Technology and Management of The Environment

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Preface

A burgeoning science-based technology, without adequate social constraints, is regarded as a primary factor in the deteriorating quality of our environment. But this technology, like the science on which it is based, can serve in both a positive and negative fashion. Much pollution abatement hinges on the adoption of existing technology; in other instances, new technology is required. Where do we stand in this complex technology-science-environment relationship? This was the basic question that served as the focal point for the seminar papers presented in this report.

Among the sub-questions for which answers were sought in the seminar were: What is the present state-of-the-art in the application of technology related to pollution abatement or control? How far can technology be expected to go in solving existing problems? What are the gaps in our present knowledge? What is the outlook for future innovations? What are or should be the constraints or restraints in applying known technology? Are there alternatives if known technology is not applied? How can technologies for economic development give greater consideration to side effects on the environment?

The weekly seminars reported here were held during the spring quarter on the campus of Oregon State University. All presentations were open to the general public, faculty members, and students. Representatives of several federal and state agencies attended many of the sessions.

Robert M. Alexander,
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Corvallis, Oregon
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Contents

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Presented April 1, 1971 by GEORGE W. GLEESON, former Dean, School of Engineering, Oregon State University, Corvallis, Oregon.

Attitudes, Assessments, and Action

The subject of this seminar is broad and overwhelming. One must admit inadequacy in facing such a title since the bulk of known technology is large and the magnitude of the many problems of environmental management have only recently become apparent. Any management or decision making in a technical-social area is difficult, and the area of the environment is one of the most complex. One does not have to be a "prophet of doom" to be deeply concerned regarding the all too evident deterioration of the quality of living over a prolonged period of time; however it is difficult to be optimistic.

Behind the entire problem of the environment, is the problem of people. It is difficult to realize that in this country we must provide living space and services for about 250,000 persons every 40 days for the next 30 years if our projections of population increase are correct. In providing for the increased numbers of people, we will challenge our technology resources; we will assume a heavy financial burden; and we will undoubtedly tax the capabilities of our manpower pool of properly trained personnel. The adverse impact on the environment currently appears to be proportional to our affluence and the number of people. It would appear that, unless we can cope with our population problem, all other considerations may be academic.

In the consideration of the general circumstances which pertain to the environment, three areas of coverage appear most significant, the attitude of people, the assessment of the current situation, and what action has been taken or should be taken toward improvement. Obviously, the coverage must be brief and perhaps superficial, and, for the sake of directness, enumerated by short statements where possible.

ATTITUDES

It is possible to briefly recite some attitudes of the present or immediate past which relate to the environment. Perhaps some of the attitudes have become national syndromes.

1. We have fostered a "chamber of commerce" attitude where "bigger" has become synonymous with "better". Impressive growth with the attendent drain upon resources has been considered a virtue. Big cities have passed the optimum size for quality living which has resulted in the surburban sprawl, ghetto development, and core deterioration. Property rights have been given priority over human rights. Interest in the gross national product (GNP) has developed to the point where it is accepted as an index of progress. GNP could well stand for "Gross National Pollution."

2. The people of the country seem prone to mass hysteria as evidenced by the many crash programs over the past two decades. With the advent of "earth day", it would appear that another hysteria came into being with the demand for instant action and "brush fire" tactics. Short term enthusiasm is no substitute for long range planning and consistent effort. A number of evaluations of accomplishments in the area of environmental improvement over the past couple of years have not been encouraging.

3. Of course, everybody is in favor of environmental improvement, but the time has come to put both our legal muscle and our money where our mouth is. Repeatedly, bond issues for environmental improvement have been turned down in spite of earth day enthusiasm. Improvements are going to be expensive, in some cases very expensive.

4. We are failing to recognize the structural changes which have taken place in our society in the past twenty to thirty years. We have only recently become a truly national society, a truly commercial society and have entered upon a developmental period characterized by social service. In this connection, we, hopefully, have brought to an end the era of growth, affluence and "the technological bug" which has been characteristic since about 1940. We, again hopefully, have entered a period of appraisal, evaluation, correction, and improvement of quality rather than size and quantity.

5. We have created paradoxes, a circumstance hard to understand in an educated society. Time after time, while we staunchly advocate environmental improvement, we continue to support enterprises adverse to such improvement because of loss of jobs, loss of trade, economic disadvantage, or personal inconvenience. Paradoxes make priorities inoperable.

6. We are prone to fragmentation. Small scale, isolated programs make little impression upon the total big problem. Environmental improvement is an excellent "band wagon" and is exploited for goodwill and public relations. Tokenism is rampant. We must develop a national conscience rather than an individual or local approach. Problems of recycle, reuse, control, and enforcement are national if not international in scope and any program or effort toward improvement must be a part of a total commitment.

7. We have chosen a whipping boy upon whom the blame for environmental deterioration may be placed. Science and technology have been so chosen. At this point it may be well to recall that although many decisions regarding the environment may be political or economic, the actions necessary for improvement or the management of the environment are multidisciplinary and in such actions, science and technology are vital.

The foregoing could be extended. There are philosophical barriers to ecological ideals. There are certain "laws" which cannot be ignored. There is a difference between policies and programs. There is resistance to change. There is a lack of patience in a burdened society. There is apathy. There is fear. There appears to be a lack of effort to understand problems in depth and a corresponding willingness to accept superficial evaluation. Although the contrary appears to be indicated, it is hoped that our current concern for our environment and quality of living is real and lasting, and that our attitudes undergo some radical changes. Attitude must be more in tune with the complexities of the problem as well as the long range planning and long time consistent effort which the problems demand.

ASSESSMENTS

In the same manner as with attitudes, assessments of the general circumstances related to the environment may be enumerated.

1. It is generally concluded that in many areas, environmental improvement could be effected by known technology if properly applied.

2. The many meetings, hearings, discussions, and publications regarding the environment raise the question of the fruitful nature of the many words compared to a corresponding lack of action.

3. There are many programs but too little policy at national, state, and local levels which will insure long range action. This statement does not refer to the establishment of standards, but rather to commitment to action to accomplish such standards.

4. Any effective action related to environmental improvement must be multidisciplinary in character. Decisions will be political-social-economic-technical and may be local, national, or international. We are not as yet, adept at multidisciplinary operation or management.

5. In many instances, particularly from a global standpoint, the necessary data for effective action toward environmental improvement are fragmentary, in instances contradictory, and in many cases non-existant. This is particularly true as related to climatic effects and to global monitoring.

6. The amount and content of the laws, regulations, standards, and programs dealing with the environment have become formidable. There appears to be definite need for consolidation and coordination and elimination of duplicate effort.

7. There is a definite need for the extension of the systems approach to environmental problems. Unless all related factors and entities can be given coordinated consideration, there is little hope for other than chaos in any long range operation.

Many assessments of the environmental pattern might be made in specific areas or regarding specific subjects; however, time does not permit. Broad gage assessment indicates the need for more study, research, and planning in a coordinated and interrelated manner -- that effective actions for improvement will be costly and in many instances will take a long time -- that adequate technology already exists in many areas, the application of which awaits funding and public support -- that in addition to development of means to regulate and enforce action, there is need for legal interpretation, political and economic decisions, and the establishment of priorities upon a policy basis, and, lastly, consideration should be given to those current operations which, when projected into the future, may result in the perpetuation of the same mistakes we have made in the past.

ACTIONS

As indicated here-to-fore, the first action program to make any other program realistic is management of the population increase so that within some limited range as to numbers of people, other programs can be planned realistically.

In spite of the fact that associations such as the American Water Works Association, the Air Pollution Control Association, the American Public Works Association, the Institute for Solid Wastes, and the Water

Pollution Control Federation have been in being since as early as 1881, and in spite of the fact that we have had the Federal Refuse Act of 1899, the Oil Pollution Act of 1924, the Water Pollution Control Act of 1948, subsequently amended in 1956, 61, 65, 66, and 1970, we are still losing ground in the quality of the environment. There has been too little action for too long a time.

Long range, coordinated action policies have yet to be formulated, but from a short term action standpoint, the recent proposals of Dr. L. B. Dworsky should be acceptable, at least as far as water pollution is concerned. Dr. Dworsky proposed that during the first half of the seventy decade we should:

a. Remove gross pollution from all municipal and industrial waste outlets.
b. Demonstrate the use of advanced waste treatment technology in 15 to 20 percent of municipal waste systems.
c. Demonstrate control of total pollution on a regional basis in 20 percent of the nations 225 sub-basin areas.
d. Gradually reduce DDT, and other hard pesticides and detergents to acceptable limits by either banning the use or provision of substitutes.
e. Reduce the rate of deterioration of inland water bodies.
f. Increase effectiveness of waste heat management from electric power generation and industrial sources.
g. Improve the control over oil exploration, production, transportation, and use.

It is significant that the technology already exists to accomplish all of the foregoing.

With consideration of all circumstances involved in the possibility of meaningful environmental improvement and the management thereof, it is believed that in spite of increased complexities in all social areas which may within near time increase by one order of magnitude, as a people, we do have the knowledge, the capability, the capacity, and the potential to do almost anything we want, which includes effective action to improve the environment and quality of life, IF:

1. We can specify what we want.
2. We have a reasonable consensus.
3. We are willing to accept change.
4. We are willing to accept risk.
5. We are willing to pay a price.

6. In relation to our wants we can establish firm policy and realistic goals.

7. That we learn to plan in long range on a system basis and act accordingly.

Many believe that the foregoing stipulations do not present choices because no reasonable alternatives exist.

Presented April 8, 1971 by MICHAEL R. SODERQUIST, Department of Food Science and Technology, Oregon State University. *

Analysis of Food Processing Wastewaters

We are witnessing the awakening of a collective environmental consciousness, the development of a sensitivity and an awareness which are piercing industrial barriers and penetrating to corporate consciences.

The food processing industry is evidencing this shift of emphasis and is responding perhaps more rapidly than most industries. Historically, the major societal contributions of the food processing industry have taken place in the spheres of public health enhancement and improvement of living standards. The development of rapid, high-volume preservation techniques for fruits, vegetables, dairy products, seafoods, meats and poultry has provided the consumer with ready access to a large variety of commodities at all times of the year. Concomitant with this ready availability, a heavy emphasis on food safety, fostered by the industry and encouraged by government, has led to unparalleled quality control and in general a confidence-inspiring lack of commercially processed food-borne disease outbreaks in this country's recent past.

The contribution of the industry to the nation's economy has also been significant. The raw product value of all domestic farm food items in 1969 was $32 billion. The value added in processing of these commodities was $63 billion, leading to a finished product value of nearly 3 times that of the raw product (Economic Research Service, 1970).

* Published as Technical Paper number 3075 by Oregon Agricultural Experiment Station.

The industry has grown faster than the population. This has led to a steady decline in relative food prices. Thirty to forty years ago the American consumer spent more than thirty percent of his net income on food. In 1970 he spent about sixteen percent.

PROBLEM MAGNITUDE

Nelson (1970) listed the various segments of the food processing industry in decreasing order of importance (based on pollutional potential) as follows: meats, fruit and vegetable canning, dairy, sugar-refining, fruit and vegetable freezing, and poultry. He estimated the population equivalent (in terms of BOD_5*) of the forestry-agricultural industry to be about 168 million people.

In this figure he included, in addition to the above, pulp and paper, cotton, hide tanning and wool scouring. Another reference (Freeman, 1969) indicated that the annual BOD_5 loading of the "food and kindred products" industry is approximately equivalent to four times the sewered population of the United States. At the very least, it can be concluded from these two widely divergent estimates that the problem merits significant attention.

The wastes produced by the industry exhibit unique features not found in those of most other industrial operations. Most (but not all) are non-toxic to microorganisms. Most are readily biodegradable and can be metabolized in secondary sewage treatment plants. Supplemental nutrients are often needed for optimum growth. The ratio frequently quoted as being the minimum required is BOD_5: nitrogen:phosphorus = 100:5:1 (Eckenfelder, 1966). The fact that the wastes are readily degraded means that they are easily broken down in natural as well as artificial environments, and therein lies a major problem.

"Assimilative capacity" is a term which was coined to describe the quantitative ability of a natural body of air or water to accept one or more contaminants without grossly threatening the ecological status quo. When one speaks of the assimilative capacity of a given receiving water body for a specific (non-toxic) food processing waste, the critical parameter involved is usually dissolved oxygen. As the nearly ideal substrate is discharged from the food processing plant into a lake, stream or estuary, certain indigenous biota begin to flourish and multiply.

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*Five-day biochemical oxygen demand (American Public Health Association, 1965).

Their higher rate of metabolism and their soon-greatly increased numbers can combine to severely alter the dissolved oxygen regime, rapidly depleting the available oxygen and leading to anaerobiosis, wherein strictly aerobic organisms are killed and the products of anaerobic organic decomposition are formed. These include malodorous gases such as hydrogen sulfide, methyl mercaptan, indole, skatole, and others.

Compounding this effect is the seasonal nature of the industry. Figure 1 was developed from data gathered in a survey of Oregon's fruit and vegetable processing industry in 1968. It clearly shows that the great preponderance of processing activity takes place during the summer months, precisely when the assimilative capacities of receiving streams are at annual ebbs; stream flows are minimal and temperatures are high, leading to decreased capacities of the waters for dissolved oxygen.

THE INDUSTRY'S ATTITUDE

The food processing industry has been aware of the pollution potential of its waste products for some time. Activity in the waste management area has been traditionally centered in the major canning trade organization, the National Canners Association, which has pioneered in the development of many water conservation, wastes reduction, by-product recovery and waste treatment techniques.

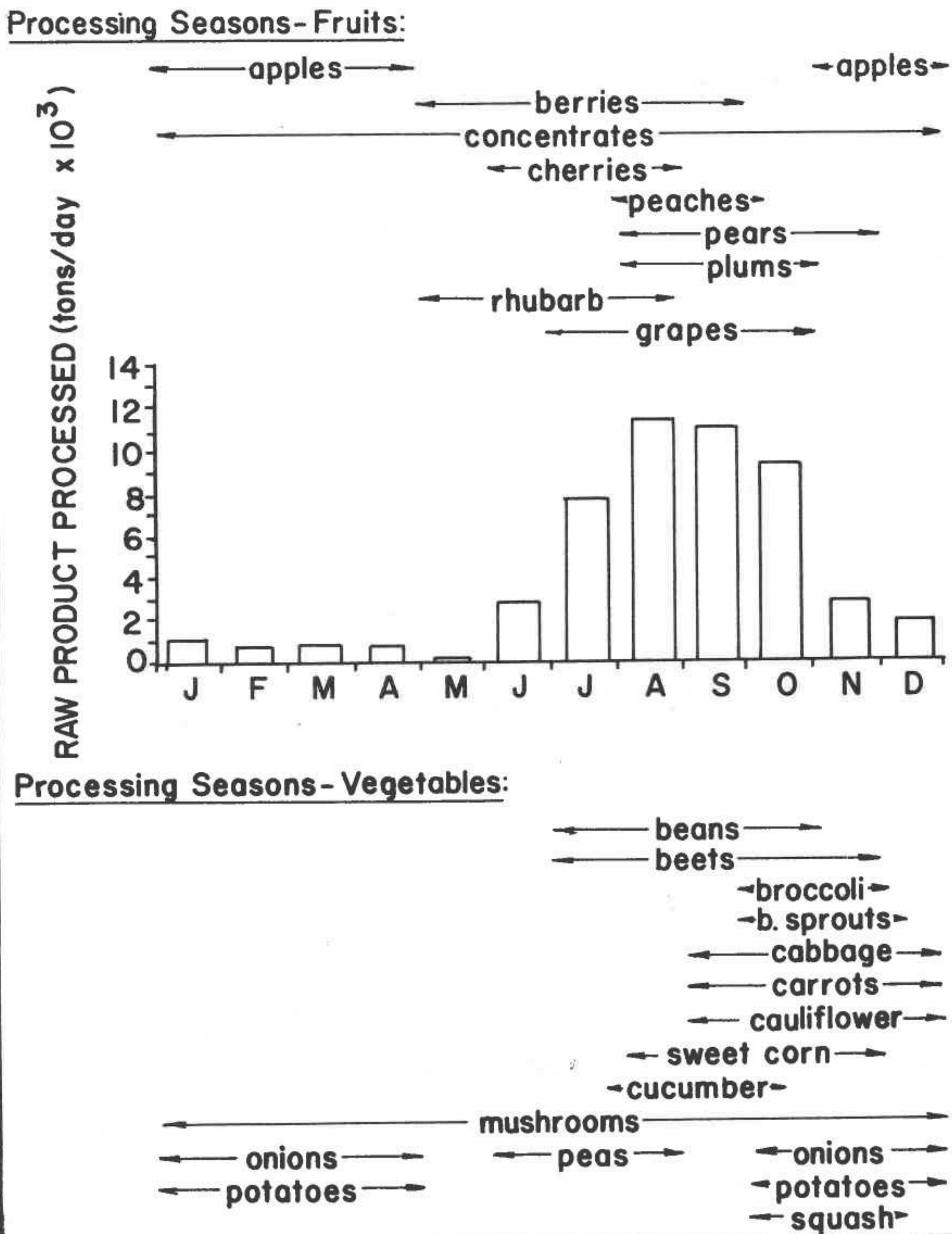
The attitude of the more responsible segments of the industry was presented by Walter Mercer, Director of NCA's Western Regional Laboratory, at a recent conference (National Canners Association, 1970):

"The industry must comply with the fact that adequate handling and treatment of wastes is a necessary cost of doing business. Research efforts must design, develop, and demonstrate raw product field-handling procedures which leave in the field as much as possible of the contaminating soil and organic debris and the unusable fruits and vegetables.

"Water use in the food plant must be reduced to the lowest volume possible which still allows an efficient and sanitary operation. Plant engineers should keep water use reduction uppermost in mind when new equipment is installed or other plant modifications made. Politically and philosophically, the industry must endorse water pollution abatement. There is no alternative. However, the industry must speak out when unreasonable requirements are proposed.

"Although it will cost billions of dollars to abate pollution, more than dollars are required. Strong legislation and massive doses of

Figure 1. Reported Oregon fruits and vegetables production, 1968 (25 respondents) (Soderquist, 1969).



money will not produce an instant pollution-free tomorrow. The industry must point out to legislators and regulatory agencies that today not all of the technical answers are available. Government supported research must continue and be expanded. Research must design large scale, demonstration-type projects which will test the economic as well as the technical feasibility of various waste handling and treatment methods.

"Finally, the industry must accept the fact that the disposal of liquid and solid wastes is a serious problem. The need for water pollution abatement must be met if we are to continue to prosper as an industry and as a Nation".

