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Institutional Arrangements for Effective Groundwater Management to Halt Land Subsidence

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INSTITUTIONAL ARRANGEMENTS FOR EFFECTIVE GROUNDWATER MANAGEMENT TO HALT LAND SUBSIDENCE

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OVERVIEW

In the Upper Galveston Bay region of the Texas coastal zone, water from naturally replenished underground aquifers provides much of the freshwater supply for municipal, industrial and agricultural needs. The availability of these easily accessible low cost freshwater supplies has contributed to the building of a strong and dynamic economic base. However use of these common water supplies in excess of natural replenishment has resulted in a gradual but accelerated and irreversible subsidence of the land surface throughout the region. The cause is long term and due to collective use of groundwater.

This natural phenomenon generally exhibits the range of characteristics expected when the carrying capacity of valuable common property resources is exceeded under dynamic socio-economic use pressures. These characteristics include competing and conflicting resource use, externalities (socio-economic and environmental impacts) and complex social, legal and political dilemmas.

Regional use of groundwater in excess of the "safe" production potential of the underground water bearing system has caused physical and economic losses in the coastal areas. Surface subsidence in excess of 8.5 feet has resulted in serious socio-economic and environmental impacts because of the loss of land elevations in already low shoreland areas. Bay waters have permanently inundated previously valuable commercial, industrial, recreational, municipal and private property. Subsidence has increased the susceptibility of much of the region to destruction through tidal surges generated by tropical storms and hurricanes. Conceivably, the somewhat inchoate interests of approximately 350,000 persons and large numbers of

state and private enterprises located in susceptible coastal areas are affected.

The natural phenomenon of subsidence, and its technical solution - decreased groundwater use and/or use of alternative surface water supplies, pose difficult institutional questions and equity issues both to public and private sectors that as yet remain unanswered and unresolved.

Traditionally, groundwater has been treated as a free good or at least a relatively cheap one. Since owners of private property overlying the water bearing system are afforded legal proprietary interest in the water in Texas, the regional groundwater resources have been developed and used primarily on an individual, uncoordinated basis with little or no concern for the relationship between extraction and natural replenishment, or regard for any collateral effects of groundwater use. Social costs are unregistered under such an arrangement and only private costs are considered by users. Institutions governing the use and allocation of groundwater resources were primitive or nonexistent. Therefore, effective action to arrest the ever increasing overdraft was absent. With increased water use, however, subsidence related costs have become apparent.

For many years the majority of groundwater users ignored the subsidence problem since it was thought to affect and indeed was only felt by a minority of local land owners and waters users bordering on coastal bays and other water courses. Even though the implication (for example, hurricane threat) of subsidence to the region was recognized, an internal cost differential between groundwater and surface water sources hindered voluntary conversion to the higher cost surface water by the collectivity of groundwater users. Aggregate social costs generated by overuse of ground

water exceeded the aggregate price differential, but these social costs were largely unregistered. They were felt only by a minority of community interests in a manner disproportionate to their use of the groundwater. Logically, therefore, intensive use of inexpensive groundwater continued.

Although industrial, municipal, agricultural and private interests were interrelated through the common use of the aquifer, a basis for collective action was difficult because of conflicting interests. In the early 1970's a movement began to form some collective organization to soften the conflict and aid individuals to allocate the regional water resources in such a manner as to abate and control surface subsidence; to enable individuals to compete peacefully for scarce resources in a manner that would lead to a satisfactory allocation of currently available or potential supplies of water resources. Water users were thus confronted with the problem of rearranging decision-making capabilities.

The execution of a solution was generally beyond individual water user's scope of action due to physical, legal and economic factors. Existing collective organizations and institutions were also viewed as inadequate for this purpose. Water related institutions were vertically and horizontally fragmented, each dealing with some aspect of groundwater use and development but political entities with adequate scope to deal with the problem were either unwilling or unable to engage in regional water management. Indeed, these political organizations and other institutions may have actually contributed to the subsidence problem. They were not only ill equipped to respond, but also were primarily designed for water use, and may have provided incentives to their constituents to continue using groundwater and to generally disregard the overall community interest.

Hence, the greater problem in the short run was not one of a shortage of water, but one of creating institutional arrangements to interrelate users of common water supplies and to obtain conjunctive use of surface water with groundwater so that effective management and subsidence control could result.

The issues to be addressed were not how shall a resource be allocated among users competing for the inexpensive supply, and the more complex question of how users shall allocate their use of groundwater as against the more expensive surface water. It is an economic dilemma of how best to use existing water supplies and how and when to expand existing water supplies as the demand for water increases. If aggregate demand for water were not met, pressure would be brought to bear upon "scarce" groundwater resources, exacerbating the subsidence of the land. A management institution was needed to devise an acceptable decision system to reorder incentives for groundwater use into disincentives and to reorder disincentives for surface water into incentives. In short, legal, physical and economic relationships between the community of interests embedded in existing institutional arrangements needed to be redefined and restructured. This implied a progressive departure from the traditional way of allocating groundwater resources.

Much time, energy and resources was spent by the local community in deciding upon an optimal institutional strategy and devising self-governing organizational arrangements to express their interests and solve their problems. However, the community was hampered in its efforts by obstructions imposed by existing institutional arrangements and by a change resistant political climate of the State Legislature whose authorization for local

proposals for an instititutional solution was needed. The political mechanism attained by the community through concerted effort was a special purpose subsidence control district which could respond to the threatening problem only in a limited fashion. The emphasis was on subsidence control through well spacing, regulation and permits, rather than on a more comprehensive approach of integrated and coordinated conjunctive water resource management. Such a district is able only to force important management issues and problems onto other political entities, and must leave many equity issues and needs unresolved and unanswered.

It is the purpose of this report to evaluate altenative political structures for comprehensive management of the subsidence area's complex water problems. Alternative arrangements of legal, economic and political institutions with the capacity and ability to conjunctively manage regional ground and surface water resources to abate and control subsidence are developed and examined. These alternative institutional arrangements are based on both practical and theoretical management methods advanced in the literature on water resource management for solving commonality problems in the use of groundwater resources.

SUMMARY AND CONCLUSIONS

Institutions are a social phenomena which facilitate the making of decisions deemed socially desirable by a community of interests. Institutions govern and condition the behavior of individuals by establishing systems of rights and duties which members of a community follow. Any institutional arrangement can be expected to generate a limited range of effects preferred by a society, but are subject to certain limitations. When these limitations are exceeded, costs associated with institutional weakness and failure arise.

That institutional limits have been exceeded is evidenced by the subsidence problem. Subsidence due to excessive groundwater withdrawal indicates that institutions have allowed an incongruence between individual groundwater users' attempts to allocate and use water resources efficiently and the best interests of the community. Subsidence has resulted in economic losses being sustained in the region as a whole, but particularly in coastal areas. These losses are experienced in a manner disproportionate to each groundwater users pumpage from the common underground water system. They are properly conceived of as social costs associated with institutional weakness and failure.

Two interrelated solutions, one physical, the other social, are relevant to subsidence control. They physical solution - reduced groundwater pumpage - involves the reallocation of regional water resources to reduce reliance on groundwater use, necessitating acceleration of the design and operation of a system of surface water works to provide a substitute water supply for displaced demands for groundwater. The social or institutional solution involves a reallocation of decision-making capabilities to enable

the physical solution to become operational while, at the same time, enabling individuals to better allocate and use regional water resources - both surface and ground.

The empirical groundwater use problem is examined from the theoretical perspective of a common pool in order to expose those basic institutional elements which need modification or restructuring in order to minimize costs associated with institutional weakness. It is shown that Texas groundwater rights, which afford individuals absolute property interest in any common water system beneath their lands, provide incentives to landowners to use groundwater in a manner and quantity which does not take account of effects on other members of the community owning property overlying the system. Because common property is used in a private and uncoordinated basis, costs and benefits are not registered in individual pumping decisions, externalities are generated, and the market system of allocation fails. When these externalities are properly included in the total costs of using groundwater, it becomes economical for the community to use alternative surface water supplies.

Since property rights provide the normative framework for the economic behavior of individuals, the system of property rights which led to institutional weakness and failure becomes the subject of direct or indirect modification or restructuring, so as to institutionalize a socially desirable structure of incentives and deterrents in groundwater use decisions. Alternative property rules provide the institutional mechanism for internalizing externalities associated with subsidence in order to enable the community to adjust to new benefit/cost possibilities.

The second institutional element giving rise to institutional weakness and failure is identified to be the fragmented nature of regional water

organizations and their inability to effectively respond to a groundwater use problem. The maze of special purpose organizations with variable political purposes and geographical scopes and overlapping and sometimes competitive functions are concerned with water supply, rather than water use control.

The second and related facet of an institutional solution is to establish organizational arrangements to unite groundwater users and integrate regional water resources such that subsidence can be controlled, and ultimately satisfy the water demands of the collectivity of groundwater users. It is demonstrated that substantial cooperation and pooling of political and private interests is required to manage both surface and groundwater use to meet water demands while providing for a smooth and efficient transition to a no subsidence condition.

Alternative organizational arrangements are examined, and it is concluded that the formation of a public water district is most likely able to provide a basis for expressing diverse community interests, for integrating fragmented water organizations to conjunctively use ground and surface water resources. It is explained that the role of the State is to authorize creation of such a district and to enable a groundwater management program to meet the needs of the subsiding region to be tailored by the local community and to assist them in doing so, without regard for management of groundwater in other areas of the state.

To reorder incentives for groundwater use into disincentives, and disincentives for surface water use into incentives, alternative institutional arrangements are developed. These arrangements were modeled after two basic institutional methods for controlling subsidence: administrative and economic. The Harris-Galveston Coastal Subsidence District, the

present institutional response to the problem, is an example of a conventional regulatory arrangement based on the administrative model. It is shown that such an arrangement actually institutionalizes the subsidence problem without really solving it, as it fails to modify the basic institutional elements which lead to institutional weakness and failure.

Four alternative institutional arrangements are developed according to the market model, which directly alters those basic institutional elements which caused institutional failure. Under these arrangements, groundwater is treated either directly or indirectly as private property and common property. These alternative property rules enable externalities to be internalized. Incentives and deterrents are modified by a system of taxation on groundwater use/subsidization of surface water use, a system of assessments and rebates for water used in excess of a required groundwater/surface water use ratio, a system of water service and price allocation, and a system of groundwater use quota rights which are traded in a centralized water exchange.

Each alternative institutional arrangement provides individual groundwater users with alternative configurations of rights and duties. However, the net effect is the same. Costs and benefits of groundwater use are internalized to the decision-making process. As such, more efficient water resource use decisions are likely to result. The optimal amount of conjunctive water resource use is more likely where groundwater is priced at its total internal and external cost.

Under each alternative institutional arrangement, a water district or authority operates the alternative systems of economic inducements while attempting to provide the community of groundwater users with an

expanding level of water supplies through conjunctive management of regional water resources.

A system of criteria are developed for evaluating how alternative institutional arrangements might be expected to perform in controlling

The set of criteria are institutional "strong points" which an optimal arrangement would display. It is shown that institutional strength is highest among the alternatives when arrangements are based on the modification of those institutional elements which led to institutional failure. These arrangements were patterned after the market model. The converse is true of the arrangement showing characteristics of the administrative model. It is likely that costs associated with institutional weakness will become evident in the future.

The net effect of the alternative institutional arrangements on individual groundwater users, corporate, public and private, is higher water costs more nearly reflecting the true opportunity costs of groundwater use to the subsiding region. To the multitude of political entities and water organizations, the net effect is simply more time required in planning appropriate strategies for adapting to the new institutional systems. However, these added costs can be expected to be exceeded ultimately by substantial benefits that will accrue if institutional arrangements for subsidence control are designed so as to minimize the costs associated with institutional weakness.

The ultimate constraints on implementing alternative institutional arrangements are political and legal feasibility. Political acceptability is enhanced in theory if, as the result of an institutional change, most everyone is made better off while few are made worse off. The alternative arrangements were designed so as to equate benefits with beneficiaries.

Legal feasibility is the greatest cause of uncertainty. It is unclear whether a statutory or constitutional basis exists for comprehensive ground and surface water management or for the public water districts as contemplated here, or even whether the Legislature can authorize use of pump taxes and other pricing schemes for allocating collective costs and water resources. It is suggested that modifying the property rule of absolute ownership by conceptualizing groundwater rights as rights to reasonable use of groundwater would provide a better legal basis for the alternative property rules proposed and around which alternative institutional arrangements are structured.

Because groundwater law is in a formative stage, the present system of law does not provide the answers to contemporary groundwater use problems such as subsidence, either expected or needed from a mature system of law. It is the role of law to provide the conditions upon which the private market might better work. This institution is, in itself, the most widely accepted mechanism for allocating resources in our society. Hopefully, this report suggest some possibilities wherein the law might be changed to enable the market to allocate water resources more efficiently and equitably.

PART I

Nature of the Problem:

Implications for Technical and Institutional Solutions

Subsidence: Cause, Effects and Technical Implications

Since early in this century, the land surface of the Upper Galveston Bay region of Texas has been subsiding as a direct result of groundwater withdrawal. The region obtains much of its freshwater from pourous sand aquifers underlying the coastal lowland and inland earth surfaces.[1] These sands, which dip toward the coast and outcrop generally in the northern part of the region, are continually replenished by the natural infiltration of surface water. These waters percolate through the system and are interdependent and common to adjacent lands. Intensive pumpage rates in excess of the natural replenishment rate have caused water pressures to decline, and this reduction in pressure is the cause of land subsidence (Winslow, et.al., 1954; Marshall, 1973; Gabrysch, et.al., 1975).[2] The amount and geographic extent of this resource use problem is shown in Figure 1.

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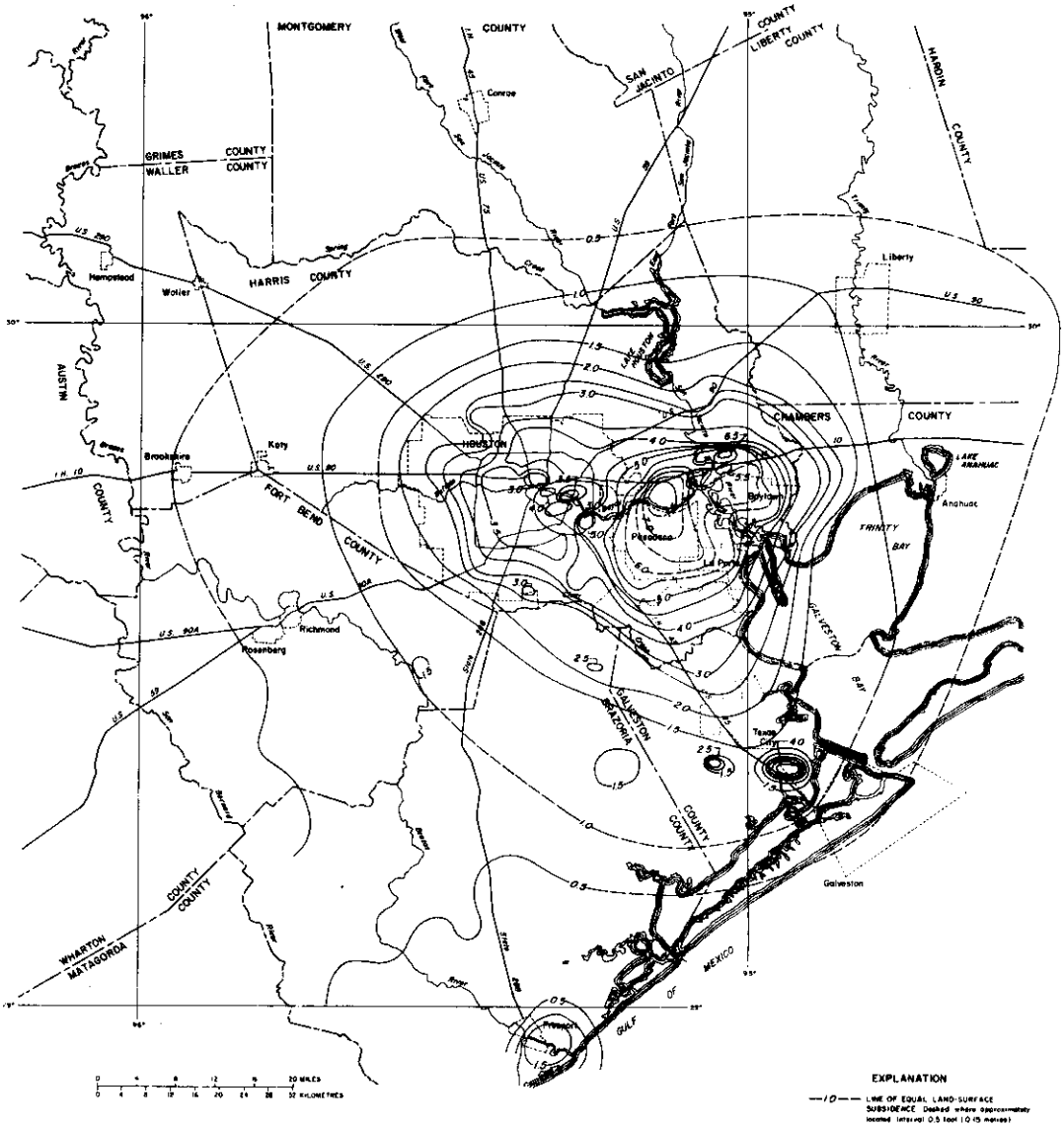
[1] The regional water bearing system is a small part of a vast hydrological unit underlying the coastal plains of the Gulf Coast States (Mack, 1971, 174-175). All water bearing strata are hydrologically interconnected (Gabrysch, 1976).

[2] Subsidence is a localized problem, mainly to the urbanized and industrialized areas broadly surrounding Houston. This is evidenced by the incidence of a cone of depression (groundwater level and land surface) which has developed around the area. Depressions become less severe as the distance from the subsidence center increases. Groundwater level declines and subsidence occuring throughout the relatively remote areas of the region are mainly due to pumpage towards the center of the cone (Gabrysch, et.al., 1975; Gabrysch, 1976).

The subsidence phenomena is not unique to the Galveston Bay region, as it occurs in other areas along the Texas coast (General Land Office, 1976), in many other parts of the nation, notably in the coastal areas of California, as well as in many other parts of the world (Poland, et.al., 1969, 221-269).

Figure 1
Subsidence of the Land Surface,
1943-1973



Source: Gabrysch, et. al., 1975.

Comprehensive studies of subsidence related damages have indicated the most obvious problems are caused by the loss in elevation of property in shoreland areas (Warren, et.al., 1974; Jones, et.al., 1975; Marshall, 1973). Subsidence has resulted in the loss of property in tideland areas, and the submergence of homes, buildings and other commercial, industrial and municipal structures located in shoreland areas. Abandonment of commercial businesses and other social dislocations are common. As the loss of surface elevation increases, more valuable land and property are potentially subjected to the natural coastal hazard of temporary flooding from either tidal surge or temporary freshwater runoff.

In inland areas more remote from the shoreline, subsidence has resulted in changes in land slopes, stream gradients, stream drainage patterns and broadening of streams and bayous. Since the rate of subsidence is not uniform, temporary runoff problems have increased in some parts of the subsiding area. Subsidence has also actuated and aggravated surface fault lines throughout the region, resulting in cracking, shifting and separation in residential and commercial structures and other surface structures such as water and sewer lines (Brown, et.al., 1974).

The most alarming affect of regional interest is the eminent threat of hurricane damage. Potential hazards from tidal surges are clearly intensified by surface subsidence in broad coastal areas of the region (Benton, 1974).

Loss of property value and submergence of improved property, remedial measures, and other impacts to both public and private sectors have been estimated to result in an annual dollar loss of $31.7 million to the seriously subsiding region (Jones, et. al., 1975). The seriously subsiding region is depicted in Figure 2; estimated damage costs are broken down by subarea in Table 1.

