OREGON'S WATER RESOURCE: A SUMMARY OF AVAILABLE INFORMATION

Prepared For
The Institute for Policy Studies
By the
Water Resources Research Institute
Oregon State University

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The Institute for Policy Studies
Conference on

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Table of Contents

	Page
Summary	1
Introduction	3
Oregon's Water Supply	5
Hydrologic Cycle	5
Precipitation	5
Streamflow	5
Ground Water	9
General Quality of Water	15
Present Use and Development of Oregon's Water	17
Functional Uses of Water	17
Compatibilities and Conflicts in Water Use	17
Current Levels of Use	27
Environmental Problems Associated with Present Water Use	30
Water Use and the Level of Economic Activity	31
Valuing Water in the Traditional Economic Sectors	31
Valuing Water Outside the Traditional Economic Sectors	36
Future Uses of Oregon's Water	39
State Projection Study	39
Irrigation Water Demand	41
On-Farm Benefits and Costs of Irrigation Development	48
Public Benefits and Costs	48
Financing Water Developments	51
Some Eastern Oregon Irrigation Relationships	52
The Economic Effects of Pricing Water	53
Impacts and Issues of Water Use and Supply Manipulation	55
Assessing Impacts	55
Grouping of Impacts	57
Impacts of Streamflow Manipulation	59
Reservoir Impacts	62
Impacts of Releasing Water at Dams	63
Key Issues	63
Impacts of In-Stream Uses	64
Without Supply Manipulation	64
Impacts of Flow Augmentation on In-Stream Use	65
Key Issues	65
Impacts of Diversion and Out-of-Stream Uses	67
Return Flows	68
Impacts of Irrigation Demand	68
Key Issues	69
The Impacts Viewed Collectively	70
Selected References on Oregon's Water Resources	71
Appendix: Common Equivalents for Water Discharge	73

Summary

This paper summarizes the nature of Oregon's water supply, its current uses, its likely future uses, the kinds of competition and tradeoffs encountered in water allocation and use, and the impacts of water use and supply manipulation.

The major current water-related problems involve seasonal, geographic and year-to-year maldistributions between water supply and water use. There is recurring water shortage and excessive runoff. In addition, overall shortages occur in arid areas east of the Cascades. Multiple-purpose reservoir storage is significant in balancing some of the seasonal maldistributions in most river basins. But while solving some problems, dams create other problems, particularly for fishery resources. In addition to water quantity problems, there are numerous water quality problems in many areas, these generally being associated with depleted streamflows and contaminated return flows.

Oregon has moved from a surplus-water to a water-constrained setting in the last decades, except in parts of Western Oregon. Even there, the current drought conditions have highlighted the vulnerability of our water-based economy to problems of water supply. Projections show that greater demands will be made on our water supplies in the future. Conservation measures and economic forces in reallocation of water among users can help meet some of the needs. New technological innovations may offer added means of meeting water needs. Alternatively or supplementally, additional reservoir storage can be provided to catch for beneficial use a larger portion of Oregon's water supply. This will heighten current conflicts and will considerably aggravate the present environmental impacts. Water supply deficits east of the Cascades might be made up from Columbia River and Snake River water importations, but the impacts of doing so are of the same magnitude as the irrigation benefits to be expected. Also, those interstate sources are subject to numerous other constraints over which Oregon has little control.

Oregon places a high value on in-stream uses of water yet relies heavily on out-of-stream uses for its economic well-being. Thus, in-stream uses have been compromised in many ways to meet our present levels of out-of-stream uses.

Several major issues have emerged that must be resolved. These can be identified as:

A. Issues of streamflow manipulation

* desirability of increasing reservoir storage capacity
* possibility for water management without added storage
* adversely affected fishery resources due to reservoirs

* loss of free-flowing stream attributes due to hydropower operation

* preservation of flood control benefits against encroaching storage and floodplain use

B. Issues of in-stream use

* protection of fishery resources

* identification of long-range minimum in-stream flow requirements

* desirability of limiting stream use based on carrying capacity

* desirability of flow augmentation to enhance in-stream uses

C. Issues of out-of-stream use

* extent of acceptable depletion of in-stream flows

* control of water quality associated with return flows

* falling ground water levels due to heavy use

* how to accomodate irrigation diversion needs from the Columbia in the light of anticipated adverse effects on power production, fisheries, navigation, recreation

* other aggravation of in-stream use problems due to growing irrigation demand.

D. Underlying issues of information base

* support of research and investigations to improve knowledge and prediction capabilities

* re-examination of Oregon's long-range requirements for water, to update the 1969 study (consider constraints, seasonal problems, changed population trends, economic conditions)

* recognition of rapid-growth uses and adjustment of water management plans

* valuation of amenity and commodity resource uses on more-comparable basis

* valuation of external costs among uses that impair other uses.

While grouped here for identification, these issues overlap and are interrelated.

Introduction

Decisions concerning water for Oregon's future must focus on long-term problems of water supply and water demand. As background to consideration of the complex issues that must be addressed in reaching decisions concerning future water use, this paper reviews the hydrologic nature of Oregon's water supply, identifies the characteristics of present uses and development of Oregon's water, examines a set of projected uses and demands for Oregon's water, and identifies the significant economic and environmental issues and impacts of various types of water uses. The ramifications of increasing the available water supply through storage and other means, including economic manipulation, are considered. Particular emphasis is given to the constraints and tradeoffs among water uses that presently exist and that might be anticipated from greater levels of water development, so that issues can be viewed for a range of options from that for the existing level of water development to that for a much greater level of development in order to satisfy "unconstrained" water demands in the future.

This paper shows what the resource is that we have to work with and the problems and tradeoffs that occur among water uses. It focuses on the reservoir storage of water and on in-stream and out-of-stream allocation of a limited resource among competing uses as key commitments affecting the environmental and economic future of Oregon. A companion paper[1] extends the information presented here, together with background information on legal and institutional aspects of water use, so that water policy issues affecting Oregon's future can be comprehensively addressed during the conference on Water for Oregon's Future.

1. Bureau of Governmental Research and Service; Water Use Issues and Decisions for Oregon; University of Oregon; Eugene, Ore.; 1977.

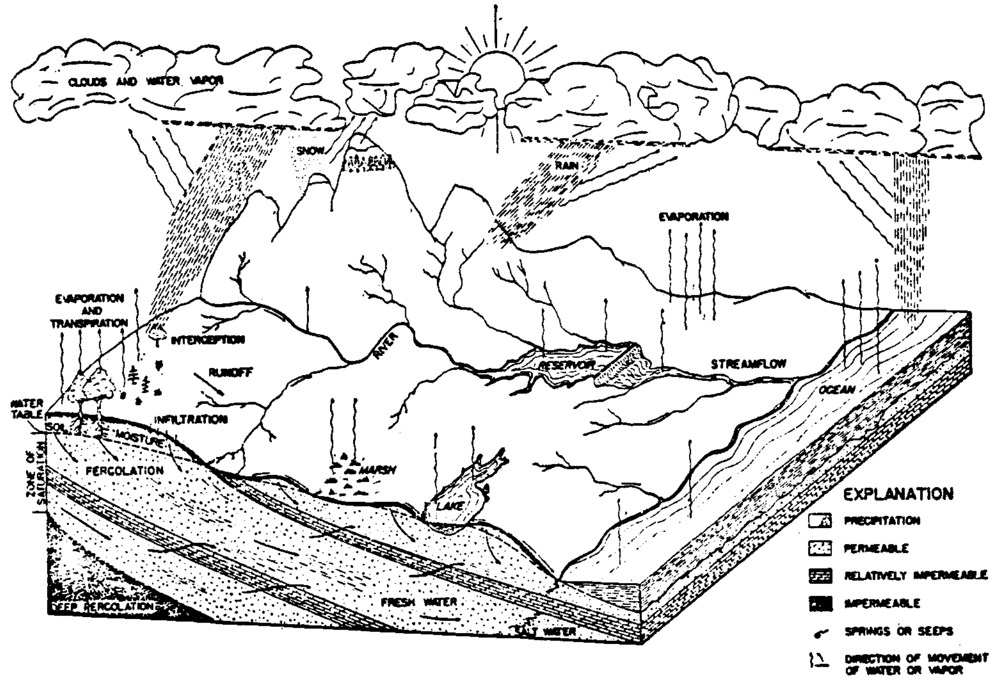


FIGURE 1. HYDROLOGIC CYCLE

Oregon's Water Supply

Hydrologic Cycle

The hydrologic cycle, illustrated by Figure 1, is a natural water circulatory system wherein water moves from the atmosphere to the land, thence across the land or through subsurface zones to streams and the sea and eventually back to the atmosphere, with many short circuits from one component of the cycle to another.

The Pacific Ocean is Oregon's principal source of moisture. Normally, large winter frontal storms drop rain and snow abundantly between the coast and the crest of the Cascade Mountains and much more sparsely east of the Cascades. Summer convective storms add to the moisture supply east of Cascades. Fallen snow holds moisture in storage at higher elevation for up to several months before releasing it to soil moisture, streamflow or evaporation to the atmosphere. Rainfall runoff, on the other hand, almost immediately seeps into the soil or flows overland to streams. Runoff may move either by surface or by subsurface means, or may change back and forth from one mode of flow to the other. Subsurface movement is much slower than surface movement (a few feet per day instead of a few feet per second). Concurrently, evaporation and transpiration of water vapor by plants transfer moisture from surface water bodies and the soil to the atmosphere.

Four features of this cycle are particularly important for Oregon. First, the majority of precipitation occurs in the winter. Second, the precipitation occurs with geographical variability, being greatest at higher elevations of the Coastal and Cascade Ranges. Third, much of the western Oregon precipitation, except that falling at the higher elevations of the Cascades, runs off very soon after falling, swelling streams briefly and recharging the soil moisture and ground-water zones in a more enduring manner. And fourth, snowmelt runoff in Oregon east of the Cascades occurs in the spring and that from the eastern Columbia Basin in Idaho comes even later and swells the Snake and Columbia Rivers in late spring and early summer. This gives eastern Oregon and the state margin along the Columbia River a different time for maximum natural streamflow availability than is the case for western Oregon.

Precipitation

The average annual precipitation providing Oregon with its water supply is shown in Figure 2. The typical seasonal and geographical variation of this precipitation is shown in Figure 3. Figure 4 shows the average seasonal cumulative precipitation at several locations, together with that for the worst previous drought at each station and that for the current winter.

Streamflow

River basins form the natural units for identifying the available water supply and the uses of water. Figure 5 shows the division of the

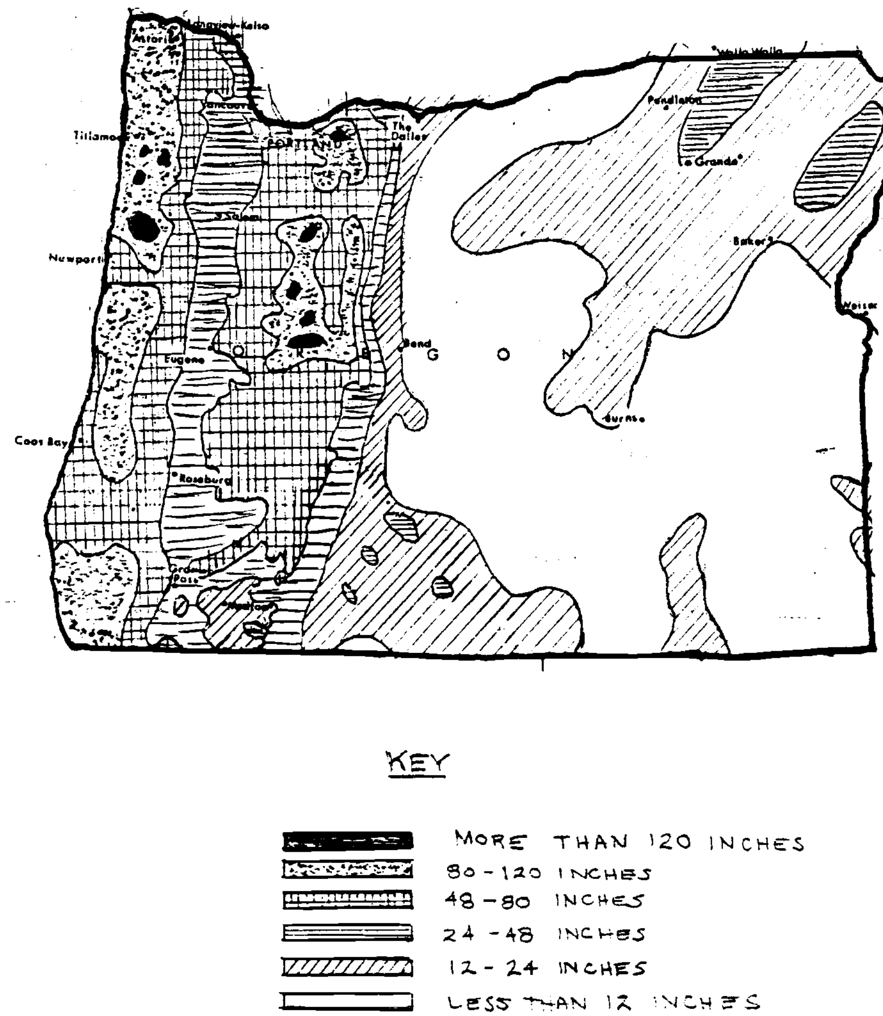


FIGURE 2. AVERAGE ANNUAL PRECIPITATION FOR OREGON

(Source: Pacific Northwest River Basins Commission; Columbia-North Pacific Comprehensive Framework Study of Water and Related Lands; Vancouver, Wash.; 1970)

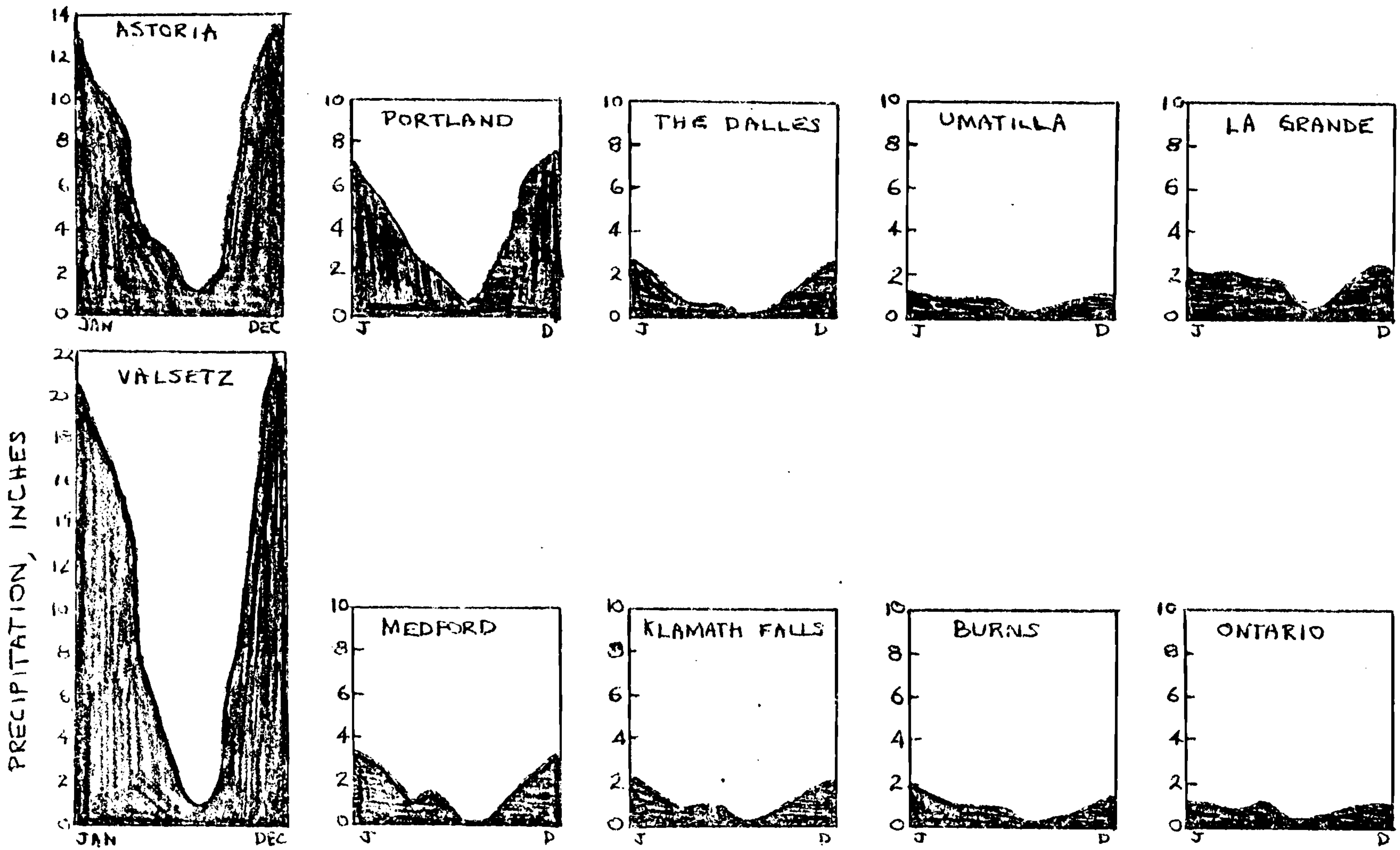


FIGURE 3. SEASONAL AND GEOGRAPHICAL VARIATION IN OREGON'S PRECIPITATION

(Source: U.S. Weather Bureau records)

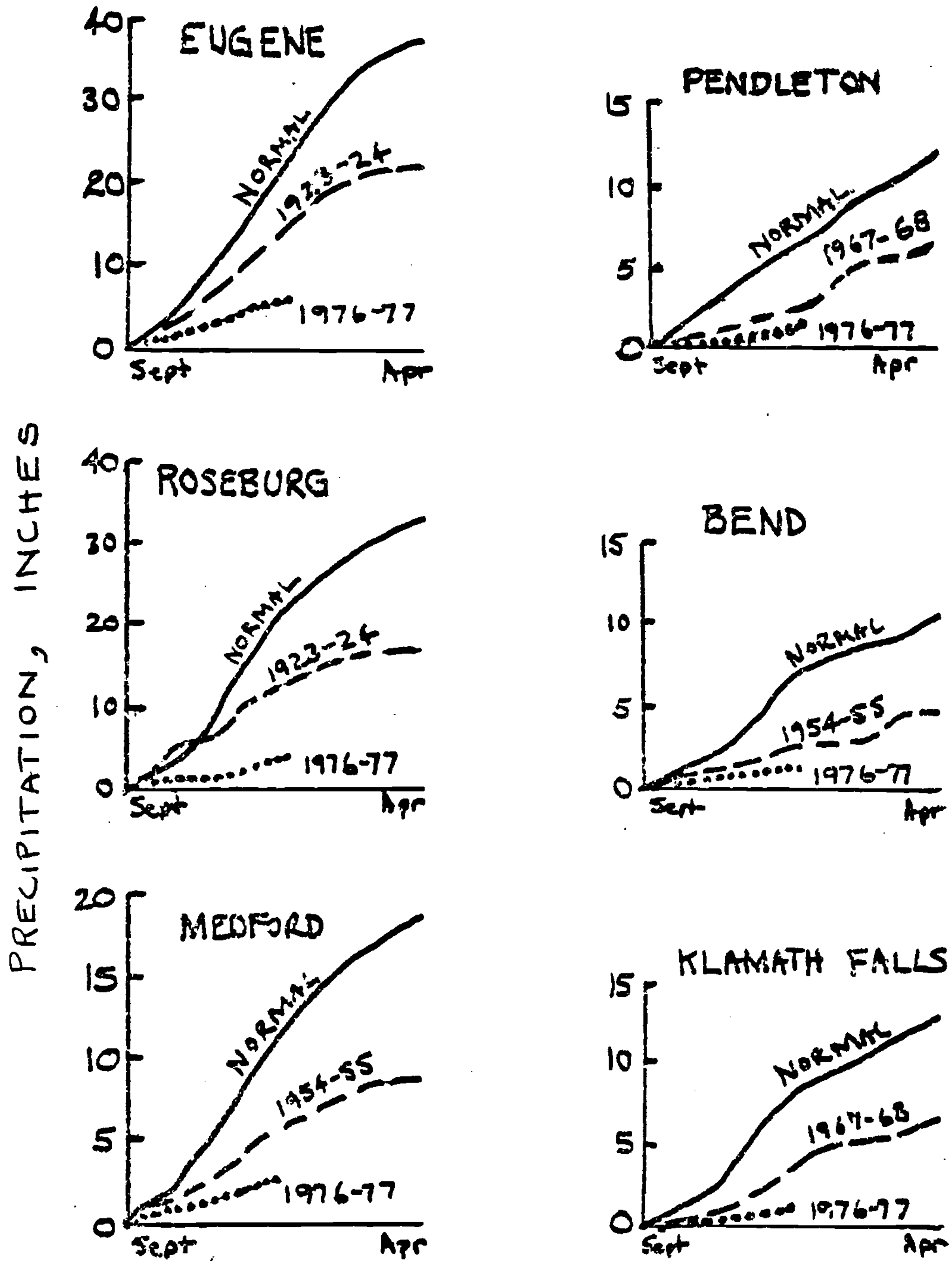


FIGURE 4. WET SEASON CUMULATIVE PRECIPITATION AT SELECTED STATIONS

(Source: U.S. Weather Bureau Records)

U.S. portion of the Columbia River Basin (219,500 square miles) into major subregions, each including several rivers. Thirty-two percent of the Basin lies within Oregon.[1] Interstate streams form a significant part of Oregon's water supply. Figure 6 shows the major basins in Oregon. While many basins are tributary to the Snake and Columbia Rivers, most coastal streams flow directly to the Pacific. In southeastern Oregon are some "closed" basins, having no natural outlets to the ocean. Thus, the Silvies River and the Donner and Blitzen River flow to Malheur/Harney Lakes, a unique "sump" from which the only exit for water is by means of evaporation or transpiration. The Klamath Basin drains into northern California, whereas the Rogue receives some flow from a small area in California, as does the Owyhee from Nevada and Idaho.

The total amount of water runoff as streamflow for Oregon is about 84 million acre feet per year (MAF/yr). Table 1 shows the average annual runoff for principal rivers originating in the state. About 85 percent originates west of the Cascade crest.

Figure 7 shows the variability of seasonal streamflow for streams in different parts of Oregon. For the 30-year period of record that was used, the mean, maximum, and minimum flow for each month are shown.

The largest floods in the Willamette, Rogue, and Umpqua Rivers have been due to extensive rain on melting snow (e.g., the 1861 and 1964 floods). Along the coast, major floods have resulted from excessive rainfall, with damage often compounded by storm tides. East of the Cascades, winter rains, spring snowmelt, and summer cloudbursts have all resulted in major floods.

For comparative purposes, it is of interest that the long-term average flow of the Willamette River at Salem (17 MAF/yr) exceeds the natural undepleted flow for the entire Colorado River Basin within the United States, a basin about as large as the Columbia River Basin! Further, the Willamette River produces almost as much water (25 MAF/yr) as the Snake (33 MAF/yr) but from an area only one-ninth as large!

Ground Water

Ground water occurrence is highly variable throughout the state. General availability is depicted in Figure 8. In contrast with streamflow data, information is quite sparse regarding aquifers, their size, extent, permeability, recharge sources, and related features. Continuing funding of studies is essential to better define this important component of the hydrologic cycle.

