, and release the various debris-holding mechanisms. The hoist is a unit that is suspended overhead and used for lifting heavy logs from the trash rack on a baffle wall. The hoist may be manually or electrically powered and may utilize either chain or wire rope for lifting. Capacities of units available range from fractions of tons up to about 10 tons. Supplemental hand tools used with cranes and hoists include a bolt hook, log chain, rope, pike pole, and chain saw.

Jib crane

60. The smallest and simplest type of crane is the jib crane, which consists of a pivot post and a carrying boom. The boom supports a cable and a hook-lifting device or chain hoist operated either mechanically or electrically. The jib crane is used to lift logs and items that do not fit in the trash rake. It can hold one end of a log while the log is sawed into manageable lengths.

Gantry crane

61. This crane is briefly described in paragraph 55. It has also been used to handle a debarking screen to remove fine debris accumulations from emergency gate slots. Also at Carillon Power House on the Ottawa River in Canada, the sole device used to remove debris from the forebay and the trash

racks is a grapple operated from the intake gantry crane. A load of debris from the bottom is slid along the trash rack face to loosen up any debris there.

Hammerhead crane

62. The hammerhead crane is a heavy-duty crane with a horizontal, counterbalanced jib. It is usually mounted on a gantry crane and has the ability to remove material from the forebay area and place it on the forebay deck or in a truck.

Whirley-type gantry crane

63. The whirley, or rotating-boom, crane is a crane free to rotate 360 deg in picking up and depositing its load. It is more versatile than a hammerhead crane in that its boom may be lowered and extended to reach farther out into the forebay, for example, to retrieve sinkers (waterlogged logs). Once retrieved, the sinker is pulled back to the intake face and lifted out; here the boom may be raised to increase its lifting capacity. The whirley crane can also perform the other functions of a gantry crane.

Truck crane

64. A truck crane of 40-ton capacity, or more, can handle most of the debris-removal tasks at a power plant. It is well adapted to small plants and can be used occasionally to remove debris that built-in devices cannot handle. When the task is finished, the truck can be driven out of the way or taken back to the construction company.

Holding Mechanisms

Grab buckets (clamshell)

65. The grab bucket, or clamshell, is an excavating device that has two hinged jaws. It is used to remove debris from in front of intakes at the surface and from the river bottom. The clamshell shown in Figure 27 was rented and is unmodified. The hydroelectric plant owner is buying a new crane and clamshell to replace an ineffective trash rake (not shown). The operator plans to weld some short teeth, or nubs, to the jaw faces for a better grip on debris.

Grapples

66. A grapple is a bucket similar to a clamshell, but it has three or more jaws (Figure 28). One common type of grapple is the "orange peel." The

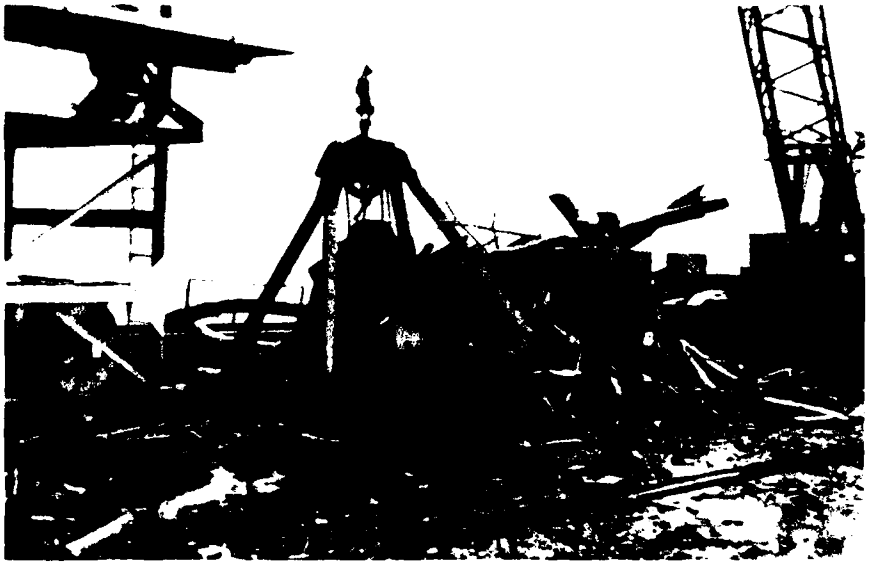


Figure 27. The 1-1/2-cu yd clamshell grab bucket used at Racine, OH, power plant to remove surface and submerged debris from forebay

greater number of sections seems to give it a good grasp of randomly oriented debris.

Tongs

67. Tongs are any of numerous devices or instruments used to grasp objects such as rails, logs, and pipes for ease and convenience of handling or for lifting, dragging, or carrying. Tongs commonly consist of two pieces hinged together like scissors or pincers. Sometimes a single pair of tongs is used to remove logs one at a time. Figure 29 shows a set of several pairs together for handling large logs or several logs at one time.

Forks

68. Forks are commonly used for handling loose, bulky materials such as hay or straw. However, considerable modification allowed one type called a Jackson fork to be used to lift debris from water to land. The original fork and its debris version, designed by Mr. Robert G. Kress of the Walla Walla District, are shown in Figure 30. The fork is inserted into the debris in the open position and then is actuated into an "L" shape. The material is lifted out, moved to the disposal site, and dumped by an automatic trip arrangement. Blefgen (1964) considered it to be "many times more efficient than the clamshell" at Ice Harbor.

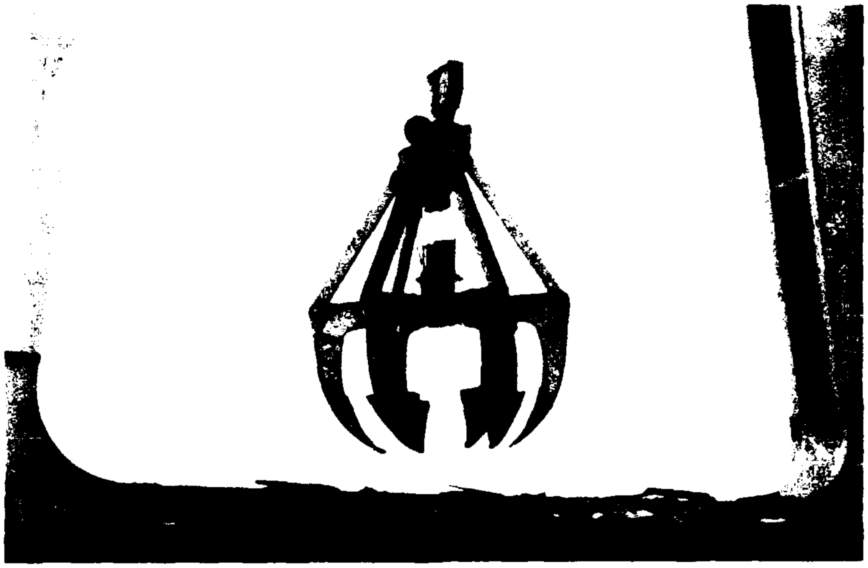


Figure 28. Gantry-operated "orange peel" grapple used at the Carillon Powerhouse, Ottawa River, Canada; its load of debris is also used to sweep the trash rack