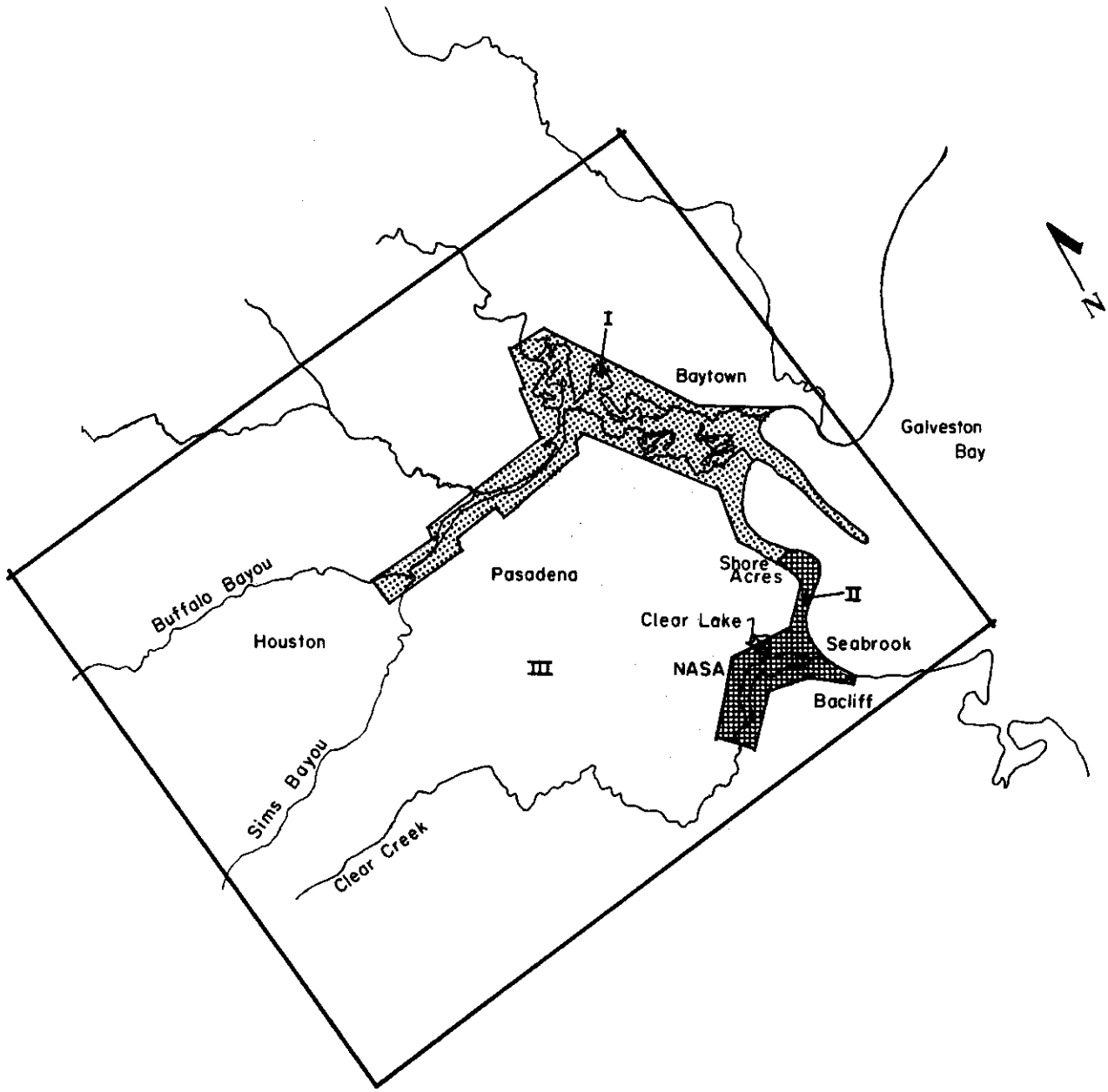


Figure 2. Approximate location of the study area and sub-areas I, II and III.

Source: Jones, et al., 1975.

Table 1. Estimated average annual costs and property losses associated with land subsidence, Upper Galveston Bay, Texas.

Sub-Area	Approximate Area Size	Estimated Average Annual Costs: Damages	Property Losses	Total	Percent of Total
	(sq. miles)	-$1000-			%
I (Pasadena-Baytown)[a]	83	3,926[d]	5,870	8,795	27.7
II (NASA-Clear Lake)[b]	25	2,108	2,900	5,009	15.8
III (Houston-other)[a]	837	9,322	8,041	17,363	54.8
Public Costs[c]		538		538	1.7
TOTAL		15,894	15,811	31,705	100.0

[a]Average annual costs and losses for the five year period 1969-73.

[b]Average annual costs and losses for the six year period 1969-74.

[c]Average annual costs for the five year period 1969-73. This estimate includes actual expenditures only.

[d]Includes $37 thousand estimated costs to industry.

Source: Jones, et.al., 1975.

The subsidence occurring to date must be considered permanent and irreversible. However, subsidence can be mitigated by reducing groundwater pumpage and properly spacing wells. With substantial restoration of water levels and water pressure heads in the critically overdrafted areas, subsidence can be halted (Marshall, 1973; Gabrysch, et.al., 1975; Jorgensen, 1975).[3]

The physical solution presents to the region a substantial engineering problem: to design, implement and operate a system of surface water works to lessen reliance on the ground water source. Associated with the design of physical facilities is the problem of pooling, rearranging and compromising community interests to design and operate organizational arrangements to facilitate or carry out the engineering solution (Ostrom, et. al., 1972). This requires a substantial reallocation, exercise and control of decision-making capabilities in the development and use of the regional water system. These decision-making capabilities are embodied in institutions and institutional arrangements. Consideration of alternative insitututional arrangements to deal with the subsidence is the primary concern of this report.

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[3]It is possible to cause a rebound in pressure by direct injection of suitable quality water into the overdrafted areas. However, direct surface water utilization and natural rebound and restoration is more economical (Gabrysch, 1976). Reduction in groundwater pumpage needs to be the greatest at the center of the cone of depression, and progressively decrease as the distance from the center increases.

Institutions and Ground Water Use Decisions

Institutions form the base for individual and collective economic decisions regarding how best to use water resources. In the broadest sense, institutions are specific rules, practices or prescriptions; systems of decision rules, and general patterns of action which serve to shape human values, influence human expectations and guide, order and condition human behavior in relation to common purposes among individuals (Leonardo Scholars, 1975, 19; Ostrom et.al., 1972, 2; Clark, 1960, 42; Casbeer, et.al., 1969, 4).[4] In addition, institutions include specific organizations with "some character mission or scope of authority" (Leonardo Scholars, 1975, 19), or stated in another way, "human enterprises concerned with the allocation, exercise and control of decision-making capabilities" (Ostrom, 1972, 1-2).[5] Whichever way institutions are defined, they are "infused with value" for participants associated with them (Leonardo Scholars, 1975, 19).

Institutions are a social phenomena: they are group-oriented control mechanisms for maintaining social order and welfare arising from collective action in response to common community problems, or special needs caused by those problems. When the community senses that events generated by an existing system of institutional arrangements pose serious threats to the community, new institutions are created or existing institutional arrangements are modified to halt or limit the activity producing the threat. Norms are set in place through collective action for the community to follow.

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[4]For example, a system of proprietary water rights, water law (statutory and common), administrative rules such as water use taxes, and other long standing water use practices, are institutions.

[5]For example, public water use and water supply districts.

As related to resource use, institutions serve specific social purposes: to delimit the activity of the group using the resource, either fixing or limiting the level of acitvity which an individual may not exceed or limiting the effects of an individual's activities on others in the group (Roberts, 1973, 390-392); or, to liberate an individual from the necessity of protecting himself from the actions of others (Jensen, et.al., 1973, 9). Institutions are structured in and in response to social settings and physical conditions to encourage the making of decisions which are most advantageous to individuals while best benefiting the community as a whole (Harnsberger, 1963, 745). They are merely man-made devices for alleviating or solving social problems and serve some positive function for members of the community (Clark, 1960, 42; Roberts, 1973, 390).

Institutions possess certain characteristics which both enhance and frustrate their social usefulness. Characteristics such as "accuracy (precisiveness of the constraining attributes), generality (applicability to a variety of conditions and circumstances), simplicity (ease of adherance) and usefulness (ability to fit the preferences of a large number of individuals in a variety of circumstances) enhance their ability to promote greater social utility than is possible without their presence" (Roberts, 1973, 393). However, because institutions tend also to produce conformity and certainty rather than change, stability and constancy rather than progress, in essence, longevity and ridgidity, they are neither infinitely malleable nor necessarily responsive to new social problem situations (Jensen, et.al., 1973, 9; Leonardo Scholars, 1975, 19-20). When the necessity arises to restructure institutional arrangements so as to foster those activities which yield the greatest utility to a community, institutions may constrain the attainment of a social optimum. If such is the case,

institutional ridigidy is a social cost born by the community (Davis, et.al., 1975, 22). These costs, for example, costs associated with subsidence, indicate institutional weakness or failure.

However, costs associated with institutional weakness may be minimized by appropriately modifying institutional arrangements (Smith, 1960, 1347). Institutions do change over time as the needs of society change. But such change must be accomplished within existing social and physical settings and such change must provide a demonstrable improvement in benefits and services in order for new institutional arrangements to be acceptable to the community which they serve (Ostrom, et.al., 1972, 1; Jensen, 1973, 12).

It is readily apparent that individual decisions regarding the manner, time and quantity of groundwater resource use are inextricably related to the institutional systems which operate within the community to guide their behavior. Any one institutional arrangement designed for the development and use of groundwater resources affords individuals a particular set of incentives and deterrents, which define the limits of an individuals' decision-making capabilities in relation to the water resource (Ostrom, 1972). These incentives and deterrents are relevant to particular conditions of a water resource system, such as the nature of the water, whether it exists above or below the ground, the supply of the water, or the physical functioning of the water system.

Each institutional arrangement defines, implicitly or explicitly, a set of economic and legal relationships between water resource users, and physical relationships between water users and the water system itself. These relationships exhibit an individuals capabilities and limitations for developing and using the water resource, such as manner of use, place of use and so on.

The relationships are embodied in institutional arrangements and defined by society so as to facilitate or deter individual decisions in relation to particular conditions of the water resource. They are engineered to be appropriate for a particular set of water conditions. If institutional or decision-making arrangements have been designed appropriately for certain conditions, they will function to effect an allocation of water and manner of water use deemed desirable by society. Costs associated with institutional weakness will be minimized.

Decision-making capabilities affect water resource conditions - the amount demanded affects the water supply; the affected supply can alter the operation of the natural water system. Conditions in turn would dictate the type of decision-making capabilities an individual can exercise in relation to the water conditions.

When water conditions change, economic and legal relationships may deviate from the norm, and existing incentives and deterrents may be inappropriate. Stress is brought to bear on existing institutional arrangements to adapt to new conditions. If decision-making arrangements can accomodate the changed water conditions, such that water remains allocated and used in a socially desirable manner, institutions remain effective. Institutional weakness is signaled if individuals can not allocate and use water resources desirably within the limits of their decision-making capacity. Incentives and deterrents under one set of water resource conditions may be inappropriate, from a social perspective, under others.

If institutional arrangements are deemed inappropriate and undesirable, and if modification of institutional arrangements would leave the community better off, then, in order to restore a socially desirable allocation and use of water resources, and adjust to changed conditions of water supply and

demand, decision-making capabilities are reallocated so as to minimize the costs associated with institutional weakness or failure (Ostrom, 1975, 773). The land subsidence problem has forced the community of coastal residents to follow this course of action. Serious problems have been experienced in the use of groundwater resources under existing institutional arrangements. Social costs associated with land subsidence have signaled that an institutional change is warrented.

In the following sections, those institutional elements which have given rise to institutional weakness, and the physical and socio-economic forces which have operated under these institutional elements, will be identified. By examining the legal, political and economic relationships as well as the structure of incentives and deterrents in individual groundwater resource use decisions inherent in existing institutional arrangements, areas of institutional weakness can be identified. These elements need be exposed in order to design alternative institutional arrangements which minimize the costs associated with institutional weakness. As well, alternative institutional arrangements must be designed in response to these institutional conditions as well as physical water resource conditions (Fox, et al., 1972).

Physical, Legal, Economic and Political Conditions

The theory of the common pool and common pool problems in water resource development has received great attention in the literature, for example, Hirshleifer, et. al., 1969, 59-61; Milliman, 1956; Friedman, 1971; Ostrom, 1975. Much of the discussion which follows is based on this literature. A sand aquifer presents the common pool in a variety of theoretical and factual contexts. This section addresses the theoretical and empirical concepts underlying the subsidence phenomenon.

The Common Pool

Throughout the subsiding region, landowners mutually benefit from the use of a common underground reservoir of freshwater. However, problems are experienced in the allocation and use of this water resource because of its common pool characteristics. A common pool resource is one which has attributes of jointness of supply, indivisibilities and commonality of use such that individuals can not effectively be excluded from access to the resource underlying another's land, even though each individual makes a separate use of the resource. The ground water system affords a common water supply which is easily accessible from overlying land and susceptible to use throughout the coastal areas. Water percolates into and flows through the system and is common to adjacent lands.

Incentives, Deterrents and Institutions

Man is assumed to be a rational, self-interested, choice-making individual who pursues those alternatives he believes will yield the greatest net benefit to him as weighed by his own preferences. He can effectively evaluate alternative courses of action because it is assumed that the relevant information is readily available. He is a profit maximizer pursuing least cost

strategies, always operating according to the efficiency criterion (Ostrom, 1975, 770). Man is assumed to operate in and respond to the context of some system of law and order. Certain rights, duties and privileges embodied in these institutions define the limits within which he pursues his maximizing strategies.

Existing institutions provide individual property owners with incentives to use groundwater. In Texas, each person is free to decide how he will use the common pool resource. Such freedom is afforded as a property right to the water that is, in many respects, as absolute as the rights in the land above. Property rights in the land extend vertically above and below the earth's surface, including the water that flows beneath his land. He may capture and use any quantity of water that he deems beneficial, and is not held liable for any neighborhood effects his capture and use may generate. He is limited only to the extent that he cannot wantonly waste the water he captures nor use it maliciously to injure his neighbors (60 Tx. Jun. 2d, sec 220-2).

Individual demand for groundwater for purposes of consumption, production, barter and sale is expressed and met in a variety of ways. Various enterprises produce water for their own use. Incorporated municipal areas have organized water departments or municipal water districts to sell water to individuals and firms within their boundaries, as well as outside their boundaries. Private water companies and water wholesalers also serve municipal needs. Unincorporated municipal areas organize water districts and water authorities to develop and supply their demand for groundwater. Private companies, industrial as well as non-industrial, agricultural interests and individual landowners produce groundwater for their own needs. Proprietary interest in the common pool water is exercised by an inchoate

collectivity of groundwater users in these ways.

Such a decentralized, fragmented system of individual choice greatly reduces the costs of complex institutional arrangements governing ground water use as long as supply exceeds demand (Ostrom, 1975, 774; Hirshleifer, et. al., 1969). Groundwater is treated as a free good. It is fugitive and captured at a very low cost. It remains a free good under such an institutional system as long as all is supplied that is demanded. If groundwater is not scarce, major water use problems exist only as a potential (Johnson, 1971), and institutions remain workable.

Socio-economic conditions

The collectivity of groundwater users in the region attach great value to the water obtainable from the common pool.[7] Water is an economic good because it produces utility and is therefore in demand (Johnson, 1971). Individuals derive utility from the use of the water because of their biological need. Industry and agriculture use water in production processes from which they draw profits (utility). They transform water into economic value. Utility derived from the production and consumption uses of water creates an economic demand for it. Being responsive to market forces, these interests determine the relative worth of particular water uses and quantities of water used. Water use is determined by economic forces and human needs.

Throughout the region the common pool continually provides water for a growing, highly urbanized and industrialized society. The availability of abundant supplies of water, under rules which created few restrictions as to manner and quantity of use, has provided enterprises with sufficient security of a water supply to justify and encourage economic development. Demand for and use of water by this sector is intense (TWDB, 1970). Water demand is derived from the demand for goods produced within the region that require freshwater. Such economic activity has produced dynamic urban economic systems, upon which the growing number of inhabitants are largely dependent. Freshwater is needed for direct human consumption and for other municipal uses. Demands upon the groundwater resource supply have been continually growing as population and industrialization expand.

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[7] Water produced from the common pool is attractive because it is of good quality and is relatively inexpensive to capture and use. The limit on the value of groundwater to an individual would be set by the alternative annual cost of purchasing the same quality and quantity of water from surface water suppliers, plus the cost of constructing surface facilities (Ries, 1967, 83; Ostrom, 1965, 527).

Conditions of the groundwater resource supply system gradually changed under intensive demand pressures (Gabrysch, et. al., 1975). Water levels slowly declined and greater effort was required of individual water users to reach the supply. The system satisfied water demand from groundwater sources. However, the safe-production potential was exceeded, and land surface subsidence began a natural response to overdraft.[8]

In a common pool resource situation, serious problems logically follow if demand exceeds a supply threshold (Ostrom, 1975). In the subsidence area these were aggrevated by the narrow economic motive of groundwater users, and the fragmented institutional system characteristic of a decentralized decision system. Hence, achievement of balanced use of the system such that groundwater pumpage equals natural replenishment of the system is beyond the scope and control of water related organizations and individual users. When demand exceeds groundwater supply under such an institutional system, institutional failure occurs, which can be explained in terms of the "common pool problem".

Common pool problems

The essence of the common pool problem is determining an optimal production rate (Friedman, 1971). Land surface subsidence and consequent environmental and socio-economic impacts are properly conceived of as a problem of externality, a divergence between private (internal, user) costs of groundwater production and social (external, neighborhood) costs of exploitation beyond a safe supply threshold (Demsetz, 1975). Commonality of

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[8]The safe-production potential of the aquifers, also known as the maximum acceptable withdrawal rate (MAWR) is that rate of use of the water system such that no subsidence occurs. Although it has not as yet been defined quantitatively, it is believed qualitatively to be close to the rate of natural replenishment (Gabrysch, 1976).

water use produces spillover costs when the costs of extra production do not fall upon the individual proportionately in relation to groundwater use but are borne instead dis-proportionately in relation to use by other individual property owners and groundwater users (Milliman, 1956). The more that is pumped, the greater the cummulative external effects.

Incentives and deterrents, and legal and economic relationships, operate as follows in a common pool situation (Friedman, 1971): A self interested individual will make his water usage decisions based on his relative costs and benefits of alternative courses of action. Given that effective ownership of the common pool water is dependent upon capture, and that an individual is not responsible to other land owners and water users for effects of his capture on their operations, an individual's cost calculus shows only the internal, marginal cost of his actions. He will capture and use water from the common pool up to the point where the benefits of him doing so equal the costs of him not doing so. Social costs imposed by his production of additional units of water may not be borne by him at all, being totally shifted to other members of the community. Or, social costs are likely insignificant depending, of course, upon his proximity to location of the externality--coastal bays or other water courses.

If an individual makes decisions based on an accounting of the relative costs and benefits, and if external costs and benefits are not included in the calculus, the real social profitability of alternatives is not accurately measured and socially uneconomic decisions result (Friedman, 1971, 866). Consequently, from a social perspective, an individual's costs are artificially low and his rate of production is undesirably high (Snyder, 1973, 292).

Under existing institutional arrangements, information relative to social costs is largely excluded from individual decisions. Short run calculations predominate over long run calculations. Individuals are prone to error under conditions of imperfect information (Ostrom, 1975). The existence of a divergence between private and social costs seriously hampers the private market in effecting an efficient allocation of water resources (Milliman, 1956, 431). An individual is induced to use what he computes to be the least cost water source - groundwater.

In a common pool situation, this logic of individual rationality becomes collective irrationality. A competitive dynamic occurs, escalating social costs to the point where operations are sustained with economic losses for the community (Ostrom, 1975, 774). Table 2 shows the relationship between the regional dynamic, water use, and rate and extent of the ensuing common pool problem. A relatively constant price ratio of surface water to groundwater of 3:1 has induced individuals to continue to rely on the groundwater source, even in the face of a threatening situation.[9]

The subsidence externality represented by the divergence between private and social costs has been quantatively estimated as economic losses to the community totaling $31.7 million (Jones, et. al., 1975).[10] If these external costs are added to the internal costs of pumping groundwater, the total marginal cost of groundwater, when compared with the marginal cost of alternative surface water sources at present prices, are, in the aggregate, of sufficient magnitude such that the subsiding area could substitute

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[9] Average costs of groundwater are about $.06 per thousand gallons, and about $.22/thousand gallons for purchase of surface water (Jones, et. al., 1975).

10 This cost does not include the potential damage of a hurricane, which can be expected to be significant (See GCWDA, 1975).

TABLE 2

Relationship of Economic Growth to
Water Use and Subsidence

YEAR	A. INDEX OF INDUSTRIAL ACTIVITY	B. POPULATION	C. GROUND WATER	D. SURFACE WATER	E. SUBSIDENCE IN FEET GREATEST	E. SUBSIDENCE IN FEET AVG.	F. AREA IMPACTED IN SQUARE MILES
1900	9.6	107,902	18	0	0	0	0
1905	NA	134,037	25	0	0	0	0
1910	NA	160,172	31	0	0	0	0
1915	NA	199,194	33	.006	0	0	0
1920	NA	239,817	50	0	0	0	0
1925	NA	311,733	64	.025	0	0	0
1930	26.5	423,729	88	0	0	0	0
1935	20.8	516,931	91	0	.62	.3	0
1940	25.8	610,134	156	0	.87	.5	80
1945	64.7	695,563	225	33.50	1.3	.85	300
1950	81.4	920,362	325	64.61	1.9	1.38	700
1955	93.0	1,173,378	365	85.70	2.9	2.09	1,100
1960	100.5	1,383,522	311	122.00	4.0	2.92	1,450
1965	119.7	1,610,600	421	144.35	5.5	4.2	1,850
1970	157.1	1,911,724	517	186.85	8.0	5.88	2,500
1975	198.00	2,060,100	550	198.00	8.5	6.72	3,000
1980	204.05	2,421,047	659	229.6	10.0	7.40	3,117
1990	251.3	2,964,247	810	288.0	13.0	9.60	3,921
2000	301.3	3,539,397	969	350.4	16.0	11.80	4,772
2010	365.8	4,279,844	1,174	430.3	20.0	14.50	5,868
2020	506.7	5,899,428	1,623	605.3	28.0	20.70	8,266

A. This index was created from taking Employment in Manufacturing, Harris and Galveston Counties, from U.S. Census, Characteristics of the Population, and County Business Reports and Texas Almanac, using 1900 as a base year and dividing by 100. Estimates for 1980-2020 created from regression coefficient of population growth to industrial activity. This coefficient explained 96% of the variance for years past.

B. Texas Almanac 1974-5, A. H. Belo Corp., 1973. 1980-2020 projections are

from, Texas Water Development Board, Population Projections, Nov. 1975 and Government Office estimates, May 1974 (unpublished).

C. Average Daily Pumpage of Groundwater in the Houston District, 1980-1960, U.S. Geological Survey, Texas Water Commission Bulletin 6508. 1960-1970, U.S. Geological Survey, Texas Water Development Board Report #153, July 1972. Given in million of gallons per day. 1980-2020 projections based on population/water use regression coefficient. (94%).