In many aquifers the water table (i.e., the upper surface) fluctuates seasonally due to recharge and withdrawal of water. Some aquifers

1. International Columbia River Engineer Board, Water Resources of the Columbia River Basin. Report to the International Joint Commission. United States and Canada; Ottawa; 1959.

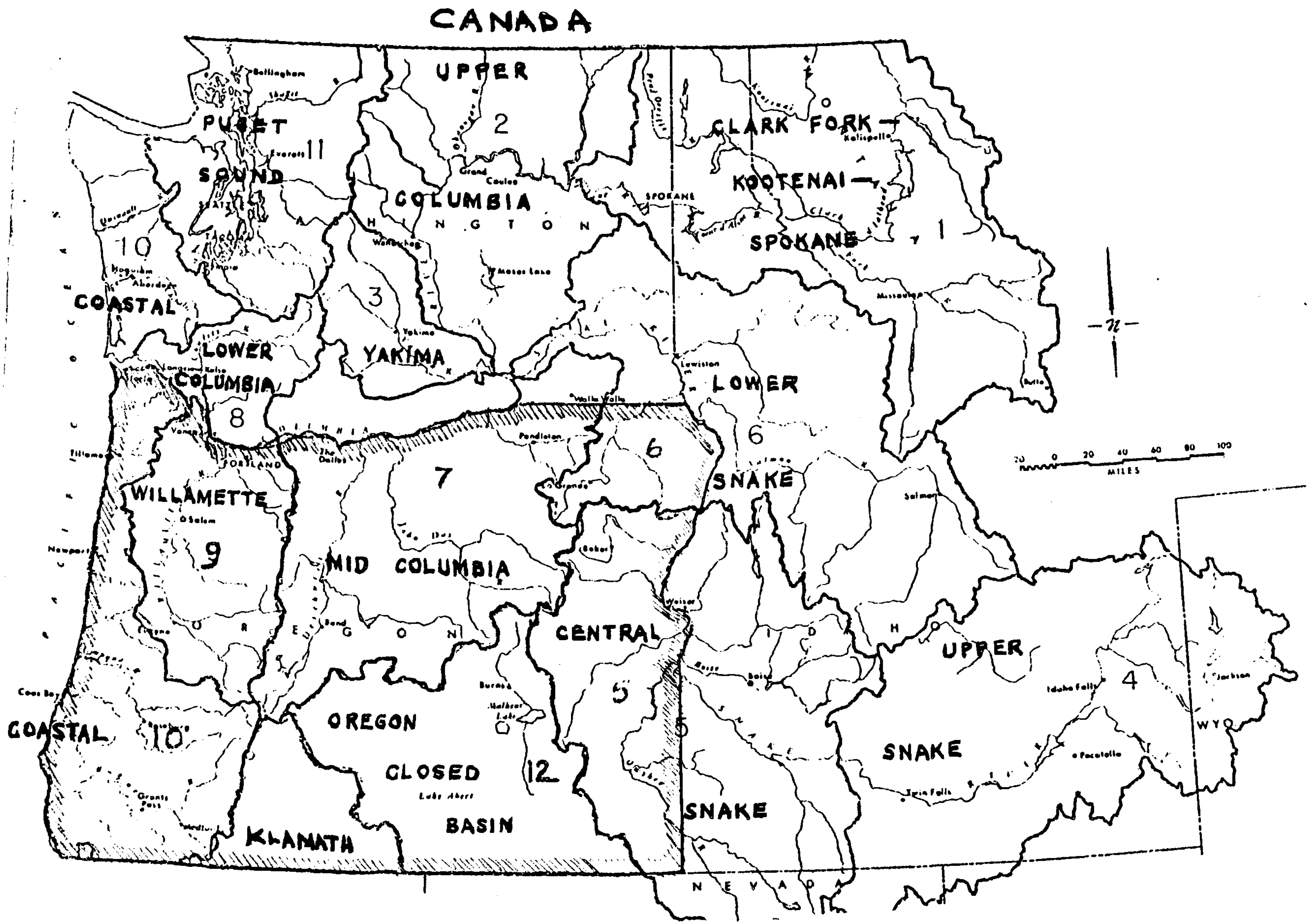
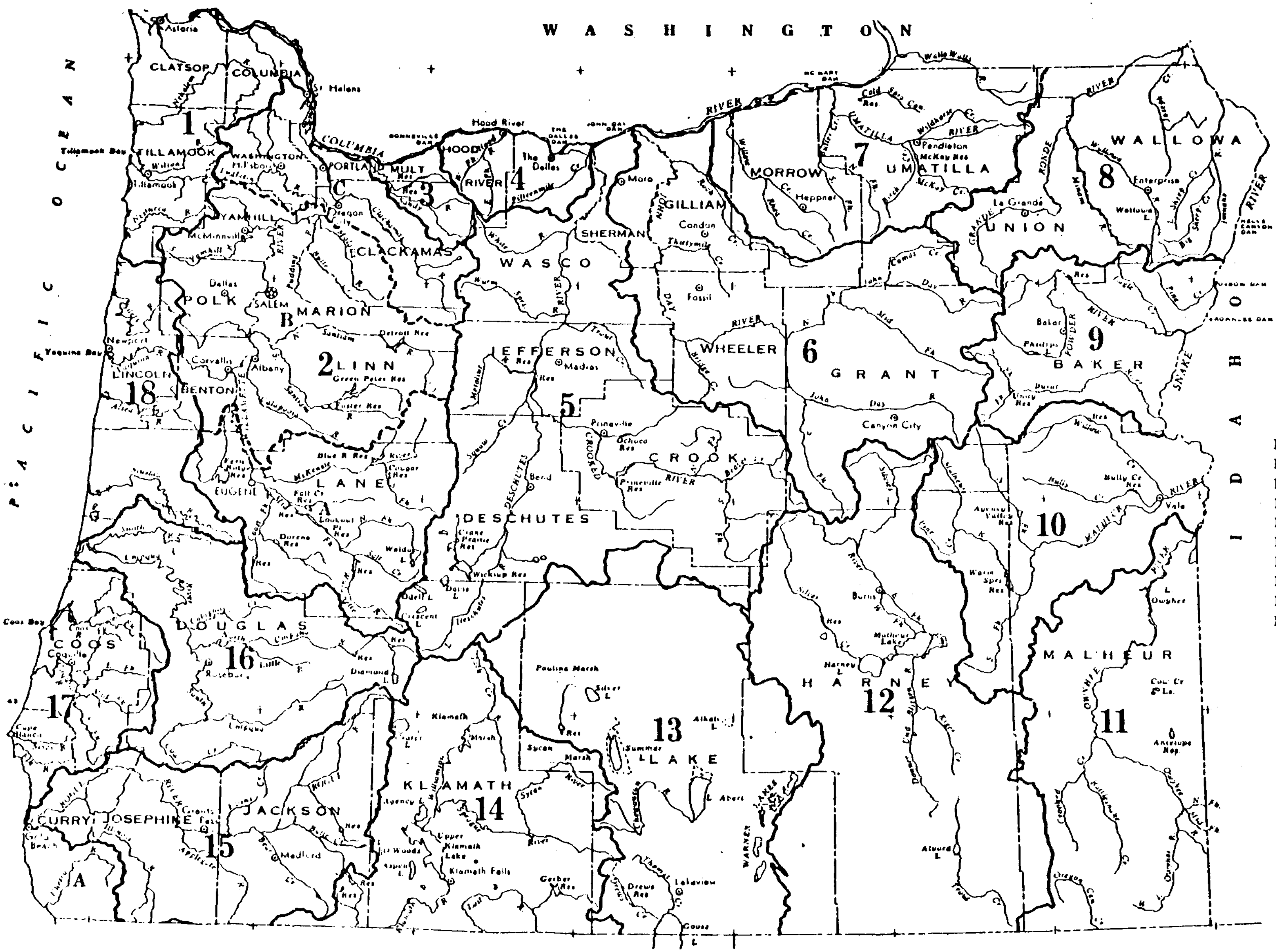


FIGURE 5. COLUMBIA RIVER BASIN SUBREGIONS



BASINS

1	NORTH COAST
2	WILLAMETTE
2A	Upper Willamette
2B	Middle Willamette
2C	Lower Willamette
3	SANDY
4	HOOD
5	DESCHUTES
6	JOHN DAY
7	UMATILLA
8	GRANDE RONDE
9	POWDER
10	MALHEUR
11	OWYHEE
12	MALHEUR LAKE
13	GOOSE & SUMMER LAKES
14	KLAMATH
15	ROGUE
16	UMPQUA
17	SOUTH COAST
17A	Chetco
18	MID COAST

FIGURE 6. MAJOR RIVER BASINS IN OREGON

Table 1. Undepleted Average Annual Flow[1] for Oregon's River Basins[2]

Rank of Flow	River Basin	Approximate Undepleted Average Annual Flow MAF/yr
1	Willamette (2)[3]	25.00
2	North Coast (1)	9.30
3	South Coast (17)	9.00
4	Rogue (15)	8.50
5	Umpqua (16)	8.20
6	Mid Coast (18)	8.10
7	Deschutes (5)	4.38
8	Grande Ronde (8)	2.84
9	Sandy (3)	1.70
10	John Day (6)	1.52
11	Hood River and Fifteenmile Creek (4)	1.38
12	Klamath and Lost River (14)	1.23
13	Powder and Burnt River (9)	0.91
14	Owyhee (11)	0.69
15	Umatilla, Walla Walla, Willow Creek (7)	0.53
16	Goose and Summer Lakes (13)	0.47
17	Malheur Lake (12)	0.26
18	Malheur (10)	0.19
	Total from Oregon	84.20
	Columbia at mouth	193.00

[1] Undepleted flows are those flows that would occur if there were no upstream diversions and consumptive use.

[2] Data Source: Oregon State Water Resources Board; Oregon's Long-Range Requirements for Water; Salem, Oregon; 1969.

[3] Parentheses show basin numbers given in Figure 6.

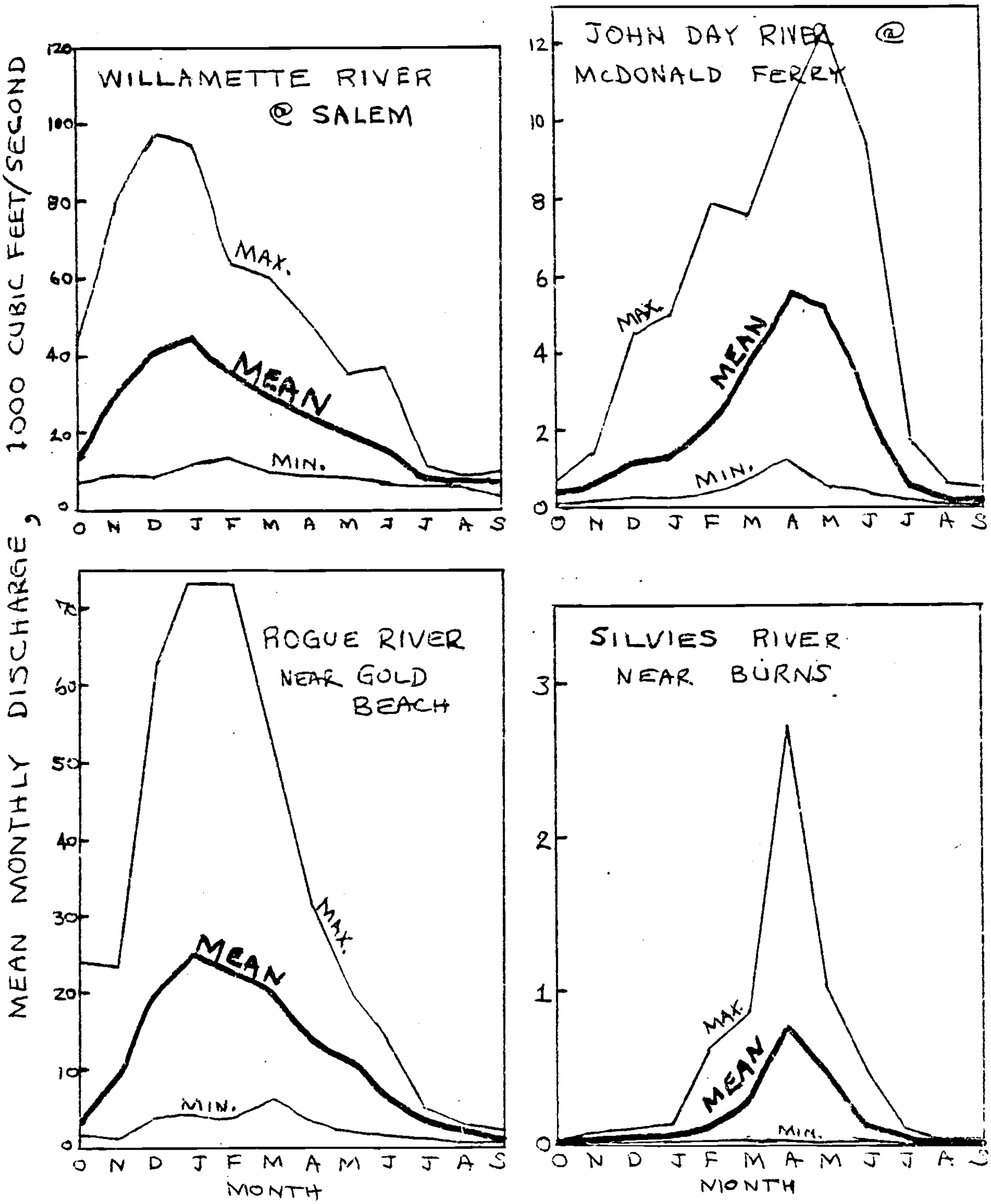


FIGURE 7. MONTHLY AND GEOGRAPHICAL VARIATION IN OREGON'S RUNOFF

(Source: Pacific Northwest River Basins Commission; Columbia-North Pacific Region Comprehensive Frame Work Study of Water and Related Lands; Vancouver, Wash.; 1970)

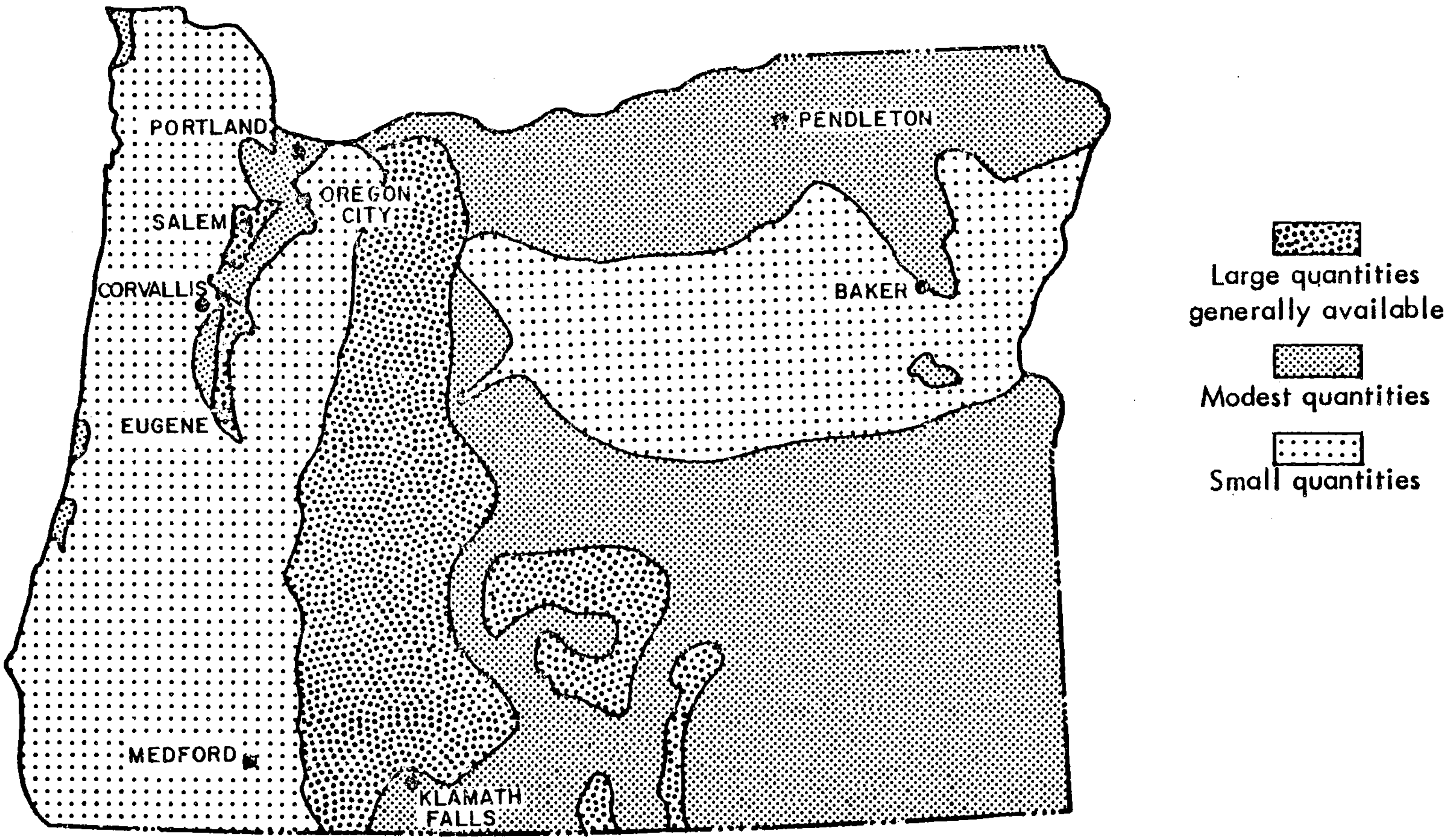


FIGURE 8. GENERAL AVAILABILITY OF GROUND WATER

(Source: Van der Leeden, et al; Ground-Water Pollution Problems in the Northwestern United States; EPA Report 660/3-75-018; Corvallis, Ore.; 1975) presently used have slow rates of recharge, such that the water table is dropping in proportion to the amount of water withdrawn. Seepage of ground water maintains the base flow that sustains streams between storms or snowmelt periods and during the summer months.

General Quality of Water

Streams in Oregon generally have a very high natural water quality, measured in terms of physical, chemical, and biological characteristics. Seasonally and locally high water temperatures, increased aquatic plant growths and human activities that cause pollution act to reduce this quality.

Ground water quality varies with source, location and, less importantly, with time. Water temperature varies with geologic conditions. Mineral springs and hot zones have been found in many parts of the state, most notably in southern Oregon.

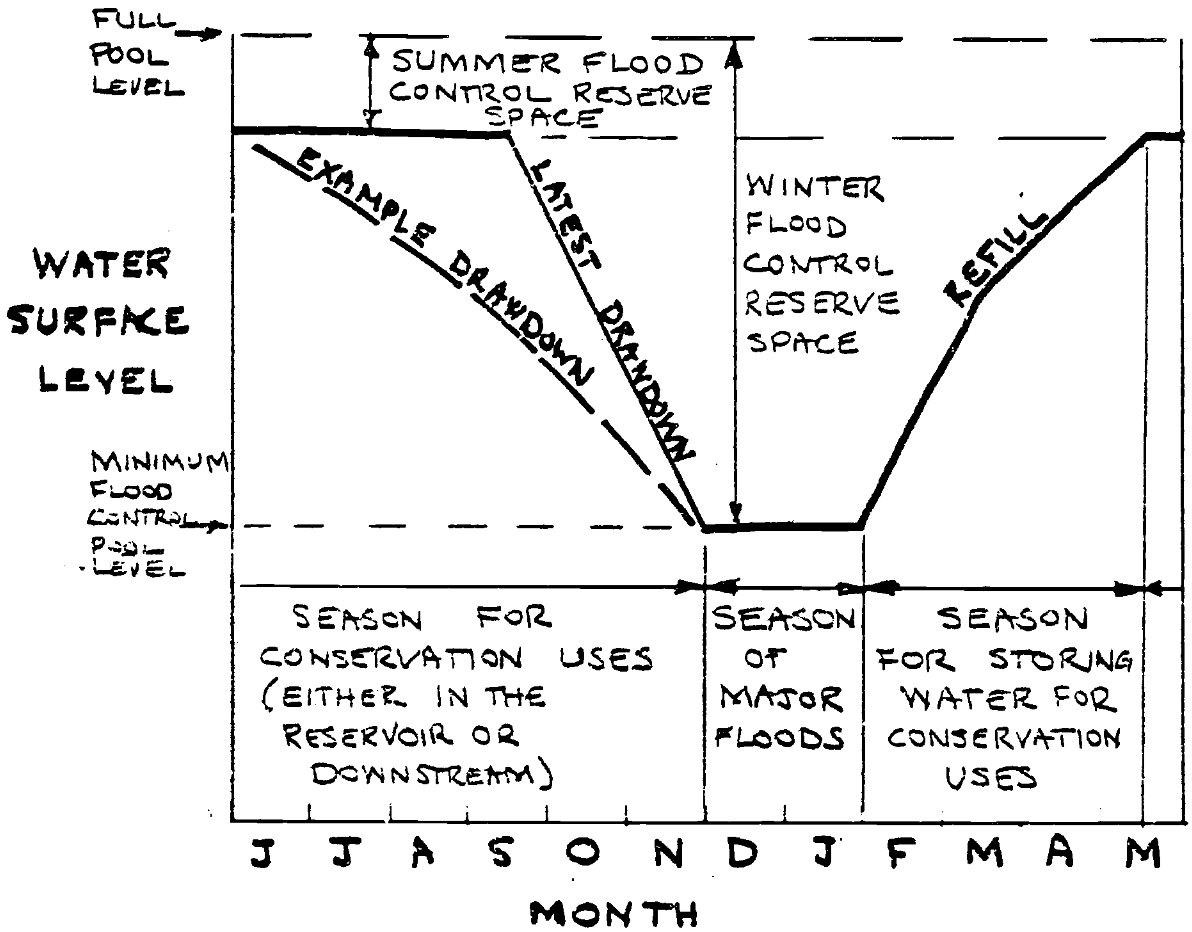


FIGURE 9. TYPICAL WILLAMETTE BASIN RESERVOIR OPERATION TO SERVE MULTIPLE PURPOSES

Present Use and Development of Oregon's Water

Functional Uses of Water

The principal uses of water and functions of water projects in Oregon are the following: (1) municipal water supply; (2) industrial water supply, including mining; (3) irrigation and other agricultural water supply; (4) flood control and damage reductions; (5) hydroelectric power generation; (6) thermal power generation; (7) navigation; (8) fishery and wildlife conservation and enhancement; (9) water quality enhancement, sanitation, and pollution control; (10) water-based recreation; and (11) esthetics and natural values. In states bordering Oregon, water has also been used for maintenance of ground-water levels and salinity control. A brief review of the characteristic features of water use to satisfy single functions is given in Table 2.

Compatibilities and Conflicts in Water Use

Multi-purpose water use, development and management is considerably more complex than is the case for single-purpose projects. Each type of water use, taken alone, has specific requirements (see Table 2). Rarely is a single use optimized. Instead, tradeoffs between uses are inevitable. In some instances, the constraints among competing uses of water may be so severe that conflicts cannot be resolved. In such instances, certain beneficial uses of water must be foregone if others are to be achieved.