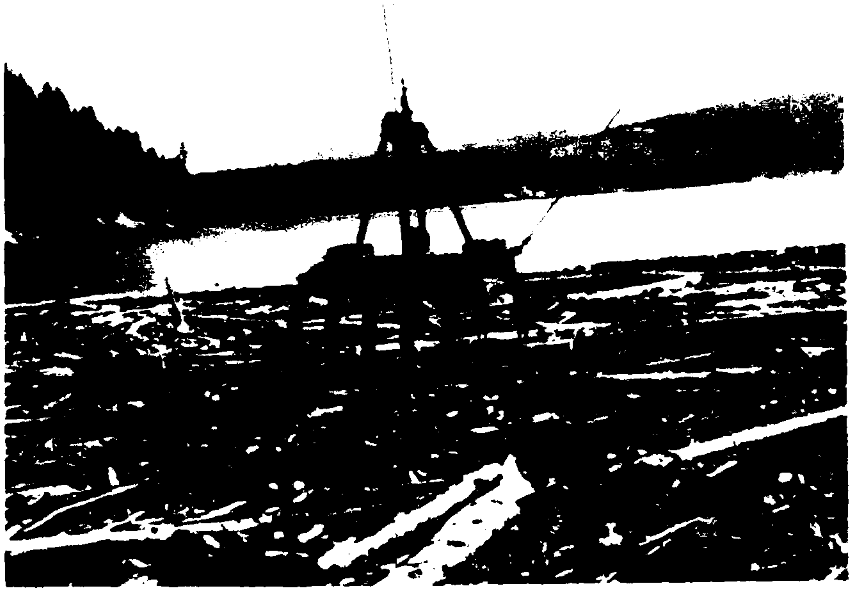
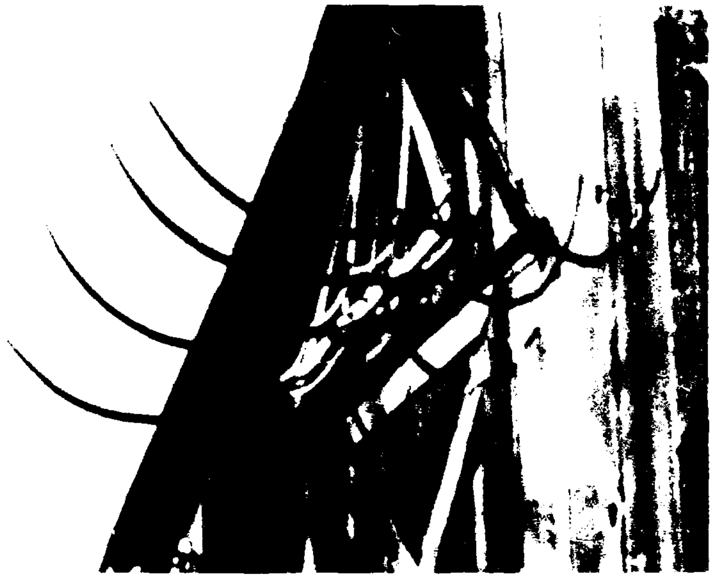
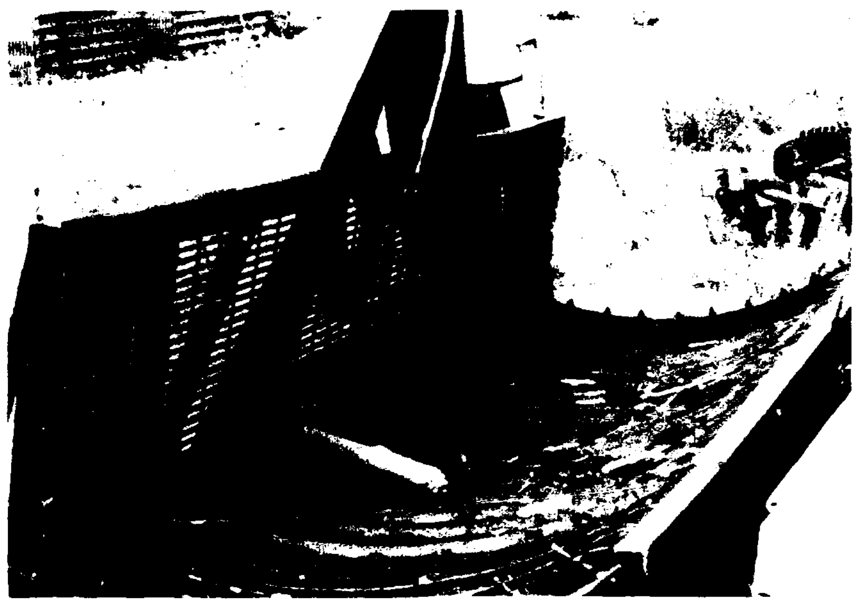


Figure 29. Log tongs for removing floating debris from a debris holding boom on the Columbia River, Washington (photo courtesy of the Bureau of Reclamation)



a. Jackson hay fork on gable end of museum building in Omak, WA



b. Debris fork used to remove floating debris at Lower Granite Lock and Dam on the Snake River in Washington

Figure 30. Jackson fork and debris fork

Loaders

69. In situations in which floating debris is deflected by booms, currents, and wind into holding areas that can be drained, it is possible to use loads to pick up the debris and place it into trucks. The two general types of loaders are the crawler type, which is based on a tracked vehicle like a bulldozer, and the wheel type, which has large wheels like certain construction vehicles. Loaders are popular in the logging industry.

70. The wheeled loaders move more rapidly than tracked vehicles and are quite maneuverable, many having articulated bodies. Their tires have deep cleats for traction, and many are protected and aided in traction by steel cages or chains. The lower ground pressure or the tracked vehicles, however, and their inherent ruggedness make them in some river areas good vehicles for collecting debris into piles for burning. A dozer blade is sometimes modified with rake teeth along its bottom edge for cleaning up the debris. Teeth welded to the top of the blade (spill guard) increase its capacity for moving material. Specialized dozer blades called brush rakes and clearing rakes are also available. Guards are necessary to protect the radiator.

Conveyors

71. A conveyor is any of various devices that provide mechanized movement of materials. Flight conveyors have scrapers, or flights, mounted at intervals, perpendicular to the direction of travel, on endless power-driven chains operating within a trough. Bulk materials, such as leaves, straw, branches, and limbs, may be pushed along the trough. An appropriate conveyor is a jack ladder, which is an inclined plane up which logs are moved from pond to sawmill. It typically consists of a V-shaped trough within which an endless chain carries the logs upward. The main problem is feeding material into the conveyor; sometimes natural currents can be used to bring the material in or perhaps a propeller can draw water through the conveyor to facilitate debris entry (Kennedy and Lazier 1964). High-pressure nozzles have been used to push debris toward the conveyor with some success, although men with pike poles are sometimes needed to push debris into the conveyor intake. Cable-pulled log tongs (Figure 31, upper right) were useful in breaking debris jams that developed outside of the intake (Biefgen 1964).

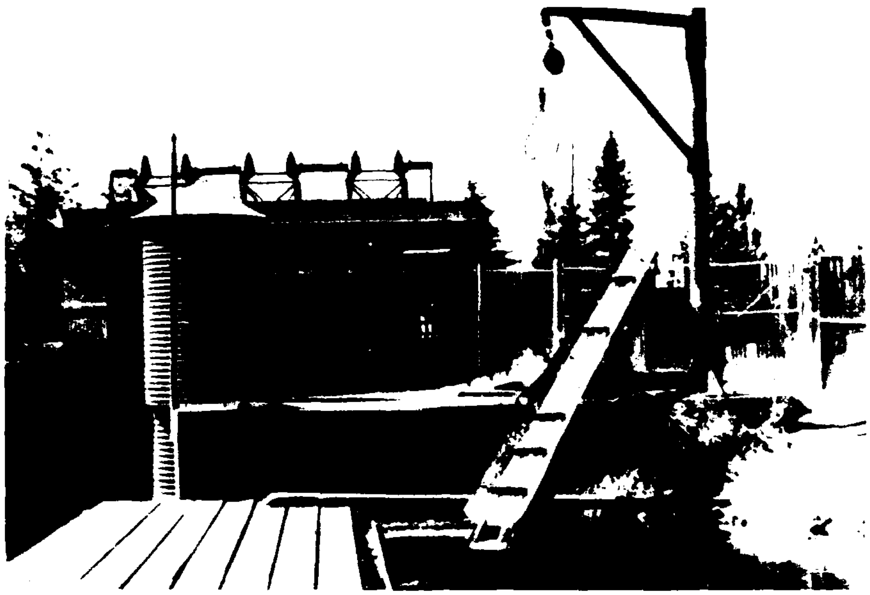


Figure 31. Several elements and artifacts of floating debris control at the upriver hydroelectric power plant on the Spokane River, Spokane, WA

Small Control System

72. A collection of debris-control equipment is shown in Figure 31. This view of the powerhouse is seen from a walkway on the downstream end of the forebay debris boom. The cylindrical structure in the foreground is housing for a water-level gage. From the left at the powerhouse are part of a series of trash racks and their supporting vertical beams; to the right end of the powerhouse is a trash rake and gantry crane mounted on the forebay deck; most of the debris, however, collects at the junction of the debris boom and the concrete wall in the foreground. At this point there is an electric-powered trash conveyor, a set of log tongs pulled by a winch mounted on a gin pole, and, to the rear, a trash bin or container. Not seen, but also necessary, are hand tools, chain saw, wheelbarrow, dumpster truck, and landfill dump.

