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THE JAPANESE REGIONAL WASTEWATER TREATMENT SYSTEMS

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ABSTRACT

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The Japanese government is undertaking a major program to provide additional sewage collection and treatment because of the severe water pollution that has resulted from rapid urbanization and industrialization. The program is characterized by strong regional planning and by the utilization of central treatment plants serving many communities and, in some cases, industries. Through a study carried out in Japan many important planning issues were identified, including: (1) cultural and historical factors; (2) cost effectiveness, including economies of scale, treatment effectiveness, and short-run and long-run flexibility; (3) potential interrelationships with drainage, water supply, and land use; (4) interactions between planning agencies and local citizens; and (5) institutional arrangements between governmental bodies. The Japanese experience is a significant one in the history of planning wastewater treatment systems and provides some guidance as similar programs are initiated in other developed and developing countries throughout the world. In general, planning such systems represents a complex public-sector problem and calls for an interdisciplinary approach.

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KEYWORDS--Cost effectiveness/Institutional arrangements/*Management/*Pollution/*Regional planning/*Sewage treatment/Social issues

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INTRODUCTION

This paper addresses issues related to planning and designing regional wastewater treatment systems which may include central treatment plants serving many communities. Throughout the world, planning such systems as well as other urban and environmental systems on a regional basis is becoming more and more common. Note, however, that regional planning may lead to completely decentralized configurations of treatment plants as well as to highly centralized ones.

A primary advantage of a centralized plant is the economies of scale in its construction and operation. The savings often significantly outweigh the added costs of interceptor sewers needed to collect the wastewater from several communities. For this reason, much attention has been directed toward using central plants in the developed countries, such such as the United States, Japan, and many European countries (2, 5, 6, 12, 17, 21). It can also be expected that developing countries will consider large central plants as they implement wastewater treatment programs in the future since the potential savings may be of critical importance for them (26).

Planning wastewater treatment systems, however, is a complex public-sector problem involving many parties, many objectives, and many constraints (10). In an effort to identify important planning factors, the authors visited Japan for six weeks during the summer of 1976 to examine the

regional programs that are underway. These programs reflect a strong national effort; they are characterized by leadership and financial support from the central govenment. Planning (called Comprehensive Basin Planning) and implementation are carried out by the prefectural governments. Typically, in major population centers the designs call for large central plants and interceptors branching out to different communities.

These regional programs are in various stages of design and implementation throughout Japan. Our exploratory project was aimed at finding out what important technical and social planning issues have arisen. The study methodology was to interview central government and prefectural government officials, university researchers, and members of private firms and professional associations. (The time and resource limitations of the study did not permit interviews or surveys of government officials below the prefectural level or of local citizens.) While many of the issues that were identified are primarily local in nature, many insights may be transferable to other impending or future planning activities.

This brief study in Japan was not designed to review or to affect the actual plans being formulated or implemented. The Japanese experience is a significant one, and many issues have been raised by supporting and opposing groups and individuals. Our purpose is not to weigh judgmentally different arguments about specific cases. Rather, it is to describe many of the different viewpoints which were identified. In addition, brief comparisons are made at some points in the discussion with similar efforts in the United States.

In future planning activities throughout the world, planning issues like those described here will most likely arise. Clearly, the relative

importance of different issues depends on local conditions in any given region of any given country and should be determined by the appropriate planning agencies. It should also be noted that an authoritative and objective opinion might indicate that a specific issue is not important at all, perhaps for economic or technical reasons, but a planning agency may be required, nevertheless, to deal with that issue since it may be raised by an opposing governmental agency or private group.

PLANNING FACTORS

Historical and Cultural Framework.-Regional wastewater treatment systems should be planned, of course, within the appropriate cultural and historical framework.

In Japan, the design of the national program can best be understood in the context of increasing environmental concerns associated with rapid industrialization and urbanization during the last three decades. Although Japan consists of a long string of islands (see Fig. 1) with a total area of 142,726 square miles (370,000 km^2), most of that area is mountainous and sparsely populated. Only sixteen percent is productive flat land, on which most of the population lives at very high densities. The major metropolitan areas are concentrated on a narrow strip, called Tokaido Megalopolis, which stretches from the Tokyo-Yokohama area west to the Nagoya-Osaka-Kobe area. This region accounts for nearly 75% of Japan's industrial production (14).

The rapid industrialization and concentration of the population in urban areas, along with the use of synthetic fertilizers (rather than night soil) and other agricultural chemicals, has produced extreme pollution of many rivers, lakes, estuaries, and bays. The mercury poisoning incident at Minamata Bay in the late Nineteen fifties (27) was one of the many cases that led to the new colloquial expression, Kogai Mondai, which translates to "public nuisance problems" and refers to the public hazards that accompanied the extremely rapid and concentrated economic development. The reader is directed to Refs. (14) and (15) for a discussion of industrialization, water usage, and environmental problems in Japan.

