6 Economic and social impacts and legal considerations, by Joseph F. Poland, Laura Carbognin, Soki Yamamoto, and Working Group

6.1 GENERAL COMMENTS

Land subsidence induces very serious economic and social problems, which unfortunately appear later than the commencement of the subsidence event and when most damages are irreversible.

Because intensive ground-water withdrawals often occur in urbanized and/or industrial areas, the subsidence effects are widespread and affect not only the natural structures but also the man-made ones. In general, and sad to say, damages may be recorded but it is nearly impossible to establish their actual cost.

The physical environment is a principal determining factor in the severity of economic and social impacts as a result of land subsidence due to ground-water withdrawal. Coastal-plain areas, initially 1 to 5 metres above mean sea level, are susceptible to severe impact if appreciable subsidence develops. The severity of the damage and the social problems to be anticipated are greatly increased if the subsiding area lies in a region subject to typhoons or hurricanes. Furthermore, the greater or more calamitous is the actual, anticipated, or potential damage, the greater is the likelihood that legal decisions may develop to modify the doctrine of absolute ownership or the doctrine of "correlative rights," with respect to liability for subsidence of the lands of others due to pumping of ground water.

Table 1.1 lists 42 subsidence areas worldwide. Of these, at least 19 border the ocean or a bay and 2 others are crossed by tidal rivers. In this casebook it is not practicable to discuss economic problems and legal considerations for all the subsiding areas. Therefore, in this chapter we will limit the discussion to a few significant socioeconomic problems and legal developments in Italy, Japan, and the United States.

6.2 ITALY

Reported cases of subsidence in Italy due to ground-water withdrawal are few because not all the occurrences have been identified and classified as of yet.

Venice and Ravenna cases (case histories 9.3 and 9.15) must be included among the more serious; the former for its precarious environmental setting in which the phenomenon occurs even if at low rates, the latter for its areal extent and intensity.

Both cases were brought about by the intensive exploitation of underground fluids, occurring with the Italian post-war industrial boom during the 50’s and the 60’s. in both cases exploitation occurred without taking into account possible consequences to the subsoil equilibrium.

After 20 years of continuous ground-water withdrawal, subsidence has by now greatly affected the environment and its consequences are dramatic and even more serious for the irreversible effects.

Both Ravenna and Venice are located in shallow coastal zones so that the well-known subsidence effects are worsened because the land-sea interaction is considerably reduced.

Ravenna, about 7 km from the coast, is periodically flooded because its defences are no Longer sufficient against seasonal stormy seas. Venice, built in a lagoonal environment, has a close relationship with its waters and even with just normal tidal events the city becomes partially submerged and socioeconomic activity nearly stops.

Whereas Ravenna’s historical center is somewhat protected from marine aggression, Venice is continually exposed to sea domination, thus assuming a dismal appearance which naturally conflicts with the goal of the picturesque tourist attraction. Damages are enormous for both the artistic patrimony and the normal life activity (ruined merchandise, failures in heating systems, short circuits in electrical systems, etc.).

These inconveniences are a menace to the increasingly unstable socioeconomic life because of the frequently occurring flooding paralyzing the city, for health reasons (a very humid environment), for sanitary purposes (faulty sewage system), etc.

All this and other social reasons contribute to the Venetian exodus. For this reason, the city is witnessing a rapid decline in population, especially of its poorer working classes which suffer more than the others for their ghetto-like living conditions.

Depopulation occurs even in the islands and in the least defended littorals (ex. Pellestrina). The closer and more modern industrial area (Marchera) is the greatest attraction for more modern living conditions even if there are more psychosociological stresses.

At Ravenna subsidence affects especially the littoral zones (beach regression) where the largest resorts are located, and the widespread land fills where the usable soil thickness for cultivation is reduced and the types of cultivation must be diversified. Moreover subsidence causes considerable hydraulic problems in river flow in the delta zone, facilitates salt-water intrusion at the river's mouth, and produces problems to inland navigation, in the sewage system, etc.

Although at Ravenna, the damages are very serious and economically severe they are not as dramatic as at Venice where subsidence becomes a factor of survival.