BY-PRODUCT DEVELOPMENT AND OTHER IN-PLANT CHANGES

The industry has taken praiseworthy action on many fronts to alleviate pollution problems. While most of these developments have been conceived within narrow frameworks and have resulted from piecemeal approaches to sudden, intense "brush fire"-type situations, they have in many cases proven to be reliable, long-range, ecologically defensible solutions.

Examples of such developments include the following. The ensiling and animal feeding of corn wastes, perhaps one of the oldest processing wastes utilization-disposal methods, still enjoys wide popularity today and has little negative impact on the environment.

Until about 1960 most of the seafoods processors of Oregon, Washington and California practiced the "hole in the floor" method of waste disposal. All wastes, liquid and solid, were simply discharged from the plant onto the beach or waters below.

In the late 1950's, however, the Oregon Moist Pellet was developed through the cooperative efforts of Oregon State University's Department of Food Science and Technology and the Hatchery Division of the Fish Commission of Oregon (Sinnhuber, 1964). The Oregon Moist Pellet is a ration designed for salmon and steelhead trout hatchery feeding and is formulated, in large part, from scrap fish and solid seafood processing wastes.

The use of this hatchery feed has created a market for the material which can not be satisfied by Oregon industry alone; scrap fish and waste solids are imported from Washington and California to meet the demand. While greatly reducing the waste disposal problems of many fish canneries, the utilization of the Moist Pellet in Oregon hatcheries has led over the past decade to a fifty percent reduction of the cost of raising each anadromous* fish.

A recent advance in the potato processing industry, which portends great reductions in water pollution, has been the development by the USDA's Western Regional Laboratory of the "dry" caustic peeling process (Graham, 1970). In this process, instead of being abrasively and/or steam peeled, the potato is sprayed with a lye solution, subjected to infra-red radiation and after an appropriate reaction time, the "skin" is gently rubbed off by a series of flexible, rubber "fingers".

Peeling pulp that is generated becomes, after ensiling, suitable as cattle feed. In this process, water use is minimized. Fluming is replaced by mechanical conveying and product wash-water is held to a minimum. This minimization of product-water contact not only reduces wastewater volumes, but minimizes the total organic load (not necessarily the concentration, however) present in the waste stream by holding to a low level the opportunity for leaching.

A more recent in-plant modification for vegetable canning and freezing plants was developed by Daryl B. Lund and associates at the University of Wisconsin (Burroughs, 1971). Working in conjunction with the U.S. Department of Agriculture, these people designed and demonstrated (at production-scale) a blanching technique which produces only one-tenth the wastes that conventional methods do. Blanching is the heat-inactivation of degradive enzymes in vegetables. Since it has traditionally been the major pollutant source in the processing plant, this development is truly significant.

Other waste management successes involving in-plant changes and by-product development include the marketing of nonfat milk and yogurt from formerly-wasted milk solids; the introduction of the frankfurter into the meat industry; and the manufacture of pet food from meat, poultry, and seafood scrap.

WASTE TREATMENT

Waste treatment methods have also received attention from the industry. The Snokist Growers facility in Yakima, Washington, for instance, has recently completed a demonstration project, funded mainly

*ascending rivers from the sea for breeding purposes.

by the Federal Water Quality Administration (Esvelt, 1970). It was shown in this project that the wastes from the processing of various fruits are amenable to several different types of primary and secondary treatment including activated sludge.

Spray irrigation has long been a method of choice for waste disposal, where climatic and soil conditions are suitable, and wastewater characteristics appropriate. Traditionally, sandy soils have been thought best for spray irrigation, high porosity being considered a necessary requisite for successful operation. The Campbell Soup Company, however, in its Paris, Texas operation, has demonstrated the feasibility of spray irrigation on sloping soil of high clay content (Thornthwaite Associates, 1969). By terracing a hillside and maintaining a vigorous cover crop, this "thin film overland flow" system has consistently produced BOD_5 removal efficiencies of about 99%.

CURRENT RESEARCH

While most of the foregoing waste management examples have represented rather isolated attempts to solve specific well-defined problems, some of the currently on-going food processing waste management research (Richter and Soderquist, 1970 and 1971) has been based on optimization of a total system from the standpoint of wastes minimization, an approach which is more compatible with cost effectiveness analysis and which will more readily assure the maximization of positive results from given investments of time and effort. The following are instances where the application of this approach has been successful.

Cottage cheese and cheddar cheese whey are extremely strong waste products which have plagued the dairy industry for decades. Now, through the use of reverse osmosis, ultrafiltration, and electrodialysis, it appears that methods have been found to recover much of the protein from the waste stream while, at the same time, rendering the effluent nearly innocuous (McKenna, 1970; Horton, 1970; McDonough, 1970).

Researchers at Louisiana State University have met with considerable success in growing a single cell protein, a yeast, on the solid wastes from sugar cane processing (Chemurgic Council, 1970). Their modest pilot plant is currently producing twenty to twenty-five pounds of high protein animal feed daily from the bagasse. The projected cost of animal feed production in a twenty ton-per-day plant is six to seven cents per pound.

One food processing operation which produces toxic wastes is maraschino cherry production. In the process, the cherries are bleached in a water solution of sulfur dioxide and calcium salts until only a pale, nearly white cellulosic matrix remains. Flavoring and coloring are then added to produce the final product. The spent brine from this process exhibits characteristics sufficient to inspire awe in the most self-assured sanitary engineer. Sulfur dioxide levels of 5,000 to 6,000 mg/l, pH's of 3.0 to 3.5, and soluble solids levels of 9 to 12 percent (almost entirely glucose) are typical (Beavers, et al., 1970).

As indicated by chemical oxygen demands of approximately 150,000 mg/l, organic levels are about 500 times those of domestic sewage. Encouraged by the results of a similar study conducted on olive brines by the National Canners Association (Ralls, et al., 1970), researchers at Oregon State University decided to attempt to renovate spent cherry brine for reuse by employing activated carbon adsorption of the color bodies (anthcyanins and other polyphenols) from the liquid (Soderquist, 1970). The system was successful; the cherries bleached in the renovated brine were of higher quality than the controls, and furthermore, it was projected that cost savings could be realized in all but the smallest processing plants.

It is anticipated, as shown on Figure 2, that agricultural waste management research programs such as those discussed above, will be expanded during the years immediately ahead. The goal should be to direct these research efforts into the most promising areas of investigation and to utilize the "systems" concept in each study.

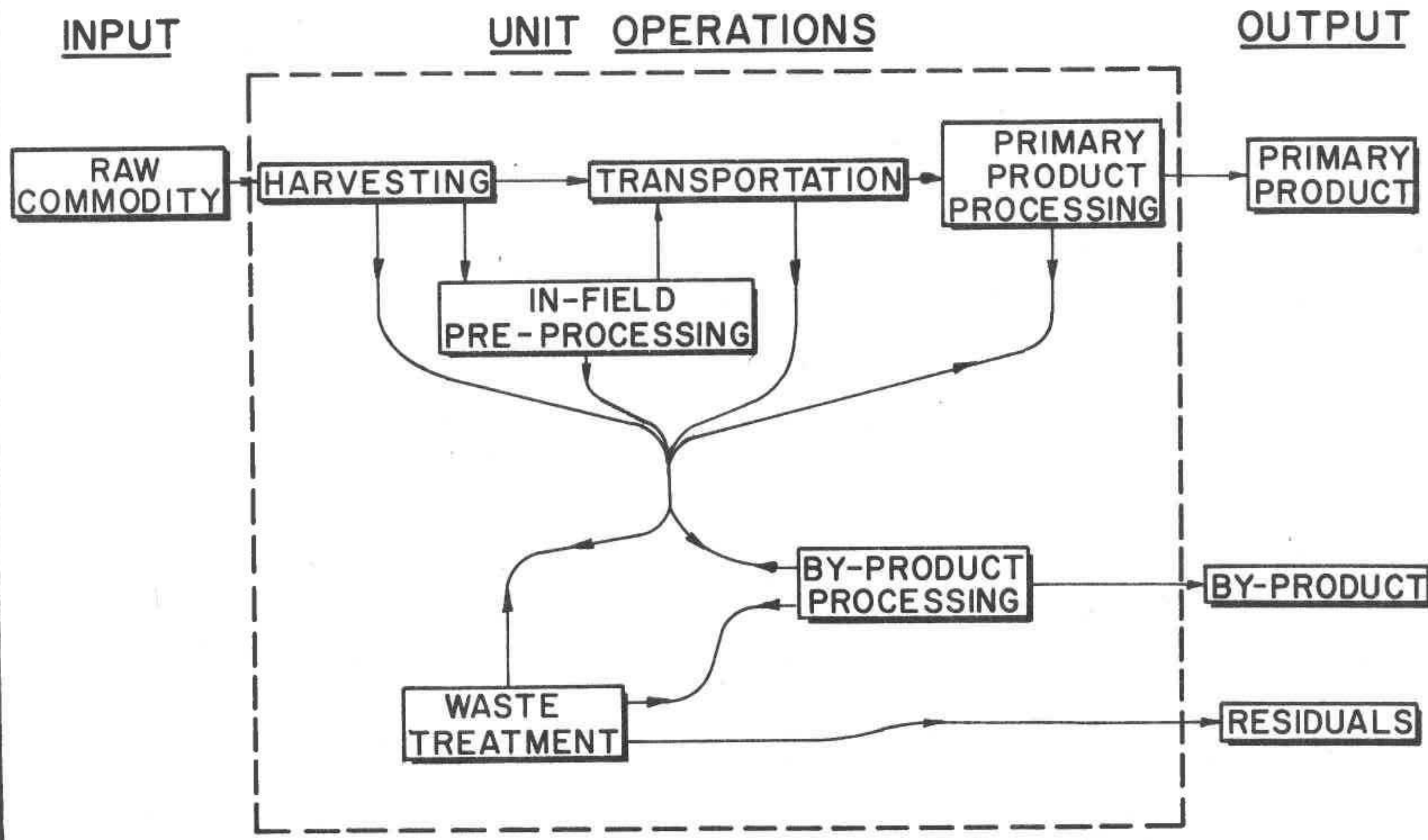
THE UNIFIED SYSTEMS APPROACH

It has been emphasized previously that too often in the past attitudes toward waste management have been narrow in scope and approaches to problem solutions have been piecemeal and therefore often lacking in long-range effectiveness. The approach of the 1970's will be a "unified systems" approach (see Figure 3); an attempt to consider the system as a whole and then to optimize it (with respect to waste production) through: 1) less wasteful harvesting methods; 2) in-field preprocessing (where applicable); 3) reducing transportation damage; 4) increasing in-plant yield; 5) minimizing water use; 6) developing new by-products; and 7) developing innovative treatment methods.

Figure 2. Pollution research in the United States Department of Agriculture, state agricultural experiment stations, and cooperating forestry schools (Byerly, 1970).

Pollution or Subject Area	1966	1977
	Scientist-man-years	
Animal and domestic wastes	27	140
Processing wastes	30	133
Infectious agents, toxins, and allergens	197	270
Sediment	96	254
Plant nutrients	200	275
Mineral and other inorganic substances	44	95
Radioactive wastes	0	10
Airborne chemicals and particulates	41	114
Noise	1	7
Socioeconomic aspects	2	32
Systems analysis	2	6
Total	640	1,336

Figure 3. Unified systems schematic for food processing.



A study of this type, for the paper industry, has recently been published (Spofford, 1970). In this study the author tried to determine the optimal recovery ratio for paper stock by assigning costs to all unit operations of the production-recovery-disposal system (see Figure 4). In Figure 4, curve number 1 represents costs of pulpwood; number 2, external damages; number 3, treatment and disposal costs; and number 4, costs of paper stock recovery and reuse. Spofford totaled pulpwood costs and paper stock recovery and reuse costs for various recovery ratios; the minimum total was defined as the "private market optimum." Totaling all costs for several recovery ratios produced the "total costs plus external damages" curve, the minimum of which became (by definition) the "social optimum."

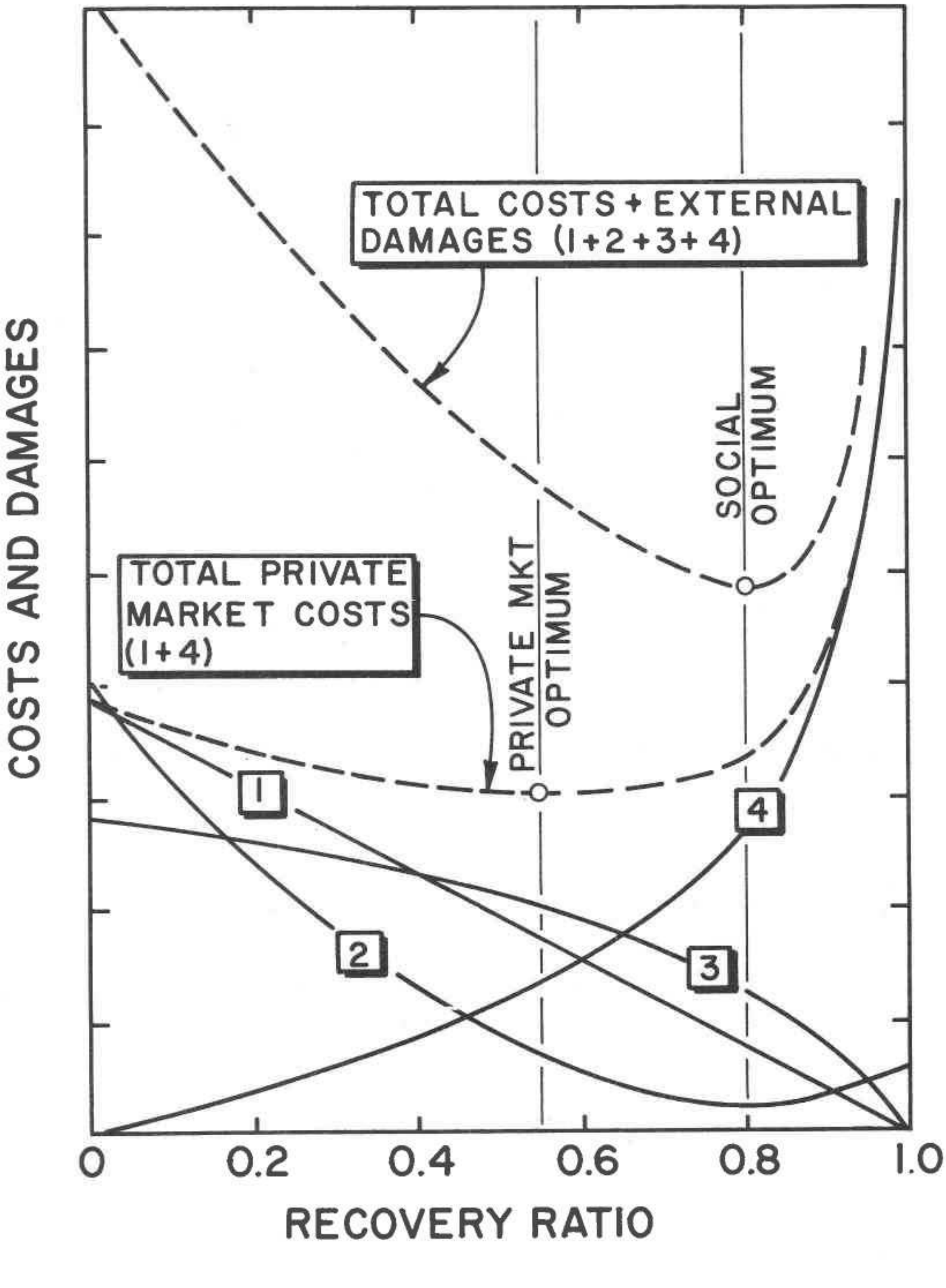
Analyses of this type are extremely difficult when the social and environmental "costs" and the external damages are included. As the author himself pointed out, the actual costs and damages accrued will depend on the assimilative capacity of the environment, the existence and proximity of other dischargers, and the relative locations of emitters and receptors, to name a few variables.

One way to avoid the nebulous area of assigning costs to these intangible "externalities" is to assume that the local regulatory agencies have already done this and have established their standards (whether they are water quality standards or effluent standards) accordingly. Thus, for a food processor, it remains only to assign cost functions to each of the subsystems indicated schematically on Figure 3, keeping in mind the required effluent quality, and to minimize the resulting total cost function. With a "real" system this can be accomplished most efficiently through the use of linear or (if the problem is more complex) dynamic programming methods.

CONCLUSIONS

The changing public attitude toward the environment is prompting the food processing industry to include ecological considerations in corporate decision-making, to admit that waste management expenses must be included in the cost of doing business. Progress will be achieved in the 1970's only through logical, systematic, knowledgable approaches to solutions. This attitude will encourage the concentration of research and development efforts in the areas most likely to yield promising results.

Figure 4. Optimal recovery ratio for paper stock (Spofford, 1970. Reprinted from Environmental Science and Technology 4: December, 1970, page 1111. Copyright 1970 by the American Chemical Society. Reprinted by permission of the copyright owner.)



The most rational approach to use in assessing the impact of present operations and minimizing the impact of future plants on the environment is the unified systems approach. This fact will become increasingly accepted as the industry proceeds through the new decade. To minimize environmental deterioration by this (and all) industries, well-conceived, long-term, sustained efforts will be required. Furthermore, equitable treatment of industry across political boundaries will be imperative to avoid a "domino effect," where governing agencies, one at a time, sacrifice "livability" for industrial development.

Finally, it must be noted that the burden of environmental quality maintenance and enhancement will ultimately be borne by the public --- as taxpayers - in the form of higher costs of governmental regulations, inspection and enforcement, and as consumers - in the form of increased costs of goods and services.

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Presented April 15, 1971 by GEORGE M. JEMISON, Department of Forest Engineering, Oregon State University, Corvallis, Oregon.

The Forest Environment -- Problems and Promises

Many of the concerns of people today directly or indirectly relate to the use of the forest and what forest lands produce as goods and services. People want a more livable environment. They want more space and solitude in which to recreate, more aesthetically pleasing countryside, more fish and wildlife, more clean air. Some of them want more fully-developed recreation facilities. The agricultural, industrial, and domestic institutions our society has created to support its wants and needs require increasing amounts of water. Our citizens demand more houses, boats, trailers, furniture, packages, disposable fiber products, and other things made out of wood.

One may summarize all of these wants into four major areas of concern:

- A livable environment with clean air, aesthetic countryside, quiet, and room to recreate.
- Plentiful supplies of high quality water.
- Adequate timber supplies for housing and other products derived from wood.
- Abundant recreational opportunities and facilities and plentiful fish and wildlife.

