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TRASH CONTROL STRUCTURES AND EQUIPMENT: A LITERATURE REVIEW AND SURVEY OF BUREAU OF RECLAMATION EXPERIENCE

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16. ABSTRACT

The Bureau of Reclamation recently initiated research project NM022, Research and Development for Better Trash Screening and Cleaning Devices, as part of the WATER (Water Technology and Environmental Research) program. This report summarizes the results of initial investigations conducted in this research project, including a literature review, a survey of field problems encountered by Regional and Project offices, and site visits to several locations experiencing problems. This report discusses recent innovations in trashrack, trash screen, and trash rake technology, and makes recommendations for further investigations to be conducted under this research project.

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UNITED STATES DEPARTMENT OF THE INTERIOR ★ **BUREAU OF RECLAMATION**

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CONTENTS

Page

FIGURES

Figure

CONTENTS - Continued

INTRODUCTION

Trash control facilities are a vital component of most water resources projects, providing protection for hydroelectric plants, pumping stations, and irrigation structures. On Bureau of Reclamation (Reclamation) projects, these structures must deal with a variety of debris, including aquatic weeds, tumbleweeds, brush, driftwood, and ice. Trash control structures must remove debris that would cause damage or operational difficulties at downstream facilities. Often these structures also must serve as safety barriers, or as barriers to the movement of fish or other aquatic animals.

Operation and maintenance problems associated with trash control facilities cost millions of dollars each year in extra labor, equipment repair costs, and interference with scheduled water deliveries. To reduce the number and severity of these problems, Reclamation has established research project NM022, Research and Development for Better Trash Screening and Cleaning Devices, as part of the WATER (Water Technology and Environmental Research) program.

The goals of the research project are:

- To summarize the current state of the art in trash screening and cleaning equipment.
- To identify significant problems with existing trash control structures and equipment on Reclamation projects.
- To seek solutions to these problems.

The emphasis of the project is on the structures and equipment most commonly encountered on Reclamation projects, namely trashracks, stationary and traveling screens, and mechanical raking equipment. This report discusses recent innovations, some of which will be selected for further testing and development.

The initial phase of the study consisted of a literature review, a survey of Reclamation's regional and project offices, and site visits to the CAP (Central Arizona Project) and San Luis Valley Project.

CONCLUSIONS

1. **Reclamation projects experience significant problems with trash control equipment, causing increased operation and maintenance expenses.** The most common problems reported in the survey of Reclamation projects were as follows:

- Excessive manual raking is required at many sites.

- Problems are caused by sediment deposition in conveyance channels and around intakes and turnouts.

- Catenary- and hoist-and-carriage-type trash rakes have many inherent problems. Catenary-type rakes have been ineffective where debris consists largely of tumbleweeds or stringy aquatic weeds. Hoist-and-carriage-type rakes have been ineffective for stringy aquatic weeds. Both rake designs are susceptible to problems caused by sediment deposition at the trashrack. Maintenance costs have been excessive in some cases.

2. **Developing and using trashracks and screens that clog less readily, are self-cleaning, or are easier to clean will reduce problems associated with manual raking of trashracks.** Perforated plate screens, wedge-wire screens, self-cleaning static screens, self-cleaning turbulent flow screens, and

trashracks with modified crossbars have shown promise in both Reclamation and non-Reclamation experiences. Investigations to determine the effectiveness of these alternatives and establish design parameters will facilitate their future implementation. Experiments to find the best intake configurations may improve the performance of systems now in use.

3. **Upgrading existing equipment to present technology, such as hydraulic-type rakes, will eliminate many problems inherent in older designs of mechanical raking equipment.** Specific mechanical problems and problems with the effectiveness of certain equipment should be dealt with individually by project personnel familiar with the equipment, debris types, and site problems. Project personnel should be encouraged to publicize successful modifications of equipment, such as those described in this report. Projects should pursue the improvement of existing trash control facilities either by replacement or modification of equipment when it is economically beneficial.

4. **Sediment problems at intakes, diversions, and turnouts are usually more closely related to the design of the structure and the sediment loading conditions in the distribution system, than to the particular trash control equipment at the site.** Specific types of trash control equipment are more susceptible to problems caused by sediment deposition. Techniques for reducing sediment problems should be considered for application at sites with significant sediment problems.

5. **Ice is not a major problem for Reclamation projects, based on the survey responses, although it can be a serious problem on some projects, especially those delivering water throughout the year.** Techniques for dealing with ice problems are well developed and can be applied to most Reclamation projects. The most effective method for eliminating problems with ice is heating the trashracks or screens. Recent research shows that the efficiency of trashrack heating systems may be greatly improved by heating only the leading edge of the trashrack bars (Daly et al., 1990).

6. **Projects reporting corrosion problems were few.** Most projects reporting problems have an active corrosion protection and preventive maintenance program. Techniques for the control of corrosion damage are also well developed and can be applied where necessary.

7. **A few projects reported problems with poor screening effectiveness, resulting in downstream problems.** These problems can usually be corrected with smaller screen openings or rack spacings, at the expense of added cleaning and power requirements and increased head loss. These disadvantages may be reduced by using the most effective type of raking or cleaning equipment, trashracks or screens with improved clogging and cleaning characteristics, or automated equipment such as traveling water screens.

RECOMMENDATIONS FOR FURTHER RESEARCH

Based on the results of the literature search, the survey, and site visits, the following items were identified for possible further study under this program:

- Conduct intake configuration studies in the Hydraulic Laboratory to determine if optimum through and bypass velocities exist that will promote self-cleaning action on trashracks and screens installed at turnouts, diversions, and intakes.
- Investigate the effectiveness of and establish design parameters for perforated plate screens, wedge-wire screens, self-cleaning static screens, self-cleaning turbulent flow screens, and

trashracks with modified crossbars. These screens have characteristics that may reduce required cleaning efforts.

- Investigate devices and operational procedures in the laboratory and at field sites that may reduce problems caused by sediment deposition around trashracks, trash screens, and intakes.

TRASH CONTROL STRUCTURES AND EQUIPMENT

The design or selection of specific trash control equipment depends on many site-specific factors. The most important factors considered are:

- Economics
- Type and size of debris at the site
- Quantity of debris at the site
- Seasonal variations in debris occurrence
- Debris disposal options available at the site
- Availability of electric power at the site, possibility of onsite power generation or use of hydraulic head for power
- Downstream equipment that may be affected by debris passing the site
- Type of structure (canal, pumping plant, powerplant, siphon, turnout), and details of any existing trashracks, trash screens, or fish screens
- Discharge amounts and seasonal variations in discharge at the structure
- Flow velocities at the trashrack
- Location of structure, and frequency at which structure will be checked and attended
- Potential for ice formation at the site
- Soil types, water quality, and other factors that may affect corrosion rates
- Preservation of fish
- Safety considerations
- Depth of water

The trash control equipment to be considered includes booms, trashracks, trash screens, combinations of racks and screens, and any associated cleaning equipment required.

Booms

Booms are often provided upstream of spillways, intakes, or screening structures for public safety and to collect large debris before it can reach the gates, trashracks, or screens. Timber boom sticks connected by chains are the most common booms used on Reclamation projects. Other water resources organizations have used a variety of materials in the construction of booms. Reclamation is currently investigating alternatives to the traditional timber booms, including booms constructed from polyethylene culvert pipe or from steel pipe (Wahl, 1992).

Booms also may be useful in the direct control of weeds. The Tennessee Valley Authority recently investigated the use of a curtain boom to divert floating masses of Eurasian watermilfoil past the cooling water intakes of the Widows Creek Fossil Plant on the Tennessee River (Hopping et al., 1991). Model studies showed that a 4-ft-deep curtain could effectively divert the weed masses downriver past the intakes.

Trashracks

Trashracks are required at powerplant and pumping plant intakes and on canals, turnouts, and diversion structures to eliminate the passage of large floating and submerged debris that would cause damage or operational problems at downstream structures and equipment. *Design of Small Dams* (1987), and *Bureau Design Standards No. 3* provide guidance and Reclamation criteria for the design of trashracks.

There are three types of trashracks, distinguished on the basis of construction and installation methods: end-bearing, side-bearing, and integral.

- End-bearing trashracks are the simplest and usually the cheapest of the three types. The trash bars, which run from top to bottom, individually carry the loads into the trashrack structure.

- Side-bearing trashracks are more economical when trash bars are excessively long for an end-bearing design. The side-bearing design uses one or more lateral support beams to make the load spans of the trash bars shorter. The lateral beams carry the loads into guides or grooves in the trashrack structure. Side-bearing trashracks that are to be raked and stacked in tiers must be kept in alignment by providing dowel pins between the panels.

- Integral trashracks are a combination of several panels made up of trash bars with lateral support beams or members. The panels are constructed by either welding or bolting the support members together. The support members make up a multisided, rigid frame that carries the loading into the trashrack supporting structure. Integral trashracks are usually used for deeply submerged intakes and are not intended to be replaced.