D. Reported Water Usage for Harris-Galveston Counties 1913-1973, Texas Water Rights Commission (data converted from acre feet per year to million gallons per day). Given in millions of gallons per day. 1980-2020 projections based on population/water use regression coefficient. (94%).

E. "Land Surface Subsidence in the Texas Coastal Zone" W. L. Fisher, April 11, 1973, presented to committee on natural resources, Texas House of Representatives. Average subsidence computed for the towns of Houston, Pasadena, Baytown, Texas City - prime bench marks within the region. 1980-2020 projections based on regression coefficients of population growth to subsidence (95%).

F. Area impacted in excess of one foot, from "Natural Hazards of the Texas Coastal Zone," Bureau of Economic Geology, University of Texas at Austin, Fig. 13, 1974. 1980-2020 projections based on regression coefficient of population growth to impacted area coefficient (98%).

Source: Swanson, Seymour, Brah. "Allocating a Common Pool Resource in a Private Manner: The Dilemma of Subsidence." Texas A&M University, 1976. (Unpublished)

surface water for groundwater and still save over $10 million annually, for all water demand (See Table 3).

The magnitude of social costs readily indicates that institutional weakness will occur when individuals act with the legal independence characteristic of decision-making in market structures in the development and use of a common pool resource. So long as the market registers costs and benefits in its traditional manner, all water users compete for the "inexpensive" source of water.

Logic of Collective Action

Effective voluntary collective action under existing institutional incentives and deterrents is difficult and unlikely. The nature of the benefit conferred by voluntarism can best be viewed as a collective good. A collective good is one which, when provided by one member of the community, confers a benefit on other members of the community. One providing the good can not exclude use by others by private means or otherwise compel payment for the benefit conferred (Olson, 1965, 35).

It is clear that some members of the region, namely shoreland property owners, would have a great interest in proposing voluntary collective action because they would receive a significant porportion of the benefit. However, organizing such action to achieve a socially optimum rate of pumpage is constrained. First, negotiation of an agreement is repleat with high transaction costs and constrained by high policing costs if an agreement were reached (Demsetz, 1975, 30). Second, there is the prospect of individuals pursuing a holdout strategy since a substantial degree of unanimity is required. The holdout will be free to capture a "lions share" of the benefit derived from the voluntary joint action of others (Olson, 1975, 35). As long as each person is free to decide his own

Table 3. Water use, costs and net difference in costs between surface and groundwater by sub-areas, Upper Galveston Bay.

Sub-area	Water Use[a]	Water Costs			
			Groundwater		Net
		Surface	Internal	External	Difference
	(bgy)	------	-million dollars-	------	------
I (Pasadena - Baytown)	5.84	1.285	0.350	8.795	7.860
II (NASA - Clear Lake)	10.66	2.345	0.640	5.009	3.304
III (Houston & other)	110.26	24.257	6.616	17.363	-0.278
TOTAL	126.76	27.887	7.606	31.167[b]	10.886[b]

[a]Water use estimates adapted from (Gabrysch 1972) and updated by personal interview.

[b]Does not include estimated public costs.

*Source: Jones, et. al., 1975.

course of action, the probability of an individual pursuing a holdout strategy is high (Ostrom, 1975). If the holdouts are many, or if a few holdouts are major pumpers, the stability of any voluntary collective action is threatened (Friedman, 1971, 870). Third, there is the difficulty of reaching a mutually satisfactory agreement. Conflicts of interest arise because of variations in the expectations of the incidence of benefits (Smith, 1968, 265). Groundwater users living in one locality will find the expectation of benefit, if it exists at all, to be quite different from that of a groundwater user living in another locality. Upon that basis, he may oppose membership in a collective group.

Anticipated benefits of surface water conversion are not uniformly distributed within the subsiding area. Since subsidence related costs are concentrated in shoreland areas, property owners and water users within these areas would enjoy the greatest reduction in total cost if the substitution of surface for groundwater halted subsidence. Property owners in areas remote from the coastline would experience higher internal, user costs for water, but may not enjoy comparable cost savings since the incidence of subsidence related costs are relatively low (Jones, et.al., 1975). Conversion to surface water in these areas could not be justified from an individual standpoint, however such action is needed to minimize total water use costs and consequently halt subsidence.

Such a situation is at the heart of the common pool problem. Although individuals are interrelated through the use of common groundwater supplies, and even though all users in areas more remote from the coastline contribute proportionately to the sinking externality, there is little basis for collective action among groups not experiencing the serious effects of the problem. Self serving interests are not conducive to cooperation in a

system which fosters competition for inexpensive but scarce water supplies.

Prospects for a Collective Solution

Olson (1965) specifies the conditions under which individuals can be expected to resolve common pool problems. He argues that an optimal amount of the collective good, the amount necessary to halt subsidence, will be obtained when each member of the group finds that his personal gain from having the collective good exceeds the total cost of providing some amount of that collective good. Each member must secure a separable benefit when his cost of providing is exceeded by his benefit from the provision (34).

Such a condition can not be expected in the subsidence case because of substantial regional disparities in costs and benefits. In this case, Olson argues that only through special institutional arrangements can individuals be induced to purchase the amounts of the collective good that would add up to the amount that would be in the best interest of the subsiding area as a whole (35). Groundwater users would have to be coerced into acting jointly in the common interest through the establishment of collective decision rules which relax the requirement of willing consent.

Some form of public intervention in a common pool situation is desirable when economic relationships radically deviates from the market model; when social welfare can actually be improved; when legal relationships are such that individuals are not parties to transactions which relate to their social welfare; when physical conditions afford interdependence of water use in common with a number of individuals and these individuals have little incentive to act jointly in relation to the common interest (Friedman, 1971; Ostrom, 1975; Trelease, 1965).

Possibility of a Public Sector Response

Groundwater users and property owners in seriously subsiding areas gradually turned to the public sector for an institutional response to the subsidence problem, but found that they were either unavailable or undesirable. Texas courts have consistently held themselves powerless to control the use of groundwater and have avoided the complex task of devising decision rules for groudwater administration (Snyder, 1973; Booth, 1974). The Texas Water Rights Commission seems to have the statutory authority to regulate groundwater production. However, it has not chosen to do so and, in any case it is unclear whether a comprehensive groundwater management program may be implemented by the agency (Snyder, 1973, 294). Indeed, repeated efforts by many local areas throughout the state to enact a comprehensive, statewide ground management program to solve common pool problems have consistently met with limited success (Woodruff, et. al., 1952).

Decision-makers throughout the subsiding area found that local groundwater regulation may be accomplished through special underground water conservation districts (60 Texas. Jur. 2nd, Aec. 230-234), but such an institutional mechanism is relatively weak for dealing with collective good, externality problems. (See Woodruff, et. al., 1952; Snyder, 1973). Decision rules are primarily designed for conservation of water and not for dealing effectively with a problem characterized by collective costs. Its effectiveness is severely limited by the complexity of the district creation process, loopholes available for those landowners, cities and counties not wishing to participate in a management program could not evolve unless local residents, acting through popularly elected directors, were willing

to impose controls on their own pumping activity (Booth, 1974; Snyder, 1973).[11] These provisions alone make such an institution inadequate. It was demonstrated that little basis for effective voluntary collective action exists in the subsidence case, and in the broad context of a common pool.[12]

The tenous institutional basis for collective action to interrelate the collectivity of groundwater users, because of divergent interests, was exacerbated by local conflict as a result of class action lawsuits which attempt to shift collective subsidence related costs from "victims" to groundwater pumpers in two local, subsiding areas.[13] Plaintiffs contend groundwater use that has caused their land to subside constitutes a permanent and continuing nuisance entitling them to monetary and injunctive relief. However, these "private" approaches offer only a narrow perspective of a regional problem (Harnsberger, 1973, 240; Teutsch, 1975). But such an approach is an effective mechanism for coercing large groundwater users to act in common with the public interest.

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[11] When implemented, underground water conservation districts (UWCD) have met with little success in instituting comprehensive groundwater management (Snyder, 1973).

[12] Regional decision-makers adamantly opposed creation of a UWCD.

[13] Brown, et. al., v. Exxon, et. al., No. 945-746, District Ct. of Harris County, 113 Judicial Dist. of Texas; Smith-Southwest Industries, Harris County, 55 Judicial Dist. of Texas. It will be difficult for the courts to distinguish "Victims" from pumpers since those harmed by groundwater use are the same ones relying on it directly or indirectly.

Institutional Implications

This theoretical and empirical construct of the common pool leads to the following conclusions. Incentives and deterrents afforded by the institutional arrangements described are ill-suited for groundwater resource conditions of demand in excess of "safe" supply. The fragmented, narrow scope and "use" nature of public and semi-public water organizations are inappropriate for balanced use of a natural underground water-bearing system. Other groundwater management institutions available are inappropriate or limited.

Institutional weakness may be corrected in theory by alteration of property rights and/or groundwater production incentives (Friedman, 1971; Milliman, 1956; Hershleifor, et. al., 1969, 59-66). In either case it may be necessary that the public sector act as if it were sole owner of the common pool. Such would provide the scope necessary to compute the total costs and benefits of alternative courses of action, which is beyond the capability of any individual user. This information would be provided to each groundwater user in some form or another, and each would be externally motivated to take account of it (Demsetz, 1964, 16). Calculated properly, the internalization of this information would induce the socially optimum groundwater pumpage rate. This course of action represents a transition from a decentralized to a somewhat centralized decision system.

The institutional solution must be one which can recognize divergent expectations of costs and benefits in order to unite the collectivity of groundwater users, such that resources are pooled to attain an effective physical solution. The institutional solution must modify those institutional elements which have led to improper use of groundwater resources such that future costs associated with institutional weakness are minimized.

The previous analysis has demonstrated how subsidence has forced the question of groundwater allocation out of the private sector and into the domain of the public sector. However, two interrelated problems need to be addressed. They concern the implementation of the technological solution, and implementation of an institutional solution. The former concerns the economic conditions generated by regional water supply and demand, and implies a need for the reallocation of water resources and manner of water resource use. The latter concerns legal and political conditions, and implies the reallocation of decision-making capabilities.

The relevant questions for designing institutional arrangements are: how to respond to the technical problem and how to respond to the institutional problem. The solution, generally, is to design an appropriate groundwater resource management organization and equip it with management tools necessary to centralize decision-making capabilities, while at the same time ensuring that the entity is responsive to the needs of groundwater users. Such a management organization would direct, govern and control the actions of individuals in relation to the groundwater supplies of the region so individuals would use the water in a manner and quantity deemed socially beneficial while, at the same time, manipulating water supplies so as to satisfy the needs of water users.

The most rational way to respond to the technological problem, while being responsive to the freshwater needs of the community, would be via a conjunctive groundwater - surface water use system. Such a system will in turn dictate in part the nature of organizational arrangements needed for effective control of land subsidence.

Conjunctive Use and Conjunctive Management

Despite the existence of a complex of aquifers with a relatively high rate of natural replenishment, the physical system has imposed restraints on the actions which individuals can take in relation to it. This has great implications for a region primarily relying on groundwater for freshwater demands. Substantial demands for freshwater will be displaced from the traditional source.

From an economic standpoint, groundwater is more valuable left relatively undeveloped in overdrafted areas, so valuable as to justify development and use of alternative surface water sources (Jones, et. al., 1975). From a physical standpoint, some, but as yet unknown quantity of groundwater can be expected to be safely used (Gabrysch, 1974). Therefore, the greatest attention will be devoted to conjunctive utilization of both ground and surface water sources, which necessitated a reallocation of regional water resources. Then the demand for freshwater which cannot be met by the groundwater system can be met by a surface system.

Although the economic development of the region led to an economically destructive subsidence problem, it also created an economic base capable of developing and using new water supplies. The relatively small amounts of surface water currently in use are obtained locally from Lake Houston and from the San Jacinto River via the San Jacinto River Authority. Other sources of surface water are being developed at Livingston, Conroe and Wallisville reservoirs. Surface water delivered from Livingston reservoir via the Coastal Industrial Water Authority to the subsiding area will soon provide some relief. The potential of these water sources provides quantities of water well in excess of current needs within the subsiding area (Texas Water Development Board, 1970; Jones, et. al., 1975).

This water is needed to maintain the urban economic systems upon which the diverse socio-economic area is dependent. However, while presently available, water resources are scarce. In addition to the surface water demand created by the transition to a more evenly distributed, combined groundwater - surface water supply, the total demand for freshwater is projected to grow significantly with continued urbanization and industrialization (see GCWA, 1974).[14] Full development of surface water resources and groundwater resources, assuming production of the latter is held to the maximum acceptable annual withdrawal quantity will probably be capable of supplying the projected demands of the area until the year 2000. Additional supplies will be required to meet longer range needs of the region (Texas Water Development Board, 1970). As much as 60 percent of these regional water needs will have to be obtained from surface water sources (Jensen, et. al., 1973).

Alternative sources are more costly and call for greater public involvement in their support. Projects will grow in scale, complexity and cost. Competition for the safe supply of groundwater will be exacerbated.

Conjunctive use necessarily implies that decision-making capabilities will need rearranging so as to facilitate the management of water supply and demand. Short run needs concern a smooth, reasoned and efficient transition to use of surface water sources to mitigate the adverse effects

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[14] Demand for water is not limited to human purposes. In addition, the coastal bays and estuaries boarding the region bid for these water resources. The economically valuable ecosystems of Galveston Bay require a certain freshwater/saltwater mix to remain productive. Development of regional surface water supplies will diminish freshwater inflow into this natural systems (see General Land Office, 1976).

of excessive groundwater pumpage. Long term needs concern the assurance of the availability of water and in turn a smooth transition from conditions of relative water resource abundance to water resource scarcity.

An overall management policy for regional water resources is required in order to avoid inefficient water resource use.[15] Commentators in the literature emphasize that successful management of groundwater resources to mitigate common pool problems involves the full consideration of surface supplies and the coordinated, conjunctive operation of surface and groundwater resources in integrated systems (Renshaw, 1963; Warne, 1964; Fowler, 1974; Valentine, 1964; Moses, 1966; Krieger, et. als., 1962; Ries, 1967; ASCE, 1972; Corker, et. al., 1971, Mack, 1971; MWC, 1973; Chun, et. al., 1964). The concept of conjunctive management directly addresses the maximization of efficient water resource use through coordinated management of the several water supply sources. The logic is derived from the reality of a naturally interconnected hydrologic unit as a supply source, embracing the supply source to satisfy the demands of water users. Water is managed collectively as a single resource serving a single aggregate need (Piper, et. al., 1958).

Conjunctive management is best understood by considering a regional water budget, with groundwater and surface water as the sum total of the regional water economy. Each supply source has a stock and flow component, and transmission and delivery characteristics. Conjunctive operation has at its disposal each of these components. Embracing these components, allocation becomes a matter of economics, a problem of providing an adequate supply of water at least cost, including any and all social costs,

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[15] Subsidence indicates that groundwater resources are being used inefficiently from a social cost-benefit standpoint.

maximizing net benefits of the entire water supply system (Fowler, 1964; Smith, 1968; Burt, 1966; Buchwalter, 1970; Ries, 1967, Piper, et. al., 1968; and Burt, 1964).[16]

With respect to subsidence control, this is of course accomplished by achieving a balance between long term inflow and outflow (pumpage) and mitigation of the disparity between water needs and water supplies. As groundwater resources become fully committed in the short run, and surface water sources become fully committed in the long term, partial demand can be satisfied through increased use of underground storage of surface runoff water (and possibly in the very long term, storage of reclaimed sewage and industrial waste of suitable quality), in time of surplus to be withdrawn in time of shortage (cyclic management) (Moses, 1966; Ries, 1967; Gabrysch, 1976; Owen, 1968). The point is to conceptualize the aquifers as a place of storage, necessitating it being a legally protected entity (Ries, 1967, 55).

The fullest development of conjunctive operation requires control over the rate, amount and geographical pattern of extraction of groundwater. To effect such operation, a management organization is required with 1) political boundaries that encompass the physical and production events needed for subsidence control; 2) authority to purchase, contract for, or otherwise

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[16]Although the supply capabilities and limitations of the groundwater system are ultimately fixed by its physical nature, the "safe" supply capability may be enhanced through proper well spacing (Jorgensen, 1976). Proper well spacing can increase the amount of water ultimately obtainable by encouragement of groundwater use in those remaining portions of the aquifers that are relatively full, for example north of Houston (Gabrysch, 1976). From another perspective, the objective of well spacing is to broaden the cone of depression (water level and land surface level) into areas where the aquifer is relatively full. Then the artesian pressure would rise in the center of the present cone of depression and thus would impede the progress of surface subsidence.

finance or arrange for the delivery of a supplemental water supply; and 3) legal authority to regulate and integrate all sources of regional water resources into a planned system of water use (Buchwalter, 1970; Warne, 1963; and others). Presently, no such organization exists within the region as well as within the nation, although the concept is widely advocated (see NWC, 1973). Less comprehensive conjunctive use - conjunctive schemes may obtain similar results.

In any case, successful conjunctive management requires, first, accurate information about the physical system to be regulated (Ostrom, 1965, 93). This information pertains to the maximum acceptable withdrawal rate, which is unknown at the present time.[17] If data are insufficient, trial and error must be used to a large extent to create a management scheme; experience will reduce uncertainty (Corker, et. al., 1971, 141-74).

Successful conjunctive management also requires a high degree of cooperation among water users and existing institutions in allocation of water and water costs. Noted experts have stated that "The complex of existing political units, each dealing with part of the problem, must not only be coordinated, but new responsibilities created by new circumstances must be woven into the political fabric" (Krieger, et. al., 1962, 74). Such requires making mutual concessions to common advantage (Piper, et. al., 1958, 24).

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[17] Geohydrologists have measured the response of the groundwater system to declining water levels, however, the opposite effect has not been measured. Knowledge about the response of the system to a rebound in water pressure is required to determine the maximum acceptable withdrawal rate. This determination is expected to be arrived at within 2 - 3 years (Gabrysch, 1976). It is tentatively estimated that the quantity reduction of groundwater pumpage required to halt subsidence would possibly be at least 50 percent of present production in the seriously subsiding area.

In practice this would require coordination of operations of all regional water related institutions, fashioning a rational water use and subsidence control plan (see GCWDA, 1975). This would involve determination of regional water demand, where water is being used now and where it will be needed in the future, analyzing how water is being supplied currently and what future plans are for water supply. Supply schemes would be developed and correlated with a subsidence control plan.

Physical water supply and demand conditions need to be controlled through manipulation of legal and political conditions to fashion the necessary institutional arrangements. This process requires a substantial reallocation of water while, at the same time, a substantial reallocation of decision-making capabilities. Management can no longer merely be a matter of restricting extractions to halt land subsidence. It should be a matter of dealing with common water problems forseen and unforseen.[18] The wider the consequences which flow from new technological solutions, the more complex the task of rearranging institutional systems (Ostrom, 1972, 5).

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[18]Two time frameworks might be adopted for water resource management (ASCE, 1972, 77). Within existing institutional, physical and socio-economic constraints, a short term subsidence control plan could be developed. The long range program would fashion a water supply and demand management scheme, to ensure that subsidence is permanently arrested, considering those short run restrictions (institutional, etc.) malleable and subject to alteration over time. Such a two faceted approach is appropriate for formulating an institutional strategy.

Part II

DEVELOPMENT AND EVALUATION OF ALTERNATIVE INSTITUTIONAL ARRANGEMENTS

Institutional arrangements for the management of groundwater resources first must be influenced by the basic characteristics of the water system. They also must give expression to the values of the community and facilitate their realization (Fox, 1962, 3). Institutional arrangements therefore need to account for economic necessities to be responsive to user preferences and economic requirements, with flexibility to adapt to technological advances and changed resource conditions. Generally inherent must be (1) the ability for application of a range of water resource management techniques for influencing efficient water use and development, (2) to equitably consider and adjust externalities stemming from commonality of groundwater use and (3) the ability to express and consider the range of political and user values relevant to water resource management decisions (Clark, 1976, 219-221).

Water is essential for community needs. However, the community would be economically better off if water is used such that land subsidence is halted. To facilitate these needs, alternative institutional arrangements need to be developed. These would provide the necessary decision-making machinery to give expression to community values and satisfy community needs relative to water resources.

Institutional arrangements are simply combinations of legal, political and economic institutions. Law is an institution through which human conduct is regulated and under which collective decisions are made (Corker, et. al., 1971, ii; Ostrom, 1972, 2). Legal institutions relating to groundwater resources management are essentially water law or water rights. Broadly interpreted, water law includes contributions by the legislative, judicial and executive branches of government. These include statutory

water law, common water law, including judicial creation of water law through decisions in individual cases of controversy, and administrative regulations by executive water agencies having the force of law (Wantrup, 1956).

Political institutions are decision-making frameworks or collective organizational structures, public enterprises or agencies concerned with the allocation, exercise and control of decision-making capabilities, with some mission or scope of authority, performing some public service related to water resource development and use.

Economic institutions can generally be conceptualized as decision rules which affect individual behavior in regard to economic decisions. Almost all institutions have a certain degree of economic significance (Casbeer, 1969, 93). Many institutions of legal origin, such as private property and contracts, play a vital role in an economic system. Variations in the legal rules governing human action can significantly influence economic behavior and resource allocation (Hirshleifer, et. al., 1969, 32 -73). Different configurations of rights and duties can influence an individual's cost-reward calculus, providing him with varying incentives for differnet water resource uses. Economic institutions also include politically imposed pricing mechanisms, taxes, user charges and the like which influence the economic behavior of groundwater users. Economic institutions are properly conceived of as all institutional forces which affect the operation of the private market.

