CALIFORNIA. DEPT. OF WATER RESOURCES.
BULLETIN.

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Survey of Small Hydroelectric ential at Existing Sites California

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ON THE COVER. Camanche Dam, located on the Mokelumne River in San Joaquin County, is owned by the East Bay Municipal Utility District. A 9.4 MW hydroelectric power plant at this location could produce 35 million kilowatthours of electricity annually. Approximately 60,000 barrels of oil are needed to generate this much electricity in a fossil fuel plant.

Photo Courtesy of
East Bay Municipal Utility District

Department of
Water Resources

Bulletin 205

A Survey of Small Hydroelectric Potential at Existing Sites in California

June 1979

Huey D. Johnson
Secretary for Resources
The Resources Agency

Edmund G. Brown Jr.
Governor
State of California

Ronald B. Robie
Director
Department of Water Resources

FOREWORD

In an energy-short society, all environmentally sound energy sources deserve highest priority. To help solve the energy problem in California, the Department of Water Resources is evaluating all possible sources of hydroelectric generation in the State. As indicated in this bulletin, there are many possibilities for small hydroelectric development at existing dams, canals, and pipelines.

In Bulletin 194, Hydroelectric Energy Potential in California (March 1974), the Department identified many potential hydroelectric sites, most with an estimated annual energy potential of more than 25 million kilowatthours. This bulletin expands that earlier study, listing primarily California's existing dams, canals, and other hydraulic facilities with an annual energy potential of less than 25 million kilowatthours. As explained herein, some of the smaller sites previously identified in Bulletin 194 are included. A few sites with an estimated energy potential exceeding 25 million kilowatthours are also included. For the purposes of this bulletin, a potential capacity of 30 megawatts or less is considered a small hydroelectric project.

In 1976, the Department distributed questionnaires to 880 water agencies; from their responses, the Department identified 212 potential sites for small hydroelectric projects. None would require construction of a dam or other hydraulic facilities to develop the potential energy of the falling water. If all 212 sites were developed, they could produce about two billion kilowatthours of electrical energy per year, equivalent to (1) the energy required to supply the residential needs of 950,000 people for one year, or (2) the energy supplied by 3.5 million barrels of oil annually.

The Department of Water Resources supports and encourages hydroelectric projects at existing dam sites where such projects will be economically and environmentally feasible. Small hydroelectric projects can help meet California's energy needs and conserve our nonrenewable fossil fuels.

In Chapter 933 of the Statutes of 1978 the California Legislature directed the Department of Water Resources to study the feasibility and cost effectiveness of equipping dams and other hydraulic structures with electrical power generating facilities. The Department is now conducting that study and will report the results in a future bulletin.

Ronald B. Robie

Ronald B. Robie, Director
Department of Water Resources
The Resources Agency
State of California

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State of California
Department of Water Resources
P. O. Box 388
Sacramento, CA 95802

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DEPARTMENT OF WATER RESOURCES
Ronald B. Robie, Director

Mary Anne Mark
Deputy Director

Gerald Meral
Deputy Director

Robert W. James
Deputy Director

Charles R. Shoemaker
Deputy Director

ENERGY DIVISION

Edward J. Terhaar . . . . Chief

Lloyd H. Harvego . . . . Deputy Chief

This report was prepared under the supervision of

Richard G. Ferreira . . . . Chief, Energy Systems Branch

by

Arnold Johnson . . . . Senior Engineer, Water Resources
Ronald Delparte . . . . Associate Engineer, Water Resources
Do T. Nguyen . . . . Associate Electric Utilities Engineer
Cary W. Meline . . . . Assistant Electrical Engineer

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Tom Y. Fujimoto
Assistant Executive Officer

The California Water Commission serves as a policy advisory body to the Director of Water Resources on all California water resources matters. The nine-member commission provides a water resources forum for the people of the State, acts as liaison between legislative and executive branches of State Government, and coordinates Federal, State, and local water resources efforts.

Lake Matthews, located on a pipeline distribution system in Los Angeles County, is owned by The Metropolitan Water District of Southern California. A 5 megawatt hydroelectric plant at this site could produce 18 million kilowatthours annually. Approximately 31,000 barrels of oil are needed to produce an equivalent amount of energy in a fossil fuel plant.

(Photo Courtesy of The Metropolitan Water District of Southern California)

I. INTRODUCTION

This bulletin presents information on the potential for small hydroelectric developments in California, including (a) an inventory of potential sites such as dams and other hydraulic structures, and (b) a brief discussion of small-scale hydroelectric technology. The economic feasibility of small hydroelectric facilities is constantly improving as the cost of other sources of energy escalates. This bulletin does not address the socioeconomic or environmental aspects of individual projects; in general, however, there are fewer environmental problems with installations at existing facilities than at new developments.

Background

The rapid rise in fuel prices in recent years and the public's increasing concern over the environmental impact of fuel-burning power plants have rekindled interest in the development of clean, renewable, and seemingly neglected small hydroelectric power plants.

Present Trends in Hydropower Development

Before the oil embargo in 1973, fuel costs were relatively low; only major hydropower projects could compete with large-capacity steam-driven generators. Nearly all economically and environmentally acceptable large hydroelectric sites had been developed, primarily due to the attractiveness of their low operating costs and high reliability. However, development of hydropower at small dams was not considered economically feasible. In fact, generation at many small hydropower plants had been discontinued. According to the Federal Energy Regulatory Commission (FERC--formerly, Federal Power Commission), since 1940, at least 770 hydropower plants in the Nation have been abandoned. As a result, hydropower's contribution to the growth of electric generation has gradually decreased. The Edison Electric Institute reports that hydropower supplied 40 percent of the country's electricity in the 1930s, compared to 13 percent today.

Recently, however, the increasing costs of fossil fuels have prompted a reevaluation of small hydroelectric potential, which was previously considered uneconomical. In addition, the reactivation of a number of abandoned plants is now being investigated.

Electric Generation Sources

In addition to existing hydropower, electrical generation is primarily obtained from plants that use natural gas, oil, coal, and nuclear energy. Because almost half of the oil used in the United States in 1977 was imported, the National Energy Act of 1978 provides incentives to increase coal production and develop renewable energy sources. In general, energy costs are continuing to increase, and thermal generating plants are becoming increasingly difficult to develop. Suitable sites for new hydroelectric developments are scarce and under the National Energy Act, oil or gas can no longer be used as the primary fuel in power plants where construction began after April 20, 1977. Temporary and permanent exemptions can be granted under certain conditions, such as the absence of an alternative power supply at reasonable price and distance; unavailability of adequate coal supplies; and site or environmental limitations. In a limited sense, geothermal, solar, wind and other less conventional generating methods will help replace conventional fuels.

Lake Pillsbury (Scott Dam), located on the Eel River in Lake County, is owned by Pacific Gas and Electric Company. A 3 megawatt hydroelectric power plant at this site could produce 10 million kilowatthours of electricity a year. This is equivalent to the amount of electricity used annually by approximately 1,700 residential households.

Advantages of Small Hydroelectric Plants

Hydroelectric plants generally share the basic advantages of high reliability, quick response to demands, and long expected life without consuming fuel resources or polluting air and water. In addition, the development of hydropower at existing dams would involve none of the usual negative effects of an entirely new hydropower project, such as inundation of valuable land, displacement of people, elimination of free-flowing streams, disturbance of fish spawning, and reduction of wildlife habitats. Also, operating costs of hydroelectric plants are lower than those of thermal power plants, because hydropower plants require no fuel, thus providing a hedge against rising fuel costs. Even when built for one purpose, a dam can serve another purpose economically. For example, Monticello Dam (Lake Berryessa) in Northern California was built in 1957, primarily for storage of irrigation water. If turbines and generators were added, the facility could generate about 43 million kilowatt-hours annually.

New or additional hydroelectric generating units can usually be installed at existing dams at less than the cost of equivalent new coal or nuclear installations. Another advantage is that the lead time for installing generation facilities at existing dams is significantly less than the ten years or more required for a large thermal power project.

As shown in Plate I, (page 14), potential sites are widely distributed throughout California. Many of these sites could provide much needed electricity to utilities, which presently rely on imported fuels. Development of hydroelectric power at existing sites can capture wasted unused energy, thereby providing a renewable pollution-free resource.

California's Activities in Small Hydropower Development

Because of the rugged terrain and abundant water runoff in many California locations, hydropower has had a significant role in the development of the State. In 1928, U. S. Forest Service District Engineer Frank E. Bonner summarized the realized and potential developments in a Report to the Federal Power Commission on the Water Powers in California. In 1928, 125 hydroelectric plants were included in the report; 114 of these plants were in California with a total maximum capacity of 1,507 megawatts. The 114 plants included 89 with capacity of 15 megawatts or less. According to a July 1977 report by the U. S. Army Corps of Engineers, California has about 7,000 megawatts in hydropower generating capacity.

Recently, the California Legislature significantly assisted small hydroelectric development when it authorized additional local agencies to construct power facilities and sell power; for example, 1977 legislation[1/] provided the basic authority for municipal water districts and county water agencies to construct and operate power plants. In addition, 1978 legislation[2/] authorized the Santa Clara Valley Water District, created by special act, to construct power facilities and sell power. Legislation[3/] was passed in 1978, which requires the Department of

1/ Chapter 146, Statutes of 1977 (Water Code Sections 71691, 71662, and 71663).