At Ravenna the hydraulic problem would almost be permanently resolved after constructing suitable sea defences and restoring older hydraulic structures. The irreversible sinking of the area greatly affects only the littorals which are diminished in their width.

In Venice the sluice gates proposed to be constructed at the inlets to control the lagoon's water level would only partially resolve Venice's complex problem; resulting changes in the lagoon ecosystem would necessitate heavy commitments for a solution.

Even if subsidence is not the main factor responsible for the slow death of Venice, without a doubt its effects have indirectly determined this evolution. This leads to the necessity of concrete interventions.

The two worst Italian cases of subsidence just described involve two very important cities because of their unusual environments and artistic patrimonies. In these cases, as well as in many other Italian cases, the cause should be sought in the haphazard territorial planning in overestimating the possibility of utilizing ground-water resources.

Strict legislation for control and regulation of environmental use plus an efficient supervising organ for the development of underground waters would have safe-guarded the areas. Unfortunately, in Italy, public institutions and laws for territorial protection against subsidence effects due to ground-water withdrawal do not exist. Underground water management is still governed by an old law of 1933, which is only effective in a few municipalities. Furthermore, such legislation deals only with the authorization to search for water and, then, the declaration of finding it.

After the 1933 law, there has been no legislation which establishes any control on artesian pumping for the defense of the territory against subsidence. Only in recent years has government's attitude changed mainly due to the alarming situations which arose in Venice and Ravenna.

So far no specific norms or restrictions have been adopted: Italian government policy leaves preventive measures restricting ground-water exploitation to the local authorities.

6.3 JAPAN

6.3.1 Socioeconomic impacts

Land subsidence has been reported in more than 40 areas in Japan; most of these areas are subsiding because of excessive ground-water withdrawal and consequent declining artesian head. Many of the large cities in Japan are built on low flat alluvial plains underlain by unconsolidated water-bearing deposits of Quaternary age. The 10 chief subsidence areas due to ground-water withdrawal (shown in Figure 1.1 and described in Table 1.1) all border the ocean; in several of these areas subsidence has lowered the land surface below sea level, creating a hazardous situation. Yamamoto (1977) reports that as of 1975 the areas of land subsidence in Japan totaled 7,380 km^2, of which about 1,200 km^2 was below mean sea level.

The prolonged subsidence since 1920 in the Koto district in the eastern part of Tokyo developed the most serious environmental subsidence problem in Japan and probably in the entire world. The artesian head in the confined aquifers, initially above sea level, declined to as much as 60 m below sea level by 1965. The long-continued head decline, due to excessive withdrawal of ground water for industrial plants, caused the subsidence. As a result, 80 km^2 of land in eastern Tokyo had sunk below mean high-tide level by 1969; the lowest ground was about 2.3 m below mean sea level (Shimizu, 1969, Table 3). Two million people live in this area bordering Tokyo Bay. To prevent flooding and loss of life many protective measures have been taken. These have been described in part by Yamamoto in Case History 9.4. Banks of through-flowing rivers have been raised several metres, a wall has been built to surround the entire area that is below high-tide level, and many water gates have been built to prevent high water from entering the depressed area.

During the early 1960’s, restrictions were established on pumping from certain depth zones and drilling of new wells, and extraction of ground water for industry in the Koto district began decreasing. By 1965 pumpage had decreased by one-half (Aihara, et al., 1969, Fig. 1). As a result the artesian head subsequently has recovered 10 to 30 m or more since the 1965 low level, and the land surface has almost completely stopped subsiding. In fact, a few centimetres of land-surface rebound has been observed. However, the rebound never will amount to more than a few per cent of the subsidence. Consequently this area and its resident population of two million people are faced with the fact that all water originating in the area below sea level, or introduced into the area for domestic or industrial supply or by flooding, will have to be pumped out as long as people live there or possibly until the land surface might be raised above sea level by a long-term project of importing a massive landfill. Despite the protective measures taken, the danger of major flooding due to typhoons or to failure of dikes or pumps caused by a violent earthquake is ever present.