Typical trashrack designs on Reclamation projects consist of rows of parallel steel bars with 1- to 12-inch clear spaces between bars, depending on the type of debris present at the site and the equipment to be protected. Crossbar spacing may be dictated by safety requirements, so that persons trapped against the racks can climb above the water surface. Racks must be designed to support forces applied by raking and cleaning equipment, debris, and ice. Racks are also designed to reduce vibrations that could ultimately lead to fatigue failures. Rectangular steel bars are preferred over round stock, because they are less susceptible to clogging and vibration (objects pass partially through a trashrack with round bars, then become firmly lodged). In addition, deep steel bars make the distance between the rack face and the crossbars larger, which makes cleaning operations easier. To simplify cleaning, hand-raked trashracks are usually inclined on the flattest slope possible. Trashracks to be raked mechanically should be sloped 5° to 30° from vertical.

Most trashrack structures are sized to provide a maximum approach velocity of 1 to 2 ft/s. This slow approach velocity reduces head losses, debris collection against the rack, and the possibility of trashrack vibration. This approach velocity also provides a safe condition for intruders such as boaters and swimmers.

An important aspect of the design of trashracks is the head loss caused by the racks. One commonly used equation (Bureau of Reclamation, 1987) relates head loss to the velocity head through the net flow area and a loss coefficient that varies with the ratio of net flow area to gross rack area.

$$H_L = (1.45 - 0.45R - R^2)\frac{V^2}{2g}$$

where:

R = A_{net}/A_{gross}
H_L = Head loss
V = Velocity through net flow area

This formulation permits the use of the equation regardless of the bar shape and angle of the rack and allows estimation of losses under partially clogged conditions. An investigation by Baca (1981) showed that this equation gives more conservative results than others in the literature. The head losses predicted by other methods are usually about 55 percent of those calculated using this equation. A literature search was unable to reveal the source or derivation of this equation. Swaminathan (1963) has recast the equation in terms of the approach velocity, and has developed a curve that can be used to obtain a modified loss coefficient as a function of R.

Head losses across various types of clean trashrack bars can be estimated using U.S. Army Corps of Engineers Hydraulic Design Criteria Sheet 010-7, which combines the results of many investigators. Head loss is dependent on the approach velocity head and a loss coefficient that varies with bar shape and the ratio of bar area to total rack area. These data are for vertically oriented trashracks.

An equation commonly used to estimate losses across inclined trashracks is (Orsborn, 1968; Chow, 1959):

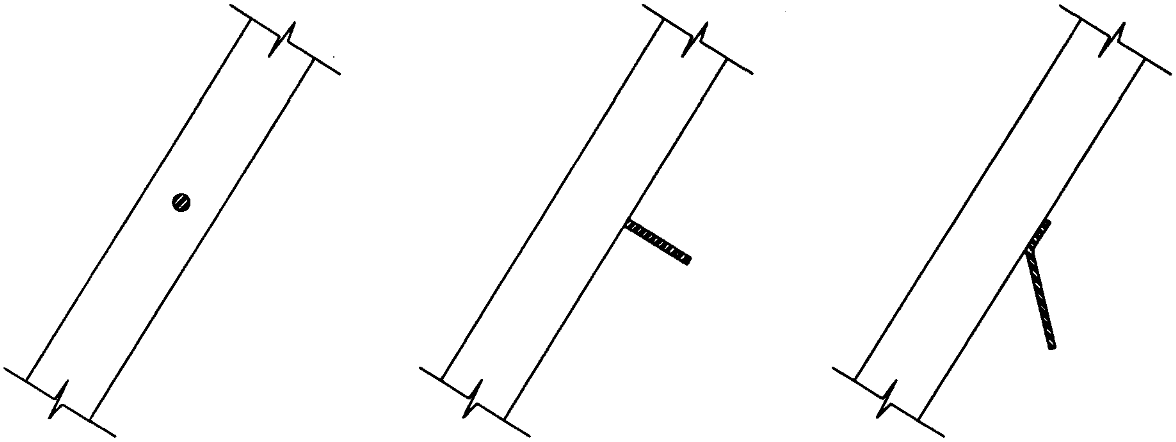
$$H_L = \phi\left(\frac{s}{b}\right)^{4/3}\left(\frac{V^2}{2g}\right)\sin\alpha$$

where:

ϕ = coefficient dependent on bar shape
α = rack inclination from horizontal
V = approach velocity
s = bar thickness
b = clear space between bars

This equation states that head losses reduce to zero for a horizontal rack. However, tests by Yeh and Shrestha (1989) on welded wedge-wire screens showed that head losses reach a minimum value at inclinations of about 30° above horizontal.

A recent innovation in trashrack designs is the use of a modified crossbar. The crossbars of most racks tend to collect debris, because they sit back from the upstream face of the rack bars and cannot be cleaned by the manual or mechanical rakes. The rakes may be modified with longer teeth, but then the rakes hang up on the crossbars. The modified crossbar shown in figure 1 is set at an angle to the flow to induce higher velocities along one side of the crossbar. The nonsymmetrical flow around the bar helps to remove long, stringy debris from the crossbar. This design also makes the trashracks easier to clean, either manually or with mechanical rakes, because the teeth of the rake can now be lengthened so that they contact the crossbar. On standard crossbar designs, the rake teeth hang up when they contact the crossbar. On the modified design the teeth will be deflected by the angled bar and will not hang up on the crossbar. Trashracks with this crossbar design are installed at several sites on Reclamation's Yakima Project and in the Columbia Basin District, and are reportedly working well.



(A) (B) (C)

Figure 1. - Standard Reclamation designs for trashrack crossbars (A and B), and the modified crossbar being used on the Yakima Project and in the Columbia Basin District (C).

Trashracks that encounter debris must be cleaned to prevent buildup of trash on the racks and excessive head loss. Manual cleaning with hand rakes is used where debris loads are light. Mechanical cleaning systems are used at sites where debris loads are large, or where manual cleaning would otherwise be impractical. Cleaning is occasionally done with heavy equipment, such as cranes, backhoes, or clamshell buckets. Mechanical rakes are often automated to begin a rack cleaning cycle when head losses across the racks become excessive. They also may be operated on timers for cleaning at specified intervals. Many systems combine both timers and differential water level sensors.

Mechanical Trash Rakes

Mechanical raking equipment may be supplied during initial construction at sites where debris loads are expected to be large, or where manual raking would be difficult because of the rack configuration. Some common types of mechanical rakes used by Reclamation are catenary, hoist-and-carriage, hydraulic, and backhoe-type trash rakes.

The catenary-type trash rake (fig. 2) consists of a continuous chain of raking beams that travel up the rack face and return along a guided path upstream of the rack. The raking beams contain a plate with teeth cut to match the trashrack bars. When raking, the teeth are perpendicular to the trashrack. At the top of the rake travel, a scraper mechanism removes collected debris from the raking bars. The performance of catenary-type rakes on Reclamation projects has been poor for stringy aquatic weeds and tumbleweeds. Problems have also occurred due to sediment deposition at the trashracks that interferes with the rake operation. As sediment collects around the trashrack, the chains, gears, and other mechanical equipment at the bottom of the trashrack become embedded in the sediment. This increases the wear on these parts, and causes mechanical failures when parts become jammed. Maintenance is also complicated by the fact that part of the rake is always submerged. Capital costs for this type of rake are high because intakes with multiple bays or wide intakes require multiple rakes.

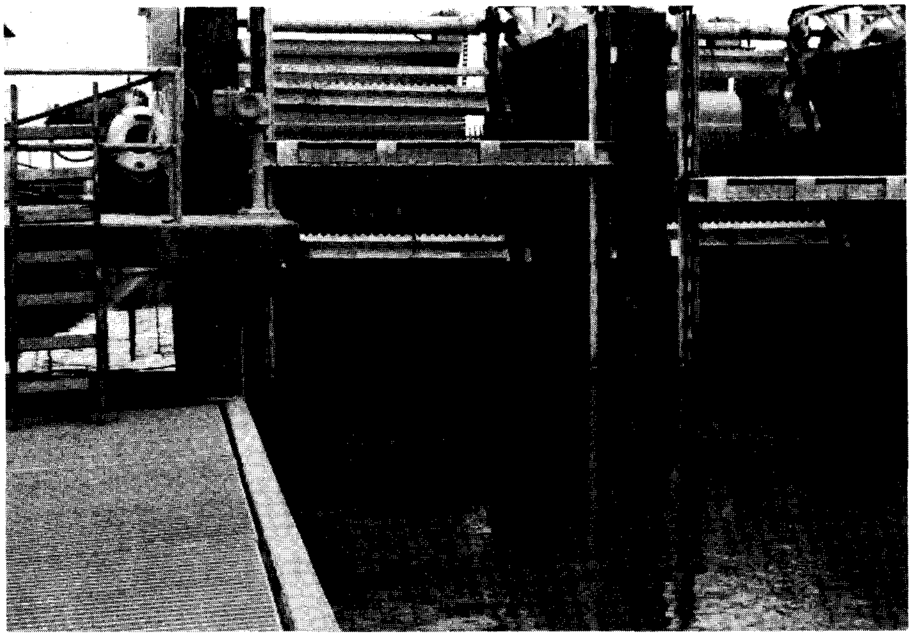


Figure 2. - Catenary-type trash rake installed on the Government Highline Canal near Grand Junction, Colorado. Note the tumbleweeds accumulated in front of the rack.