The operation of a typical Willamette Valley federal reservoir illustrates one manner of accommodating multiple purposes (authorized and benefited unauthorized purposes) in a single project. Figure 9 shows that the reservoir level can be lowered during autumn to its minimum winter pool level to regulate rainfall and rain-plus-snowmelt floods, can be refilled with late winter and spring snowmelt, and can be used to gradually release the "conserved" water for downstream usage such as hydropower generation, irrigation, municipal and industrial water supply, and for greater quantities of in-stream flow for navigation, pollution control, recreation, fishery and wildlife uses. The highly seasonal storm and flood period is a definite favorable factor in reducing the severity of the conflicts. Numerous tradeoffs occur, such as between recreation in the reservoir and downstream recreation, and between esthetics and natural values for an undeveloped river and those for a reservoir "lake" with a fluctuating water level.

The key factor in successful multiple-purpose water use is compromise. Greatest cooperation can be achieved if coordinated water planning is carried to the point of developing a water management program that recognizes the specific needs for each use, acknowledges the conflicts, and incorporates the tradeoffs into a scheme that provides a flexible measure of protection and water supply to each use.

Comparisons of compatible and conflicting uses of water may readily be made in several ways. First, instream uses can be compared with out-of-steam uses. Second, uses requiring reservoirs can be compared with

Table 2. Characteristic Features of Single-Function Water Use

Use	Typical Features and Requirements	Typical Physical Facilities	Compatible Uses[1]	Conflicting/ Competitive Uses[1]	Types of Benefits	Principal State Agencies Involved
1. Muncipal Water Supply (out-of-stream use)	Individual wells and stream diversions in low-density areas. Community wells and river intakes for diversion for more populated areas. City storage reservoirs to provide long-term supply and to meet seasonal fluctuating demands. Extensive measures (e.g., limited access and activity) to protect municipal watersheds from contamination. River supplies need greater treatment than ground water and watershed supplies. Demand has daily and seasonal patterns of use. Demand grows slowly over time to match population growth and related commercial/industrial growth. Cannot risk interruption of supply. Conservation measures can reduce use during crises (e.g., curtail lawn, garden and park watering, street washing). Use is largely non-consumptive, with 20-30 percent annual loss due to evaporation-transpiration (may reach 50 percent during summer; is nearly 0 percent during winter). Effluents returning to rivers are stringently monitored and regulated. Extensive treatment of return flow is needed to remove transported wastes after use. Waste treatment is costly in dollars and energy used. Alternative of no treatment is environmentally costly to the receiving water.	Wells, dams, reservoirs, pipelines, pumping plants, intakes, water treatment plants, distribution systems, collection systems, wastewater treatment plants, outfalls.	a) All uses requiring storage facilities (2,3,5,6) b) Seasonal flood control (4) c) All in-stream uses upstream of the withdrawal point (7,8,9,10,11,13)	a) All b) All other out-of-stream uses (2,3,5,6,12) c) All in-stream uses downstream of the withdrawal point (7,8,9,10,11,13) d) All uses requiring keeping water in storage for later use (e.g., 5,10) e) All in-stream uses downstream of the return flow point (7,8,9,10,11,13)	Economic Environmental Health	Water Resources Health Environmental Quality

[1] The amount of water available to be shared as a result of storage will determine whether this use is compatible or competitive with other uses for that water.

Table 2. Continued

Use	Typical Features and Requirements	Typical Physical Facilities	Compatible Uses[1]	Conflicting/ Competitive Uses[1]	Types of Benefits	Principal State Agencies Involved
2. Industrial Water Supply and Mining (out-of-stream use)	(see Municipal Water Supply) Separate supplies (rather than municipal supplies) are common. Treatment requirements for supply often differ from municipal requirements. The quality of the supply water can be critical for some industries, unimportant for others. Demand may be highly seasonal, as with food processing. Demand may remain very steady, grow gradually or change in abrupt steps, all related to population growth, plant expansion, remodeling or closure, and policies that attract or discourage new industry. The cost of water supply is not a major influence (it is easily absorbable in most product prices) but the costs of air, water, and land pollution control can be significant, both in dollars and in energy requirements. Most industries do not have large water storage systems and are more sensitive than municipalities to risks of supply interruption. Operation cutbacks and plant closures during droughts are likely. Use is largely non-consumptive (less than 10 percent), principal consumptive uses being water tied up with the product (e.g., canned foods), landscape watering, and cooling ponds or towers. Return flows carry different wastes than for municipalities. Large waste loads usually require separate treatment or pretreatment before effluent delivery to municipal wastewater treatment systems. Turbidity control is essential for in-stream or near-stream mining activities, such as sand-and-gravel extraction. Acidity and undesirable minerals may be associated with other mining.	Wells, dams, reservoirs, pipelines, pumping plants, intakes, water treatment plants, distribution systems, collection systems, wastewater treatment plants, outfalls. For some industries, holding and tailings ponds, pretreatment plants.	a) All uses requiring storage facilities (2,3,5,6) b) Seasonal flood control (4) c) All in-stream uses upstream of the withdrawal point (7,8,9,10,11,13)	a) All b) All other out-of-stream uses (2,3,5,6,12) c) All in-stream uses downstream of the withdrawal point (7,8,9,10,11,13) d) All uses requiring keeping water in storage for later use (e.g., 5, 10) e) All in-stream uses downstream of the return flow point (7,8,9,10,11,13)	Economic	Water Resources Environmental Quality Geology & Mineral Ind. State Lands

[1]The amount of water available to be shared as a result of storage will determine whether this use is compatible or competitive with other uses for that water.

Table 2. Continued

Use	Typical Features and Requirements	Typical Physical Facilities	Compatible Uses[1]	Conflicting/ Competitive Uses[1]	Types of Benefits	Principal State Agencies Involved
3. Irrigation and Other Agricultural Water Supply (out-of-stream use)	Most existing development is based on gravity flow from river diversions and from pumped wells in shallow aquifers. New development focuses on pumping from rivers to higher ground. Seasonal storage reservoirs greatly expand the availability of irrigation water late in the summer, after snow has melted, in central and eastern Oregon. Most storage is at higher elevations and permits gravity flow in canals to irrigable land. Maximum irrigation use involves heavy drawdown of supply reservoirs by season's end. Some reservoirs are large enough (e.g., Owyhee) to provide addition to the normal winter-spring refilling. Demand is extremely seasonal (March through September). Demand is influenced by day-to-day weather conditions. Risks of water shortage can be handled by timely choice of crops and of acreage to be irrigated. Water shortage has severe economic effect. Demand growth over the years is likely to be as a series of step increases from new projects, rather than a gradual increase. Irrigation based on ground water supplies may experience falling water tables as use expands beyond available supply. Use is highly consumptive (evapotranspiration to atmosphere). Consumptive losses may be as high as 80 percent of irrigation water, depending on the type of irrigation system. Return flows carry dissolved mineral matter that has leached from the soil. No treatment of return flows has been practiced in Oregon. Land drainage to lower and control shallow water tables, to reduce waterlogging of soils and related problems.	Wells, dams, reservoirs, ponds, pipelines, canals, intakes, pumping plants, desilting works, distribution systems, drainage and return flow collection systems, outfalls, farmland grading, earthmoving ditches, tile drains, soil treatment.	a) All uses requiring storage facilities (2,3,5,6) b) Seasonal flood control (4) c) All in-stream uses upstream of the withdrawal point (7,8,9,10,11,13)	a) All b) All other out-of-stream uses (2,3,5,6,12) c) All in-stream uses downstream of the withdrawal point (7,8,9,10,11,13) d) All uses requiring keeping water in storage for later use (e.g., 5,10) e) All in-stream uses downstream of the return flow point (7,8,9,10,11,13)	Economic	Water Resources Agriculture Soil & Water Conservation Comm. Forestry Land Conservation Development Comm.

[1] The amount of water available to be shared as a result of storage will determine whether this use is compatible or competitive with other uses for that water.

Table 2. Continued

Use	Typical Features and Requirements	Typical Physical Facilities	Compatible Uses	Conflicting/ Competitive Uses	Types of Benefits	Principal State Agencies Involved
4. Flood Control	Catch and hold back storm runoff and snowmelt runoff in reservoirs at critical times for subsequent release at rates not exceeding downstream channel capacities. Straighten, clear out, and provide protective linings for channels so that flood waters move through them more rapidly and efficiently. Construct levees to exceed height of design floods; provide drainage and lift stations to pump seepage flow and local runoff into river. Establish floodplain land use limitations so that little development exists in frequently flooded zones. Establish building codes and require flood-proofing of structures to reduce damage risk in floodplain encroachment areas or along margins of floodplains. Establish flood forecasting network to give shortrange forecasts and alert residents to dangers. Ideally, should have reservoir level as low as possible before the start of flood runoff, so that maximum storage space is available. Ideally, should re-empty reservoir soon after passage of flood danger, to prepare for the next flood. During floods, operate reservoir to minimize the downstream flood peak. Flood protection is mainly a seasonal (winter) requirement west of the Cascades. Flood protection is needed at all seasons east of the Cascades (winter rains, spring snowmelt, summer cloudbursts). Many non-structural land uses are suitable within floodplains (e.g., agriculture, parks, recreational uses). Less frequently flooded lands are suitable for a broader range of uses. Flood risk is random, from year to year, and influenced by the weather, prior precipitation and runoff, and basin land use. Flood damage potential is also influenced by management of operations at flood control projects, etc.	Dams, storage reservoirs, channel improvements, floodways, pumping stations, floodplain zoning, building codes, flood forecasting.	a) All uses that have different season for demands	a) All uses requiring full reservoir storage (1,2,3,5, 6,7,9,10,11,12, 13)	Economic Environmental	Water Resources Soil and Water Conservation Comm. Land Conservation Development Comm. Intergovernmental Relations Division

Table 2. Continued

Use	Typical Features and Requirements	Typical Physical Facilities	Compatible Uses[1]	Conflicting/ Competitive Uses[1]	Types of Benefits	Principal State Agencies Involved
5. Hydroelectric Power Generation (in-stream use)	Types: low, intermediate, or high in height; storage, pumped storage, run of river; main dam, re-regulating dam. Principally along Snake and Columbia Rivers, along the Deschutes River, and in the Willamette Basin. Choice dam sites are deep, narrow canyons with larger valleys upstream for storage (small dam, large reservoir). Most of the best sites are already developed. Willamette power production is most significant in late autumn, when the Columbia-Snake system is at its lowest flow. Ideally, all reservoir water is released through the turbines. Demand fluctuates hourly, daily, weekly, and seasonally. Base-load and peak-load power production. Operation as part of a large power supply network. Must respond quickly to load demand changes. Smaller re-regulation dams downstream of peaking power plants provide pool to temporarily hold water surges and deliver a more-nearly constant flow downstream (e.g., Big Cliff, Foster, Dexter Dams in Willamette Basin). Non-consumptive use, other than reservoir evaporation and seepage losses during storage period.	Dams, reservoirs, power plants, transmission lines.	a) All uses requiring storage facilities (2,3, 5,6) b) Seasonal flood control (4) c) All uses requiring in-stream flows (7, 8,9,10,11,13)	a) All uses requiring keeping water in storage for later use (e.g., 5,10) b) 8,10 c) All out-of-stream uses, particularly 3.	Economic	Water Resources Public Utility Comm. Energy Fisheries & Wildlife

[1]The amount of water available to be shared as a result of storage will determine whether this use is compatible or competitve with other uses for that water.

Table 2. Continued

Use	Typical Features and Requirements	Typical Physical Facilities	Compatible Uses[1]	Conflicting/ Competitive Uses[1]	Types of Benefits	Principal State Agencies Involved
6. Thermal Power Generation (out-of-stream use)	Divert water from stream for plant use. Create semi-closed loop system at plant, with storage/cooling pond. Add makeup water from river to compensate for evaporation losses. Return blowdown water to river using diffuser to spread and mix heated water with river. Temperature control of return water is critical to meet effluent standards. Return flows have higher concentrations of dissolved solids, left behind by evaporated water. Choice sites are along large water bodies (e.g., Columbia River or Pacific Ocean) due to large supply available and large "heat sink" into which return flows can mix. Use is largely consumptive, with make-up water withdrawn to offset losses and blowdown water returned to the stream.	Diversion or intake structures, pumping stations, conduits, treatment plants, storage ponds, cooling towers, return conduits, diffuser outfalls.	a) All uses requiring storage facilities (2,3,5, 6) b) Seasonal flood control (4) c) All in-stream uses upstream of the withdrawal point (7,8,9,10, 11,13) d) 3	a) All b) All other out-of-stream uses (2,3,5,6, 12) c) All in-stream uses downstream of the withdrawal point (7,8,9,10, 11,13) d) All uses requiring keeping water in storage for later use (e.g., 5,10) e) All in-stream uses downstream of the return flow point (7,8, 9,10,11,13)	Economic	Water Resources Environmental Quality Energy Public Utilities Comm.
7. Navigation (in-stream use)	Principally along Snake-Columbia Rivers, in lower Willamette and along Coast. Must bypass natural obstructions (e.g., Willamette Falls or at Cascade Locks). Must dredge channel or add streamflow, or both, to maintain necessary channel depths. Slackwater navigation (e.g., Columbia and lower Snake Rivers) by means of dams and locks provides increased water depths and reduced river velocities. Except on largest rivers, can be highly seasonal unless up-stream (headwater) storage is created to augment the seasonal low flows. Non-consumptive use.	Dams, reservoirs, canals, locks, channel bank and alignment improvements, harbor/port improvements, dredging, jetties, dikes, channel markers, safety and rescue facilities.	a) All other in-stream uses (8,9, 10,11,13) b) 1,2 if point of return flow is near withdrawal point c) All uses involving headwater storage for downstream uses (1,2, 3,4,5,8,9,10,11, 12,13)	a) All out-of-stream uses (1, 2,3,5,6,12) b) 5 c) 8 with respect to dredging d) 9,11 due to spill risks	Economic	Water Resources State Lands

[1]The amount of water available to be shared as a result of storage will determine whether this use is compatible or competitive with other uses for that water.

Table 2. Continued

Use	Typical Features and Requirements	Typical Physical Facilities	Compatible Uses[1]	Conflicting/ Competitive Uses[1]	Types of Benefits	Principal State Agencies Involved
8. Fishery and Wildlife Conservation and Enhancement (in-stream use)	Wells or stream diversions provide hatchery water supplies. Quality of water supply to hatchery is critical. Hatchery effluent contains wastes, requires treatment. Protection and improvement of spawning areas. Protection and improvement of habitat. Reduction or prevention of biological resource losses associated with man's works. Enhancement of sports opportunities. Enhancement of commercial fishing and seafood harvesting. Provision of fish passage past natural or man-made barriers (e.g., falls, dams). Reduction of extremes of streamflows, both floods and low-flows. Augmentation of streamflow to protect and enlarge habitat. Management to accommodate recreational, commercial, and Indian tribe interests. Use in-stream is non-consumptive. Wildlife water use may be consumptive (e.g., meadow watering).	Fish hatcheries, wildlife refuges, fish ladders and screens, water supply well's and reservoirs, pollution control, land management, stocking of streams, lakes, reservoirs and lands, streamflow regulation.	a) 9,10,11 b) All uses requiring storage facilities c) All uses that augment flows, for river reaches where flows are augmented	a) All out-of-stream uses (1,2,3,5,6,12) b) All uses requiring storage facilities c) 7,10 with respect to possible contamination or habitat disturbance	Economic (Commercial) Environmental (Sports and Ecological)	Water Resources Fisheries & Wildlife
9. Water Quality Enhancement (in-stream use)	Wastewater treatment (municipal and industrial). Reduction of non-point source pollution from forest, agricultural, and urban lands. In-stream activities are oriented to upstream water storage to allow downstream flow augmentation during critical periods such as dry summer months. Basis of in-stream activity is dilution. Water released from storage reduces the concentration of suspended solids and other matter and increases the dissolved oxygen level. Temperature reduction in summer can also be achieved, as water stored in deep reservoirs along valley foothills is cooler than that flowing across valley floor in streams.	Treatment facilities, reservoir storage, legal control measures.	a) All in-stream uses (7,8,10,11,13) b) All out-of stream uses if withdrawal point is downstream (1,2,3,5,6,12) c) All uses requiring storage facilities	a) All out-of-stream uses (1,2,3,5,6,12) b) In-stream uses that cause contamination (7,8,10)	Economic (For re-use) Environmental	Water Resources Health Environmental Quality Fisheries & Wildlife Land Conservation Development Comm.

[1] The amount of water available to be shared as a result of storage will determine whether this use is compatible or competitive with other uses for that water.

Table 2. Continued

Use	Typical Features and Requirements	Typical Physical Facilities	Compatible Uses	Conflicting/ Competitive Uses	Types of Benefits	Principal State Agencies Involved
10. Water-Based Recreation (in-stream or out-of-stream use)	Highly seasonal; related to summer vacation periods and warmer weather. Two types: lake and reservoir (flat-water), free-flowing streams. Lake and reservoir swimming and boating are enhanced by large surface areas of water (full lakes and reservoirs) and sufficient access. Stream boating and floating is enhanced by sufficient water (including flow augmentation) to avoid shoals and portaging and by sufficient access. Provision of additional reservoirs for recreation is often at the expense of free-stream recreation sites. Minimization of short-term water level fluctuation is desirable. Demand steadily growing over the years. It has been more rapid than population growth due to shifting public interests and growth of the "outdoor recreation" lifestyle. Water quality is not a strong factor as long as the quality is generally good and exceeds minimizing water quality concerns. Portland-area water recreation is greatly influenced by public perception of water quality.	Reservoirs, recreational use facilities, access facilities, water and pollution treatment works, navigation markers, reserves for specific activities (e.g., fly fishing, non-motor boating)	a) All in-stream uses (7,8,9,11,13) b) All uses that require keeping water in storage	a) All out-of-stream uses (1,2,3,5,6,12) b) 5 regarding peaking	Economic Environmental	Water Resources Transportation Marine Board Health Environmental Quality Fisheries & Wildlife
11. Esthetics and Natural Values (in-stream use)	Certain rivers qualify for wild, scenic, or recreational status due to preserved natural and esthetic values (e.g., the Rogue below Grants Pass). Others have high natural value due to possibility of giving nearby relief from urban living (e.g., the Willamette). Ideally, the natural appearance should be preserved and developmental activities held to those that are absolutely essential or are compatible with esthetic concepts that are part of management philosophy (e.g., the provision of rural farm setting close to large city).	Legislation and/or zoning, protection from encroachment and development.	a) All in-stream uses (7,8,9,10, 13)	a) All out-of-stream uses (1,2,3,5,6,12) b) All uses requiring keeping water in full storage	Economic (Tourism) Environmental	Water Resources Transportation

Table 2. Continued

Use	Typical Features and Requirements	Typical Physical Facilities	Compatible Uses	Conflicting/ Competitive Uses	Types of Benefits	Principal State Agencies Involved
12. Maintenance of Ground Water Levels (out-of-stream use)	Management of ground water basin so as not to exceed long-term safe yield pumping rate. During periods of excess surface runoff, its storage may allow recharge to the ground water by means of wells, pits, or spreading grounds. Treated wastewater can also be recharged into the ground, either to add to the water supply or to provide a freshwater barrier against salinity intrusion.	Legal action to restrict use, storage facilities, desilting and treatment facilities, recharge wells or pits or spreading ground.	a) All uses requiring storage facilities (2,3, 5,6) b) Seasonal flood control (4) c) All in-stream uses upstream of the withdrawal point (7,8,9,10, 11,13)	a) All b) All other out-of-stream uses (2,3,5,6,12) c) All in-stream uses downstream of the withdrawal point (7,8,9,10, 11,13) d) All uses requiring keeping water in storage for later use (e.g., 5,10)	Economic	Water Resources
13. Salinity Control (in-stream or out-of-stream use)	Augment low streamflows for streams to prevent salinity intrusion from ocean or brackish water bodies. Recharge ground water basins to reverse flow gradients from brackish aquifers.	Dams, reservoirs, barriers, ground water recharge, desalination facilities.	a) All in-stream uses (7,8,9,10,11) b) All uses requiring storage facilities	a) All out-of-stream uses (1,2,3,5,6,12)	Economic Environmental	Water Resources

those otherwise impacted by reservoirs. Third, economic and environmental aspects of water uses can be compared. In Table 2, several of these comparisons are shown for the listed individual uses. The comparisons will be expanded upon in subsequent paragraphs.

Current Levels of Use

Current out-of-stream water use in Oregon is about 7 MAF/yr, less than one-tenth of the annual runoff for the State.[1] Principal out-of-stream uses are shown in Table 3. Irrigation accounts for 81 percent of total out-of-stream use, self-supplied industry for 12 percent of that total, public municipal, commercial and industrial supply for 4 percent, and rural domestic and livestock supply for 3 percent. Figure 10 contrasts these uses. About 84 percent of the total supply is obtained from surface water sources, including both reservoir storage releases and stream withdrawals. Of the total amount of water used, about 69 percent is consumptively lost rather than returned to streams. Irrigation is the most significant use in terms both of water diversion and streamflow depletion. Irrigated acreage in 1970 was 1.9 million acres, with an average use of 3 acre-feet of water per irrigated acre.

Common in-stream uses of water include hydroelectric power generation, navigation, fishery and wildlife maintenance and enhancement, water quality maintenance and enhancement, water-based recreation, and esthetics and natural values. Each shares the same water, whereas out-of-stream diversions normally do not. These uses draw upon both the natural streamflow and that from reservoir storage. Some of the uses are highly seasonal (e.g., fish runs, recreation).

While reservoir storage is presently providing for many needs and augmenting streamflows in some rivers (e.g., roughly doubling the summer low flow in the Willamette), reservoir capacity is inadequate to store as much water as might be used if available, as evidenced by the severe drawdown of many reservoirs during dry periods.

The annual pattern of power demand for the region is shown in Figure 11, together with the natural (unregulated) flow in the Columbia River at the Dalles. The Columbia Basin currently relies on hydroelectric power for 90 percent of its power needs. Power demand is greatest in the winter because of added heating and lighting requirements. However, the seasonal pattern is not very pronounced, due to the large and relatively constant year-round industrial demand. Headwater storage reservoirs compensate for the variable natural runoff by storing excess runoff (snowmelt) for release during low-flow periods (see Figure 12).

Hydroelectric power from the Columbia is provided by 11 plants on the U.S. main stem of the Columbia and two storage reservoirs in British Columbia. These, together with 34 projects on tributary river systems, are operationally integrated.

1. Murray, C.R. and E.B. Reeves; Estimated Use of Water in the United States in 1970; U.S. Geol. Survey Circ. 676; U.S. Govt. Printing Office; Washington, D.C.; 1972.