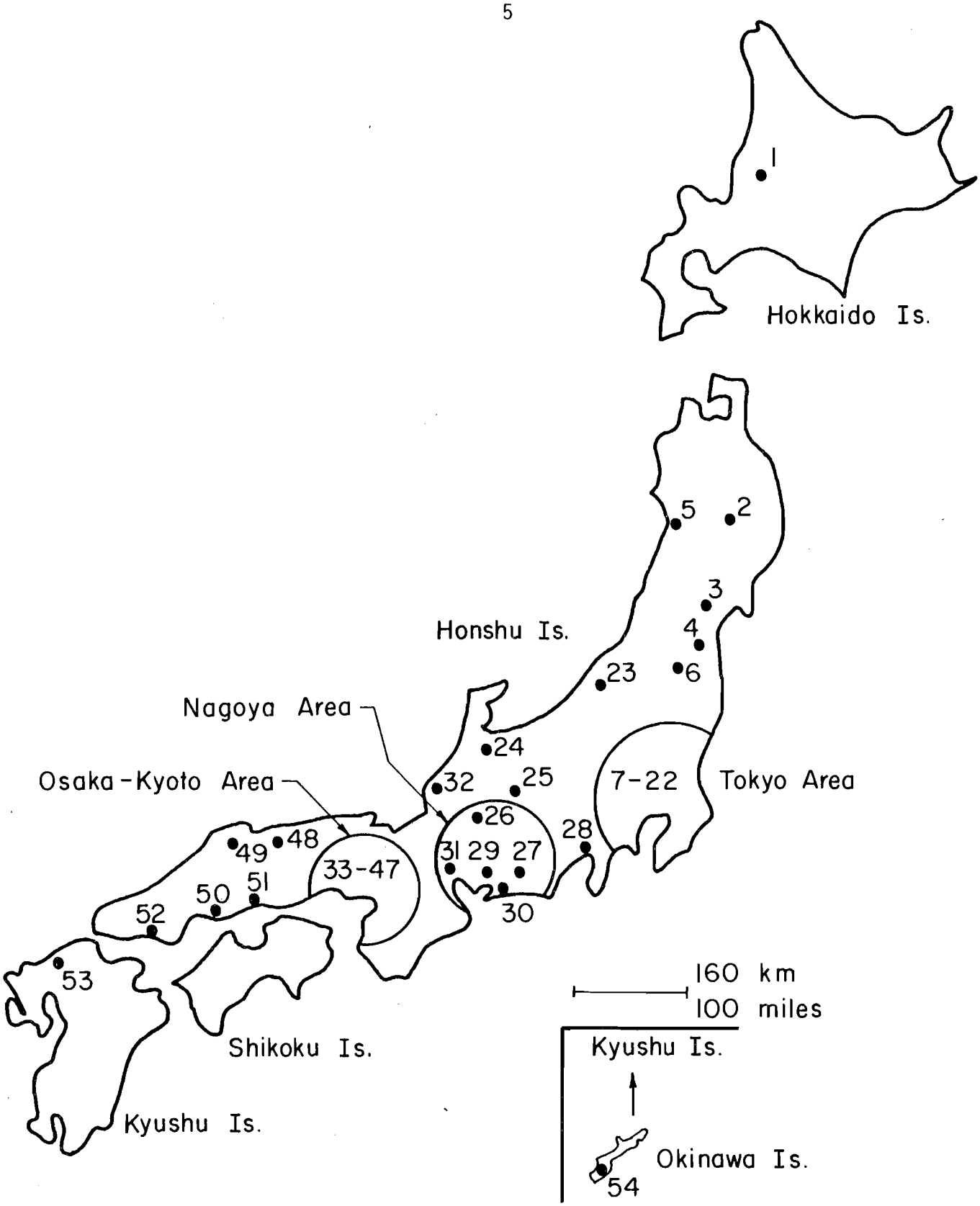

Fig. 1. Map of Japan Showing the Fifty-Four Regional Wastewater Treatment Systems

During this period there was also increased interest in providing sewerage systems to upgrade the quality of urban life. Although the first sewerage act in Japan was enacted in 1900, by the mid nineteen sixties only a small number of sewerage systems had been constructed. As shown in Table 1, at that time a relatively small portion of the country was served by these systems.

In recent years, Japan has become very concerned about public nuisances and environmental problems. Under the Water Pollution Control Act of 1970, the Environmental Agency was established; its mission is to set national environmental standards and to regulate waste discharges. The impetus for constructing sewerage facilities stems from the Ammended Sewerage Act of 1970, which calls for comprehensive regional planning by the prefectural governments; this program is administered through the central government's Ministry of Construction. Also, the Ministry of Construction established what is now the Japan Sewage Works Agency, which manages the construction of sewerage systems for understaffed municipalities and is also responsible for research and development and for training technical personnel to operate treatment plants. These national laws, along with other environmental legislation in 1970, laid the foundation for the comprehensive and large-scale governmental effort to control water pollution.

TABLE 1. - Comparison of Sewage Treatment Services (1961-1964)[a]

	Japan	United States[b]	England	France	India
Percent population with sanitary sewage drainage	11	64	98	40	6
Percent population with sewage treatment	7	56	Not Avail.	14	2

[a] After Ref. 19.

[b] After Ref. 4 for 1962.

As of 1976, fifty-four regional systems (see Fig. 1) were at some stage of planning or construction. A region is a large area within one prefecture or covering parts of several prefectures. Each region is served by one or more central treatment plants, and the area served by one of the plants is called a drainage district. Twenty-nine drainage districts in fifteen regions have already started service; most are in the Tokyo and Kyoto-Osaka areas. Many of the regional systems encompass large suburban areas rather than inner-city areas, such as Tokyo and Osaka, where municipal facilities already exist.

Several of the regional systems were started as early as 1965--five years prior to the legislation mentioned above (9). The emphasis of the early wastewater systems was on drainage, although treatment plants were also included. Traditional public works, in fact, were aimed at draining the naisui (inner water, i.e., flood water) to the gaisui (outer water, i.e., water within the flood embankments). Thus, combined sanitary and storm sewers, which also provided drainage, were well received by local governments and citizens. Increasing environmental concerns, however, subsequently led to greater emphasis on wastewater treatment, and separate sewer systems were used in more recent designs.

The national commitment to ameliorating water pollution has continued, generally according to the original plans. As shown in Table 2, the extent of sewerage service and wastewater treatment is increasing, and it is expected that 40% of the population will have both services by 1980.

The historical conditions of rapid industrial and urban growth and of minimal sewerage service have necessitated this urgent and large-

scale national program (8). As shown in Table 2, the investments have increased rapidly in recent years. The 1975 expenditure of approximately $2 billion is on the order of one-half percent of Japan's gross national product. As shown in Table 3, projected expenditures are even greater for the next five-year period.

The national approach has been to undertake--through planning guidelines, subsidy incentives, and treatment regulations--similar regional designs throughout the country. The regional systems generally feature a small number of large central treatment plants and large interceptors connecting many adjacent communities. Typically, both domestic and industrial wastewaters are treated by the regional plants.