Figure 3. - Hoist-and-carriage-type trash rakes at Bouse Hills Pumping Plant, Arizona.

Hoist-and-carriage-type trash rakes (fig. 3) have a large rake head that travels in guides mounted along the sides of the trashrack structure, parallel to the trashrack. The rake head folds away from the rack face during the downward travel sequence of the rake operation. At the bottom of the rack, the head swings into position and the teeth extend into the spaces between the rack bars. The rake head is then raised along the trashrack. At the top of the rack, the rake head dumps the collected debris into a trough or other collection system. The rake head never touches the rack itself. The clearance between the rake head and the rack face must be kept to a minimum to obtain effective cleaning. This requires tight tolerances in the manufacturing and installation of the rake, guides, and trashracks. Sediment deposition at the bottom of the trashrack also may interfere with the operation of this rake by preventing the rake head from reaching the bottom of the rack. This prevents the rake head from swinging into raking position. The hoist-and-carriage-type rake has the same cost disadvantages as the catenary rake because multiple bays and wide intakes require multiple rakes.

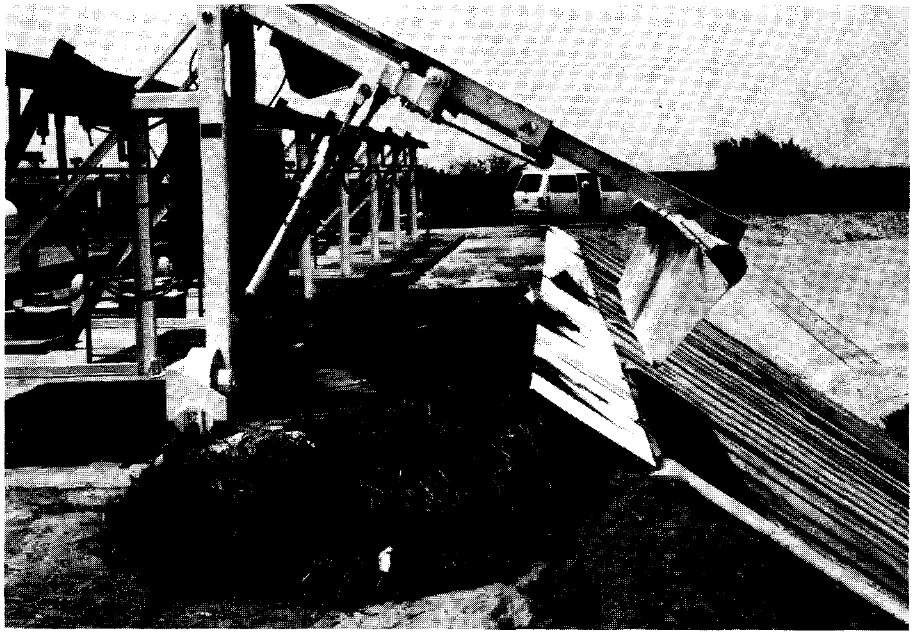


Figure 4. - Indexing hydraulic-type trash rake installed at the Santa Rosa Turnout, Arizona.

The hydraulic-type trash rake (fig. 4) is a new design that mimics the physical motions used in manual raking operations. It consists of a telescoping rake head that lifts clear of the rack face during the downward travel of the rake head. Once fully extended, the rake head swings into position to bear on the rack face. The rake head then retracts along the rack face with the hydraulic system maintaining contact between the rake head and the rack face. At the top of the rack, the rake head continues to retract, pulling weeds completely off the rack face. The rake head can be supplied with or without teeth. These trash rakes have worked well with both stringy weeds and mosses, and bulky weeds such as tumbleweeds. These rakes also have lower maintenance costs due to low numbers of moving parts, and because the entire rake is stored above the water surface when not in use. This allows for easier maintenance and reduces corrosion problems. Also, since there is no mechanical equipment at the bottom of the trashrack, sediment deposition around the base of the trashrack is less likely to cause problems. For use on large rack areas, indexing rake heads can be used so that one rake head serves multiple rack sections. This reduces the cost per unit area in comparison with catenary or hoist-and-carriage-type trash rakes.

The backhoe-type trash rake is a backhoe with a rake or cleaning head installed on it. This trash rake clears weeds, trash, and even large, bulky debris from trashracks. The rake can dump the debris on either side of the rack, can push debris away from the trashrack (at canal or river turnouts) to be carried downstream, or can carry debris along the top of the structure to be dumped at a specific site. Backhoe-type rakes can be designed to operate using electricity, diesel fuel, or gasoline. The rake can be installed on rails mounted on the trashrack deck, or can be provided with rubber tires. In either case, some type of counterweight or support rail is required for stability when lifting.

The backhoe-type rake requires a person to guide the rake. The operator, when sitting in the cab, cannot see the rake head, especially below the water surface and on steeply sloped (near vertical) trashracks. This disadvantage could result in excessive loading on the trashracks due to operator error. Like the hydraulic-type rake, a single unit can be used to clean multiple intakes. Also, when not in operation, all components of the rake are out of the water.

Trash Screens

Trash screens at turnouts and diversions prevent the passage of very fine debris, such as moss or weed seeds, that are undesirable in the diverted flows. Screens also may be used to control fish movements. Typically, screens are protected by upstream trashracks that prevent large debris from damaging the screen material.

Screens may be either traveling or stationary. Traveling screens with automatic cleaning systems, such as high-pressure water jetting, are very effective for small debris removal, but are also expensive. Stationary screens are also effective, but require additional cleaning effort. Intakes are usually sized to provide approach velocities to the screens of about 0.5 ft/s or lower for stationary screens, or 1 ft/s or lower for traveling screens. Higher velocities cause accelerated clogging and make cleaning more difficult.

Traveling Water Screens. - Traveling water screens are used at high-capacity turnouts, or in locations where debris loads are especially heavy. The traveling screen is located some distance downstream of the actual turnout, with trashracks installed at the turnout to remove large debris. The most common materials used for traveling screens on Reclamation projects are stainless steel wire mesh or monofilament mesh screen panels. Screen cleaning cycles may be started manually, or automatically by a differential water level sensor, a timer, or both the timer and sensor, so the cleaning system operates as little as necessary. The preferred cleaning method for traveling screens on Reclamation projects has been the use of high-pressure water spray. Traveling water screens have been very effective but have a high capital cost.

One variation on the typical traveling water screen is the drum screen. Drum screens have been used in canals as part of fish barrier/fish bypass structures. This type of structure diverts fish from the canal and bypasses them back into the river. A trashrack must be located upstream of the drum screens to remove any large debris. The drum screens are submerged to about 0.7 to 0.8 times the diameter of the drum. As the drum rotates, debris that does not pass through the wire mesh but sticks to the screen will be lifted and passed on to the other side. At some installations, a rotating brush is positioned at the downstream water surface to clean debris off the drum. Another cleaning method used is spraying with high-pressure water. Drum screens have been used successfully on the Yakima, Umatilla, and Central Valley Projects.

Stationary Screens. - A variety of stationary screens is used on Reclamation projects, including mesh screens, perforated plate screens, and welded wedge-wire screens. Other innovative screens discussed in the literature include self-cleaning static screens and self-cleaning turbulent flow screens.

Mesh screens. - Mesh screens are the most common type used on Reclamation projects. Typical screen materials are stainless steel or monofilament meshes, with openings sized depending on the type of debris to be removed. These screens are very effective for the removal of small debris and moss-type weeds, but are difficult to clean. Most sites with mesh screens have two sets of screens placed in series, so that one screen is in place while the other is cleaned. The preferred cleaning method for stationary screens is water jetting. However, at sites without power, screens are usually dried, then scrubbed with a stiff brush. Due to the time required for this type of cleaning, additional sets of screen panels may be required.

Perforated plate screens. - The perforated plate screen consists of a plate with punched orifice holes and was developed to address problems with the common mesh-type screen. Perforated plate screens are well suited to areas with moss, because moss lays on the plate, rather than becoming entangled in the mesh fabric. The open area ratio is usually about 50 percent, and does not vary significantly with the size of the orifice holes. Manufacturing requirements limit the hole diameter to the thickness of the plate or smaller. Perforated plate screens have been used on the Government Highline Canal, near Grand Junction, Colorado (Haider, 1989). Performance of the perforated plate screens has been good when approach velocities are 0.3 ft/s or lower.

Effective cleaning methods for perforated plate include water jetting, manual cleaning with a rubber squeegee, vacuuming with a swimming pool-type vacuum, or mechanical cleaning by sweeping bars with bristle brushes. On the Government Highline Canal, a squeegee to push the debris to the bottom of the screen panel is the preferred cleaning procedure. Flow parallel to the screen face then carries the debris on downstream. A vacuum also has been used successfully at this site. The choice of a specific cleaning method depends on the type and amount of debris and the availability of power at the site.