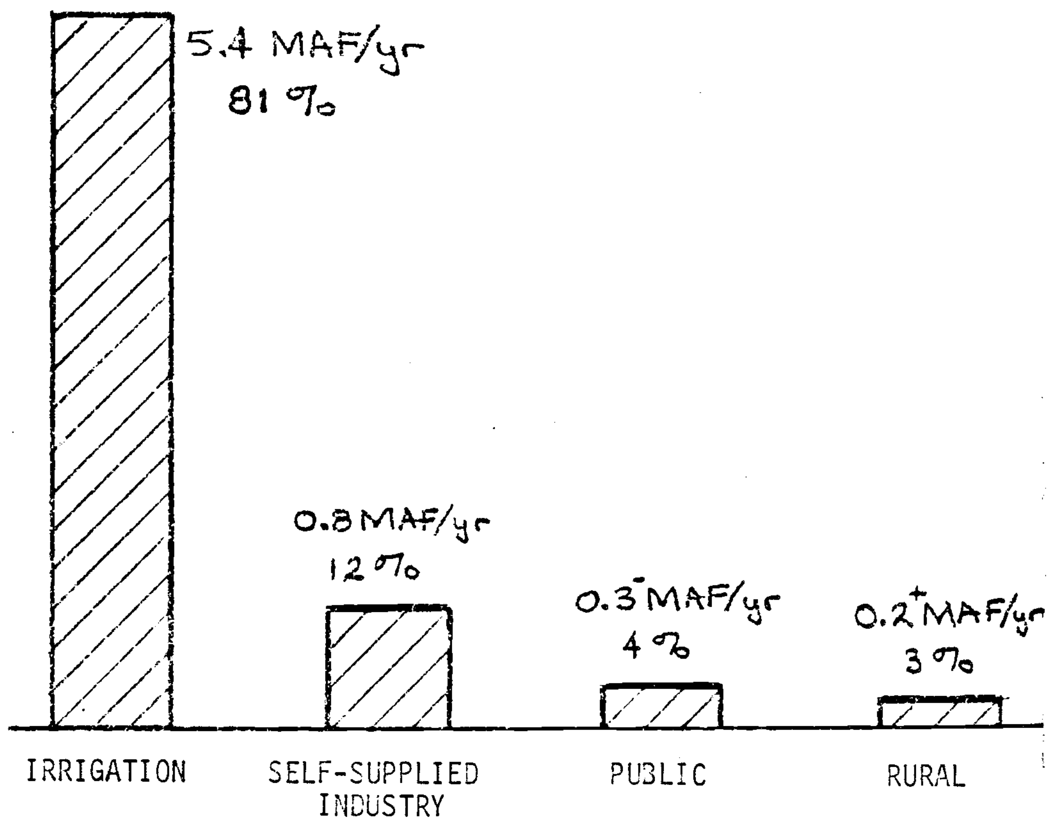


FIGURE 10. 1970 LEVEL OF OUT-OF-STREAM USE

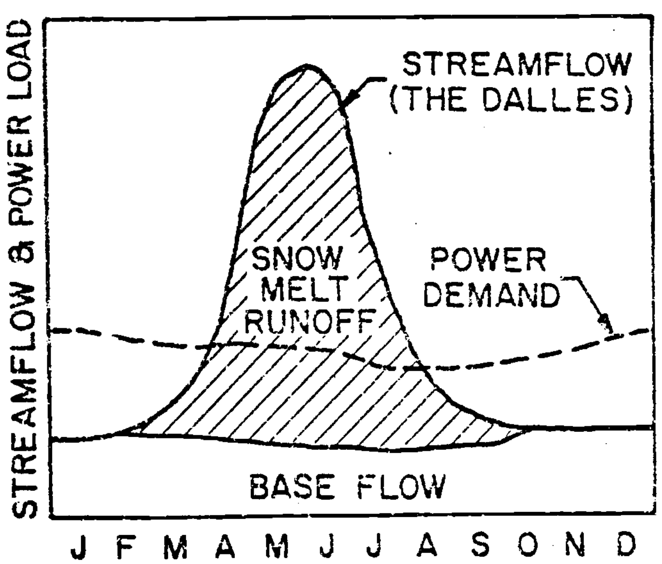


FIGURE 11. REGIONAL ANNUAL POWER DEMAND PATTERN AND NATURAL COLUMBIA RIVER FLOW

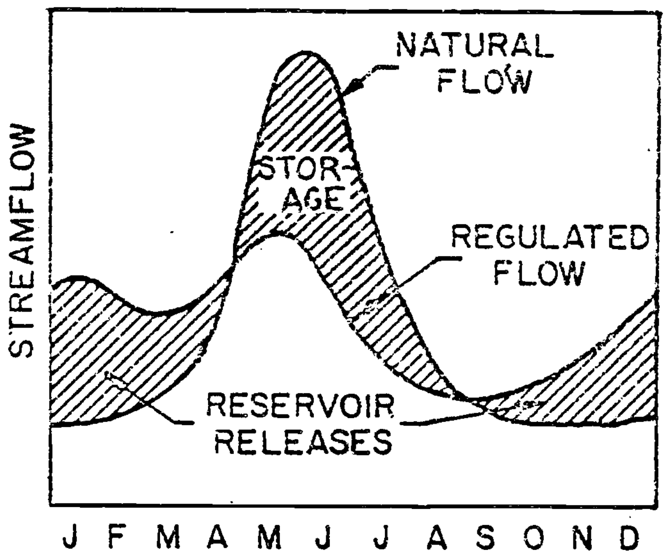


FIGURE 12. EFFECT OF RESERVOIR REGULATION ON COLUMBIA RIVER FLOW

Table 3. 1970 Levels of Water Use in Oregon[1]

Type of Use	Use (Supply), Acre-feet/year			Consumptive Use, Acre-feet/year
	From Surface Water Sources	From Ground Water Sources	Total Use	
Irrigation	4,700,000	710,000	5,410,000	2,600,000 consumed 1,700,000 conveyance loss 4,300,000 (79%)
Self-Supplied Industry				
Thermal power	25,000	0	25,000	
All others	661,000	123,000	784,000	
	686,000	123,000	809,000	29,000 (4%)
Public (Domestic, Industrial Commercial)	179,000	75,000	254,000	54,000 (21%)
Rural (Domestic, Livestock)	37,000	179,000	216,000	216,000 (100%)
Totals	5,602,000	1,087,000	6,689,000	4,599,000 (69%)

[1]Data source: Murray, C.R. and E.B. Reeves; Estimated Use of Water in the United States in 1970; U.S. Geol. Survey Circ. 676; U.S.Govt. Printing Office; Washington, D.C.; 1972.

Columbia flood control storage is provided mainly from the British Columbia reservoirs and at Grand Coulee and John Day reservoirs, with lesser storage available at other projects. Storage usable for flood control is also available on tributary streams, particularly the Willamette.

The Columbia is navigable from the Pacific Ocean to the mouth of the Snake River; the Snake River is navigable to Lewiston, Idaho. Grain, petroleum products and miscellaneous products account for about 3 million tons of cargo per year passing Bonneville Dam. About 80 percent of the tonnage moves downstream and 20 percent upstream. Commercial traffic has little seasonal variation whereas pleasure boating is highly seasonal.[1]

The Columbia and its tributaries provide for migrations of valuable anadromous fish, salmon in particular. Many game fish species are also native to the region. The region's rivers, lakes and reservoirs also provide habitat for waterfowl and furbearers.

Environmental Problems Associated with Present Water Use

Oregon's economy is based primarily on renewable natural resources, including water. To reach Oregon's present level of water resource development, significant alterations have been made to the natural environment. Heavy reliance has been placed on dams and reservoir storage. Seven major federally operated dams border the state on the Columbia and Snake Rivers. Thirteen federal dams are in the Willamette Valley and dams can be found in most parts of the state, both publicly and privately operated. Most of the choice dam sites (technically and economically) have already been occupied. Significant alterations to nature have resulted from existing dams.

Use of dams along the Columbia and Snake Rivers to provide the high-priority needs for hydroelectric power generation and flood control has dominated all other in-stream and out-of-stream water uses. Maximization of power production has required tight control over the time of storage releases. Other water uses have had to adjust to the requirements for hydropower. Impact upon the anadromous fishery, which dominates in its commercial and recreational value all forms of fish and wildlife resources, has been tremendous. Severe problems of the physical blockage of fish passage have been compounded by high mortality rates due to "the bends" from nitrogen-supersaturated water below spillways and due to the blades of turbines. Streambeds have been deeply inundated by reservoirs and lost to shallow-water spawning. The overall tradeoff, in simplest terms, has been a substantial degradation of the anadromous fishery in order to provide the energy basis for the region's tremendous economic growth since the 1930's. Mitigation efforts in recent years have sought to improve the fishery through hatcheries to supplement the dwindling natural stocks of fish, physical alterations

1. Pacific Northwest River Basins Commission; Seasonality of River Use; Columbia and Lower Snake Rivers; Power Planning Committee, PNWRBC; Vancouver, Wash.; 1975.

to dams, and other measures. These have not yet re-established the large fish runs of bygone years. Navigation has likewise made tradeoffs with power production. Lockage water reduces power generating capabilities during low flows, whereas peak load generation causes flow fluctuations that disturb navigation.

For waters other than the Columbia and Snake, hydroelectric power is a much less dominant feature of storage projects. For example, several in-stream and out-of-stream uses co-exist on relatively equal terms in the Willamette Basin. In the Deschutes Basin, out-of-stream agricultural use and in-stream fishery and recreation uses dominate. Key problems on in-state waters generally are associated with degraded water quality and its effects upon fishery and wildlife uses. Many other problems also exist, but the fishery problem is particularly important because it is compounded by the severe losses in the Columbia and Snake River and a desire to develop replacement stocks on other streams. A most notable success is the cleaning up of pollution in the Willamette Basin and the concurrent expansion of the anadromous fishery there. These benefits have introduced new constraints on other water-related activities most particularly on sand and gravel removal from the river and other types of channel works.

Discussion of the more extensive impacts of current water use are treated in a subsequent chapter, following discussions of the relation of economic activity to water and of estimated future water needs, so that all impacts can be evaluated together.

Water Use and the Level of Economic Activity

The relationship between water use and economic activity is complex. To analyze it, we ask first what is the use of water?" Only in a few important cases is water considered a "commodity resource" technically related to the production of some goods or services (e.g., crops and manufactured products). In these cases (the traditional economic sectors), the value of water is estimable. In other use categories, it is difficult to derive a technical relationship between quantities of water in use and value of output. Water retained in an undeveloped watercourse is sometimes referred to by economists as water being used as an "amenity resource". Evaluating some uses of water, notably fisheries or recreation, is problematical since they involve water neither as a pure commodity resource nor as a pure amenity resource, but rather some imprecise combination of the two.

Valuing Water in the Traditional Economic Sectors

The analysis of water use and economic activity in the traditional sectors involves principally a calculation of the average volume of water used for every dollar of gross output (or total transactions) generated in the economy. For the State of Oregon in 1963, for example, gross

TABLE 4: Representative Water Use Coefficients for Three Western States

Industrial Sector	California withdrawals[a] 1960 (gal/$ of gross output)	Colorado withdrawals[b] 1970 (gal/$ of gross output)	Colorado consumptive use[b] 1970 (gal/$ of gross output)	Washington withdrawals[c] 1970 (gal/$ of gross output)	OREGON GROSS OUTPUTS[d] 1969 (current dollar estimates)
Livestock, poultry	890	807	478	680	$ 386,000,000
Irrigated crops	2250	6282	3701	5070	} 580,000,000
Other agriculture	1.75	32	17.8	24	
Metallic minerals	754	} 326	} 39.2	-	} 79,000,000
Nonmetallic minerals	275				
Construction	0.45	-	-	1	335,000,000
Food and kindred products	208	593	349	460	700,000,000
Textiles and apparel	0.40	-	-	1	44,000,000
Lumber and wood products	28.5	1.1	0.21	15	1,690,000,000
Pulp and paper products	41.6	100	19.3	124	249,000,000
Printing and publishing	0.66	2.0	0.3	1	75,000,000
Chemicals	21.8			30	} 109,000,000
Petroleum products	140	} 7.18	} 1.21	97	-
Rubber products	1.67			-	-
Stone, clay, glass	29.6	51	13	36	82,000,000
Primary metals	9.9			26	183,000,000
Fabricated metals	0.59			1	195,000,000
Machinery manufacturing	0.60	} 3.7	} 0.8	2	
Electrical machinery	0.60			-	} 443,000,000
Transportation equipment	2.04			4	
Electrical energy	2844	} 26.7	} 6.9	-	} 382,000,000
Other utilities	2.22			10	
Trade	4.03	8.1	3.0	7	1,568,000,000
Services and financial	6.92	9.28	1.6	7	2,090,000,000
Public administration	-	13.9	5.0	8	-

[a] E. M. Lofting and P. H. McGauhey, 1963, "Economic Evaluation of Water 3, An Inter-industry Analysis of the California Water Economy": Contribution 67, Water Resources Center, University of California, Berkeley.

[b] S. L. Gray and J. R. McKean, 1975, "An Economic Analysis of Water Use in Colorado": Fort Collins, Colorado, Environmental Resources Center Completion Repeort Series 104.

[c] G.G. Parker, 1971, "Municipal, Industrial, and Irrigation Water Use in Washington [State]": U.S. Geol. Survey Open File Report.

[d] J.R. Wilkins, 1976, "Methods and Economic Analysis, Comprehensive Joint Plan, Pacific Northwest: An Application of Interindustry Analysis to Natural Resource Development": Corvallis, Oregon, U.S. Dept. of Agriculture, Economic Research Service, mimeo.

industrial activity of $8.6 billion[1] was associated with an apparent estimated withdrawal requirement of 8.5 million acre-feet of water,[2] giving a gross average of $1000 of activity per acre-foot withdrawn. It is more meaningful to dissaggregate economic activity by industrial sector (including public sector activities) and list the water requirements, both withdrawals and consumptive uses, per dollar of gross output for each sector. Although a detailed set of water use "coefficients" has not been developed specifically for Oregon, Table 4 shows the similarity among coefficients developed for other western states. The values should not be greatly different for Oregon.

The figures in Table 4 suggest that water use per dollar of output in the natural resource-based sectors (irrigated agriculture, livestock, food processing, paper and pulp) is much greater than in the remainder of the economy. (Table 3 showed that approximately 81 percent of total withdrawals of water in Oregon are used in irrigated agriculture.) Based on estimates of the value of irrigated crop production in 1969 of $310 million,[3] and corresponding withdrawal and consumptive use values, Oregon irrigated agriculture water use coefficients are 5,830 gal./dollar and 3,170 gal./dollar for withdrawal and consumptive use, respectively. These numbers are similar to those reported for other western states in Table 4. If the other sectors in Oregon's economy have water requirements in the ranges shown in Table 4 (500 gal./dollar or less), it is necessary to explore further the meaning and consequences of such a significant difference between agriculture and the other uses.

Table 4 does not include "households" as an economic sector. Household consumption of water in metered areas of Western states has been estimated to be 250 gallons per day per dwelling unit (gpd/du) for domestic uses only and 450 gpd/du during periods of lawn sprinkling. Without question, water has a high value in domestic uses, both to individuals and to society. Since, however, any estimate of value in this sense is problematical, an alternative approach is to simply note the costs of municipal water incurred by individuals. In Oregon in 1972, for example, the cost of a first 3000 gal. increment of water was $3.26 using the median of metered base rates for all cities.[4] The cost of 6000 gal. (a typical

1. D.A. Watson and R.L. Allen; Oregon Economic and Trade Structure; University of Oregon, Bureau of Business and Economic Research; Eugene, Oregon; 1969. (Amount expressed in current 1963 dollars.)

2. Adapted from C.R. Murray; Estimated Use of Water in the United States, 1965; U.S. Geol. Survey Circ. 556; 53 p., 1968; and K.C. MacKichan and J.S. Kammerer; Estimated Use of Water in the United States, 1960; U.S. Geol. Survey Circ. 456; 26 p.; 1961.

3. F.P. Linaweaver, Jr., J.C. Beebe, and F. A. Skrivan; Data Report of The Rèsidential Water Use Research Project; John Hopkins University; Baltimore, Md; 1966.

2. Bureau of Governmental Research and Service; Water Connections and Service Charges: Oregon Cities and Water Districts; University of Oregon, Eugene; 1973.

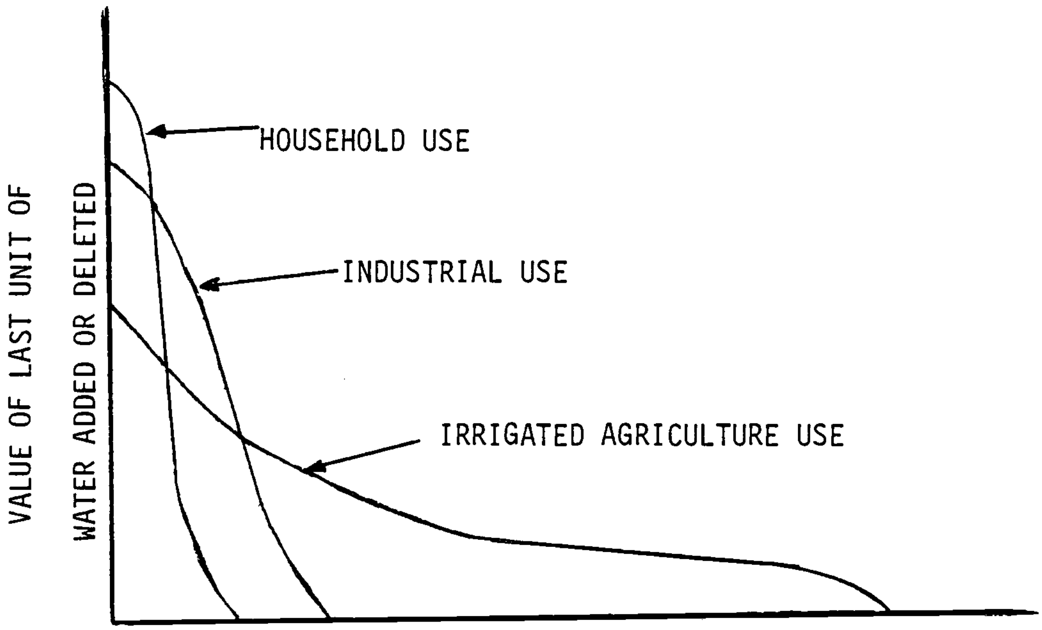


FIGURE 13. VALUE IN MARGINAL USE VERSUS QUANTITY FOR SEVERAL INDIVIDUAL TYPES OF USERS[1]

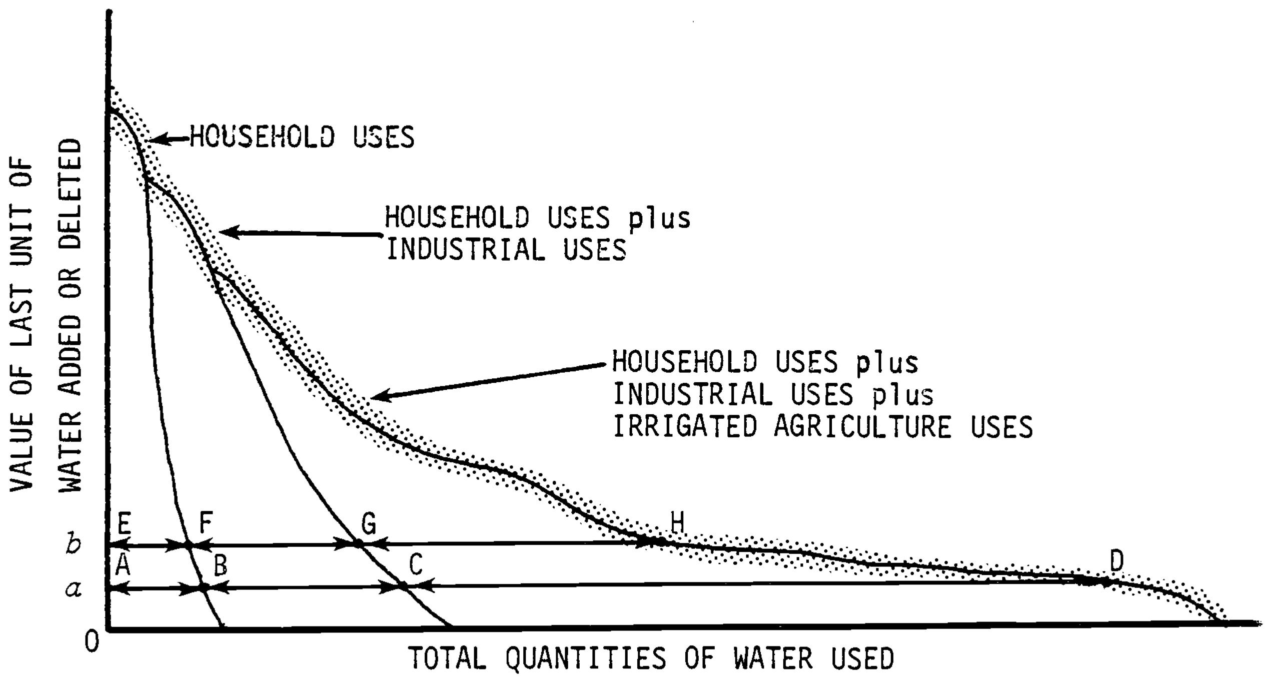


FIGURE 14. VALUE IN MARGINAL USE VERSUS QUANTITY FOR COMBINED USERS[1]

[1] Adapted from M. M. Kelso, and others, 1973, Water Supplies and Economic Growth in an Arid Environment: Tucson, Arizona, Univ. of Arizona Press, p. 30-31.

family's monthly water use in winter) was $4.08. Although a "gallons per dollar" figure can then be derived, it is not strictly comparable to the notion of a water use coefficient.

One interpretation of the meaning of the water use coefficients involves the question "what is likely to be the use of water?" If water availability (within limits) does not constrain economic growth, as is commonly assumed, then estimates of the expected increases in gross industrial output can be used to calculate the extra volumes of water required. But if water supplies do constrain economic activity, there is little likelihood that the existing water use coefficients will be of much use for allocative purposes. The normative question of "what should be the use of water?" must be approached differently from the questions of "what is" or "what is likely to be", because the water use coefficients reflect not only use patterns of past decades of surplus water, but also the peculiar set of incentives and sanctions formed during those periods.

As water becomes increasingly scarce, there are fundamental economic forces that can enter into the process of water allocation and change the outcome very significantly. The extent of impact of this increasing scarcity upon water allocation depends upon the extent to which water allocating insitutions are designed to either take into account or to be isolated from information on the increasing scarcity value of water.

The critical information concerns the measure of value to be given to water. The correct measure is the value of water in the marginal use. This is different from the average (coefficient) values of water discussed above because water use is consistent with the "law of diminishing returns". Additional units of water yield successively smaller additions to the value of total output, thus causing those last water units applied to be valued less and less. Figure 13 shows the diminishing value of water in marginal use as a result of increasing the quantities of water applied. The shapes of these curves reveal, for example, that households attach a high value to relatively small quantities of water, whereas irrigators attach lower values to large quantities of water. In each case, however, the law of diminishing returns may cause the value of the last unit of water applied to approach zero.

The heavy curve in Figure 14 results from adding up the value-quantity relationships for municipal, industrial, and irrigated agriculture uses. One can now examine the relationship that the "value of water marginally used" has with the price of water in the economy and determine the effect of this relationship on the allocation of water to the competing uses. Given a hypothetical price of water represented by the vertical distance $\overline{0\text{-}a}$, a total quantity of water $\overline{AD}$ will be consumed in these sectors. This consists of municipal use $\overline{AB}$, industrial use $\overline{BC}$, and irrigated agriculture use $\overline{CD}$.

If the price of water were to rise from $\overline{0\text{-}a}$ to $\overline{0\text{-}b}$, the total water use in the economy would be reduced drastically (from $\overline{AD}$ to $\overline{EH}$). The greatest share of this reduction would be borne by irrigated agriculture. It is in this sense that irrigated agriculture is the "most marginal" water user in the economy. Thus, water use decisions in agriculture have tremendous impacts on the total quantity of water consumed.

It is important to recognize, however, that not all use of water in crop production is "marginal". Only the lower-value uses fall into this category. Furthermore, there are also marginal water uses in other applications than agriculture. For example, given the price change discussed above, consumption will decline from $\overline{AB}$ to $\overline{EF}$ as households cease to use water for their least valued purposes and from $\overline{BC}$ to $\overline{FG}$ as industries do the same.