The demands of society and the concern for meeting the demands produce the conflicts we see everywhere today about the use of the forests and plans for their management in the future. The conflicts spring from existing or predicted shortages in the resources brought about by burgeoning population of growing affluence, highly mobile, and with more and more leisure.

Are these predicted shortages real? Is there a justified basis of concern? Do the conflicts over the allocation of forest resource uses primarily arise from emotional misunderstandings? Will apprehensions disappear as intelligent people learn more about alternative solutions to problems and the requirements for the management of timber, water, and recreational resources? Will an advancing technology provide us with the know-how and the tools to replace concern with a confidence in the forestry future?

These are not easy questions to answer. Maybe I can shed some light on the problem if I review with you some of the more significant trends in forestry--trends that are arising out of the concerns people have about the forest resources of this country. In keeping with the over-all theme of these seminars, I also want to discuss some of the technological changes that may lie ahead and that may alleviate the concerns we feel.

THE RESOURCE SITUATION

Recurring national inventories of timber supplies show we are growing more wood than we currently use. However, quality and size is decreasing and the supply of the preferred softwood growing stock is being reduced more rapidly than it is being replaced. Analysts estimate that for the economy as a whole, the annual demand for softwood sawtimber could exceed current levels by 40 percent in the next seven years, assuming prices remain stable. They agree, by almost any yardstick used, that the over-all demand for wood-based products will greatly overtax our supply capabilities unless current timber management and utilization practices are substantially improved.

The wood supply problem is being intensified by a steady encroachment of other demands on timber-producing lands. Nationally, about a million acres of forest land per year is taken over for city expansions, urban sprawl, highways, transmission lines, airports and other non-timber growing purposes. Rapidly increasing land values are making many small landowners wonder if they can afford to keep land for timber growing or whether they should shift to uses which promise greater returns. In Oregon, as elsewhere, there is a steady shift of small forest tracts to owners who want a rural homesite, a recreation base, or who just want to own a piece of land.

We are a nation of prolific water users. Every year the domestic, industrial, agricultural, and recreational demands for bounteous supplies of high quality water increase. The forests and associated mountainous range lands of the nation produce about three-fourths of our total water supplies. But even in a well-timbered and well-watered state like Oregon, we have water management problems. Just about everything we do affects the quality, quantity, or the availability of water in point of time.

For years, Oregonians have been expressing fears that neighbors to the South may some day raid the Columbia Basin for badly needed water. Just three weeks ago in the Corvallis Gazette-Times, Congresswoman Julia Butler Hansen was quoted as believing that the votes traded in the SST squabble boded ill for keeping Columbia River water out of the arid Southwest.

We have controversies over further impoundments of some waters as in Hell's Canyon on the northeastern boundary of the state. Studies are being made of a number of Oregon's rivers under provisions of the Wild and Scenic Rivers Act for special designation and special future restrictions in use.

Anyone who uses our famous outdoor recreational resources in Oregon must surely be impressed with the increasing pressure from recreationists who live here or come as visitors. From beaches to mountaintops, mounting pressures every year add to the problems of providing adequate experiences for those who wish to enjoy the beauty, fish and game, solitude, or developed mass-recreation area of the state. Pressure by users of some wilderness area in the High Cascades threatens to destroy the very purpose for which these lands were dedicated.

So there seems little doubt that resource shortages are real and are likely to become more critical unless our demands somehow level off.

DON'T BET ON THE WRONG HORSE

Most of the uncertainty and concern over forest resource activities in Oregon tend to center on timber harvesting or management activities directly related to wood production. Logging and road building can cause erosion and stream sedimentation, impairing fish habitat and the calm good nature of steelhead fishermen. Clearcutting is aesthetically displeasing to many. The burning of logging slash fouls the air with smoke. The use of pesticides or herbicides to control insects or aid establishment of desirable seedlings contaminates soil, air, and water--or so at least many people claim.

If predictions are correct that we do indeed need increasing quantities of wood--wood to build 26 million new homes in the next eight years, for example--what, then, is the answer?

Some critics of timber production reason that substitutes for wood can take over and meet the needs of 300 million people for fiber and solid wood products. Parenthetically, one may observe that constraints on efficient production of wood might actually price wood for some uses right out of the market. But how about iron and steel as a substitute for 2 x 4's, timbers, wooden roofs, and siding for houses? Now that our excellent iron ore supplies are largely depleted, we process taconite and dump huge amounts of finely divided silica and toxic metal ions into Lake Superior.

High tonnages of coal are needed to process the iron oxide. Much of this comes from strip mining which has already ruined 1.8 million acres of land. Exposed bed materials with high sulfur content leach sulfuric acid into hundreds of miles of streams. Furnaces belch out clouds of SO_2-laden fumes. Is this a good trade-off for lumber and plywood production?

Aluminum, another wood substitute, requires large quantities of power in its manufacture. But environmentalists are concerned about more impoundments on choice waterways still unspoiled, or worry about water temperature changes induced by nuclear reactors that generate the needed power.

Substitution of plastics for wood fiber products means more petroleum used with the dangers of more off-shore drilling disasters, more super-tankers and super oil spills, more "Alaska pipelines." The disposal problem brought about by all sorts of non-biodegradable plastic containers is worrying most of us.

If we need wood, water and recreation and if wood production conflicts with the other resource uses, why not allocate forest lands selectively to the best single use? This practice has been followed to a degree as evidenced by the 14 million or more acres of dedicated wilderness, the thousands of developed recreation areas and hundreds of municipal watersheds. No less a body than the Public Land Law Review Commission has recently recommended that:

> "There should be a statutory requirement that those public lands that are highly productive for timber be classified for timber production as the dominant use ..."

much to the dismay of recreation-oriented interest groups.

WHAT SHOULD WE DO?

In our system of government, the wishes of the people are the bases on which policy is formed. Sometimes we take a long time and much backing and filling before sound policies are generated. So it behooves all of us to understand as well as we can the alternatives open to us in forest resource management and the consequences of each.

Most professional foresters believe that the best way to overcome our concerns based on a short supply of all forest resources is through optimizing the mix of goods and service through intelligent and effective coordinated use. Said another way, we must learn how to make multiple-use work. Multiple-use practices must be applied with judgment and skill. They must be based on sound knowledge of production and utilization processes and their interactions.

Professional forest land managers of the future will be able to make multiple-use work within the context of society's constraints only if they have an array of technically feasible alternatives. Many of these are being developed now. Forestry research is being tailored to provide the manager with the knowledge that gives him a range of choices. The manager is becoming far more conscious of the user's desires and therefore better able to develop the course of action that comes closest to meeting the concerns of those he serves.

NEW TECHNOLOGY IS PART OF THE ANSWER

Some in today's society would have us abandon technological advances on the grounds that new technology creates new problems. I disagree. We are not going to go backwards. We are not likely to uninvent the wheel. As a matter of fact, our hope in overcoming the concerns we feel for our Oregon forest resource situation lies largely in more sophisticated technology. Let us look at a few of the obvious changes in sight.

Dr. Jerome Saemen of the U.S. Forest Products Laboratory believes that research will show us how to produce four times as much usable material out of our timber as we get now. Think what such an achievement might do to the logging slash disposal problem in the Northwest where 23 million tons of coarse residues are produced annually. Probably far less broadcast burning would be necessary with accompanying air pollution if we had a profitable use for logging debris.

Studies of the chemistry of lignin (an unusable by-product of most methods of pulp manufacturing) may lead to commercially feasible products from this material which is now burned, ponded, or dumped into streams with all the attendant pollution problems. Also, studies of bark utilization are likely to yield practical methods for converting this problem material into products of value which at the same time will extend our wood-based resources.

Regeneration and silviculture research, based on a thorough knowledge of ecology and ecosystem responses to the impacts of man, will yield new techniques of timber culture. It seems quite obvious that some modifications to clearcut silviculture will have to be developed. This does not mean that clearcutting is on the way out. But it does suggest, perhaps, that making multiple-use work in the Oregon west-side Douglas-fir type need not always start with the constraints of a system of relatively pure, even-aged, clearcut-and-regenerate, Douglas-fir silviculture.

Thus, in some situations, the land manager may be better equipped to deal adequately with landscape aesthetics without surrendering entirely the wood producing capability of the land.

Hopefully, forest geneticists will come up with new races of trees in the future, selected and bred to satisfy the demands of an altered environment. Already we have in sight improved selections of Douglas-fir that may grow 10 percent faster than average trees. Thus, perhaps, more growth can be concentrated on fewer acres. Who knows but that a more shade tolerant selection of Douglas-fir might be developed? It would lessen the need for broadcast burning and herbicide treatment of brush, a practice now desirable to give the sun-loving native Douglas-fir varieties a chance to grow. The use of such a genotype, where feasible, would contribute to a cleaner environment.

MORE CHANGES

Past basic research on biological control of forest pests is on the threshold of a big payoff. Biological agents will be available in the years ahead to combat insects that can no longer be dealt with by highly effective chemicals which are now outlawed because they persist in soil, water, and animal tissue. Sex attractants for bark beetles have already been synthesized and will be used in the future without endangering the environment.

We have every reason to expect that advances will continue to be made in road building and timber harvesting technologies with great gains in the way of soil stabilization and reduced stream sedimentation. A better understanding of geology and soil characteristics, and an ability to forecast reactions to disturbances from roads and logging is sure to come. We have seen the basic energy source used to move a log from a hillside change in the last 70 years from a team of oxen to a steam donkey to a diesel engine to a balloon, to a helicopter. I do not believe we have reached a final plateau where there will never again be an advancement in how to do such a job better.

But I expect many of the things we do today in timber harvesting will have to be changed to make multiple-use work. It seems incongruous that as our logging in the Northwest moves to steeper and rougher ground and to smaller and smaller timber we create larger and more costly machines to do the job. Probably the constraints of over-all sound resource management will bring about changes here.

We are likely to develop modified timber harvesting systems that are more compatible with aesthetics and soil and water values. You may have read in the local paper the other day of the conference on moving pulp chips by pipeline. Most of the engineering principles have been worked out. You have read about advances in balloon and helicopter logging. These developments mean that fewer roads are needed and the environment suffers less disturbance.

Today we really have a poor record of forest landscape management but foresters are learning. Landscape management and the art of developing and managing outdoor recreation depends on an understanding of people, their behavior, and reactions to various situations and stimuli they encounter.

Here, too, is an area where much research needs to be done. Few foresters have been trained in psychology and sociology. But there are scientists skilled in evaluating human needs and responses. One thing is sure for the future--the needs of people for amenities supplied by the forest will not be overlooked. We can expect much more skillful handling of "people problems" in future years.

Private industry and public land managing agencies are aware of many of the institutional factors that stand today as obstacles in making multiple-use work. Would an improved incentives program be desirable in solving some of the land management problems? What kind of a program? Are there legislative or regulatory road blocks that need overhauling so we can better tailor multiple-use management to each problem situation? Are there better marketing systems that would make desirable but currently unprofitable practices attractive for the logging contractor or landowner and thus enable him to do a more acceptable job of land management?

WHAT IS THE REST OF THE ANSWER?

If new technology is only part of the answer to making multiple-use work, what else can be done?

Most researchers who are responsible for getting the necessary background knowledge for resource managers have not yet fully recognized the importance of dealing with the entire system. Usually the physiologist cares little about understanding the broader context within which his own special work lies. The forest engineer works hard and effectively to improve the efficiency of a particular operational technology but with little close tie to the biological aspects of a problem. The silvicultural researcher concerns himself with maximizing tree growth and is not entirely conversant with wildlife food and cover problems. And so it goes.

Somehow we must begin looking at the whole system and be willing to observe, study, and evaluate together the interrelationships of biological, physical, and social processes. Such an approach still requires the individual work of the specialist but calls for an over-all comprehensive and coordinated degree of research planning we have not yet had in very many instances.

Also of key significance in the whole question of making multiple-use work is how to allocate the costs. If the public demands that forest resources be so managed as to relieve the concerns they have for solitude, wood, water, or whatever, only one person pays--the consumer. Of course, the distribution of costs among consumers can be regulated by governing bodies. But before sound regulation can be imposed the nature and distribution of benefits must be understood.

Some of us feel that the trade-offs required to make multiple-use work are not well understood. We must strive for a better understanding lest faulty decisions cause us to make fateful mistakes in seeking the many benefits we extract from the forest.

In a recent talk before the Redwood Region Conservation Council, John Zivnuska of the University of California spoke of the current derogatory twist given to any form of "conservation" that has utilitarian aspects. He said,

> "There is, I think, some strange aberration or form of tunnel vision involved. Much the same aberration is apparent in the current debate on the allocation of the resources of wildlands. There are certain values of these resources which are normally captured and made available through the operation of the market economy, and there are other values which are characteristically made available outside the market system, either through public ownership of resources or as externalities of private ownership (that is, as benefits from the private lands which are not internalized through capture and sale by the private owner). In current discussions one repeatedly hears the first group referred to as economic values and the second group as social values.
>
> "This is absurd in conception and unfortuante in effect, since it tends to impute a higher value to the second group than to the first. I submit that there are important social values to having lumber and plywood for housing and to having low-cost wood-based printing papers to undergird mass literacy, just as there are social values to an attractive landscape and the opportunity to escape our metropolitan area. Further, there are important economic values and economic issues in the values obtained outside the market system."

So, one of the things we must do is establish a better understanding of the total resource values we enjoy and the costs of obtaining each. We have among us different groups of users of the forest. The ghetto dweller in a substandard home does not place the same value on a roadless wilderness as the person who lives in a penthouse and can afford a summer, guided, pack-trip through the Eagle Cap Wilderness area.

Those who are concerned about the forest as an ecosystem -- and rightly so--should not forget they and it are part of a bigger ecosystem. The environment we are trying to improve, or to save as some may put it, is not just the forest wilderness.

It is not just the stand of fast growing timber. It is not just a clear-flowing stream.

The environment is the whole complex of the world we live in--the city, the air, the forest, all parts of our country. The forest has a unique place, perhaps, in this complex because it supplies so many things we find necessary to life itself as well as to the pleasures and joys we extract from it. But we must realize we cannot tamper with one part of the system without affecting all other parts in one way or another.

I am confident that forests forever will supply us with rich renewable resources. The technology and capability is within our grasp. But patience and understanding are ingredients we must be willing to add. If we do this the concerns we have will lessen and fade in the future.

Presented April 22, 1971 by L. GENE SUHR, CH_2M/Hill, Corvallis, Oregon.

The Concept of Wastewater Reclamation

The concept of wastewater reclamation is neither new nor unique. Even in Biblical times it was known. Ecclesiastes, Chapter 1, Verse 7, states: "All the rivers run to the sea, yet the sea is not full. Unto the place from whence the rivers came, thither they return again."

Like any "new" concept, water reclamation has its friends and its foes. Both sides have many arguments supporting their positions. By way of a comparison, detractors of the Wright brothers said of man's early attempts to fly, "If God intended that man should fly, He'd have given us wings"! In answer to similar hysteria over the reuse of wastewater, we could as easily retort, "If God had meant us to use only new water, He'd either have given us more of it or created far fewer of us".

The purposes of this paper are twofold: to advance some of the many logical arguments in favor of wastewater reuse; and to cite some actual case histories of wastewater reuse operations as a means of showing what has already been accomplished.

ALTERNATIVE CONCEPTS

There is at least one alternative approach to most concepts. If we consider the reclamation concept as one possibility, its antithesis might be termed the wastewater concept. These two concepts are briefly defined below.

1. The Reclamation Concept

Water, once used for domestic and industrial purposes, still constitutes a natural resource that can be renovated and reused. To be justified, the reuse must be shown to be beneficial, economically feasible, and above all, safe public health practice. Benefits accruable to reclamation and reuse include the identifiable economic, ecological and social impact on receiving waterways because of greatly reduced pollutional loads. These benefits are to some extent intangible since a dollar value or "price tag" for elimination of pollution is difficult to calculate.

In addition, other benefits, including reduced costs for development of alternate sources of potable water supply, maximum development and use of the existing water resource, the ability to serve more people and industries and the increase of the tax base, must be considered. Failure to recognize both tangible and intangible benefits of water pollution abatement will generally result in making economic justification of water reclamation and reuse impossible.

2. The Wastewater Concept

This approach implies continued acceptance of the premise that sewage is merely wastewater, something fit only to be discarded. This concept would logically lead to the conclusion that the pollution problem can be solved by much the same methods presently used; i. e. , removal of as much of the pollutants contained in wastewater as is necessary to meet disposal requirements.

Certain modifications in treatment and disposal techniques would have to be developed and implemented as pollution abatement standards become more strict, but the main idea would be to dispose of the water as a waste product, as simply as possible, consistent with the needs of the ecology of the receiving waters. Benefits accruable to this concept include the intangible aspects of pollution abatement, as in the water reclamation concept (although often to a lesser extent, depending on the purity of the effluent). Other benefits might be possibly lower costs for wastewater treatment facilities, increased stream flow for downstream users and ready public acceptance. However, the wastewater concept also has what might be termed "negative benefits, " are costs of developing alternate sources of potable water supply to replace effluent wasted downstream, and the possibility of placing a limit on area growth by virtue of a finite limit on available new water. Failure to recognize these and possibly other "negative benefits" may in fact constitute the major justification (and a false one) for continued waste of treated sewage effluents, at least in areas where water is a critical factor.

BENEFITS OF WASTEWATER RECLAMATION

1. Pollution Abatement

One of the major benefits of any wastewater reclamation program is the removal of pollutants from wastewater to a degree greater than that obtainable from conventional secondary waste treatment processes. Generally, the quality standards required to make water reuse practical are such that advanced waste treatment is necessary to reduce oxygen demand; to reduce the nutrient content; to avoid undesirable algal growths; to remove final traces of suspended solids; to remove color, taste and odor; and, finally, to remove refractory materials.

Removal of pollutants causing oxygen demand is generally measured either in terms of BOD or COD removal. Items which contribute to BOD or COD in wastewaters cause a depletion of dissolved oxygen content within receiving waters. Consequently, unless the receiving water has a sufficient capacity to assimilate the oxygen demand of the incoming wastes, dissolved oxygen levels fall below desirable levels, with attendant loss of desirable aquatic fauna.

Nitrogen and phosphorus are the primary algal nutrients. Wastewaters rich in phosphorus and nitrogen stimulate the growth of algae. In clean reservoirs and streams, a delicate balance is maintained between the growth of algae and the growth of other aquatic flora and fauna. In water which receives an over-abundance of nitrogen and phosphorus, the usual result is the stimulation of greatly increased algal activity with attendant "blooms" of these minute plants. A stream or reservoir which suffers from a continuing over-abundance of nitrogen and phosphorus inevitably is on the road to degradation and eventual death as a usable body of water.