Boats

Workboats

73. The workboat is a multipurpose boat that can move debris barges,

tow roundup booms, shove debris along a boom, or flush it away from some location with propwash. An example of a workboat is shown in Figure 21. At Ice Harbor it was found that a 50-ft by 14-ft boat with a 5-ft draft and 300-hp engine was ideal to tow a boom into the floating debris, bag a load, and tow it upstream to open water (Kress (1965). Devices such as booms and debris blades aid in moving and collecting debris.

Snagboats

74. The snagboat is a twin-hulled, steam-engine-powered boat, invented by Henry Miller Shreve and first built in 1829 for the purpose of removing snags from the Mississippi. The boat had an A-frame "snag beam," or shear, on the bow; in the raised position it would hoist snags with its tackle. When fully lowered, it became a ram for loosening snags from the silt. The vessel was ironclad in strategic locations to withstand impacts and abrasion. One of the first snags to be removed was a tree 3-1/2 ft in diameter and 160 ft long (Dobney 1976).

Debris-collection boat

75. A boat similar to the snagboat is the debris-collection boat (Figure 32) used by the USAED, San Francisco, to remove floating debris from critical areas in San Francisco Bay to keep the debris from damaging various fixed and moving devices such as wharves, ships, and boats. The debris boat has twin bows with a 20-ft-wide space between the bows. A coarse net made from chain (Figure 18) is positioned as a scoop in this space with the front of the next approximately 4 ft underwater. Because of the water currents, debris often collects in a linear manner on the bay, and the boat moves along this line scooping up the debris. An onboard crane is used to set a full net on the deck and to replace it with an empty net. Four nets are available, and as much as 60 tons of debris can be removed in a day. Large logs and timbers are towed alongside the vessel. The debris is deposited on a debris dock in Sausalito, where it is cut up and put into large containers for removal by a contractor (USAED, San Francisco 1985). The vessel is similar to the "drift master" debris boat, the Hayward, built in 1947 and used by the Corps in New York harbor.

Traveling Screens

76. A traveling screen is a flexible screen surface that moves like a conveyor belt, or it is a rotating, perforated drum. The screen blocks or

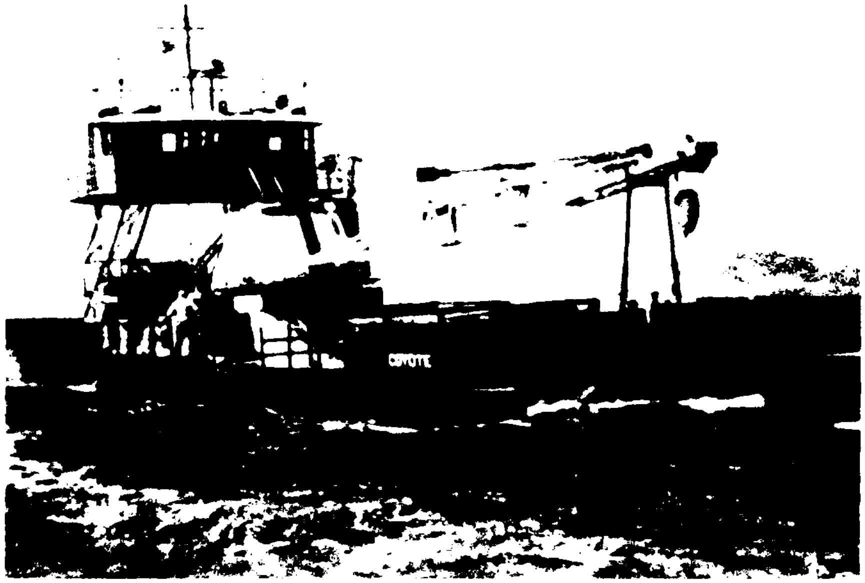


Figure 32. The Corps twin-bow, debris-collection boat, the Coyote, plying the waters of San Francisco Bay (photo courtesy of USAED, San Francisco)

covers the water intakes so that water must flow through it to the turbines and pumps. The screen moves slowly up into a location where the accumulated debris is removed by water jets and falls into a sluice that transports it to a holding tank for later removal. The device works well in the English land drainage and pumping systems (Thorn 1966), which have to carry a lot of grass and small debris. The system automatically bypasses the flow to a conventional trash rack in case of screen failure.

Air Bubblers

77. An air-bubbler system removes small-sized debris such as leaves twigs and branches up to 3 in. in diameter from vertical trash racks at the Wilder Dam, Wilder, VT, on the Connecticut River. It consists of a horizontal brass pipe with multiple holes anchored at the bottom of each trash rack and is fed from a large tank at normal shop pressures. The intake water flow is stopped prior to the air's being discharged. The debris rises to the top, where it is passed over a submersible gate. The larger materials, such as trees, logs, and stumps, are removed once a year by truck crane and clamshell.

The frequency of operating the system depends upon the amount of incoming debris; in the spring the air bubbler may be needed three times a day.*

Debris Passage

78. Before man constructed dams on various rivers and streams to support his endeavors, debris was floating along in them as a consequence of strictly natural events. The dams tend to stop the debris and collect it, and unless flood conditions carry the debris over the dam, it continues to collect, possibly in very large quantities. The debris can become a hazard to the operation, if not the integrity, of the dam. To avoid problems of this nature at many hydrodams, the appropriate gate or gates are opened to the necessary height or depth to send the floating debris downstream.

Dam gate

79. Dam gates can be raised to flush debris downstream provided this action does not cause scour downstream of the dam. Because debris floats on the surface, gates, in general, must be raised a substantial distance to achieve the water velocities needed to take the debris down and through the opening. One must not induce these flows if there is any question of failing the downstream foundation material.

80. Some gates such as the rollerdrum gate contain a flap gate, which is lowered for the purpose of washing the surface debris over the top. Some tainter gates can be lowered to perform the same function. Emergency lock gates of the vertical-lift type only can be set in a position that allows flow through a navigation lock to pass large quantities of debris and ice, i.e., approximately 5 ft of water over the gate. At Racine L&D, this amount is the equivalent of a 1-ft opening on a tainter gate (Perham 1986).

Logways, sluiceways

81. Many dams in areas where logging is an important industry, such as the northwestern United States and Canada, will contain logways and sluices for passing logs and pulpwood through the structure. The logway is mainly a sloping flume through which water flows to carry the logs to a point below the dam. The passage may contain a conveyor system.

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* Personal Communication, 1986, R. Brock, Assistant Superintendent, Wilder Station New England Power Company, Wilder, VT.

Trash sluice

82. Locations that receive substantial amounts of floating debris each year may have a sluiceway built into the dam structure. Some material may enter the sluice by passing over a weir. A large log may block the weir and have to be removed by other means, sawed into shorter lengths, and dumped into the sluice. Also material raked from the trash racks is dumped into the sluiceway. The amount of water passing through the sluice is controlled, even to the extent that a sluiceway may be dry most of the time and have water passed through it only when there is enough material to bother flushing it downstream.*

83. At Bonneville Dam, where traveling fish screens are used in the emergency gate slots, significant amounts of small, floating debris collects in the surface openings. It is removed by crane and a debarking basket, but the equipment is cumbersome and the process is slow. The operators experimented with boring a sizeable hole through the vertical, concrete bulkhead between the slot and the trash sluice and found that the water flowing out of the gate slot easily removed the material. The hole is gated and is used only when necessary. Eventually this feature will be used on the 29 other slots.**

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* Personal Communication, 1985, J. B. Coyle, Resource Manager, Albeni Falls Project, Newport, WA, USAED, Seattle, Seattle, WA.