2/ Chapter 417, Statutes of 1978.

3/ Chapter 933, Statutes of 1978.

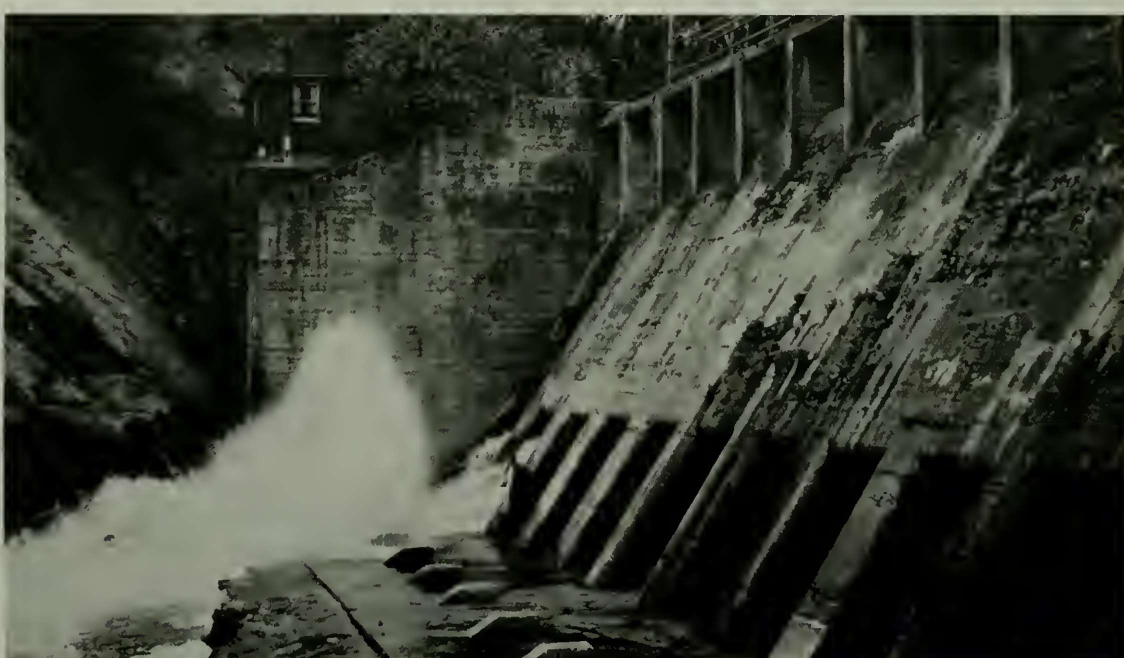
Ruth Reservoir (Robert W. Matthews Dam), located on the Mad River in Trinity County, is owned by the Humboldt Bay Municipal Water District. A 3 megawatt hydroelectric plant at this location could produce 6 million kilowatt-hours of electricity a year. This amount of energy will supply the annual needs of 1,000 residential households.

Water Resources to study the feasibility and cost-effectiveness of equipping existing dams and hydraulic structures with electrical power-generating facilities. The legislation directs the Department of Water Resources to prepare a report specifying those existing dams and hydraulic structures for which retrofitting would be feasible. The report is to be submitted by January 1, 1981, to the Governor, Legislature, California Public Utilities Commission, and the Energy Commission. The Department of Water Resources started work on this program in April 1979.

Various public agencies in California are also evaluating the potential for small hydroelectric developments as a possible new source of energy and revenue to local communities. For example, the Nevada Irrigation District near Auburn, California, is developing a 12-megawatt hydroelectric project at the Rollins Dam on the Bear River to recapture power presently being wasted by energy-dissipating valves. This project will produce 60 million kilowatthours of energy each year.

The economic changes in energy costs have prompted many water agencies to examine their present methods of controlling flow in their water distribution systems. For instance, the Metropolitan Water District of Southern California (MWD) has actively carried out a program to recover part of the energy presently being dissipated by pressure-reducing valves. Phase I of the project consists of five recovery plants with a total capacity of 30 megawatts and an annual output of 180 million kilowatt-hours. Phases II and III consist of ten power plants with a total capacity of 45 megawatts.

In October 1978, the Turlock Irrigation District's Chief Electrical Engineer presented to the Board of Directors a comprehensive list of potential power sources, including installation of a



Clear Lake Dam, located on Cache Creek in Lake County, is owned by the Yolo County Flood Control and Water Conservation District. A one megawatt hydroelectric plant at this site could produce 2 million kilowatthours of electricity annually. This amount of energy will supply the residential needs of 950 persons annually.

mini-hydroelectric generating facility where the Districts main canal spills into the Tuolumne River near Hickman.

On a much larger scale, the Kings River Conservation District (KRCD) plans to construct a 165-megawatt power plant at the existing Pine Flat Dam near Fresno, California. This project will generate over 400 million kilowatthours annually and save the equivalent of about 650,000 barrels of oil each year. The Department signed contracts with both the MWD and KRCD to purchase the power output of their projects.

Federal Activities in Small Hydropower Development

U. S. Department of Energy

In a recent study, the Federal Energy Regulatory Commission (FERC) indicated that there are 113,000 megawatts of undeveloped hydropower in the United States as compared to 66,000 megawatts now in operation. To speed up development, in April 1978, FERC sought to modify its regulatory process by proposing a short-form license for small hydroelectric projects. In September 1978, FERC amended its rules to simplify procedures for licensing small hydroelectric projects of 1.5 megawatts or less, and is now revising regulations for projects of up to 15 megawatts located at existing dams or other facilities.

In late 1977, the Department of Energy (DOE), through its Program Research and Development Announcement (PRDA), solicited proposals to assess the feasibility of adding generating facilities at existing dams with heads less than 20 metres (66 feet) and with installed capacity between 50 kilowatts and 15 megawatts. DOE was interested primarily in diversity to illustrate the feasibility of a wide range of potential sites, developers, and power uses. On April 26, 1978, DOE announced that 56 of 224 proposals were selected for negotiating contracts for DOE funding assistance to evaluate dam sites in 30 states and Puerto Rico, including three in California. The government subsidy is expected to total about $3 million.

Stony Gorge Dam, owned by the U. S. Bureau of Reclamation, is located on Stony Creek in Glenn County. A 6 megawatt hydrolectric plant at this site could produce 14 million kilowatthours of electricity annually. This amount of energy will provide the annual electrical residential needs for 6,700 persons.

In June 1978, DOE issued a Program Opportunity Notice (PON I)to provide financial assistance of up to 25 percent of the cost of design, construction, and operation of generating facilities at existing sites where feasibility studies had been completed. The competition for awards was limited to existing dams with potential capacity of 15 megawatts or less and with heights of up to 20 metres (66 feet). DOE received 23 applications before the deadline, November 1, 1978. In February 1979, DOE announced that seven projects were awarded grants totaling $4.2 million.

As part of the National Energy Act, the Secretary of Energy was directed to establish a loan program to encourage the development of small hydroelectric power projects at existing dams not currently used for power generation. Authorized are loans up to 90 percent of the cost of feasibility studies and up to 75 percent of project costs. The term of the loan may not exceed 10 years for feasibility studies and 30 years for project costs.

A total of $10 million in loans for feasibility studies has been authorized for each of FY 1978, FY 1979 and FY 1980; such funds are to remain available until expended. Congress has appropriated $10 million for feasibility study loans but has not appropriated funds for construction loans.

In January 1978, DOE and the City of Idaho Falls, Idaho, entered into a cooperative agreement to demonstrate the economic feasibility of using bulb turbines to increase the hydroelectric generating capacity at the City's three existing small dam sites, from 5 megawatts to 22 megawatts. DOE will provide $7.3 million of the estimated cost of $43.8 million.

Early in 1979, DOE announced its plan to issue a PON II program in June 1979, to solicit additional proposals for hydroelectric demonstration projects at existing dams. This PON II will coincide with the completion of the feasibility studies being performed under the Program Research and Development Announcement. The competition for funds is not limited to projects for which DOE funded feasibility studies. All proposed projects must have an installed capacity of 25 megawatts or less. Because of the new "Small-Scale Hydroelectric" criteria set forth in the National Energy Act, there will no longer be a 20-metre head limitation.

U. S. Army Corps of Engineers

In a study released in July 1977, the U. S. Army Corps of Engineers (USCE) reported that less than 3 percent of the 50,000 dams in the country produce power, and estimated that a nationwide capacity of 54,600 megawatts could be developed at existing dams under 100 feet high, each with a power potential of less than 5 megawatts. Such facilities could produce collectively 85 billion kilowatt-hours annually.

U. S. Bureau of Reclamation (USBR)

In February 1977, the USBR issued a report on its Western Energy Expansion Study, focusing on hydropower development at both new and existing dam sites. USBR significantly increased its hydroelectric planning activities in FY 1978, and its General Investigation Program in FY 1979. In December 1978, USBR, in cooperation with DOE, awarded the Tudor Engineering Company in San Francisco a $264,570 contract to study the economic potential of low-head hydropower generation in the United States. The purpose of the 21-month study is to develop cost data to compare with the costs of alternative energy sources and help identify the most economically feasible lower limit of head.

