demands. With a pressure-regulation station at the up-stream end of the system, the pipeline could be designed to withstand the lowest source-delivery pressure (which was the only pressure guaranteed by the supplier), rather than the highest pressure. Enough savings were realized to pay for the cost of the pressure regulation station.

In the case of spreading-grounds, thought should be given to the surrounding neighbourhood. If operations are sustained, insect problems will undoubtedly occur. If they are serious enough, then the public will apply pressures to the extent that operations be changed to minimize the problem. If the grounds are large enough to permit considerable latitude in operations, this may not be serious; if not, then unit costs of water-spreading will undoubtedly rise. In addition, it may be necessary to make the facility aesthetically pleasing to the neighbourhood. This may involve screen planting. Initial costs may be high, as water supply facilities, as well as plants, are required. Maintenance costs are likely to be high, too.

Another area which cannot be overlooked is the cost of a highly trained technical staff. High costs demand that operations be efficient. To make them efficient requires that good records be kept, and proper reporting and careful analysis of the system be made periodically.

B. Legal aspects

Although one would assume it to be accepted without question that a resource as valuable as ground water should be controlled and managed in accordance with modern concepts of resource development, the fact is that ground water in most parts of the world is still subject to little or no control of this kind. The explanation lies mainly in the widespread ignorance of how, where and why ground water occurs. Even in very recent times, for example, it was commonly believed that ground water flowed mysteriously in underground rivers and that the sources of these rivers were in remote regions. Few people had any notion of the science of hydrogeology and, under those circumstances, it is easy to understand why Governments and legislators could not devise rational control measures.

A second complicating factor is that ground water has been thought of as a property or mineral right, so that the landowner believed that he owned the ground water and could do with it as he pleased. Thus, if one man pumped large amounts of ground water from his own wells, and if this, in turn, caused a depletion of ground water on neighbouring tracts of land, little or nothing could legally be done about it. However, as the science of ground water has developed in recent decades, it has become apparent that many of the old views of this resource are incorrect. More and more, Governments are coming to realize that the waters beneath the surface of the land constitute a common resource, to be utilized by a number of users for the benefit of all. Ground water cannot be apportioned on the basis of artificial property boundaries, because a withdrawal of water by any individual user quite clearly affects the ground water beneath adjacent tracts of land. With this growing understanding of the science, has come a greater appreciation of the need for control and management by public regulatory authorities. The systems of acquisition of ground-water rights, which are the rights granted or recognized by law or custom to take possession of water occurring in a natural source of water-supply, and generally to put it to beneficial use, vary widely from one country to another, mainly according to a climatic pattern. Thus, in areas where there is a water surplus, the "private ownership" doctrine is generally accepted; whereas, in areas

basin + country = OT, 15

Table 8. Costs of artificial recharge
(1971 dollar per 1,000 m^3)

Area and description	Capital costs	Operation and maintenance costs	Total	Type	Remarks
France					
Croissy area; chalk reservoir annual spreading, 11,000,000 m^3			60.00	Spreading	
Federal Republic of Germany					
1. Dortmund area; alluvium reservoir; annual spreading, 5,000,000 m^3			30.00-40.00	Spreading	
2. Dusseldorf area; alluvium reservoirs; annual spreading, 60-70,000,000 m^3			120.00	Spreading	High cost attributed mainly to treatment
3. Frankfort, alluvium reservoir			10.00	Injection	A lateral leaching line from the river
Israel					
1. Sandstone and limestone formations 80,000,000 m^3 annually injected		14.30	14.30	Injection	Multipurpose wells; capital costs justified for extraction purposes, therefore only operation costs attributed to injection
2. 20,000,000 m^3 maximum; local water spread annually into sand dunes then into sandstone			50.00	Spreading	All costs included; costs vary widely, depending upon abundance of water
Japan					
Unconsolidated formation; injection test, fixed-assets cost ¥97,353, represents first year's operation, injection of 1,947,175 m^3 from November 1961 to September 1962		19.00		Injection	

Table 8. (continued)

Area and description	Capital costs	Operation and maintenance costs	Total	Type	Remarks
Switzerland					
Basel area; alluvium formation			25.00	Spreading	
United States of America					
Los Angeles area; spreading in unconsolidated formation; injection into confined but unconsolidated formation					
1. Local storm run-off; costs based on seven spreading grounds, and 683,492,000 m^3 total spread	4.16	6.25	10.41	Spreading	
2. and five spreading basins; costs based on 98,796,508 m^3 total spread	7.52	7.18	14.70	Spreading	
3. Imported, untreated Colorado River water, costs based on 1,472,101,000 m^3 total spread		0.78	0.78	Spreading	Utilizing existing facilities which were justified for spreading local storm run-off therefore, only operations and maintenance costs are attributed to spreading, not including cost of water, which at 1969 prices is \$16.21 per 1,000 m^3