This process of enrichment, because of nutrients, is termed eutrophication. Eutrophication is a naturally occurring process; eventually, the fate of most streams and lakes would be conversion first to swamps, and eventually, meadows, even without the enrichment provided by the activities of man. The rate at which eutrophication occurs is unfortunately tremendously stimulated by the activities of man, primarily because of wastewater discharges, but also to a significant degree because of the use of agricultural fertilizers on crop lands, lawns and gardens.

Suspended solids carried in wastewater effluents tend to settle in quiescent pools, in reservoirs, or receiving streams, forming sludge deposits on the bottom. These deposits are commonly known as benthal deposits and have at least two major detrimental effects. If the benthal deposits remain on the bottom, they are subject to decomposition. If this

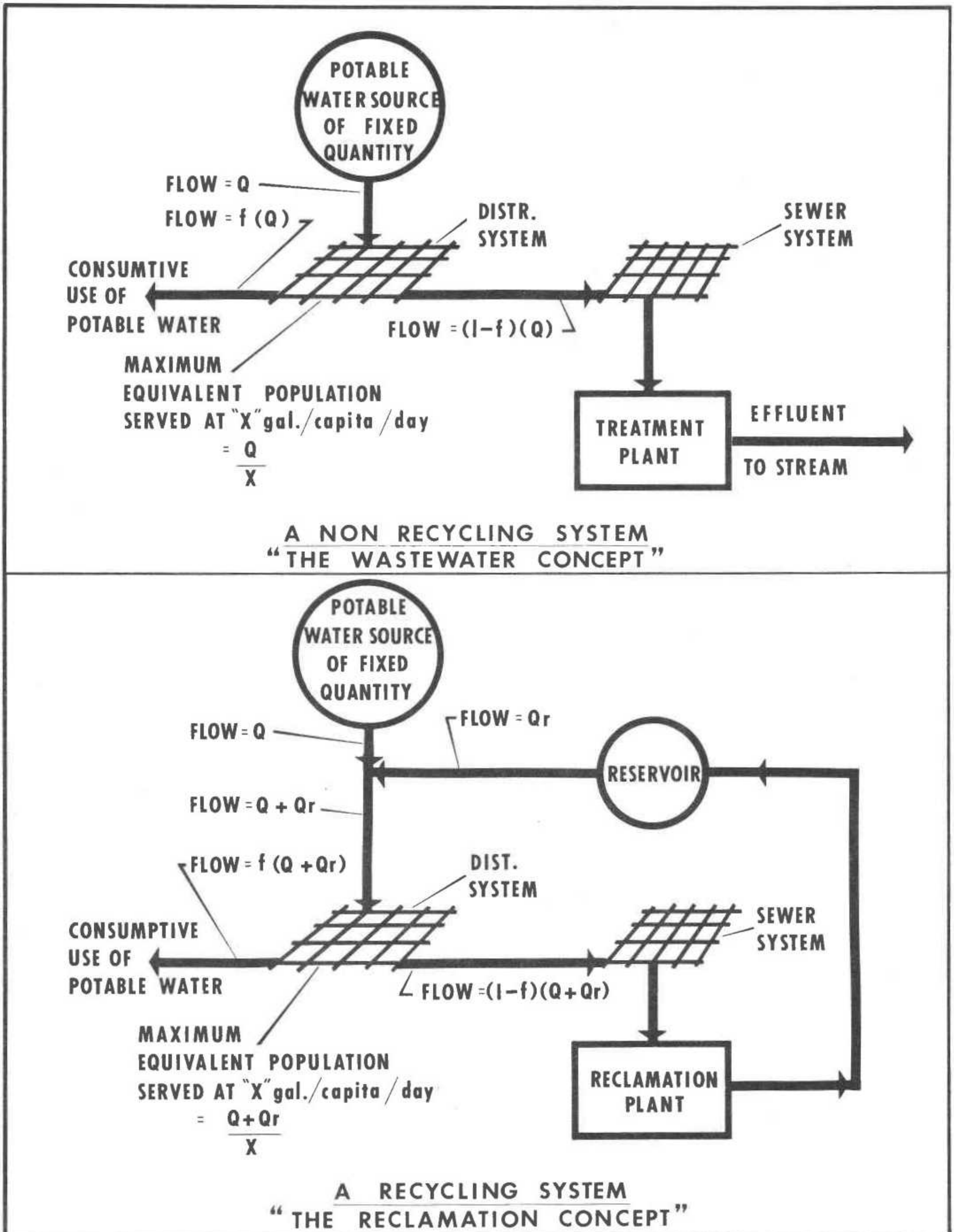

POTABLE
WATER SOURCE
OF FIXED
QUANTITY
FLOW = Q
FLOW = f (Q)
DISTR.
SYSTEM
SEWER
SYSTEM
CONSUMTIVE
USE OF
POTABLE WATER
FLOW = (I-f)(Q)
MAXIMUM
EQUIVALENT POPULATION
SERVED AT "X" gal./capita / day
= Q / X
TREATMENT
PLANT
EFFLUENT
TO STREAM
A NON RECYCLING SYSTEM
"THE WASTEWATER CONCEPT"
POTABLE
WATER SOURCE
OF FIXED
QUANTITY
FLOW = Qr
FLOW = Q
RESERVOIR
FLOW = Q + Qr
FLOW = f (Q + Qr)
DIST.
SYSTEM
SEWER
SYSTEM
CONSUMPTIVE
USE OF
POTABLE WATER
FLOW = (I-f)(Q+Qr)
MAXIMUM
EQUIVALENT POPULATION
SERVED AT "X" gal./capita / day
= Q+Qr / X
RECLAMATION
PLANT
A RECYCLING SYSTEM
"THE RECLAMATION CONCEPT"

FIGURE 1

decomposition takes place in the presence of oxygen, it represents an oxygen demand. If the decomposition takes place in the absence of oxygen, malodorous conditions result. Even if suspended solids did not settle to the bottom, they represent an undesirable condition by causing increased turbidity, which decreases the aesthetic appeal of a receiving water. In addition, if present in large quantities, suspended solids have an adverse effect upon aquatic life, especially the more desirable fish species such as salmon and trout.

The presence of materials which cause color, taste or odor in receiving water probably needs little discussion since these materials are readily ascertainable to anyone who takes the trouble to use his senses.

Refractory substances, in general, may be defined as those substances which contribute to the total organic carbon content of water, but do not generally represent either a BOD or COD demand. In particular, these include synthetic detergents and many of the organic pesticides which may find their way into waters. These substances can definitely be linked to such diseases as cancer in humans and, even if not carcinogenic, may cause undesirable side effects such as foaming or frothing of receiving waterways.

2. Supplementing the Water

Another major benefit of water reclamation and reuse is the supplementing or enlargement of what may otherwise be a fixed quantity of water available for use to a given area. In many areas of the U. S., the quantity of water available from either surface or subsurface sources is limited; such a limit in turn imposes a limit on the total number of people and/or the total amount of industry which can be supported in a given area. Water reclamation and reuse can multiply the apparent supply by recycling reclaimed water without the necessity of developing new sources of water. Figure I illustrates this concept graphically.

In conjunction with water reclamation and reuse, the quality of water required for various uses often dictates the most desirable form of reclamation and reuse. For example, water for most agricultural uses and many industrial uses need not be of as high a quality as that used for human consumption. In such cases, water reclamation may take the form of irrigation of crops and use of treated effluents for industrial purposes. The net result is that the potable water supply source and system can be relieved of the burden of supplying these needs.

In areas which depend laregly on groundwater sources, artificial recharge of the groundwater resource either by injection or spreading of reclaimed water is often possible. This also results in augmenting the available source by essentially "banking" reclaimed water in the subsurface against the time when withdrawal of groundwater exceeds the natural recharge.

Finally, in areas where sufficient potable water is not available, highly purified reclaimed water can be recycled into the potable water system, thus increasing the overall quantity of potable water available. Such action certainly should not be implemented without considerable study and research covering all possible effects. It is not, however, an action without precedent; direct domestic recycling is now being practiced in some areas of the world and will undoubtedly become more widespread in the future. A case history involving such a direct potable water recycle is discussed later in this paper.

3. Economic Advantages

The final major benefits of water reclamation and reuse may very well prove to be economic in nature. For example, the State of Nevada recently adopted water quality standards for the Las Vegas area which are so stringent that, if met, treated wastewater would be purer in nearly all respects than the waters of Lake Mead. However, Lake Mead, after the completion of the Southern Nevada water project, will constitute the major source of potable water for the Las Vegas area. Under the present Nevada water quality standards, desalinization of wastewater before discharge into Lake Mead would be required.

It would therefore be far superior in many characteristics to natural Lake Mead water. Hence, unless the wastewater were to be reused it would, at least in some respects, be polluted by admixture with Lake Mead water. Thus, the very high cost of treatment would be lost for the most part, since the relative volumes are such that Lake Mead itself would be but little improved. On the other hand, reclamation and reuse plans currently under study include the use of some of the wastewater for cooling thermal power generation facilities and, in conjunction with such generation facilities, recovery and desalinization of some of the wastewater by multiple effect distillation.

The desalinized reclaimed water would then be fed directly into the potable water system, actually improving the quality of the supply from the standpoint of dissolved solids content. At this point in time, the estimated net costs involved appear to be less than the cost of merely treating wastewater for disposal.

In other areas where treatment requirements may not be as restrictive, savings may still be realized by planned water reclamation. Certainly a portion of water use in nearly any sizable community may be satisfied with less than drinking water quality. The City of Colorado Springs provides such an example. For a number of years the City has maintained a nonpotable water system to supply irrigation water.

This system has utilized both untreated surface water and sewage effluent that has passed through secondary treatment. Recently, the City began construction of a tertiary treatment system to augment their nonpotable water supply system. Their tertiary treatment plant will provide additional treatment for about 12 mgd of secondary effluent and produce two qualities of nonpotable water: a high grade water for cooling thermal power generation and a water of lower quality for irrigation. The system will, in addition, significantly reduce the amount of pollution entering Fountain Creek, which is the receiving stream for the effluent.

Even without considering any costs for possible development of other sources of water to meet increasing demands, Colorado Springs found water reclamation to be economically justifiable. Certainly if the costs of new source development and the intangible benefits of pollution abatement were to be added, water reclamation at Colorado Springs would be even more economically favorable.

A BRIEF HISTORY OF RECLAMATION

1. The Chanute Story

The City of Chanute is a relatively small community in southeastern Kansas. Its sole source of water supply is the Neosho River. Chanute maintains and operates a conventional rapid sand filtration plant to provide treatment for Neosho River water prior to introduction into the City's potable water distribution system. During the years 1953 through 1957, a record drought struck the tributary area of the Neosho; and as a result, flow in the river became progressively smaller until in early 1956 it practically ceased. Although all possible water conservation measures and limited flow augmentation procedures were pressed into use at Chanute, the water supply continued to dwindle.

The situation became progressively worse until on October 14, 1956, without fanfare of any sort, City officials opened a valve which permitted mixing of sewage effluent which had received conventional secondary treatment, with water stored in the Neosho River channel behind the water treatment plant impoundment dam. During the period of water reuse, the waste treatment removed, on the average, 86 percent of the BOD and 76 percent of the COD content of the wastewater. It substantially reduced both total and ammonia nitrogen concentrations; detergent concentrations decreased an average of 25 percent.

The recycling process was employed for a total of five months during the fall and winter of 1956 and 1957. It was estimated that one complete cycle through the waste treatment and back through the water treatment required about 20 days. Thus, during the total period of time during which water recycling was practiced, the same water passed through the treatment plant approximately seven times.

The treated water discharged from the water treatment plant had a pale yellow color and an unpleasant musty taste and odor. It foamed when agitated and contained undesirable quantities of minerals and inorganic substances. However, there were no known cases of water-borne disease or other adverse effects upon health resulting from the use of the recirculated water supply.

As a young sanitary engineer with the Kansas State Board of Health at the time, I vividly remember, in particular, one of the humorous anecdotes that arose from this episode. The comment was made that the water at Chanute "finally got so damn strong that we shut off the high service pumps and it pushed itself through the mains."

2. The Windhoek Story

Since the Chanute episode in 1956, the technology of wastewater treatment has indeed come a long way as represented by the latest example of reclaiming waste for domestic water supply at Windhoek in Africa.

Near the end of 1968, Windhoek, the capital of South-West Africa, became the first city in the world to practice large-scale and continuous reclamation of wastewater effluent for drinking purposes. Its wastewater reclamation plant has a design capacity of 1.2 million imperial gallons per day. Treated wastewaters constitute approximately one-third of the City's total water supply.

Prior to installation of the reclamation plant, Windhoek's main sources of water supply were a number of wells and a surface water supply from a nearby impoundment. In order to maintain the City's rate of development, augmentation of these sources of supply became necessary. The City of Windhoek is situated in a very arid region and surface water resources are scarce and expensive to develop because they involve the pumping of water over long distances. Under these circumstances, reclamation offered the cheapest solution to the problem.

The reclamation process involves the following unit process use: flocculation-flotation, detergent removal by foam fractionation, lime treatment, sterilization by chlorination, settlement of calcium carbonate sludge, sand filtration, filtration through activated carbon, and final rechlorination.

The quality of the reclaimed water easily complies with World Health Organization standards for drinking water. Excessive build-up of total dissolved solids is limited by the high natural consumptive water use in the area so that desalting is unnecessary.

No public opposition to the final scheme has become apparent.

The Windhoek plant was officially opened on January 21, 1969, by the South African Prime Minister, Mr. Vorster. The prime minister stated in his formal address that, "... in the future it might prove more advantageous to subsidize local authorities to reclaim their effluents than to build new reservoirs which would involve the piping of water over long distances."

3. The Tahoe Story

There are only about five full-scale advanced wastewater treatment plants in the U. S. that are capable of producing the high degree of treatment required for domestic recycling of reclaimed wastewater. Perhaps the most notable of these, and certainly the first to go into full-scale operation, is the South Tahoe Public Utility District water reclamation plant at South Lake Tahoe, California.

Since March 31, 1968, the South Tahoe plant has operated without shutdown, 24 hours a day, and has continuously produced an effluent quality exceeding all the stringent requirements of regulatory agencies exercising jurisdiction in the area. At the present time, it is probably the only such facility in the U. S. which has for nearly three years produced an effluent capable of meeting drinking water standards.

Figure 2 is a simplified, schematic flow diagram of the process employed at STPUD to provide the high degree of purification and nutrient removals required. The process consists of 10 major component systems as follows:

1. Conventional Primary Treatment
2. Completely Mixed Activated Sludge Secondary Treatment
3. Chemical Coagulation and Sorption with Lime
4. Nitrogen Removal by Air Stripping of Ammonia
5. Filtration Through Mixed Media Separation Beds
6. Granular Activated Carbon Adsorption
7. Disinfection by Chlorination
8. Coagulant Recovery by Recalcination
9. Thermal Activated Carbon Regeneration
10. Sludge Incineration

The continuously high degree of pollutant removal from the reclaimed water achieved by the Tahoe Process is shown by the data in Table 1, which gives the average overall efficiency since commencement of operations in March 1968.

TABLE 1

REMOVAL EFFICIENCY FOR THE SOUTH TAHOE PUD WATER RECLAMATION PLANT

Parameter	Percent Removal
BOD	99.4
COD	96.4
MBAS	97.9
Phosphorus	99.1
Suspended Solids	100
Color	100
Odor	100
Turbidity	99.9
Coliform Bacteria	100
Virus	100

While the efficiency of removal of pollutants shown in Table 1 is indeed impressive, it is perhaps of greater significance to compare the average quality of reclaimed water from the Tahoe Process to various recommended drinking water standards. This comparison is made in Table 2.

TABLE 2
COMPARISON OF RECLAIMED WATER FROM THE TAHOE PROCESS AND THE RECOMMENDED AWWA GOALS FOR POTABLE WATER

Parameter		Recommended AWWA Goals for Potable Water	Reclaimed Water from STPUD Plant	Remarks
MBAS	mg/l	0.2	0.2	Meets Standard
Cl^-	mg/l††	250	28	Meets Standard
SO_4^{-}	mg/l††	250	36	Meets Standard
Color	units	3	0	Meets Standard
Odor	ton	None	None	Meets Standard
TDS††	mg/l	500	300	Meets Standard
COD†	mg/l	10	11	Exceeds Standard by 1 mg/l
BOD†	mg/l	6	1.5	Meets Standard
NO_3	mg/l as N	10	0.2	Meets Standard
S. S.	mg/l	1.0	0	Meets Standard
Turb.	mg/l	0.1	0.3	Better than most U.S. water supplies
Coliform	MNP	None	None	Meets Standard
Hardness	mg/l as $CaCO_3$	80	150	
PO_4^{---}	mg/l as P	No Standard	0.1	

†† USPHS Drinking Water Standard – Not AWWA Goal.
† World Health Organization Standard – Not AWWA Goal.

Reclaimed water from the Tahoe system is not reused for domestic supply purposes. Rather, in conformance with state law, it is exported out of the Tahoe basin. However, beneficial use is made of the reclaimed water. All effluent is impounded in a new man-made reservoir located some 30 miles from the treatment plant in Alpine County, California. The reservoir has a capacity of about 3,000 acre-feet, and since its initial filling has consistently maintained a very pleasing appearance. It has been approved by local and state regulatory agencies for all water contact sports.

The reservoir supports a thriving population of rainbow trout and a state grant has been awarded for construction of additional recreation facilities. Its water is sparkling clean and Secchi disc observations have been recorded as high as 20 feet. The low level of phosphorus in the water, coupled with the very low organic carbon content, appears to control algal growth adequately. During the irrigation season, a portion of the water in the reservoir is released for irrigation of forage crops by downstream ranchers in the area.

4. The Denver Successive Reuse Program

The Denver Board of Water Commissioners has long been recognized as one of the most progressive bodies in the water utility field. Their past engineering achievements in supplying high quality water to the City and County of Denver include some of the most difficult projects ever constructed. For example, the H. D. Roberts tunnel, completed in 1962, is the world's largest major underground tunnel (23.2 miles). The tunnel bore is as deep as 4,465 feet below the earth's surface and provides transmountain diversion of Blue River water to the Denver system.

With what must be termed typical foresight, the Denver Water Board has recognized that the time is approaching when even such enormous projects as transmountain diversion of west slope water will not assure totally adequate reserves of fresh water for Denver. They have therefore embarked on a research and development program to investigate and design reclamation systems to reuse wastewater. Initial plans call for a 100 mgd industrial reuse system.

The Board proposes to expand the reclamation system to an ultimate capacity of 100 mgd of wastewater, with a large portion being recycled into domestic use. This project represents the largest reuse plan yet undertaken anywhere in the world and certainly is in keeping with the past achievements of the Denver Water Board.