Also in cooperation with DOE, the Bureau is sponsoring a study of the marketability of energy produced by low-head hydroelectric generation. The study is being conducted under contract by Systems Control, Inc., of Palo Alto, California. The study began in June 1978 and should be completed by July 1979, at an estimated cost of $59,000.

The Bureau's FY 1979 budget contains funds for appraisal studies of small hydropower projects, including the Red Bluff Diversion Dam in California, and three other sites in Montana, Wyoming, and Idaho. However, the Bureau's planning process takes one to two years for appraisal studies and an additional one to two years for feasibility studies. Therefore, actual construction of such facilities may be a decade away.

II. SURVEY OF POTENTIAL CALIFORNIA SITES

The Department of Water Resources (DWR) Bulletin 194, Hydroelectric Energy Potential in California (March 1974), identified most of the potential sites for hydroelectric development with an energy potential of 25 million kilowatthours or greater. Bulletin 205 tabulates small hydroelectric sites in California, including several small sites previously identified in Bulletin 194. Some sites with an annual output greater than 25 million kilowatthours that were not reported in Bulletin 194 are also included in this report.

In preparing this bulletin, DWR conducted a survey of water agencies throughout the State to identify additional, and primarily small sites, where energy could be developed from existing hydraulic facilities (dams, canals, and pipelines) not presently equipped with generating facilities. Questionnaires were distributed to 880 water agencies, and a preliminary report was issued in August 1976. Many additional responses were subsequently received as a result of a follow-up survey. A total of sixty percent of the 880 agencies responded to the survey.

The survey identified 212 sites with a total capacity of 450 megawatts and an estimated energy potential of 2 billion kilowatthours annually. Most sites have a potential of 2 megawatts or under and would produce less than 10 million kilowatthours per year. The total annual energy of 2 billion kilowatthours is equivalent to the energy produced by burning about 3.5 million barrels of oil in a thermal power plant.

In the survey questionnaire, water agencies were asked to furnish information concerning previous studies of each hydroelectric site. In some cases, the data on potential sites reported by water agencies were insufficient to enable estimates of capacity and potential energy generation; these sites are so indicated in Table 1, which presents the results of the survey.

Some smaller sites may not be economically feasible, because the limited energy potential would not warrant construction of additional civil works and new transmission lines to load centers. Economic feasibility of small potential sites is enhanced when they are located near load centers and require only minimum modifications. Studies now being conducted under Chapter 933, Statutes of 1978, which requires the Department of Water Resources to study the feasibility and cost-effectiveness of equipping existing dams and hydraulic structures with electrical power-generating facilities, will identify those sites which could be economically developed. The larger sites, about 20 percent of the sites shown in Tables 2 and 3, are likely to be economically feasible.

At existing dams, these small hydropower developments would have little adverse environmental effect, and could help conserve dwindling supplies of fossil fuels. In each case, the environmental impact of installing a power plant would have to be analyzed, but unless the downstream flow will be significantly changed, the impact should be minimal. The impact of new power lines would also have to be considered.

Table 1

Small Hydroelectric Sites Survey
Hydroelectric Potential at Existing Facilities

Owner	County	Site Name	Estimated Capacity, MW	Estimated Energy, Million kWh/yr	Status of Investigation 0/
1. Academy Water District	Fresno	Unknown	*	*	1
2. Adamson Companies	Los Angeles	Rindge Dam	0.6	**	1
3. Amador County Water Agency	Amador	Jackson-Sutter Creek Outfall Pipeline	0.06	**	2
4. Anderson-Cottonwood Irrigation District	Shasta	Anderson Flume Diversion	0.1	**	1
		Lake Redding (ACID Diversion Dam)	9.0	50	2
5. Bakersfield, City of	Kern	Kern River Diversion (4 total)	2.6	*	1
6. Bard Water District	Imperial	New Siphon Drop (Canal)	2.0	9	1
7. Big Bear Municipal Water District	San Bernardino	Big Bear Dam	0.04	**	1
8. Browns Valley Irrigation District	Yuba	Harding Canal	2.2	*	1
	Yuba	Merle Collins Reservoir (Virginia Ranch Dam)	1.8	*	1
	Yuba	Upper Main Canal	0.4	*	1
9. Calaveras County Water District	Calaveras	White Pines Dam	0.1	**	2
10. Calistoga, City of	Napa	Kimball Creek Dam	*	*	1
11. California Youth Authority	Amador	Preston School of Industry (Dam)	*	*	1
12. California State Department of Finance	Napa	Rector Creek Dam	*	*	1
13. California State Dept. of Water Resources	Plumas	Antelope Dam	1.0	3	2
	Los Angeles	Castaic Outlet (Dam)	0.3	1	2
	Los Angeles	Cottonwood No. 1 (Canal)	15.0	115	3
	Los Angeles	Cottonwood No. 2 (Canal)	12.0	90	2
	Alameda	Del Valle Stream Release (Dam)	0.4	1	2
	Plumas	Frenchman Dam	2.0	3	2
	Plumas	Lake Davis (Grizzly Valley Dam)	2.0	3	2
	San Bernardino	Las Flores Turnout (Canal)	0.2	**	2
	Butte	Palermo Canal Release (Dam)	0.4	2	2
	Los Angeles	Pyramid Stream Release (Dam)	2.0	4	2
	San Bernardino	Silverwood Lake Inlet (Canal)	5.0	30	2
	Butte	Thermalito Afterbay River Outlet (Dam)	9.0	45	2
	Butte	Thermalito Diversion Dam	4.0	23	2

* Insufficient data received
** Under one million kWh
0/ Status of study or investigation:
1. Unknown
2. Preliminary investigation complete
3. Feasibility studies complete
4. Under construction

Table 1 (Contd)

Small Hydroelectric Sites Survey
Hydroelectric Potential at Existing Facilities

Owner	County	Site Name	Estimated Capacity, MW	Estimated Energy, Million kWh/yr	Status of Investigation 0/
14. Calleguas Municipal Water District	Ventura	Conejo Pump Station	*	*	1
15. Chowchilla Water District	Madera	Ash Main Canal	0.1	*	1
	Madera	Califa Canal	0.2	*	1
	Madera	Madera Canal (2 Sites)	2.8	*	1
	Madera	Main Canal (3 Sites)	0.8	*	1
16. Contra Costa County Water District	Contra Costa	Mallard Reservoir (Pipeline)	0.2	*	1
17. Cucamonga County Water District	San Bernardino	Deer Creek Collection Pipeline	0.2	1	1
18. East Bay Municipal Utility District	San Joaquin	Camanche Dam	9.4	35	3
19. El Dorado Irrigation District	El Dorado	Distribution System, Pipelines (14 total)	2.7	*	1
20. Fresno Irrigation District	Fresno	Fresno Main Canal	0.5	1	1
	Fresno	Fresno Headworks (Canal)	0.5	1	1
21. Glendale, City of	Los Angeles	Distribution System (Pipeline)	0.4	1	1
22. Humboldt Bay Municipal Water District	Trinity	Ruth Reservoir (Robert W. Matthews Dam)	1.6	8	1
23. Jackson Valley Irrigation District	Amador	Lake Amador (Jackson Creek Dam)	*	*	1
24. Los Angeles County Flood Control District	Los Angeles	Alamitos Barrier (Dam)	0.3	1	1
	Los Angeles	Big Dalton Dam	0.03	**	1
	Los Angeles	Big Tujunga No. 1 Dam	0.7	2	1
	Los Angeles	Cogswell Dam	0.8	3	1
	Los Angeles	Dominguez Gap Barrier (Pipeline)	0.5	2	1
	Los Angeles	Pacoima Dam	0.4	1	1
	Los Angeles	San Dimas Dam	0.1	**	1
	Los Angeles	San Gabriel Dam	6.0	17	2
	Los Angeles	Santa Anita Dam	0.3	**	1
	Los Angeles	West Coast Basin Barrier (Pipeline)	2.0	7	1
25. Los Angeles Department of Water and Power	Los Angeles	Franklin Inlet (Pipeline)	0.8	7	3
	Los Angeles	Stone Canyon Dam	0.3	3	3
	Los Angeles	Van Owen Regulating (Pipeline)	0.6	5	3
	Los Angeles	16 Other Sites on Distribution System	5.4	34	2
26. Lost Hills Water District	Kern	Eastside Pipeline	1.0	3	1
27. Mammoth County Water District	Mono	Lake Mary & Twin Lakes Open Diversion (Pipeline)	0.3	**	2
28. Merced Irrigation District	Merced	Canal Drops (7 total)	5.0	18	2

* Insufficient data received
** Under one million kWh
0/ Status of study or investigation:
1. Unknown
2. Preliminary investigation complete
3. Feasibility studies complete
4. Under construction

Table 1 (Contd)