** Personal Communication, 1985, Q. O'Brien, Chief of Maintenance, Corps of Engineers Bonneville Lock and Dam, Cascades Locks, WA.

PART V: DISPOSING OF DEBRIS

Useable Materials

84. An accumulation of floating debris contains a wide variety of materials, some of it of some value. All debris has a certain negative value (cost) associated with it when it has to be disposed of. Something as simple as flushing it over a sluiceway costs, in terms of water lost for generating electricity or upland irrigation. The following categories of materials apply. The majority of floating debris is virgin wood, not contaminated in any way. However, there may be, on occasion, mixed in with the woody debris certain hazardous materials such as propane tanks and oil containers or health hazards such as a large dead animal. One should be cognizant of the various governmental guidelines associated with waste materials, including those of the United States Environmental Protection Agency (1984), and use care and common sense in handling suspected problem debris.

Structural materials

85. Many logs are large enough for some structural applications. If the logs are in good condition, they may be dried, treated with preservative, and used as support posts for small buildings, guard posts for roads and parking lots, soil stabilization structures, and structure protection pilings.

Firewood

86. In general, a fair portion of floating debris can be dried and cut up for firewood, but the extent of its usefulness depends on its cleanliness. For example, some environmentally sound plans to use the debris as firewood for campers and for facility heating at the Mount Morris Dam recreational area in New York were set aside after a brief application. Upstream of this flood-control site, the woody debris had become encrusted with slit and gravel and was very damaging to the contractors' chain saws, enough so as to offset the cost benefits.*

Marked logs

87. A small percentage of floating debris may be branded logs in certain parts of the country. According to state regulations in Washington,

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* Personal Communication, 1987, J. D. Boyle, Chief, Lock and Dams Section, USAED, Buffalo, Buffalo, NY.

Oregon, and Idaho, the owners have to be notified of the whereabouts of the logs and be given a certain period of time in which to retrieve them. If unclaimed, the logs may then be disposed of (USAED, Portland 1976).

Chipping

88. The chipper is a powerful machine used to turn trees into piles of wood chips. It has as major components a gasoline engine of 200 to 300 hp, a log-feeding chain conveyor, and a multiblade cutter head. The blades are made from tough alloy steel and have carbide inserts in each tooth. The chipper needs supplemental devices to operate efficiently. These are a truck-mounted hydraulic crane with a log grapple to place material onto the infeed conveyor and an outfeed conveyor to carry chips to a pile or some type of holder, such as a barge.

89. The wood chips produced by the chipper can be used for many purposes. The most common use is probably as cover to protect bare earth against erosion. Another desirable use is as fuel in a wood chip-fired steam-generating plant for municipal heating for electrical generation. Transportation costs and chip dryness are important factors in this application.

Unuseable Materials

90. Useless material should be discarded in a locally acceptable manner. Some methods are described briefly in the following paragraphs.

Burning

91. Direct burn means that the material is burned at or near it collection site with a minimum of handling and transportation required. The material is burned as is, although some time may be allowed for drying.

92. Onland. The debris is brought to shore by workboat and bag boom or similar scheme where it is lifted out and piled on the ground in windrows and burned. After being burned, the area is bladed with a dozer to concentrate the unburned material, which is rekindled. The piles are hosed or sprinkled with water to keep the burning safe. At one location in mountainous terrain, a 4-ft-high protective barrier of steel was constructed to shield railroad tracks from the intense heat to prevent their warping.

93. Certain river locations are adaptable as collecting and holding grounds for floating debris if the appropriate structures are installed. Dropping the water level a few feet leaves the floating debris grounded and

drained. As mentioned above, the debris is pushed into windrows and piles by D7- or D8-sized Caterpillar™ tractors that have specially toothed blades, and this debris burned until there is nothing left.*

94. On water. Floating debris can be burned on water, where permitted, using a barge and an air-curtain burner. For example, this type of burning has been used at the confluence of the Kettle River and the Columbia River. Floating debris coming from this tributary is collected by a system of shear and holding booms. A workboat and bag boom bring debris to the barge, which also supports a crane. The crane loads debris into the air-curtain burner, and the wood is ignited with a torch. The air-curtain burner has a high-volume fan, which blows air through a system of passageways in the refractory material-lined tank and at the bottom of the debris mass. The debris burns quite rapidly in this forced draft, at temperatures in excess of 1,000 deg F. The combustion process is nearly complete, and the appearance of smoke is minimal (Figure 33). A medium-sized unit can burn 10 to 15 tons/hr. The method used by the USAED, New York, is to store the debris on the decks of large barges until the conditions are right and then haul the debris out to sea under EPA permit at least 20 miles and burn it.**

Burial

95. Guidance is provided in the Engineer Manual EM 1110-2-1913 for burial of debris. Debris from clearing, grubbing, and stripping operations can be disposed of by burning in areas where this is permitted. When burning is prohibited by local regulations, disposal is usually accomplished by burial in suitable locations near the project, such as old sloughs, ditches, and depressions outside the limits of the embankment foundation but within project rights-of-way. Debris may also be stockpiled for later burial in excavated borrow areas. Debris should never be placed in areas where it may be carried away by streamflow or where it blocks drainage of an area. After disposal, the debris should be covered with at least 3 ft of earth, and vegetative cover should be established.

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* Personal Communication, 1985, R. Bute (deceased), Grand Coulee Project Office, US Bureau of Reclamation, Grand Coulee, WA.

** Personal Communication, 1986, R. Goodrow, Master Tug Foreman, Operations Division, USAED, New York, New York, NY.

Figure 33. Barge-mounted, forced-draft burner for disposing of floating debris; the combustion process is nearly complete, and little smoke is given off (photo courtesy of US Bureau of Reclamation)

Trucking of dumps

96. When debris is to be transported an appreciable distance between the removal and disposal sites, trucking is the most common form of conveyance. Capacities upwards of 60 cu yd are in use. Barges and railroad cars may be the best mode under some circumstances. At the Racine hydroelectric plant on the Ohio River, an initial removal of debris from the intake and forebay was put into a barge and towed away. Subsequent debris removals were transported by ore trucks.

Contract removal

97. At least one hydroelectric plant's (Carillon's) debris is transported by a contractor. The debris is removed from the trash racks and the forebay by the plant operators, who put it into the plant's own truck. The contractor then takes the material to a private yard, where he is responsible for its disposal. In that particular location, most of the floating debris is wood, which is frequently used for fuel.

Trucks

98. An ore truck is a large tractor trailer with an end dumping trailer

body. A representative vehicle with a capacity of approximately 30 yd is shown in Figure 34.

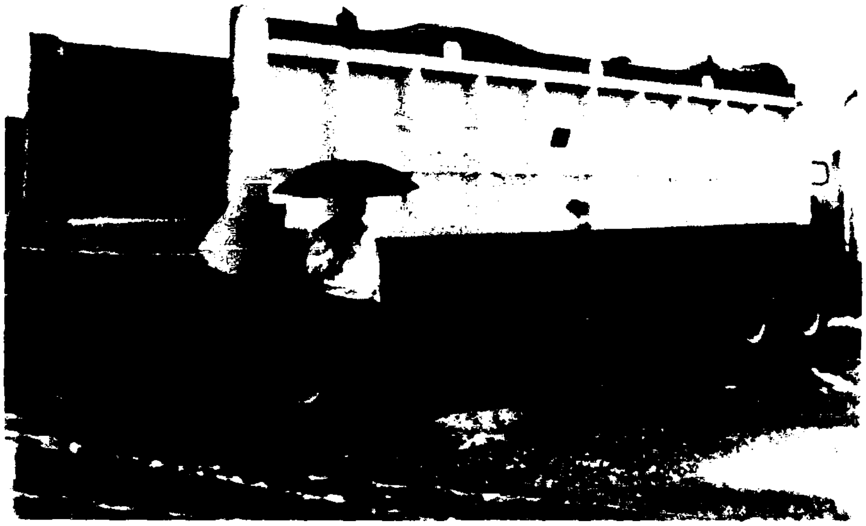

Figure 34. Ore truck used to transport debris accumulations from Racine Lock and Dam, Ohio, with a body that may be tilted to dump its load

99. Logging trucks have utility in some situations; a truck with a log-handling boom can provide supplemental lifting and hauling capacity to an overtaxed removal system.