5. Other Reclamation Examples

The foregoing examples are but a few of the many operational or projected reclamation systems. Another example of direct domestic reuse will soon be operational in South Africa with a one mgd potable water reuse plant now in experimental operation at Daspoort, Pretoria, South Africa. The Daspoort plant is very similar to the Tahoe system, using lime coagulation, ammonia stripping, and activated carbon filtration.

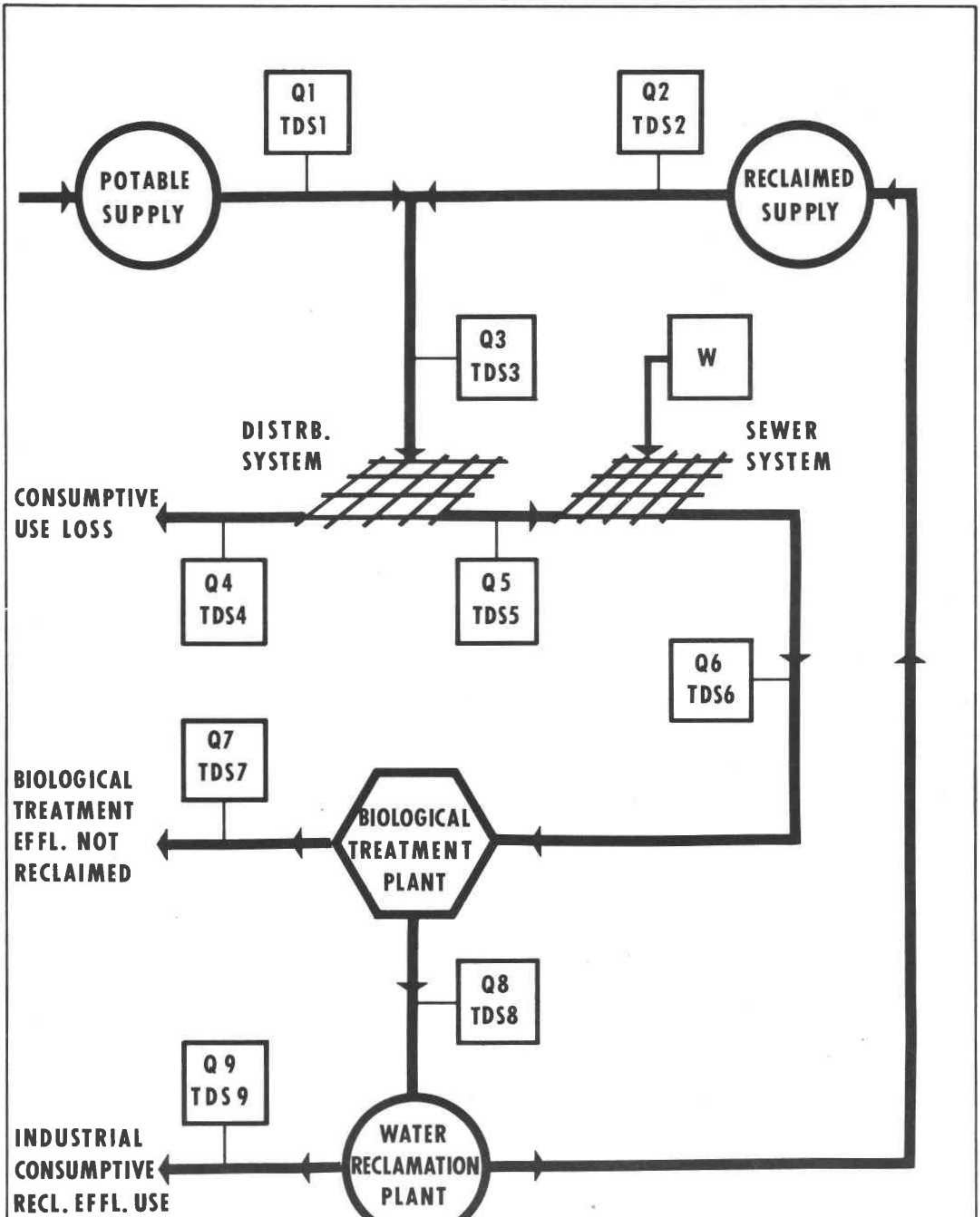
In our own country, no listing of reclamation projects would be complete without mention of the Santee, California, project which provides reclaimed water for recreational uses. Other examples include Hyperion, California, and Long Island, New York, where reclaimed water is injected into subsurface formations to provide a salt water barrier. Finally, numerous examples of advanced wastewater treatment for pollution abatement are now under construction in the U. S. These include plants at Blue Plains (Washington, D. C.), Rocky River, Pennsylvania, and Chicago, Illinois.

PROBLEMS ASSOCIATED WITH REUSE

There are still problems to overcome before wastewater reclamation, at least for domestic reuse, can become an everyday occurrence. First, the reliability of treatment processes must be improved, and along with this, the rapidity with which analysis of various pollutants can be made must be increased. Until these improvements are possible, it will probably be necessary to impound reclaimed water in reservoirs prior to release to raw water intakes at potable water treatment plants.

Bacteriological and virological testing techniques also need improvement. Today, our techniques are extremely limited. Even though extensive virological testing at both Tahoe and Windhoek have indicated no passage of viable virus through the treatment system, we are not certain that no such passage occurs, because of the difficulty of culturing any but a very few of the known viral organisms.

The progressive build-up of dissolved solids is another potential problem in water reclamation. Fortunately, this is a problem which can be solved by current technology, albeit at considerable cost, by such techniques as distillation, ion exchange, reverse osmosis and dialysis. Also, fortunately, the build-up of dissolved solids in most cases is not great due to the natural "blow-down" of dissolved solids from conventional



Q1
TDS1
Q2
TDS2
POTABLE SUPPLY
RECLAIMED SUPPLY
Q3
TDS3
W
DISTRB. SYSTEM
SEWER SYSTEM
CONSUMPTIVE USE LOSS
Q4
TDS4
Q5
TDS5
Q6
TDS6
Q7
TDS7
BIOLOGICAL TREATMENT EFFL. NOT RECLAIMED
BIOLOGICAL TREATMENT PLANT
Q8
TDS8
Q 9
TDS 9
INDUSTRIAL CONSUMPTIVE RECL. EFFL. USE
WATER RECLAMATION PLANT

FIGURE 3

NOMENCLATURE (For Figure 3)

Q1	= Flow into system from potable water supply	mgd
Q2	= Flow recycled into system from water reclamation	mgd
Q3	= Total flow to distribution system	mgd
Q4	= Consumptive water use in distribution system	mgd
Q5	= Flow to sewer system from distribution system	mgd
Q6	= Q5 = flow to biological treatment plant	mgd
Q7	= Flow from biological treatment plant not reclaimed	mgd
Q8	= Flow from biological treatment plant to reclamation	mgd
Q9	= Flow from reclamation plant to consumptive industrial use	mgd
TDS1	= Dissolved solids concentration of Q1	mg/l
TDS2	= Dissolved solids concentration of Q2	mg/l
TDS3	= Dissolved solids concentration of Q3	mg/l
TDS4	= TDS3 = Dissolved solids concentration of Q4 or Q3	mg/l
TDS5	= TDS3 = TDS4 = Dissolved solids concentration of Q3 or Q4 or Q5	mg/l
TDS6	= Dissolved solids concentration of Q6	mg/l
TDS7	= TDS6 = Dissolved solids concentration of Q6 or Q7	mg/l
TDS8	= TDS6 = TDS7 = Dissolved solids concentration of Q6 or Q7 or Q8	mg/l
TDS9	= TDS6 = TDS7 = TDS8 = Dissolved solids concentration of Q6 or Q7 or Q8 or Q9	mg/l
W	= Increase in TDS due to passage through sewer system	mg/l
X	= Decimal fraction of Q3 consumptively used	
Y	= Decimal fraction of Q6 not reclaimed	
Z	= Decimal fraction of Q8 not recycled	

EQUATIONS

$$Q1 = \text{Given}$$
$$TDS1 = \text{Given}$$
$$Q2 = \text{Given}$$
$$Q3 = Q1 + Q2$$
$$TDS2 = W + \frac{(Q1 \times TDS1 + Q2 \times TDS2)}{(Q1 + Q2)}$$
$$TDS3 = \frac{(Q1 \times TDS1 + Q2 \times TDS2)}{(Q1 + Q2)}$$
$$X = \text{Given}$$
$$Q4 = X(Q1 + Q2)$$
$$TDS4 = TDS3$$
$$TDS5 = TDS3$$
$$Q5 = (1 - X)(Q1 + Q2)$$
$$Q6 = Q5$$
$$TDS6 = TDS2$$
$$W = \text{Given}$$
$$Q7 = Y(1 - X)(Q1 + Q2)$$
$$Y = \frac{Q7}{(1 - X)(Q1 + Q2)}$$
$$TDS7 = TDS2$$
$$Q8 = (1 - X)(1 - Y)(Q1 + Q2)$$
$$TDS8 = TDS2$$
$$Z = \text{Given}$$
$$Q9 = Z(1 - X)(1 - Y)(Q1 + Q2)$$
$$TDS9 = TDS2$$

U. S. water systems because of our prevailing rather high consumptive water use practices. The equilibrium concentration of dissolved solids that can be anticipated in any given recycling water system can be rather easily computed for any given moment if proper records are available. Figure 3 shows the general formulations necessary to solve such a problem. The technique shown was developed for computer solution with an IBM 1130 system, but it is adaptable to any computer system, or even hard calculations for that matter.

An interesting example may be obtained by using average figures for Denver (1968 data).

DATA

1968 average monthly potable water produced -- 150 mgd
1968 average monthly TDS content of potable water -- 135 mg/l
1968 average monthly TDS content of wastewater -- 480 mg/l

ASSUMPTIONS

1. Assume 90 mgd reclaimed water recycled to domestic raw water supply.
2. Assume 50% of total flow consumptively used.
3. Assume 10% of reclaimed water consumptively used by irrigation and/or industry.

By using the formulations shown on Figure 3, and solving the problem for the equilibrium concentration of TDS in the blended domestic water supply, we find that such a practice would result in an increase in TDS to the consumer of 207 mg/l. Stated in other terms, drinking water at the homeowners tap would have increased from a TDS content of 135 mg/l to 342 mg/l. It would not rise above the value of 342 mg/l unless the relative volumes of 90 mgd reclaimed water to 150 mgd of "virgin" water were changed. It is doubtful if the consumer could detect such a change in TDS content, and furthermore the final TDS concentration would still be well below the USPHS allowance of 500 mg/l TDS.

Finally, we must be cognizant of public reaction to water reuse. The general public will not welcome the idea of drinking their own wastes. Experience has shown that the only way to overcome this rather natural reaction is by means of public education. The establishment of recreational reservoirs such as Indian Creek at the Tahoe project and the Santee Lakes at the Santee project have helped the cause immeasurably. Such reservoirs may well be a vital key to public acceptance of wastewater reclamation; they may also be required unless or until better testing techniques are available to insure an absolute guarantee of safety for domestic reuse.

SUMMARY

In this discussion, I have attempted to show the merits of water reclamation as a concept. It may be that in some areas of the world, wastewater reuse, aside from its merits, will soon become an absolute necessity, as it already is in Africa.

We have seen what our nation's scientific and technological forces have been able to accomplish in both the nuclear and outer space areas when given unlimited financial support. If our national government supports their verbal pledges with actual appropriation of funds, we can expect that a large part of the nation's technical resources will move into the environmental control fields. Probably, in our usual manner, we will waste a lot of money and effort in our rush to develop solutions. However, there can be no doubt that the end result will be the development of many valuable new processes not known today.

The decade of the 1970's may well mark the era when America realizes that only "wastewater" fit to drink is fit to throw away. If that criterion should indeed be adopted by our society, I am certain that the technology will exist to accomplish that goal at a cost which we will be able to bear.

Finally, I would leave you with this thought: If the only water fit to throw away is fit to drink, then there is obviously no such thing as "wastewater." I believe we should discard this word from our vocabulary and along with it such terms as sewage and refuse liquids.

We should come to realize that there is no such thing as new water; nearly all water on the earth's surface has been used and reused in one way or another. Perhaps we should refer to the water which carries our wastes as "transport water." Then in our treatment plants we can remove the pollutants from the water used to transport the pollutants to the plant and end up with plain water. The result might be far more acceptable to the public than trying to get them to drink "reclaimed sewage."

Presented April 29, 1971 by ROBERT E. PAILTHORP, P. E., CH_2M/HILL, Engineers, Planners, and Economists, Corvallis, Oregon

Industrial Effluents of the Northwest

Many industries in the Northwest use water to process raw products into consumer products. The increase in our population, industrial growth, and an increase in water associated recreation in the Northwest are major factors in the need for effluent improvements. Treatment methods have been developed to solve many identified water problems, and treatment systems have been constructed and are being planned to reduce the impact of industrial discharges on receiving waters in the Northwest.

Many of our industries have an impact on our streams, but those of major interest are:

<u>Lumber & Wood Fiber Industries</u>

Pulp and paper

Re-pulping plants

Lumber:

- saw mills
- plywood mills
- hardboard plants
- preservative plants

Food Processing

Canning (including root-crop soil):

- vegetables:

  corn, peas, potatoes, pumpkins, beets, beans, carrots

- fruits:

  pears, peaches, apples, cherries (cherry brining)

- berries

Meat and Poultry

Beverages (beer, wine, vodka)

Wheat Processing

Dairy (cheese, milk, ice cream)

Metals

Aluminum, zirconium, titanium

Clothing

Woolen Mills

Tanneries

The waste from these industrial operations have a variety of undesirable impacts on receiving waters. These are:

Temperature increases
Turbidity (suspended solids)
pH changes
Sludge beds (settleable solids)
Color changes
Low dissolved oxygen
Toxicity
Taste and Odor
Foam
Floating Materials

Treatment of industrial wastes in the Northwest in general was begun in the period from 1950 to 1965. The first treatment systems consisted of primary treatment or spray irrigation. In the period from

1960 to 1971 many secondary treatment systems have been constructed. In this same period industries have made inplant process changes to reduce water use and materials losses.

To reduce waste discharges industry has focused its efforts on:

1. Bringing less material to the processing plant
2. More complete utilization of the raw material
3. Converting to dry manufacturing processes
4. Recycling water
5. Producing by-products
6. Treating the effluent

Most treatment work has concentrated on the removal of:

1. Floating material and foam
2. Settleable solids (sludge beds)
3. Suspended solids (turbidity)
4. BOD

Work is now being directed to problems of:

1. Bio-Stimulatory compounds
2. Toxic compounds
3. Color
4. Temperature

Several treatment processes have been developed. These systems are based on liquid-solid separation, conversion and concentration. The methods are:

Physical:

straining and screening
settling
floatation
freezing
evaporation

Chemical and Chemical-Physical:

flocculation
neutralization
oxidation
adsorption
ion exchange
biological

Treatment methods in most common use now are:

1. Screening
2. Sedimentation
3. Biological stabilization
4. Chlorination
5. Irrigation

It is difficult to enumerate all things which have been done by industry because specific actions have varied greatly. There are, however, general trends and actions within specific industries which are of interest.

Pulp & paper. Most plants have now converted to chemical recovery processes including incineration of lignin. Inplant pretreatment and reuses has been broadly applied. Storage and controlled release of high strength waste when river flows are high has been used in the past. Primary and secondary treatment is now used by many mills.

Repulping plants. These plants which produce flower pots, pipe and some grades of carton and box material have developed water reuse systems and have used treatment technology from the pulp and paper industry. The waste is difficult to treat and the plants in general operate on a low profit margin and can support limited treatment costs. Unfortunately, these are the very plants that are our hope for recycling some solid wastes.

Lumber. Log storage is necessary to maintain a raw material supply when it is not possible to log. Since logging was started in the Northwest, it has been universal practice to transport and store logs in rafts on rivers, lakes and estuaries. This practice is now being modified to reduce bark loss. Many logs are handled in bundles or are now stored on land.

Plywood. The waste resulting from treating logs to be peeled with saturated steam and from cleaning the machines used to spread glue. Progress has been made by discontinuing the use of some glues and recycling of effluents.

Hardboard. New plants use dry processes or are treating effluents.

Preservative plants. Most of the compounds used as wood preservers are by design very toxic. These plants have reduced water use, recycled preservatives, or evaporate the waste.

Food Processing. This industry has developed improved processing equipment and water reuse systems. Spray irrigation was first used as a disposal method by canneries. In the Northwest many food processors are served by municipal waste treatment plants. The seasonal nature of most food processes adds a dimension of difficulty to providing economical waste treatment. Biological systems have been widely used to treat canning waste. Many demonstration and research projects are in progress which will give more reliable design data for future systems.

Metals. Treatment systems are being used to neutralize and precipitate undesirable constituants.

Clothing. Treatment systems have been applied to these plants.

Our present technology can solve the problems which presently exist. We should recognize, however, that industrial growth will continue and that new problems and requirements will be established. Technology is now available which could make almost complete recycle possible in some industrial plants. The costs, however, are still prohibitive Complete recycle of water is extremely difficult to achieve and as it is approached concentrated waste flows result in increased treatment problems.

There are many needs to improve our present technology of waste treatment. The ones which are most obvious to me are:

1. Salt removal systems
2. Nitrogen removal systems
3. Solids concentration and disposal methods
4. Methods to control the biology of waste treatment systems
5. Better monitoring and testing methods
6. Definition of the effects of dynamic changes in waste characteristic and quantity on treatment units
7. Definition of specific water quality needed by industry for process purposes
8. Improved process equipment which will reduce product losses

Equipment for processing products and for treatment of effluents are developed by equipment companies on the basis of competing with existing equipment and not on developing a better overall system. I believe that great strides would be made if associations of industries could work jointly to develop new process equipment and processes. If industry does not undertake this effort with enthusiasm, Government will be forced to undertake added development programs.

The application of present technology will be limited by the assimilative capacity result of r eceiving waters and land to accept waste products of processes and waste treatment as well as other wastes such as agricultural and municipal. The final solution may be to limit all processing and population.

In the future I see added government control, regulation and involvement. We will at times be frustrated by the limitations of time and money to solve problems rapidly even when decisions have been made to clean up.

It is interesting to contemplate alternatives if our present technology is not applied. Perhaps we could outlaw some crops (peas, corn, peaches, pumpkins) which result in high pollution loads. We could develop dry processing techniques, or perhaps we could restrict industry to areas and periods of low rainfall so the effluents can be used for irrigation.