Two other subsidence areas in Japan have extensive areas that have sunk below high-tide level. They are Osaka (100 km^2 below high tide) and the Nobi Plain (363 km^2 below high tide). Together with Tokyo they contain about half of the land that has subsided below hightide level in Japan. More than one million people lived in the two areas in 1969. Beginning in the early 1960’s the use of ground water in Osaka has been regulated as an alternate supply of surface water became available. As a result a sharp recovery of artesian head occurred in Osaka, beginning in 1962 (see Case History 9.5, Figure 9.5.4); by 1965 the rate of subsidence had decreased markedly. Protective measures taken are similar to those adopted in eastern Tokyo. All areas below sea level are faced with the problem of how to minimize damage from a typhoon.

6.3.2 Ground-water law in Japan

Japan has two laws which regulate and or prohibit ground-water utilization. One is the "Industrial Water Law" and the other is the "Building Water Law." Japan has no law regulating ground-water withdrawal for irrigation (agricultural use).

The Industrial Water Law (law No. 146 CF 1956) is aimed at making contributions to the sound development of industries and the prevention of subsidence of the ground by ensuring a rational supply of industrial water and achieving the conservation of ground-water resources.

The areas where drawing of industrial ground water is controlled are designated by Cabinet Order out of areas where drawing of ground water is causing an abnormal drop in the ground-water level, salinization or contamination of ground water, or subsidence of ground, and water services for industrial use are already installed or the installation work is expected to be commenced within a year.

Prefectural governors issue pumping licenses mentioned if the position of the strainer for the well and the sectional area of the discharge port of the pump fulfill certain technical criteria.

The Building Water Law (law No. 100 CF, 1962) is aimed at protecting the lives and properties of the people by exercising necessary control in order to prevent the subsidence of ground as a result of drawing ground water for buildings at the specified area.

Areas where drawing of ground-water for buildings is controlled are designated by Cabinet Order out of areas where drawing of ground-water for buildings is liable to cause the subsidence of ground and resultant damage due to the high tide and flood.

Prefectural governors or mayors of the designated cities issue licenses upon request from interested individuals provided the position of the strainer for the pumping facilities and the sectional area of the discharge port of the pump fulfill certain technical criteria.

Those who are already drawing ground water for buildings when the area concerned is designated shall be considered to have obtained the license, if their methods of drawing ground water for buildings fulfill the technical criteria, and even in the case of failure to fulfill the technical criteria, they shall be treated as having a license, in principle, for a certain limited term exceeding two years.

The pumping of ground water without a license is punishable with a prison term of less than one year or a fine of less than ¥100,000.

In Case History 9.4 for Tokyo, Yamamoto describes in chronologic order the application of restrictions under the "Industrial Water Law," beginning in 1961, and restrictions under the "Building Water Law," beginning in 1963. The restrictions under the "Industrial Water Law" are designed to reduce ground-water withdrawals by supplying substitute water. The restrictions under the "Building Water Law" are designed to limit the pumping of ground water for air conditioning and other non-drinking purposes in medium and high-rise buildings (see also Figure 9.4.9).

The local Metropolitan Environmental Pollution Control ordinance restricted the drilling of new wells in areas not covered by the two National laws described above. Also, in 1972 the Tokyo Metropolitan Government bought the mining rights to ground water containing natural gas, thereby stopping the pumping of gas-bearing water from wells 800-2,000 m deep tapping the Kagusa Group of Pliocene age.

The case history of the Nobi Plain (ch. 9.6) contains, two pages of detailed regulations for the withdrawal of ground water. Two small areas (see Figure 9.6.7) designated by the Industrial Water Law are supplied by industrial water from surface sources. Ground-water withdrawal in the remainder of the area is covered through regulation by ordinances of prefectures or of cities (by regulation zone determined by rate of subsidence per year). These ordinances specify depth of well or strainer, inside area of discharge pipe, the power of the pump motor, and the total daily discharge of the well. These complex regulations doubtless are related to the fact that 248 km^2 of the Nobi Plain were below mean sea level in 1976. The regulations have been established in an attempt to minimize the decline of artesian head, the compaction of sediments, and the rate of land subsidence.