Strong and Ott (1989) report that perforated plate screens with mechanical brush cleaning systems have been used by the CDFG (California Department of Fish & Game) at many sites. However, there are several inherent problems:

- Lack of electric power at remote sites.
- Icing of mechanical equipment.
- Clogging by small rocks, leaves, pine needles, or filamentous algae not efficiently removed by the brushes.
- Requirement for bypass flow along the screen face to carry debris downstream after it is swept off the screen by the brushes. This limits the usefulness of perforated plate at dead-end locations.

Some of these screens have been replaced successfully in recent years by the self-cleaning static screen described below. The installation cost of perforated plate screens has been estimated at about \$150 per ft^3/s (Strong and Ott, 1989).

Karrh (1950) conducted tests to evaluate head loss through a perforated plate fish screen similar to those used by CDFG. These tests compared the head loss through a 16-gauge, perforated plate with 5/32-in-diameter holes staggered on 7/32-in centers, to that through a 19-gauge, galvanized wire screen with 5/32-in-square openings. These screens have similar sizes of openings and thus provide similar debris removal capabilities. Tests were conducted with the screens placed perpendicular to the flow, and at 45° to the flow. With the screens placed perpendicular to the flow, the head loss through the perforated plate was 8.5 to 12 times higher than that through the wire mesh screen for the same discharge and total screen area. When the screens were placed at 45° to the flow, the perforated plate head loss was 5.8 to 8 times higher. The difference in head loss is largely attributed to the difference in the open area ratios of the two screens.

Welded wedge-wire screens. - Welded wedge-wire screens are constructed of wedge shaped wires, mounted so that the minimum clear space between wires is at the upstream face of the screen. A sectional view of a wedge-wire screen panel is shown in figure 5. Any debris small enough to enter the upstream face of the screen will pass through without becoming wedged in the screen. Wedge-wire screens are usually constructed of stainless steel to reduce corrosion. For use on intakes, these screens are often built in a circular configuration (passive water screens) similar to a well screen, and are usually equipped with an air back-flush system to clean the screens. These screens are often arranged in a tee structure, with two drum screens teed onto a single intake pipe. When installed on an intake with flow past the screen, these screens are somewhat self-cleaning, and debris flushed off the screens by the air back-flush system is carried downstream. The intakes to Diamond Creek Pumping Plant at Buffalo Bill Reservoir are currently being fitted with this type of screen. Although the air-burst backflush system will clean the screens, the intakes for this plant are located at the end of a dead-end channel, allowing debris to collect over time around the intakes. Collecting and removing debris occasionally from the intake area will be required.

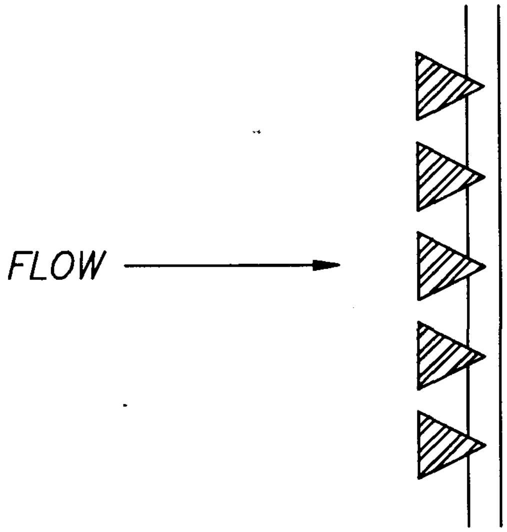


Figure 5. - Sectional view of a welded wedge-wire screen panel.

Drum-type welded wedge-wire screens also can be made somewhat self-cleaning by rotating them in a crossing flow. This technique was evaluated in studies for screens required for the proposed Peripheral Canal in California. The tests showed that small debris still accumulated and eventually clogged the screen, but larger debris was washed off the screen by the crossing flow.

Self-cleaning static screens. - The self-cleaning static screen is an overflow-type screen constructed with wedge-wire panels. The panels are installed on the downstream face of an overflow weir, as shown in figure 6. A layer of water is sliced off by each wire; the solids continue over the panel, and are deposited in a debris pit or other waterway downstream. If flows are high enough, all debris is carried off the screen, along with some bypass flow. When bypass flows are lower, debris will accumulate on the lower portions of the screen. V-notch weirs have been used at some sites to maintain higher unit discharges at low flows, thus maintaining some bypass flow and a self-cleaning action over a wide range of flow conditions.

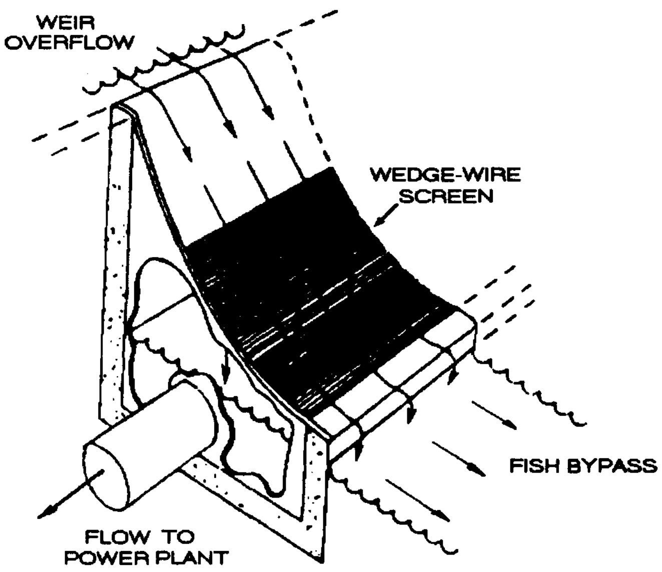


Figure 6. - General arrangement of a self-cleaning static screen used to exclude fish from small hydropower intakes (Strong and Ott, 1989).

The self-cleaning static screen was originally developed for wet screening slurries in the mining industry, and has since been applied at sites in California and Minnesota for screening of small debris, fish, and fish eggs (Strong, 1989; Strong and Ott, 1989; Ott et al., 1988). At sites in California, these screens replaced perforated plate-type fish screens, which had been difficult to maintain due to clogging by leaves. The self-cleaning static screens were found to have lower maintenance requirements than perforated plate, and do not require power to be supplied to the site. The cost of the screening material and supports for self-cleaning static screens has been estimated at \$500 per ft^3/s (Strong and Ott, 1989). The greatest disadvantages of the self-cleaning static screen are the head required for their operation, and the requirement for a bypass flow to maintain the self-cleaning characteristics.

Self-cleaning turbulent flow screens. - The self-cleaning turbulent flow screen (Kemper and Bondurant, 1982) was developed for the removal of fine debris and weed seeds at on-farm sites. Water drops onto a taught horizontal screen that separates the debris from the irrigation water. Vibration of the taught screen helps to move debris to the edges of the screen, so that the screen does not become plugged. If the drop is sufficient, the screen may be placed so that it hangs over the sides of the canal or stilling basin, allowing the debris to fall off the screen into a collection pit on the sides of the canal. Field tests showed that the self-cleaning action of the screen could be improved by the addition of a deflector, paddle wheel, or vortex shedding inducer to increase turbulence in the flow dropping onto the screen. Another variation uses a circular screen fed through the center by a fountain. This design also performed well in field tests, and was reported to have lower head requirements for operation of the screen.

Screen Performance Tests. - Smith and Ferguson (1979) and Smith (1982) reported on an extensive testing program for fish screens on the proposed Peripheral Canal in California. These tests considered clogging, cleaning, and corrosion characteristics of woven wire mesh, perforated plate, and wedge-wire screens. The clogging studies considered both the growth of aquatic organisms on the screens and the effect of debris accumulation. The studies showed that in the Sacramento River environment, clogging by debris accumulation was the critical factor in determining the clogging rate. This is in contrast to studies in salt-water environments in which biofouling was the dominant clogging mechanism.

For screens with similar fish screening efficiency, the perforated plate clogged quickly to a specified level of head loss. Woven wire mesh screens took about 1.5 times as long to clog to a similar head loss level, while welded wedge-wire screens took 3 times as long to clog as perforated plate. The clogging rate for all screens was affected by the debris concentration in the flows approaching the test screen, and the velocity normal to the screen. Correlations were developed to allow prediction of required cleaning frequency as a function of Sacramento River discharges. Tests to evaluate the effect of variations in the velocity component parallel to the screen face showed that the parallel velocity had no significant effect on the clogging rate.

Data were also collected to evaluate the trap efficiency of the tested screens at various levels of clogging. Although one would expect the screens to trap more debris as they become more clogged, in the majority of tests the trap efficiency decreased as the screens became more clogged. As the screen becomes clogged, the through-hole velocity increases, thus dislodging some material already accumulated on the screen. The tests did not identify any significant difference in the trap efficiencies of the different screen types.

Cleaning Options for Trash Screens. - Manual cleaning of stationary screens usually requires removing the screen. If debris is not tightly woven into the screen material, brushes or squeegees can be used to clean the screen immediately after removing it from the water. When debris is more difficult to remove, screen panels may be left to dry before cleaning. Once dry, scrubbing with a stiff brush will usually break the debris loose. In some cases screens may be brushed or cleaned with a squeegee in place.