Legal, economic and political institutions are clearly interrelated. Political institutions typically provide the organizational superstructures or vehicles for public water resource management; such an organization has both a defined jurisdiction or scope of authority, and defined functional relationships with other water-related agencies or entities. Water rights

compose the basic structure of institutional arrangements, and both legal, economic and legal-economic institutions or rules can be used to modify the authority of a person to use and control his water right. These decision rules are properly conceived of as the constitution of a water management entity.

Each institutional arrangement, or combinations of legal, political and economic institutions can be expected to generate a limited range or preferred effects and each will be characterized by inherent capabilities and limitatitons. The effective institutional arrangements will minimize the costs associated with institutional weakness or failure. Institutional failure can be predicted and identified by the development of an evaluation system. Such a system will simply be a set of basic "strong points" generally held necessary to be displayed by alternative institutional arrangements, if institutional strength is to be maximized.

CRITERIA FOR EVALUATION OF ALTERNATIVE INSTITUTIONAL SYSTEMS TO HALT LAND SUBSIDENCE

Institutional arrangements for conjunctive water resource management are simply sets of decision rules for establishing capabilities and setting limitations on the discretion which choice-making individuals can exercise in using the common pool resource. The particular sturcture of problems associated with the exploitation of the regional groundwater resources form the context within which institutional arrangements must operate.

From a review of literature, certain preferred or optimal effects, qualities, characteristics and outcomes have been identified for public organizational arrangements designed to operate within the context of the structure of events associated with common pool resources. These can be stated as criteria, and as such, form a set of preferred strengths for water management institutions. Since each institutional arrangement can be expected to generate a limited range of preferred effects, with implicit capabilities and limitations, the preferred set of criteria, when applied to each institutional arrangement, will illuminate relative strengths and weaknesses. Further, since the optimum choice of institutional arrangements would be those which minimize the costs associated with institutional weaknesses, the criteria serve as a basis for delimiting choice among the alternative institutional arrangements (Ostrom, 1975, 773).

For purposes of analysis, three sets of criteria are stated. They are relevant to (1) the necessary preconditions for institutional implementation; (2) the preferred capabilities of institutional arrangements

for performing the allocative (water and costs) function; and 3) the preferred results or outcomes of the allocative function of institutional arrangements. Objectively, each criteria within a set and each set of criteria is deemed important and is integral to institutional effectiveness.

In short, criteria, as widely preferred standards and attributes of institutions for water management, function to: 1) judge effectiveness; 2) appraise the performance of an institutional system; and 3) treat the existing institutional systems.

Set of Preconditions

Institutional arrangements are only viable if they can operate in the context of the existing physical, social and institutional setting (Fox, 1962). These settings form the preconditions for, and as such, constrain implementation of a particular institutional arrangement. It is clear then, that restructured institutional arrangements, representing departures, however slight, form existing rules, practices and patterns of action, must be acceptable socially and compatible physically. It is also evident that existing physical, social and institutional conditions are dynamic and subject to change. However, at any point in time, these conditions need to be indicated, as they bear upon the feasibility of implementing alternative institutional arrangements.

The importance of institutional feasibility is implicit and explicit in the literature, but best stated by Ostrom (1972). He identified the following set of feasibility criteria:

1. Technical Feasibility

Is a potential course of action possible given existing knowledge and technical capabilities? Here it is recognized that success of resource management institutions is dependent upon the availability of information about the physical system to be regulated.

2. Economic Feasibility

Do benefits expected from an institutional change exceed costs including forgone opportunities? If this criterion is not met, community members will be worse rather than better off.

3. Financial Feasibility

Can sufficient revenues be generated by an institutional system to cover expenditures? Financial feasibility depends on funding from permits, user charges, taxes or politically imposed pricing mechanisms.

4. Legal Feasibility

Is a proposed program of action lawful and constitutional?

5. Political Feasibility

Is a particular institutional arrangement acceptable to those whose behavior it is designed to condition? Can the appropriate decisions be sustained?

Determination of political feasibility would ideally be based on an empiracal attitude canvassing of regional decision makers and other political actors. However, in the absence of this information, political feasibility of alternative institutional arrangements can be roughly estimated according to a predictive model developed by Lowi, Salisbury and Heinz, as described in Godwin and Sheppard (1974).

Political acceptability is relevant to the political costs to decision-makers (e.g., constituent support) and other political consequences of implementing alternative institutional arrangements. The model divides policies into four types, the regulatory category being relevant here. Regulatory policies are those which redistribute power and authority, that is, reallocate decision-making capabilities. Each type of policy to some degree results in winners and losers, although they might not be readily identifiable. Generally, regulatory policies are clearer as to both their winners and losers (Goodwin and Sheppard, 1974).

Stated simply, the clearer the winners and losers are as the result of a reallocation of decision-making capabilities, the less politically feasible an alternative institutional arrangement can be expected to be. Conversely, the most politically acceptable arrangements are those in which the disparity between winners and losers is mitigated or absent. Such a yardstick of "winners and losers" can indicate the political acceptability of alternative institutional arrangements, in the absence of empirical information.

The feasibility of various institutional arrangements will influence the determination of which particular one can be selected (Davis, 1975). However, institutions are malleable and feasibility is not unchangeable. Feasibility criteria are important because they uncover institutional elements which would need revision in order to be acceptable.

Set of Operational Characteristics

The following characteristics are relevant to the optimum spatial relationship (to institutional and physical environment) and temporal

characteristics of institutional arrangements for water resource management, as they function to allocate water resources and water costs between users and uses.

1. Capacity to Regulate Events

Physical conditions of water supply and subsidence, as well as socio-economic conditions of individual and group behavior in relation to common pool resource, from the structure of problems needed to be embraced by a water management institution. In the literature on water management, it is implicit and explicit that institutional arrangements for water resource management be evaluated in terms of their capacity to regulate the events needed to be controlled (e.g., Ostrom, 1965, 520; ASCE, 1972, 63).

Adequate decision-making capabilities, of whatever form, must be inherent in an institutional arrangement to attain and sustain a conjunctive management program.

2. Capacity for Political Negotiation and Coordination

A public water management organization functions in a political environment characterized by vertically and horizontally fragmented water institutions. Each of these public and semi-public water institutions has a particular scope or jurisdiction and each deals with various and overlapping aspects of regional water use, supply and development.

Since a comprehensive conjunctive management program requires a high degree of coordination among water institutions (ASCE, 1972, 64-65), it is suggested that a public water management enterprise be evaluated in terms of its capacity to reach satisfactory solutions to water problems through negotiation, or other means, and to coordinate the efforts

of formally independent public and private agencies (Ostrom, 1965, 520).

3. Accountability to Community of Interests

Ostrom (1975, 778) states that the optimal organizational arrangements for the managment of a common pool resource "would take account of diversities in user preferences and in production economies, relationship of demand to supply, and relationships in which one pattern of use may impair other patterns of use." He concludes that a management unit need be, among other things, immediately accountable to the relevant community of interest for which it is acting in order for a more optimal condition to be attained in a common pool situation. Such a conclusion is partially based on the premise that public organizations, using coercive measures to force groundwater users to act in the public interest, need to provide opportunities for all constituents to signal their agreements and disagreements, so as to minimize conflict and maximize social welfare and institutional effectiveness.

The degree to which a water management institution is accountable to the community of interests can be expected to be the degree to which community interests are reflected in a water management program, which is deemed desirable in the literature generally (e.g., ASCE, 1972).

4. Flexibility

Allocation of decision-making capabilities among a community of interests occurs within the context of existing physical (hydrologic system) socio-economic, legal and political conditions. These conditions among the community of interests can be expected to change.

For example, over time, the heterogeneity of community interests may change and demand a modified set of water services, as well as water

management services (Smith, 1960, 1357-8). Continued regional growth affect the demand for and supply of water resources. Traditionally low water costs will escalate as demand increases and new supplies are developed. As supply and demand conditions change, new technological solutions can be expected which will affect water production potential and may implicate reallocation of both water use and decision-making capabilities.

To be effective under such dynamic conditions, it is widely held that water management institutions require the capacity to rearrange decision-making capabilities to adapt to changing conditions among the community of interests (Ostrom, 1972; Snyder, 1973; Smith, 1960; Smith, 1968; Bagley, 1961; Flint, 1968; Wantrup, 1956; Murphy, 1970). This ability is provided by elements of flexibility.

Flexibility implies that institutional arrangements for water management are not only responsive to meet current needs, but remain responsive as needs change. Flexibility focuses on those elements of water insitutions which facilitate or obstruct changes over time in the allocation of water resources between uses and users in response to varied supply and demand conditions (Clark, Sec. 63.4, 1967). Stated as a criterion, flexibility indicates that institutional arrangements are responsive and have the capacity for change in decision rules. Problems in the use of a common pool resource cannot be avoided in the absence of capability to respond (Ostrom, 1975, 777).

5. Minimization of Policing Cost

Certain costs are incurred by a water management institution in effecting an optimum allocation of water resources. These costs have

been characterized as the costs of policing a particular water management scheme (Demsetz, 1964, 16). Such costs involve the time, energy and dollars spent in administering and enforcing management rules and regulations. These costs can be expected to vary with each institutional arrangement, and are dependent upon the particular type of institutional rules used (legal, economic, legal-economic, etc.). Because water management institutions are generally publicly supported under some equitable apportionment of costs, it is not only politically expedient, but efficient to prefer a least cost (but effective) method of policing a management scheme to be employed.

Cost of policing will be predicted and qualitatively described for each institutional arrangement; each arrangement will be evaluated by the degree to which police costs are at a maximum or a minimum. Indications of the relative police costs further serves as a basis for choice among alternative institutional arrangements.

Set of Preferred Outcomes

Each institutional arrangement generates a limited range of effects or outcomes. Certain preferred effects or outcomes are widely subscribed to in the literature. The following set of criteria state the preferred effects expected to be generated by effective water resource management institutions.

1. Social Welfare Maximization

In the literature on common property and common pool resource management, there is confidence that economic logic can be successfully applied to a great range of practical resource problems. The relationship

between institutions and outcomes is central to the literature of welfare economics (Nath, 1973). The dominant theme, explicitly or implicitly, is the evaluation of particular institutional arrangements, and is accomplished by comparison of the relative welfare positions of each individual under various institutional systems (Stubblebine, 1975, 16).

Welfare can be defined as the well-being of an individual, while social welfare the well-being of groups of individuals. Since institutions condition behavior, welfare economists suggest that an individual (or groups of individuals in similar welfare positions) will seek those institutional modifications which will induce others to make choices conveying on him (them) an increased sense of satisfaction or well-being (Stubblebine, 1975, 15).

Since the subsidence problem is one of economics, resource allocation and institutions, which are variables of social welfare, institutional arrangements can be treated with and tested by the techniques evolved in welfare economics.

Tweeten (1970, 519-520) has summarized various welfare criteria developed to indicate the welfare consequences of alternative institutional arrangements, and whether institutional alternatives move the community to or towards an economic optimum state.

A widely acceptable definition of an improvement in the collective welfare of the community is given by the Pareto criterion:

1. An institutional system A is preferred to an institutional system B if, by changing from B to A, someone is made better off while no one is made worse off. When no additional change can be made without at least making one person worse

off, community welfare has increased to an optimum level (Johnson, 1971, 362).

It is argued, however, that any change in an economic situation frequently affects the distribution of welfare to some degree (Mishan, 1967, 180). Consequently, an actual improvement in community welfare such that no one is worse off would be a rare event due to the fact that some gain while others usually lose. This impasse is resolved in theory by determining whether the community as a whole is better off, that is, whether collective gains exceed collective losses. This determination is made by a compensation test, embodied in the following criteria:

2. An institutional system A is preferred to an institutional system B if, by changing to A, those who gain compensate (to the full extent of the losses) those who lose and still be in a better position than under institutional system B. (Kaldor criterion)
3. An institutional system A is preferred to an institutional system B if those who lose by changing to A cannot bribe those who gain into not making the change from B to A. (Hicks criterion)

Stated in simplest terms, these criteria condense to the following criterion: an alternative institutional arrangement is an improvement in community welfare if those who gain evaluate their gains at a higher figure than the value which losers set upon their losses (Moore, et al., 1969, 414).

Social welfare criteria are readily applicable to the subsidence problem. Excessive use of groundwater resources has resulted in

substantial regional welfare consequences (income disruptions, social dislocations). External costs are not borne in proportion to the rate of water use, but instead are imposed on community property owners in an independent fashion. While disproportionate external costs are experienced, disproportionate benefits could accrue as a result of comprehensive water resource management. Furthermore, the subsidence problem lends to social welfare evaluation because various groups in the region experience similar external costs as well as similar water supply and cost conditions.

It is important to note tht the cardinal concept of modern welfare economics is the maximization principal of obtaining the largest possible net social returns from the use of a resource (Trelease, 1965, 3-4). Therefore, in evaluating institutional arrangements for water resource management, the basic theoretical question is whether social welfare has been maximized.

2. Efficiency

If a social optimum condition in which everyone gains and no one loses is not achievable and if potential or actual compensation is impractical, that is, if conditions are less than optimal, welfare economics condenses to the maxim that an institutional arrangement is recommended or desirable if it either increases the value of goods and services produced with given resources or reduces the resources required to produce a given output (Tweeten, 1970, 506; Wantrup, 1956, 307). This is stated as the criterion of economic efficiency and it is generally accepted that aggregate welfare is maximized where economic efficiency is greatest (e.g., Milliman, 1965; Burt, 1967). Properly defined and applied, economic efficiency in the use of water is an objective nearly universally subscribed to in the literature on water resource management.

Efficiency in the allocation of water resources requires that all costs and benefits be registered in the market (Savage, 1974, 16) and that water resources be allocated so that each resource is devoted to its most valued use (Ostrom, 1965, 525). In addition, efficiency requires that the resource composition of the total output is such that community welfare cannot be improved by any change in the resource output mix. That is, no reassignment of water resources to different uses and users would increase the total value obtained (Meyers, et al., 1971-B 48-52).

In the subsidence situation, at least two resources are involved, groundwater (possibly including the storage and filtration capacity of the aquifer) and surface water. Efficiency thus describes that combination of both resources which produces the maximum net benefits to the owners, users and beneficiaries of the resources over time (Corker, et al. 1971, 128; Moore, et al., 1969; Castle, 1970). In this case, efficiency means that there is no remaining possibility for net saving by substitution of one resource for another.

The outcome of all institutional arrangements will be evaluated by whether or not it is consistent with the efficiency criterion.

3. Equity

Economists agree that the efficiency criterion alone is an inappropriate consideration for evaluating institutional alternatives, since changes in the direction of efficiency involve certain intrinsic distributions of gains and losses among members of the community (Milliman, 1965). A host of conflicting and complementary values must be considered in the allocation of these gains and losses between members of the communtiy. Hence, an additional criterion which will be employed to evaluate institutional

effectiveness is equity. Equity refers to the distribution of gains and losses--the distributional consequences of alternative institutional arrangements (Tweeten, 1970, p. 506).

Principles of equity are less developed in the literature relative to other institutional evaluation criteria. Indeed, equity considerations are not readily amenable to hard and fast rules or prescriptions. As generalized from the literature, nevertheless, equity, as a universal principle, connotes fairness, reasonableness and equality.

It must again be noted that the pertinent feature of an environmental spillover, manifested by subsidence, is that the impact on the welfare of community members is substantial: disproportionate external costs. A spillover, which in this case is an income redistribution, poses a problem of equity between producers and/or users of the spillover creating good (groundwater) and the public at large, even though the users of spillover-creating goods and the affected public are all but indistinguishable (the cumulative effects of the actions of many pumpers in the same general vicinity cause significant subsidence damage to individual property owners) (Mishan, 1975, p. 23). External control of the spillover presents income distribution consequences as well: disproportionate benefits.

Hence, there appear to be two considerations to which equity is related: spillover creation and spillover abatement and control. To the first, it is suggested that the classic liberal maxim could be applied (Mishan, 1975, 405). This holds that the freedom of a member of a community to pursue his interests is qualified insofar as it tends to reduce the freedom or the welfare of other members of the community. It follows then that when a

property owner exercises his water right in the common pool, he should be responsible for his contribution to the collective social costs or be held liable for the major collateral effects of his pumping activity (Meyers, et al., 1971-B, 594; American Law Institute, 1971, Sec. 858A; Cobey, 1967).

As concerns spillover abatement and control through institutional systems, equity calls for a greater coincidence of the incidence of benefits with beneficiaries, that is, the costs of provision of the collective good (subsidence control) should be borne in proportion to the benefits received (Castle, 1970; Ostrom, 1975, 779). In addition to an appropriate distribution of benefits and costs, equity requires equality of impact between groups which experience similar spillover effects and water supply and cost conditions, and equality of impact among individuals within each group (Baker et al., 1974, 7).

It is clear that institutional systems applied to a problem characterized by substantial welfare effects and complex spillover patterns, and resource users competing for a safe yield of groundwater and/or facing utilization of an alternative and more expensive water source, are readily amenable to equity evaluation.

4. Certainty

To sustain projected regional growth, entrepreneurs need the assurance that a continuing supply of water is forthcoming, otherwise they will not risk capital and labor for investments subject to water supply failure (Trelease, 1965, 23; Snyder, 1973, 307).

Traditionally, groundwater resources have been available as a relatively "free good" -- good quality water easily accessible to overlying landowners at a low cost. Such water conditions have enhanced the value of the land for investment opportunities. Water-related institutions have provided

incentive for entrepreneurs to fully develop regional groundwater resources.

The incidence of common pool problems has necessitated a reallocation of decision-making capabilities, effectively centralizing traditionally decentralized (individual) decisions regarding groundwater use. As alternatives available to these choice-making individuals are reduced, an element of uncertainty as to the quantity and duration of water supplies appears. The possibility exists that uncertainty may retard development which might otherwise occur.

Certainty is recognized as one of the most important aspects of property rights (Milliman, 1959, 47). It has been pointed out that certainty of a water right has at least two aspects: physical certainty and tenure certainty (Wantrup, 1956). In such a context, physical certainty connotes protection against the variability over time of the quantity of water usable under the right. Tenure certainty refers to protection against variability over time of the quantity of water usable under the right due to lawful acts of others. Physical uncertainty (certainty) is reduced (maintained) by physical means, such as water storage, recharge and conjunctive use. Tenure uncertainty (certainty) is reduced (maintained) by legal means. Both are within the province of water resource management institutions.

Although cognizant that nothing is absolutely secure in the property field, it is widely preferred that institutions designed for water resource management provide a reasonable degree of assurance as to a water supply (Moses, 1968, 517; Sherrod, 1972, 730; Trelease, 1965, 24; Flint, 1968, 50). Uncertainty as to the quantity and duration of the water supply may retard development.

Therefore, in the evaluation of institutional arrangements for water resource management, certainty will be used as a criterion, referring to

the assurance of security of a water supply.

The problem of institutional choice often involves comparison and selection of institutional arrangements which are not optimum in terms of all sets of criteria, since any institutional arrangements can be expected to generate a limited range of preferred effects (Davis, et. al., 1975). Using the evaluation matrix that includes all criteria, it can be expected that some arrangements will show increases in terms of some criteria, while others will show increases in terms of other criteria. It should be noted that comparison is made relative to existing institutional arrangements as well as among alternatives. Therefore, net increases in effectiveness, in terms of the criteria, become the rule in a non-optimal situation.

GROUNDWATER RIGHTS - LIMITATIONS AND SUGGESTED REFORMS

The basic structure of institutional arrangements for water resource management is established by the decision rules which comprise the law of water rights. "The law of water rights is a form of property law which establishes the authority of persons to use, control and dispose of claims upon a water supply" (Ostrom, 1972, 6). In general, water law defines in absolute terms the extent to which an individual may enjoy a right to the copus of water or the right to the use of water (Piper, et al., 1958, 8). In one instance, water law establishes the nature of groundwater allocation; it establishes the nature of the permission given to individuals to use water. In addition, water law defines legal relationships by establishing certain correlative rights and duties among individuals in the use of underground water resources (Corker et al., 1971, 144). By creating property rights, water law provides the basis for the operation of economic forces that govern individual transactions.

Ideally, a well conceived water law would create incentives for individuals to make the best decisions as to groundwater use in their own interest which would ultimately be in the public interest (Trelease, 1965, 8). The law would allow the largest possible net social returns from the use of groundwater resources.

In practice, however, such a law is rare. Groundwater law is in a formative stage of development and does not provide answers expected from a matured system of law (Corker, et al., 1971, 127). Instead, water law is relied upon to respond to various needs which arise out of its defects to provide solutions to commonality problems stemming from the use of complex hydrological systems. It properly provides the bases upon which

mutual concessions to common advantages, or compromises, can be effected such that benefits from the use of the water resource are maximized (Piper, et al., 1958, 8).

Water law is of two types: common and statutory. Common water law expresses basic equities or legal relationships between users and potential users of groundwater resources, such arising from cumulative experience with particular hydrological and economic conditions (Piper, et al., 1958, 8). Water law created by statute projects legal relationships defined by common water law to adapt to new water and economic conditions (Boerschinger, 1965, 110-111).

Common law essentially establishes private proprietary interests in the groundwater as a species of property. The policy of the common law is to encourage groundwater use by permitting more or less unrestricted development of the supply by those who have access to it (Trelease, 1974, 523). Common law rights exist solely by reason of the situation of the land over the aquifers and are obtained by acquiring title to the land; the right itself is not a separable species of property.

Texas strictly adheres to common water law originally developed for conditions of water supply in excess of water demand. As described earlier, each landowner overlying a common pool is granted absolute ownership of the water flowing beneath his land, and can intercept this water before it leaves his premises to make whatever use of it he pleases. The absolute ownership doctrine recognizes neither communal rights nor liabilities in the supply or use of groundwater, though in fact the supply is communal and communally owned.