6.4 UNITED STATES

6.4.1 Economic and social impacts

Table 1.1 lists 18 areas of land subsidence in United States due to ground-water withdrawal and Figure 1.2 shows the geographic location of 17 (not including the Alabama sinkhole area). Four of these areas border the ocean or bays but two--Savannah and New Orleans--have relatively minor subsidence problems compared to the Houston-Galveston area, Texas, and the Santa Clara Valley at the south end of San Francisco Bay in California. Ranked in terms of the severity of socio-economic problems the three principal subsidence areas in the United States due to ground-water withdrawal are (1) the Houston-Galveston area in Texas, (2) the San Joaquin Valley in California and (3) the Santa Clara Valley in California. Environmental and economic effects of subsidence in these three areas are discussed briefly in following pages. For an expanded analysis of economic effects in these and several other subsiding areas, the reader is referred to a report by Viets, Vaughan, and Harding (1979).

6.4.1.1 Houston-Galveston area, Texas

The principal detrimental effects of land-surface subsidence in the Houston-Galveston area are (1) structural damage, probably due to faulting, that has cracked buildings and disrupted pavements; (2) damage to well casings as a result of compressional stresses; (3) lessened efficiency of storm-drainage facilities and (4) submergence of coastal lowlands. According to Gabrysch (Case History 9.12), most of the damage is related to the lowering of land-surface elevations in the vicinity of Galveston Bay and the subsequent inundation by tidal waters. Several roadways have been rebuilt at higher elevations; ferry landings have been rebuilt; and levees have been constructed to protect some areas. Jones and Larson (1975) estimated the annual cost of subsidence in terms of property value losses during 1969-74 to be about $32 million in 2,450 km^2 of the area most severely affected by subsidence.

The Brownwood subdivision on the west side of Baytown is an outstanding example of both the social and economic impacts of subsidence. The subdivision has subsided about 2.8 m since 1915; some homes are permanently flooded with bay water. After a feasibility study including eight alternative plans, the U.S. Army Corps of Engineers has proposed that the entire subdivision, including 456 homes and 1,550 residents be relocated above the 50-year flood plain, at an estimated cost of about $40 million (using May 1979 price data).

Although no detailed appraisal has been made of overall costs of subsidence in the Houston-Galveston area, partial estimates, including the costs just cited, indicate that total costs to date have been several $100 million.

The most critical socioeconmic hazard to the Houston-Galveston area is the threat of catastrophic flooding by hurricane tides. The severity of the hazard will increase as long as subsidence of the coastal areas continues. Gabrysch reports (Case History 9.12) that hurricanes resulting in tides of 3.0-4.6 metres above sea level strike the Texas coast on the average of once every 10 years. This problem is discussed in more detail by Teutsch (1977).

6.4.1.2 San Joaquin and Santa Clara Valleys, California

San Joaquin Valley.--As discussed in Case History 9.13, the extensive major subsidence in the San Joaquin Valley has caused several problems, primarily economic rather than social. (1) The differential change in elevation of the land surface has created problems in the construction and maintenance of water-transport structures, including canals, irrigation and drainage systems, and stream channels. Three major canals have required remedial work because of subsidence. (2) Many hundreds of irrigation wells 200-900 m deep failed between 1945 and 1970 due to compressive rupture of casings caused by the compaction of the aquifer systems. Costs of well repair or of replacement attributable to subsidence have been many millions of dollars. (3) The need for preconsolidation of deposits susceptible to hydrocompaction increased the construction costs of the California Aqueduct by an estimated $25 million. (4) Increased cost and number of surveys made by governmental agencies and by private engineering firms to determine the elevations of bench marks to establish grades on construction sites, for revision of topographic maps, for construction of subsidence maps, and for land leveling to compensate for effects of subsidence.

No overall estimate has been made of the costs attributable to subsidence in the San Joaquin Valley but if partial estimates are correct, total costs must be in excess of $50 million.