It was seen, then, that the average value of water differs greatly among its various uses. More importantly, discussion of the value of water in marginal use indicates that there is a considerable possibility for transferring water from lower-valued uses to higher-valued uses. To gain the efficiencies obtainable from such water reallocations, it is important that both private and public decisions about water use take into account the relevant economic values.

Valuing Water Outside the Traditional Economic Sectors

There are several use categories in Table 2 where it is difficult to estimate the economic value to be given to the units of water in those uses. These include hydropower, commercial fisheries, navigation, flood control, and collective recreational uses.

Hydroelectric Power. Hydropower generation in Oregon can be considered to consist of two major regimes: the Columbia-Snake system (7 facilities) and the interior streams of Oregon (33 facilities having at least 5,000 kw capacity each). The average annual hydroelectrical energy output in Oregon for a recent five-year period has been about 23.8 billion kilowatt-hours (kwh) with 18.1 billion kwh originating from the Columbia-Snake system[1] and 5.7 billion kwh originating from the rest of Oregon. It is difficult to value this output because of the mixture of public and private ownership. Typical wholesale values of 0.3¢ to 0.5¢ per kwh may be applied to obtain a gross value. However, general estimates of the dollar value of a unit volume of water in this use are not meaningful because of significant differences in plant efficiencies, reservoir configurations, and reservoir operating rules. In a later discussion of impacts, however, such an estimate is given for particular reservoirs.

Commercial Anadromous Fisheries. These fisheries in Oregon may also be considered to consist of two regimes: the Columbia River fishery and the marine salmon fishery operating out of Oregon ports. The former involves only anadromous fish propagating in the Columbia, whereas the latter involves fish propagating in all Pacific Coast rivers including Oregon coast rivers. While it is thus impossible to determine Oregon's contribution, via its water resources, to the marine salmon fishery, the

1. This assumes that one-half of the output of each hydroelectric plant in this group is attributed to Oregon.

Columbia River salmonid fishery has been monitored closely. In 1975, Columbia River commercial landings were 8.2 million pounds of salmon (4 species) and steelhead.[1] Assuming a recent range of ex-vessel prices of $1.75/lb to $2.25/lb.,[2] one could estimate a value of the commercial catch in the Columbia. Even when the value of the sports fishery landings (discussed below) are included, it is not apparent that a total value of this fishery will be obtained. The <u>total</u> value significantly involves the necessary numbers of fish to insure propagation and, more importantly, the nature of consumer demand for salmonid fish. Even more problematical is the relationship of fishery size to the quantity-quality characteristics of the fresh water habitat. It is possible, however, to estimate minimum streamflows to insure survival of the fishery. When these minimum standards are violated, it is possible to make rough estimates of monetary losses due to deficit quantities of water.

<u>Navigation</u>. Local and internal movements of commerce on the Columbia-Willamette-Snake system of navigable waterways involved approximately 11 million tons in 1973.[3] Since barge traffic is described according to weight and distance (i.e., cents per ton-mile), only an in-depth study of all the haulage and alternative means of transportation would reveal some estimate of the economic value of the Columbia River navigation system. In lieu of this information, it is known that upsteam of Portland about 80 percent of the cargo is the downstream shipment of wheat, and that about 15 percent is upstream shipment of petroleum products. It is apparent, therefore, that there are limited opportunities for return trip haulage of cargo which adversely affects the economic performance of the system.

<u>Flood Control</u>. The valuation of flood control measures, structural and non-structural, involves knowing the reduction of expected damages which may result from flood waters. These potential cost savings can be estimated for any local area where a flood would cause a certain depth of water inundation for some duration. Several areas in Oregon designated as floodplains may then either attempt to adopt structural or non-structural (i.e., insurance and zoning) programs so as to realize these cost savings should a flood occur. For this reason, flood control as a purpose of river system management is similar to other uses discussed here, since the potential cost savings are like a benefit.

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1. Beiningen, K.T.; "Fish Runs": in <u>Columbia River Fisheries Project; Pacific Northwest Regional Commission</u>, Portland, Ore.; 1976. (Includes Indian commercial catch.)

2. Brown, W.G., et.al; <u>Improved Economic Evaluation of Commercially and Sports-Caught Salmon and Steelhead of Columbia River</u>; Oregon State University Agricultural Experiment Station Special Report 464; 1976.

3. Pacific Northwest River Basins Commission; <u>Draft -- Pacific Northwest Regional Program</u>; Vancouver, Wash.; 1976.

Recreational Uses. Many items listed in Table 2 fall into this category due to the essential use of water as an amenity resource: sports fisheries, sports boating, hunting, and all types of water-related recreation, including appreciation of wilderness scenery. These differ from the four uses just discussed (hydropower, commercial fisheries, navigation, and flood control) in that these latter in-stream activities are generally assigned monetary values in water project design. Until the 1960's, however, it was uncommon to attempt to quantify the recreational experience (in the broad sense) in monetary terms. It was merely attempted to describe the impact in terms of some physical measure of recreational use. But now significant attention is given to attaching monetary values to all kinds of recreation, including the appreciation of pristine natural areas. The analysis of water resource impacts is increasingly taking place in the realm of careful enumeration of the cross-effects of competing uses and in the monetary evaluation of those effects. Determination of the dollar value of a unit of water in recreational use requires much still-undone social science research on user tastes and preferences.

Future Uses of Oregon's Water

Each of the various uses of water described in the preceeding section figures to be a key element in Oregon's long range future. Below we outline two approaches to the issue of water use in the decades to come. The first, drawing upon careful assumptions of demographic and economic trends results in some broad guidelines for water use estimation. The second approach is more relevant to near future decisions on water allocation.

State Projection Study

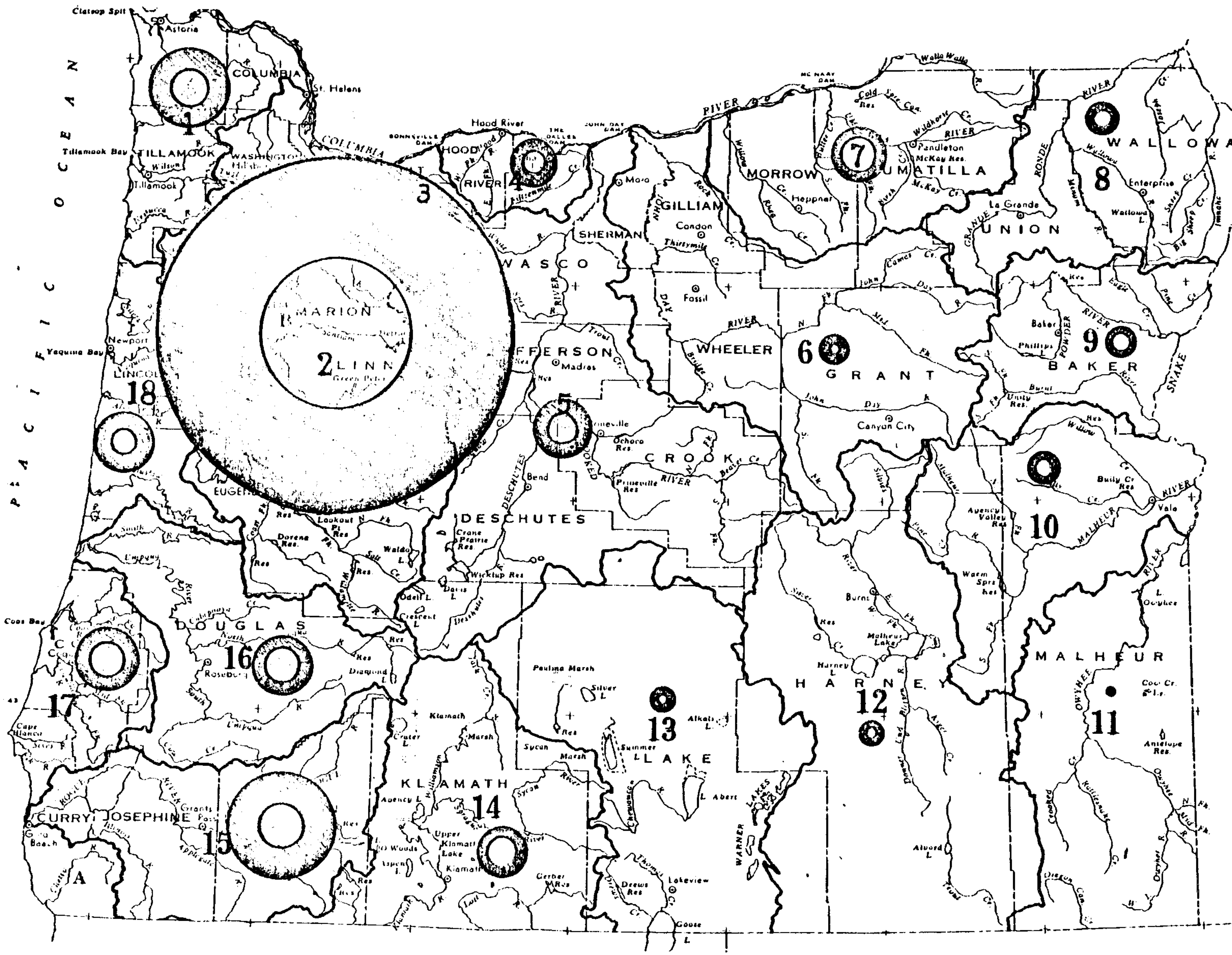
The Oregon State Water Resources Board completed and published in 1969 a study titled Oregon's Long Range Requirements for Water.[1] The study is generally regarded as a generous estimate of water needs to assure that Oregon will adequately protect its water for future uses. Some of the assumptions made about future conditions need re-examination in the light of changed population growth, lifestyles, energy availability, federal spending policies, and concerns over particular water use that have arisen in the 10 years since projections for that study were made. The study assumed that potential water deficiencies in basins will be met through importation of Columbia or Snake River water. Hence, the constraints normally imposed on water use due to water scarcity and competition among uses are largely ignored. In spite of shortcomings of the study of long range needs, it is the only projection study of this type available and gives an upper limit to future water requirements for the state. Actually, constraints will hold use to lower levels.

The projections were made 50 years and 100 years into the future (2020 and 2070, respectively). However, the projected 2020 population of 4.1 million to 5.3 million is much larger than federal projections of 2.9 million people, made shortly after the state study was completed.[2] Therefore, the actual dates of projection should be disregarded. Instead, the study should be viewed as "unconstrained" long-term projections to contrast with present uses in order to know the broadest range possible needs in developing policies on water use.

Not dealt with in such long-range projects are the seasonal variations of water supply and requirements that will create many future water crises, even in areas west of the Cascades where the total annual supply may still exceed the annual use. Furthermore, dry years will heighten such crises to an even greater extent than is presently the case.

1. Oregon State Water Resources Board; Oregon's Long-Range Requirements for Water; Salem, Oregon; 1969.

2. U.S. Water Resources Council; 1972 Obers Projections; Regional Economic Activity in the U.S.; Series E Population; Washington, D.C.; 1972.



BASIN	2070 POPULATION
1 NORTH COAST	324,000
2 WILLAMETTE. 3 SANDY	6,560,100
4 HOOD	110,400
5 DESCHUTES	176,200
6 JOHN DAY	37,600
7 UMATILLA	145,600
8 GRANDE RONDE	53,200
9 POWDER	48,900
10 MALHEUR	50,000
11 OWYHEE	7,500
12 MALHEUR LAKE	24,000
13 GOOSE & SUMMER LAKES	20,300
14 KLAMATH	124,100
15 ROGUE	584,900
16 UMPQUA	194,300
17 SOUTH COAST	212,500
18 MID COAST	191,400
OREGON TOTAL	8,865,000

1960 ○ 2070 ●

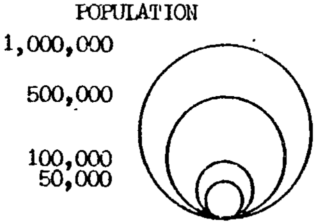


FIGURE 15. LONG-RANGE PROJECTED POPULATION

(Source: Oregon State Water Resources Board; Oregon's Long-Range Requirements for Water; Salem, Ore.; 1969)

The long-range projected population is shown in Figure 15. The long-range projections for municipal and light industrial water largely correspond to population growth projections. Projections for heavy industrial and mining water requirements, in Figure 16, do not as closely correspond to population but instead show the relatively greater importance of coastal basins due to ocean shipping. It is significant that thermal power water requirements were distributed (in the report) mainly on the basis of projected population, whereas current trends suggest that a different distribution will be likely, away from population centers. Irrigation water projections are shown in Figure 17. Figure 18 combines the preceding to give a comparison of the projected needs for out-of-stream use. The expected continuing domination of irrigated agriculture over water use in Oregon is clear.

In contrast to the large increases of use projected for out-of-stream uses, only relatively modest increases are projected for in-stream water use, as shown in Figure 19. Howvever, in-stream flow needs may need particular re-evaluation in the light of on-going fishery resource programs (e.g., the expansion of the anadromous fishery in the Willamette to augment the Columbia-Snake fishery) and the very great energy and dollar costs of higher levels of pollution control when population and industrial growth continues but no additional flow augmentation is possible.

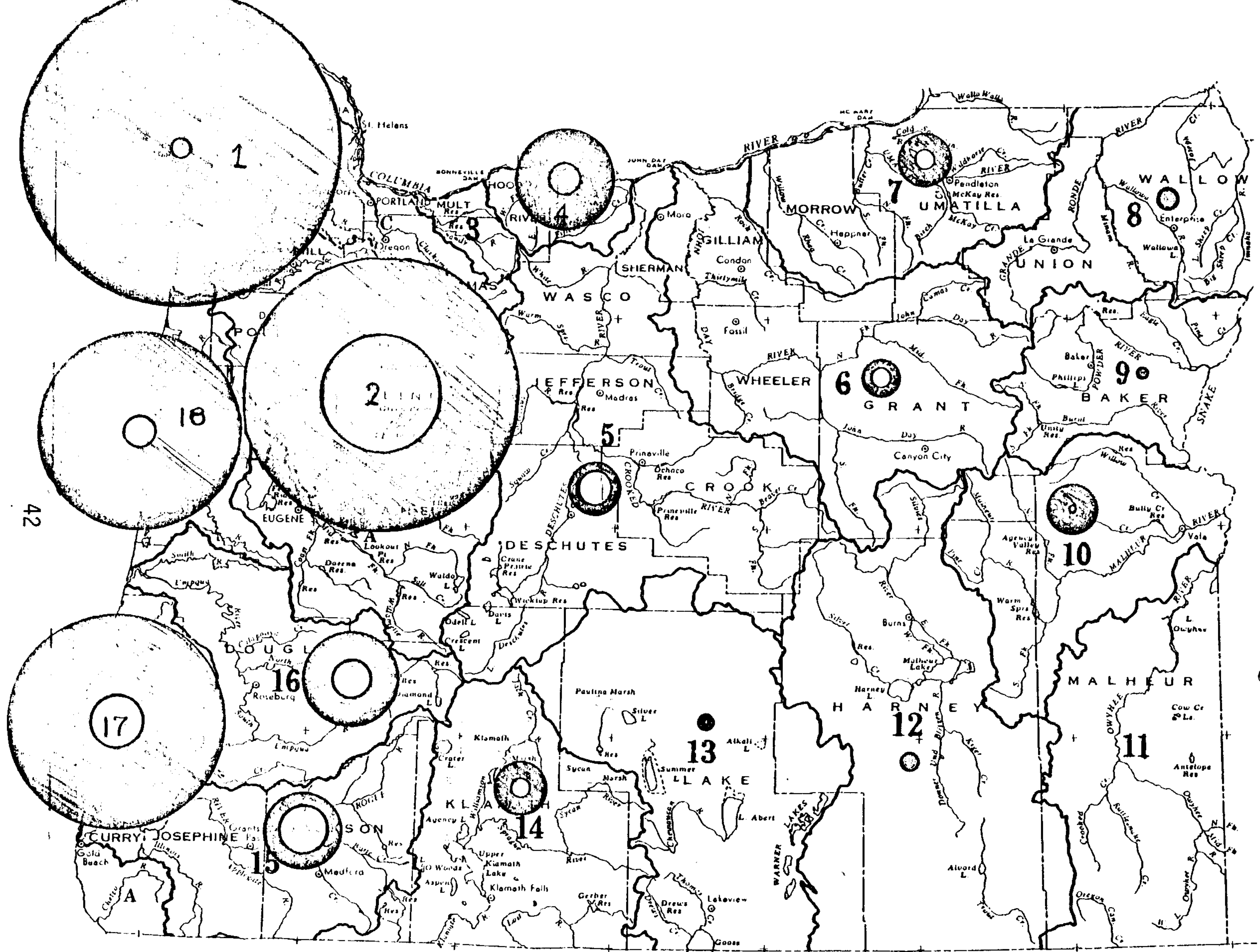
The total projected requirements for water to serve in-stream and out-of-stream uses are summarized from the study in Table 5. The long-range need is for an amount of water almost equal to the 84 MAF/yr water supply for Oregon.

Figure 20 compares the projected total water requirements with the available supply for each drainage basin. The need for supplemental water supplies is strongly shown east of the Cascades, if water use were to expand at projected rates without constraint.

<u>Irrigation Water Demand</u>

We shall now sketch some of the forces which drive irrigation water use. Their analysis lets us depart from the projections of future requirements discussed above. For the purposes of this conference it may be instructive to focus on irrigation water <u>demand</u> instead. We shall not present quantitative estimates of demand, but shall emphasize the forces which are likely to determine it. This distinguishes the concept of "demand" from that of "projected requirements." The former views the determination of the quantity of water used as the result of the action of economic variables which are generally observed to determine the quantity consumed of any commodity. The latter relies upon projecting into the future relationships which have been observed to exist in the past.

Our emphasis on irrigation in this discussion does not imply a judgment on the merits or demerits of further irrigation developments. Instead we call attention again to the fact that irrigation represents 81 percent of all consumptive water use in Oregon and that the scope for increasing and conserving water use in this area is greater than in all other uses combined.



BASIN	2070 DEMAND (ACRE-FEET)
1 NORTH COAST	1,324,000
2 WILLAMETTE	1,004,000
3 SANDY	
4 HOOD	133,000
5 DESCHUTES	43,000
6 JOHN DAY	21,000
7 UMATILLA	38,000
8 GRANDE RONDE	9,000
9 POWDER	7,000
10 MALHEUR	36,000
11 OWYHEE	-
12 MALHEUR LAKE	6,000
13 GOOSE & SUMMER LAKES	7,000
14 KLAMATH	44,000
15 ROGUE	72,000
16 UMPQUA	112,000
17 SOUTH COAST	630,000
18 MID COAST	506,000
OREGON TOTAL	3,992,000

PRESENT ○ 2070 ●

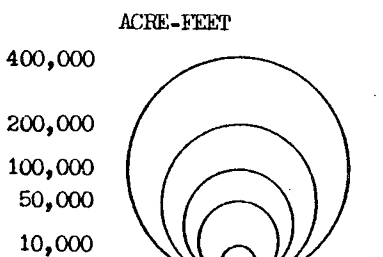
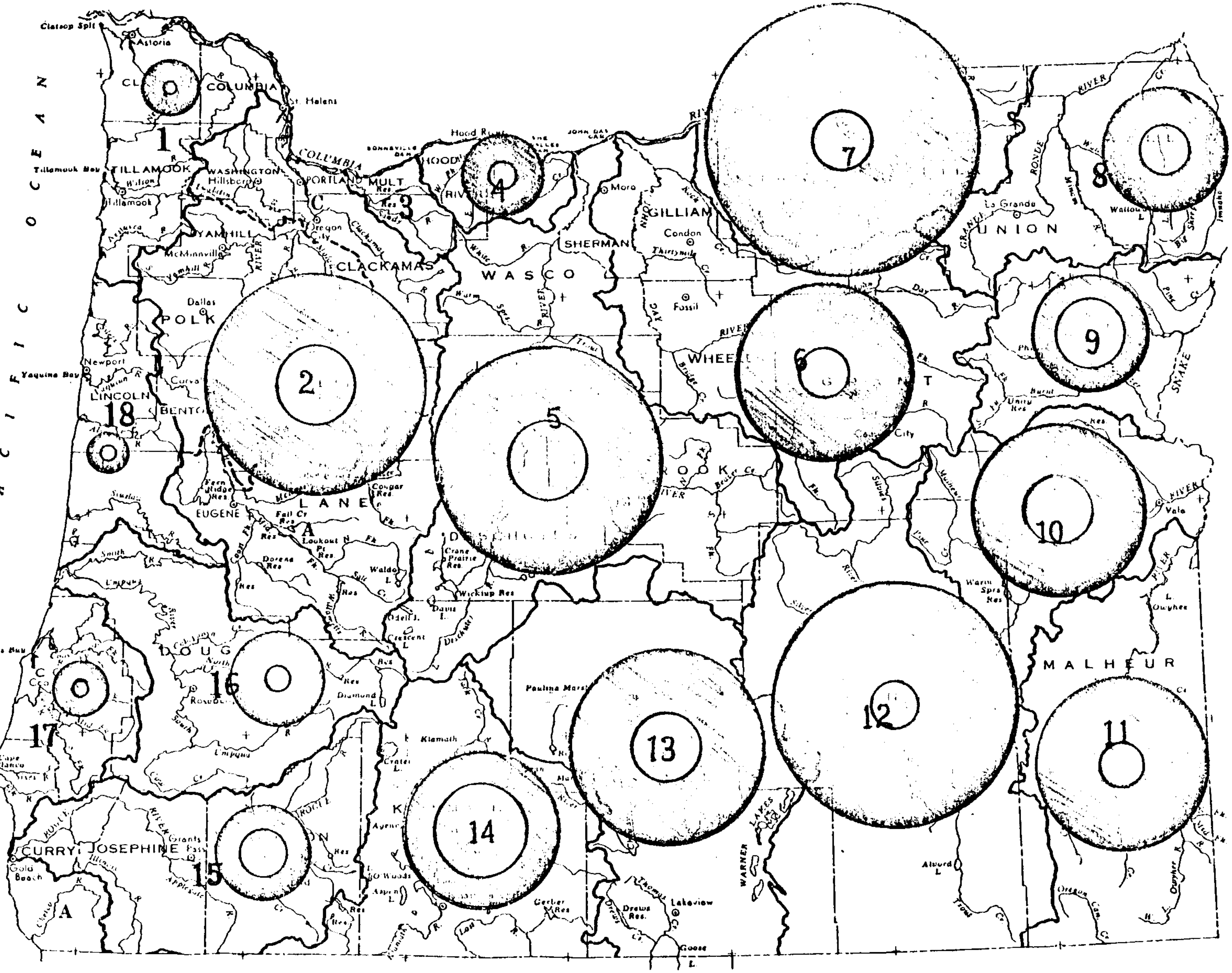


FIGURE 16. LONG-RANGE PROJECTED HEAVY INDUSTRIAL AND MINING WATER DEMAND

(Source: Oregon State Water Resources Board; Oregon's Long-Range Requirements for Water; Salem, Ore.; 1969)



BASIN	2070 DEMAND (ACRE-FEET)
1 NORTH COAST	222,000
2 WILLAMETTE	4,073,000
3 SANDY	
4 HOOD	544,000
5 DESCHUTES	4,135,000
6 JOHN DAY	2,512,000
7 UMATILLA	5,707,000
8 GRANDE RONDE	1,251,000
9 POWDER	988,000
10 MALHEUR	2,576,000
11 OWYHEE	2,319,000
12 MALHEUR LAKE	4,569,000
13 GOOSE & SUMMER LAKES	3,286,000
14 KLAMATH	1,951,000
15 ROGUE	858,000
16 UMPQUA	718,000
17 SOUTH COAST	180,000
18 MID COAST	119,000
OREGON TOTAL	36,010,000