Japanese officials recognized many advantages of implementing a series of similar regional systems instead of a less-defined local-option program allowing each community to plan its own system (9): (1) In general, such a uniform effort can be initiated relatively easily in a national political arena, where many types of programs compete for funds, partially because it can be more easily described and understood by a wide array of public officials whose support is necessary. (The Japanese political environment, important in understanding support and opposition to their program, is beyond the scope of this paper.) (2) A uniform program can be administered relatively easily and implemented relatively quickly--an important consideration in Japan because of the severe environmental pollution. (3) This approach is especially practical in a country with a limited number of design engineers and other technical personnel since they can efficiently transfer experience from one project to another. (4) For any nation just initiating such a widespread sewage collection

TABLE 2. - Trend in Sewerage Service in Japan[a]

	1963	1967	1971	1973	1975
Urban area, in square miles	1,467	1,853	2,496	2,885	3,278
Urban area drained, in square miles	245	381	586	736	840
Percent area drained	16.	20.5	23.5	25.5	25.6
Population, in millions	96.2	100.2	105.0	108.7	110.9
Population served, in millions	7.1	11.1	17.6	21.2	25.1
Percent population served	7.4	11.1	16.6	19.5	22.6
Expenditures, in billion yen	49.8	127.7	373.8	545.9	604.2
National government subsidies, in billion yen	8.4	27.7	98.3	156.0	249.5

[a] After Ref. 18

Note: 1 sq. mile = 2.59 km^2; 300 yen ≈ $1.00

TABLE 3. - Growth of Expenditures for Sewerage Systems in Japan[a]

	Investment for Each Five-Year Plan			
	(1963-1967)	(1967-1971)	(1971-1975)	(1976-1980)[b]
Billion yen	440	930	2,600	7,500
Billion dollars	1.47	3.1	8.67	25.0

[a] After Ref. 18.

[b] After Ref. 29.

and treatment program, cost savings from economies of scale are likely to be especially important. Japan also has a recognized national policy of supporting and protecting a newly developed industrial base. Industries which join the regional systems must pay their complete share of the costs, but they gain the advantages derived from economies of scale. This benefit may be especially important for small or marginal industrial plants. (The economies-of-scale issue itself is discussed in detail below.)

Cost-Effectiveness. - Short-run economies of scale and treatment effectiveness and both short-run and long-run flexibility are important planning issues, which are discussed in order:

1. Short-run economies of scale - It is widely recognized that there are significant economies of scale in constructing, operating, and maintaining treatment plants (23). The cost savings of large regional plants may more than offset the increased cost of the interceptors that are necessary to connect nearby areas (13). There are also significant economies of scale in constructing interceptors (22), which typically account for a major portion of the cost of wastewater systems and which may reach 15 miles (24 km) or more in a regional system.

As illustrated by the following examples, the regional systems being planned and implemented in Japan include very large treatment plants and interceptor networks--largely because of the significant economies of scale.

The regional system in Nara Prefecture serves as a good example. This prefecture is located approximately 25 miles (40 km) south of Kyoto

and 20 miles (32 km) east of Osaka. It is characterized by residential and light-industrial development as well as by a large tourist flow to visit historic sites (the area contains capital cities from the period 600 AD). Twenty percent of the prefecture is in the lowland basin of the Yamato River. This land, however, holds roughly 80% of the prefecture's population. Pollution of the Yamato River is quite severe, especially during low-flow periods.

Within the city of Nara, approximately 70,000 people are served by an existing sewerage system and two fairly new treatment plants which will be phased out. Figure 2 outlines the first drainage district of the regional system to be implemented; this district will serve about one-half of the region. Twelve communities with a total estimated population of 1,140,000 will be served by the treatment plant, which will occupy 145 acres (586,000 m^2). The maximum daily design wasteload is 223 million gallons (848,000 m^3), of which 30% is industrial wastewater.

The complete regional system is designed to serve an ultimate population of 2,120,000 from twenty-four communities divided into three drainage districts. The total maximum daily wasteload of the three treatment plants is estimated at 402 million gallons (1,527,000 m^3), and approximately 90 miles (145 km) of interceptors will be constructed. Expenditures are estimated to total 190 billion yen ($633 million).

As another example, Saitama Prefecture has been primarily agricultural but is becoming a densely populated suburb just north of Tokyo. Most of its waterways, which flow directly into Tokyo Prefecture, are seriously polluted. Three regional systems are being planned; they will serve 43 communities with populations ranging from 20,000 to 340,000.