Numerous mechanical or automatic cleaning options are available depending on the type of screen and debris: high-pressure water jetting; water or electric-operated bristle brushes or squeegees; portable, swimming pool-type vacuum cleaners; or air burst backflush systems, such as those used on cylindrical wedge-wire screens. The testing program for fish screens on the proposed Peripheral Canal in California evaluated the performance of water jetting and wiper brushes for cleaning of wire mesh, perforated plate, and welded wedge-wire screens (Smith and Ferguson, 1979; Smith, 1982). Wiper brushes were tested out of water only, while water jetting was tested both above water and under water. In these tests, all cleaning methods worked well, as measured by residual head loss following the completion of a cleaning cycle. Visually, water jetting with the screens out of water was the most effective.

Two disadvantages of brush cleaning were identified. First, brush cleaning was less effective during the summer algae season, due to algae buildup on the back side of the screens; water jetting did a better job of removing algae on the back side of the screen. Second, brush cleaning of woven wire screens was more difficult, primarily because the woven wire screen is less rigid than perforated plate or welded wedge-wire, and sagged away from the brush between supports. The perforated plate and wedge-wire screens had enough stiffness that good contact was maintained between the brush and screen face.

SURVEY OF RECLAMATION FIELD PROBLEMS

To determine the most common problems being experienced at Reclamation projects, a one-page questionnaire was sent to Reclamation's regional and project offices. Many offices forwarded the questionnaire to individual irrigation districts. A total of 26 offices or irrigation districts responded to the survey, providing information on 85 different sites. Fifteen of these sites reported that their trash control equipment was working satisfactorily. A copy of the questionnaire and results are included in appendix A.

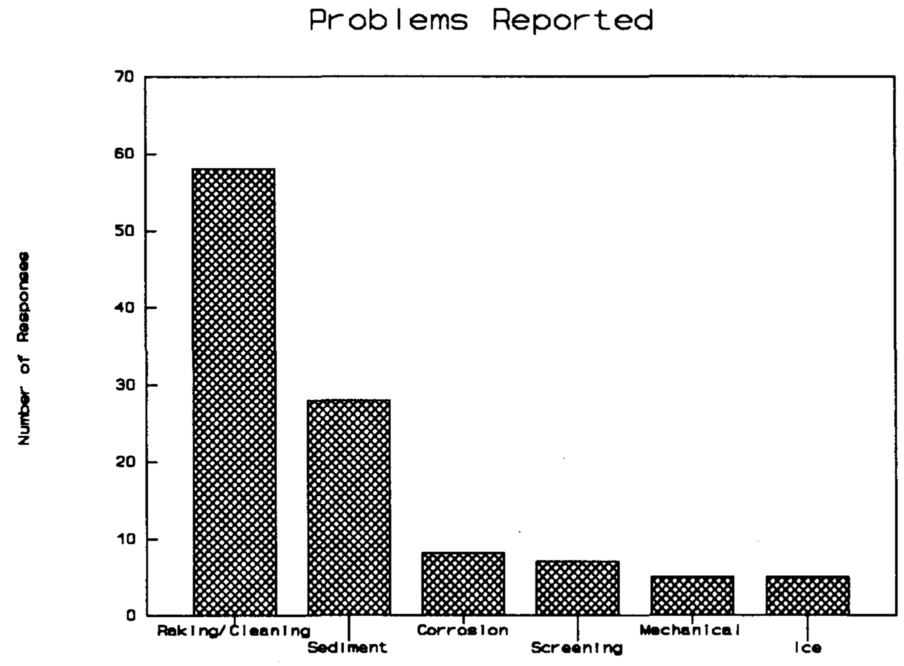


Figure 7. - Problems reported in the survey of project offices and irrigation districts, classified by problem type.

The survey responses are summarized in figure 7, categorized by the type of problem reported. Raking and sediment problems comprised about 77 percent of the survey responses. Other responses are split among corrosion, poor screening efficiency, mechanical problems, and ice problems.

The most common types of debris cited as problems were moss and other aquatic weeds, floating debris and driftwood, windblown weeds, and sediment (fig. 8). No special distinction was made concerning specific weed species.

Approximately two-thirds of the sites reporting raking and cleaning problems use manual cleaning methods (fig. 9). About one-fourth of the sites reporting problems use mechanical rakes or other automated equipment. Eleven percent of the respondents reported the use of other cleaning methods, such as cleaning by divers, or the use of cranes and other heavy equipment.

About 50 percent of the problems reported occur on canals and associated structures, such as turnouts, laterals, and check structures (fig. 10). The remainder of problems identified occur at pumping plant intakes, diversions, and hydropower intakes.

Manual Raking

The majority of raking and cleaning problems were reported for sites where manual raking occurs. Some complaints came from sites without trashracks or screens; trash must be removed by hand when gates or other equipment becomes blocked. Many projects and irrigation districts report significant costs associated

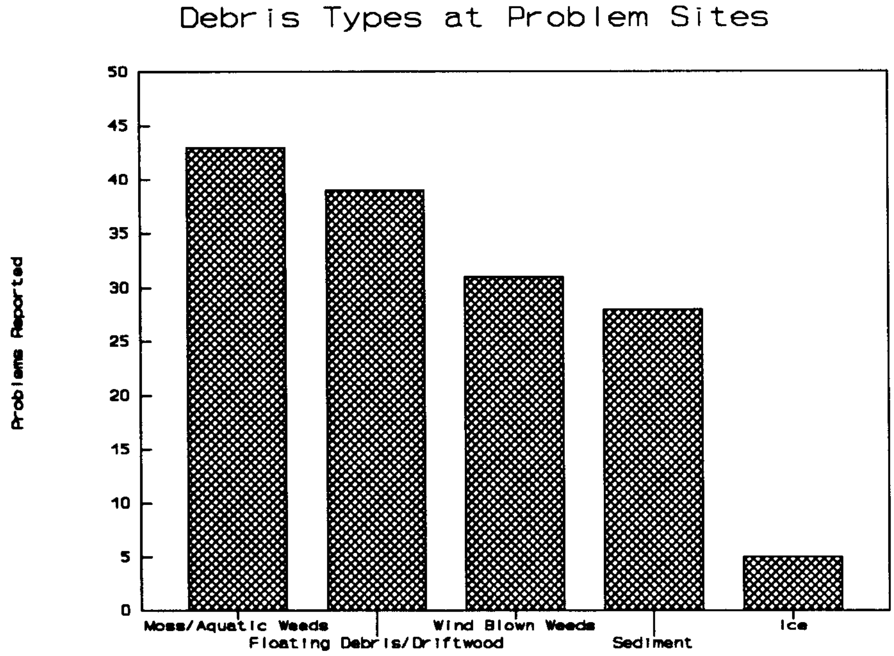


Figure 8. - Types of debris causing problems with trash control equipment.

with manual raking and cleaning, although some projects consider raking and cleaning problems to be no more than a nuisance. Some projects also noted operational problems caused by excessive trash buildup on the racks. Manual raking may be chosen over mechanical raking systems during the design of a project for the following reasons:

- No power available at the site
- Limited construction money available
- Debris loads and associated O&M costs projected to be low

An example where debris loads were projected to be low is the San Luis Valley Project, Closed Basin Division, near Alamosa, Colorado. This project pumps ground water from the Closed Basin for use in satisfying downstream water rights on the Rio Grande River. An extensive network of shallow wells delivers water through closed conduit laterals into a main conveyance channel that eventually discharges into the Rio Grande. Flows are also diverted from the conveyance channel into nearby San Luis Lake and into nearby wetlands. The project is being constructed in phases, and is in the fourth of five phases of development. Flow rates in the conveyance channel are currently well below the final design flows. This has caused excessive weed growth in the canal system, creating severe problems at check structures and turnouts that are primarily manually cleaned. The conveyance channel is constructed with a geomembrane liner to prevent seepage losses from the conveyance channel back into the shallow aquifer. High ground-water levels prohibit the dewatering of the conveyance channel, because excessive uplift pressures would fail the canal liner. The inability to dewater the canal is believed to have increased the weed growth problems. Also, control of weed growth by chemical means is restricted because of the use of the water in the nearby wetlands. The project is currently testing the use of grass carp for weed control.