Small Hydroelectric Sites Survey
Hydroelectric Potential at Existing Facilities

Owner	County	Site Name	Estimated Capacity, MW	Estimated Energy, Million kWh/yr	Status of Investigation 0/
29. The Metropolitan Water District of Southern California	Riverside	Corona (Pipeline)	3.0	15	3
	Los Angeles	Covina (Pipeline)	3.0	17	3
	Orange	Coyote Creek (Pipeline)	3.0	24	3
	Los Angeles	Foothill Feeder (Pipeline)	9.0	60	4
	Los Angeles	Greg Avenue (Pipeline)	0.7	4	4
	Riverside	Lake Mathews Outlet (Pipeline)	5.0	18	4
	Riverside	Perris Dam	7.0	41	3
	San Diego	Red Mountain (Pipeline)	3.5	30	2
	Los Angeles	Rio Hondo (Pipeline)	2.0	12	3
	Los Angeles	San Dimas (Pipeline)	10.0	68	3
	Orange	Santiago Creek (Pipeline)	3.0	16	3
	Los Angeles	Sepulveda Canyon (Pipeline)	9.0	56	3
	Riverside	Temescal (Pipeline)	3.0	15	3
	Los Angeles	Venice (Pipeline)	10.0	60	3
	Orange	Yorba Linda Feeder (Pipeline)	5.0	34	3
30. Modesto Irrigation District	Stanislaus	Modesto Reservoir (Dam)	1.0	3	1
	Stanislaus	Stone Drop (Canal)	1.0	4	1
31. Montague Water Conservation District	Siskiyou	Lake Shastina (Shasta River Dam No. 60)	0.2	**	1
32. Monte Vista County Water District	San Bernardino	Benson Feeder Pipeline	*	*	1
33. Montecito County Water District	Santa Barbara	Jameson Lake (Juncal Dam)	0.06	**	1
	Santa Barbara	S. Portal Doulton Tunnel	0.2	2	1
	Santa Barbara	Picay Pressure Break (Pipeline)	0.1	**	1
34. Monterey County Flood Control & Water Conservation District	San Luis Obispo	San Antonio Dam	6.0	26	2
35. Napa, City of	Napa	Lake Hennessey (Conn Creek Dam)	*	*	1
	Napa	Milliken Dam	*	*	1
36. Nevada Irrigation District	Nevada	Bowman Dam	3.0	15	2
	Nevada	Combie Dam	0.9	4	2
	Nevada	Jackson Meadows Dam	4.0	9	2
	Nevada	Rollins Dam	12.0	60	4
	Nevada	Scotts Flat Dam	*	*	1
37. Oakdale Irrigation District	Calaveras	Goodwin Dam	1.0	4	2
38. Orange County Water District	Orange	Pipelines (2 sites)	*	*	1
39. Oroville-Wyandotte Irrigation District	Plumas	Little Grass Valley Dam	14.0	70	2
	Butte	Sly Creek Dam	10.0	45	2
40. Pacheco Pass Water District	Santa Clara	Pacheco Lake (North Fork Dam)	0.06	**	1

* Insufficient data received
** Under one million kWh
0/ Status of study or investigation:
1. Unknown
2. Preliminary investigation complete
3. Feasibility studies complete
4. Under construction

Table 1 (Contd)

Small Hydroelectric Sites Survey
Hydroelectric Potential at Existing Facilities

Owner	County	Site Name	Estimated Capacity, MW	Estimated Energy, Million kWh/yr	Status of Investigation 0/
41. Palmdale Water District	Los Angeles	Little Rock Dam (No Storage Allowed)	*	*	1
42. Paradise Irrigation District	Butte	Paradise Dam	0.5	2	2
43. Pacific Gas and Electric Company	Lake	Lake Pillsbury (Scott Dam)	3.0	10	2
	Tuolumne	Lyons Dam	0.1	**	1
	Placer	South Canal	8.0	37	2
44. People's Ditch Company	Tulare	People's Weir (Canal)	*	*	1
45. Placer County Water Agency	Placer	Hell Hole Reservoir (Lower Hell Hole Dam)	0.4	3	1
46. Plumas County Flood Control & Water Conservation District	Plumas	Lake Davis-Portola Pipeline	*	*	1
47. San Bernardino Valley Municipal Water District	San Bernardino	City Creek Turnout (Pipeline)	2.0	3	3
	San Bernardino	Lytle Creek Turnout (Pipeline)	1.3	8	3
	San Bernardino	Santa Ana Low Turnout (Pipeline)	1.4	4	3
	San Bernardino	Sweetwater Turnout (Pipeline)	0.9	2	3
	San Bernardino	Waterman Canyon Turnout (Pipeline)	4.0	7	3
48. San Diego, City of	San Diego	Point Loma Wastewater Treatment Plant (Pipeline)	1.2	8	1
49. San Diego County Water Authority	San Diego	Alvarado Treatment Plant (Pipeline)	1.1	7	2
	San Diego	Miramar Filtration Plant (Pipeline)	0.9	4	2
	San Diego	San Vicente Reservoir (Pipeline)	0.3	3	2
	San Diego	Sweetwater Reservoir (Pipeline)	0.6	4	2
50. San Dieguito Water District & Santa Fe Irrigation District	San Diego	Water Filtration Pipelines No. 3 & 4	1.0	4	1
51. San Francisco, City & County of	Tuolumne	Hetch Hetchy Reservoir (O'Shaughnessy Dam)	2.5	6	2
	Tuolumne	Moccasin Lower Dam	1.5	12	2
52. San Juan Suburban Water District	Placer	Sidney N. Peterson Water Treatment Plant	0.4	*	1
53. San Luis Obispo County Flood Control & Water Conservation District	San Luis Obispo	Lopez Dam	0.05	**	1
	San Luis Obispo	Terminal Reservoir Inlet Pipeline	0.08	**	1

* Insufficient data received
** Under one million kWh
0/ Status of study or investigation:
1. Unknown
2. Preliminary investigation complete
3. Feasibility studies complete
4. Under construction

Table 1 (Contd)

Small Hydroelectric Sites Survey
Hydroelectric Potential at Existing Facilities

Owner	County	Site Name	Estimated Capacity, MW	Estimated Energy, Million kWh/yr	Status of Investigation 0/
54. Santa Barbara, City of	Santa Barbara	Gilbraltar Dam	0.07	**	2
55. Santa Clara Valley Water District	Santa Clara	Almaden Dam	0.03	**	2
	Santa Clara	Calero Dam	0.2	**	2
	Santa Clara	Coyote Dam	0.3	**	3
	Santa Clara	Guadalupe Dam	0.1	**	2
	Santa Clara	Leroy Anderson Dam	2.0	6	3
	Santa Clara	Lexington Dam	1.0	3	2
	Santa Clara	San Felipe Pipeline	6.0	17	2
	Santa Clara	Stevens Creek Dam	0.1	**	2
56. Santa Monica, City of	Los Angeles	Distribution System (Pipeline)	0.3	1	1
57. Siskiyou County Flood Control & Water Conservation District	Siskiyou	Box Canyon Dam	4.0	20	2
58. South San Joaquin Irrigation District	Stanislaus	Frankenheimer Drop (Canal)	4.0	12	2
	San Joaquin	Parker Drop (Canal)	0.3	**	2
	Stanislaus	Woodward Dam	2.0	6	3
59. South Sutter Water District	Placer	Camp Far West Dam	4.0	17	2
60. South Tahoe Public Utility District	Alpine	Indian Creek Dam	0.05	**	1
61. Thermalito Irrigation District	Butte	Concow Dam	*	*	1
62. Tulare Lake Basin Water Storage District	Kings	Laterals A & B Chutes (Canal)	3.0	11	1
63. Turlock Irrigation District	Stanislaus	Canal Drop No. 1	3.3	12	4
	Stanislaus	Canal Drop No. 9	1.1	5	4
	Merced	Canal Drops (3 others)	1.5	8	2
	Stanislaus	Ceres Spillway (Canal)	2.0	5	2
	Stanislaus	Dawson Lake Dam	3.0	15	2
	Stanislaus	Hickman Spillway (Canal)	2.0	5	3
64. U. S. Army Corps of Engineers	Tehama	Black Butte Dam	5.0	34	1
	Madera	Buchanan Dam	2.0	9	1
	Madera	Hidden Dam	2.0	8	1
	Kern	Isabella Dam	20.0	50	2
	Tulare	Lake Kaweah (Terminus Dam)	17.0	38	2
	Mendocino	Lake Mendocino (Coyote Valley Dam)	4.0	10	1
	Calaveras	New Hogan Dam	2.0	8	2
	Tulare	Success Dam	3.0	7	2
65. U. S. Bureau of Reclamation	Imperial	All American Canal Drop No. 1	4.7	27	2
	Imperial	All American Canal Drop No. 5	5.0	24	2
	Nevada	Boca Dam	1.5	6	2
	Ventura	Casitas Dam	0.7	2	1

* Insufficient Data received
** Under one million kWh
0/ Status of study or investigation:
1. Unknown
2. Preliminary investigation complete
3. Feasibility studies complete
4. Under construction

Table 1 (Contd)

Small Hydroelectric Sites Survey
Hydroelectric Potential at Existing Facilities

Owner	County	Site Name	Estimated Capacity, MW	Estimated Energy, Million kWh/yr	Status of Investigation 0/
65. U. S. Bureau of Reclamation (Contd)	Contra Costa	Contra Loma Dam	*	*	1
	Colusa	East Park Dam	0.9	2	1
	El Dorado	Jenkinson Lake (Sly Park Dam)	0.4	3	1
	Napa	Lake Berryessa (Monticello Dam)	15.0	43	2
	Fresno	Millerton Lake (Friant Dam)	23.0	100	2
	Nevada	Prosser Creek Dam	1.0	5	2
	Tehama	Red Bluff Diversion Dam	11.0	70	2
	Santa Barbara	S. Portal Tecolote Tunnel Tunnel	0.2	1	1
	Sierra	Stampede Dam	3.0	16	2
	Glenn	Stony Gorge Dam	6.0	14	1
	Shasta	Whiskeytown Dam	3.0	11	2
66. United Water Conservation District	Ventura	Lake Piru (Santa Felicia Dam)	1.0	3	1
67. Ventura County Flood Control District	Ventura	Matilija Dam	0.7	2	1
68. Yolo County Flood Control & Water Conservation District	Lake	Clear Lake Impounding Dam	1.0	2	2
	Lake	Indian Valley Dam	4.2	5	2
		Total	456.13	2,000	