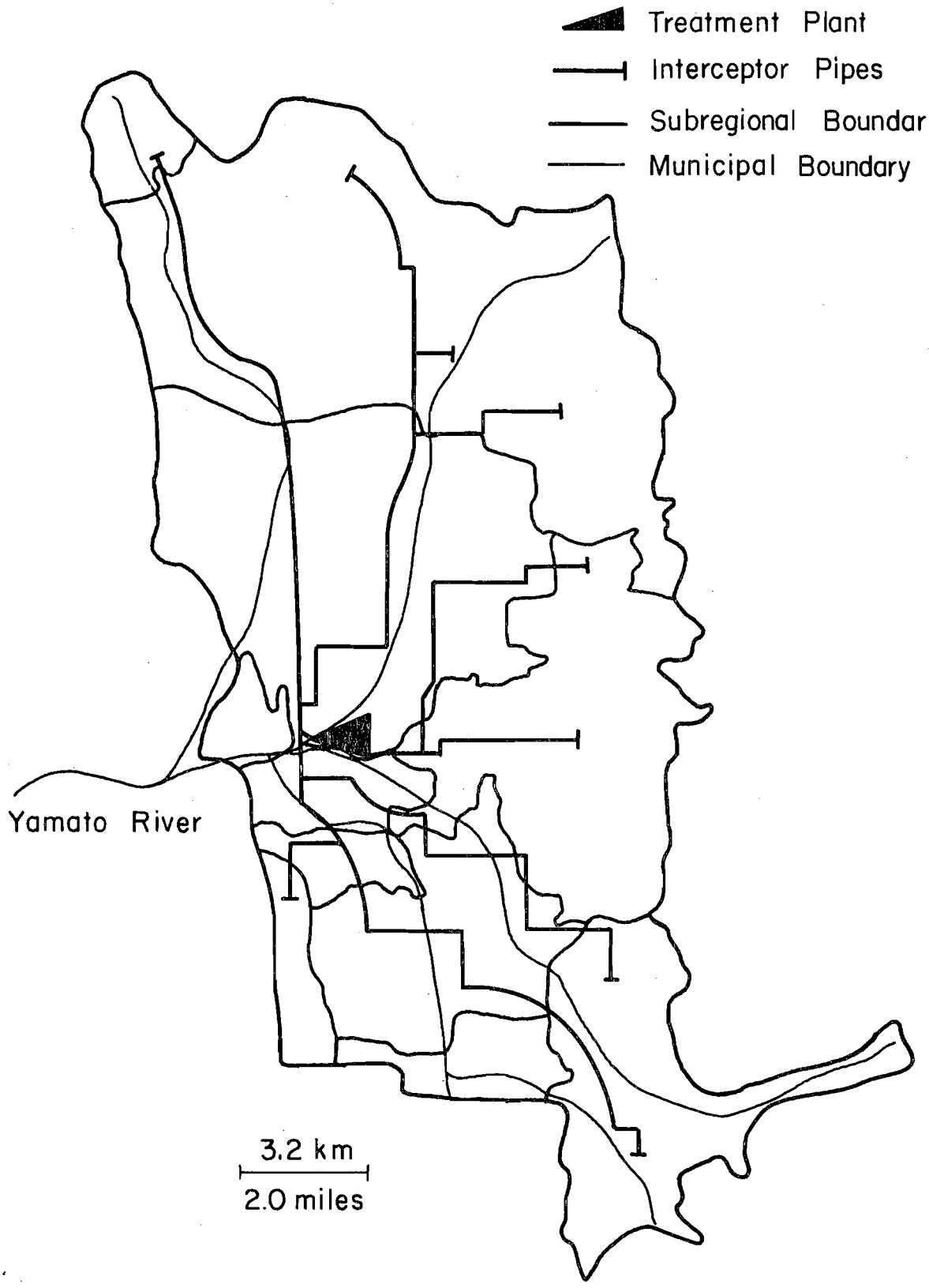

Fig. 2. First-stage Regional System in Nara Prefecture

Many of these communities currently have practically no sewerage service. The three systems are described in Table 4. The Arakawa Sagan regional system is divided into two drainage districts; the Ugan and Nakagawa systems each have a single district. As shown, the planned capacities of all four treatment plants are quite large, and extensive interceptor networks will be constructed.

In Tokyo Prefecture there are two regional systems planned for the area outside of the inner city. (The inner city is already served by nine plants owned by the Tokyo Metropolitan Government.) The two new systems will ultimately contain eight drainage districts, each with a large treatment plants, and will serve approximately 40 communities with a total population of four million. Construction is underway in six drainage districts--five in the Tamagawa region and one in the Arakawa region; these two systems are described in Table 5. Again, very large treatment plants are utilized.

In general, highly centralized systems are being planned in many populous areas in Japan to take advantage of economies of scale and because of the other advantages discussed below. In comparison, regional systems in the United States are centralized to varying degrees. Many metropolitan areas, of course, are served by very large treatment plants, but this is not always the case. For example, the Illinois Pollution Control Board (11) selected a regional plan for DuPage County that calls for nine treatment plants to serve 30 communities. This Chicago suburban area is growing rapidly, and the population is expected to reach 850,000 in the early 1980's. As discussed in the section on institutional arrangements, the nine-plant configuration was selected because of the prior existence of treatment plants under community ownership and because of many practical issues related

TABLE 4. - Saitama Prefectural Regional Systems

	Regional System			
	Arakawa Sagan[a]		Arakawa Ugan	Nakagawa
	A	B		
Number of cities and towns	8	6	12	17
Design drainage area, in square miles	85.7	59.1	93.1	98.8
Design population, in thousands	1,818	606	1,720	2,004
Design maximum daily wasteload, in million gal.	363.9	138.4	330.8	536.8
Total interceptor, in miles	54.0	31.1	46.0	55.9
Land requirement for treatment plants, in acres	79.1	44.5	81.5	153.2
Total budget, in billion yen	195	123	157	209

[a] A and B refer to the Arakawa Sagan Nanbu and Hokubu Drainage Districts respectively, each of which is served by one regional plant.

Note: 1 acre = 4.047 m^2; 1 gal = 0.0038 m^3; 1 mile = 1.61 km.

TABLE 5. - Tokyo Prefecture Regional Systems

	Regional System					
	Tamagawa[a]					Arakawa Ugan
	A	B	C	D	E	
Number of municipalities	6	6	3	7	5	10
Design drainage area, in thousand acres	17.4	20.1	6.2	33.6	23.9	30.5
Design population, in thousands	545	616	186	392	550	830
Design maximum daily wasteload, in million gal.	A through D total: 152.1				46.3	135
Total interceptor in miles	12.0	13.5	9.6	19.4	14.2	19.9
Land requirement for treatment plants, in acres	Not Avail.	34.6	Not Avail.	Not Avail.	33.6	Not Avail.
Total budget, in billion yen	A through E total: 355					115

[a] A: Nogawa Drainage District
B: Kitatama 1 Drainage District
C: Kitatama 2 Drainage District
D: Tamagawa Joryu Drainage District
E: Minamitama Drainage District

Note: 1 acre = 4.047 m^2; 1 gal = 0.0038 m^3; 1 mile = 1.61 km.

to local autonomy.

The highly centralized designs in Japan have led to many planning issues which are discussed in the following section.

2. Short-run effectiveness - Effectiveness is discussed with respect to treatment plant design and operation and ambient quality control.

One benefit from using a central plant is that the required plant capacity is generally less than the sum of the capacities that would be needed in a decentralized system. The total plant inflow is smoothed out because the peak flows from different sources arrive at different times. There are two reasons: (1) travel times differ for the various sources, and (2) peak flows from individual sources usually occur at different times of the day, week, and year. Industrial peak flows especially might occur at different times compared to each other and compared to domestic sources. Also, the variability of wastewater characteristics is reduced because of dilution. For example, an accidental spill of a small amount of toxic material may be sufficiently diluted so as not to be a major hazard.

Another advantage of constructing a small number of large central treatment plants is that a nation like Japan can concentrate a limited supply of professional engineers and technicians at these locations. Also, in the Japanese case maximum use is made of automation in operating the plants; the expensive equipment required, including computer systems, is feasible only for large plants. On the other hand, if many very small plants are in service, it may be too expensive for the small communities to hire technical personnel and to maintain an effective level of treatment. This factor has also frequently been a consideration

in the United States and was a major reason why the Illinois Pollution Control Board (11) developed a regional plan for DuPage County whereby many small plants would be eliminated.