100. Dump trucks of the type found on most construction jobs are often used to haul debris to a disposal site. Side boards may be added to increase the volumetric capacity of the body. A dump truck being loaded by a conveyor may have a raised side board on the side away from the conveyor to avoid material loss. A debris truck that is a little different was seen in Canada (Figure 35). The whole front panel of the truck body serves as an ejector. Propelled by hydraulic pistons, it moves rearward to shove the load of debris horizontally out of the truck. A primary benefit of this arrangement, besides not having to lift a heavy body, is the ability to maintain a more compact pile of material at a dump site.

101. At some locations the floating-debris quantities are minor, and the debris is put into bulk refuse containers located near the trash racks. Some of the debris must be cut up to fit in the container, but it is hauled away by the usual refuse-compactor truck.

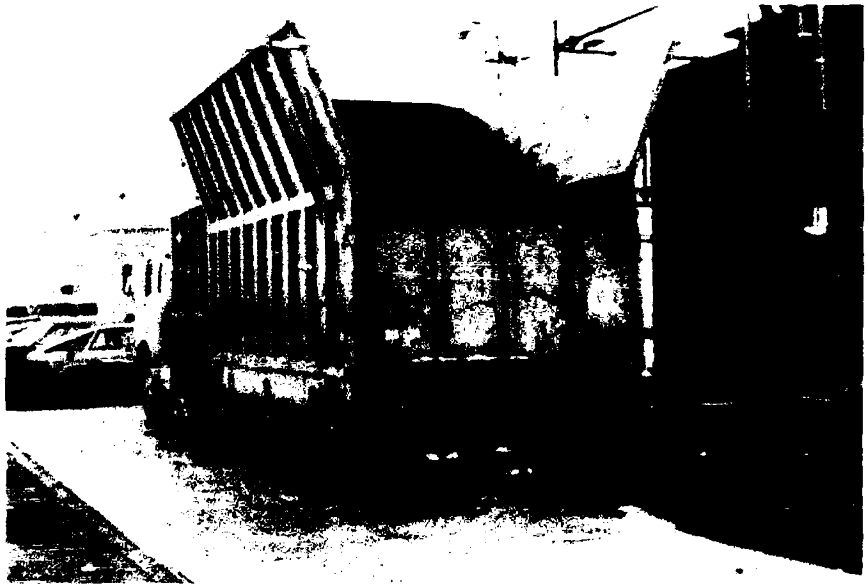

Figure 35. Utility trailer truck incorporating a hydraulic load-ejector mechanism in the body, Carillon Powerhouse, Ottawa River, Canada

Present Dumping Practice

Landfill

102. A considerable amount of debris can be accommodated in landfill areas where it is packed down and covered with dirt. The material will gradually decompose, but the process could take a long time, depending on the chemical and moisture conditions in the soil (HQUSACE 1984).

Surface dump

103. At surface dumps debris is dumped onto the ground and left there until consumed by natural processes. The dump area is usually in a remote location and is shielded from roads and abutters. The area is posted, but people often find a way to remove some of the debris for firewood. There are several undesirable features about surface dumps, but mainly they are not safe places for people. Log piles can tumble, and one never knows for sure what the debris might contain. In some remote locations surface dumping may be a logical way to dispose of debris, but generally it is used only as a last resort.

PART VI: SUMMARY

104. Floating debris is a continual problem for all users of water bodies. Some of the damage caused by debris is minor, but too often it is quite costly. It is destructive to locks, dams, bridges, electric plants, municipal water systems, and even to recreational boaters. Wetlands, fish-spawning grounds, and streambanks can be disturbed by debris.

105. A floating-debris control system consists of collecting, removing, and disposing of the debris. Various types of booms, trash racks, trash struts, and deflectors have been used effectively for collecting floating debris. Hand-powered, self-powered, and gantry crane-operated rakes are used to remove the debris from intake gates, bulkheads, deck gratings, and trash rack sections. Heavy debris, such as water-soaked logs or fallen trees, are removed with cranes and hoists, supplemented by such implements as bolt hooks, log chains, and chain saws. Some of the removed debris has value. Many logs are large enough to be used as structural materials: supports for small buildings, guard posts for parking lots, and supports for soil stabilization. Also, some of it can be dried and cut up for firewood. The debris that cannot be used must be burned, buried, or dumped on the ground surface. All of these processes require careful monitoring so that they are not and do not create health hazards. Surface dumping should be used only as a last resort.

106. An effective floating-debris control system requires time, effort, and money; however, its benefits more than offset its requirements.

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APPENDIX A: FLOATING-DEBRIS CONTROL SYSTEMS ELEMENTS OF FLOATING-DEBRIS CONTROL, INFORMATION SOURCES

Clark Fork Debris Control Facilities

Mr. John B. Coyle Jr., Resource Manager
Albeni Falls Dam
PO Box 310
Newport, WA 99158 Telephone: (208) 437-3133

Racine Hydroelectric Plant

Mr. F. J. Accetta, Asst. Mgr. Civil Engineering
American Electric Power Service Corp.
1 Riverside Plaza
PO Box 16631
Columbus, OH 43216-6631 Telephone: (614) 223-1000

Columbia and Kettle River Debris Facilities

US Bureau of Reclamation
Grand Coulee Project Office
PO Box 620
Grand Coulee, WA 99133

Chief Joseph Dam Debris Facilities

Mr. Eric E. Nelson
Civil Project Management
US Army Engineer District, Seattle
PO Box C 3755
Seattle, WA 98124 Telephone: (206) 764-3557

Mr. Harry F. Twombley
Chief Joseph Dam Project
PO Box 1120
Bridgeport, WA 98813-0670 Telephone: (509) 686-5501

Bonneville Lock and Dam Debris Facilities

Mr. Quinn O'Brien, Chief of Maintenance
Corps of Engineers, Bonneville Lock & Dam
Cascade Locks, OR 97014 Telephone: (503) 374-8363

Lower Granite Lock and Dam Debris Disposal Facilities

Mr. Charles Krahenbuhl
Lower Granite Project
Route 3, Box 54
Pomeroy, WA 99347 Telephone: (509) 843-1493

Mr. Lynn Reese
US Army Engineer District, Walla Walla
Bldg. 602, City-County Airport
Walla Walla, WA 99362

Moose Creek Dam, Chena Lakes Flood Control Project

Mr. Vern Thompson
US Army Engineer District, Alaska
PO Box 989
Anchorage, AK 99506-0898 Telephone: (907) 7753-2741

Carillon Powerhouse and Lock

Mr. Pierre LaTourelle
Hydro Quebec
1450 City Councillors, 6th Floor
Montreal, Quebec, Canada Telephone: (514) 842-7861

Beauharnois Powerhouse

Mr. Jean-Guy Fournier, Superintendent
Hydro Quebec
Case Postale 2001
Beauharnois, Quebec, Canada J6N 1W5 Telephone: (514) 429-6481

Mount Morris Dam

Mr. Gary Frankish
US Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207 Telephone: (716) 876-2231

Vernon Station

Mr. Charles Schmitt, Superintendent
Vernon Project
New England Power Company
Vernon, VT 05354

Deerfield #3

Mr. Al Mooney
New England Power Company
Shelburne Falls, MA 01370

Winfield Powerhouse

Mr. Ted Pendleberry
Winfield Powerhouse
Appalachian Electric Power Company
Winfield Lock and Dam Winfield, WV 25213