PRESENT ○ 2070 ●

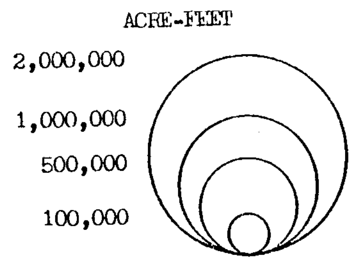


FIGURE 17. LONG-RANGE PROJECTED IRRIGATION DEMAND

(Source: Oregon State Water Resources Board; <u>Oregon's Long-Range Requirements for Water</u>; Salem, Ore.; 1969)

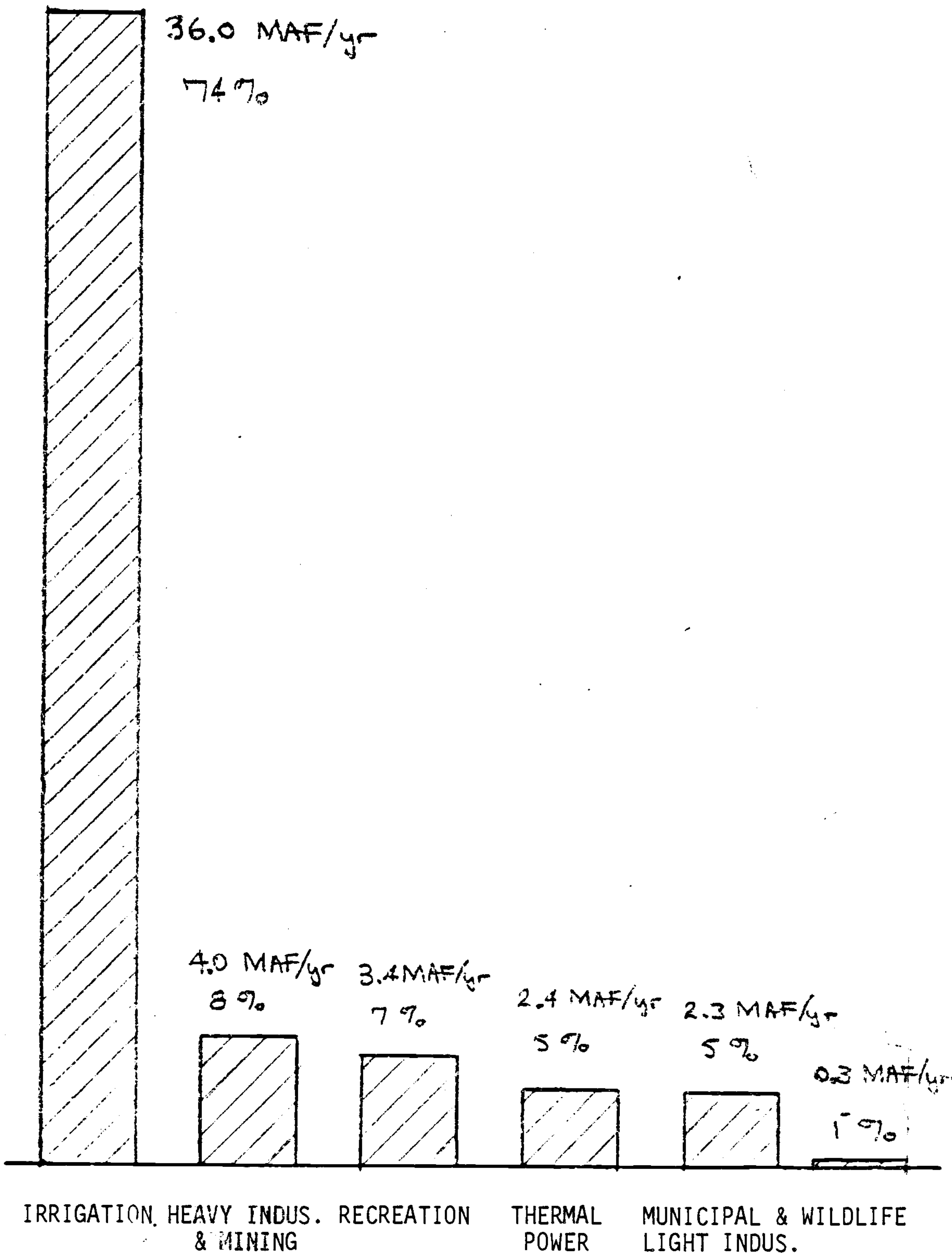
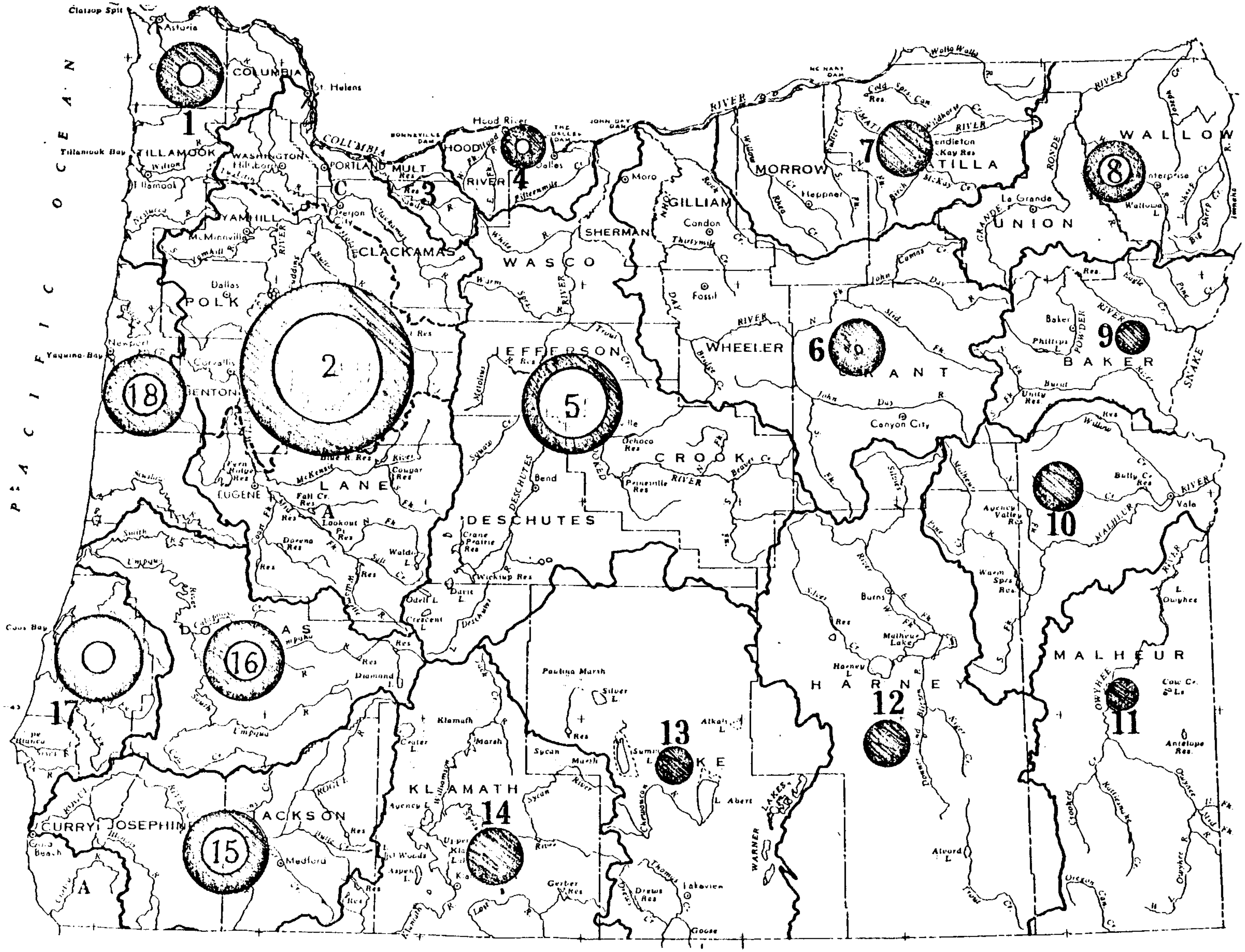


FIGURE 18. COMPARISON OF PROJECTED UNCONSTRAINED OUT-OF-STREAM DEMANDS

(Source: Oregon State Water Resources Board; <u>Oregon's Long-Range Requirements for Water</u>; Salem, Ore.; 1969)



BASIN	2070 DEMAND (ACRE-FEET)
1 NORTH COAST..	3,410,000
2 WILLAMETTE.. 3 SANDY.......	13,238,000
4 HOOD...........	749,000
5 DESCHUTES....	4,547,000
6 JOHN DAY.....	1,297,000
7 UMATILLA.....	1,305,000
8 GRANDE RONDE.	1,657,000
9 POWDER.........	419,000
10 MALHEUR........	898,000
11 OWYHEE.........	357,000
12 MALHEUR LAKE...	737,000
13 GOOSE & SUMMER LAKES...	550,000
14 KLAMATH......	1,174,000
15 ROGUE........	2,760,000
16 UMPQUA.......	2,543,000
17 SOUTH COAST..	3,322,000
18 MID COAST....	2,633,000
OREGON TOTAL	41,596,000

PRESENT ◯ 2070 ●

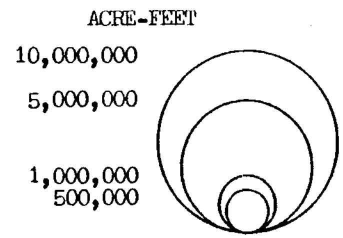


FIGURE 19. LONG-RANGE PROJECTED IN-STREAM DEMAND
(Source: Oregon State Water Resources Board; Oregon's Long-Range Requirements for Water; Salem, Ore.; 1969)

Table 5. Projected Unconstrained Requirements for Water

Type of Use	Demand, MAF/yr	
	2020 Projection	2070 Projection
Out-of-Stream		
Municipal and Light Industrial	0.9	2.3
Heavy Industrial and Mining	1.5	4.0
Irrigation	7.7	36.0
Thermal Power	0.5	2.4
Recreation	1.4	3.4
Wildlife	0.1	0.3
Subtotal	12.1	48.4
In-Stream		
Water Quality	5.4	8.6
Fish Life	23.1	22.0
Navigation	1.8	1.7
Subtotal	30.3	32.3
Total	42.4	80.7

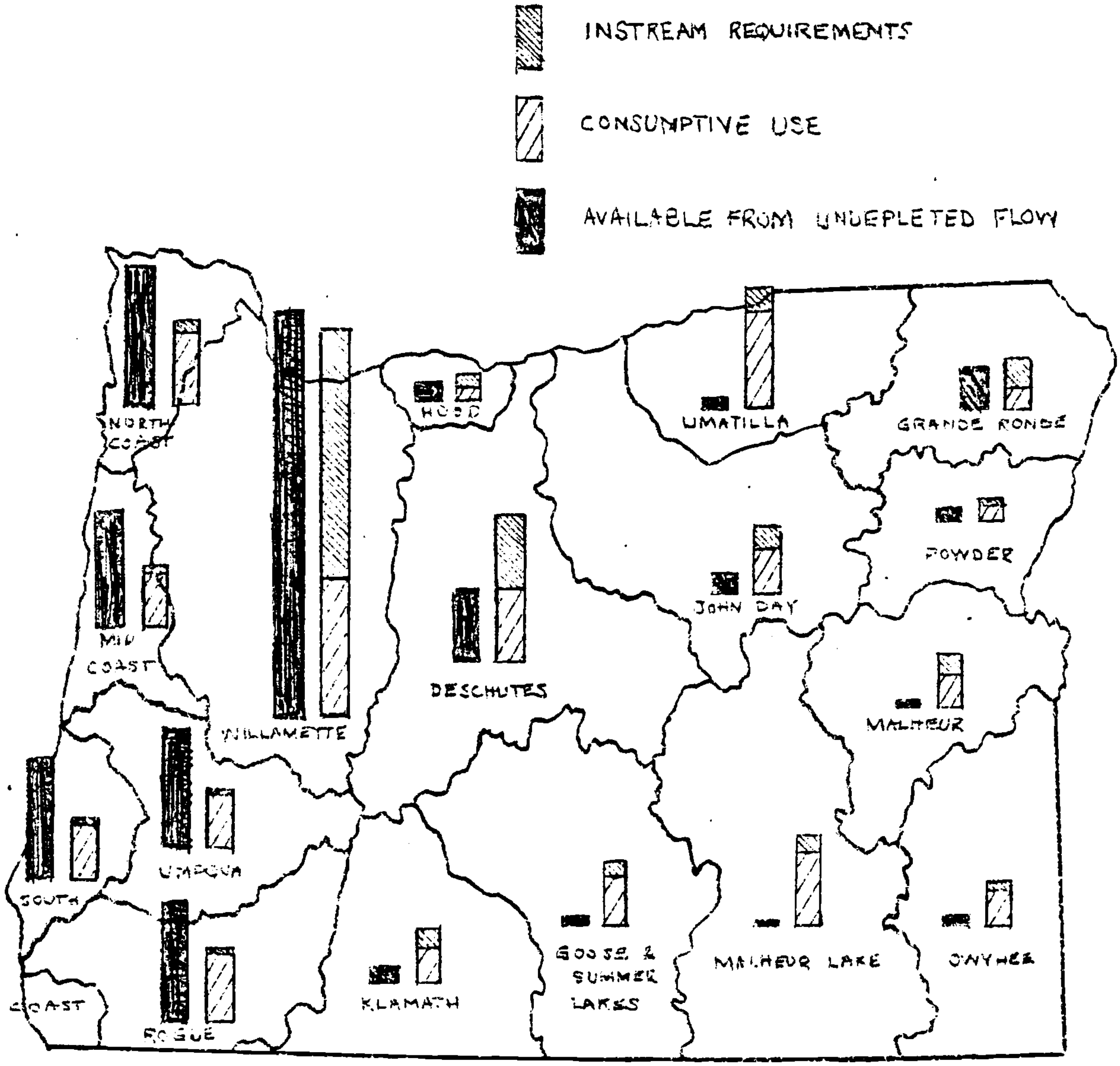


FIGURE 20. COMPARISON OF BASIN SUPPLY AND LONG-RANGE TOTAL DEMAND
(Source: Oregon State Water Resources Board; Oregon's Long-Range Requirements for Water; Salem, Ore.; 1969)

The manner in which the beneficial and adverse effects of irrigation development are borne by the various affected groups determines largely the direction of the forces affecting irrigation demand. Hence we shall discuss briefly (a) the benefits and costs as they appear to private irrigation developers, (b) the broader public view of benefits and costs relevant to decision-makers at the state level, and (c) the financing of irrigation developments.

On-farm Benefits and Costs of Irrigation Development

Farmers play a central role in the decision to irrigate or to place additional acres under irrigation. Any prediction of future water use by Oregon agriculture must take into account how farmers evaluate from their viewpoints the costs and benefits of the irrigation decision.

On the cost side, the greatest unknown is technological development. The introduction of the center pivot irrigation system facilitated irrigating land with certain characteristics than would otherwise have been possible. Thus water use was stimulated where this new technology was best adapted. Development of water-saving technology or of technology which favors non-irrigated agriculture would cause water use to decline, or the comparative advantage in crop production to shift to non-irrigated areas.

On the benefit side, the greatest uncertainties are related to the demand for agricultural products. In the long-run the most important factors here are the rate of growth of population and the increase in per capita incomes in the poor countries.

For private investments in irrigation to take place, farmers' evaluation of the benefits and costs of irrigation development must be sufficiently favorable given the uncertainties indicated above, to warrant the commitment of their investment funds. The farmers' investment climate may be changed through public action, but the private cost and benefit calculus remains a central part of the decision.

Public Benefits and Costs

The impact of irrigation developments on the level of economic activity in the local area in which the development occurs must first be considered. Even the casual observer recognizes quickly the greater economic base provided for a community by irrigated agriculture than by dryland farming or grazing use of the land. The more intensive land use under irrigation requires more labor and purchased inputs which must at least partially be supplied locally. Payments for these inputs stimulate further economic activities in the area. A similar chain of events may be set in motion by the greater volume of farm output to be processed locally. Generally, estimates of these "multiplier effects" on local economies have indicated that for each dollar generated in the agricultural sector, economic activity in the local economy will increase by an additional dollar.

Of course, the increase in total volume of output or economic activity stimulated by irrigation development is not an appropriate measure of community economic benefits associated with such development. Instead, it is necessary to turn to net returns resulting from the increase in overall output. These net returns accrue to the local economy's basic resources and are registered as returns to the economy's labor force, land resources, and other capital stock.

Benefits accruing to the labor force are indicated by higher payments for salaries and wages as the result of higher employment levels and wage rates. At least in the short-run the local labor force will be the beneficiary. One should expect, however, that low unemployment levels and relatively high wage rates in the developing area will serve as a signal to attract workers from other locations so that the advantages to the indigenous work force will be dissipated in part.

A similar situation exists with respect to the return to locally-owned capital assets. For example, as economic activity increases, competition for the available commercial building space will drive up the return to these assets. But this higher rate of return is likely to attract outside funds into the construction of commercial building space until rates of return in the local area are again roughly equivalent to those elsewhere.

The temporary benefits to the local labor force and local investors are in contrast to the more permanent increases in returns to the local land resource. The total physical supply of the local land resource is, of course, fixed. Competition for land will move parcels to more intensive uses and returns to the land will increase. Thus it appears that the beneficial community impacts will in the long-run be concentrated largely as returns to the land resource. Although temporary increases in returns to labor and capital and the widening in the range of choice in local employment and investment opportunities may also be important.

If we assume that labor and capital resources are fully employed, there are offsetting costs to the local benefits just identified. Output must decline somewhere else as resources are attracted to the area of development. However, from the local area's point of view the decline in output elsewhere does not matter. It may not matter even from the state's point of view if the offsetting decline in production occurs beyond the state's borders.

This brings us to the point of evaluating water development benefits as they are relevant to the state's planning objectives. If it is an explicit state goal to stimulate economic growth in the area in which the irrigation development takes place, the community benefits identified above are relevant also to the evaluation of the development by the state. If the state does not have such a specific growth objective in mind for the area in question, the above benefits should be counted only if no offsetting costs occur within the state.

One other issue must be mentioned in regard to the state's evaluation of this type of benefit from water resource development. It may be that because of economic linkages between the rural areas of the state in which water developments take place and the urban service centers, similar multiplier effects obtain statewide as we have described for the local area. Such effects would lead to statewide growth impacts. If this is the case, a parallel set of considerations as were presented above for the local community should be made to evaluate these benefits from the state's viewpoint. In addition, there would be the need to evaluate any negative impacts (especially environmental) of growth per se.

The costs which are not likely to be considered by farmers when planning irrigation activities using surface water relate to the diminished flow downstream from the point of diversion and to possible reductions in water quality because of the irrigation return flow. A number of downstream water uses may be affected. The exact magnitude of these impacts depends upon physical and economic circumstances associated with the diversion.

1. There may be losses from forgoing hydroelectric power generation. These should be valued by the least cost method of replacing the lost generating capacity.
2. Irrigation withdrawals may limit the navigation use of the river. This impact should be valued by the costs required to maintain the navigational use of its previous level or by any increase in transportation costs, whichever is lower.
3. Perhaps most importantly, irrigation withdrawals are likely to affect commercial and sport fishing and other recreational uses. These impacts are often difficult to measure physically and their economic evaluation is complex. While we have alluded earlier to some possibilities of measurement in this area, these impacts are likely to remain a source of uncertainty in water resource decision-making for some time in the future.

There is one other way in which it is possible for the calculation of irrigation benefits and costs by farmers to yield results which do not reflect important social considerations. This relates to the failure of the prices paid by farmers to reflect the socially relevant costs of his inputs. One example may be the wages paid by farmers for the construction of the irrigation system. Farmers pay the market wage rate but there may be considerable unemployment in the construction sector and wage rates therefore overstate the social costs of labor. If the decision to construct irrigation developments were strictly up to farmers, fewer irrigation projects might be built than would be desirable from a social viewpoint. Of course, the failure of input prices to reflect real costs may also have the opposite effect on the outcome of the social evaluation of a project. An example may be the prices paid by farmers for electricity used in driving irrigation pumps. These are likely to understate the social cost of electricity. New additions to electric generating capacity are more costly than is reflected in the prices paid for electricity.

When social evaluations of these projects are made, it is important to recognize these divergences between private and public costs and to make adjustments for them whenever possible.[1]

Financing Water Developments

Water development financing is one of the most important subjects in the economics of water use in Oregon. In its simplest form the question is: "Who pays and how?"

It is easy to arrive at the wrong scale of irrigation development when cost-sharing between the public and private sectors are disproportionate to the public and private benefits involved. It is for this reason that we took some care to discuss the relationships between private and public benefits and costs in the foregoing sections. Furthermore, there is the very important issue of water conservation. The latter is most directly affected by the manner in which costs of water provision are recovered from those using the water. Unless the relevant costs are borne in proportion to the amount of water used, there are not the proper incentives for economizing in the use of an increasingly scarce resource.

The following guidelines may be considered for designing financing arrangements:[2]

1. That the costs of capital construction be borne
   (a) by farmers on the basis of irrigable acreage in the project,
   (b) by other members of the local community who are likely to experience increases in real property (especially land) values,
   (c) by the broader public (perhaps the state) if the relevant public benefits are deemed to be significant
2. That the costs of system operation and water delivery and any public costs of irrigation be paid by irrigators on the basis of the quantity of water used.

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1. The points raised in this discussion are consistant with recent recommendations made for Federal water resources planning. See National Water Commission; Water Policies for the Future - Final Report to the President and to the Congress of the United States by the National Water Commission; Washington, D.C., Government Printing Office; 579 p.; 1973.

2. Our discussion has benefitted from an article by S. H. Hanke; "Options for Financing Water Development Projects," Forty-First North American Wildlife Conference; March 1976.

Some Eastern Oregon Irrigation Relationships

Some of the above issues are illustrated by current water use problems in Eastern Oregon. In the last decade, irrigated acreage in northern Morrow and Umatilla Counties has increased by approximately 140,000 acres. The value of crop output has quadrupled. The application of about 500,000 acre-feet of water drawn form subsurface aquifers, intermittent surface streams, and the Columbia River has resulted in a direct infusion of 100 million dollars into the local economy. Processing plants and other agribusiness industries have been attracted to the area, generating another 50 million dollars in sales. Population has doubled, and jobs have kept pace. Benefits, measured in income and employment opportunities, have been widely distributed throughout the local citizenry, while the direct costs of water development have been borne by the farmers alone.

But water-based economic growth has generated other costs that cannot be ignored. It has been estimated that every acre-foot of water withdrawn from the Columbia River in the vicinity of these two counties is worth five dollars in terms of benefits foregone in the generation of hydroelectric power,[1] and between 150,000 and 200,000 acre-feet of water are currently being withdrawn from the river. Neither have increased withdrawals of ground water been costless.

In 1976, the State of Oregon declared that the ground water was being rapidly depleted in this area forcing many area farmers to abandon individual water development decisions. These farmers combined in a plan to withdraw water from the McNary Pool on the Columbia River, and distribute it through 50 miles of canals and pipes to irrigate 116,000 acres. Included are both lands presently irrigated from threatened ground water sources plus 70,000 acres of presently unirrigated ground.