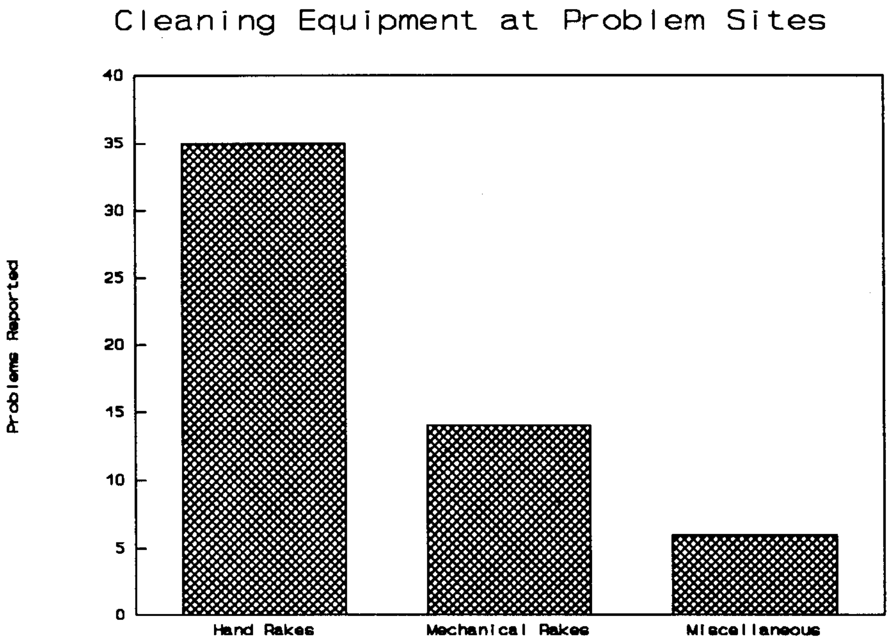


Figure 9. - Cleaning equipment in use at sites reporting problems.

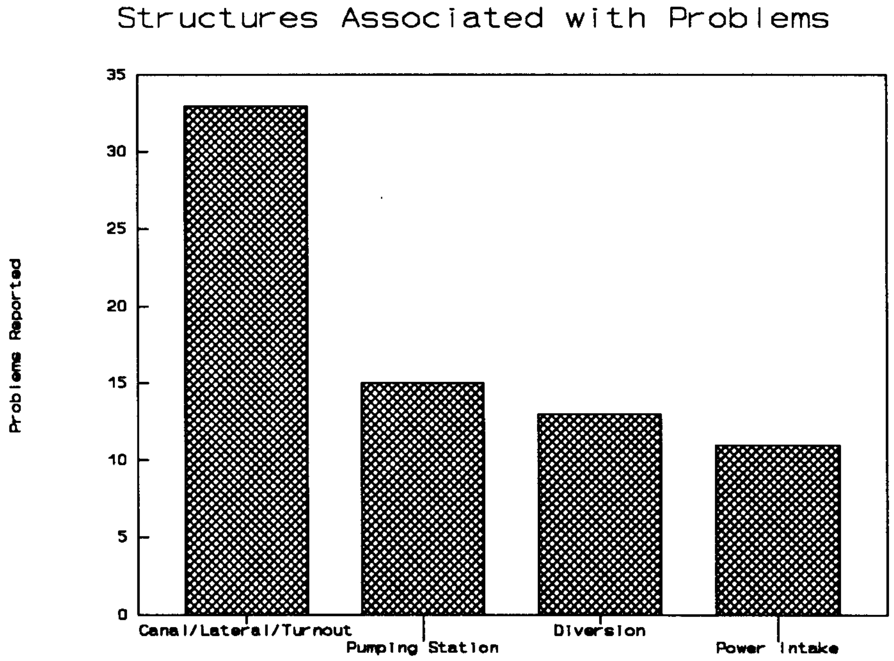


Figure 10. - Types of structures at which problems were reported with trash control equipment in the survey of project offices and irrigation districts.

Mechanical Raking

Several projects reported problems with mechanical raking equipment, either due to ineffective operation, or persistent mechanical problems with the equipment. The CAP has reported problems with catenary-type and hoist-and-carriage type rakes. These rakes have performed poorly with stringy aquatic weeds, and have also suffered from persistent mechanical problems.

Figure 11. - Photograph showing the wiper installed by field personnel on the catenary rakes at Brady Pumping Plant (CAP). The wiper is constructed from rubber conveyor belt.

Eight catenary-type rakes are installed at Brady Pumping Plant on the CAP. The rakes at Brady perform poorly, because long, stringy weeds are difficult to remove from the raking bars. These weeds are either dumped back into the water to be raked again, or become tangled in the mechanical equipment. The rakes are ineffective with tumbleweeds, which simply fall off the narrow raking bar. Field personnel have made several modifications to the scraper bars on these rakes in attempts to improve the removal of debris from the raking bars, eventually replacing them with wipers made from heavy sections of rubber conveyor belt (fig. 11). Even with these changes, workers must manually remove weeds from the trash rake bars.

The San Juan-Chama Project reports that sediment deposition around the base of the trashracks at Oso Diversion Dam has caused failures of the catenary-type trash rakes. The chains and beams that carry debris to the top of the trashrack will not pull through the deposited mud. This causes the drive chain to jump off the drive gear, or shatters the end of the drive shaft. The project has had minor success using compressed air and a long blow pipe to clear sediment away from the base of the trashrack.

A total of 20 hoist-and-carriage type rakes are installed at Bouse Hills and Hassayampa pumping plants on the CAP. These rakes also perform poorly with long, stringy weeds. While the pumping units are in operation, the rake does not efficiently remove weeds from the rack, because the rake does not bear directly on the rack face. Also, the long stringy weeds that are collected by the rake head often fall back into the water, rather than into the collection trough. This is partially due to the clearance between the rake teeth and the concrete headwall, which allows the weeds to fall or be pulled between the headwall and the rake teeth as the rake moves up the headwall. At Hassayampa the rake operation is also hindered by sediment buildup around the bottom of the racks. This sediment buildup prevents the rake head from traveling to the bottom of the rack, thus preventing the rake head from swinging into the raking position.

The CAP has also experienced a variety of mechanical problems with both catenary and hoist-and-carriage type rakes, including problems with hoist cables, drive motor alignment, and limit switch operation. Field personnel have solved many of these problems.

One type of mechanical trash rake that has been used successfully at many Reclamation projects is the hydraulic-type rake. Nearly all survey responses concerning hydraulic-type trash rakes indicated that they are working well. The only significant problem with a hydraulic-type rake was reported by the Grand Coulee Project Hydroelectric Authority for a rake installed on the intakes to Smith Powerplant. Heavy cross currents caused large deflections of the boom and rake head. A heavier duty model is now performing satisfactorily.

The hydraulic-type rake is now the only type of rake being specified for new construction on Reclamation projects. Hydraulic-type rakes have also successfully replaced older style mechanical rakes and have been used to upgrade installations that were previously raked by hand. The CAP has successfully modified two trashrack structures by using hydraulic-type rakes. A small, nonindexing, hydraulic rake was installed at the Harquahala Valley Irrigation District turnout, and the Santa Rosa turnout, which was originally designed to be manually raked, was retrofitted with a large, indexing rake. The PG&E (Pacific Gas & Electric Company) has recently retrofitted four installations with hydraulic-type rakes (Stutsman et al., 1989). The Grand Coulee Project Hydroelectric Authority has also successfully retrofitted several sites using indexing and nonindexing hydraulic-type rakes.

Screening Effectiveness

Some respondents indicated that poor screening of mossy weeds and algae is a problem. Passage of moss and algae can cause problems with downstream equipment such as gates, valves, and flowmeters. The majority of sites reporting this type of problem were only using trashracks to catch the debris. The Yuma Desalting Plant is experiencing severe problems; a rope-type algae passes through the 2-in bar spacing of the intake trashracks or wraps around the rack bars, especially when the upstream irrigators clean the canals. This algae completely clogs the pretreatment system of the plant. Traveling water screens are presently being added to these intakes.

Effective debris removal can be achieved in most cases by reducing the bar spacing, or adding screens with small openings. However, this will increase the amount of debris that must be handled. Such modifications should be planned carefully so that debris loads are accurately estimated, and operation and maintenance costs associated with the modifications are anticipated.

Ice Problems

Ice problems identified in the survey ranged from clogging of trashracks due to frazil ice collecting on rack bars, to icing of exposed portions of mechanical rakes and traveling screens. Burgi and Johnson (1971) provided an extensive review of the ice formation process and Reclamation experiences with ice problems. Through the efforts of Reclamation's Ice Research Management Committee, extensive research has been conducted on ice control using ice booms (Burgi, 1971; Hayes, 1974). Effective control of ice problems can also be obtained using bubblers or heating of trashracks and screens (Logan, 1974).

One design feature that helps reduce icing problems is using discontinuous trashrack bars. At sites where trashrack bars must extend above the water surface, the upper portions of the bars are separated from the lower bars by a gap or a section of material having poor heat transfer properties. This prevents the loss of heat energy from the lower bars during periods of extreme cold above the water surface.

The San Luis Valley Project, Closed Basin Division, recently experienced ice problems on a set of racks installed to prevent migration of grass carp out of the project canals into the Rio Grande River. The racks were constructed from small diameter steel water pipe, and were initially installed before grass carp introduction, to verify that they could be maintained during the winter. Ice buildup completely clogged the racks, and they had to be removed from the canals. The next winter the racks were fitted with resistance heating elements placed inside the rack bars. This system has now been in use through one winter season and has kept the racks free of ice during that time.