Table 8. (continued)

Area and description	Capital costs	Operation and maintenance costs	Total	Type	Remarks
United States of America (continued)					
4. Reclaimed waste water, costs based on 65,080,000 m^3 total spread	1.64	1.64		Spreading	Utilizing existing facilities, which were justified for spreading local storm run-off; therefore, only operations and maintenance costs are attributed to spreading, not including cost of water, which at 1969 prices is \$14.59 per 1,000 m^3
5. West Coast Basin Barrier Project; about 55,000,000 m^3 injected annually; total fixed assets costs about \$7,000,000 (all construction not yet complete)	5.87	7.49	13.36	Injection	Not including cost of water, which at 1969 prices is \$20.26 per 1,000 m^3
6. Alamitos Barrier Project; about 5,550,000 m^3 injected annually; total fixed assets costs about \$2,500,000 (all construction not yet complete)	20.96	35.95	56.92	Injection	Not including cost of water, which at 1969 prices is \$20.26 per 1,000 m^3, not including operation and maintenance for extraction wells

The table presents actual costs of artificial recharge now being carried out in various parts of the world. Where known, costs have been broken down to show both capital expenditures and operation and maintenance expenditures. If the operation and maintenance cost is considered to be the only cost, it is shown in both the "Operation and maintenance" column and in the "Total" column. In the case for Japan, only the operation and maintenance cost was known; no figure was included in the "Total" column.

where there is a water deficiency, especially those located in arid or semi-arid zones, ground waters are generally considered to be public property and, therefore, part of the public domain. A number of other situations related to the main concepts of private ownership and public property are summarized below.

The common-law rule of absolute ownership recognizes ownership of ground water by the owner of overlying land and places no restriction upon the owner's right of use of the water on his overlying land, or elsewhere. This doctrine considers the owner of the land to be the owner of all the water in the underlying aquifer, and not merely to have the right to the use of this water; in England it is also known as the rule of "unlimited use"; and in the United States of America as the doctrine of "land-ownership". It is a common legal concept in Canada, most of Europe, part of Latin America and in the eastern portion of the United States.

The rule of "reasonable use" recognizes ownership of ground water by the owner of overlying land, but limits the right of use of the water to such use on, or in connexion with, his overlying land, as is reasonable with regard to the similar rights of all other owners of lands which overlie the same source of water supply. A variation of this rule is the doctrine of "correlative rights", which stipulates not only that the use should be reasonably beneficial to the owner's land, but that the owner is entitled only to his reasonable share, if there is not enough water to supply the needs of all. These doctrines are mostly in force in certain states of the United States in order to attenuate the rule of absolute ownership. Similar doctrines are found in southern Europe and in some countries of Latin America.

According to other doctrines, the owner of the overlying land is entitled to use the ground waters under it only if he complies with certain legal provisions which put his activities under government control. Usually, he merely has to notify the administrative authority concerned. Sometimes, however, the stipulations go so far as to require prior authorization from the administrative authority in the form of a permit or a concession. In most cases, such notification or authorization is not necessary when the water is used only for domestic purposes and the watering of animals.

Under doctrines somewhat similar to the one just mentioned, private ownership with appropriate administrative control is still the rule, but there are areas of a country, sometimes known as "restrictive areas", where more rigorous administrative regulations are applied. In some cases, for example, a permit may be required for the drilling of a well, but there are special areas where it is further stipulated that drilling must be carried out according to very strict administrative specifications.

According to the concept of public property, ground waters are part of the public domain and belong to the public. Consequently, the Government has a duty to ensure that ground waters are used in the best interest of all concerned and that ground-water rights are under administrative control. Where ground waters are held at law to be public property, their use by private individuals must be reported to the appropriate administrative authority and may require official sanction.

In some countries any individual may, with administrative authorization, obtain a concession for water rights on or under any person's land without having to pay an indemnity to the landowner. However, where the concept of public property prevails, there are usually restrictions on the free use of ground water by any individual or corporation.

shown in both the "Operation and maintenance" column and in the "Total" column. In the operation and maintenance cost was known; no figure was included in the "Total" column.