Studies have shown that farmers in the area can afford to pay between $80 and $160 per acre for water, depending on their location and rates of return to land.[2] When evaluated from the farmers' viewpoint, the project is at best marginally feasible. If secondary income and employment effects in other sectors of the local economy were taken into account, the feasibility of the project would be enhanced. But as mentioned above there are important public costs which must also be considered.

One of the options in the above example is a public subsidy of the irrigation development to shift part of the cost burden for the project to some of the external beneficiaries of the project. The sale of

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1. Whittlesey, N.K. et al.; Preliminary Report on a Planning Study for Irrigation Development in Washington; Department of Agricultural Economics; Washington State University; Pullman; 1976.

2. Nelson, A. Gene and David L. Holst; "Oregon's Northern Columbia River Basin Development Project," Project Working Paper No. 3; Department of Agricultural and Resource Economics; Oregon State University; Corvallis; May 19, 1976.

general obligation bonds by the State has been suggested as one method to achieve greater public participation in bearing the costs of the project. Capital would be made available to farmers at lower than market interest rates. This type of a subsidy would have a considerable impact upon the economic feasibility of the endeavor.

It is premature to make judgments about the advisability of using general obligation bonds to support water developments in Oregon. There certainly has been much criticism at the national level for making capital available to these developments without insisting upon competitive rates of return on these funds. Not all of the arguments are relevant, however, from the viewpoint of the State of Oregon. Its citizens are likely to bear only a disproportionately small share of the negative impact of diverting this capital to a use in which the private returns are less than elsewhere. One important issue then becomes how extensive additional non-private benefits are from these developments. Stimulating economic growth in rural areas may be one such type of benefit. Here it is necessary at least to evaluate how irrigation water developments would rank relative to other investments in natural resources. Other necessary evaluations would relate to negative impacts on downstream water uses which may not have been taken into account in the private rate of return calculations and on any adverse impacts on Oregon's position in the bond market.

The Economic Effects of Pricing Water

Perhaps less dramatic, but no less significant, are improvements in water allocations which may be brought about by achieving conservation of an increasingly scarce water resource through greater reliance on economic incentives. For irrigation a variety of pricing schemes are in effect in Oregon. Each of them leads to different technical and economic results.

Fixed cost pricing, usually consisting of a flat charge for a given quantity of water, essentially treats water as a free good once the fixed charge is paid. Farmers respond accordingly by maximizing water use relative to other variable resources since water is the least expensive resource relative to these other inputs. Fixed cost pricing does not promote more efficient water use by irrigated agriculture.

Variable cost pricing, usually consisting of a graduated charge per unit of water use, can promote more efficient water use. In a recent study of two irrigation districts in central and northeastern Oregon, it was estimated that district water diversions could be reduced from seven to 32 percent annually by adopting a variable cost pricing policy which made it profitable for irrigators to at least use sprinkler systems instead of more water consuming methods. However, because of this pricing policy, water costs relative to fixed cost pricing were estimated to be from $12 to $21 per acre higher and crop returns in excess of cash costs were estimated to be from four to 67 percent lower. The smallest reduction in net returns were projected for full-time farmers who use water efficiently in the production of low water-consuming crops. More important, however, are the significant reductions in net returns of farmers in marginal or part-time enterprises (e.g., alfalfa hay production) where water use is inefficient in the production of a high water-consuming crop. It is expected that these farmers would try to improve their economic position by adopting more water efficient irrigation methods such as center pivot systems or changing cropping patterns to include more profitable crops.[1] The responsiveness of water use to variable cost pricing is, however, likely to vary according to the different economic relationships facing individual farms within an irrigation district as well as the different conditions found among all irrigation districts.

The opportunities of conserving water through pricing are not restricted to agriculture. Although the quantities of water which can be conserved in municipal use by variable cost pricing are not as great as in agriculture, the amounts of water conserved may help to forestall the need for installation of new, higher cost municipal supplies.

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1. Schmisseur, W. E.; "Economic and Water Use Impacts Associated with Alternative Pricing Policies of Established Irrigation Districts," WRRI-47; Water Resources Research Institute; Oregon State University; Corvallis; September 1976.

Impacts and Issues of Water Use and Supply Manipulation

Assessing Impacts

Virtually every water allocation and use has some type of impact, whether environmental, economic, socio-political or institutional. Furthermore, natural resource activities rarely have just simple cause-and-effect relationships. Usually, only the obvious "tip of the iceberg" impacts are evident. Others are often not fully understood, even by resource specialists. Man has a much greater ability to alter his environment, stimulated by the application of existing and evolving technology, than to predict the effects of such alteration. This results in a knowledge gap in understanding how the natural system functions and responds to various uses of water and how the economy might be affected.

Each river basin or reach of river has unique features, as well as features common to all. Therefore, identification of impacts involves verification of the significance, degree, and extent of the common impacts for a particular situation, together with a detailed investigation to characterize specific additional impacts of water use.

A representative framework for assessing the impacts of water allocation and use is shown in Table 6. Water systems and land systems are normally interdependent, so that impacts on both must be considered.

It has been national policy for some time[1] to consider all effects of water projects, but past practice has been to focus on the directly measurable economic benefits, principally income. More recently, environmental quality has become a specific goal of project planning[2] and is often competitive with other project objectives. The need is recognized to accurately account for environmental effects[3] and to place dollar values on these effects. Before a water supply project can be constructed, then, it is necessary to weigh the conventional monetary net benefits against environmental losses or damages.

The matter of enjoyment of the environment (recreation) has emerged as a key issue in the evaluation of environmental impacts of water projects. "Scientific preservationism" has emerged as a means to approach

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1. U.S. Congress, Senate; Policies, Standards, and Procedures in the Formulation, Evaluation and Review of Plans for Use and Development of Water and Related Land Resources; Washington; Govt. Printing Office, (Senate Document 97); 1962.

2. U.S. Water Resources Council: "Proposed Principals and Standards for Planning Water and Related Land Resources"; Federal Register; vol. 36, no. 245, Part II; p. 24144-24194; 1971.

3. National Water Commission; Water Policies for the Future - Final Report to the President and to the Congress of the United States by the National Water Commission; Washington, D.C.; Govt. Printing Office 479 p.; 1973.

Table 6. Representative Framework for Assessing Impacts of Water Allocation and Use

I. Detailed specification of the proposed use or allocation:
where, when, over what time period, how?

II. Broad and specific identification of the resources and systems affected:
- aquatic, terrestrial
- animal, vegetable, mineral
- physical, chemical, biological effects

III. Probable impacts
- Resources impacted
  - Aquatic
    - Biologic
    - Mineral
    - Other
  - Terrestrial
    - Biologic
    - Mineral
    - Other
  - Interrelationships of resources
- Time frame
  - Short-term (e.g.,during construction)
  - Long-term (during use and after end of use)
- Areas involved
  - Immediate (local) area
  - Distant areas
  - Interrelationships of areas
- Character of impacts
  - Direct vs. indirect
  - Primary vs. secondary
  - Avoidable vs. unavoidable
  - Isolated vs. cumulative
  - Beneficial vs. detrimental
  - Enhancement vs. deterioration
  - Reversible vs. nonreversible
- Possibilities for future modification
  - Renewability of resources affected
  - Reversibility and retrievability of resource commitment
  - Loss of future options
  - Restriction on range of beneficial uses

the controversies of preservation versus development through careful observation and quantification rather than through emotional appeals. This approach recognizes that people express a willingness to pay for different kinds of recreation, including not only fishing, hunting, and boating, but also pure appreciation of scenic wilderness areas. Furthermore, it is contended that this willingness to pay extends through time and is likely to be an inclination of generations yet unborn. The federal and state designations of Wild and Scenic Rivers and Scenic Waterways in Oregon in part reflects these concerns and a desire of today's citizens to reserve a future option to enjoy river recreation.

In analysis of the allocation of increasingly scarce water supplies among competing uses, economic efficiency and equity are given particular importance. In many uses, water is considered as a commodity resource in some productive activity. As a result, water attains a production value equal to its contribution to the total value of the good or service which is being produced. In addition, the value of water is subject to the law of diminishing returns, a fact that facilitates interpretation of the problem of water allocation. A key assumption in that analysis is that there is sufficient information to enable an implicit determination of the value of water. However, for some in-stream productive activities, notably fishing and recreation, it is very difficult to determine the production values of water, even though water still serves (at least partially) as a commodity resource. In other uses, including sports fishing and recreation, water becomes more of an amenity resource, not technically related in some predictable and precise fashion to the produced good or service. Water preserved in natural watercourses for the benefit of its pristine state (i.e., no other uses permitted) would be labeled a pure amenity resource.

Where water is a commodity resource in each of two alternative productive uses, a degradation of streamflow caused by the upstream user may raise the costs of production for the downstream user. This impact or extra cost is termed an externality. It is not always measurable and most often is not equitably distributed among water users. Invariably, society as a whole bears the total cost. But cost analyses can yield solutions to minimize and equitably allocate the total impact costs.

An even greater conflict arises when water is used as a commodity resource at or near the same place where it is used as an amenity (or near-amenity) resource. When the former use affects the latter, an externality is again involved, but the popular term "environmental impact" conveys more aptly what is happening. In this case, neither the monetary cost of the impact nor the"price" of the amenity being impacted can be accurately assessed. Again, the only certainty is that society bears the total cost, however defined. Little progress has been made in determining how to minimize those costs and to allocate them equitably. In general, a number of surrogate measures have been adapted in lieu of cost data in the hope of obtaining approximate solutions.

Grouping of Impacts

Various impacts arise from water allocation and use. Three categories appear to be particularly useful in identifying issues of critical concern

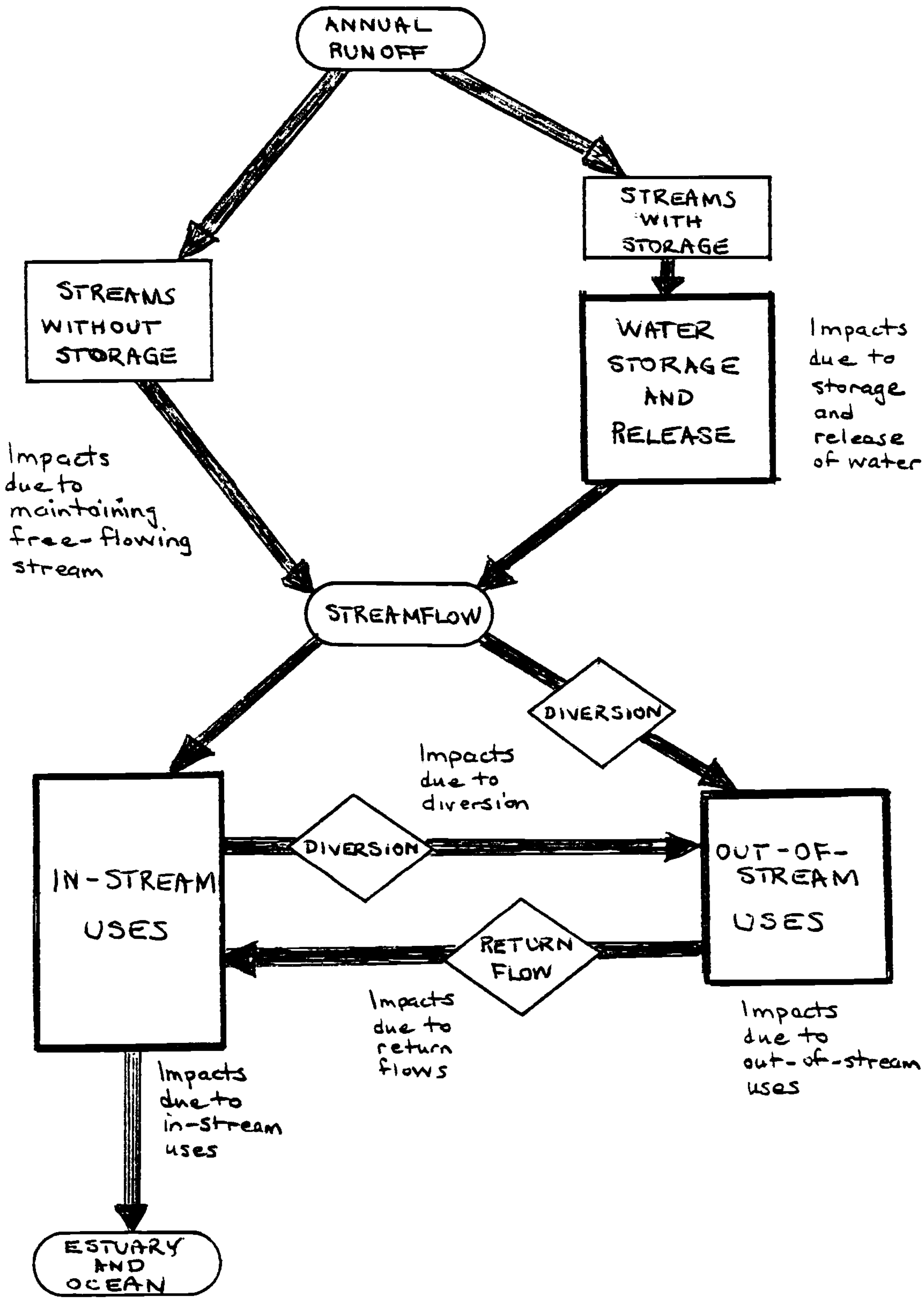

FIGURE 21. IMPACTS OF SUPPLY MANIPULATION AND WATER USES

for Oregon's future use of water resources. The first concerns man's ability to manipulate streamflow, making water available when and where it is needed or preventing it from going where it is not needed. The second category of impacts concerns the various in-stream uses of water. The third concerns the consequences of diversion from water courses for out-of-stream uses.

Streamflow manipulation requires dams and reservoirs. Consequently, all of the uses described in Table 2 can be impacted, either directly or indirectly. The in-stream use category of impacts specifically involves hydroelectric power production, navigation, fisheries and wildlife, water quality control, recreation, esthetic values, and (potentially) salinity control. Out-of-stream use impacts specifically involve municipal and industrial water supplies, irrigation, thermal power generation and ground water maintenance.

Figure 21 illustrates in a systems fashion the impacts associated with water use. The three groups of impacts discussed above are emphasized in this figure. However, it should be clear that nearly all facets of water supply and use are interrelated.

Impacts of Streamflow Manipulation

One of the most critical decisions regarding the allocation and use of water is the decision on whether or not to manipulate the magnitude and/or time of water supply. There is perhaps no other area of water resources management which is more sensitive to the environmental impact question than is the decision to invest in dams and appurtenant facilities designed to augment the supply of water. The economic and environmental impacts can be immense, particularly if large dams and storage reservoirs are contemplated. A broad spectrum of decision-making uncertainty as to technical questions arises: will the project produce the desired results? where? how beneficial? will it have adverse consequences? Where? How adverse? should it be done? (Recent cloud seeding decisions reflect all of these uncertainties in supply manipulation.) It should be noted that there are feasible technological alternatives to dams for augmenting the supply of water, but these do not involve streamflow manipulation as much as the manner and efficiency with which water is used.

Figure 22 illustrates that there are many interactions between supply manipulation decisions and water uses, such that additional water can be made available to all uses by means of storage that traps and holds back part of the excess flood season runoff.

Figure 23 illustrates some typical consequences of upstream water manipulation on downstream flows. Three sets of situations are shown: (1) those where upstream diversion occurs without storage, such that the magnitude of downstream supply is altered but not its time of delivery; (2) those where upstream storage occurs without upstream diversion (e.g., for low-flow augmentation only), such that the total magnitude of streamflow is relatively unchanged but its time of delivery is greatly altered; and (3) those where both upstream storage and diversion occur, such that the magnitude and time of delivery of streamflow are greatly changed. All

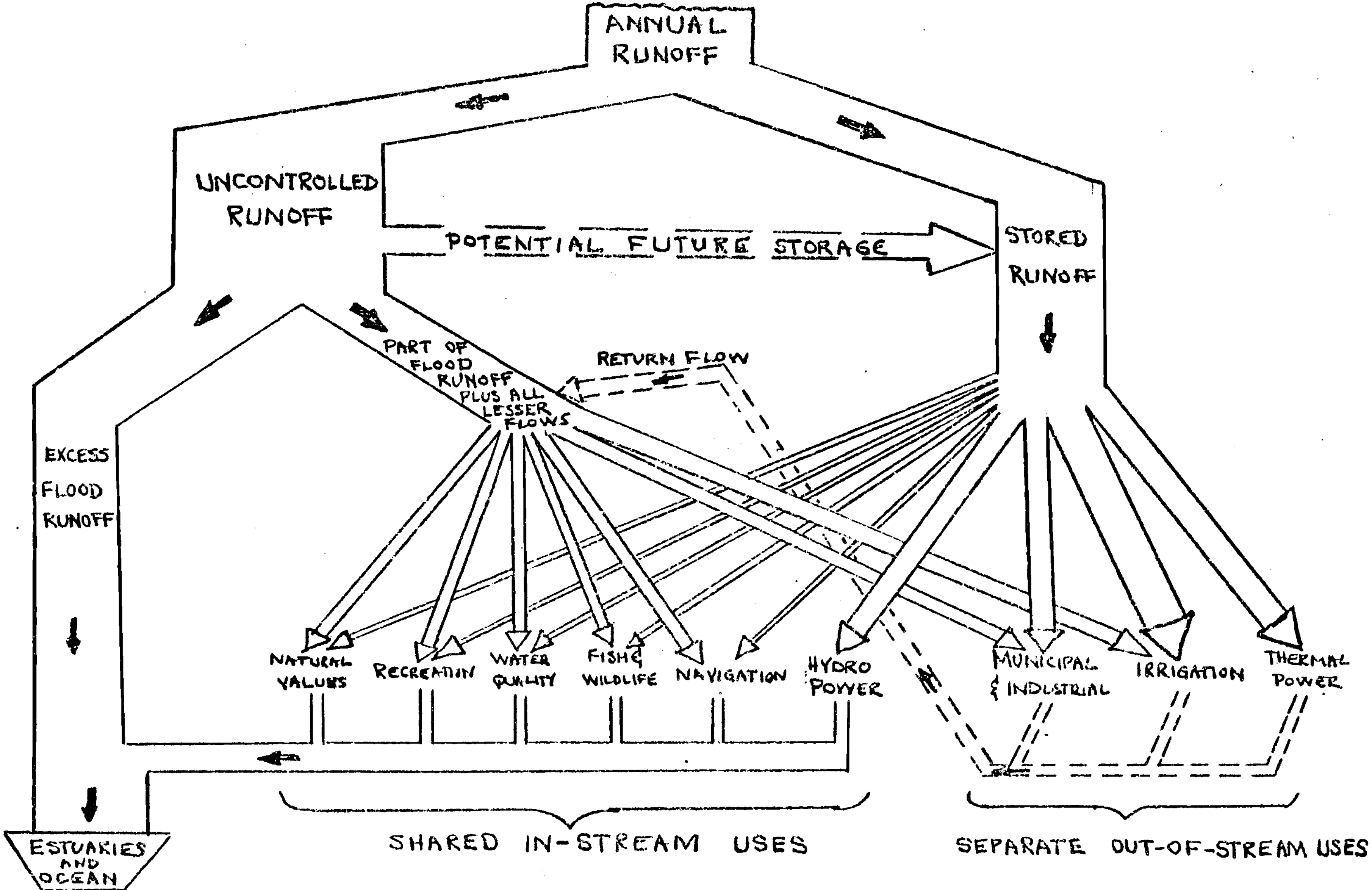

FIGURE 22. INTERACTIONS OF WATER USES

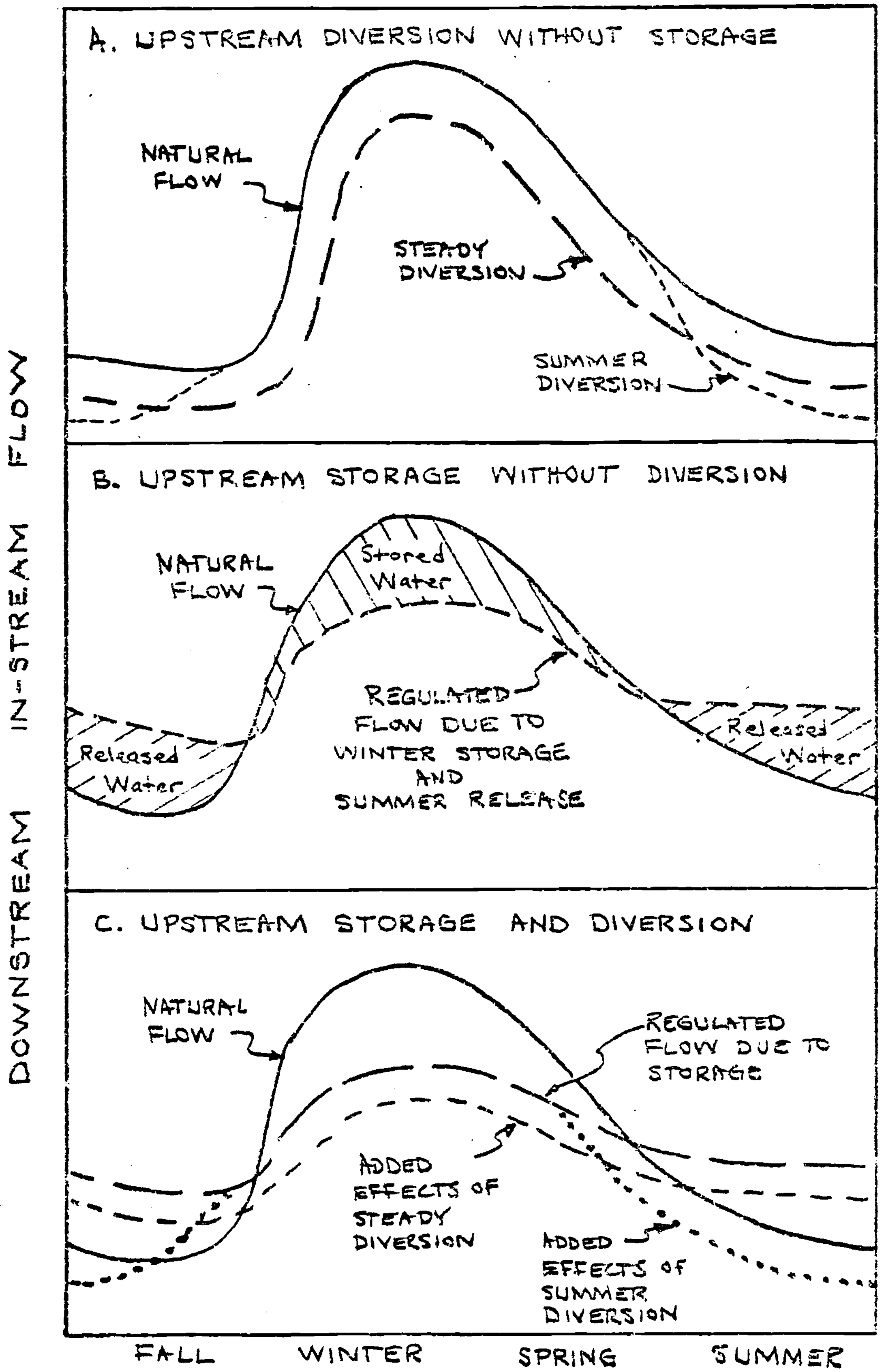

FIGURE 23. SOME CONSEQUENCES OF SUPPLY MANIPULATION ON DOWNSTREAM FLOW

significant forms of upstream streamflow manipulation have effects on the entire river basin downstream from that manipulation.