Two new approaches to frazil ice control are the use of ice-phobic coating materials and the vibration of trashracks to remove and prevent ice accumulations. Mussalli et al. (1987) conducted tests of frazil ice clogging of trashracks in a refrigerated flume. These tests combined the use of coatings and rack vibration. The tests showed that vibration levels of 15 g for a duration of 1 to 3 minutes were sufficient to both break ice loose, and prevent adherence of ice to coated or uncoated trashracks. The use of a polyamine, 2-part 100 percent epoxy coating also reduced the rate of ice buildup on the rack, and decreased the vibration duration to dislodge ice from the rack. Unfortunately, vibrations of this magnitude may lead to early structural failure of the trashrack, and ice-resistant coatings are easily damaged by debris and cleaning equipment.

Heating of trashracks and screens remain the most effective technique for preventing frazil ice accumulations. Recent research on the frazil ice accumulation process shows that frazil ice first accumulates on the leading edge of trashrack bars. Thus, one need only heat the leading edge of the bars to eliminate frazil ice accumulations. This promises to greatly reduce the power requirements for trashrack heating systems (Daly et al., 1990).

Corrosion

A small number of the survey respondents expressed concern with corrosion. Oversizing components to allow for corrosion has been the typical practice in the past for design of trashracks on Reclamation projects. The use of corrosion resistant materials or other special protective measures has generally not been economical. Most projects responding to the survey with corrosion concerns have an active program of preventive maintenance to minimize problems due to corrosion. The use of sacrificial anodes or impressed currents can greatly reduce corrosion problems. Development of trashracks and trash screens using materials such as stainless steel, plastics, or special protective coatings may help further reduce corrosion problems. Special coatings also may help to reduce problems due to frazil ice as discussed above.

The tests for California's proposed Peripheral Canal included a series of corrosion tests of possible fish screen materials (Smith and Ferguson, 1979; Smith, 1982). Corrosion tests were conducted on perforated plate, wire mesh, and welded wedge-wire screens constructed from mild steel, weathering steel, several types of stainless steel, and two types of aluminum. Algaecide and enamel coatings were tested on mild steel samples, and the aluminum samples were tested with and without protective seal coatings. No other corrosion prevention measures were used. Samples were tested over a 4-year period in an environment similar to the location at which the fish screens would be installed. Perforated plate and welded wedge-wire screens constructed from type 304 stainless steel showed no evidence of corrosion during the test period. Woven wire mesh screens of type 304 stainless steel showed slight corrosion, as did screens constructed from other types of stainless steel. Coatings applied to the mild steel samples slowed the corrosion rate initially, but were ineffective in the long term. Bubbles and fractures in the coatings allowed corrosion to occur, especially at the edges of holes in the perforated plate, and at locations where the wire mesh screens were scratched from handling. The aluminum screens pitted badly and accumulated deposits of aluminum oxide in the screen holes, which were difficult to remove. The uncoated mild steel and weathering steel samples corroded so badly that the samples were lost.

Sediment Deposition

Several projects reported sediment problems affecting the operation of trash raking equipment. One type of trash rake particularly prone to problems with sediment was the hoist-and-carriage type rake. This rake, described previously, has a rake head that swings into position at the bottom of the rack panel. This action is triggered when the rake head reaches the bottom of its travel and engages a trip mechanism. As sediment builds up in the region of the trashrack, the rake head is prevented from traveling to the bottom of the rack, and never reaches the trip mechanism. Other trash rake designs with mechanical components located at the bottom of the trashrack are also susceptible to sediment problems.

In addition to detrimental effects on the trash rake, sediment accumulating around the intakes also may reduce the capacity and efficiency of the intake and cause other operational problems. The majority of projects reporting sediment problems deal with those problems only on an annual basis. During the nonirrigation season sediment deposits can be easily removed. For many structures the costs associated with this annual maintenance are minimal. Higher maintenance costs are incurred if sediment must be removed during canal operation, or if sediment must be removed from a large portion of the distribution system.

Changing the geometry of intakes or the flow channel to control the location of sediment deposition can help alleviate sediment problems. Vanes installed on the channel bed can be useful in this regard (Odgaard and Wang, 1991a, 1991b). Often, successful modifications require detailed hydraulic and/or computer model studies. Studies conducted during the initial design stage can help to avert future sediment problems, especially when the potential for sediment problems has already been identified.

Preventing the passage of fine sediments through trashracks or screens is infeasible due to the fine screen sizes and large intake areas required. Larger gravels and cobbles may be controlled by appropriately designed racks or screens, but present a disposal problem. Often, accumulated sediment can be bypassed downstream periodically through a sluiceway. However, the San Juan-Chama Project reported severe sediment problems despite the presence of a sluiceway. On this project, public concerns over sediment releases have prevented the use of the sluiceways, causing massive sediment accumulations behind Oso, Blanco, and Little Oso diversion dams. These sediment accumulations regularly plug the manually raked trashracks on the project, and interfere with the operation of automatic rakes.

Sedimentation basins are another alternative for sediment control. The size of the basin required is dependent on the flow, sediment quantity, and particle sizes. Periodic cleaning of the basins is required. This may be accomplished by a dredge or by draining the basin and then using a bobcat or front-end loader.

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APPENDIX

Questionnaire and results

QUESTIONNAIRE

Please use one questionnaire sheet for each site or group of similar sites. Attach any additional material to this sheet. Please xerox additional questionnaire sheets if necessary.

Office ____________________
Project Name __________ Site Location __________
Name of person completing questionnaire __________
Contact person for follow-up __________ Phone: __________
Structure type (e.g. canal, pumping plant)__________
Equipment type (e.g. screen, rack, auto/manual) __________
Avg. number of days of operation per year __________

<-----------------------**PROBLEM**----------------------->

	Poor Screening	Raking/ Cleaning	Ice	Corrosion	Sediment	Structural Failure	Specify Other
No. of structures with problem							
Total no. of similar structures on this project							
Maintenance interval to deal with problem							
Days per year that problem exists							
Type of trash causing problem (e.g.aquatic weeds)							
Approx. economic cost of problem (due to downtime, maintenance, etc.)							

In addition to your responses above for this site, please include other details below, including the conditions under which these problems occur, any safety hazards associated with the problem, and drawings, sketches, or photos of the structure. If a solution has been attempted, please describe it, including drawings or photos if possible. Also, estimate the cost of the solution and any benefits derived from it. Please attach additional pages/materials as necessary.

Survey Results

X = Problem Reported
0 = No Problem
F = Problem Fixed

	PROBLEM							DEBRIS						
	Rake/ Clean	Poor Screen	Corr.	Mech.	Ice	Sed.	None	Float Trash	Moss	Aqua. Weeds	Wind Blown Weeds	Drift wood	Ice	Sed.
GP, North Platte R. PO														
8 Kendrick	X					X		X	X		X			X
9 Goshen ID	X					X			X		X			X
10 Gering-Ft. Laramie	X					X			X		X			X
11 Pathfinder ID	X					X			X		X			X
12 Mitchell ID	X					X			X		X			X
13 Farmers ID	X					X			X		X	X		X
14 Farmers ID	X							X	X		X			
15 Northport ID	X					X					X			X
16 Northport ID	X										X			
17 All ID's						X								X
18 Kendrick-Alcova Res.	X					X		X			X			X
19 Guernsey Dam	X		X			X		X			X	X		X
20 Whalen Div. Dam	X					X		X			X			X
21 Pathfinder ID	X	X							X		X	X		
22 Mitchell ID	X							X			X	X		
23 Farmers ID	X							X	X		X			
30 GP, Bostwick ID, Nebr.	X							X						
GP, Belle Fourche PO														
33 South Canal	X	X							X	X				
34 North Canal	X										X			
GP, Bighorn Basin PO														
41 Highland Hanover ID	X								X	X				
42 Upper Bluff ID	X								x					
GP, Montana PO														
64 Canyon Ferry Proj.	X				X	X					X	X	X	X
65 Canyon Ferry Power Pl.							0							
GP, Montana PO														
72 Huntley	X		X			X					X	X		X
73 Yellowtail Dam							0							
77 GP, Missouri-Souris	X										X			
GP, Shosh-Heart Mt. ID														
78 Garland Power Plant							0							
79 Eaglenest Spillway							0	0						
80 Bitter Creek pickup						X		X						X
81 Bauee drain pickup						X		X			X			X
82 Alkali pickup						X								X
UC, Grand Junction PO														
4 Grand Valley	X				X				X				X	
5 Paonia	X							X						
6 Uncompahgre	X					X		X						X
7 Collbran	X								X	X				
29 UC, Flaming Gorge	X											X		
UC, San Luis Valley														
31 Franklin Eddy Canal	X	X			X				X	X	X		X	
32 San Luis Lake	X				X					X			X	

Survey Results [continued]