In certain countries of North Africa and the Middle East, ground water brought to the surface by human effort can be used freely only by the person or persons who have done this work. However, when the extraction of water is made for the purpose of investigating natural subsoil resources other than water, the water can be used by those engaged in these investigations only to the extent necessary for such work. Any surplus water goes back to the public domain.

Elsewhere, anyone who has beneficially used ground water from a natural source on or under any land, for a certain period of time, is the rightful user of this water. This is the doctrine of "prior appropriation", which is prevalent in most of the western states of the United States and in several countries of Africa and the Middle East. The time element alone, the fact of being the first to use the water, confers preferential rights. Logically, misuse of the water should result in loss of these water rights, and from this stems the doctrine of "prescriptive rights". Such prescription of rights is sometimes applied to owners of overlying land who have not been using their ground waters for a certain period of time.

A summary of the variety of legislations and customs presently existing in the world for ground water is presented in a recent United Nations publication on water legislation. 4/ The need for legislation for water resources as a whole which would take into account the close links which often exist between water in surface streams and ground water stored under riverbeds in banks, or up-stream of springs, is now acknowledged in a number of countries.

In several industrial countries, legislation has been established to protect ground water in storage against pollution and over-draught. However, it should be noted that very often these measures have been taken under emergency situations, such as when pollution and over-draught had already significantly endangered the resource. Such examples should serve as a warning for areas where ground-water development is expanding and where new industrial and housing projects are being implemented. For too long ground water has been considered as a kind of self-renewing mineral which could be indefinitely extracted by anyone on his own piece of land or under concession by the landowner, without any further restrictions. The lack of a sound legal basis often has made it very difficult to introduce efficient administrative control-measures.

A workable legal basis for ground-water administration must take cognizance of the following points:

(a) Ground water occurs in natural hydrogeological units which have to be defined by experts. These boundaries commonly do not coincide with political or administrative boundaries;

(b) Ground water should not be regarded as property of any particular user or landowner; but rather as a natural asset of the whole community; and

(c) Ground-water exploitation should proceed under license and in a controlled fashion, keeping in mind previous customary rights, as well as the need to maintain the natural asset for the benefit of the whole community.

4/ Abstraction and Use of Water: A Comparison of Legal Régimes (United Nations publication, Sales No. E.72.II.A.10). See, in particular, chapter II.

Even if the legal basis of ground water is adequate, there arise a number of administrative questions. For instance, owners of private wells have little inclination to measure accurately the quantities of ground water which they pump. Quite mistakenly, owners of private wells feel inclined to conceal the truth, if asked questions by inquisitive government officials about pumpage. Conceivably, they do not themselves know how much water they actually extract. In order to obtain reliable information on the degree of exploitation and to apply control measures, water meters must be installed, maintained and periodically read by the competent authority. All other methods, such as estimates based on irrigated areas and hours of operation of the pumps, are only makeshift measures. Controls should also be extended to the construction and modification of bore-holes, which should proceed only under licence from the competent authority. It is advantageous to make the driller legally responsible for holding a licence for each bore-hole he drills. If the driller contravenes the law, his rig may be temporarily impounded on the spot and the illegal work may be stopped at once. If the law holds the client legally responsible for obtaining the licence, it may be difficult to actually locate the client, as the driller need not have to know the client, in the legal sense of the term, and the work may proceed practically unchecked.

Owners of private wells usually do not have the feeling of sharing an asset with their neighbours, although they may only be a short distance away. This peculiarity stems from the rather mysterious attributes with which ground water is bestowed in the eyes of most people. A patient effort of education is, therefore, necessary. Water users have to be informed of the characteristics of the reservoir they are tapping. The periodic publication of maps showing ground-water level, salinity and other data, would help make them aware of the realities involved.

Ground-water legislation has proved to be ineffective in a number of cases for three reasons: first, the landowners often consider that ground water underlying their property is equally their private property, and that dumping on their property is their right; secondly, it is difficult to check the quantity of water which is extracted from hundreds or thousands of wells in an area, even the use of metres has often proved to be ineffective for this purpose; thirdly, the laws and usages of many countries do not permit easy access into private property by the personnel who normally would be in charge of enforcement. A special effort should therefore be made to make the users of ground water aware of their common interest in obeying the regulations and accepting the controls. The need for making land available as public property, or for reserving space in development projects for recharging ground-water reservoirs should also be mentioned. Certain aspects of this problem were mentioned in chapter III and are illustrated in part two (case studies No. 17, Long Island Recharge Schemes and No. 18, Los Angeles County.)