Upriver Hydroelectric Plant

Mr. George W. Miller, Chief Engineer
Department of Public Utilities
914 Grace Avenue
Spokane, WA 99207   Telephone: (509) 456-4384

Upstream Hydroeletric Plant

Mr. Donald R. Brown, Manager
Construction and Maintenance
The Washington Water Power Company
E. 1411 Mission Avenue
Spokane, WA 99202   Telephone: (509) 489-0500

Drift Deflector Barge

Mr. Robert M. Templeton, Manager
Huntington Terminal
The Ohio River Company
2025th Street
PO Box 470
Huntington, WV 25709   Telephone: (304) 523-6461

Woody Debris

Frederick J. Swanson, Research Geologist
USDA Forest Service
Pacific Northwest Forest & Range Experiment Station
3200 Jefferson Way
Corvallis, OR 97331   Telephone: (503) 757-4398

Reservoir Debris Removal

Mr. Mike White
US Army Engineer District, Huntington
502 8th Street
Huntington, WV 25701-2070   Telephone: (304) 529-5488

Hydraulic Trash Rack

Mr. Lincoln H. Berry
L. H. Berry Inc.
Box 501
Conway, NH 03818   Telephone: (603) 447-2701

APPENDIX B: LOG BOOM CONFIGURATIONS

1. The sizes, configurations, and composition of log booms that are used to control pulpwood logs and floating debris vary markedly from one location to another. There are many reasons for these differences, not the least of which are the design forces and the types of materials that are available in the different areas, including surplus stock. For example, large logs may be rather easy to obtain in the Western United States but not in the East. In the East, therefore, one often sees steel pontoons used or an assembly of smaller sized timber beams. Furthermore, Douglas fir timbers, common to the West, have an appropriate combination of bending strength and buoyancy. Steel pontoons and even assemblies of wooden timbers often contain polystyrene or polyurethane foam flotation to ensure long-term buoyancy. The objectives of this section are to give the planner or designer a better understanding of this variety to help avoid "reinventing the wheel" at some later time.

2. Figure B1 is a collection of end-view and front-elevation sketches for a number of log booms. They vary from the simplest to the most complex, but for brevity only their more general features are shown. All of the booms, except possibly one, are in use or have been used. More details may be obtained from the users (see code letter) or from the author. Booms E and F were selected from about 20 types shown in Kennedy and Lazier (1984).* These booms are given also in Perham (1987), a Repair, Evaluation, Maintenance, and Rehabilitation (REMR) report. The one design that may not have been used is the concrete boom (boom P) that was described in a proposal; however, structures of this general type and construction are used as floating guide walls at Kaskaskia Lock and Dam in Illinois and Lower Granite Lock and Dam in Washington. Though strong and long-lived, the concrete structure is expensive to build. Steel boxes, i.e. large rectangular pontoons, are an alternative design, and in some locations with abundant steel supplies and metal-handling facilities, they are used for ice booms instead of timbers.

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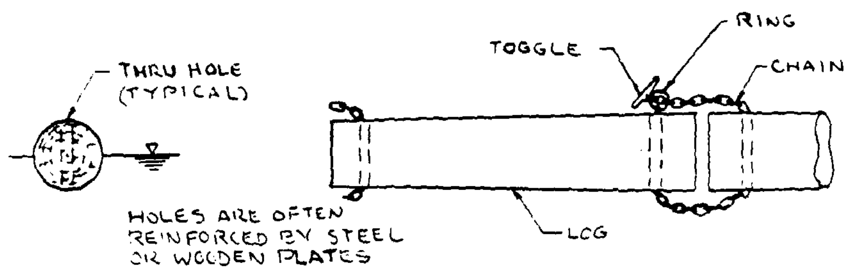
* See References at the end of the main text.

TABLE B-1

EXAMPLES OF LOG BOOM DESIGN AND CONSTRUCTION

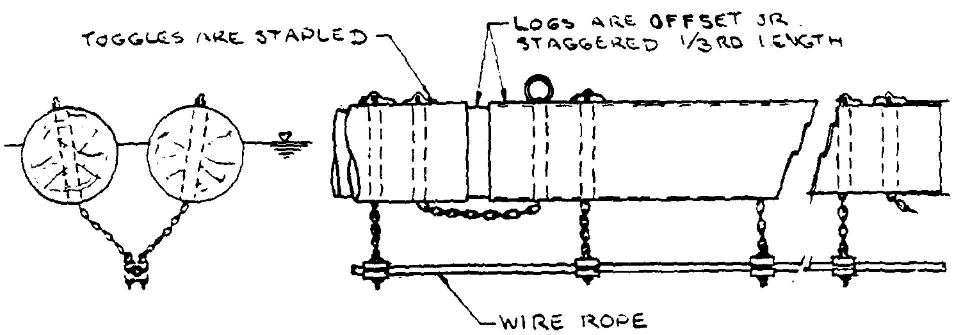
Wooden Construction

A



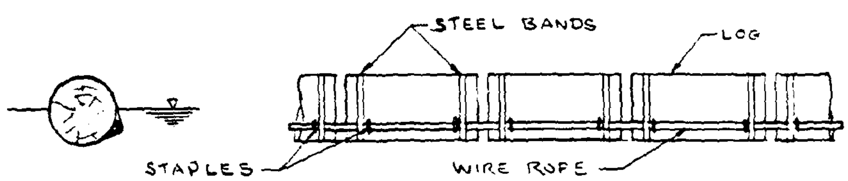
LOG BOOM

B



DOUBLE LOG BOOM

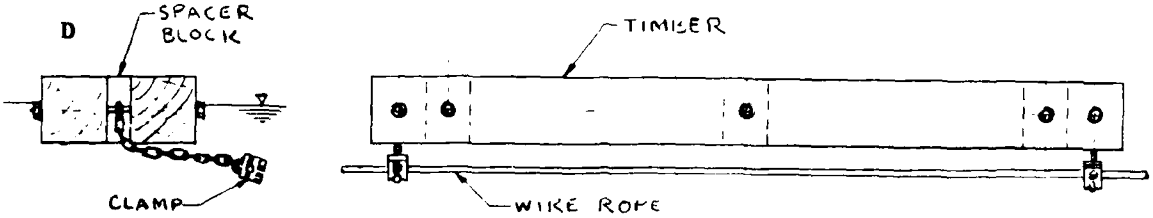
C



SINGLE LOG BOOM

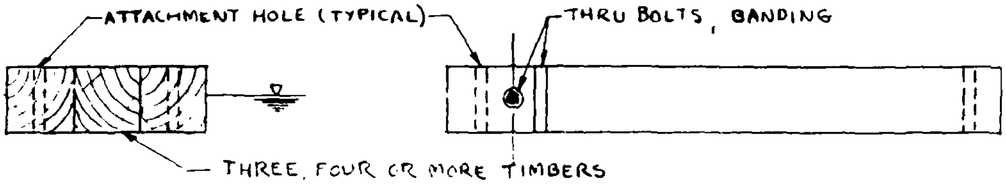
Figure B1. Collection of end-view and front-elevation sketches for a number of log booms (Sheet 1 of 5)

D



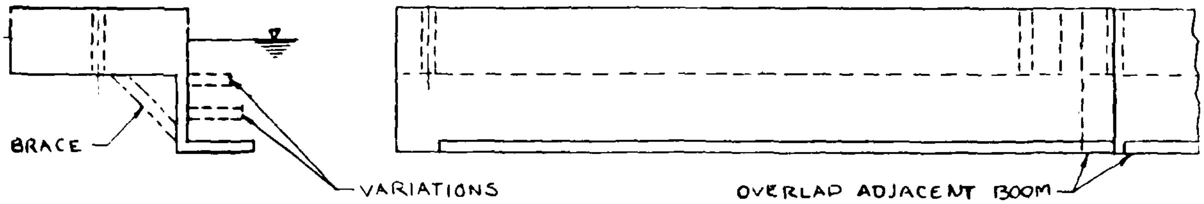
DOUBLE TIMBER LOG BOOM
(Mt. Morris Dam, Reference)