* Insufficient Data received
** Under one million kWh
0/ Status of study or investigation:
1. Unknown
2. Preliminary investigation complete
3. Feasibility studies complete
4. Under construction

Table 2

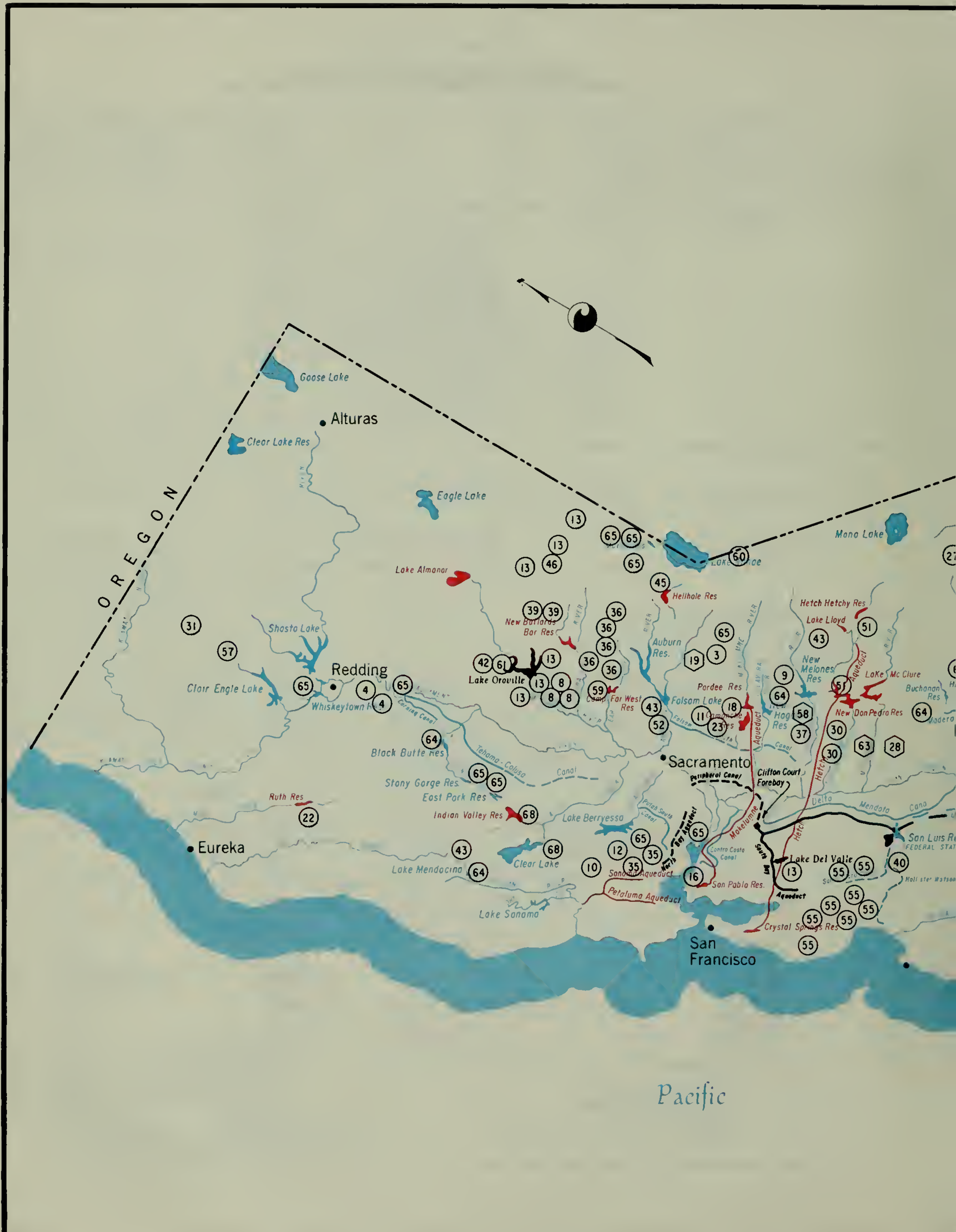
Small Hydroelectric Sites Survey
Distribution of Sites by
Estimated Energy Generation

Annual Energy, Million kWh	Sites
Under 1	39
1 to 5	56
6 to 10	21
11 to 20	21
21 to 40	12
41 to 60	10
61 to 90	3
100 to 115	2
Subtotal	164
Number of sites with insufficient data received	48
TOTAL	212

Table 3

Small Hydroelectric Sites Survey
Distribution of Sites by
Estimated Capacity

Installed Capacity, Megawatts	Sites
0.5 and under	87
0.6 to 2.5	55
3 to 4	24
5 to 10	20
11 to 20	8
21 to 30	1
Subtotal	195
Number of sites with insufficient data received	17
TOTAL	212


OREGON
Goose Lake
Alturas
Clear Lake Res
Eagle Lake
Lake Almanor
Shasta Lake
Redding
Clair Engle Lake
Whiskeytown Res
Corning Canal
Black Butte Res
Tehama-Colusa Canal
Stony Gorge Res
East Park Res
Indian Valley Res
Ruth Res
Eureka
Lake Mendocino
Clear Lake
Lake Sonoma
Lake Berryessa
Putah South Canal
North Bay Aqueduct
Sonoma Aqueduct
Petaluma Aqueduct
Contra Costa Canal
San Pablo Res.
San Francisco
Crystal Springs Res
Lake Del Valle
South Bay Aqueduct
Clifton Court Forebay
Peripheral Canal
Sacramento
Mokelumne Aqueduct
Hetch Hetchy Aqueduct
Delta Mendota Canal
San Luis Res
FEDERAL STATE
Lake Oroville
New Bullards Bar Res
Hellhole Res
Auburn Res.
Folsom Lake
Folsom Canal
Camp Far West Res
Pardee Res
Camanche Res
New Hogan Res
New Melones Res
Hetch Hetchy Res
Lake Lloyd
Lake Mc Clure
New Don Pedro Res
Buchanan Res
Mono Lake
Pacific

SMALL HYDROELECTRIC SITE SURVEY

Site Location

DWR ENERGY DIVISION- 1979

III. PROGRESS ON SMALL HYDROPOWER DEVELOPMENT

In the years following the 1973 oil embargo, with its rapidly escalating oil prices, several public agencies examined their own facilities for potential power development. From this examination 38 sites have been determined to be economically attractive and are now in various stages of development.

Construction has started at six of these sites, representing a total installed capacity of 30 megawatts (MW) and an average annual generation of 160 million kilowatthours. Final designs of several sites are in progress, 17 license or preliminary permit applications have been or will soon be filed with the Federal Energy Regulatory Commission (FERC), and feasibility studies are under way at a number of additional sites.

The following 38 sites, under seventeen agencies or jurisdictions, have a total installed capacity of 230 MW and an

Monticello Dam, on Putah Creek, built in 1957 by the U. S. Bureau of Reclamation at Lake Berryessa in Napa County. A hydroelectric power plant here could generate about 43 million kilowatthours of electricity annually, energy that would replace the need for about 73,000 barrels of oil per year in a conventional power plant.

Box Canyon Dam, owned by Siskiyou County Flood Control and Water Conservation District, is located on the Sacramento River in Siskiyou County. A 4 MW hydroelectric power plant at this site could produce 20 million kilowatthours of electricity annually. This is equivalent to burning 34,000 barrels of oil in a fossil fuel plant.

average annual generation of approximately 1.1 billion kilowatthours.

Box Canyon Dam -- Owned by Siskiyou County Flood Control and Water Conservation District and located on the Sacramento River. In April 1977, the District filed an application for a preliminary permit with FERC for development of a 4 MW power plant. The owner is negotiating with prospective purchasers.

Camanche Dam -- Owned by the East Bay Municipal Utility District and located on the Mokelumne River. The District has a preliminary permit from FERC for development of this project. Construction of a 9.4 MW power plant is scheduled to begin by May 1981. Negotiations are under way for a power purchaser.

Camp Far West Dam -- Owned by the South Sutter Water District and located on the Bear River. Owner is meeting with prospective power purchaser for the planned development of a 4 to 5 MW power plant. The District plans to file an application with FERC in September 1979 for a preliminary permit to develop the project.

Canal Drop No. 1 -- Owned by the Turlock Irrigation District and located at Turlock Lake. A 3.3 MW power plant is under construction and is scheduled for completion by June 1980.

Canal Drop No. 9 -- Owned by the Turlock Irrigation District and located on the Main Canal near Hickman. Construction of a 1.1 MW power plant is scheduled for completion by July 1979.