Santa Clara Valley.--As described in Case History 9.14, the subsidence in the Santa Clara Valley has created several major problems, primarily economic. They include: (1) Land adjacent to San Francisco Bay has sunk 2-3 m since 1912, requiring construction and repeated raising of levees to restrain landward movement of bay waters onto lands now below sea level; and also requiring continued maintenance of 60 km of subsiding salt-pond levees. Also, Santa Clara County has built and maintained flood-control levees to correct for subsidence effects at a cost of $9 million. (2) Many hundreds of water-well casings have failed in vertical compression due to compaction of the confined-aquifer system. The estimated cost of repair or replacement is at least $5 million. (3) construction and maintenance of a pump station at the regional sewage treatment plant, needed because of subsidence, at a cost of $10 million (Viets and others, 1979). (4) Costs involved in repair of railroads, roads, and bridges; replacing or increasing the size of storm and sanitary sewers because of change in grade due to subsidence; establishing and resurveying the bench-mark net, and making private engineering surveys; and finally the reduction in value of 44 km^2 of land standing below high-tide level as of 1967 compared to its value if it all still stood above sea level.

No overall estimate has been made of the costs attributable to subsidence in the Santa Clara Valley but the partial relatively firm estimates suggest that total costs must have been at least $35 million.

6.4.2 Legal developments in California and Texas

In California, until the start of the 20th century, the English common law rule of absolute ownership of percolating waters prevailed. According to this doctrine: in the absence of any malice or any contractual or statutory restriction, the owner has the absolute right to intercept the water before it leaves his property and make whatever use of it he pleases, regardless of the effect that such use may have on an adjoining or lower proprietor through whose land the water infiltrates, percolates, or flows (Kooper and Finlayson, 1979).

In 1903, however, the California Supreme Court in Katz v. Walkinshaw (141 Cal. 116) spelled out a set of rules for ground water known as the "correlative rights" doctrine. Owners of land overlying a ground-water basin who used the water on the overlying land were recognized as holding the paramount right. Such owners among themselves were to share the water on a correlative basis, similar to the sharing of surface waters by riparians. Any water surplus to the needs of these overlying owners remained available for appropriation by others (Governor’s Commission to review California water rights law, 1978).

According to Koopman and Finlayson (1979), the rule of law governing liability for subsidence caused by the removal of ground water is not settled in most jurisdictions although the trend appears to be toward greater liability. This change in the law is reflected by a reversal of the position of the American Law Institute in the Restatement of Torts II compared to the Restatement of Torts I.

The Restatement of Torts I stated the rule: "to the extent that a person is not liable for withdrawing subterranean water from the land of another, he is not liable for subsidence of the other’s land which is caused by the withdrawal." Restatement of Torts, Section 318 (1938). The position stated in the restatement of Torts II is: "One who is privileged to withdraw subterranean water, oil, minerals or other substances from under the land of another is not for that reason privileged to cause the subsidence of the other's land by such withdrawal." Restatement of Torts II, Section 318 (1969).

In 1958, the United States of America sued all the oil and gas producers in the Wilmington oil field in southern California, claiming that their operations had withdrawn undergound support from its Naval Base on Terminal Island and other properties, thereby causing subsidence which seriously damaged the government property. This case was the largest damage suit in United States history for subsidence caused by pumping fluids from the ground. The case was settled out of court. The government was assured of the control of subsidence by passage of the Anti-Subsidence Act of 1958, which compelled the oil producers in the Wilmington field to unitize and undertake to repressurize the depleted reservoir.

Again, according to Koopman and Finlayson (1979), "the statute clearly reflects a desire to retain the economic benefits of the Wilmington oil production, while relying on technology to prevent damage to private property rights. . . The Act shows the intent of the California Legislature to prevent further subsidence, but not to set liability."

As summarized by the Governor's Commission to review California water rights law (1978) "there have been two main approaches in California to instituting successful ground-water management. One has been by formation of a water district with powers to carry out a ground-water management program. The second has been management by a court-appointed watermaster with powers similar to those of a management district, after an adjudication of substantially all rights to extract ground water in the management area.

"The orange County Water District has been the leader in the water district non-adjudication approach to ground-water management. The district has a wide range of management powers, including the power to require pumpers to file periodic 'water production statements' with the district.