The defects of this system are evidenced by the subsidence situation, in that the doctrine provides no equitable mechanism to harmonize the relationship between groundwater producers and those members of the community whose property is damaged by pumping activity (Snyder, 1973, 292). For this reason, this rule has been criticized widely as inappropriate and inadequate to meet the needs of an industrialized and urbanized community (elg., Boerschinger, 1965, 110).

In Texas, the absolute ownership doctrine has survived repeated well reasoned attacks and has been upheld without limitation by a long line of Texas court decisions (for a discussion, see Booth, 1974). Simply describing this system as a legal institution does not truly demonstrate its strength. Absolute water rights are essentially part of the institution of private property. They have arisen from years of common experience with groundwater conditions and are firmly established. Their influence is most powerful, as considerable amounts of sentimentality and allegiance are attached to them. Texas court decisions precisely reflect the strength of the absolute ownership doctrine.

This system of water rights poses perhaps the greatest limitation to comprehensive groundwater management. First, the structure of incentives inherent in this doctrine is clearly not sufficient to constitute collective management organizations for reasons shown earlier. No mutual interests are recognized in law, although they exist in fact. Perhaps the most serious problem, however, is the question of the legal feasibility of comprehensive groundwater management. It is suggested that absolute ownership of groundwater is virtually immune to the comprehensive public regulation needed for conjunctive management (Murphy, 1970, 67). Yet, sustainment

of the constitutionality of equitable groundwater control is absolutely necessary when commonality problems arise.

The constitutionality of groundwater regulation is at best unclear in Texas and subject to legal rhetoric (see, e.g., Casebier, et. al., 1956, and Tyler, 1976).[19] The type of groundwater management contemplated for effective resolution of the subsidence problem has never been undertaken in Texas, let alone in many other parts of the nation experiencing similar problems. Therefore, constitutional issues have only been addressed from an academic perspective in Texas, and answers are speculative. The question of the constitutionality of controlling groundwater rights in itself "is a time honored retort" to proposals for innovative and forward looking groundwater management schemes (Hutchins, 1958, 425, note 36).

While no firm conclusions can be drawn as to the constitutionality question, the following arguments, pre and con, are advanced. It has been argued that in a given jurisdiction, if enough court decisions have previously been rendered declaring the rights to use groundwater inherent in the ownership of the overlying land, and in reliance thereon, enough action has been taken by land owners and water users to make out a "prima facie case of establishment of a rule of property," the constitutionality of rules subordinating these rights are particularly vulnerable (Hutchins, 1958, 431).

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[19] One rationale for the constitutionality of groundwater legislation in Texas proceeds on the basis of the "Conservation Amendment" of the Texas Constitution (Art. XVI, Sec. 59) (Woodruff, et. al., 1952, 865). This amendment gives the Legislature constitutional authority to conserve the natural resources of the state.

A retort states that, in fact, groundwater users have no absolute right to a particular quantity of groundwater, as the quantity is undefined, rather only the right to capture what they can. Therefore, limiting the amount of water a common pool user may pump does not interfere with a vested right, but merely regulates the manner of its use (Snyder, 1973, 314). This argument has been used successfully in sustaining constitutional attack on a comprehensive groundwater management program in California, which adheres to a correlative rights doctrine recognizing private proprietary interest in the water (Hutchins, 1958, 454).

The argument stands, however, in the subsidence case, comprehensive groundwater management meets a vital need affecting all persons within the region. And for a collective public enterprise to act in the public interest is a proper exercise of police power. The police power is defined as the inherent power of the sovereign to protect public health, safety, morals or general welfare (Boerschinger, 1965, 120). All property is subject to these interests under the police power. Comprehensive groundwater management would be a valid exercise of the police power of the state for protection, safety and general welfare. Management is a reasonable means to a reasonable end, however, the decision rules employed must also be reasonably related to the end.

The question of whether an action is a valid exercise of the police power is important, for if control rules curtail the use of private property, it might be argued that it is a "taking" of private private property for which compensation need be paid. For a constitutional exercise of the police power to be sustained, the public interest must not be outweighed by the individual "demunition" in property rights (Sherrod, 1972, 734, Note 135).

A noted authority on water law argues that if the loss to an individual "that renders him 'worse off' is merely shifting back to him costs which he had originally shifted to others or to the community, he deserves no compensation for a corrective measure that deprives him of the expectation of continuing his use." Such is no more than the "withdrawal of a subsidy" (Trelease, 1965, 37).[20]

Such an argument is enhanced by the concept of conjunctive management. Conjunctive management is specifically designed to allow all water users to survive. Water demands are met, but from a more expensive source. Thus the need is satisfied, but a disparity exists between what an individual traditionally "paid" for water and what he will "pay" for water in the future. The constitutional question becomes in essence the legal feasibility of raising the price of water, that is, withdrawing the subsidy.

This situation will be the case for many users, but there remains the problem of limiting the groundwater demand of those users without a readily available alternative water source. Thus, the more serious constitutional question arises of whether, given that the public benefit of such a policy outweighs significantly the private "losses", such a policy can be sustained. A denial of use under the present legal system would probably not be tolerated (Bush, 1974).

In any case, the exercise of the police power in Texas relative to groundwater control has been uncomplicated because nothing has been taken

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[20]Hutchins (1958, 440) reports that "Court decisions in other jurisdictions indicate a growing awareness that the perpetuation of 'illused' rights in an overdrawn groundwater reservoir is not in the public interest."

away and only nominal requirements on groundwater users to spend money have been imposed. At best, the constitutionality of groundwater regulation is unclear in Texas, and poses a serious problem for a management entity whose control decisions are suspect and susceptible to challenge. Practical means must be found to effectively limit the use of groundwater without interfering unduly with private property interests.

A more indirect method than assertion of the police power is to rely on the state's function as arbitrator and sole legitimate user of force to effectively limit the use of groundwater (Murphy, 1970). By recognizing that certain mutual property rights in the use of a common pool resource and are obligated to regard the rights of others in their manner or quantity of use of the water, then limitations in effect protect private property interests (Hutchins, 1955, 183; Murphy, 1970, 63-64).

In any case, at least two methods appear readily applicable for resolving the legal impasse present by the absolute ownership rule. The first is relevant to the perception of the nature of the water right, making the subtle distinction as to whether the right is "corporeal" or "usufructuary." At the present time, groundwater (percolating) is regarded as the property of the owner of the surface. The right is therefore conceived of in law as corporeal (see 60 Tx. Jr. 2d. Sec. 221). However, this is a legal fallacy simply because the groundwaters actually flow, although slowly, under land owned by one individual to and under land owned by another and so on. If it is not intercepted, it is eventually discharged into the sea. Furthermore, groundwater is common and interdependent to adjacent lands, and subject to joint use.

An individual's property interest in groundwater is usually conceptualized as an individual right to make use of a common property (Ostrom, et. al., 1972, 6), that is, it is a usufructuray right in reality, susceptible to personal ownership through capture. The interest is in the use of water and not in the private ownership of the corpus of the water while flowing underground. Many commentators in the literature adhere to this interpretation (see, e.g., Clark, 1967, Sec. 53.2; Maloney, et. al., 1971, 767-768, Milliman, 1959, 42).

The distinction is important, because courts in other jurisdictions have pinned the results of the constitutionality of groundwater control on their perception of the nature of the water right. Courts apparently find it easier to uphold the validity of statutes purporting to regulate groundwater when they conceive the right as usufructuary rather than a proprietary corporeal right. It is also speculated that legislative modification of water law to bring the absolute rule into harmony with urban and industrial conditions would not be subverted by a "hostile judiciary" (Hanks, et. al., 1970, 641-642).

By recognizing groundwater rights for what they in fact are - usufructuary, then public regulation would not interfere with a vested right, but only with its manner of use. Then, the use could be expressed in terms of the acts that may be done both in relation to the water, and relation to acts of other persons (Trelease, 1964, 26). Thus, another improvement in the system of water rights is relevant to the manner of the use of the water right.

Although continuing to recognize proprietary interests in the use of groundwater, the national trend is moving toward restricting the common law

of groundwater rights by the imposition of a qualification of reasonableness of use. Various judicial jurisdictions have added various limitations to groundwater use, depending upon particular circumstances of the case and perceived conditions of supply and demand. In Texas, the only limitations are that a landowner may not maliciously take water for the sole purpose of injuring his neighbor, or wantonly or willfully waste it (Steelhammer, et. al., 1970, 205). These limitations, however, inhere in the original common law (60 TX. Jr. 2d, Sec. 221). Hence groundwater use is beneficial if not malicious nor wasteful. Actually, a landowner is limited to make non-spiteful and non-wasteful, but otherwise unlimited use of his groundwater, as evidenced by the subsidence problem.

Other jurisdictions have gone further, interpreting and reinterpreting over time the "reasonableness" of a groundwater use. These concepts of reasonableness have emerged into what is called the "American Rule of Reasonable Use" (Hanks, et al., 1970).

This qualification is subject to reinterpretation as the case may be. However, the latest reinterpretation proposes a rule of nonliability for interference with the use of groundwater by another user of groundwater unless withdrawal of groundwater causes unreasonable, substantial harm by lowering the water table or reducing artesian pressure (American Law Institute, 1971).

In humid jurisdictions, the majority of which adhere to the absolute ownership common law doctrine, problems of commonality of groundwater use have led to the broadest interpretation. Reasonable use of groundwater is interpreted in terms of the reasonableness of its impact on the community

of users (Sherrod, 1972, 735; Maloney, et al., 1971, 770). Classified as the "Eastern Correlative Rights Doctrine," the rule recognizes that no property right is so absolute that it may be used to unreasonably damage the property of other members of the community. It also recognizes correlative rights and communal interests in the use of a common groundwater reservoir. In any case, such a rule adds flexibility and adaptability to a legal system to respond to changing economic conditions of water supply and demand (Wantrup, 1956; Boerschinger, 1965). Groundwater pumpage may thus be limited on a reasonable use basis.

Public intervention might be dictated when groundwater use becomes unreasonable when legal relationships deviate from the norm. Because groundwater is not exclusive, but instead used in common, individuals experience problems in pumping the resource in a reasonable and socially desirable manner. Their scope is too narrow to recognize their particular contribution to any social costs or collateral affects of their pumping activity. The public sector could coerce individuals to pump in a reasonable manner and, at the same time provide for solutions to the displacement of groundwater as their sole source of supply. The situation predisposes the type of institutional arrangements needed for protecting individual property interests (water availability) and communal property interests (no subsidence).

If the judicial system would come to recognize mutual property interests and sustain the consitutionality of groundwater control, then the legislature could proceed under greater legal certainty in supplying innovative solutions to commonality problems in the use of the region's groundwater resources.

As was stated earlier, the proper role of statutory water law is to project legal relationships defined by common water law to adapt to new economic and resource conditions.

These subtle modifications of the common water law however leave nearly untouched the problem of operating a common water pool in the collective interests of those who use it (see Corker, et al., 1971, 201). However, they do create a significant predisposition toward the type of collective undertaking required for subsidence control and water resource management. What is being dealt with are water rights, regardless of the subtle limitations. The collective undertaking therefore must go to great lengths to fashion a scheme to maximize the possibility of a pareto optimum condition, such that no holder of water rights is left radically or arbitrarily worse off than he is at present. What is needed is an equitable system of decision rules which are sensitive and flexible to meet the diverse needs and preferences of the collectivity of groundwater users. Even if groundwater rights are conceived of as correlative rights to use in a reasonable manner, the rule must be to protect, as best and practically possible, the bundle of water-related interests property owners have in their soil.

Interests and Limitations in Common Water Law

Common water law essentially establishes and defines rights to use groundwater underlying an individual's land, and are incidents of the ownership of the land. Statutory water rules are sought which can project these rights so as to adapt to the subsidence condition. What is needed is a water law and water rights system appropriate for purposes of groundwater resource management. The ideal groundwater law would make it economically inexpensive to allocate use of the water in terms of amount, place and time differently than the allocation of water rights under the common law (Corker, et al., 1971, A1-11). However, in order for this to be accomplished, it is important to recognize and reasonably protect the interests afforded and enjoyed under a common law water right (Clark, 1967, Sec. 53.1).

A water right is essentially a bundle of water related interests, the most important being the right to use a supply of water (Clark, 1967, 53.5A). Since the right to a supply inheres in a tract of land overlying a groundwater reservoir, the supply can be described in terms of amount, access, time, quality and cost (Ries, 1967; Corker, et al., 1971, A1-11: Gindler, 1963, 5). These characteristics are relevant to the groundwater resource, and describe the interests enjoyed under the water right. Legal and physical security are also important aspects of any water right (Wantrup, 1956). In regard to physical security, that is, protection against the variability over time of the quantity of water usable under the right, all water rights are subject to certain natural constraints, both imposed by the operation of the hydrologic system, such as subsidence and sea water intrusion, and constraints imposed by other natural forces such as the changeability in weather (Milliman, 1956).

Specifically with regards to a common law right, an owner stands relatively exposed to the entry of others under the same "incentive structure" who may initiate new patterns of use (Ostrom, 1972, 7). New uses and users created by economic change compete on an equal basis since water rights are incidents of a tract of overlying land. New users obtain water rights that are no less secure against physical uncertainty than "older" or other rights (Wantrup, 1956, 305). Therefore, common law rights fail to secure an individual landowner against physical uncertainty.[21]

It was already seen that the essential interest under a water right, is a right to use a supply of water, yet, this right may be unenforcible if the supply of groundwater has become inadequate to meet all demands as is the case in the subsidence situation (Clark, 1967, Sec. 53.3). Under a reasonable use qualification of a common law water right, each landowner may take only his fair or proportionate share if the supply is inadequate (Steelhammer, 1970, 207). Thus, each landowner stands relatively equally exposed to curtailment of demand in a control situation. In any case, common law water rights are usually not given quantitative description, being all that can be captured. Therefore, there is little protection against tenure uncertainty, the amount of water usable under the water right due to lawful acts of others (Ostrom, 1972; Wantrup, 1956).

Both physical and tenure uncertainty can be greatly reduced through

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[21] "Loosening" common law water rights from ownership of the corpus of the water underlying a common law proprietor's land to use of the water underlying ones land would greatly enhance the ability to use the aquifer as a place of storage without acquiring a right to do so from the individual proprietor (Corker, et al., 1971, 183-184; Valentine, 1964, 99). By affording legal protection to the water contained in the aquifer, physical uncertainty would in turn be mitigated.

a politically based organization which effectively administers a conjunctive management program. However, water rights, as presently conceived, will provide the greatest limitation to effective management. But, if they are conceived of as previously suggested, at least a "better" basis can be provided for the establishment of organizational arrangements for subsidence control and water management.

Political Organization for Subsidence Control

Conjunctive management and subsidence control require the development of rules and regulations which establish the "proper" capabilities and limitations among the collectivity of groundwater users in their use of the water system. The relevant question is who shall allocate and control these decision-making capabilities. This answer must necessarily precede the question of how decision-making capabilities are allocated, although both political organization and institutional control mechanisms are related.

According to organization theory, political organization for groundwater management must be at a level of government which affords the greatest possibility of minimizing the costs associated with institutional weakness or failure (Ostrom, 1975, 773). At least two decision forums are possible: either internal to the problem or external to the problem. The former is usually associated with self-governing local districts, the latter with direction through a state water agency.

The question of who governs and of "minimizing institutional weakness" can be determined by the comprehensiveness of the management needs, which is a function of the relevant hydrological, institutional and economic problems characterizing the groundwater use problem. The rule is that the more comprehensive the needs, the greater the need for a local public management enterprise, embracing the hydrological problem, to engage in a comprehensive management program (NWC, 1973, 234).

A widely acceptable approach to hydrological conditions suggests that the organizational level of public intervention should be a direct function

of the extent and peculiarity of the water resource problem in question (e.g., Hirshleifer, et al., 1969, 364). The geographical scope of a public entity should be adequate to embrace the events needed to be controlled. Accordingly, if the particular hydrological or water use problem is of a statewide nature, then a management organization must have a statewide scope; if at a regional level, then organization should be at the regional level, and so on. The rationale of this approach is that a management program should be framed within the context of the special hydrological conditions and objectives of the water users within the problem area (Piper, et al., 1958, 14). Generally, it has been recognized that state attempts to frame groundwater management programs suitable to a local or regional problem have been largely unsuccessful (Buchwalter, 1970, 47).

The economics of the subsidence problem and solution is also relevent to the establishment of a management program. Hydrological conditions alone might not justify a regional organization, although the economics of the subsidence problem and solution add a new and related dimension to the pervasiveness of the "hydrological rule." If subsidence is to be halted, then the disparity between groundwater supply and demand must be mitigated, while at the same time, entrepreneurs must be provided with an expanding level of water supply in general. These conditions can be overcome by conjunctively managing regional water resources, although a relatively high level of capital outlays will be required of the community of groundwater users to expand existing surface supplies. Groundwater management programs tailored to the area of needs are more flexible, responsive, and adaptable to these economic needs.

Local or regional decision-making organizations enable the community residents to select those alternatives which will net the maximum value to themselves (Corker, et al., 1970, 140-141). A local or regional political organizational structure, controlled by community members, would be able to recognize production economies, take account of diversities in user preferences and better relate supply to demand.

A further economic theoretical rule is relevant to the incidence of costs and benefits. A coincidence of benefits with beneficiaries is considered appropriate, that is, a management program should be financed only by those who benefit, indeed, by those who have generated the problem and associated costs in the first place (Rayner, 1972; Sherrod, 1972, 738). The separation of beneficiaries from those who bear the costs should always be avoided, although it rarely is accomplished (see Havemen, 1973; Ostrom, 1972). Accordingly, state control of a local problem would, to some degree, subsidize local groundwater users at the expense of the public at large.

The combined rules, then, are to relate management programs to the geographical or hydrological problem while, at the same time, relating benefits to beneficiaries.

The capability of various governmental organizational forms of expressing and representing collective proprietary interests in the development of common property resources, such as groundwater, has been analyzed in depth by Ostrom (1975). He concludes that decision structures external to the problem are only necessary when adequate remedies are not available for resolving local user and use problems within a local organizational arrangement and where spillover costs negatively affect others outside the boundaries of a local organization.

Hence, institutional weakness has the greatest chance of being minimized, according to the above rules and considerations, when the subsidence problem is embraced by an organization encompassing the events needed to be brought under control, which would be at the regional level, since the problem transcends local jurisdictional boundaries. In addition, the pressures for self government are usually of such magnitude as to make external decision making politically unacceptable.[22] However, the state does have a role to play, indeed, effective groundwater management requires that a proper political relationahip be struck between regional and state levels of government.

Ideally, local communities experiencing groundwater resource use problems would register their management needs and objectives with the state legislature, since statutory authorization is required for the management program tailored to the local level. Hence, the proper role of the state would be to create and endow a local, self-governing groundwater management organization with powers adequate to make local objectives realizable, and to assist such an organization in the fulfillment of its objectives and geographic coverage (Buchwalter, 1970, 10; NWC, 1973, 335). Over time, there

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[22]Texas has recognized that groundwater managment is more acceptable when programs are implemented through local participation and self government at the local level, tailored to local circumstances. The notable example is state legislative authorization to local communities for creation of underground water conservation districts. It thus has recognized that immenent policing restrictions are more readily accepted if they are promulgated by those who are affected. It is ironic, however, that these organizational forms are inherently weak, seriously suffering from political parochialism (see Snyder, 1973; Woodruff, et al., 1952).

would be a continuing adjustment or augmentation of management powers and correction of problems as justified and defined by the local organization representing the communities' needs. Most importantly, this process should ideally be undertaken without regard to water users and their specialized problems in other parts of the state, except, of course, where problems are common and interrelated (See Hutchins, 1955, 190).

However, the possibility of the Texas State Legislature endowing the subsiding region with comprehensive conjunctive management powers is ultimately constrained because of a conservative political sentiment, abhorrence of any disturbances of private property (groundwater rights) and fears of establishing a precedent that would be unacceptable to other areas of the state, or that would extend statewide at some future time. This problem is not unique to Texas. Most local groundwater management district throughout the nation lack comprehensive control over all surface and groundwater resources and the water right in question which is needed for complete and effective management (Trelease, 1974, 520; NWC, 1973, 235). Perhaps the only tools for overcoming this disdain of creativity are education, lobbying and negotiation.

However, a well conceived and empowered public water district has been recognized as an effective political institution for organizing collective action for conjunctive water resource management, especially where statewide statutory administration of groundwater rights is lacking, as is the case in Texas (Smith, 1965 and 1968; also Bagley, 1961). A self governing district provides the framework through which community interests can function and express their preferences; in this manner, conflicts and water use problems

are settled internally. By virtue of their water rights, the collectivity of groundwater users are in a controlling position. Integration of water sources as well as community interests is accomplished by placing total management responsibility at one point of decision-making (see Smith, 1965 and 1968). Perhaps the greatest advantage of a public water district is its ability, due to its geographic scope and relation to the local economic base, to make the necessary computations of costs and benefits incident to a groundwater management program. It thus is in a position to distribute operating and other costs so that they fall upon the benefited interests (Smith, 1968, 266). Conceivably, demand or need for management services can be readily met by either increasing or decreasing the "scale of the enterprise" appropriately (Ostrom, 1965, 521).

Accurate computation of costs and benefits is analytically possible only when a district's scope of control is coterminous with the extent of the underground water system, since all users are interrelated by a common water supply (Corker, et al., 1971, A1-49). Both political and physical practicalities in some cases would make this unattainable. The subsidence problem is indeed localized to a multi-county region, however, the underground hydrologic system underlies a large part of the entire Gulf Coast area. The scope of a public water district thus must only be large enough to control those events contributing to the problem in question, and structured to include only those who reasonably benefit from its management program.