Cottonwood -- Owned by Department of Water Resources and located on the East Branch of the California Aqueduct. Development of a 15 MW power plant is in the final design stage and construction is scheduled for completion in 1984.

A second power plant will be built at this site in conjunction with the planned future enlargement of the East Branch of the California Aqueduct. The size of the plant will depend on the need for additional water in the area.

Coyote Valley Dam -- Owned by the U. S. Army Corps of Engineers and located on the East Fork of the Russian River, Mendocino County. On June 13, 1978, the FERC issued a Notice of Application for Preliminary Permit filed by the City of Ukiah for development of a 4 MW power plant.

Friant Dam -- Owned by the U. S. Bureau of Reclamation and located on the San Joaquin River. In December 1978, the Terra Bella Irrigation District filed an application for a preliminary permit with FERC for development of a 22.7 MW power plant.

Lytle Creek Turnout -- Owned by the San Bernardino Valley Municipal Water District and located on the Lytle Creek Pipeline, San Bernardino County. On May 15, 1979, FERC issued a Notice of Application for Preliminary Permit for development of a 1.3 MW power plant.

MWD Hydro -- Owned by The Metropolitan Water District of Southern California and located on distribution facilities in Los Angeles, Orange and Riverside Counties. Phase I development has five recovery plants with a total capacity of 30 MW. Construction of the first power house will be completed in 1979, three more will go on line in 1980, and the fifth will be completed in 1981.

Phase II and III developments have 10 recovery powerhouses with a total capacity of 45 MW. These plants are scheduled for commercial operation in the early 1980s.

Monticello Dam -- Owned by the USBR and located on Putah Creek. In April 1979, FERC granted a preliminary permit to the Solano Irrigation District for a planned 15 MW power plant.

New Hogan Dam -- Owned by the U. S. Army Corps of Engineers and located on the Calaveras River. In January 1979, the Calaveras County Water District filed an application for a preliminary permit with FERC to develop a 2 MW power plant.

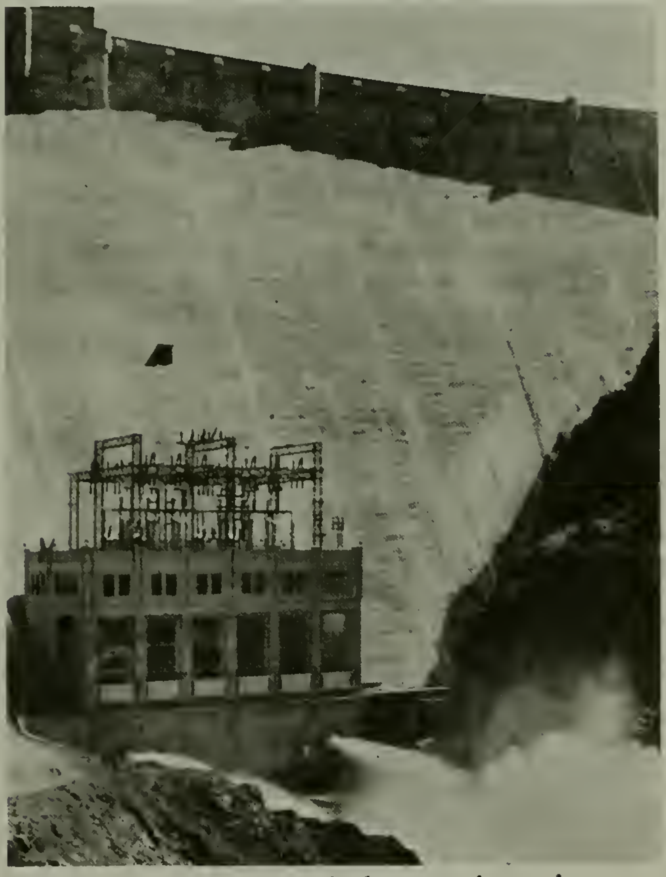
Red Bluff Diversion Dam -- Owned by the U. S. Bureau of Reclamation and located on the Sacramento River. In December 1977, the City of Redding filed an application for a preliminary permit with FERC, and in January 1978, the County of Tehama also filed a competing application for development of an 11 MW power plant.

Rollins Dam -- Owned by the Nevada Irrigation District and located on the Bear River. A 12 MW power plant presently under construction is scheduled for completion by December 1979.

San Antonio Dam -- Owned by the Monterey County Flood Control and Water Conservation District and located on the San Antonio River. In June 1979, FERC issued a preliminary permit for development of a 6 MW power plant. The owner is seeking a power purchaser.

Santa Ana Low Turnout -- Owned by the San Bernardino Valley Municipal Water District and located on the Foothill Pipeline, San Bernardino County. On May 15, 1979, the FERC issued a Notice of Application for Preliminary Permit for development of a 1.4 MW power plant.

Sly Creek Dam -- Owned by the Oroville-Wyandotte Irrigation District and located



Pardee Dam on the Mokelumne River in Amador County, Owned by the East Bay Municipal Utility District. An enlarged 28 MW hydroelectric plant at Pardee Dam could produce 108 million kilowatthours of electricity annually. This amount of energy is equivalent to burning 184,000 barrels of oil in a fossil fuel plant.

on Lost Creek in Butte County. The District plans to apply, in November 1979, for an amendment to their FERC license for construction of a 10 MW power plant at this site.

Sweetwater Turnout -- Owned by the San Bernardino Valley Municipal Water District and located on the Foothill Pipeline, San Bernardino County. On May 15, 1979, the FERC issued a Notice of Application for Preliminary Permit for development of a 0.9 MW power plant.

Thermalito Afterbay River Outlet Dam -- Owned by Department of Water Resources and located on the Feather River. Development of a 9 MW power plant is in the feasibility study stage.

Thermalito Diversion Dam -- Owned by Department of Water Resources and located on the Feather River below Oroville Dam. Development of a 1.5 to 4 MW power plant is in the feasibility study stage.

Waterman Canyon Turnout -- Owned by the San Bernardino Valley Municipal Water District and located on the Foothill Pipeline, San Bernardino County. On May 15, 1979, FERC issued a Notice of Application for Preliminary Permit for development of a 4 MW power plant.

Whiskeytown Dam -- Owned by the U. S. Bureau of Reclamation and located on Clear Creek, Shasta County. In November 1978, the City of Redding filed an application for a preliminary permit with FERC for development of a 4 MW power plant.

Woodward Dam -- Owned by the South San Joaquin Irrigation District and located on Simmons Creek, Stanislaus County. In September 1978, the owner filed a FERC application for a preliminary permit to develop a 2 MW power plant.

IV. AVAILABLE HYDROELECTRIC TECHNOLOGY

The United States hydroelectric industry has undergone a significant change over the past 70 to 100 years. Originally, our mills were powered by water wheels, and small hydroelectric plants were widespread. At first, these small plants, which could generate sufficient power for local use, were considered quite efficient. Then, as the demand for electrical energy--and the need to transmit it long distances--increased, the trend toward large, centralized plants began, and small hydroelectric plants became less cost-effective. In addition, alternative generating facilities, such as thermal plants, were developed. At that time, the capital investment required to develop a thermal plant was lower than that required for a comparable hydroelectric plant. That, coupled with the abundance of low-cost fossil fuels, led to the gradual demise of small hydroelectric developments.

However, as fossil fuels have increased in cost and environmental restrictions have gradually reduced thermal-plant efficiences, interest in developing small hydroelectric projects has been renewed. Whereas small hydroelectric plant technology has existed for many years in the United States, European countries have made more extensive use of low-head facilities for power generation. Consequently, much of the small hydroelectric water-turbine technology has been developed outside North America. Today, however, the recent renewed interest in small hydroelectric power throughout the United States--particularly at existing dams--has encouraged manufacturers to develop low-head turbines for hydroelectric application.

A major United States Corporation now markets standardized turbine-generator units that operate over a wide range of specific speeds. The availability of these predesigned units has significantly reduced engineering and design costs; furthermore, advanced development of control systems associated with small hydroelectric plants has further reduced operating costs by minimizing the need for operating personnel. Several foreign manufacturers also have standardized units and are prepared to market their equipment in the United States to meet this growing demand for low-head turbines.

The following descriptions of various hydroelectric turbines used at small hydroelectric sites reflect the adaptability and application of present technology to specific problems of most sites. Most hydroelectric sites in the United States with high heads have already been developed; therefore, small hydroelectric projects will generally deal with low to moderate heads (up to 20 metres, or 66 feet) using either (1) a propeller turbine or cross-flow impulse turbine for low heads, or (2) a Francis turbine for moderate heads.