"The district's financing powers are extensive. It was the first district to levy a pump tax ('replenishment assessment'). The pump tax applies to all ground-water extraction, so there is no advantage to being an overlying landowner or an early appropriator. The district uses 'basin equity assessments' either to increase or decrease the cost of ground water in order to influence the relative amounts of ground water and surface water that are used, and to regulate pumping patterns.

"A central function of the Orange County Water District is to use imported water to replenish the ground-water supply. The district's replenishment operations include 'spreading' the water in areas chosen because they allow the water to percolate rapidly into the ground-water basin, and 'in-lieu' replenishment. In-lieu replenishment involves substituting a surface water supply for ground-water pumping in a particular area to allow the ground-water level to recover as a result of natural recharge.

"The San Gabriel adjudication watermaster program indicates the direction that the adjudication-watermaster approach to ground-water management is taking. The San Gabriel watermaster has a much more sophisticated range of powers and authority than the California Department of Water Resources has as watermaster for the court in four areas in Southern California. The San Gabriel watermaster, composed of nine members appointed by the court pursuant to an agreement among ground-water users in the adjudicated area, is a policy maker. It can levy a 'replacement water assessment,' which is a charge on pumping in excess of a pumper's adjudicated share of the basin's yield, can conduct a ground-water replenishment program, and has authority to control storage in the basin."

The Santa Clara Valley Water District in Santa Clara County, California, was formed by a special act of the California Legislature that was approved by the voters in 1929. A principal goal of the district in its subsequent management of all available water supplies, to balance supply and demand and hence to stop the land subsidence, has been the reduction in pumpage of ground water. (See Case History 9.14) The annual pumpage of ground water decreased about 20 per cent from 1960-65 to 1970-75. A principal reason for the decrease in pumpage was a use tax levied on a ground-water pumpage since 1964. The enactment of the 1929 legislation providing for the local management of ground-water resources, including the taxing power, represented a major departure from the early rule of absolute ownership.

Historically Texas has followed the English common law rule of absolute ownership to withdraw water from beneath his property with no liability for damage to other lands. In the past five years, however, the trend has clearly been toward holding pumpers of ground water responsible for damage from subsidence. First came the creation of the Harris-Galveston Coastal Subsidence District in 1975, followed by two major legal decisions involving subsidence and liability.

The Harris-Galveston Coastal Subsidence District was created by the Texas Legislature in May 1975 "to provide for the regulation of the withdrawal of ground water within the boundaries of the district for the purpose of ending subsidence which contributes to or precipitates flooding, inundation, or overflow of any area within the district, including without limitation rising waters resulting from storms or hurricanes" (Neighbors, 1979).

The act creating the district provides that water wells located within the district, with casing diameter in excess of five inches, are required to have a permit to withdraw a specified amount of water for a period of not less than one year nor more than five years. The district is supported financially by the permit fees. The current permit fee rate is $4.50 per million gallons (3,785 m^3).

A major court decision in Coastal Industrial Water Authority v. W. B. York (1976) involved the submergence of York's land in the Houston Ship Canal due to the subsidence. The court held that the property owner did not lose title to the land due to the fact that it had become submerged from subsidence as a result of pumping of ground water.

In 1978, according to Neighbors (1979), the Texas Supreme Court reinforced the Legislature's authority to regulate ground-water withdrawal for the purpose of controlling subsidence. In Smith-Southwest Industries, Inc. v. Friendswood Development Co. (1978) the Court referred to the creation of the Subsidence District and other legislative acts in establishing the intent of the Legislature to limit the common-law rule of absolute ownership of ground water. The Court held that ground-water users were not liable for subsidence damages caused by past actions, but could be held responsible for damages due to future pumpage if such were conducted in a negligent or malicious manner. The opinion concludes "Therefore, if the landowner's manner of withdrawing water (in the future) is negligent, willfully wasteful or for the purpose of malicious injury, and such conduct is a proximate cause of the subsidence of the land of others, he will be liable for the consequences of his conduct."

6.5 REFERENCES

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