E



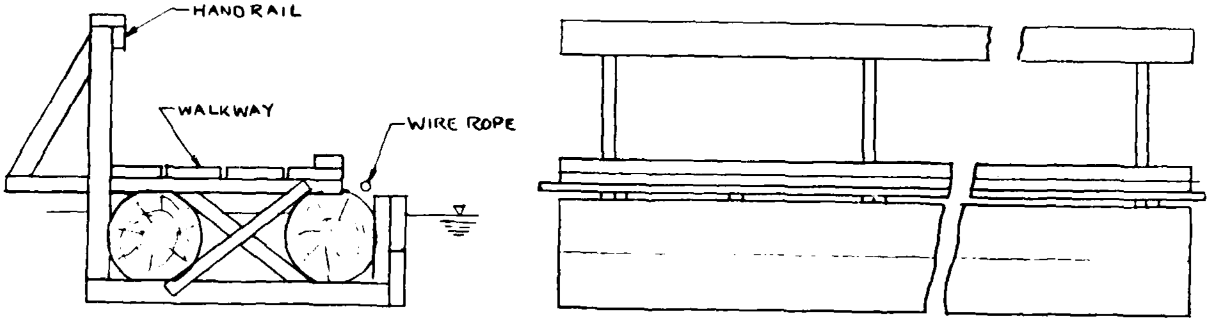
SINGLE LAYER FLAT, OR WALKING, BOOM

F



GLANCE, OR DEFLECTOR, BOOM WITH LIP

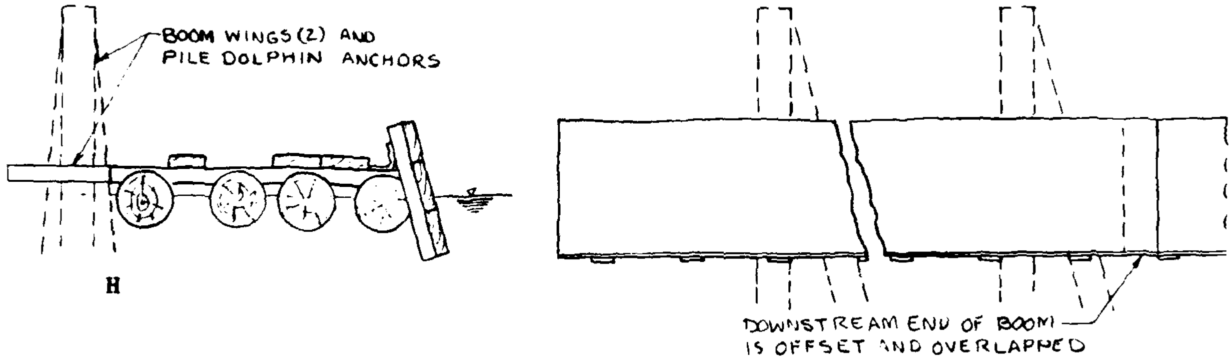
G



DOUBLE LOG LOG BOOM

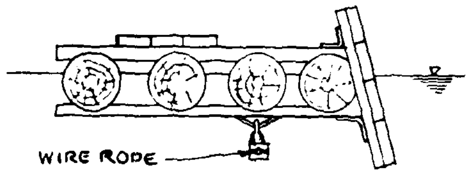
Figure B1. (Sheet 2 of 5)

H



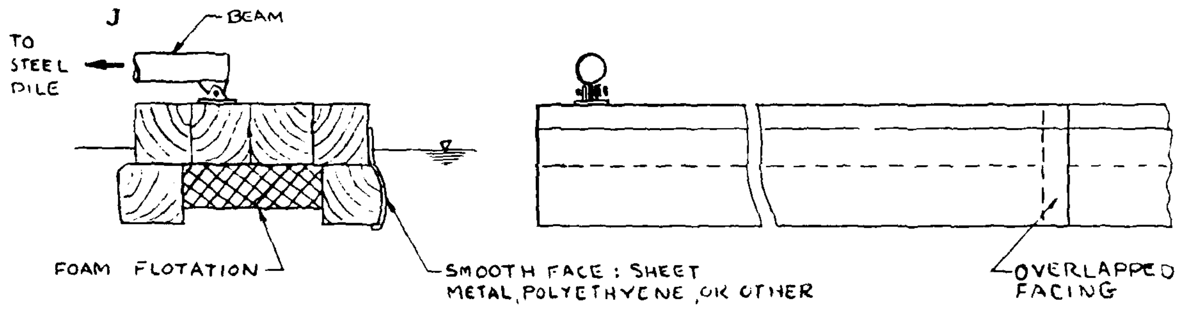
LOG DEFLECTOR BOOM, DOLPHIN ANCHORED

I



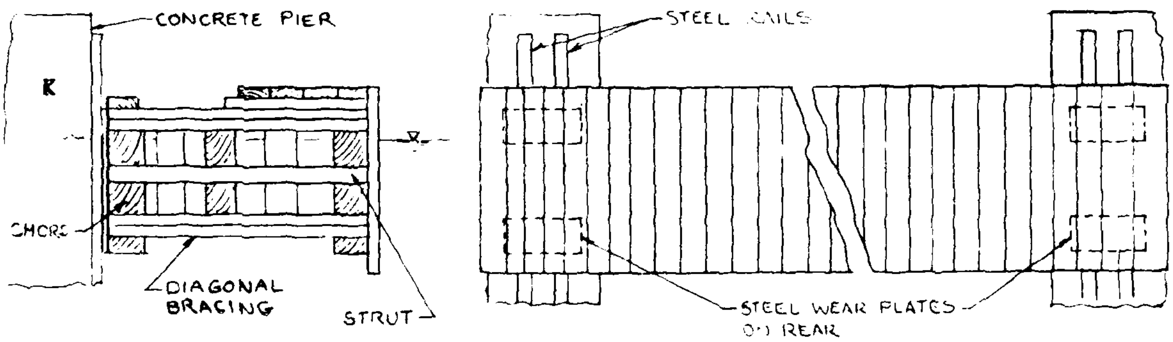
LOG DEFLECTOR BOOM, CABLE ANCHORED

J



FINNISH GUIDE BOOM

K

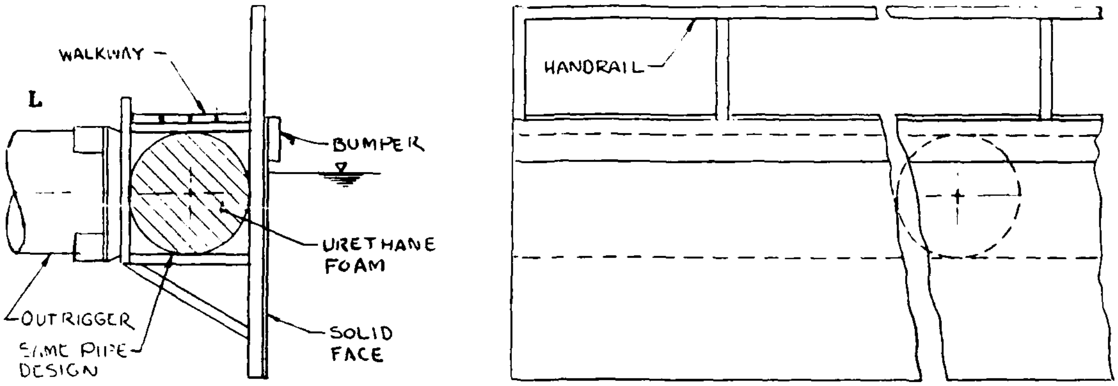


TIMBER TRUSS LOG BOOM

Figure B1. (Sheet 3 of 5)