A related issue, however, is that very large plants--particularly those accepting industrial wastes--tend to have more complex mixtures of wastewater constituents, and a wide array of problems may arise. In a more decentralized system, the operators of a small plant may come to be quite expert with the special types of problems that arise at their plant. Thus, the scale of the treatment plants--coupled with the availability of operators and the nature of the waste streams--is a major determinant of treatment effectiveness.

As mentioned above, in many of the Japanese regional systems the central treatment plants handle large industrial waste flows (e.g., 30% of the flow for the Nara Prefecture system described above and almost 50% for the Lake Biwa system to be described below). Typical industrial wastes include those from food, metal, chemical, textile, pulp and paper, steel, automobile, and other manufacturing industries. In addition to these already discussed, there may be technical advantages of combined treatment. For example, a nutrient-deficient industrial waste flow may be readily treated by biological processes (all of the Japanese systems use the activated sludge process) after mixing with domestic waste flows.

On the other hand, there are potential problems which may result from combining industrial and domestic wastes. In Japan, as in the United States, several major public controversies have arisen over the issue of toxic metals (e.g., chromium, cadmium, copper, zinc, and lead) that are discharged from industrial sources to combined biological-treatment

plants. One major incident on the national level arose in the early 1970's over the case of a plant operated by the Tokyo Metropolitan Government. Opposition movements stemmed from studies conducted by university researchers and from widespread coverage by the national media.

For one discussion of the opposition movement's position, the reader is directed to Ref. (16). The basic position goes as follows: First, the toxic metals are not treated (reduced in strength) by biological processes. Rather, diluting such pollutants makes them more difficult to remove than if they were removed at the original source. In addition, such quantities as remain in residual sludges are exceedingly difficult to remove, and incinerating these sludges would tend to distribute the pollutants over the air shed, potentially causing environmental hazards to people in urban areas and to crops as well in rural areas. While pretreatment regulations, monitoring, and user charges can be used to control industrial inflows, accidental or intentional spills may still enter the regional system. Complete monitoring of waste inflows is very difficult and, once in the system, it may be very difficult to trace such a spill to its origin.

Recognizing such problems, the central government has promulgated pretreatment regulations to limit the flow of toxic materials into the regional systems. Also, the Public Works Research Institute of the Ministry of Construction and several university groups are carrying out additional studies of the behavior of toxic materials in treatment processes and in the environment. Nevertheless, environmental groups have continued to oppose plans to treat industrial wastes in the regional systems. (See Nakanishi (2) for a discussion of the regional system for the Yahagi-Sakai

Basin in Aichi Prefecture. Approximately 50% of the flow in this system is from industrial sources, including automobile manufacturing plants.)

Another aspect of effectiveness which has received attention in both Japan and the United States is the quality of the receiving waters. A regional system with a large central plant discharges a large volume of effluent at one point to the receiving water (1). Routine discharges of this nature may be acceptable because of high wastewater treatment levels. In the event of a breakdown or operating failure, the fact that large plants are designed with many parallel units reduces the likelihood of catastrophic flowthrough of the plant influent. Nevertheless, there remains some possibility of a large-scale problem. For example, a large accidental spill of a toxicant by an industry conceivably could enter the regional system and destroy the secondary treatment capability. The entire region's waste flow would then be discharged at a single point after only primary treatment. A system of small dispersed plants would reduce this hazard.

Thus, the scale of a regional interceptor system and of central plants is extremely important in many ways. It may be undeniable that preventing or replacing an array of very small, inefficient, and poorly operated plants is cost effective. In any country, however, planning large central plants that serve many commnities requires consideration of many other important issues, such as those raised above and in the following discussions.

3. Long-run and short-run flexibility - One feature of large treatment plants and interceptors is that they are "cast in concrete" and do not remold easily for dealing with unexpected problems. This issue has been raised repeatedly in Japan. An analogy offered by Tambo (25) is that at one time in history combined storm and sanitary sewers might have appeared to be cost effective compared to separate systems; at a later date,

however, new levels of awareness might identify the need for tertiary treatment of the sanitary wastes. The combined system, being the less flexible design, would be more difficult to adapt to the new requirement. Similarly, should future policy dictate higher waste removal levels, large-scale regional systems could be disadvantageous. Upgrading a central plant with a large waste flow might be considerably more expensive than providing advanced treatment at selected strategic sources. In general, long-run flexibility is desirable in the face of uncertainty about future environmental goals, regional growth (population and industry), technological developments, and other changes in society and national policy.

Also, note as a philosophical aside that the myriad combinations of local issues, such as those discussed herein, may call for local short-run flexibility in exercising originality and creativity while addressing unique local problems. In this regard, uniform national programs can give the appearance of encouraging suggested technologies. (As one example, U.S. Environmental Protection Agency provides guidelines and suggests technologies for compliance with Public Law 92-500; as a similar example, all of the Japanese regional systems employ large-scale activated sludge plants and, in general, are based on a design manual prepared by the Japan Sewage Works Association.) While such guidelines may ensure that minimal performance requirements are met, they may tend to inhibit creativity in forming new and significant technological approaches which could be more cost-effective in unique local situations. (It should be noted that government officials in Japan recognize that different types of solutions must be sought in dealing with future problems with unique local conditions.) Another potential difficulty with any such uniform national approach is that a tremendous inertia is developed within governmental agencies. Furthermore, the

support of many governmental officials may have been gained on the basis of a specified approach. As new and unexpected problems are identified, it may be very difficult to adjust quickly the direction of national energies and monies.

Drainage, Water Supply, and Land Use - Other factors to be considered in designing and implementing regional wastewater treatment systems are related to drainage, water supply, and land use. In Japan, as mentioned above, the early emphasis of the regional systems was on drainage, and many of the first systems were designed with combined sanitary and stormwater sewers. Such a cultural factor might be very important in gaining public support for a wastewater management program. In addition, if large central plants are built, they almost always lie near the downstream boundary of the region, and the water withdrawn for use upstream is not returned to the source but is instead conveyed downstream via the interceptor system. Similarly, stormwater may be diverted to downstream discharge points. Thus, the water flow pattern of the region is modified; between the withdrawal points and the downstream discharge point the flow is reduced.