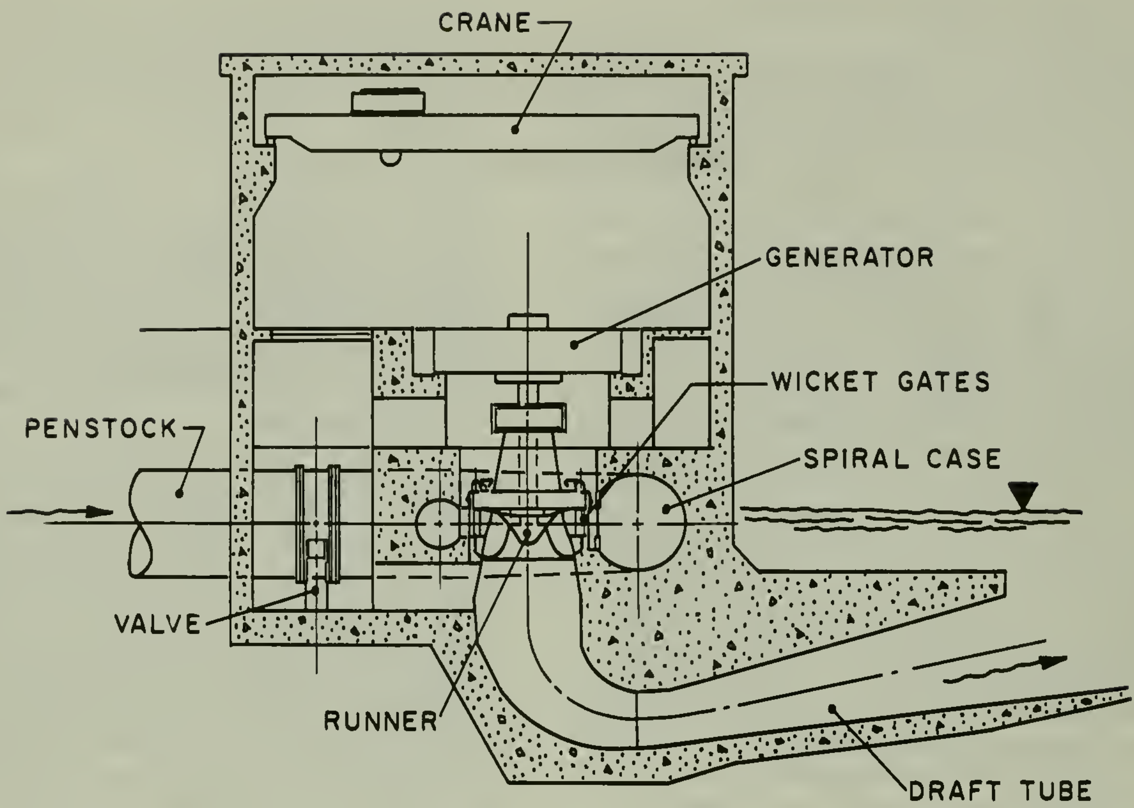


FIGURE 1. FRANCIS TURBINE

Francis turbines are generally used for medium-head range of between 45 to 460 metres (150 to 1,500 feet). They commonly consist of a spiral case to guide the water, a vertical or horizontal shaft runner, and an elbow type draft tube. The typical water flow in a Francis runner is first radially outward, gradually changing to axial.

Adjustable vanes, called wicket gates, control the quantity and direction of the flow of water to the runner to achieve greatest efficiency under a limited range of operating conditions. After leaving the runner, the water enters a draft tube that gradually increases in cross-sectional area to reduce the velocity of the discharged water. The Francis turbine is efficient over a relatively small range of operating conditions.

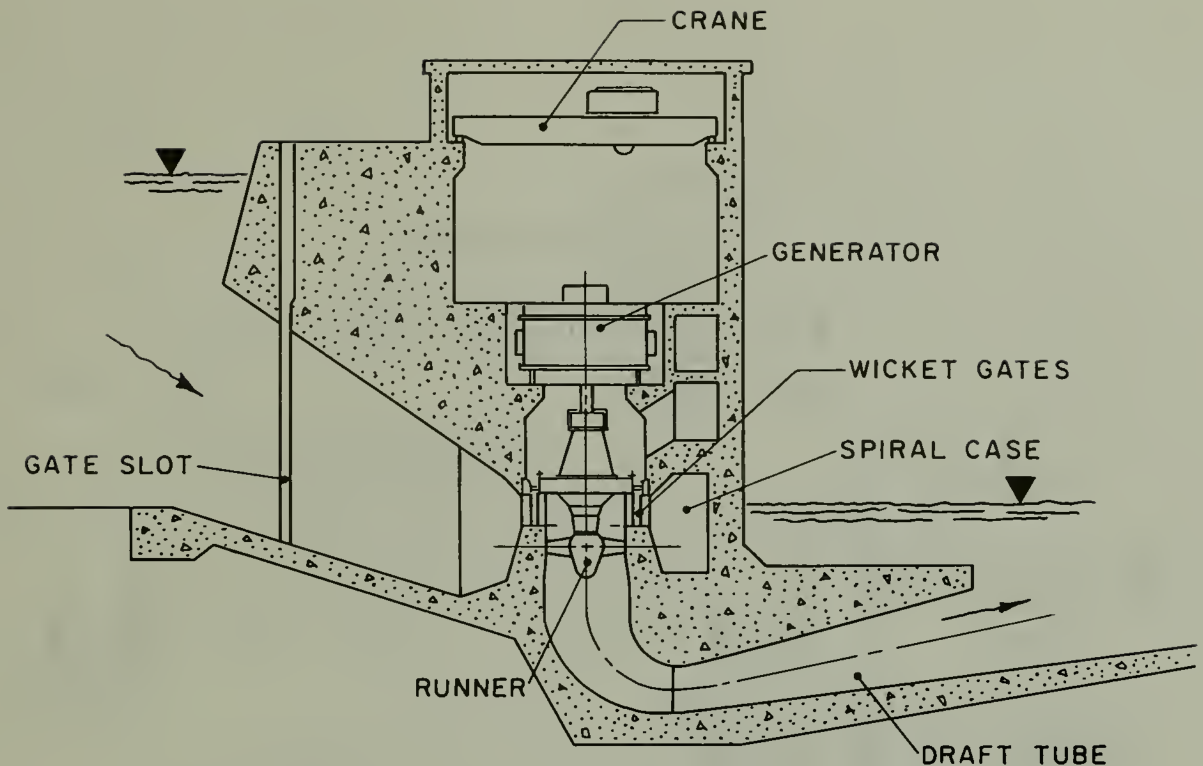


FIGURE 2. PROPELLER OR KAPLAN TURBINE

Propeller turbines are used for a low-head range of between 1.5 to 45 metres (5 to 150 feet). Their arrangement is similar to a Francis turbine, except (1) runners are the fixed-blade propeller type, and (2) the spiral case often has a simplified shape formed in concrete. Propeller turbines operate efficiently over a very narrow range of heads and flows.

Kaplan turbines have propeller-type runners with adjustable blades, allowing high efficiency over a wide range of heads and flows. Otherwise, they are similar to the propeller turbine. Variations of the propeller and Kaplan turbines that fall into three specific groups, e.g., the rim generator, the tube turbine, and the bulb turbine, are frequently more adaptable for small hydroelectric installations. These variations have a horizontal or slightly inclined shaft, and the water flow is coaxial with the turbine axis, reducing head losses associated with the changes in direction of flow, and decreasing the scope of structural work required for the plant structures.

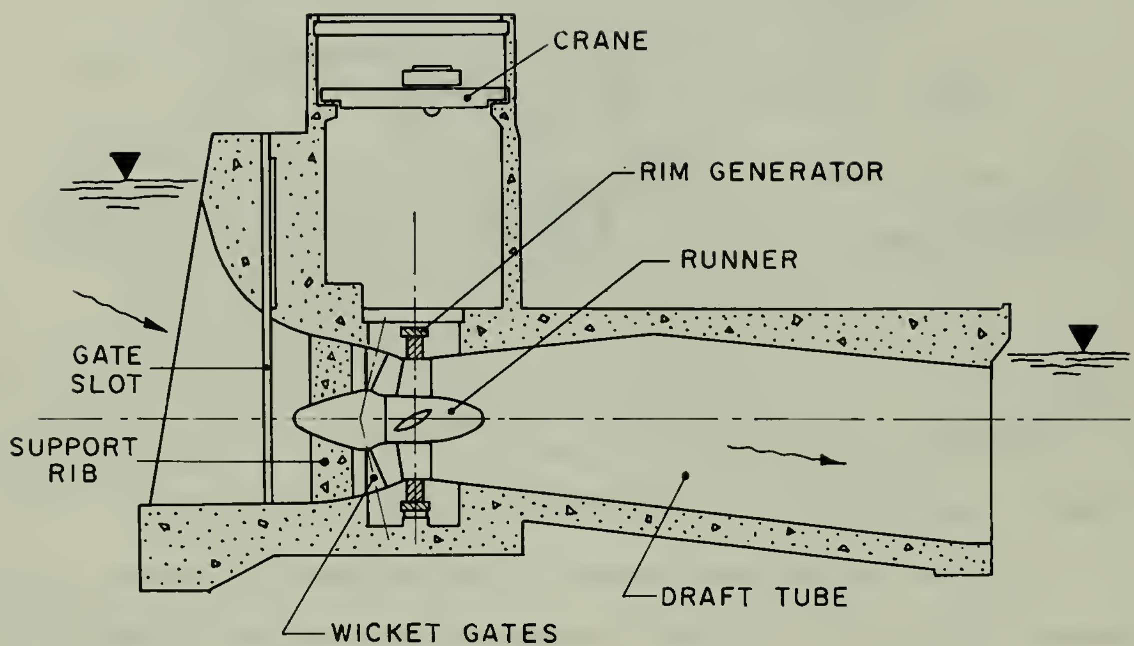


FIGURE 3. RIM GENERATOR TURBINE

Rim generator turbines have the advantage of compactness with adequate space on the periphery of the runner for a large generator. Two problems experienced with the rim generator turbine are (1) supporting the generator's weight and (2) the sealing arrangement between the turbine casing and the rotating outer rim. Recent development work, however, indicates that those problems can be overcome.