Because of the extent of the hydrologic system in question, external economies and diseconomies are possible. The obvious example is socially suboptimal pumping along, but outside the geographic perimeter of such a public

water district. Many external benefits could accrue as well, even though not completely apparent or recognized at the outset (Shiff, ed., 1965, I-14). Problems of this nature are not serious if adequate institutional remedies are inherent in the water district. To account for costs or benefits, the district could enlarge its domain or enjoin damaging external pumping, if such determinations can be made and adequate supporting evidence can be gathered (Corker, et al, 1971, A1-49-50).

A public water district seems to be the proper organizational form for management of a local groundwater use problem. Institutional weakness could be minimized if the district were adequately conceived and empowered. Since a public water district must operate in political environment, certain political relationships are also required if costs associated with institutional weakness are to be held at a minimum. As was explained earlier, conjunctive management requires a large degree of inter-agency cooperation due to the fragmented nature of ground and surface water development and use decisions. Coordination is necessarily a difficult task for this very reason.

There are two basic types of water related organizations operating within the subsiding region whose cooperation is necessary. The first set includes the extensive maze of closely situated and in some cases overlapping special purpose public districts, including water supply, control and improvement districts, municipal utility districts and other semipublic utilities, municipal corporations, and the smaller water authorities. Each has been organized by local communities to supply freshwater and other utility services, and each obtains its primary water supply from the ground. Each has special authorities and responsibilities, and a large degree of autonomy. Each is an economically oriented enterprise with accumulated assets and liabilities.

A public water district must allow sufficient autonomy to these local entities as regards water use mix decisions, although assuring that they act in the public interest. It might also aid these districts in undertaking water use programs which are mutually beneficial, such as consolidating and pooling resources and capital facilities for the reception and distribution of surface water or for more efficient use of groundwater. Thus, while the public water district must allow decisions of these grass roots districts to remain reasonably decentralized, it must have a certain degree of control over their management practices in order to assist in the recognition of mutually beneficial actions (See Hirshleifer, et al, 1969, 364). In some cases, the scopes and authorities of these smaller districts could be expanded or new local agencies could be created to handle water use and supply problems of one or more of the existing districts.

As opposed to the vertical political relationships, a public water district must also deal horizontally with the surface water supply organizations if it is to effect a conjunctive management program. These agencies include river authorities and the larger municipal corporations and water authorities with access to or control over surface water supplies. Again, these organizations are substantially autonomous and formally independent, each with a specific and sometimes overlapping service supply radius. The public water district must in some way bargain with these agencies to provide the necessary surface water to meet displaced groundwater demand, if the public water district is conceived of as agent for the collectivity of groundwater users.

Cooperation on this horizontal political level is of utmost importance if a smooth and efficient transition from a subsidence to a no subsidence condition is to result. Cooperation must at least be mandatory such that the water

district can require these otherwise autonomous organizations to join in the planning and implementation of an effective subsidence control-conjunctive use program (Ostrom, 1965, 521; ASCE, 1972, 64-65). The legal technique would involve contractual arrangements or other interagency agreements, necessarily having to be of the nature of bargaining for concessions of mutual benefit (Fowler, 1964, 57 and Ibid). The most effective method of organizing a conjunctive management program, however, is to superimpose the public water district, as a water authority, upon the existing network of water organizations, such that it would have limited but sufficient powers over existing water organizations enabling it to effectively coordinate their multiple activities and channel them into a program of action (Krieger, et al., 1962, 75; ASCE, 1972, 64-65).

To summarize, it was shown that through integration of political and community interests on the basis of solving a common subsidence problem, conjunctive management can evolve. This integration can be accomplished through a well conceived public water district at the regional level. It was shown that such a water organization is both flexible spatially, and if the "proper" political relationship is struck with the State Legislature, the district will be flexible temporarily. Most importantly, the public water district can provide local entrepreneurs and residents with a high degree of certainty as to a water supply, providing that the proper legal and political relationships are institutionalized.

The public water district will provide the organizational forum for a subsidence control-conjunctive management program. How such a program can evolve will be determined by groundwater rights. The law of water rights is essentially

a rule of property. Property rules determine who can legally claim ownership to groundwater resources, and how groundwater is used. Property rules establish the structure of alternative institutional arrangements. They determine how the public water district can allocate ground and surface water resources and costs. The public water district must be firmly based on and responsive to the proprietary interests in groundwater as determined by property rules.

It has been argued that the present property rule, absolute but non-exclusive ownership of groundwater, is the major source of the commonality problem and institutional weakness and failure. Alternative systems of property rules thus must become the central forces in developing alternative institutional arrangements for subsidence control. Property rules will largely determine whether the public water district can allocate ground and surface water resources efficiently, that is, the degree to which groundwater rights can be subjected to control.

Alternative Property Rules

While it was seen that water rights pose perhaps the greatest limitations to groundwater management they are, at the same time, a most effective tool for fashioning institutional arrangements appropriate for subsidence control and groundwater management (ASCE, 1972,58). Through statutory water law, property rights may be used for allocating both water resources and cost differentials between alternative water supply sources. In general, rules of property can be modified to form frameworks for alternative institutional arrangements (Snyder, 1973, 300).

Property rights establish a normative framework for the economic behavior of individuals with regards to water and water use. As economics is the most conspicuous aspect of the subsidence problem, property rules can be restructured and modified to effect desirable economic behavior, so long as those interests presently enjoyed under a groundwater right are recognized and reasonably protected (Clark, 1967, Sec. 53.1). In addition, rules of property could be fashioned so as to provide individual water users security against physical and tenure uncertainty. Many commentators in the literature argue that a water user is unlikely to be concerned with water law and institutional arrangements so long as water of certain specifications appears when the tap is turned (e.g., Trelease, 1965, 48; Reis, 1967; Corker, et al, 1971, A1-11).

Institutional solutions to the subsidence problem must, in some manner, internalize to the collectivity of groundwater users the externalities associated with subsidence. Solutions must directly address the commonality problem inherent in nonexclusive groundwater ownership. Property rights are integral

to an institutional solution, as they provide an institutional basis for internalizing externalities. Of course, the heart of the subsidence problem is the prepensity to pump groundwater, which is an economic problem, and as such must be addressed in light of specific economic purposes and particular political control. Property rules can alter an individual groundwater pumper's decision making capabilities, and as such, can provide new structures of incentives and deterrents which in turn will modify a pumper's cost-reward calculus, and his propensity to pump groundwater.

Demsetz (1975) argues that the primary function of property rights is to guide individual incentives to achieve a greater internalization of externalities. Property rights develop to internalize externalities when the gains of internalization become larger than the cost of externalization; when it becomes economic for those affected by externalities to internalize benefits and costs. This proposition recognizes that restructuring or adjusting property rights allows the community to adapt to new benefit-cost possibilities.

Adjustment to new benefit-cost possibilities can be largely accomplished by recognizing and institutionalizing either one of three idealized forms of groundwater ownership: communal, private, or public (state). Public ownership implies that the state may exclude anyone from the use of the groundwater right so long as it follows accepted political procedures in determining who may use or may not use state-owned property. Communal ownership is a right which can be exercised by all members of the community owning land overlying the water resource. Private ownership recognizes the right of an owner to exclude others from exercising the owner's private right (Demsetz, 1975).

Elements of the latter two idealized forms of property ownership are clear in the present common law concept of absolute ownership. "Absolute" implies private ownership, but its nonexclusive nature prohibits it since rights are not specific. It would be a logical extension to make these rights specific and seperable, thereby creating real private property rights. However, at the same time, it would be logical to recognize communal ownership, because the rights now are nonexclusive and can be exercised by all landowners overlying the common pool. Hence, it should be clear that the present property doctrine illogically combines two opposed concepts: "absolute" and "nonexclusive." Such a combination, however, conceptually facilitates alternative systems of property rules.

Public Property Rule

Property rights in natural resources are undergoing a basic shift from exclusive ownership and control by individuals to public (state) ownership (Ostrom, 1975, 765). In this manner, states can determine who shall be allowed or who shall be prohibited from using resources in order to protect the "public interest." Assertion of public ownership is a direct result of increasing and competing demands being brought to bear on these resources, many of which, when consumed in common but in an ad hoc manner, have been damaged in quality and value, and otherwise degraded.

Underground water resources are no exception to this trend of institutionalizing a public or state ownership property rule. Many western states have abrogated the common law property rules of private ownership and control in favor of public ownership and control, realizing that landownership water rights were incompatible with "proper" exploitation of groundwater resources

(Hutchins, 1955; Clark, 1960; Chalmers, 1974).[23]

The political procedures for determining which users can have access to and use of groundwater resources have been largely established by statute through application of the public ownership doctrine of appropriation. Under this doctrine, groundwater use is subject to appropriation usually under a beneficial use criteria by preference classes established administratively. The public interest is the sole determinant of maximization of resource value or public benefits (Castle, et al., 1960, 151). When there is a disparity between groundwater supply and demand, use is scaled to supply in reverse order of the priority of established use rights, which are established by time of permit application.

There are problems in institutionalizing such a system for controlling land subsidence, although it would remove completely the major cause of the commonality problem - nonexclusive ownership and allocation under private decision rules. First, the appropriation system has been recognized as inadequate for scaling supply to demand in times of "shortage" (Piper, et al. 1958), simply because of the great administrative costs involved in determining priority rights. Also, if priority could be established, it is reasonable to expect that some users would be required to leave the field, but in any case, a serious misallocation of resources is likely to occur because there is no assurance that those remaining in the field obtain the highest value from groundwater use (Castle, et al., 1960). If rights could be made transferable, this latter condition could be mitigated (Clyde, et al.,

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[23]Texas has institutionalized public ownership and control of the surface water resources within its boundaries, but recognizes private ownership of percolating groundwater. Because all water resources are hydrologically interrelated, it is argued that legal rules governing their use should be integrated and unified (NWC, 1970; Fowler, 1964).

1971). It is conceivable that if the state were to declare groundwater as publicly owned, then, in short supply areas, use would be scaled such that most would be permitted to survive, simply because of political pressure.

The major problem with such a property rule, however, would be its application statewide to all groundwater resources, use being controlled by or through a state agency. Such a drastic subordination of proprietary interests in groundwater statewide would be unnecessary to provide the basis for solving a localized subsidence problem (see Snyder, 1973). Moreover, the political and legal feasibility would be questionable. Because of the variability in both climate, groundwater resource conditions and peculiar resource use problems, local property rules could be applied on an ad hoc basis, such that they are not disruptive to other areas statewide.

The rationale of public ownership and "supply" of groundwater resource services can be institutionalized through implementation of the alternative property rule which follows.

Communal Property Rule

Communal rights are ones which can be exercised by the community, that is, those who own the rights are every member of the community. The property rights under the present institutional system are in fact individual rights to make use of a common property (Ostrom, 1972, 6), since groundwater is common and interdependent to adjacent lands, freely appropriable by all who own overlying land tracts but subject to joint use. In law, however, no common property of communal rights are recognized. Instead, individuals are afforded the right to claim what is in fact common property as their own. Common property is thus allocated in a private manner. Normally, when

common property is used privately, great externalities result. Each individual will proceed to maximize the value of the use of the common property, and because the preperty is nonexclusive in fact, use costs will be borne by other members of the community, and the "common" will be used in a socially undesirable manner (Demsetz, 1975).

However, if the groundwater resources can be recognized in law what the resources are in fact, the common property of the community, then it follows that the community would attempt to maximize the value of the use of its own property, that is everybody's property. If all present proprietary interests in groundwater can be integrated and interrelated by a blanket communal title, recognizing common property and community ownership as opposed to private ownership,[24] then the collectivity of groundwater users would automatically find their property is being over used, and that benefits have been transformed into costs. A communal title would enable the community to adjust to the new benefit/cost possibility of no subsidence, by curtailing usage so as to maximize the value of common property. The communal title would in effect afford landowners the right to use common property in a manner considered by the community to be beneficial.

At present, there is no basis for interrelating property owners overlying the "common." Thus the type of communal property right needed would be one which relaxes the requirement of voluntary cooperation among a diversity of interests. Indeed, the scope of any individual user is too narrow

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[24]A subtle but important distinction exists between the property rule as now exists and a communal property rule. The former recognizes private but nonexclusive ownership of common property; the latter recognizes a common right to use common property.

to afford effective cooperation. Thus, the title would need to be sufficiently general to afford coverage of all groundwater users but sufficiently particular to make computation of costs and benefits analytically possible (Murphy, 1970).

A contemporary suggestion for groundwater law is a property right analogous to a common sans nombre, although with sufficient flexibility for interrelating groundwater users under dynamic socio-economic conditions (Murphy, 1970). A common sans nombre[25] is a right of common without limit as to number of users. The underground water pool is common for the benefit of all landowners to use and is available for all to use, number of users being indefinite or fluctuating. The right is not fee simple absolute but incorporeal; it is collective and not individual. Although the title is without restriction as to number, it may be restricted as to use by the numbers. Implicit in a common sans nombre is supervision and control by a public trustee of the common in order that the benefits which the right seeks to confer may be equitably enjoyed. The publid authority to regulate the use of the common is unquestioned.

The communal title becomes functional in contemporary usage when the aquifers underlying the subsiding region are blanketed with a public water district which acts as a trustee of the common. Absolute rights would be abolished, all titles to the groundwater resources being vested in the public district. The right extended to individual users would be a right to use the common, subject to equitable rules of the public water district. Ideally, the community of users would voluntarily give up their absolute

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[25]This common law concept is English in origin, and is explained in 56 F. Supp. 120 (U.S. V. 1,010.8 Acres, more or less. Situate in Sussex County, Del., et al.).

rights to enable the public water district to control and manage the groundwater in such a manner as to maximize the benefits of its use for every member of the community. Because the common has been over used, other water must be provided to the community, and as such, the public water district would begin functioning as a commercial enterprise providing water service, and extending to each user of the community a right to a water supply.

The logic of the communal title, of course, is recognition that the groundwater underlying the region is common property both in fact and in the law, thus allowing the community, whose resource has been over used, to adjust to the new benefit cost possibility by allowing a sole owner to produce the resource efficiently on their behalf and for their benefit. This style of groundwater management, that is, recognizing a single owner and single seller, is widely advocated in contemporary literature as a model toward which successful groundwater management must strive (e.g., Corker, et al., 1971, 202; Murphy, 1970; Meyers, et al., 1971-b, 49; Swanson, et al., 1976).

The logic of sole ownership is powerful. In the operation of the water system, a sole owner's problems are likely to be exclusively hydrologic and economic, but not legal (Corker, et al., 1971, 202). The sole owner's problem is how to manage its resource in its best interest. The sole owner has a legally enforceable right to all capitalized future values of using the resource, since it can determine how it can be used. Any collective costs represent a more costly form of behavior for the owner (Meyers, et al., 1971-B, 49). Scope is sufficient to compute costs and benefits and allocate them appropriately. Therefore, when the right to property is exclusive, the property is more likely to be allocated to its most valuable use. It should

be readily apparent that a transition to exclusive ownership is the most direct method for solving problems of commonality of groundwater use (see Hirshleifer, et al., 1969, 59-66).

The analytical alternative to sole ownership, of course, is to treat the groundwater resources as far as practicable as if they were in single ownership, even when ownership is fragmented. Centralization of decision-making capabilities and the power of implementing decisions is analogous to decision powers inherent in a sole owner (Corker, et al., 1971, 208). A public water district with sufficient powers of decision over what is treated as the common property of the district could thus enable the community to adjust to new benefit cost possibilities by engaging a strategy of paying users not to use the common property where it is in the community's interest to do so, alternatively, requiring users to pay to use the common property. The sole ownership concept thus would translate into the kind of public trusteeship inherent in management, the public water district being responsible to the collectivity of groundwater users in whose behalf it acts (Corker, et al., 1971, 203). Mergering interests, pooling water resources and unified control collectively provide the rationale for this alternative property rule. Of course, the rule of common property need not be recognized as a legally conceived title, but only treated as common property in practice.

Alternative institutional arrangements will be developed around the logic of the sole owner, the property rule being either legally explicit or implicit.

Private Property Rule

Another property rule which is conceptually compatible with the present property rule is institutionalization of a private property rule that permits

a clear definition of the extent of the absolute property rights in groundwater but particularly adapted to eliminate the externality physically evidenced by land subsidence (Milliman, 1956 and 1965; Meyers, et al., 1971-B, 49; NWC, 1973, 242; Hirshleifer, et al., 1969, 62). The problem of nonexclusive private ownership of groundwater can be eliminated by making the right exclusive and transferable through the assignment of annual and permanent quota rights to use underground water resources. If rights are reduced proportionately to the maximum acceptable annual withdrawal quantity, externalities become internalized physically. If allowed to be transferable in a simulated quota exchange market, groundwater and surface water would automatically move to their most valued uses. Hence the private property rule would enable the community to adjust to the new benefit/cost possibility of no subsidence, and aggregate value obtained from water resources use would be maximized. The only prerequisite for such a property rule is that the collectivity of groundwater users be given equitable recognition of their beneficial interests in the groundwater resources, and that there be remedies to any impairment of these interests.

The quota right system directly attacks the source of institutional weakness by replacing "commonality of rights" with "specificity of shares" (Milliman, 1956, 431). Conceptually, parcelling out private water rights is a decentralized adaptation to the establishment of a "single owner." Both centralized and decentralized owners are able to exclude others from using their groundwater use quantity while being assured of realizing the benefits associated with their decisions. Private ownership offers the possibility of concentrating or internalizing costs and benefits on owners and can create incentives for the groundwater to be used efficiently (Demsetz, 1975).

Institutionalizing such a private property rule will eliminate the nonexclusivity problem inherent in the present property rule of absolute ownership while providing the basis for institutional simulation of a workable market for groundwater/surface allocation.

Alternative property rules can significantly alter the economic behavior of individual groundwater users. These rules, judiciously used so as to reasonably simulate or preserve the bundle of water related interests inherent in the present system of groundwater rights, are effective in that they strengthen the ability of an organizational arrangement, that is, the public water district, to function in the common interests of all groundwater users. It should always be kept in mind that an individual groundwater user is likely to be largely oblivious to institutional arrangements so long as he receives water to his liking. Also, the more creative the law can be, the more effective an institutional arrangement can be. The more effective an institutional arrangement is, the more satisfaction that can be provided to individual water users, in the long run and in relation to minimizing costs associated with institutional weakness. Individuals must eventually bear the brunt of these costs, some more so than others. When individuals are faced with minimizing these costs, the forthcoming solution is likely to be worked out in a compromise manner that attains the best arrangements possible, the one that maximizes benefits given the circumstances.

It will be shown how alternative property rules can be used to advantage of most every groundwater user, effecting both producer efficiency and consumer utility. There will be winners and losers, but gains, if of a sufficient magnitude, can be redistributed to losers so as to minimize their costs. Property rules, when combined with economic and administrative

measures, make such a situation possible.

All of these considerations are, of course, relevant to institutional arrangements. There are basic ways to model these arrangements: most will provide the necessary institutional means to make the above condition possible.

BASIC INSTITUTIONAL MODELS FOR GROUNDWATER MANAGEMENT AND SUBSIDENCE CONTROL

Based upon alternative systems of property rules and organizational arrangements are alternative systems of decision rules. Decision rules are relevant to the allocation of capabilities and limitations among the collectivity of groundwater users in the use of the resource and directly or indirectly affect the economic behavior of individuals and institutions in relation to the use of regional water resources. Institutional arrangements are formed by decision rules based on legal and political relationships; these arrangements can be differentiated in a manner that describes how legal, political and economic rules are used and combined to arrive at a physical solution to the subsidence problem.

The general tendency in the development of institutional arrangements for groundwater management has been to either modify the basic operation of the market or completely replace market procedures (Ostrom, 1965, 4). These methods might be characterized as either market or economic models, which either correct those institutional elements which give rise to market failure, leading to a quasi or simulated market allocation of water resources, or create public enterprises which provide water through market procedures; or administrative models, which use conventional legal-political regulatory schemes for water allocation or water use control.[25] Both models in a sense

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[25]The basis for differentiation among systems of water allocation and management derives from a conceptual dichotomy between public goods--those best allocated administratively in the "political market"--and private goods --those best allocated through an economic market. A common property resource such as groundwater contains elements of both public and private goods, and is therefore allocated in practice by either economic or administrative procedures. See Davis, et al., 1975.

transform the operation of the market, either directly, indirectly or by substitution, and both involve the process of permitting individuals to use water.

Whether based upon administrative or market models, institutional arrangements must facilitate equitable consideration of a host of conflicting and complementary values in the allocation of water in those areas where individuals are competing for the "safe" groundwater supply and in other areas, where individuals must allocate their water between ground and surface supplies. At the same time, institutional arrangements must facilitate the maximization of the net economic value of groundwater, simultaneously achieving the efficient use of regional water resources. Following is a discussion of the characteristics and structure of administrative and market models, and the development and evaluation of institutional arrangements based on each model for subsidence control through conjunctive management.

Administrative Model

In only limited instances do institutional arrangements for groundwater management deviate from the conventional administrative model. Under such a model, public regulatory bodies are established and legal-political rules are imposed to control the behavior of the users of groundwater resources. A substantial degree of centralized decision-making is involved.[26]

Several characteristics of an administrative model are evident (see generally Haveman, 1973; Clyde, et al., 1971, 19-25). The primary

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[26] See Sherrod (1972) for an excellent example and description of an institutional arrangement developed after the administrative model for the control of a sea water instrusion-land subsidence problem in Savannah, Georgia.

management instrument for groundwater allocation is the use permit, granted on the basis of sets of criteria or decision rules which are appropriate to control the groundwater use problem in question. Criteria facilitate administrative decisions on how to divide a maximum permitted level of groundwater withdrawal among those having a claim. Rather than being designed to indicate efficiency, criteria used under an administrative model serve to indicate the public interest, which is the controlling feature of administrative models. Approval or rejection of permits for groundwater use are generally determined by beneficial use considerations, informal and relative cost/benefit determinations, or set priorities, which are administratively established to indicate the public interest (Clyde, et al., 1971, 19-25). Distributive justice is thus based upon the reasonableness or acceptance of the criteria among those regulated.