This reduction in flow may have significant impacts on the receiving stream (1, 25). The reduction may be especially critical for small streams during parts of the year when treatment plant effluents constitute all or a major portion of the flow. Even for a large river, reduced flows may interfere with in-stream water uses and may limit withdrawals. On the other hand, if wasteflows are diverted to a downstream discharge point, remaining water supplies may be of higher quality although diminished in quantity (25).

Another major issue raised by several researchers (7, 24, 25) in

Japan concerns water supply in areas with potential water shortages where water reuse and recycling may be practiced in the near future. Many of the major metropolitan areas of Japan are beginning to exhaust readily available water supplies. A regional system employing one or a few large central plants might tend to restrict recycling and reuse in several ways. Although large effluent flows would be available at the plants, there would likely be significant pumping and piping costs if these water supplies were returned to the users. Also, residual pollutants from a complex waste stream containing mixed industrial and municipal flows might inhibit reuse for some purposes. Central plants, however, might be cost effective for treating residual waste flows even if extensive reuse and recycling is practiced prior to discharge. Available water supplies and projected water losses during reuse and recycling would indicate the needed capacities of plants and interceptors.

In comparison, a decentralized regional system would allow users to take ready advantage of existing treatment capabilities prior to reuse and recycling, and it would allow individual matching of local reuse opportunities and local spent water supplies. One discussion of a complex pattern of multilevel reuse is given by Sueishi (24).

Land-use issues are also frequently important in planning regional systems. First, it is necessary to find plant sites. Large central plants require large land areas, but fewer sites are needed than for a more decentralized design. Thus, availability of land and parcel sizes might be very important in designing a regional system. In Japan only 16% of the land is reasonably level, and extreme measures may be taken, as illustrated by an example below. Japan has a long history of bitter

struggles during the acquisition of land for public projects. In open areas, many farmers typically own small plots and are very reluctant to part with land which may have been held by the family for many generations. Furthermore, since farmland is rarely placed on the market, it is very difficult for displaced farmers to replace their land. In many cases, they have had social problems in adapting to different occupations. As of now, no governmental program is in effect to help them relocate.

An example which demonstrates the difficulty in obtaining plant sites in Japan is the Lake Biwa regional system. This area is located about 50 miles (80km) north of Osaka and just east of Kyoto. The lake, with 263 square miles (680 km^2) of surface area, is the largest in Japan; it is used extensively for recreation and commercial fishing as well as for domestic and industrial purposes. The current plan in this region calls for four distinct drainage areas around the lake; each area will have one treatment plant.

One of these districts is expected to produce 263 million gallons (1 million m^3) of wastewater per day, with almost 50% being industrial. Since no adequate land site for such a large plant is available, an artificial island (153 acres, or 260,000 m^2, in size) is being planned in the lake. The sheet piles for this island have already been driven, as shown in Fig. 3.

Opposition has arisen because of the potential impact of this island and because of the large volume of industrial waste. The latter issue is of concern to the people in the immediate area of the plant site and downstream along the river which flows from the lake. Construction of the plant was halted pending an interdisciplinary assessment of the pro-

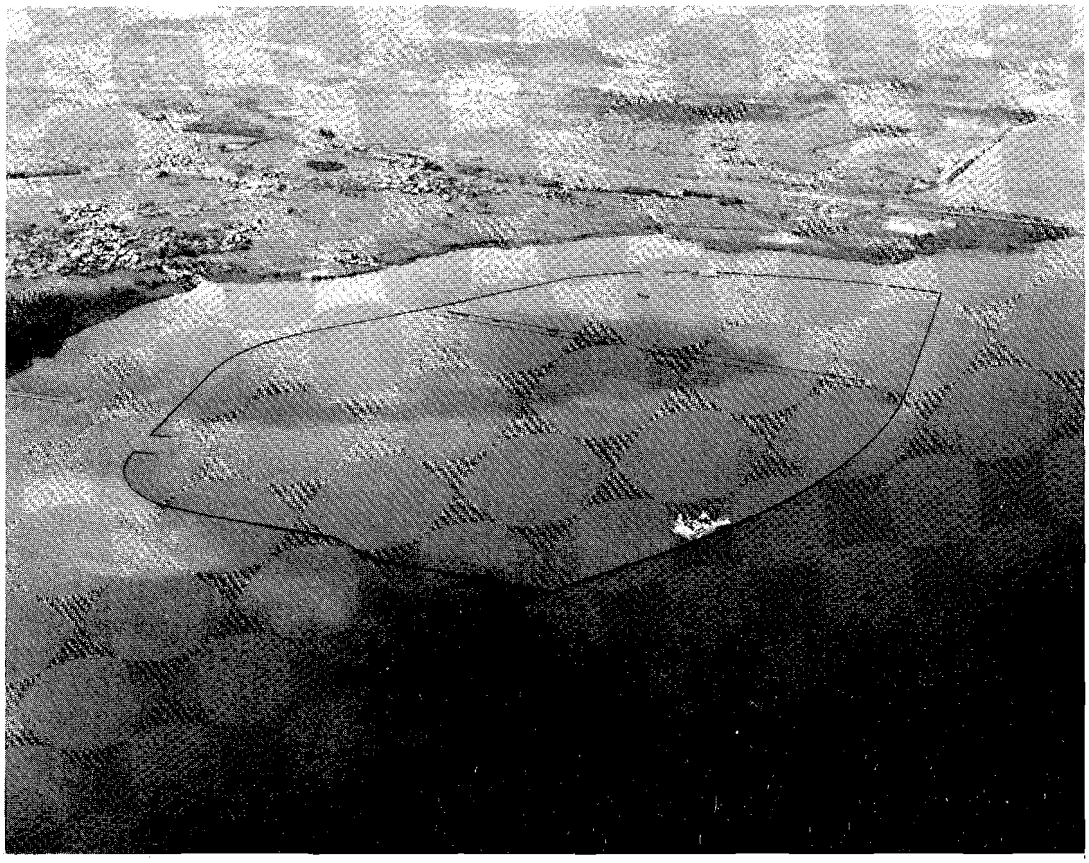

Fig. 3. Artificial Island for a Plant Site in the Lake Biwa Regional System

ject's impact. Although significant impacts were identified by this assessment, the prefectural government has decided to continue construction of this single project. The governor of the prefecture has concluded, however, that additional projects endangering Lake Biwa will not be undertaken.