In the first case, a steady diversion might occur due to year-around municipal, industrial, and thermal power requirements, so as to reduce downstream flows by some amount that could become critical during summer-fall months; seasonal withdrawals might occur for irrigation, ground-water recharge, and seasonal municipal and industrial uses; or some combination of these situations might occur. The amount of withdrawal (and its consumptive use) may be great enough to totally deplete the stream, if no legal minimum flow has priority over diversions.

The second case shows that flow augmentation by storage releases can significantly increase the streamflow during the low-flow season. This might be desired for navigation, hydropower generation, fish and wildlife enhancement, water quality control, recreation, salinity control and, possibly, esthetic reasons, all of which are shared in-stream uses (see Figure 22). Environmental conditions will be affected year-around, and not just during the low-flow season.

The third case shows that more complex situations may occur when upstream storage and diversion both exist. Previously cited situations can occur in various combinations to compound the possibilities for altered magnitude and timing of downstream in-stream supply.

Reservoir Impacts

Expected impacts of providing reservoir storage include altered timing of downstream flow delivery, provision of a fluctuating lake, loss of free-flowing stream, tradeoffs of fish habitat and spawning areas, tradeoffs of wildlife habitat, changed shoreland use, altered sediment transport, tradeoffs in opportunities for water recreation, fishing and hunting, tradeoffs in esthetics between stream and lake environments, altered water quality (e.g., dissolved oxygen and temperature) due to environmental conditions at the reservoir and to delays in releasing water downstream, obstacles to fish, and recreation and navigation passage (generally alleviated via fish ladders and navigation locks).

Some water uses clearly benefit from the presence of storage reservoirs whereas others do not. The timing of water availability is important, in addition to the quantity provided. Thus municipal, industrial and irrigation water use, flood control, hydroelectric and thermal power generation, navigation, and water quality enhancement benefit by the seasonal storage of excess water and its release at times of low flow. However, fishery and wildlife enhancement and water-based recreation are not always benefited and for some types of uses may be adversely affected (e.g.,fish passage problems and rapidly fluctuating water levels). Instead, many tradeoffs between benefits and disbenefits occur. Esthetics and natural values are generally disbenefited, although there are short seasonal periods when full reservoirs can be as attractive as natural lakes.

Even uses that clearly benefit from the existence of reservoirs are subject to competition and conflict. The requirement of empty reservoirs for flood control, for example, are just opposite to the preference for full reservoirs for other purposes. Requirements to release water for downstream uses are in conflict with desires to hold the water in the reservoirs for recreation, fish and wildlife, esthetics, or to maintain sufficient head for efficient future power production. The need to release water for downstream uses at one time may conflict with the need to have it for later release. One important use of reservoir water in the Willamette Valley during summer months, water quality enhancement, is not even an authorized purpose of project operation for the reservoirs that provide this flow. Instead, this beneficial use "shirttails" on the authorized beneficial use of maintaining navigability in the Willamette River -- two highly compatible uses!

Impacts of Releasing Water at Dams

The expected impacts of releasing water from storage include those of fish migration past turbines, surges and water level changes in the downstream channels due to hydropower load fluctuations, and nitrogen supersaturation of the water (causing gas bubble problems to fish) below some types of spillways. Also, water must be withdrawn from reservoirs, causing in-reservoir impacts noted above.

Key Issues

The key issues that must be addressed regarding streamflow and supply manipulation are:

* whether it is desirable to manipulate streamflow in quantity and time of availability, using new dams and storage reservoirs so as to hold a larger portion of the total streamflow for out-of stream uses and for dry-season in-stream uses;

* how it is possible to manage the water supply by conservation, pricing, technological innovation and other means to achieve greater water availability without construction of additional storage reservoirs;

* how to deal with altered habitat conditions for fish and wildlife and adversely affected fishery resources due to the presence of reservoirs and their manner of operation for non-fishery uses;

* how to accommodate altered streamflows as storage projects shift from base load to peaking hydropower production and affect the free-flowing river attributes for uses such as recreation or wildlife habitat.

* how to preserve existing flood damage reduction benefits without construction of new reservoirs, should future growth of water use demands and urbanized areas tax the available facilities.

* how to best support research and investigations that will reduce the technical/scientific uncertainties underlying water decisions so that better predictability can be achieved regarding impacts of water projects.

* revision of the State's study of long-range requirements for water, so as to account for technological changes, improved population and economy projections, likely constraints and competition for a limited supply, and seasonal problems of water availability.

Impacts of In-Stream Uses

Without Supply Manipulation

Even when streamflow is not manipulated, in-stream use of water has many impacts. The most evident impacts come when rivers are used for hydroelectric power generation. Low-head, run-of-river dams on large rivers, even those as large as Bonneville Dam, do not impound much water nor seasonally alter streamflow. The impacts described in the previous section apply here also. Navigation also has impacts on other in-stream uses, such as through requirements for controlled river depths and velocities, potential water contamination, waterfront dock requirements, and cargo storage space needs. Even recreational use of water may conflict with other uses such as esthetic enjoyment. Thus, certain lakes are restricted to non-motorized boats to protect pristine waters and preserve tranquility of the surroundings.

The degradation of the anadromous fishery due to the system of hydropower/navigation dams has already been mentioned. Degradation of shoreline wildlife habitat in the Columbia also occurs due to the nature of hydroelectric reservoir operation. The first impact significantly affects the viability of a commercial fishing industry, while both relate to recreation benefits derived from the water resource.

Future reservoir operating rules to provide greater power peaking capability may result in extremely low flows in some reaches of the river. These impacts must be dealt with in order to guarantee survival of the fishery and the commercial and recreational benefits derived from it. These benefits are estimated to be significant enough to warrant the investment in such measures as additional hatcheries, transporation of fingerlings by truck, installation of fish screens on turbines, installation of flip-lip spillways, and foregone revenue from electrical energy lost due to maintenance of minimum flows.

Environmental impacts of in-stream use often are heightened because of intensification of one or more of the in-stream uses. For instance, increased navigation, fish and wildlife, usage, and recreational use contributes greater waterway crowding and pollutant loadings to the streams. These then lead to the environmental impacts associated with crowding and pollution. One growing demand can create a demand for more water in another use (e.g., growing navigation and boating use may cause more contamination which calls for more dilution water to protect fisheries). When it is evident that adverse conditions prevail, modifications of use often must result as a compromise to achieve better compatibility. The control of river recreation on the Willamette near Eugene and on wild-and-scenic rivers illustrate this. The alternatives to compromise are the degradation of some uses to permit others and perhaps the seeking of additional water to offset degradation, the additional water coming from reservoir storage projects.

Much compromise centers upon the protection of in-stream water uses for fish and wildlife, based upon the setting of minimum streamflows and of water quality standards. Together with wastewater treatment, these have been instrumental in protecting existing stocks and allowing programs that expand the availability of fish and wildlife in many areas, even above natural levels. For example, the current program to expand the anadromous fishery in the Willamette Basin is the direct result of improved water quality, with little change in the levels of regulated minimum-in-stream flows in the last several years.

Impacts of Flow Augmentation on In-Stream Use

Flow augmentation to benefit in-stream water uses has important impacts on those uses. Many impacts can occur even if there is no change of intensity of use or level of use activity. As illustrated by the solid line in Figure 24 A, augmented flow will directly improve water quality through the added dilution of wastes (the converse is also true). Similarly, as shown by the solid line in Figure 24 B, various other activities are likely to be improved by more in-stream flow, including navigation, recreation, fish and wildlife, and run-of-river hydroelectric power generation. Crowding may serve to place a limit upon the marginal improvement from added increments of augmentation.

Additional environmental impacts are associated with in-stream uses when flows are augmented <u>and</u> the intensity of various uses and activities increases. This is also shown in Figure 24 by the dashed lines. Greater in-stream activity produces its own water quality degradation and adds to crowding so that flow-augmentation improvements are not as great as for constant activity levels.

Key Issues

The key issues that must be addressed regarding in-stream uses are:

* how to protect fishery resources;

* how to better assess the long-range minimum in-stream flow requirements for particular streams and for anticipated future use levels;

* what are the carrying capacities of particular water bodies for such uses as recreation and pollution assimilation; and should stream uses be limited on the basis of carrying capacity.

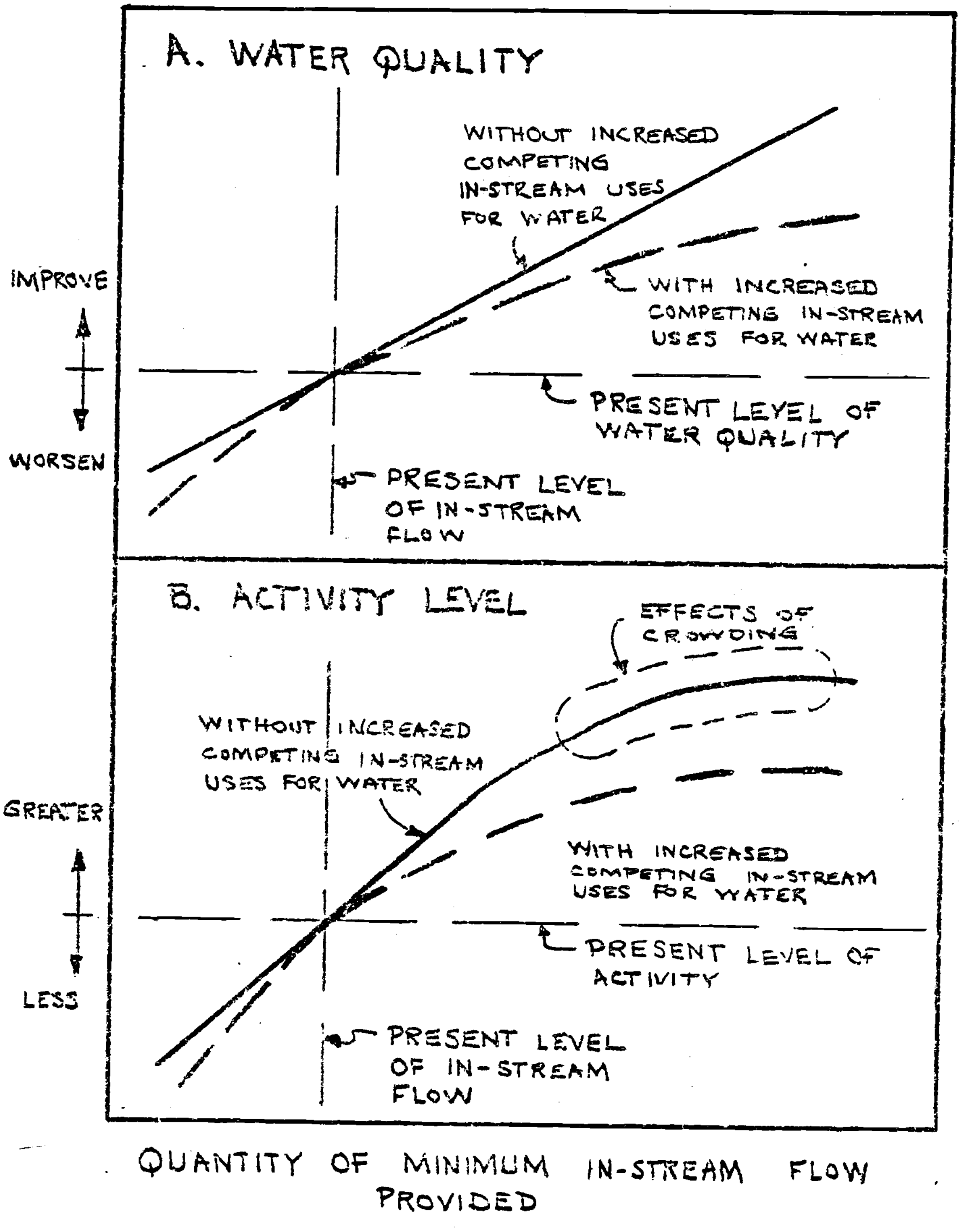

FIGURE 24. IMPACTS OF FLOW AUGMENTATION ON IN-STREAM USES

* how desirable is flow augmentation as a specific measure to enhance in-stream uses.

* how to recognize and incorporate rapidly expanding uses (e.g., water recreation) or expanding resource management programs (e.g., fishery enhancement) into long-range water resource management plans that are based on a different "mix" of the various uses so as to minimize dislocations and conflicts;

* how to value amenity resource uses of water, such as esthetics, and near-amenity resources, such as sports fishing and recreation, for comparison with commodity resource uses, such as navigation, hydropower production, commercial fishing and water quality control, and how to improve the comparability among commodity resource uses;

* how to value, minimize and equitably allocate external costs arising from the damage to one use by the effects of another;

Impacts of Diversion and Out-of-Stream Uses

The expected impacts of diversion for out-of-stream use may be associated in four groups. First, at the point of withdrawal there will be impacts from the manner in which water is removed (some type of structure will be required), the energy requirements to remove the water (e.g., pump stations), and the way in which this removal system interferes with local river processes. Included in the latter are altered currents, blocked fish passage, altered sediment transport and abrupt reduction of streamflow due to the diversion. Second, there will be impacts away from the river due to out-of-stream use. Included are such impacts as pipeline and canal construction, seepage, evaporation, phreatophyte growth, blockage of animal trails, soil moisture and water table changes at irrigated lands,altered vegetation (natural and planted), chemical additives to the environment, microclimate changes, and land use changes with attendant impacts when the out-of-stream use is municipal or industrial. Third, out-of stream use will have impacts on in-stream uses downstream of the diversion point because there will be less water for in-stream uses, downstream impoundment, or downstream withdrawal. The reduced quantity of flow in the channel will result in shallower water depth and slower moving flows. These will affect the sediment transport processes and provide opportunities for greater ambient heating of the water, more prolific biological and aquatic growth, and worsened water quality. The alterations of water quantity and quality then become the springboards for further environmental effects, such as changed groups of biological species present (including fish life, its food chain, bacteria, etc.). Fourth, depleted return flows to the river from out-of-stream uses will have impacts at and downstream from the outfall points. The impacts will be due to such conditions as higher salinity (total dissolved solids), particular chemical and mineral constituents, higher temperatures, increased oxygen demand, reduced water clarity, and added nutrients.

Return Flows

Flow augmentation can provide enough water in-stream to compensate for the consumption losses from out-of-stream withdrawals. But the environmental impacts caused by return flows will continue to be a principal river problem in the future. The return flows alter the quality of the receiving water due to modified physical, chemical, and biological characteristics of the return flow compared to that of the river.

Although every river has some assimilative capacity, it was very common to overload rivers. This happened to the Willamette River as early as the start of this century, resulting in its having become highly polluted, in effect making it very costly to use in downstream locations and largely prohibiting its use in recreation. All municipalities and industries using the Willamette River water, including the paper and pulp mills and food processors, were eventually forced to treat their wastewater in order to meet state-imposed quality standards for return flows. The Tualatin is another example of a heavily overloaded stream, due to irrigation withdrawals and municipal/industrial return flows.

Solving point-source pollution problems by the imposition of standards and penalties raises the cost of using water. Each activity, whether it is productive or not, is considered as a process subject to technical changes which may mitigate the discharge of pollutants. After careful study, a least-cost/best-practice technology may appear to be suitable. In some areas such as logging, the costs of adapting such practice may be significant, yet capable of being absorbed in the operation. In other cases, the costs are high enough such that the operation may have to be curtailed.

Proposed national water quality standards that require the eventual total removal of all wastes from effluents create their own environmental problems, in addition to ignoring any assimilative capacity of the streams. First, excessive amounts of energy will be required to produce the technological systems and chemicals to perform this removal (each added level of waste treatment has higher marginal costs in dollars and energy). This energy production creates its own environmental problems. Second, the wastes will have to be disposed of in some other manner which will lead to further environmental problems. The waste disposal problem is thus seen to be one for which the solution is extremely complex.

Impacts of Irrigation Demand

Irrigation provides major economic benefits, both in the direct value of agricultural commodities and in the establishment of agriculture-related industries. Irrigation impacts require special consideration because of the magnitude of present and projected future use of agriculture (over 80 percent of Oregon's total out-of-stream use), its significant effects, both beneficial and adverse, on all river uses, and because of the several ways in which policy can affect this use. At present, less than two million acres of a potential 16 million acres of irrigable land is being irrigated. This land, as well as the anticipated irrigation demand, is well distributed about the state, rather than concentrated near the Snake and Columbia Rivers. In some areas water tables are rapidly falling. As much as 36 MAF/yr might eventually be needed (see Table 5), approaching half of the 84 MAF/yr of streamflow runoff from Oregon, if technological improvements to conserve water are not applied and if future economic conditions are not constraining.

To meet some of the future irrigation water demand without too many constraints on other uses of water, it is likely that additional water from the Snake and Columbia Rivers will be required. Furthermore, additional energy will be needed to produce the required construction materials, build the needed facilities, and provide the operating equipment. Then energy will be needed to pump water to higher elevations away from the rivers. Each unit of water withdrawn for out-of-stream consumptive use (79 percent, for irrigation) is not available for hydroelectric power generation downstream in those rivers. It has been estimated that every acre-foot withdrawn from the Columbia River in the vicinity of Morrow and Umatilla counties is worth five dollars in the generation of downstream hydroelectric power.[1] But in addition to the loss of generating capability is the need for a greater amount of electric energy in order to move the diverted water to agricultural lands, thus greatly compounding the irrigation-hydropower conflict.

But the intertwining of effects is not limited to irrigation and hydropower. For a 1,000 megawatt thermal plant (slightly smaller than Trojan nuclear power plant and twice as large as Bonneville Dam in power capacity) about 15,000 acre feet of water may be consumptively used per year. This is roughly equivalent to the irrigation need for 5,000 acres of land. Grossly oversimplified, one might say that there is a water quantity tradeoff between 100,000 acres of irrigation development and about 20 thermal power plants. Furthermore, if either or both are developed, the interacting effects of thermal water and irrigation diversions from the Snake and Columbia Rivers can be expected to call for additional protective measures for downstream fisheries, navigation and river recreation, particularly when seasonal uses are greatest (e.g., summer pleasure boating).

Without following along to other water uses, it should be evident that irrigation, already the dominating use of water in Oregon, will play a most significant role in future water allocations, uses and impacts.

Key Issues. The key issues that must be addressed regarding out-of-stream uses are:

* how much depletion of streamflows can be tolerated downstream of diversion points, particularly those associated with irrigation diversions, (since their consumptive loss is appreciable and the return flows are relatively small);

1. Whittlesey, N.K., et al; Preliminary Report on a Planning Study for Irrigation Development in Washington; Dept. of Agric. Economics; Washington State Univ.; Pullman, Washington, p. IV-10; 1976

* control of water quality at and downstream of points of return flow entry to streams;

* falling ground water levels due to use exceeding recharge rates, particularly in areas of appreciable irrigation use;

* how best to accommodate the growing irrigation needs for diversion from the Columbia River, in the light of adverse effects on hydroelectric power generation, navigation, fisheries, river recreation and on thermal power generation;

* how to generally cope with the aggravation of conflicts with in-stream uses if irrigation diversions grow throughout Oregon.

The Impacts Viewed Collectively

Seasonal and overall water scarcity is common in many parts of Oregon. In-stream and out-of-stream uses are greatly compromised by one another at the present level of water use. Dams and reservoir storage are dominant causes of many of the current problems in water use. Out-of-stream diversions, with attendant depletion of streamflow, add to current problems, whether the water is supplied from storage or from natural flows. Most current uses for water were initiated long before environmental impacts were understood. Current uses do not necessarily function "economically". Much manipulation of water use is possible by treating water more as a commodity resource and permitting the marketplace to operate. This would cause adjustments of water use within the agricultural sector and among agricultural, industrial and public sectors. But amenity and near-amenity resource uses of water do not participate in the "traditional" marketplace. Applications of new technology (e.g., drip irrigation) can also contribute to efficient use of water, although often at higher costs than for current methods.

To meet future water requirements, expected to be greater than today's water needs, economic and technological efficiency are desirable measures to minimize impacts on other water uses. However, efficiency in one use may create additional demands for energy or stimulate the need for water in other uses and thus still cause impacts to other uses.

More of Oregon's available water can be caught and held if additional reservoirs are built. Added storage will alleviate some current water shortage problems and provide for future growth of water use. But at the same time, some of the conflicts and damages to in-stream uses that presently exist will generally worsen, perhaps even if more water for in-stream flow is concurrently provided. Out-of-stream uses stand to be the main beneficiaries of added storage. (To protect current in-stream uses, the amount of additional storage required might be set to match the growth of out-of-stream demand.) Added storage will make the major state industries less vulnerable to adverse climatic conditions.

Control over water is equivalent to control over Oregon's natural resources. Multiple-purpose water use has not been without severe problems and constraints. In the future, it can be expected that compromises and trade-offs will be central to all natural resource decision making, involving a broader range of land use and energy constraints than have previously influenced water planning.

Selected References on Oregon's Water Resources

Battelle Pacific Northwest Laboratories; Oregon Areas of Environmental Concern; Richland, Wash.; 1973.

Oregon State Study Team; Oregon State Report, Western U.S. Water Plan; Draft report; Salem, Oregon; 1973.

Oregon State Water Resources Board; Oregon's Long-Range Requirements for Water; Salem, Oregon; 1969.
(Summary Report, Main Report, and Seven Appendix Reports)

Pacific Northwest River Basins Commission; Columbia-North Pacific Region Comprehensive Frame Work Study of Water and Related Lands; Vancouver, Wash.; 1970 through 1973.
(Brochure Report, Review Report, Main Report, and Sixteen Appendix Reports)

Pacific Northwest River Basins Commission; Partial Preliminary Draft of Pacific Northwest Regional Program for Water and Related Resources; Vancouver, Wash.; 1976.
(Technical review draft for use in preparing the Comprehensive Coordinated Joint Plan)

Pacific Northwest River Basins Commission; Preliminary Draft of Basic Source Material for the State of Oregon; Vancouver, Wash.; 1976.
(Technical review draft for use in preparing the Comprehensive Coordinated Joint Plan)

Pacific Northwest River Basins Commission; Seasonality of River Use; Columbia and Lower Snake Rivers; Power Planning Committee, PNWRBC: Vancouver, Wash.; 1975.

Pacific Northwest River Basins Commission; Willamette Basin Comprehensive Study, Water and Related Land Resources; Willamette Basin Task Force, PNWRBC, Vancouver, Wash.; 1969.
(Main report, Appendices A-M)

U.S. Army Corps of Engineers; Columbia River and Tributaries Review Study; Irrigation Depletions/Instream Flow Study; Walla Walla District, Report CRT 29; Walla Walla, Wash.; 1976

Appendix

Common Equivalents for Water Discharge (Flow Rate)[1]

Unit	Equivalent				
	gallon per minute, gpm	million gallons per day, mgd	cubic feet per second, cfs	acre-feet per day, AF/day	acre-feet per year, AF/yr
gallon per minute,	1	0.00144	0.00223	0.00442	1.6
million gallons per day, mgd	694	1	1.55	3.07	1120
cubic foot per second, cfs	449	0.646	1	1.98	724
acre-foot per day, AF/day	226	0.326	0.504	1	365
acre-foot per year, AF/yr	0.620	0.000893	0.00138	0.00274	1

[1]To illustrate the use of this table:

a) multiply mgd by 1120 to obtain AF/yr

b) 1 cfs ≡ 449 gpm ≡ 0.646 mgd ≡ 1.98 AF/day ≡ 724 AF/yr