In an institutional system based on the administrative model, efficiency may be achieved by the use of quantity rationing instead of price rationing, which is the central feature of market models (Corker, et al., 1971, A1-52). The decision rules of the administrative entity must be designed so as to determine what a market model automatically determines: the highest valued use and user of the available groundwater resource supply. That is, the groundwater/surface water use mix must be such that the communities' value from water use is maximized while, at the same time, either increasing or decreasing the water supply source mix of any individual would not increase the communities net revenue position. The major problem is that criteria must be so designed or other non-market means must be found so as to produce information about the value of groundwater and surface water in alternative use.

Additional characteristics of institutional arrangements based on an administrative model are evident. Those with access to the groundwater are not charged a price for the resource which represents its full economic or social value. Also, groundwater users are faced with the same institutional structure of incentives and deterrents which characterized the commonality problem at the outset.

The institutional response to the subsidence problem presently pursued is an arrangement based on the administrative model.

I. Harris-Galveston Coastal Subsidence District: A Description and Analysis of a Conventional Regulatory Arrangement

Existence of the Harris-Galveston Coastal Subsidence District represents a chain of compromises not only among local decision-makers and the community of interests, but between these interests and the Texas State Legislature. Various institutional schemes, some more comprehensive than others, were offered to the Legislature for their examination and approval.[27] However, it became clear that "comprehensiveness" would have to be sacrificed in favor of pursuing a strategy of obtaining the best institutional arrangement that could be salvaged. The region was constrained in their efforts to have implemented locally tailored and acceptable institutional arrangements by

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[27] One institutional approach called for the creation of a public district which would be empowered to levy surcharges on groundwater production of sufficient magnitude to provide an economic incentive for surface water conversion, if supplies were available. The charge would be based on permits and selectively levied according to "use" classification in "zones" of critical subsidence, the most critical areas being assessed first. The intent obviously was to avoid legal problems of direct regulation of private property, instead using indirect economic incentives to achieve objectives (Working Paper of the Ad Hoc Committee on Land Subsidence of the Harris and Galveston Counties Mayor's and Councilman's Association, Jan. 9, 1975).

A second proposal envisioned legislative authorization of a regional metropolitan water authority to conjunctively regulate and manage the use of surface water and groundwater. The authority would provide water supply service to all persons within the authority would fashion a groundwater management program to halt subsidence. It would have water authority over all municipal corporations and special public districts within its geographical boundaries (H.B. 1974, 64th Session of the Texas State Legislature, 1975).

A third and largely unpopular institutional scheme attempted to amend the Texas Water Code so as to make it mandatory that all counties and cities in which groundwater pumping needed to be brought under control, would be required to become supporting members of an underground water conservation district encompassing the subsiding region (S.B. 992, 64th Session of the Texas State Legislature, 1975).

the conservative persuasion of the Legislature and by the general uncertainty as to the availability and type of institutional response needed for control of a rather unique problem.

Organization

The Legislature authorized establishment of a specially tailored conservation and reclamation district, known as the Harris-Galveston Coastal Subsidence District (HGCSD), constituted as a body and corporate politic of the State.[28] The District is mandated to regulate the withdrawal of groundwater only to the extent that such withdrawal materially contributes to coastal subsidence. The District was not expressly authorized to initiate a groundwater management program in the public interest nor engage in conjunctive water resource management.

The District includes all of the areas located within the boundaries of Harris County and Galveston County, which encompasses the seriously subsiding areas. Counties contiguous to the District may be included within the District by voluntary application or by election within the county to be included.

The District is a self governing political entity, comprised of a 15 member rule making Board. Members of the Board are appointed by decision-makers within the region under a scheme so designed as to provide representation to agricultural, industrial, municipal and county interests, both from

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[28] Ch. 284, General Laws, Acts of the 64th Texas Legislature, Regular Session, 1975. The District was created under the authority of Article XVI, Sec. 59 of the Texas Constitution, known as the "Conservation Amendment," which provides that "the conservation ... of all of the natural resources of this State ... are delcared public rights and duties; and the Legislature shall pass all such laws as may be appropriate thereto."

inland and coastal areas. The District may cooperate with and request the technical assistance of any political entities in fashioning and implementing the subsidence control program.

Powers

Current and potential operators of groundwater production wells are required to obtain a permit from the District, which specifies the quantity of current and expected use of groundwater. Permits are subject to district decision-rules; the term of the permit may range from not less than one year to no greater than five years. An exemption from permit requirements is provided for small wells less than five inches in diameter. Permits are nontransferable.

Generally, the District may provide for the spacing of wells and regulation of groundwater production from the wells, based on the information provided by the permits. The sale and distribution of groundwater and surface water is prohibited.

Property Rules

Absolute ownership of groundwater underlying an overlying land tract is preserved, subject to the rules and regulations of the District.

Finance

District operations and administrative expenses are financially supported by revenues obtained from a permit fee, either fixed or sliding, in any case based on the quantity of groundwater pumped. The fee is determined annually as the size of the District's budget dictates.

Initially, the permit fee schedule was of the fixed type, amount determined by budget requirements and public hearings. The fee for operating year 1976 was set at 1.2 cents per one thousand gallons of groundwater pumped. This policy was not unanimous as some Board members favored a sliding fee schedule, decreasing as the distance from the zones of greatest subsidence increased. The attempt was to reflect disparities among the collectivity of groundwater users' expectations of benefits, and as this was not accomplished, many marginal operators and other remote enterprises were voracious in their criticisms (see Minutes of the HGCSD, Oct. 8, 1975).

The magnitude of the initial permit fee represents normally high "start up" costs, including construction of subsidence compaction monitors, and is expected to substantially decrease with future operating budgets.

Decision Rules and Operation

Groundwater allocation decisions are determined adminstratively, based on the grant, denial or conditioning of groundwater use permits. In determining the grant, denial, terms and conditions of permits, the District considers the effect of the pumping on the subsidence of the land surface, the quality, quantity and availability of alternative surface water supply sources within the area at competitive prices, and the economic impact on the applicant from a grant a denial of a permit, or the terms prescribed by the permit, in relation to the effect on subsidence that would result. The District is mandated to grant a permit when there is no available substitute or supplemental source of surface water at competitive prices, or where the conditioning and other terms of the permit would result in arbitrary or undue economic hardships or other burdens on the applicant (see Statement of the Chairman of

the Board of Directors Before Public Hearings on Well Permits). Thus there is a general balancing of benefits and costs, that is, the costs to an applicant of surface water conversion and other permit terms with the corresponding benefit to the public.

Decision rules are also based upon the District's subsidence control plan, both temporary and formal. Initially, permits for groundwater production within a designated surface water supply service radius were granted conditionally. Applicants were either requested to investigate the availability and feasibility of converting to surface water or were requested to make "detailed engineering studies" for ultimate surface water conversion, specifying the costs that would be incurred. In either case, applicants were requested to report back to the District within a specified time relative to their findings and progress (see, for example, Minutes of the HGCSD, March 12, 1976). In this manner, the District becomes cognizant of the availability of surface water supplies, and of the magnitude of the relative costs and time involved in construction of surface water works facilities.

The main feature of the District's formal subsidence control plan is the designation, subject to additions, of an "area of concentrated emphasis," which corresponds generally to coastal areas most critically affected by subsidence, both because of the degree of surface elevation loss and topographic elevation generally (Minutes of the HGCSD, July 9, 1976). Areas presently included in this designated area are all of Galveston County and southwest Harris County, including a large portion of the city of Houston, the largest single user of groundwater in the subsiding region. Within these areas, groundwater production can be expected to be limited.

The net effect of the application of the District's decision rules has been to generally grant conditional permits to existing operators of groundwater wells relative to new permit applicants, although some permits in the former case have been reduced. The District's policy must necessarily be permissive, as it operates under uncertainty relative to the response of the underground water system to decreased pumping. The ultimate policy of the District will depend upon the effect of "voluntary" surface water conversion of some major industrial users at the heart of the subsiding region, initiated years hence, upon the rebound of groundwater table levels. Upon analysis of this hydrologic information, the critical maximum acceptable annual groundwater withdrawal quantity can eventually be computed.

The ultimate financial burdens imposed on municipalities, which will be incurred as the result of requirements to lessen groundwater demand, are likely to be mitigated by surface water conversion subsidies currently being provided by the Texas Water Development Board. Thus, all residents of the State are indirectly and to a limited extent "bailing out" the subsiding region for its overuse of groundwater.

Present Status of Conjunctive Management

Presently, groundwater management, and conjunctive management of the regional water system is a fragmented venture. Numerous independent water related agencies and other relevant political organizations, each with varying powers, purposes and scopes of jurisdiction, operate for related, but by no means identical purposes. In some cases, the activities of these water organizations are competitive rather than complementary. These institutions form a somewhat inchoate institutional structure, tenuously but informally and

indirectly related by the subsidence problem. Because of this fragmentation, effective resource management becomes difficult. When the special purpose approach is taken, long range planning is constrained and coordination and cooperation is limited.

Conjunctive management exists only as a potential. The Subsidence Control District in effect indirectly forces conjunctive management decisions upon other water organizations throughout the region and in this manner, these organizations assume roles similar to those that would be required of them in a centralized conjunctive management institutional structure. However, the critical element of the rationale of conjunctive management is formally absent: planned and coordinated surface and groundwater development, use, supply and investment decisions. There is little incentive for these organizations to cooperate, save cases where it would be in their best interests to do so.

Ultimate surface water delivery and cost decisions and policies are exercised by municipal corporations, namely Houston, water authorities, and by various river authorities who have impounded surface water, in some cases in cooperation with municipal corporations and water authorities, as well as various state agencies, and offer the impounded water for sale. Prices are set in an ad hoc manner, usually based on long term supply contracts. Some organizations act as intermediate suppliers, selling water at wholesale cost, while others act as water retailers, selling water to their customers. Some act as both developers and retailers. This network of water organizations is somewhat related through development or supply contracts or agreements. However, contracts are between segments which are largely

unrelated.[29]

The Coastal Subsidence District has neither formal nor direct input into surface supply decisions, and cannot act as coordinator. Instead, by its mandated goal of reducing groundwater pumpage and subsidence, the District creates among the collectivity of groundwater users demand for surface water. Displaced demands for groundwater are, strictly on an individual basis, directly registered with the surface water wholesaler or retailer serving their particular area. These organizations then must plan accordingly on an organization by organization basis.

The City of Houston can be conceived of as a surrogate surface water coordinator for the seriously subsiding region. This municipal corporation, through cooperative arrangements with various river authorities, is the major developer and retailer of both potable and raw surface water, supplying it to municipalities, residences and industries within its boundaries, as well as to the greater subsiding areas surrounding the City. In this regard, it is largely in a monopolistic position.

Many groundwater users will ultimately be supplied surface water from this entity. Surface water rates are set by the city council in cooperation with the Water Department. Surface water prices are based on "declining

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[29]These water organizations include the Brazos River Authority, Galveston County Water Authority, San Jacinto River Authority, Trinity River Authority, Coastal Industrial Water Authority, City of Houston, all of which are active surface water developers and suppliers, either wholesale or retail; and the numerous and various public freshwater supply, control and improvement districts, including municipal utility districts and other municipal corporations, all of which use and supply groundwater, but will increasingly be forced to bargain and otherwise negotiate with the above surface water organizations. For a good discussion of the powers, duties and scopes of all of these water organizations, and for a limited discussion of their interrelationships, see "Texas Water Administration," Senate Regional Councils on Water Resources, 1973, and "A Water Inventory of the Texas Coastal Zone." Texas Water Development Board, 1970.

block" pricing and supply is offered through "take or pay" contracts. In effect, larger surface water users pay less per unit than smaller users, as the more used, the less the price. "Take or pay" adds another dimension: the quantity of water use specified in the contracts, which usually increases with time, must be paid for regardless of whether it is actually used or not. Until recently, Houston stood firm in its policy of not allowing "contract" water to be resold if not used, in addition to prohibiting pooling of water demands by smaller users.[30]

Not only do such practices encourage and facilitate inefficient water use, but many groundwater users imminently facing surface water use eye with skepticism the prospects of negotiating with Houston without any assurances of either equitable treatment or assurances against "arbitrary" rate increases designed for quick debt amortization. Surface water policies could be ultimately improved by abandoning "declining block" pricing in favor of cost based pricing, abandoning "take or pay" in favor of metered sales, and by encouraging pooling of surface water resource demands, as well as providing the means for regional coordination of surface and groundwater development, supply and use decisions and policies.

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[30]For example, the city of Pasadena, at the very heart of the seriously subsiding region, is under contract (1972) with the City of Houston to "take or pay" for at least 17 million gallons per day of surface water, however, due to planning errors and engineering mistakes, the city can only use 5 million gallons per day. At 16 cents per one thousand gallons "used," the city unnecessarily spends over 1600 dollars per day for the water it does not use. Pasadena intends to seek an injunction against the City of Houston to alter the policy (Minutes of the HGCSD, June 9, 1976).

Critique of Administrative Model

Institutional arrangements for groundwater management based on the administrative model have been widely criticized on the basis of the propensity for inefficient allocation of water resources, and the separation of benefits from beneficiaries, or the separation of those who are responsible for the costs associated with the groundwater use problem from those who will ultimately bear the costs of solving it. Also, commentators in the literature point out that these systems fail to ensure that decision-makers using conventional decision criteria will allocate or manage water resources such that decisions affect social welfare maximization, including efficiency and equity; and that these systems are structually unable to account for varying degrees of utility in water allocation (Haveman, 1973; Johnson, 1971; Milliman, 1956 and 1965). What largely occurs is the preservation of the existing structure of incentives and deterrents, and institutionalizing measures which mitigate the effects of institutional weakness and failure.

Economic or Market Model

When goods desired by individuals are not exclusive, determinant and easily transferable, individuals experience problems in their attempt to allocate the goods to their most valuable use in a private market. So long as the market registers costs and benefits in its traditional manner, problems will continue, as in the case if groundwater, which will be produced in a socially suboptimal and inefficient manner.

Economic models of water resource allocation correct the inadequacies of the market by various strategies which seek in some way to internalize the externalities associated with groundwater use, signals of institutional weakness and failure. The market mechanism is itself the most widely accepted way by which resources are efficiently allocated in our society (Corker, et al., 1971, 131), Yet in only limited instances has it been used as a tool for groundwater management.

In order to make a market for a common pool resource reasonably operate as if it were allocating private goods, certain conditions are needed (Davis, 1975, 22). The first requirement is a provision for some type of ownership or property rules, such as centralized ownership or decentralized ownership, either actual or effective. Whether externalities are allowed to exist would depend on how ownership is defined, and, under some arrangements, whether there is a basis for exchange. The second condition is that the act of buying or paying for the good or service must be related to the use or consumption of it. The third requirement concerns the possibility of exclusion. Perfect exclusion need not be required for some institutional variations under the market allocation model, however, under others it is

required to provide the basic motivation for exchange. Market models designed to achieve the optimum level of regional water resource use and to equate marginal private and marginal social costs typically involve market simulating policy instruments based upon the above conditions. These include prices, user charges, assessments and rebates, as a means of correcting market failure and achieving management objectives (Haveman, 1971, 870; Meyers, et al., 1971A, 2-7; Corker, et al., 1971, 222).

If the conditions upon which a market for a common property resource are reasonably met, then application of the following economic principles would produce an efficient allocation of groundwater/surface water resources (Milliman, 1967; Hirschleifer, et al., 1969, 36-41). Since the management objective is to allocate a flow of water, or the maximum acceptable groundwater withdrawal rate, the economic principle is to equalize marginal values in uses, which will maximize the total value of the safe supply of groundwater resources to society. If groundwater is allocated so that all users and consumers derive equal marginal values in use, then no amount of groundwater can be transferred to a higher valued use.

A complementary economic principle is marginal cost pricing. This requires that consumers or groundwater users should be charged, directly or indirectly, prices which are equal to marginal costs of pumping additional quantities of groundwater. Total marginal costs, correctly viewed, should include social costs of external effects as well as the real capital or internal user cost of groundwater use, which would lead to a better use of existing groundwater supplies. In order to equalize marginal value in use, however, the price should be made equal to all consumers, depending, of course, on differing locations, differing use patterns and thus differing

marginal costs of consumers or users. However, users having similar water supply and cost conditions would need to be charged equal prices. The combined economic principles, then, make prices equal to marginal costs for all users, which ensures an economically efficient allocation of groundwater/surface water.

In practice, institutional arrangements for subsidence control and water resource management can be constructed according to the market model, based on the conditions and principles discussed above. Both a taxing scheme and a quota scheme equate marginal private and marginal social costs of groundwater use, although the former operates on the demand side, the latter on the supply side. However, both serve identical purposes; a reduction in pumping to the maximum acceptable withdrawal quantity in proportion to each pumper's contribution to the collective overdraft. Both methods deal with the divergence between private and social costs by destroying the central feature of the commonality problem in the use of groundwater, as evidenced by subsidence--nonexclusive ownership--and internalize externalities through the use of alternative rules of property ownership.

A quota method equitably parcels out private title to specific shares of the groundwater resource, and provides some means for transfer or trading of these shares. A use tax effectively places a public entity in the position of sole owner, treating the groundwater resource as the common property of a public water district. Neither method is mutually exclusive, rather they can be combined in various ways in the development of institutional arrangements. In any case, both methods automatically allocate regional water resources being allocated to uses and users where they can be used most efficiently (see Milliman, 1956; Hirschleifer, et al., 1969).

Price is used as a rationing device - based on a determination of the value of water in alternative uses (Castle, et al., 1960, 153).

Thus, pricing systems based on market simulating conditions and economic principles can be used to the advantage of a water management entity in the development of an effective subsidence control and groundwater management program. When marginal private and social costs comprise the price of groundwater, groundwater will be automatically and efficiently allocated to uses and users attaining the highest marginal benefit. A pricing system will in turn function to apportion water use between groundwater supplies and surface water supplies. It also permits flexibility in the use of groundwater and does not necessitate extensive knowledge on the part of a public management entity as to the value of water in alternative uses and among different users, as market models involve a substantial degree of decentralized decision-making (Renshaw, 1963, 294).

Market or economic models of groundwater management have been recommended extensively in the literature to improve resource policy and effect conjunctive use (e.g., Haveman, 1973; Smith, 1968; Hirschleifer, et al., 1969; NWC, 1973; Corker, et al., 1971; Fox, et al., 1962). Alternative property rules create conditions upon which a market can operate.

Development and Evaluation of Institutional Arrangements Based on the Market Model

The following institutional arrangements, structured according to the market model, are based on a contemporary concept of public enterprise (See Ostrom, 1965; Ostrom, 1975). Operating within the political and legal context of a public water district or authority as a corporate body politic, each enterprise is designed so as to facilitate the systematic and purposeful economic activity of controlling and preventing land subsidence while arranging for an expanding level of water services to the subsiding areas within the region, regardless of the particular institutional scheme. The enterprises control groundwater rights through bargaining and contractual arrangements and when necessary, coercive schemes. In all cases, however, these collective enterprises act in a feduciary capacity as the agent for all groundwater users within the region, being empowered to negotiate and act on their behalf (Corker, et al, 1971, 205). The costs of management are funded by constituents in proportion to the benefit received, or under some other rule of equity.

As the public trustee of the groundwater resources underlying the region, the enterprises act in the same capacity either as, or as if they were the sole owner of the groundwater resources, prescribing the terms and conditions which are designed to advance the common welfare. An attempt is made to ensure that no one is left worse off and everyone is made better off within reasonable and practical limits.

The public enterprises operate relatively independently at the regional level, being immediately accountable to the relevant community of interests for which they act. However, the functional political relationships

will vary. When the enterprise is designated as a Water District, it will be able to enter into inter-agency contractual arrangements for joint operations and purposes when necessary. In any case, the enterprise can require political and technical cooperation in regards to regional water supply, development planning, pricing and policy decisions when political cooperation is required, necessarily limited to fashioning and implementing a rational groundwater management and subsidence control plan of action. When the enterprise is designated as a Water Authority, it is politically structured and legally constituted as a master water agency which can exercise control over and compel cooperation of all water related entities within its jurisdiction in the management of regional ground and surface water resources and control of land subsidence.

Whatever the political relationship, the public enterprises function to make management decisions that control the allocation of regional water resources in a general way, while allowing water supply districts, utilities, etc., sufficient autonomy to continue making largely decentralized decisions regarding the mix of surface water / groundwater use, although assuring that these decisions are in the public interest (Ostrom, 1965, 88). In order for these enterprises to be constitutional, however, substantial political consensus must exist regarding the terms and conditions of the collective enterprise (Ostrom, 1975, 781).

II. A Coastal Water District: Allocation of Water Through Taxation

If the subsidence problem is correctly conceived of as an economic problem of externality, a divergence between private and social costs evidenced by the loss of income to the community from overuse of a common property, then the logical solution would be to correct those institutional elements which give use to the divergence.