The Northwest has industries which cause water pollution. Major work has been done since 1950 to reduce the impact of industrial effluents by process and inplant changes as well as effluent treatment. Technology is available to solve many of our present problems. Application of available technology continues within the limitations of economics and time. Added technology will be needed soon to solve water pollution problems. Production limits may be necessary in the future to control pollution.

Presented May 13, 1971 by DR. DAVID A. BELLA, Department of Civil Engineering, Oregon State University, Corvallis, Oregon.

Subtle Aspects of Eco-System Management

Man's influence on his environment is increasing at a rapid rate. Maintaining a desirable ecosystem involves consideration of a wide spectrum of man's activities extending beyond the classical definitions of pollution.

The purpose of this paper is to discuss some of the less obvious aspects of aquatic ecosystems which may be significant for the development of satisfactory water resource management policies. This discussion will not include the dispersal of substances throughout water bodies, but will focus on the general relationships between the biological and non-biological components of ecosystems.

ECOSYSTEM MODELS

In seeking to understand the nature and behavior of ecosystems, we organize our observations from the real world into conceptual models. It is intended that the model will simply describe certain aspects of the real world. Satisfactory models may then be used in a variety of ways to develop management policies. The model may be loosely conceived or it may be mathematically defined. The process by which models (both non-mathematical and mathematical) are usually developed will be divided into two steps (although the separation of these steps often may be difficult). These steps are:

1. the definition of components of the model and,
2. the development of relationships between these components.

A model is thus a system of interacting components. If we carefully analyze the components of any such system, we will find that each component is a sub-system which also contains interacting components. We find that each new set of components constitutes sub-systems which contain further components. The level at which we cease the partitioning and take components as elementary is somewhat arbitrary, depending to a large extent on the intended use of the model.

Thus, the same physical system may be conceptually partitioned into components of varying degrees of resolution. A low resolution partitioning would result in relatively few components while a high resolution partitioning would result in a greater number of components for the same real world system. Different professional disciplines are often distinguished by the level of resolution used in defining the components of conceptual models.

Each time sub-systems are grouped into larger components, the individual nature of the sub-system components and the relationships within these sub-systems are largely lost. If, however, the components are increased in number, allowing the components of sub-systems previously grouped into components, to now become separate components of the model, it then becomes more difficult, and often impossible, to define the relationships between the components.

In determining the resolution of the components, one thus trades between detail and the ability to develop the relationships within the model. That is, one trades between precision and perspective (Weiss, 1967). Developing meaningful models, thus, depends to a large extent on the proper selection of the components of the model.

NUMEROUS COMPONENTS

Two general methods by which sub-systems are grouped into components will be discussed. The first method is based on the reasoning that real world complex systems exhibit a hierarchal structure (Simon, 1965, Wilson, 1969). That is, natural systems may be broken down into collections of sub-systems in which the internal relationships are substantially stronger than the external relationships.

As an example, an individual organism is a collection of sub-systems which are so closely related as to essentially define the organism as a basic component of the next higher system. In the development of conceptual models, it is quite natural to select, as components, the hierarchal components; that is, those sub-systems with relatively strong internal relationships.

Often the number of hierarchal components is too numerous and a second method is utilized to form components of a model. Similar hierarchal components are grouped into larger components. The characteristics of the larger components are determined by the common characteristics of the grouped hierarchal components. Such grouping removes the individual characteristics of hierarchal components and thus decreases the potential information of the model.

The fewer number of components will likely, however, permit the development of the relationships between the components. As an example, individual organisms may be grouped into functional groupings such as trophic levels, thus making general relationships more observable. The biochemical oxygen demand, BOD, is a common functional low order resolution grouping used in water quality models.

When the components of the model have been established, the relationships between these components must be defined. Two extreme methods by which the components of an organized model might be arranged are illustrated in Figure 1.

Systems characterized by their disorganized complexity and studied by statistical methods, (Weaver, 1948, Rapoport and Horvath, 1959) will not be included in the following discussion. The arrangement in Figure 1 (a) is called a chain relationship because each of the components is related to only a small portion of the total components. Branching may occur in chain systems, however, such branching will only rarely result in closed loops. The few relationships connecting each component enable components or groups of components to be studied apart from the system.

A complex system consisting of many chain related components can thus be largely understood by examining its component parts. When the simpler component parts have been analyzed, the total complex system may be built up and thus, the complex system consisting of many components may be understood.

Each step in this build-up procedure involves only a small fraction of the relationships of the system. This method of breaking down complex systems into simple organized systems has been the basis of classical science (Weaver 1948, Rapoport and Horvath 1959, Rapoport, 1966).

The second arrangement shown in Figure 1 (b) is characterized by dispersed relationships. Each component in this system is related to a large number of the remaining components. In addition, each of the relationships between the components may be related to the remaining

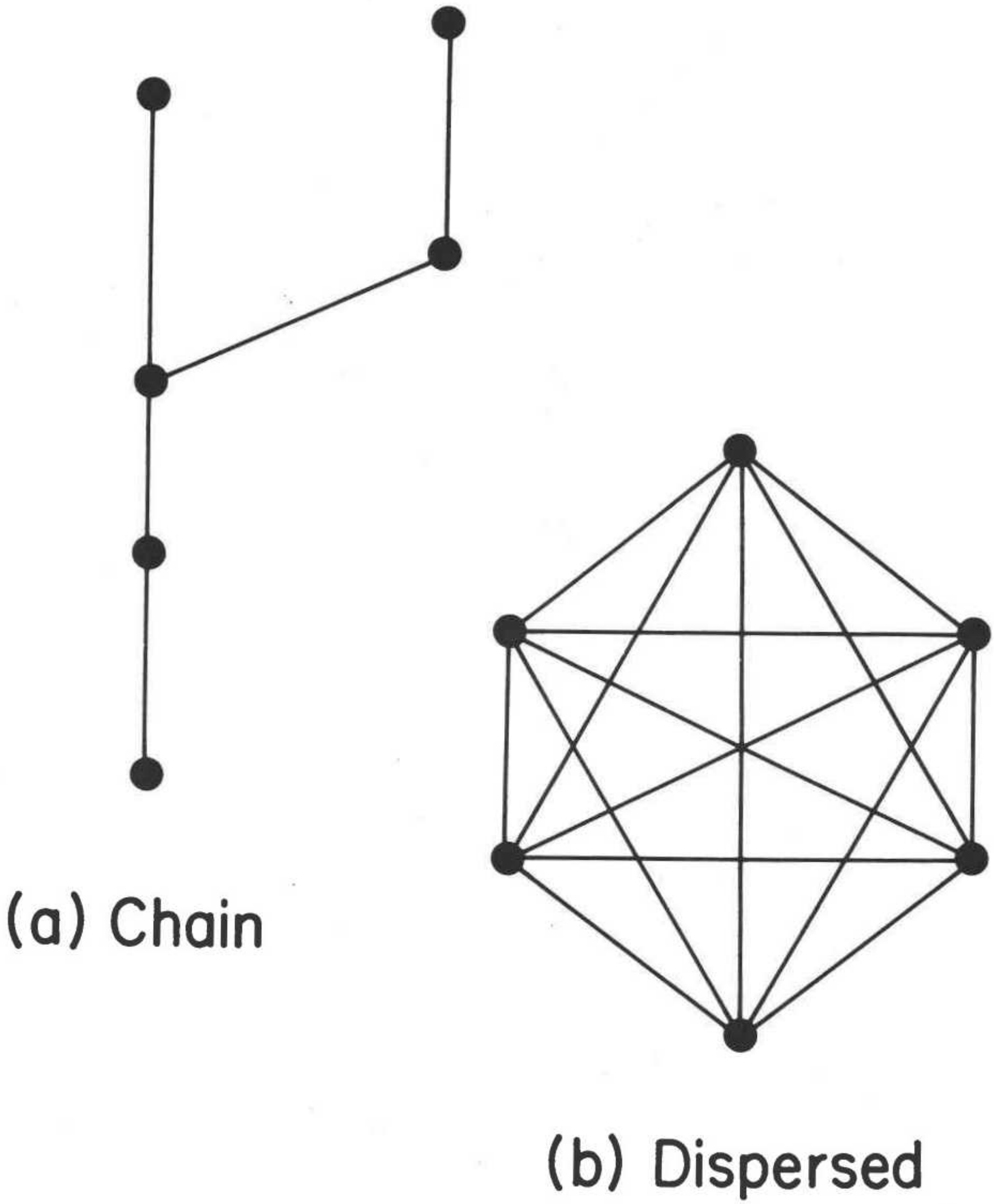


Figure 1. Two types of systems.

components and relationships not illustrated in Figure 1 (b). Numerous relational loops are present. That is, referring to Figure 1 (b), one may start at a given component and proceed along the relational lines connecting the components and return to the given component by many paths.

If a component in a dispersed system changes, it is difficult to define which relationships or combinations of relationships led to that change. Likewise, a change in one of the components will lead to changes throughout the system. It is extremely difficult, therefore, to isolate the relationships between the individual components. The behavior of each part depends on its relational position within the whole, thus, the method of isolating simple components and relationships of a complex system, defining the behavior of the parts and building up the complex system from the parts is not suited for dispersed systems.

As an example, consider a social system (a dispersed system). The behavior of each component (each person) of this system depends in a complex way on its relationship to many of the remaining components. It should be quite obvious that it would be ridiculous to study the social behavior of an individual by completely isolating him from the social system (society). His behavior would change (possibly to the point of insanity if the study were of sufficient duration).

Lower resolution components, obtained by grouping sub-systems, are usually far less hierarchal for dispersed systems than for chain systems. Thus, when a lower resolution model is formed, more information is lost from a dispersed system than from a chain system. Increasing the resolution of a model, however, is far more difficult with dispersed systems than with chain systems.

Dispersed systems are thus characterized by their "organized complexity" (Weaver 1948, Rapoport 1966). Neither the classical scientific methods which deal with "organized simplicity" nor the statistical methods which deal with "disorganized complexity" are suitable for the analysis of such systems (Weaver 1948). Though different methods of analyzing systems have been developed and applied to simplified cases of dispersed systems (power grids, pipeline networks etc.) (Frank and Frisch, 1970), the difficulty in analyzing systems characterized by their organized complexity appears to be a universal problem faced by science (Bertalanffy, 1969).

MAN-MADE AND NATURAL SYSTEMS

There are numerous examples of organized man-made systems. In general, organized man-made systems tend to be less dispersed in structure than do natural ecosystems. That is, each component and each relationship between components is directly influenced by a relatively small portion of the remaining components and relationships. The design methods used to develop these systems are largely responsible for this structure.

Thus, in general, man-made systems can be readily broken down into a series of simply organized systems. Individual components or groups of components can be then analyzed separately from the system. The chain structure also facilitates the modification of components with relatively small changes in the remaining components. As an example, parts within a complex machine can often be changed and replaced without changing the behavior of the remaining components.

Chain systems can also be expanded with little change in the behavior of the original system. Thus, new pieces of machinery can be added to a factory without producing significant changes throughout the factory. Analysis of man-made systems which are more dispersed, such as power grids, gas pipelines etc. (Frank and Frisch, 1970) is simplified greatly by the similarities between the components and the relative simplicity of the relationships between the components. Such simplicities enable one to study the behavior of the system's components apart from the system (unlike the social system previously described).

Natural ecosystems have evolved over long periods of time during which complex relationships have been continually developed between the different components. As a result, natural ecosystems tend to be of a more dispersed nature than are man-made systems. Each component and relationship depends on a large number of the remaining components and relationships. The difficulties of analyzing dispersed systems as previously discussed are thus common to natural ecosystems. Methods such as information theory used to study man-made dispersed systems have generally not been successful when applied to the more complex biological systems (Johnson, 1970).

OBSERVATIONS RELATING TO MANAGEMENT

In a natural ecosystem, certain relationships are more observable than others due to the nature of the relationships themselves and due to the limitations and bias of the observers. Models of ecosystems are often constructed using only these observable relationships. Most often, chain models of ecosystems (which are dispersed) result. Whether chain models of dispersed ecosystems result from limited observations or whether the observations are limited (and biased) because the observer is seeking to build a chain model is difficult to determine.

The end result in both cases is a tendency to develop models which are biased toward a chain type structure and away from the more difficult dispersed structure. Many established scientific methods, such as the bioassay, are largely based on a preconceived notion of a chain system. That is, it is assumed that a component and the relationships between components can be isolated from its system for study with relative ease.

As a result, available knowledge concerning natural ecosystems tends to be biased toward the more easily conceived chain type structure. Management decisions based on such knowledge will reflect this bias and as a result, such decisions may not be the most beneficial, and can often be detrimental (though well intentioned). Management decisions must therefore be based on the recognition of the bias and limitations of available information.

As an illustrative example, consider the development of the Oregon Coast. Two different general policies listed below might be followed.

> (A). Spread the development in a relatively even fashion along the entire coast.
>
> (B). Confine development to certain areas leaving other areas relatively undeveloped (that is, preserve developmental gradients).

The first policy (A) might be supported by the best available information. As an example, pollutant concentrations would be kept to a minimum by dilution (presumably below harmful levels determined by bioassay procedures.)

If the possibility of adverse changes due to the more subtle (and unknown) relationships was considered, policy (B) might be more acceptable as this policy would result in the containment of possible problems within a smaller more controllable area, freeing the remaining area from possible, though still unknown, adverse changes.

In short, because man-made systems tend to be less dispersed in structure than do natural ecosystems, man-made systems are more amenable to analysis by established analytical methods. One can then expect that the ability to expand man-made systems will increase at a more rapid rate than will the ability to determine the effects of these expansions on the more complex and dispersed ecosystem. That is, the ability to change the ecosystem can be expected to increase at a greater rate than the ability to determine what these changes will be. One should not therefore expect control of man-made systems for environmental reasons to be based completely on scientific proof. Environmental decisions must be based, to a large extent, on the possibility of unknown environmental changes.

CONCLUSION

Environmental changes cannot be considered innocent until proven guilty; for man's ability to produce such changes will exceed, by an ever increasing amount, man's ability to determine the consequences of these changes.

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Cattle Feedlots and Alternatives for Waste Management

The investigation into the control of pollution from cattle feedlots is just one of many that must be made in attacking the pollution from all problem sources. The point sources such as the discharges from municipal or industrial sources are much more amenable to capture and treatment than those which are dispersed or diffused because the point of entry into the surface or subsurface water supplies cannot be located and there is no opportunity for treatment.

The best approach is to develop management practices and techniques that reduce the opportunity of water pollution from occurring by control programs which never let a polluting situation develop. This same philosophy holds for pollution from other sources, particularly those categorized as being from rural sources, such as irrigation, forestry and logging, rural runoff, recreation, watercraft wastes, dredging and the effects of land disturbances during or as a result of construction activities for highways, powerlines, railroads, or pipelines.

THE CAUSE

First, I would like to explain why the problem of cattle feedlots is becoming apparent now when previously it was not evident or did not exist. There are many reasons, but ultimately they all reflect back to the initiating cause -- that of people.

More than half the people that have ever lived are now alive. Half of the people now living are under the age of 27.

According to the Conservation Foundation (Washington, D. C.) the world population at various times in history and predicted in the future are as follows:

	Population (in billions)
Beginning of Christian era	1/4
1650	1/2
1850	1
1930	2
1966	3. 3
1978	4
2000	6. 6

The time needed to double the human population was shortened from 1, 650 years, to 200 years by 1850, to 80 years by 1930. With world population now increasing by about 2 per cent (60 million) a year, it will take only 48 years to double again, from 1930 to 1978. Demographers estimate the present 3. 3 billion total will double by about the year 2000 -- or in just 35 years!

If the trend were to continue, the next doubling would occur in less than 30 years, or by 2030 the world population would exceed 13 billion. The annual increase is about 70 million people a year or enough to repopulate the United States every three years at the present population level of about 206 million.

In the United States, the population growth has about tripled since the turn of the century making the least increase in the decade of the 30's and the most in the 50's as shown in the following table.

	Population (in millions)
1900	76
1910	92
1920	106
1930	123
1940	132
1950	152
1960	181
1970	205

Of equal or even more importance to the population increase is the trend of where the population lives. In 1850, there were four cities in the world with a population of a million, in 1900 there were 15, and in 1960 there were 141. The cities have been growing 30 times as fast as the population, which helps explain the urban problems we have today.

With less people down on the farm there has had to be an increase in technology and efficiency in order to keep up with the demands for food. Even so, if all of the world supply of food were distributed equally, everyone would be malnourished. If the food supply were distributed at the rate of U. S. consumption only 1/3 of the world's population would be fed.

This year's Nobel Prize winner, who received the award for developing more productive strains of grain, estimates that we have bought only about a 30 year extension of time before many areas of the world face starvation if the population continues to increase or if additional technological advances are not made. This brings us to the problems that are developing as the producers of our meat attempt to meet the growing demands.

The per capita consumption of meat increased 15 per cent in the decade from 1950 to 1960 but the increase in beef consumption was 34 per cent. The consumption of beef was almost 104 pounds per capita in 1966 in the United States. Coupled with the annual increase in the U. S. of 2 1/2 million population, this means that annually, in order to meet this demand, there must be produced somewhere in the world an extra 630,000 head of beef cattle.

In the U. S., the number of beef cattle has jumped from 85 million head in 1945 to 108 million in 1965 or an increase of 27 per cent. Even more startling in the meat production effort is the 600 per cent increase in broiler chicken production from 365 million to about 2.2 billion, but that waste problem is another story.

THE PROBLEM

Before we attempt to scope the cattle waste problem in the Northwest and offer some solutions to the problem, perhaps we should identify the undesirable characteristics of the wastes from cattle and other animals. These include oxygen demanding wastes, total solids, nutrients, including nitrogen and phosphorus, and the pathologic organisms such as bacteria, virus, fungi, and parasites, and are of concern because of the effects on man and animals, particularly in relationship to water quality both surface and subsurface.

There are more than 150 diseases affecting animals that can be transmitted to man which include:

Bacterial:	Salmonellosis	Anthrax	Brucellosis
	Leptospirosis	Tularemia	Erysipelas
	Tuberculosis	Tetanus	Colibaccillosis

Q Fever and other Rickettsial diseases
Over 500 animal virus which include cholera and hoof and mouth disease
Numerous fungi and numerous parasites including flukes and worms

A table of the daily fecal bacteria production of several animals compared to man is given below:

Per Capita Contribution of Indicator Organisms
from Some Animals - 24 hour contribution

Animal	Fecal Coliform Millions	Ratio to Man	Fecal Streptococci Millions	Ratio to Man
Man	2,000		450	
Duck	11,000	5 1/2	18,000	4
Sheep	18,000	9	43,000	96
Chicken....	240	0.1	620	1.5
Cow	5,400	2.7	31,000	69
Turkey.....	130	0.06	1,300	2.9
Pig	8,900	4.5	230,000	510

The daily fecal coliform production of a cow is about 2.7 that of man but a sheep is 9 times as many. Although the fecal streptococci production of a cow is 69 times that of man, it doesn't compare to that of a pig which is a multiple of 510.