Additional difficulties which are inherent in siting large facilities in densely populated areas are obvious by inspecting Fig. 4, an aerial view of a large plant operated by the Tokyo metropolitan government. In addition to problems in finding plant sites, there may be limits on the interceptor sizes that can be used because of the narrow roads in such areas. Furthermore, there is a tremendous potential in these areas for interrupting local social systems, such as neighborhoods and transportation, and creating local nuisances--both on a temporary basis during construction of plants and interceptors and on a permanent basis during plant operation.

Measures can be taken to ameliorate many of these problems and to use the site as a neighborhood asset. Many of the central plants constructed or planned in Japan are designed like the one shown in Fig. 4. Facilities are covered and vented, and vented air is sometimes treated to control local odor problems. Also, as shown, covered facilities can be landscaped and the entire site can be used to provide valuable open space and recreation opportunities. Many existing or planned sites provide baseball fields, tennis courts, swimming pools, and other recreational facilities for local citizens. Additional features of this sort, of course, may add significant expenses. For example, the covered facilities at the Kitatama No. 1 regional system in Tokyo Prefecture were estimated

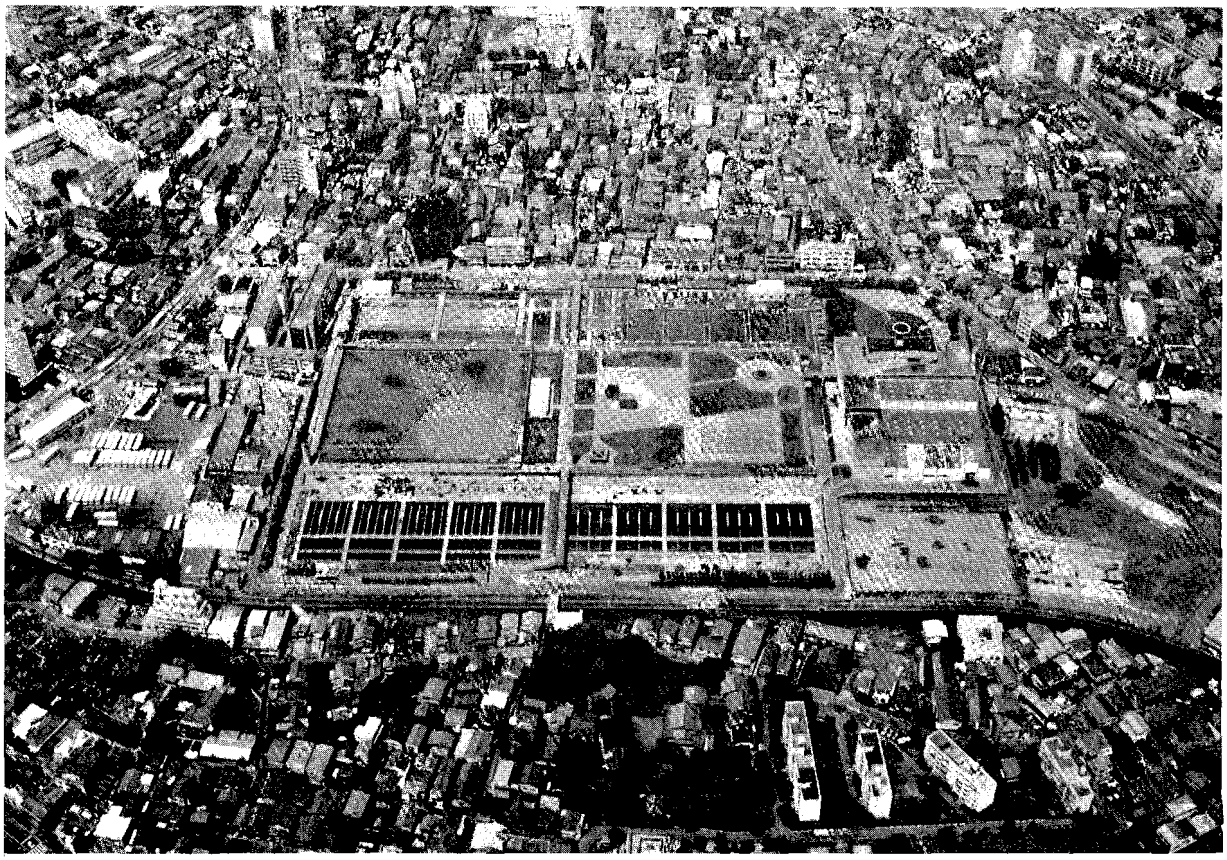

Fig. 4. Treatment Plant in Tokyo Metropolitan Area

to cost 2.5 to 3 times as much as similar uncovered facilities.

Residual pollution problems may also be feared by local citizens in both rural and urban areas. Heavy metals and other hazardous materials, or residual water pollution, may cause alarm among farmers, fishermen, or other nearby inhabitants. Together with the possible nuisances described above, these fears (however well founded) may form the nucleus of local opposition.

Other land-use issues are also important--particularly those associated with regional growth. An interceptor constructed to tie together different communities may promote urban sprawl along its route. Surprisingly, this issue did not seem to be a major one in the prefectures visited. In fact, large interceptors are sometimes planned prior to development between communities to avoid problems with future traffic. Interestingly, in some cases the prefectural governments construct "sewerage roads" which are likely to be paved to form new roads when development occurs. In comparison, the potential relationship between interceptor routes and urban sprawl is often a major issue in the United States (3).

Also, regional facilities are usually planned using projections of municipal and industrial growth; as a result, they have been opposed by no-growth advocates in Japan. While central plants as well as decentralized plants can be built in stages as growth develops, the sizes of the plant site and of the main interceptors, which are built at the outset, are frequently determined on the basis of an ultimate design population. In this regard, regional treatment systems require more detailed planning, while decentralized systems offer greater flexibility in adapting

to future developments. A counterpoint to this argument is that it is easier to predict growth for a region than for individual communities since there are local perturbations which may tend to average out when summed. Thus it may be easier to project waste treatment needs on the average (but not necessarily interceptor capacity needs).