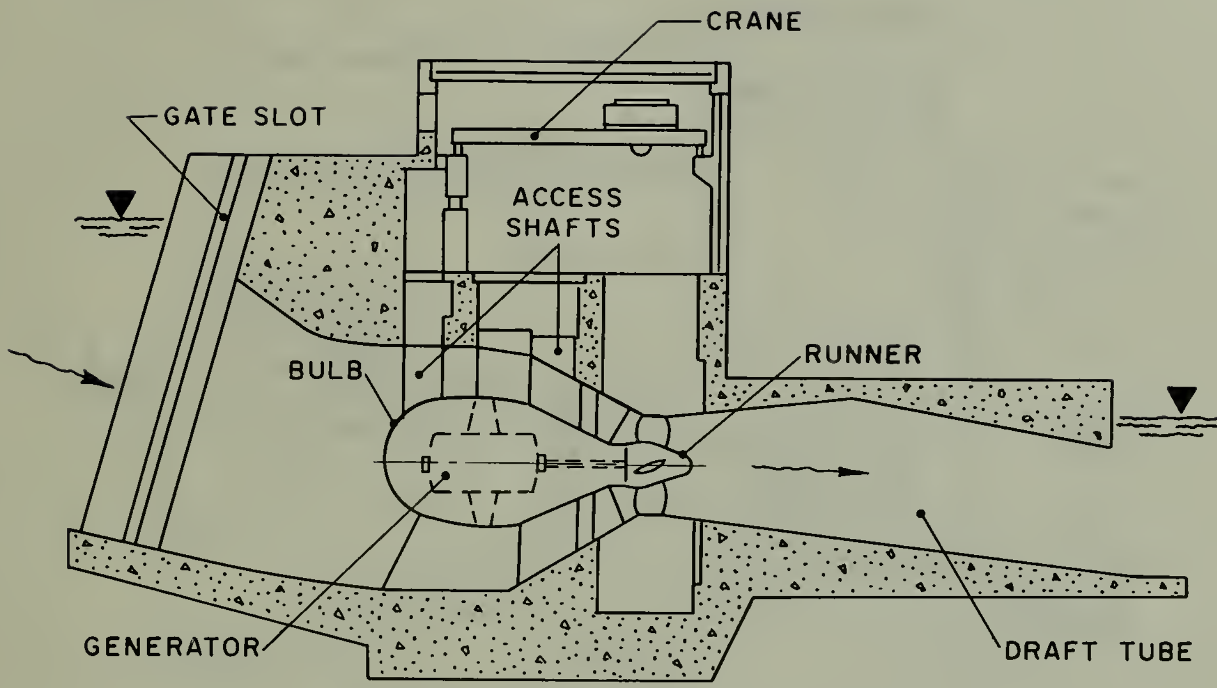


FIGURE 4. BULB TURBINE

Bulb turbines are compact and self-contained units. Both generator and runner are enclosed in a steel capsule or bulb submerged in the water passage. The bulb turbine units are constructed in line with the water stream flow, thus improving the hydraulic performance. This also leads to economies in civil construction. Maximum economical size for the bulb turbine has a 7-metre (23-foot) runner diameter, with maximum head in the 15-18 metre (50-60 foot) range.

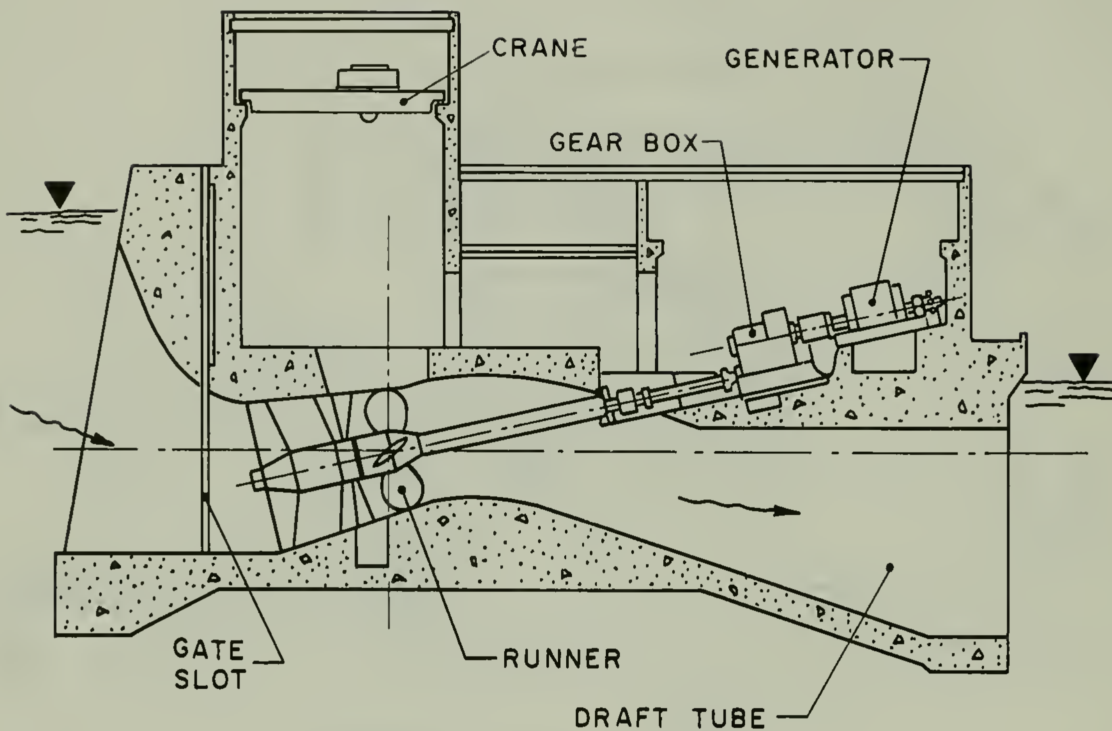


FIGURE 5. TUBE TURBINE

Tube turbines have a relatively simple seal arrangement, and the generator is accessible for maintenance and repair. This type readily adapts to installations at existing plants. Tube turbines are used in the low-head range of between 1.5 and 30 metres (5 and 100 feet).

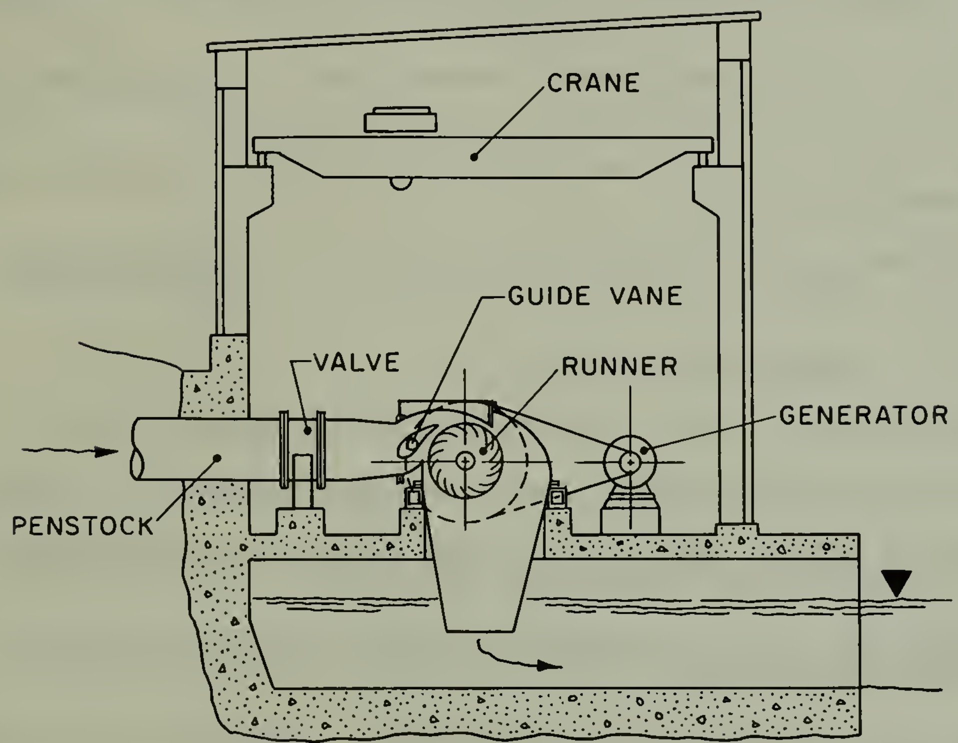


FIGURE 6. CROSS-FLOW IMPULSE TURBINE

Cross-flow impulse turbines have cylindrical runners with a guide-vane system that forces the water against and through the periphery of the runners. The water then flows through the interior of runners and out the periphery on the other side, discharging into a rectangular draft tube. The guide-vane system can be segmented to allow shutting off water flow to a portion of the runner when the water supply is limited. The cross-flow impulse turbine can operate within a wide-range of water flows and can be designed for a large range of heads, from very low heads to heads up to 200 metres (656 feet).

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