The solid waste of the cattle industry in the United States is a tremendous quantity with an estimated two billion tons annual production and more than half is from concentrated production areas.

The total animal waste production of the U. S. is about 10 times that of the current human population. Of the 60 pounds per day of cattle wastes, about 50 pounds is moisture and the remaining 10 pounds is solids. Another way of presenting this statistic is to relate production to wastes. For the production of one quart of milk there is three pounds of wastes while for one pound of beefsteak there is about 25 pounds of wastes produced.

Previously, when the production of cattle was directly related to the production of feed, the wastes were recycled back to the land. With the present practice of increasing the livestock concentration on smaller areas of land in the intensive beef feeding with an eye to pounds per day growth per units of feed, the manure disposal becomes a problem. The disposal was not part of the flow chart in master planning of beef production and adequate acreage generally has not been provided for land disposal.

The characteristics of these wastes compared to those of man are:

1/	Man	Cattle	Ratio - Cattle/Man
BOD_5	.16	1.04	6
N	.03	.37	12
Total solids	.55	10.00	18
P	.002	.05	25

1/ All units in pounds/day.

From the preceeding tables you can see that if you are talking about population equivalents they could vary from 2.7, 6, 12, 18, 25, or 69, depending upon the characteristics being discussed.

The PE (population equivalent) values based on total amount of animal production have little meaning with regard to water pollution. What is really of concern is the amount that enters ground and surface waters. Also of importance is the difference in the solids of the cattle wastes which contain more cellulose and lignins than human wastes, so the BOD and treatment methods cannot be easily compared.

Much of the nitrogen of the cattle wastes occurs as ammonia and is particularly deadly to fish if the wastes are washed into the waters. Of concern also is the occurrences of nitrate contaminating the ground water affecting its use for human or livestock consumption. Both the nitrogen and phosphorus and perhaps other constituents of the wastes promote unwanted aquatic growths which can reduce the oxygen content of receiving waters.

THE NORTHWEST PROBLEM

The more than 110 million animals of the cattle feeding industry are located mainly in the central part of the U. S. where more than 70 percent of the cattle are fed, about 20 percent are located in the Western States, and less than 10 percent in the Atlantic States. In the Northwest

States of Idaho, Oregon, and Washington, there is a total of about 4.6 million cattle on farms, in dairies and in feedlots. Whereas more than half of the fed cattle in the U. S. are in confined feeding only about 10 percent of the cattle in the Northwest are in feedlots and about an equal amount in dairies, with the remainder on farms, pasture, or range. The table below shows the distribution in the Northwest by States, the number of feedlots, and their size.

Cattle in the Northwest

State	In Feedlots	No. of Feedlots	Feedlots larger than 1,000 head	Dairy Cattle	Total Cattle
Idaho	156,000	313	30	192,000	1,285,000
Oregon	75,000	338	44	126,000	1,609,000
Washington	225,000	740	83	165,000	1,735,000
TOTAL	456,000	1,391	157	483,000	4,629,000

Economic studies made for Bonneville Power Administration predicted a doubling of beef production by 1975 over the 1960 level and a tripling by 1985. As yet, the massive problems of the large feedlot operations have not plagued the Northwest, but they are on their way. Development is underway for a 60,000 head feedlot operation near Pasco, Washington.

WASTE MANAGEMENT ALTERNATIVES

As was mentioned earlier, the pollution problem is developing 1) because of more cattle and 2) because of the concentrated confinement and feeding. Where the cattle wastes were once assimilated in the soil of the pasture, cropland or range, these are now accumulating in one place. The problem resolves down to collection and disposal of the wastes. The objective, of course, is to prevent the liquid or solid factions from entering the waterways and imposing the unwanted health hazard, toxicity, nutrient effects, or oxygen demand upon the receiving waters and undesirable effects on subsequent users.

Some feedlot operators mound the manure in the center of the lot and as it dries, it serves as a place for the cattle to lie when lower sections of the lot are wetted during rainstorms or during winter conditions. Other operators scrape the feedlots and pile the manure on adjacent land. Since there is more liquid runoff and higher strength runoff from paved lots, an unpaved lot is preferable from a pollution control viewpoint.

The density of cattle concentration does not make too much difference in the strength of the wastes in feedlot runoff from summer rainstorms but is more than double in the winter runoff when the feedlot density is 100 square feet per animal compared to that of 200 square feet per animal. Of course, some feedlot operators never or rarely clean their feedlots. Dust, odor, and fly control are attendant problems.

Dry storage is preferable to wet storage but in many cases where wastes are removed by water or there is surface runoff, the wastes can be treated to allow for bacterial dieoff and to reduce the oxygen demand of the wastes.

The liquid fraction of the wastes and other surface runoff or waste from hydraulically operated systems can be stored in covered or open concrete or earthern lagoons where they can undergo anaerobic or aerobic treatment. The anaerobic system allows the bacterial decomposition to proceed in the absence of oxygen and in the first stage produces foul odors.

The methane production of the second stage is subject to disruption from many adverse conditions such as low temperature, ammonia toxicity, uneven waste loading or presence of oxygen. The foul odors make this system of treatment unacceptable near urban areas. The liquid and solid fractions must still be disposed of by application to land by sprinkler, spreading, injection, or deep plowing depending on the moisture consistency.

The aerobic treatment requires shallow ponds and depends upon large surface areas for the natural diffusion of oxygen. Some oxygen may be supplied by the photochemical reaction of algae during warm weather. Compressed air diffusers, sprayers, aspirators, surface aerators and agitators are mechanical means of supplying oxygen. An oxidation ditch depends on rotors to incorporate oxygen and move the wastes around a channel.

The aerobic system is sometimes used to further treat the effluent from the anaerobic system which oxidizes the organic and ammonia forms of nitrogen to nitrates. Some losses of nitrogen occur from volatilization. The effluents are low in carbon, low in ammonia, high in nitrates and offensive odors are uncommon. The effluent still is not acceptable for discharge into fresh waters and must be disposed of to land or evaporated.

OTHER OPTIONS

Other options to disposal of solid wastes is incineration (destructive decomposition) and composting. Composting is actually another method of land disposal but allows for some bacterial decomposition of the organic material which utilizes some of the nitrogen for the bacterial action.

Land disposal should be the ultimate disposal of both the liquid and solid fraction of the cattle wastes. Soil has the unique ability to fix and immobilize phosphorus and transform nitrogen. Phosphorus applied to soil becomes water-insoluble in a matter of hours in the top few inches of soil and up to 30% is utilized or recovered in the first cropping with some additional available to subsequent crops.

Phosphorus contamination of streams is believed to be mainly a result of erosion. Nitrogen from animal wastes can contaminate ground water. Nitrification is the biological transformation of ammonia (and urea) to nitrate form and converting organic nitrogen to soluble nitrates. Denitrification is the biological reduction of nitrates to gases, particularly nitrous oxide and molecular nitrogen. In terms of pollution control, the nitrates are the most significant since they are soluble and can be leached into the ground water or washed to the surface waters.

The fertilizer value of the wastes is of significance but it cannot compete with commercially prepared mixtures. One ton of manure provides about 14 pounds of nitrogen and 4 pounds of phosphorus. Nonetheless, despite the low nutrient content, there can be up to a 400 percent response in crop growth and yield from application of up to 130 tons of manure to test plots compared to plots fertilized from commercial fertilizer, indicating that the organic matter or other constituents are being beneficially used.

Disposal of values of up to 450 tons per acre of manure have been used, incorporating it into the soil by deep plowing, injection, or disking as a method of disposal. These disposal rates may be satisfactory for a one time application and should only be used where climatic or ground water conditions permit. Cropping of these soils for feed or forage could run the risk of having the livestock fed from it developing nitrate poisoning.

Another potential use of the manure is as cattle feed. The cow is not a very efficient machine, utilizing 18.5 pounds of dry matter and 54 pounds of water to produce a 2.5 pound daily gain in body weight, but the wastes would be 34 pounds of feces and 14 pounds of urine. Dried manure supplemented with both cellulose and protein feed are acceptable to the cattle and produce comparable daily body weight gains. Similar feed trials using biuret or urea with roughage have been successful.

The feed is made more acceptable or palatable with the addition of portions of molasses. Thus, it may be possible with the aid of supplements and sweeteners to recycle the waste to get the maximum nutrient potential from the feed source. This practice has some cautions for little is known about the potential transmission of diseases.

COSTS

Of course, the alternative method of waste management or disposal is controlled by costs. On a thousand head basis, incineration or composting cost about $9.00 per head per year. Anaerobic or aerobic lagoons cost about $18.00 per head per year. Another consideration is the land requirements for the different options. The land requirements for the various treatments per 1,000 head are:

	Acres
Oxidation (aerobic pond)	33
Oxidation ditch	.29
Anaerobic lagoon	.37
Anaerobic lagoon plus oxidation pond.	16.9
Anaerobic lagoon plus oxidation ditch	.51
Land disposal (rate 100 tons/acre)...	.3
Land spraying	7.3

It can be seen that land requirements are more favorable for the oxidation ditch, anaerobic lagoon, and land disposal. Land disposal has the edge because it does not have the additional costs of the other two. It is readily apparent that the most direct, least cost alternative is land disposal. It not only offers a solution to disposal but offers some return benefits in the way of crop response. Instead of considering the cattle manure as a total waste and a disposal problem, it can be considered partly at least, as a resource out of place, awaiting a relocation.

One of the considerations in the location of a cattle feedlot would be to assure that sufficient land is available not only for the feedlot itself but also adequate land to utilize or dispose of the solid and liquid wastes. A requirement that goes along with the land need is for land use planning with the zoning which sets aside lands for this use. This concept should be expanded to include not only the cattle feedlot wastes but lands to utilize the solid and sewage wastes of the urban and suburban areas.

GUIDELINES

Having presented various alternatives and having concluded the most acceptable would be followed, there are still many management details which must be considered in order to prevent pollution of surface and subsurface waters by cattle feedlots. I would like to close with this "should do" list concerning the feedlot location, design, waste management and other management considerations, and admonish that "it ain't what you do, it's the way that you do it."

Site Selection

1. Feedlots should be located at elevations above floodplains or areas subject to flooding.

2. Be located at least 100 yards from high water level of lake or reservoir, storm channel, irrigation drain, or irrigation canal, with corrals or fences restraining the animals from the waterways.

3. Be located on ground with slopes from 3-10 percent.

4. Be located in an area with at least 30 feet of medium textured or heavier soils overlying the ground water table.

5. Be located in an area where there is ample land for manure spreading.

6. Be located in areas of low amounts of annual precipitation (or provide complete animal cover).

Design Criteria

1. Holding ponds should be provided to retain liquid wastes and runoff.

2. Two holding ponds in a series -- the first of which would serve as a settling basin and the second as a storage basin.

3. Provide adequate holding pond capacity for the acreage involved and runoff expected.

4. Holding ponds should be in impervious materials to prevent ground water contamination.

5. Flood water diversion should be provided around the animal enclosure utilizing grassed waterways or other erosion measures.

6. Dikes and ditches should be built to carry the liquid wastes and runoff to the holding ponds.

7. Feed storage and silage areas should have drains to the holding ponds.

8. Provide non-overflow watering tanks or drains from watering tank areas to the holding ponds.

9. Provide portable pumping capacity sufficient to drain the retaining ponds within four or five days.

Waste Management

1. Retain manure on feedlot premises until it can be disposed of.

2. Direct drainage from manure stockpile to holding ponds.

3. Slotted floors with manure storage beneath could be used in the feedbunk area.

4. a. Liquid wastes--holding ponds should be emptied by spraying on disposal lands at frequent intervals to maintain pond storm runoff capacity and help odor control.

   b. Solid wastes:

      1) Manure spread on agricultural land should be cultivated into the soil, providing one acre per fifty head of feedlot capacity.
      2) Provisions should be made for retaining and reusing the natural or irrigation runoff from pasture lands or other lands where the wastes are not cultivated into the soil.

OTHER MANAGEMENT

Provisions should be made for dust, fly, and odor control and for disposal of dead animals.

The goal of cattle feedlot and barnyard control is to prevent rural runoff by developing new or utilizing known conservation practices and utilizing the wastes to achieve the objectives of maintaining water quality as well as those of soil and water conservation.

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Presented June 3, 1971 by RALPH C. D'ARGE, University of California, Riverside.

Evaluation Strategies and Water Resource Development

Most of what I am going to describe today evolved from discussions of an interdisciplinary Technical Committee which governs an OWRR funded Western State Project entitled "Development of Techniques for Estimating the Potential of Water Resource Development in the Western Region of the United States for the Achievement of National and Regional Social Goals."[1] Obviously, this is a research project embodying clear, concise, and illuminating research designs as is suggested by it's "descriptive" title. Since it appears to be impossible to delineate which Technical Committee members contributed (or were responsible for) the individual ideas and/or unifying conceptualizations, I will credit them collectively for any merits and absolve them collectively for any errors or deficiencies in mind which are embedded in my discussion.

National leaders in the United States, since it's inception, have thought it necessary and desirable to identify and advocate broad and encompassing social goals or objectives. The Constitution establishes such broad goals as insuring domestic tranquility, promoting general welfare, and securing liberty for present and future generations. It then proceeds toward identifying how these encompassing objectives are to be achieved.

Leaders in the field of water resources development have been no less embracing in their identification of sweeping goals. The first comprehensive plan for waterways in 1808 cited such objectives as economic development, political cohesion, and national defense. In a

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[1] The Technical Committee includes: D. F. Peterson, Utah State University, Chairman; H. Caulfield, Colorado State University; D. Gordon, University of Idaho; M. Marts, University of Washington; T. Roefs, University of Arizona; and R. Roelofs, University of Nevada.

more modern perspective, Circular A-47 of the Bureau of Budget issued in the early 1950's and "Senate Document 97" issued in 1962, establishing standards and procedures for evaluating water resource development projects by Federal Agencies, set forth broad objectives.

In Senate Document 97, full consideration was to be given to the multiple objectives of development, preservation, and the well-being of people. More recently a Special Task Force of the Water Resources Council developed an interim report called the "Blue Book" which has now evolved into the "Orange Books."[2] The "Orange Books" identify four distinct categories of objectives including increased national economic growth, enhanced environmental quality, greater social well-being, and greater regional development.

INABILITY TO ARTICULATE

Although attempts were made in these documents to define and identify the domains of such broad objectives, an immense chasm appears to exist between the definition of national objectives on the one hand, and implementation of programs to achieve such objectives on the other. Specifically, little was done to achieve consistency or display inconsistencies between the accepted national objectives and the actual implementation of local or regional plans. This, in my opinion was largely due to the inability to articulate the extent and meaning of national objectives by policymakers.

One of the first questions the Technical Committee addressed was how a consistent integration could be achieved between National Goals and individual water related actions of Federal Agencies. To illustrate by example, the concern was with what types or characteristics of water resource development would not enhance environmental quality or inhibit greater economic development?

It was tentatively concluded that the way a consistent relationship could be established between water resource actions and national objectives was to precisely identify all (or at least most) of the principle characteristics or words which gave meaning to national objectives. It was assumed that an adequate representation of an objective could be made by discovering a finite and relatively small number of sub-objectives or word groups defining the domain of the objective.

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[2] Report to the Water Resources Council by the Special Task Force, Findings and Recommendations, United States Water Resources Council, Washington, D. C. (July 1970).

As an example, if increased environmental stability is a national objective, then it's domain is partly identified by improved air quality. The domain of improved air quality, is likewise partially defined by reduced concentrations of oxidants.

Given the strategy of identifying the definitional domain of national objectives by listing sub-objectives which are determinants of achievement in national objectives, a hierarchical-like set of objectives held by individuals in our society is obtainable. If all goals or objectives of society and human endeavor are weighted equally, then there is no necessity for analyzing different objectives; any single objective accomplished is as good as accomplishing any other objective. [3]

Likewise, if all objectives can be accomplished simultaneously, there is no requirement for analyzing objectives since no choice between objectives need be undertaken. These two rather tautological statements are suggestive that embodied in the concept of objectives are several implicit ideas which may prove worthwhile examining in more detail.

HIERARCHY OF VALUES

The first statement implying differences in weighting of objectives needs some clarification in the meaning of weights. Weights are taken here to mean some measure of subjective value. For example, some individuals place a very high value on preserving all species of wildlife even if such preservation induces the loss of human lives. In terms of their subjective values, human life ranks somewhat lower on these individuals scale of values than man's responsibility as guardian of the natural environment.

This example is cited to emphasize one point; within the mosaic-like concept of objectives is embedded the idea of a hierarchy (or scale) of values. Of course, if there is only one objective <u>and</u> only one way of achieving that objective, then hierarchies of values are ruled out. However, if there is more than one way of pursuing even a single objective, a hierarchy of values might appear. As an example, let it be assumed the objective is for one man with no tools to move a pile of soil from point A to point B. However, which criterion should he pursue: to move the pile of soil in the least time, with least physical effort, with the

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[3] This in fact is implicitly presumed in planning studies which focus only on the National income objective as a measure of project performance.

least monotony in terms of repetition or some other criterion or combination of criteria?

It could be argued that the objective should be made more precise, i. e., move the pile of soil in the least time; but note that by so doing, a hierarchy of values has been implicitly imposed, namely that time has a high value when compared with physical effort or monotony. Different degrees of specificity in defining objectives necessarily must embody a hierarchy of values. If within the nature of objectives no hierarchical value system exists, then objectives are equally weighted, but even equal weighting implies a particular hierarchical value system. . . . . one of implicit equality.

When all objectives can be accomplished instantaneously, there is no reason for analyzing objectives since no constraint or hinderance to their immediate achievement appears. Human activities requiring no effort or expense thus cease to be objectives. Likewise, if there is no scarcity of resources to be applied to a single objective, the objective can be readily accomplished. If this is the case, the objective, once accomplished, is no longer of concern.

The fulfillment of one objective in certain instances may preclude the achievement of some other objective. For example, achieving the highest level of opportunity for private investment may induce a substantial reduction in environmental amenities, especially through over-use of the environment's waste assimilative capability. Thus, there is a degree of incompatibility between the two objectives of private investment opportunity and environmental security. There are two other possibilities: the fulfillment of certain objectives does not influence the achievement of other objectives, i. e., there are no linkages between them, and the cases where fulfillment of certain objectives results in partial fulfillment of others.

As an example of this last case, the objective of a high level of recreational opportunity may require little or no environmental degradation. If the recreational objective is achieved so must be, at least in part, the objective of maintenance of non-degraded natural environment.