Another often-heard argument (in Japan and the United States) regarding growth is that since facilities are designed with excess capacity, there is a tendency for the plans to be self-fulfilling: if the capacity is provided, there is a tendency to use it. According to this argument, the reasons are that unit user charges may be lowered if new users are added and that there is too great an incentive for waste-producing activities if treatment is, in actuality, subsidized. These incentives may encourage additional growth.

Land use, growth, and water reuse and recycling are also interrelated. As pointed out by one Japanese official, it is possible that regional systems could be designed for limiting populations and industrial activity and could be used to some extent as a brake on additional growth. In contrast, recycling and reuse throughout a region might allow unchecked development.

Institutional Arrangements - In Japan, regional planning is carried out by the prefectural governments with the cooperation of the local communities. The prefectures also own and operate the central plants and the interceptors connecting the communities. (Each community must provide its local collection system with some financial support from the central government.) The central government subsidizes one third

of the costs of the planning activity and pays approximately 75% of the construction costs of the regional systems. The prefectural and local governments share the portion of the construction costs not subsidized, and the communities pay for the operation and maintenance (O+M) costs. Industries must pay the prefectural government for their full share of the amortized construction costs as well as O+M costs. Interestingly, the prefectural governments retain the payments for the portion of the construction cost subsidized by the central government; this arrangement provides an ongoing revenue source for managing the regional systems.

In most of the Japanese prefectures visited, opposition has arisen within the community where the central plant is located from citizens in the immediate neighborhood of the proposed site. In the United States, additional opposition frequently occurs within such a community because wastewater is imported from other communities; traditional rivalries and local autonomy may lead to resistance. In addition, the other communities may oppose the plan because they may want to retain control over their own waste treatment system since this control may be -- or be perceived to be -- important in the future with regard to issues such as controlling growth and land use (28). Efforts, such as those in Japan described above, to develop neighborhood amenities and to control nuisances may offset some of the local problems. In general, however, issues of ownership, management authority, cost allocations, and incorporation of existing facilities may complicate the formation of a regional system; all of these factors have been observed to be important, for example, in the DuPage County, Illinois case.

In the Japanese prefectures visited, however, institutional arrangements for implementing the regional programs were reached relatively easily. The central and prefectural governments provided strong leadership, and the local governments are less autonomous than in the United States. Also, the new systems were planned for the many regions that previously had very limited sewerage service; most existing plants were inadequate, unpopular, and easily phased out of service. The few large metropolitan systems already in existence (such as in Tokyo) were not included. Thus, very few difficulties arose because of existing facilities. Many other ownership issues are avoided because the facilities are owned by the prefectural governments.

Political boundaries have cause surprisingly few major disputes in Japan. At the prefecture level, there are some problems in cases when the final waste discharges from one prefecture flow into another. Also, some interceptors have been routed so as to avoid crossing prefectural boundaries when more direct routes would have been slightly less expensive to construct. In general, disputes have been few in cases where one prefecture covers both sides of a major river, and delays have arisen in cases where the major river divides two prefectures.

Also, because implementation and planning are carried out by the prefectural governments in Japan, many local issues are transcended. Cases were found where the prefectural government was able to offer various types of compensation for the inconvenience to communities where plants were located. Compensation took the form of commitments for other grants to the community (e.g., for new town halls, roads, or recreational facilities) or of agreements to provide such facilities earlier than had been previously planned. Thus, if planning and implementation

is carried out by a higher body dealing with more than simply wastewater treatment, political compromises may be more easily attained because of the additional degrees of freedom.

A similar and fascinating observation about one regional system in Japan is that seven communities reached a compensation agreement with an eighth community which was the most economical location for a central treatment plant. Approximately $100,000 each year for seven years is paid to that community (of 75,000 people) solely as compensation for the nuisances associated with the treatment plant.

It should be emphasized that regional planning by the prefectural governments has made it possible to look at all planning factors, such as water quality, water supply, and cost, for the region as a whole. In some cases throughout the world, a prior institutional structure may not exist. In such cases, the use of a newly created centralized system may allow a streamlined and comprehensive approach to planning and implementation. Furthermore, the ongoing administration is simplified. Together, these characteristics may lead to clear-cut responsibilities and a high degree of accountability for a region as a whole.

Public Information - Japan has traditionally placed limited emphasis on public participation in planning such projects, and public involvement is not required by law. As in the United States, however, the importance of public involvement has been recognized to a greater extent in recent years. As one step in this direction, government officials found that public information programs were needed to describe exactly what would be done at the treatment plants. Several officials indicated to the authors that many citizens initially opposed the plants because they believed that night soil would be

collected there and that nearby areas would suffer massive odor problems. Public information programs that have been undertaken by the prefectural governments include hearings, meetings with citizen groups, and open houses and tours at the regional plants once constructed. (Many plants are designed to include large observation decks for this purpose.) As a comparison, the scale of these programs significantly exceeds that of similar efforts in the United States.

Similar approaches were taken in constructing interceptors which caused temporary inconveniences. One private construction firm employed a full-time public relations person to keep the citizens in the vicinity of the construction personally informed of the purpose of the project and its progress. Prior surveys conducted by this firm indicated strong displeasure on the neighbors' part, but after the information campaign was underway, the surveys showed acceptance based on understanding. Such public relations measures are routinely undertaken in Japan.

SUMMARY AND CONCLUSIONS

This paper provides an overview of the intensive effort underway in Japan to provide sewage collection and wastewater treatment. The emphasis on regional planning and on the utilization of central treatment facilities is described.

Based on a study in Japan, a discussion is provided of many factors which are potentially important--regardless of the country--in planning a regional wastewater treatment system. Cultural and historic conditions have been shown to be important in Japan. Economies of scale, effectiveness, and flexibility are discussed in relation to the use of large central treatment plants. An overview of interrelationships between wastewater systems and drainage, water supply, and land use is then given. Interactions between planning agencies and local citizens are also discussed, as are interactions between communities. The discussion provided here is by no means complete; wastewater collection and treatment represent a social service with a unique and extensive array of constraints and objectives to be evaluated in any given case.

The Japanese experience, still underway, is a significant and valuable one in the history of planning regional wastewater treatment systems. The planning issues identified through that experience should provide additional guidance as new systems are planned in the United States and throughout the world. It has been shown that such planning activities are extremely complex public-sector problems and call for an interdisciplinary approach.

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