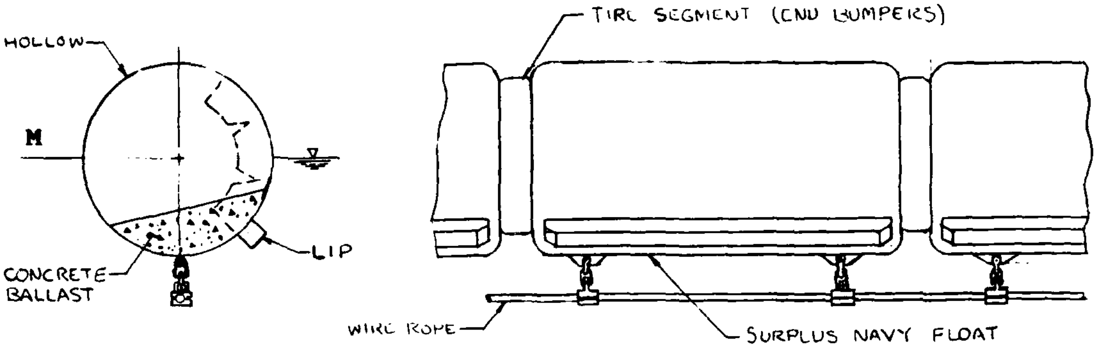
Steel Construction

L



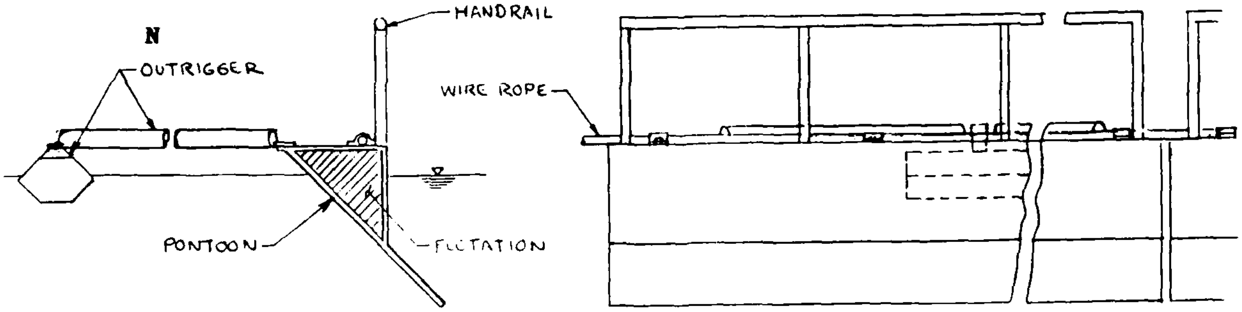
SINGLE PONTOON WITH OUTRIGGER

M



SINGLE PONTOON WITH LIP AND BALLAST

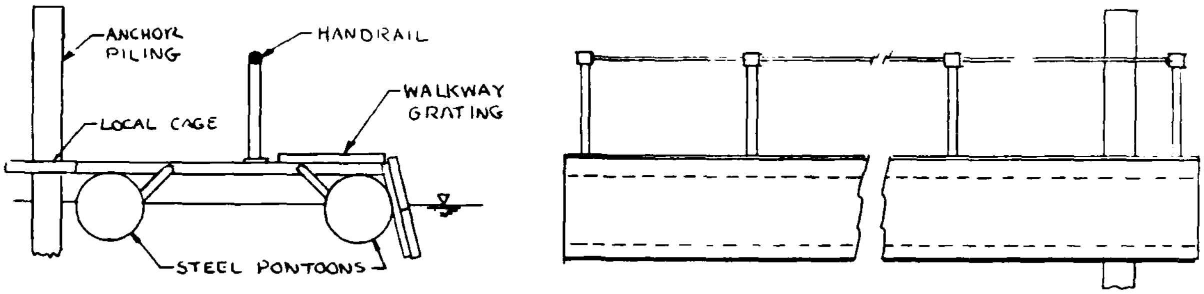
N



SINGLE PONTOON WITH LIP AND OUTRIGGER
(NORWEGIAN GUIDE BOOM)

Figure B1. (Sheet 4 of 5)

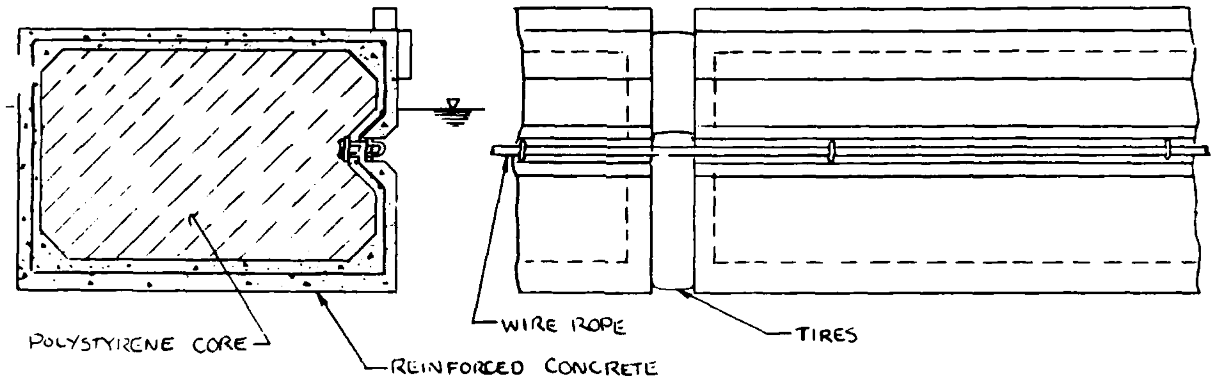
O



DOUBLE PONTOON LOG BOOM

Concrete Construction

P



CONCRETE BOX LOG BOOM
(Design Example)

Note: The above figures are not drawn to any particular scale; nor are all parts in each figure shown in correct proportion.

Figure B1. (Sheet 5 of 5)

LEGEND FOR FIGURE B1

Code Letter	Boom Location or Reference	Source*	Paragraph**	Figure**
A	Kettle River Kettle Falls, WA	Columbia and Kettle River Debris Facilities	33, 37, 38, 45	9
B	Snake River Pomeroy, WA	Lower Granite Lock & Dam Debris Disposal facilities		
C	Hudson River Lake Luzerne, NY	None - Contact this Author		
D	Genesee River Mount Morris, NY	Mount Morris Dam	39	14
E and F	Canada Kennedy & Lazier, 1965	None - Contact this Author		
G	Snake River Ice Harbor, WA	See B Mr. Lynn Reese		
H	Clark Fork River Clark Fork, ID	Clark Fork Debris Control Facilities	41	16
I	Snake River Pomeroy, WA	See B		
J	Finland Jaatinen, S., et al. 1984	None - Contact this Author		
K	Connecticut River Vernon, VT	Vernon Station	36	12
L	Collins River Great Falls Proj., TN	None - Contact this Author or TVA, Norris, TN		
M	Columbia River Bridgeport, WA	Chief Joseph Dam Debris Facilities	40, 47	15

(Continued)

* See Appendix A.
** See main text.

LEGEND FOR FIGURE B1 (Concluded)

Code Letter	Boom Location or Reference	Source*	Paragraph**	Figure**
N	Glomma River Kongsvinger, Norway	None - Contact this Author		
O	Spokane River Spokane, WA	Upriver Hydro-Electric Plant		31 similar
P	Design Memorandum #34, Part B, Debris Disposal Facilities	None - See G or Contact this Author		

APPENDIX C: GLOSSARY

Dead Head - nearly submerged log or tree trunk floating vertically in the water

Drift - floating debris; a commonly used word is "drift wood"

Log Bundle - several logs bundled loosely with wire or metal bands

Log Raft or Flat Raft - logs stored and towed loose inside a series of channel boomsticks

Shear - hoisting apparatus consisting of two or sometimes more upright spars fastened together at their upper ends and having tackle for masting or dis-masting ships or lifting heavy loads (as guns)

Sinker - log that becomes waterlogged and sinks to the bottom

Snag (forestry) - dead tree that remains upright

Snag (navigation) - tree or branch embedded in a lake or streambed and constituting a hazard to navigation

Windrow - row of material raked up to dry before being handled further