X = Problem Reported
0 = No Problem
F = Problem Fixed

	PROBLEM							DEBRIS						
	Rake/ Clean	Poor Screen	Corr.	Mech.	Ice	Sed.	None	Float Trash	Moss	Aqua. Weeds	Wind Blown Weeds	Drift wood	Ice	Sed.
UC, NAPI-Farmington,NM														
43 Canals				X		X								X
44 Turnouts	X							X			X			
45 Pumping Plant	X					X			X		X			X
UC, Durango PO														
68 Florida						X						X		X
69 Hammond	X									X	X	X		
70 Mancos						X						X		X
71 Dolores							0							
2 PN, Grand Coulee PO	Boom deterioration											X		
3 PN, Grand Coulee PO			X											
28 PN, Minidoka-Palisades	X											X		
PN, Minidoka PO														
66 Ririe Flood Channel	X									X	X			
67 Minidoka Dam		X			X					X			X	
PN, Grand Coulee Proj. Hydro Authority														
74 PEC 66.0 Power Plant	F						0			F	F			
75 Smith Power Plant	F			F			0			F	F			
76 EBC 4.6 Power Plant	F						0			F	F			
1 MP, Klamath Proj.							0							
MP, Tracy Office (CVP)														
24 Fish Facility	X	X	X	X						X		X		
25 New Melones				X										
26 Tracy Pump Plant	X	X								X	X			
27 O'Neill Pump Plant							0				0			
MP, Fresno Office														
35 San Luis & Coalinga	X		X											
36 Pleasant Valley	X										X			
46 MP, Folsom Office(CVP)	X									X		X		
MP, Shasta Office(CVP)														
47 Shasta Dam			X											
48 Keswick Dam	X	X						X				X		
49 Clear Cr. Tunnel	X							X						
50 Lewiston Dam	X							X		X				
51 Spring Cr. Debris Dam	X											X		
52 Keswick Power Plant	X									X		X		
LC, Arizona PO														
37 Havasu Pump Plant							0							
38 Bouse Hills & other	X			X		X			X	X				X
39 Brady, Red Rock, other	X		X						X	X	X			
40 HVID, Santa Rosa							0							

Survey Results [continued]

X = Problem Reported
0 = No Problem
F = Problem Fixed

	PROBLEM							DEBRIS						
	Rake/ Clean	Poor Screen	Corr.	Mech.	Ice	Sed.	None	Float Trash	Moss	Aqua. Weeds	Wind Blown Weeds	Drift wood	Ice	Sed.
LC, Yuma PO														
56 Coachella	X		X	X						X	X			
57 Wellton-Mohawk I&DD	X									X				
58 Canals	X					X				X				X
59 Major pump stations	X					X				X				X
60 Mid-size pump stations	X					X				X				X
61 Gila Project	X									X				
62 Gila Canal	X							X			X			
63 South Gila Canal	X									X	X			
UC, San Juan-Chama PO														
83 Little Oso Div. Dam	X					X		X		X				X
84 Oso Diversion Dam	X					X		X		X		X		X
85 Blanco Diversion Dam	X					X		X		X		X		X
Total With Problems	58	7	8	5	5	28	0	20	18	25	31	19	5	28
Total With No Problem	0	0	0	0	0	0	15	1	0	0	1	0	0	0
Total W/Problem Fixed	3	0	0	1	0	0	0	0	0	3	3	0	0	0

X = Problem Reported 0 = No Problem F = Problem Fixed	EQUIPMENT									STRUCTURE						
						RAKE										
	None	Boom	Fixed Screen	Trav. Screen	Trash Rack	Hand Raked	Auto Rake	Hydr Rake	Heavy Equip	Canal	Lat-eral	Turn-out	Siphon	Pump Sta.	Power Intake	Diver-sion
GP, North Platte R. PO																
8 Kendrick					X	X				X						
9 Goshen ID					X	X				X						
10 Gering-Ft. Laramie					X	X				X						
11 Pathfinder ID					X	X				X						
12 Mitchell ID					X	X				X						
13 Farmers ID					X	X				X						
14 Farmers ID					X	X						X				
15 Northport ID					X	X				X						
16 Northport ID					X		X			X						
17 All ID's					X							X				
18 Kendrick-Alcova Res.					X	X										X
19 Guernsey Dam					X	X									X	
20 Whalen Div. Dam	X															X
21 Pathfinder ID					X		X									X
22 Mitchell ID	X															X
23 Farmers ID					X	X										X
30 GP, Bostwick ID, Nebr.					X	X				X			X			
GP, Belle Fourche PO																
33 South Canal					X	X				X		X				
34 North Canal					X	X				X		X				
GP, Bighorn Basin PO																
41 Highland Hanover ID					X		X							X		
42 Upper Bluff ID					X		X							X		
GP, Montana PO																
64 Canyon Ferry Proj.					X	X				X						
65 Canyon Ferry Power Pl.					0										0	
GP, Montana PO																
72 Huntley	X															X
73 Yellowtail Dam																
77 GP, Missouri-Souris					X	X								X		
GP, Shosh-Heart Mt. ID																
78 Garland Power Plant															0	
79 Eaglenest Spillway		0								0						
80 Bitter Creek pickup	X										X					
81 Bauee drain pickup	X										X					
82 Alkali pickup					X	X					X					
UC, Grand Junction PO																
4 Grand Valley			X		X	X	X			X				X		
5 Paonia					X	X										X
6 Uncompahgre					X	X										
7 Collbran					X	X										
29 UC, Flaming Gorge					X										X	
UC, San Luis Valley																
31 Franklin Eddy Canal			X		X	X				X						
32 San Luis Lake				X										X		

X = Problem Reported
0 = No Problem
F = Problem Fixed

	EQUIPMENT									STRUCTURE						
						RAKE										
	None	Boom	Fixed Screen	Trav. Screen	Trash Rack	Hand Raked	Auto Rake	Hydr Rake	Heavy Equip	Canal	Lateral	Turnout	Siphon	Pump Sta.	Power Intake	Diversion
UC, NAPI-Farmington,NM																
43 Canals										X						
44 Turnouts					X	X						X				
45 Pumping Plant				X										X		
UC, Durango PO																
68 Florida					X					X						
69 Hammond					X		X							X		
70 Mancos					X											X
71 Dolores					0	0	0							0		
2 PN, Grand Coulee PO		X													X	
3 PN, Grand Coulee PO					X											
28 PN, Minidoka-Palisades					X	X			X						X	
PN, Minidoka PO																
66 Ririe Flood Channel					X	X				X						
67 Minidoka Dam					X	X									X	
PN, Grand Coulee Proj. Hydro Authority																
74 PEC 66.0 Power Plant					F			0		F					F	
75 Smith Power Plant					F			F		F					F	
76 EBC 4.6 Power Plant					F			0		F					F	
1 MP, Klamath Proj.					0				0					0		
MP, Tracy Office (CVP)																
24 Fish Facility					X		X									
25 New Melones				X											X	
26 Tracy Pump Plant		X				X			X					X		
27 O'Neill Pump Plant					0		0							0		
MP, Fresno Office																
35 San Luis & Coalinga				X						X						
36 Pleasant Valley					X		X							X		
46 MP, Folsom Office(CVP)					X				X						X	
MP, Shasta Office(CVP)																
47 Shasta Dam					X										X	
48 Keswick Dam		X													X	
49 Clear Cr. Tunnel			X		X										X	
50 Lewiston Dam					X	X										X
51 Spring Cr. Debris Dam					X											X
52 Keswick Power Plant					X	X	X								X	
53 Trinity Dam					0										0	
54 Whiskeytown Dam					0										0	
55 Spring Creek Intake					0										0	
LC, Arizona PO																
37 Havasu Pump Plant					0									0		
38 Bouse Hills & other					X		X							X		
39 Brady, Red Rock, other					X		X							X		
40 HVID, Santa Rosa					0			0				0				

X = Problem Reported
0 = No Problem
F = Problem Fixed

	EQUIPMENT									STRUCTURE						
						RAKE										
	None	Boom	Fixed Screen	Trav. Screen	Trash Rack	Hand Raked	Auto Rake	Hydr Rake	Heavy Equip	Canal	Lat-eral	Turn-out	Siphon	Pump Sta.	Power Intake	Diver-sion
LC, Yuma PO																
56 Coachella				X						X						
57 Wellton-Mohawk I&DD					X	X				X						
58 Canals					X	X				X						
59 Major pump stations					X	X	X							X		
60 Mid-size pump stations					X		X							X		
61 Gila Project					X	X								X		
62 Gila Canal					X	X				X	X			X		
63 South Gila Canal					X	X				X						
UC, San Juan-Chama PO																
83 Little Oso Div. Dam					X	X			X							X
84 Oso Diversion Dam					X		X		X							X
85 Blanco Diversion Dam					X	X			X							X
Total With Problems	5	3	3	5	56	37	14	0	6	23	4	5	1	15	11	13
Total With No Problem	0	1	0	0	9	1	2	3	1	1	0	1	0	4	5	0
Total W/Problem Fixed	0	0	0	0	3	0	0	1	0	3	0	0	0	0	3	0

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Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.

A free pamphlet is available from the Bureau entitled "Publications for Sale." It describes some of the technical publications currently available, their cost, and how to order them. The pamphlet can be obtained upon request from the Bureau of Reclamation, Attn D-7923A, PO Box 25007, Denver Federal Center, Denver CO 80225-0007.