To summarize our viewpoints thus far, objectives must be implicitly or explicitly connected with a value system . . . a system which ranks certain objectives equally with, higher than or lower than other objectives. Even in the case of a single objective, a value system exists provided there is more than one way of accomplishing that objective. A hierarchical value system emerges even in the process of definition of national objectives.

As greater degrees of specificity of national objectives are set forth, the hierarchical value system becomes more pronounced. Objectives may be competitive in that achievement of one precludes the achievement of others, neutral in that achievement of one will not influence the prospect of the achievement of others or complementary in that achievement of one results in partial achievement of other objectives.

Each broad, encompassing, national objective usually embodies many sub-objectives which define the domain of the national objective. [4] Finally, with the possible exception of national economic development, very little has been done to achieve consistent linkages between national objectives in water resource development and actual water resources agency planning efforts.

OBJECTIVES IN PLANNING

The national objective of enhancing environmental quality postulated in the "Orange Books" include the definitional statements of "enhancement of areas of natural beauty and human enjoyment," "enhancement of especially valuable or outstanding archaeological, historical, biological, and geological resources," and preservation of these resources.

But what does enhancement of human enjoyment or natural beauty mean? Or, what are the "especially valuable" resources? Even for the Orange Book national objective of economic development, not only is an increase in national product a definitional statement of this objective but also "improved market conditions," "availability of public goods," and "resource development for increased power." Similar broad and almost uninterpretable statements defining national objectives can be found in earlier government water resource planning documents.

In light of this and the viewpoints expressed thus far, I will make three assertions on how national objectives can be used in the planning process:

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[4] A question can be raised whether philosophically a national objective is anything more than all of the sub-objectives delineating the national objective's domain. Certainly one can assert that improved environmental quality may not only be reduced land, air, noise, and water pollution in isolation but also synergistic effects on our perceptions of the environment as all four are reduced simultaneously. I will leave to the philosophers the metaphysical question whether a national objective contains undefined or definable components not identified by describing it's domain.

1.) Inherent in our political system is the need to define and discuss broad, sweeping, national objectives. There are many reasons for this of both a historical and informational nature. These national objectives, while being multifaceted or N dimensional in scope, have meaning to policymakers and the body public, i.e., they are able to conceptualize and establish priorities in terms of multifaceted aggregative objectives.

2.) The relationship between a national objective such as enhancement of the quality of the environment and a subordinate statement (or sub-objective) defining it's domain such as improved water quality is generally not empirically measurable but can be subjectively evaluated as to sign. For example, improved water quality means that the quality of the environment has been improved as perceived by the policymakers and general public.

3.) By determining the logical subordinates of national objectives and the logical subordinates of logical subordinates, in many instances this process will yield a subordinate list which is quantitatively measurable.

The implications of these three assertions are illustrated in Figure 1. The arrows denote a linkage between the national objective and subordinate objective defining partially the domain of the national objective. Signs adjacent to the arrows denote the subjectively expected signs as specified in the second assertion. Quantifiable subordinates are also listed. The linkages between measurable subordinates and national objectives is thus specified by a series of signs.

While the vertical sign linkages are almost tautologically obvious in Figure 1, horizontal linkages may also appear. As an example the erection of a dam may yield a shorter route to markets for certain rural residents, but it may also reduce downstream nutrient flow and thereby cause a deterioration in water quality.

The hierarchical set of objectives is thus presumed to relate an ever increasing specificity of subordinates defining the domain of a national objective to itself through sign linkages. Linkages can presumably exist between sub-objectives within the domain of each national objective and between domains of mutually exclusive national objectives. As an illustration, improved consumer access to markets may increase economic efficiency such that GNP increases, where both GNP and consumer access to markets are distinct logical subordinates under the

FIGURE 1

National Objectives	National Economic Development	Enhancement of Environmental Quality
	↑ +	↑ +
Sub-Objectives (or word groups identifying the domain of National Objectives)	Improved Market Conditions	Improved Water Quality
	↑ +	
	Greater Access to Markets by Consumers	↑ +
	↑ +	
Measurable Subordinates	Reduced Travel Time	Increase in Stream D. O.

national objective of economic development.

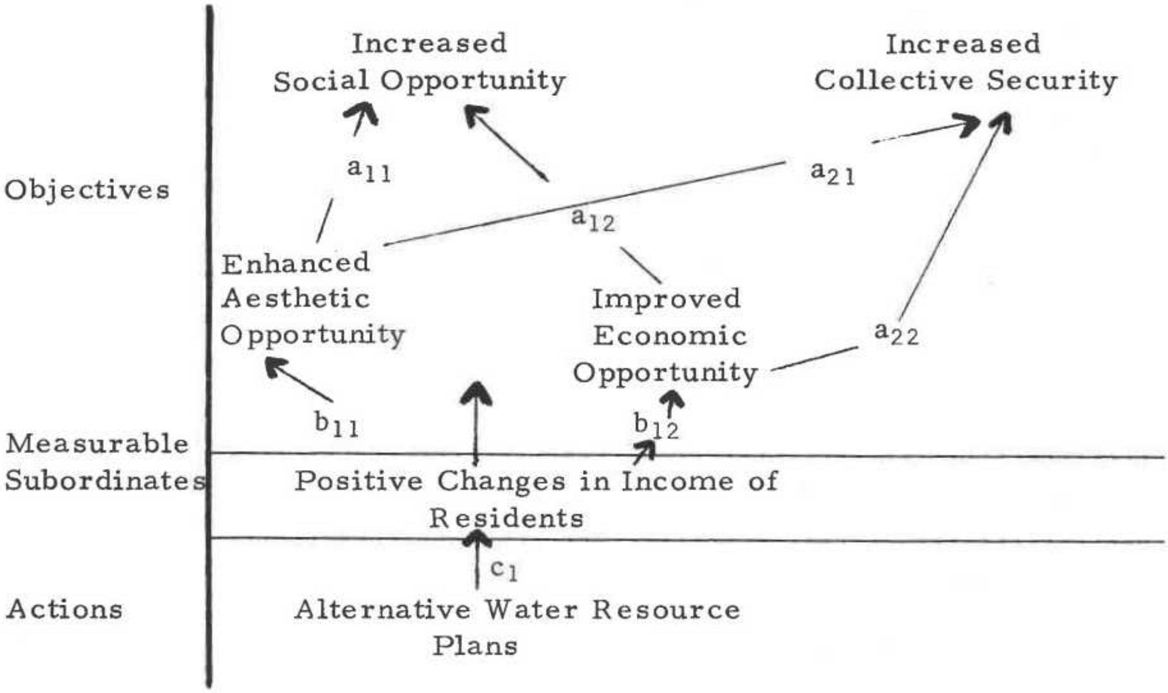
Likewise, greater incomes may induce more demand for outdoor recreation but simultaneously could cause a deterioration in water quality resulting from increased production of goods. A sub-objective (or subordinate) of the national economic development objective may influence a sub-objective within the domain of improved environmental quality. Feedback loops are also identifiable within and between the domains of national objectives.

In order to give my remarks on objectives some additional clarity, let us trace through a very simple and naive example. Assume that there are only two national objectives of a hypothetical social system called Portlandia. The policymakers of Portlandia have established two overriding objectives, social opportunity and collective security of its citizenry, including security against immigration of the hordes into their paradise!

In giving social opportunity meaning, the policymakers have decided that the domain of social opportunity is identified by two sub-objectives, namely aesthetic opportunity and economic opportunity. Let us momentarily presume that a satisfactory level of collective security has been achieved in Portlandia through stationing and provision of grizzly bears at strategic border points.

But Portlandia policymakers are considering a set of water resource development plans which increase the income of residents and thus affect the system's objectives. In Figure 2, a description of this hypothetical system which is consistent with the three earlier assertions is presented.

FIGURE 2



In order to simplify our description we will also presume that Portlandia is a linear world, i. e., all linkages in the social system are expressible by measured or non-measured linear coefficients. The following system of definitions and equations completely specifies the Portlandia world of decision making:

P = National objective of social opportunity.

S = National objective of collective security.

AP = Subordinate of social opportunity described as aesthetic opportunity.

EP = Subordinate of social opportunity described as economic opportunity.

ΔY = The change in income of Portlandia residents.

ΔI = Amount of investment resulting from a particular water resource development plan.

Given the assumption of linear coefficients, although some are assumed nonquantifiable, a system of simple equations can be written defining the linkages between subordinate objectives and national objectives where Δ denotes change in the objective:

$$a_{11}\,\Delta AP + a_{12}\,\Delta EP = \Delta P$$

$$a_{21}\,\Delta AP + a_{22}\,\Delta EP = \Delta S$$

As is stipulated in this equation set, both subordinate objectives under social opportunity are expected to influence collective security. For example, if the residents of Portlandia exhibit too much economic opportunity "wetbacks" from California maybe tempted to immigrate illegally. And if Portlandia remains too aesthetically pleasing, camping tourists may turn into squatters.

Next, we want to add the equations specifying the connection between changes in objectives and changes in income of Portlandia's residents and finally between investment in water resources and changes in income:

$$\Delta Y = b_{11}\,\Delta AP + b_{12}\,\Delta EP$$

$$\Delta Y = c_1\, I$$

While the system of linkages is identified by a set of linear coefficients, it is extremely doubtful that many of these linkages are quantifiable, particularly the linkages between objectives. For example, in the objective set, it seems almost ludicrous to presume the linkage between social opportunity <u>per se</u> and economic opportunity could ever be quantified. However, if the linkage can be identified as to sign, i. e. , as economic opportunity increases so also does social opportunity, then some very useful qualitative planning information can be obtained.

As an example, the signs of the coefficients a_{11}, a_{12}, and a_{22} are likely to be positive as are the coefficients c_1 and b_{12}. If b_{11} equaled zero or was positive in sign, then it clearly could be established that a positive change in water resources investment in Portlandia would increase the overall objectives of social opportunity and collective security.

However, if the sign of b_{11} was negative, the change in national objectives may well be either positive or negative. Provided $a_{21} = O$, even though the sign of b_{11} was negative, it could be asserted that the national objective of collective security is increased although the effect on social opportunity would remain ambiguous. This is true even though the system has fewer equations than variables.

Hopefully, what this extremely naive example illustrates is that it is possible in some instances to document the qualitative effects of water resource planning alternatives on national objectives where linkages are not completely quantitatively determined but signs of linkages are known a priori. Several algorithms have been identified which can be used for determining these effects (in terms of signs) on the objective set for large scale systems of objectives.[5] But even if a consistent qualitative effect cannot be identified for some objectives, the approach envisioned here would provide information as to the reasons for ambiguity. Identification of key signs on linkages leading to ambiguities would also be illuminating for iterative analysis of the preliminary objective set.

FOUR DISTINCT COMPONENTS

What I have briefly sketched out for your consideration today is a methodology of planning which embodies four distinct components. The first is a set of objectives in a hierarchical ordering where the ordering is derived by postulating national objectives or goals and then, through a process of logical subordination, defining the domains of these national objectives.[6] Logical subordination yields increasing numbers of subordinates or sub-objectives which at some point of disaggregation may yield measurable quantities.

These measurable entities, the second component of our conceptual planning mechanism, such as changes in national or regional income, changes in the level of unemployment, migration rates, B O D. discharge rates, etc., define, in quantitative terms, the changing state of the social and environmental system. Thus, these measurable subordinates are analogous to social indicators (or empirical measures of social, physical, or biological phenomenon that are socially significant). They differ from the usual methods of establishing lists of social indicators in that they are a result of a logical subordination process applied to a particular set of national objectives.

It is presumed that the linkages within and between national objectives cannot be quantified but qualitative properties such as the signs of linkages can be subjectively determined. Also, only qualitative linkages can be established between the measurable logical subordinates of national objectives and the next higher level subordinates.

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[5] See for example, K. Lancaster, "The Solution of Qualitative Comparative Static Problems," Quarterly Journal of Economics, May (1966).

[6] It is doubtful that a value-free identification process of logical subordinates is obtainable in light of the earlier conclusions.

The complete planning system then is envisioned to couple a qualitative system of objectives to a quantitative system of measurable subordinates or (for lack of a better descriptive term) social indicators. In turn the social indicators can presumably be linked to water resource planning actions, the third component in our conceptual planning system, through the more traditional benefit-cost, cause-effect, input-output, stimulus-response, interaction multiplier, materials balance, Streeter-Phelps equation, logistic growth relationship, or other tools currently employed or being tested in water resources planning studies.

The complete system is visually illustrated in Figure 3. The heavy arrow in Figure 3 denotes the presumed linkages between actual water resource development plans and local, regional, and perhaps national social indicators. These linkages, along with those specifying relationships within and between objectives and sub-objectives comprise the fourth component of our conceptual planning mechanism.

If value weights could be established for each local, regional, and national social indicator, then conceptually the optimal set of water resource projects or programs could be deduced through a maximization of the weighted set of social indicators. Such writers as Marglin, Maass & Major, and others appear to ascribe to this conceptualization of the planning process where the value weights are explicitly established by policymakers from above.[7]

The methodology for planning described here does not require a set of value weights for maximization of the social indicator set although it can easily accommodate such weights. Rather, policymakers are viewed as individuals who identify broad objectives and perhaps establish implicit weights on these objectives but do not establish value weights at the local or regional level on social indicators or outputs of particular water projects or programs.

It is one thing to ask national leaders to establish aggregate priorities of objectives; it is quite another to presume these leaders can effectively establish value weights comparing an increment of employment in Roy, New Mexico versus a positive change in dissolved oxygen in the Willamette River.

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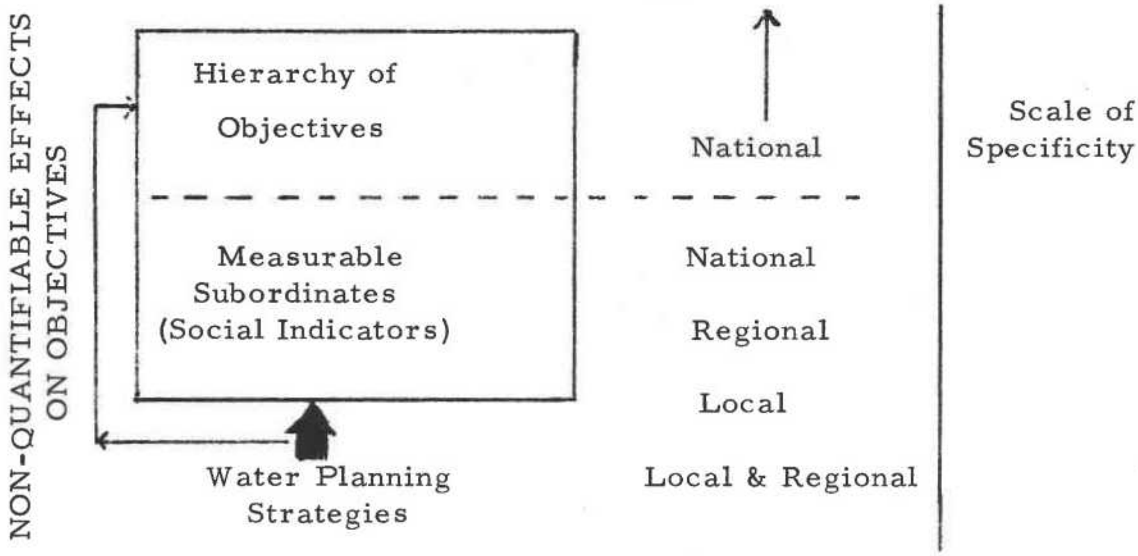
[7] See for example, D. C. Major, "Benefit-Cost Ratios for Projects in Multiple Objective Investment Programs," Water Resources Research, Vol. 5 No. 6 (December 1969); Arthur Maass and David Major, "Economics in Regional Water Research and Policy: Comment, "American Journal of Agricultural Economics (February 1970); S. A. Marglin, Public Investment Criteria, Cambridge: MIT Press (1967).

FIGURE 3



Thus, while a Maass-Major-Marglin world may be the ideal one, such a conceptualization in my opinion, tells us very little about how a more consistent planning process can be established in the "real world."

In Figure 3, a scale of specificity is hypothesized in terms of the methodology set forth here. At this time, it is my feeling that most water resource programs have very pronounced local effects, some regional impact, and very little national impact except that which manifests itself through local and regional impacts. In view of this, I have arbitrarily divided the social indicator set into three layers, local, regional, and national. Also, I have presumed the hierarchy of objectives is entirely national in scope.

HYPOTHETICAL, CONCEPTUAL STRUCTURE

All objectives of water resources planning are presumed to be national in extent. I would argue that objectives may be of a regional or local nature but must be identified nationally for inclusion in regional or national strategies of water resource development, particularly if most of the funding originates in the Federal sector. Of course, if all objectives are of a local nature and not descriptive of other localities objectives, it appears that comprehensive and consistent planning across regions is almost impossible. There would be little incentive to derive a methodology for analyzing local and regional water resource developments in fulfilling national goals.

It is most difficult to state what the premises and structure of a particular planning methodology is before it is actually tested. Perhaps you have noted certain vagaries and sweeping conclusions in the bill of fare offered. This is, I assure you, quite intentional. Next year following field testing, a much more comprehensive statement of the planning methodology will become available. For now, one must be satisfied with only the hypothetical, conceptual structure.

There are several indications, at least, that only following empirical and field testing can this methodology be documented as being viable for actual planning decisions. First, we must be able to establish that the effect on local social indicators, i. e., on employment rates, improvement in stream quality can be adequately related to national social indicators. If all such relationships are of the "second order small" variety one may doubt whether consistency between national objectives and water resources planning effects are achievable.

It is my own judgement that the impact of any given water resource project is of the second order variety, but that a comprehensive basin wide plan for any of the seventeen major water resource regions may well not be.

A complete classification system for water resource development actions or plans needs to be accomplished in order to adequately define these actions actual and potential effects on objectives. Such a classification system would also aid in the estimation of linkages between local-national social indicators and water resource plans.

Most importantly perhaps, since values are implicitly established in the development of the objective set, a thorough review process embodying almost continuous re-evaluation needs to be designed. Such a process hopefully will lead to consensus on the domains of national objectives and prevent a "locking in" of outdated values.

It appears to me that a planning methodology must be constructed which aids in planning for the future and for future generations. Such a methodology should prevent the reoccurrence of channeling water resource planning actions to meet a single objective, as has happened in the past with the national income objective.

What I have attempted to describe is not a complete or panoramic decision making methodology for water resource planning, but a decision-aiding methodology. It is one step, but only a very small one, in the direction of a comprehensive, practical, and useful decision making methodology for water resource development.