The classical economic solution for subsidence problem, as an externality, would be to face groundwater pumpers with the marginal social cost of groundwater production, thus mitigating the divergence between private and social costs, and ultimately equating marginal social costs with marginal social benefits (Burt, 1966; Milliman, 1956). The externality is corrected by modifying the structure of incentives in individual groundwater pumping decisions - the incentives that led to institutional weakness and failure. Social welfare will not be maximized, and groundwater will not be produced efficiently, if each pumper does not determine his annual groundwater withdrawals on the basis of the true marginal cost, including the externality. If a tax just equal to a pumper's ignored externalities is imposed on each gallon of groundwater pumped, marginal private cost will be equated with marginal social cost and decisions resulting from each pumper's attempt to maximize individual profit will yield the desired social optimum rate of groundwater pumpage. The tax essentially extracts from the collectivity of groundwater users an amount just equal to the present value of the loss of income to the community if each groundwater user were to pursue a self-interested resource use strategy in the absence of the tax (Brown, et al., 1967).

The logic of a use tax is simple: the more costly any given behavior, the less of it that can be expected to be observed. If individuals pay the social costs of their activities, they will reduce their groundwater production rate to the optimum level, or will seek out an alternative source of water which does not create the externality.

Conjunctive use of the most efficient combination of ground and surface water resources is accomplished by the imposition of a use tax on groundwater pumpage, correctly conceived of as an economic value rationing device. Given that the maximum value of any quantity of groundwater pumped is equal to the total cost of purchasing and using the same amount of surface water of comparable quality, and that a use tax is imposed on the production of groundwater representing each groundwater user's proportionate contribution to collective social (subsidence) costs, then the following events can be expected to occur. Each groundwater user determines how much to pump by comparing the total marginal cost of groundwater use with the value of the water to him, to whatever uses he is applying it. Each water user will pump groundwater to a point at which the value to him of the last gallon pumped just equals the total cost to him of the alternative surface water source. Thereafter, the balance of his water demand will be obtained from the cheapest source: surface water. Thus an individual attempts to maximize his benefits by minimizing his costs (See NWC, 1973, 240; Hirshleifer, et al, 1969, 64-66; Milliman, 1956, 430-434; Corker, et al, 1971, A1-21--A1-29).

An institutional arrangement for conjunctive use-conjunctive management of regional water resources and subsidence control can be constructed around

the economic system of user charges. Such a groundwater management scheme is widely advocated in the literature (e.g., NWC, 1973, 241; Corker, et al., 1971; Friedman, 1971; Milliman, 1956; Brown, et al., 1967).[32]

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[32]The concept of applying a system of taxes and assessments for indirect value rationing of ground and surface water resources, as opposed to a system of quantity rationing by direct groundwater production control, has been employed successfully by the Santa Clara Valley Water District in California to limit groundwater pumping and land surface subsidence. (The California subsidence problem provides striking physical and economic parallels to the Texas subsidence phenomena, for example, coastal location (San Francisco Bay), largely urbanized area, increased rates of sinking, severity of economic impact, and a common law system of groundwater rights).

The primary management tools of the Santa Clara District are zones of benefit and pump taxes and ad valorem taxes applied within these zones to finance the delivery and use of imported surface water and for spreading of surface water to recharge the groundwater basin to reduce overdraft and land subsidence. The pump tax is used to recover the costs of purchasing surface water for recharge, and also, to a limited extent, to induce the direct conjunctive use of groundwater and surface water (See "Santa Clara Valley Water District," Cal. Water Code Ann. App. Sec. 60-1 to 60-35, as amended; Talley, Randall, "Annual Survey Report on Groundwater Conditions 1973-1974, February, 1975; Poland, J. F., "Water Imports to Santa Clara County, California Greatly Reduce Land Subsidence," Presentation to California Water Commission meeting of May 7, 1971, at Sacramento, California; and Poland, J. F., "Land Subsidence and Aquifer-System Compaction, Santa Clara Valley, California, USA," International Symposium on Land Subsidence, Tokyo, Japan, 1969, UNESCO).

The primary difference between the California subsidence control scheme and the institutional arrangement which follows is that the pump tax will be used to directly induce conjunctive use of regional ground and surface water resources, as artificial recharge is the more expensive alternative (Gabrysch, 1976). However, the concept of developing an institutional arrangement based on the "market model" to halt subsidence is common to both institutional schemes, and it is demonstrably effective.

Organization

A Water District would be established for the purposes of subsidence control through conjunctive management of regional ground and surface water resources. The jurisdiction of the District would be of a size necessary to halt and control land subsidence and to account for all substantial costs and benefits of subsidence control, but shall in no case be smaller than Harris and Galveston counties, and in any case, ultimate boundary delimitations should be based on hydrological and economic considerations, as established in public hearings and otherwise.

The District would be a self-governing body politic of the State, comprised of a Board of Directors, representing and directly accountable to the people and local governments for which it acts. The Board would be comprised of representatives of the region as appointed under some equitable representation scheme.

The District so organized would coordinate the activities of all groundwater and surface water users and entities throughout the region to carry out its mandated objectives.

Property Rules

Each owner of property overlying the underground water system, which of course includes municipal corporations, water supply districts as well as other private land owners, would have a common law groundwater right to the use of the resource, subject to the qualification of reasonableness of use, as determined by the Water District. The groundwater resources would be treated as the common property of the Water District, and as such, the Water District as a trustee of the common, would be conceived of as the

effective sole owner of the groundwater, subject to a feduciary duty relative to the users of the resource.

Powers

The District would be mandated to expeditiously halt and control the subsidence of the land surface. To accomplish this purpose, the District may manage conjunctively ground and surface water resources within the region. To further the implementation of a conjunctive management and subsidence control program, the District may require the full cooperation of all water supply, control and improvement districts, water authorities, municipal utility districts, municipal corporations and all other such political bodies established under the laws of the State, as well as all surface water suppliers within the region, where it is reasonably necessary to do so. The District may buy and sell surface water, construct and cooperate in the construction of surface water treatment and delivery facilities, and may enter into contracts with political entities for the purchase of surface water and groundwater, as well as enter into contracts with groundwater users to preclude the exercise of their groundwater rights. The District may store water beneath the land surface without the permission of the landowners, so long as the landowners are protected from injury.

The District must formulate a conjunctive management and subsidence control plan, which may be revised as necessary. For the purpose of the plan and management program, the District may delineate, after public hearings, zones of benefit for the purpose of collecting reimbursement of costs and controlling subsidence. Within these zones of benefit, the District may levy extraction charges based on groundwater production, and

ad valorem taxes, based on assessed land valuation, to finance the District's management program and further the District's management plan. All groundwater producing facilities within the District must be registered and water metering devices may be required. Each operator of a groundwater production facility must furnish a semi-annual water production statement to the District stating past, present and anticipated groundwater pumpage.

The District may sue and be sued. It may initiate injunctive proceedings against groundwater users in areas surrounding the District not under control, only when it can be demonstrated that pumping groundwater in the outlying areas causes an unreasonable and adverse effect upon the subsidence of the land surface within the District's jurisdiction. Similarly, the District may sue for the recovery of costs, when, as a result of the District's water management program, landowners and other groundwater users in areas surrounding the District net an appreciable benefit for which they would not normally be required to be liable. In any case, the District may petition the State for inclusion within its jurisdiction any outlying areas when it can be demonstrated that such an action is necessary and beneficial for furtherance of the District's mandate.

Decision Rules and Operation

All water resources of the region would be aggregated and allocated under a generalized water resources pooling concept, accomplished by pricing schemes and surcharges which equalize water costs and recognize special benefits which accrue or might accrue to certain water users. This provides flexibility over the amount of water used and for selective uses of water from different sources (ground or surface) (ASCE, 1972, 210).

The dual objectives of the District are to allocate ground and surface water resources efficiently and allocate the social costs associated with the subsidence externality equitably, such that assessments on each groundwater user's pumpage reasonably reflect the benefits each can be expected to receive from a subsidence control program. Considerable political and legal risks exist if the District assesses groundwater users larger quantities than the benefit they receive (Ostrom, 1965, 588).

To accomplish an equitable apportionment of social costs, that is, effect a coincidence of benefits with beneficiaries, the disparities between costs and benefits among groundwater users within the subsiding areas need to be recognized. The provision of zones of benefit permits the District to recognize that some areas within its boundaries will receive greater benefits than other areas in the implementation of a comprehensive management program (Moore, et al., 1969, 408-9; Krieger, et al., 1962). Although such would ultimately be created after public hearings, a scheme such as the following might be established.

The first zone of benefit covers the entire area within the District's boundaries. Because of the common pool nature of the groundwater resource, it is recognized that all users contribute to the subsidence problem, however significantly or insignificantly, simply by pumping the groundwater resource in common. The benefit accruing to all is a managed and conserved groundwater resource, resulting either in an increased or maintained underground water table level, thus allaying any fears of resource exhaustion and creating security or certainty as to a groundwater supply.

Such a benefit might be recovered by an ad valarem tax. The use of an ad valorem tax is based on the rationale that the overdraft and use of "cheap" groundwater resources has made possible the intensive development (industrial, urban, agricultural) in subsiding areas, and the accompanying increase in property values. Property, therefore, could finance the expense of the remedial actions of the District to alleviate the overdraft, consequently halting subsidence (Buchwalter, 1970, 27; Ostrom, 1965, 36). The ad valorem tax can be used in large part to pay the general administrative expenses and costs of operating the District, but is not limited to these purposes.

A second zone of benefit encompasses the seriously subsiding areas of the District, sufficiently large to control pumping of groundwater users who substantially contribute to the problem, and in any case would cover all groundwater users whose pumping needs to be controlled and/or reduced in order to abate land subsidence. This zone is based on the hydrological reality that the pumping causing subsidence is localized to the areas near the heart of the District (Gabrysch, 1976). The benefit, of course, would be the net present value of future subsidence related costs (community income reductions) foregone. A pump tax could be levied on groundwater extractions within this zone to internalize these costs.[33]

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[33] In theory, the revenue obtained by the District from the imposition of a pump tax must not be returned to groundwater users in proportion to the quantity of groundwater used (NWC, 1973, 240). In practice, the proceeds from a pump tax can be used to purchase pumping rights of groudnwater users who could not afford the pump tax; to subsidize certain groundwater users to induce them to convert to surface water; and for the development of a fund for the pumping and construction of surface water delivery and treatment facilities (Ibid).

The ideal pump tax would be a sliding scale equaling, for any quantity of groundwater withdrawn, the divergence between marginal private cost and marginal social cost (Hershleifer, et al., 1969, 64; Corker, et al., 1971, A1-5). The primary function of a pump tax, however, is to deter groundwater overdraft and subsidence, which requires that it be set at the appropriate level. The tax needs to be set at a level which induces the most efficient amount of conjunctive use of groundwater and surface water resources.[34]

Jones, et al. (1975) has quantified a substantial amount of the social costs associated with subsidence, and has demonstrated that this amount exceeds the total cost of converting to surface water, at the current average price, if all pumpers within the seriously subsiding region were to convert to the alternative surface water supply source. Again, however, substantial disparities in benefits exist within this zone. It was demonstrated earlier that subsidence related costs are experienced in a fashion disproportionate to each groundwater user's contribution to the problem. These social costs are instead experienced disproportionately in coastal areas, as shown in Table 2. Groundwater users in these coastal areas would be better off if the alternative surface source was used. Groundwater users in the remaining inland areas would be worse off if required to use surface water. However, if surface water conversion occurred in relation to these costs and benefits, it is unlikely that it would be the optimal amount since the greatest quantity of groundwater pumped is in inland areas (See Jones, et al., 1975).

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[34] A brief transition period during the implementation of a full scale tax system would allow groundwater users to adjust to the new arrangement.

It is readily apparent, therefore, that some equitable social cost allocation scheme needs to be developed, while assuring that subsidence is halted. Equity, in the first instance, requires that collective social costs be borne by groundwater users in direct proportion to each individual's contribution to the subsidence problem (Cobey, 1965, F-5). In addition, equity requires a greater coincidence of the incidence of benefits with beneficiaries.

The District must approximately determine the total amount of the reduction in groundwater pumping within the zone required to abate and control subsidence. The disparity created between groundwater supply and demand would be made up by obtaining water from surface supplies. The District then would multiply the quantity represented by the required amount of groundwater reduction by the total average cost of obtaining an equal quantity of similar quality surface water. This figure essentially represents collective social costs saved by discontinuing the amount of groundwater pumpage causing subsidence, and would be allocated equitably in proportion to each groundwater user's current pumping rate per gallon within the zone. Thereafter, the pump tax would be modified by a series of successive approximations until subsidence is halted.

In order to achieve a coincidence of the incidence of benefits with beneficiaries while, at the same time, achieving an efficient allocation of ground and surface water resources, the District would need to use the revenues collected from the tax on groundwater extractions to selectively contract to pay groundwater pumpers whose tax assessment plus marginal private cost is less than the marginal cost of purchasing surface water, to purchase surface water. Such a scheme enables the District to "rent" groundwater

rights to as to preclude their use (Ostrom, 1965, 586; Renshaw, 1963).[35] A groundwater right, like any other property interest, may be leased or acquired by contract (60 Tex. Jur. 2nd, sec. 221).

Thus the advantage of applying a pricing scheme in the second zone of benefit is an equitable and efficient subsidence control program. Price is used as a management tool to equalize water costs and to limit pumping in those areas where the cost of delivering surface water is greater than the internal, user cost of pumping groundwater plus assessed external costs. Funds collected by the use of a pump tax are used in part to make up the difference between cost differentials when it is in the public interest to do so.

The surcharge on groundwater use applied within second zone of benefit is the key to the conjunctive use and subsidence control program. All individual groundwater users remain free to follow their own choices, so long as they are willing to pay the price (Corker, et al., 1971, 71). Each adjusts to the tax, and determines whether it is more efficient to use surface water or groundwater, or a combination of both. The District allows the collectivity of groundwater users to adjust to the pricing system, functioning to assure that the most efficient combination of groundwater and surface water is pumped by the selective use of subsidies.

In order for the District to successfully manage regional water resources conjunctively, all water users would have to notify the District of

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[35]The incidence of social costs are of such a magnitude and so distributed that a substantial portion of groundwater users and property owners within coastal shore areas could afford to in effect "bribe" inland groundwater users into converting to surface water while converting to surface water themeselves. Such a payment is made possible under this arrangement, such that no one is made worse off (See Jones, et al., 1975).

their willingness to use either surface water or groundwater. When demands are so registered, the District acts to ensure that demands for the surface water source are met. Where surface water is available from existing suppliers, the District coordinates its delivery and guards against discrimination in the setting of the price. Where surface water is not available, but is demanded, the District either coordinates its development and delivery, or in some cases, may build surface water delivery facilities and/or treatment facilities itself, selling the water to those who demand it. These facilities would be financed by revenues obtained from the imposition of the pump tax within the second zone of benefit.

In any case, having adequate scope to determine where surface water is demanded and groundwater demanded, the District is in a position to recognize economies of scale in the construction of surface water delivery and treatment facilities. It may notify a group of water users that it would be less costly if joint surface water pooling projects were undertaken, and it may assist in such a situation.

Under such an institutional arrangement, planning, coordination and management are centralized, but to a large degree, individual water use decisions remain decentralized under a structure of incentives and deterrents. The District functions to price groundwater as a scarce resource so that it is rationed out efficiently, and to engage in and facilitate economic activity to assure an expanding level of water availability while, at the same time, controlling land subsidence and managing regional groundwater resources by indirectly reordering incentives for groundwater use into disincentives and disincentives for surface water use into incentives.

III. A Coastal Water District: Allocation of Economic Water Values Through an Exchange Pool

The basic feature of the following institutional arrangement is the structure of incentives and deterrents which approximate the allocation of ground and surface water resources in a workable market. Again, individuals are faced with the social costs of using groundwater, but through a management scheme which incorporates aspects of limited quantity and maximum value rationing but with maximum efficiency and management flexibility. Each individual has the right to pump as much groundwater as desired, however, along with this right goes the duty to pay the appropriate costs of producing the groundwater.[36]

Organization

A Water District is created to conjunctively manage surface water and groundwater use to expeditiously halt and control land subsidence while providing for an expanding level of water supplies to meet regional water demand. The Water District is constituted as a regional corporate body politic of the State, to be governed by a Board of Directors comprised of representatives of the region appointed under some equitable scheme of representation. The District would extend geographically to include all of

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[36] While this institutional arrangement differs in certain basic respects, the economic assessment and basic management scheme central to the following institutional arrangement is based on an "equity assessment" developed and levied by the Orange County Water District, California, which has successfully halted problems of groundwater basin overdraft and saline water intrusion into their aquifers. The assessment/rebate scheme is one of the most widely publicized and rare examples of a comprehensive groundwater resource management schemes currently operating. For an in-depth description see Buchwalter, 1970; also Corker, et al., 1971; ASCE, 1972, 122, Ries, 1967).

Harris and Galveston counties, and all other contiguous areas that are necessary to abate and control land subsidence as established through public hearings, and upon presentation of relevant technical information. The Water District would be directly accountable to the community of interests and local political entities for which it acts. It may require the cooperation of all regional water related organizations where necessary to conjunctively manage surface and groundwater resources to abate and control land subsidence.

Property Rules

The common law water rights of landowners, including municipal corporation and the various public freshwater supply districts and utilities are recognized. However, the water rights are conceived of as "usufructuary" rather than "corporeal" ownership, that is, rights to the use of water underlying property. Use must be reasonable, as determined by the correlative rights and mutual interests of other property owners and groundwater users. Each holder of groundwater rights is limited in quantity use by the Water District's determination of their fair and reasonable share of the available portion of the safe groundwater yield.

The groundwater resources underlying the Water District's geographical jurisdiction are treated in effect as the common property of the District, use subject to equitable and reasonable rules and terms prescribed by the District to halt and control surface subsidence.

Powers

The Water District is empowered to conjunctively operate and manage regional surface and groundwater resources so as to halt and control land

subsidence and salt water intrusion. It may exercise control over the rate, amount and geographical pattern of groundwater pumpage by creating economic inducements provided by ad valorem taxation and other assessments. The Water District may exchange water resources among all users within its jurisdiction. The Water District may purchase, contract for or otherwise finance, plan and coordinate the delivery and use of alternative supplies of surface water where it is economically feasible and in the public interest to do so. The Water District may regulate and integrate regional and imported surface water with groundwater into a planned system of water use for purposes of subsidence control. The Water District must allocate water among users and uses in accordance with dual goals of efficiency and equity.

All users of groundwater, and all potential users of groundwater are required to file with the Water District annually a notice of intent to pump specifying the quantity anticipated to be used. The Water District will in turn notify the user of his allowed ground/surface water use ratio. A pumper is free to beneficially use as much groundwater as he needs, but is liable for the appropriate amount of the assessment, if such exists.

The Water District may require the cooperation when necessary of surface water suppliers and other public water authorities and water supply districts in the fashioning of a water resource management and subsidence control program.

The Water District may petition the State for inclusion within its jurisdiction areas contiguous to but outside its boundaries where the following can be demonstrated: that sufficient and substantial benefits of the Water District's groundwater management program accrue to areas outside but contiguous to its boundaries warranting an estimation of its general ad valorem

assessment to these areas (for those purposes the Water District may propose to the State extra zones of benefit); that pumping groundwater is areas outside but contiguous to its boundaries are subversive to and cause a substantial effect upon the subsidence of the land within the District such that the equity assessment is warranted for application to such areas. In any case, where the effect of uncontrolled pumping seriously and substantially endangers a no subsidence condition, the Water District may seek an injunction against such pumping to limit withdrawals.

Decision Rules and Operation

The Water District operates under a generalized concept of regional water resources pooling, having adequate control over surface and groundwater to effect the critical and most efficient combination of regional groundwater surface water use. The District functions to ensure an adequate supply of water to meet the total demand of the region at optimal cost. It focuses on the economics of the subsidence problem, the propensity for demand to be satisfied by using water from the ground, and entails the creation of economic incentives to mitigate the subsidence problem.

The District may levy two charges to support its management operations. The first charge is an ad valorem tax, levied on all property owners within the District. The revenues generated support the general operation of the water management program and can be used for anything the District does. A second charge is an ad valorem tax established to reduce the accumulate groundwater overdraft and subsidence; it may be levied at the option of the District to purchase surface water and make capital investment if necessary. The District may establish zones of benefit for the purposes of the charge,

as delineated through public hearings. The central feature of the Water District's management scheme, however, is equalization of ground and surface water prices among regional water users through the levy of an equity assessment, as follows.

Within any designated area of the District, or for the District as a whole, the Water District determines that quantity of groundwater that can be safely pumped from the underground water system without generating land subsidence. This quantity constitutes the allowed groundwater production. The disparity between total groundwater demand and the allowed groundwater production quantity will be mitigated by using surface water supplies. Based on the allowed groundwater production, a ratio of groundwater/surface water use is computed. Each water user is required to meet their water demand in this proportion. The Water District can vary the ratio in certain areas in order to achieve particular management objectives, thus permitting pumpage from portions of the aquifers where maximum recovery is possible. In any case, the groundwater production percentage is considered to be each pumper's fair and reasonable share of the groundwater supply. Potential users are free to enter the field, but subject to pump in the required ratio.

The Water District then computes the average price of surface water and the average, internal cost of pumping groundwater in the area covered. The cost differential is what each groundwater user saves by using groundwater instead of surface water to the extent of all water taken over the allowed production share. Jones, et al., (1975) has computed the average user cost differential to be $.16 per thousand gallons in favor of groundwater between the two water supply sources available to the seriously subsiding region generally.

For examplative purposes, it will be assumed for any area that the required groundwater/surface water use ratio for each water user is 60/40. Based on this ratio, the Water District levies an assessment of $.16 per thousand gallosn (the cost differential) on each water user for each one thousand gallons of water pumped in excess of the 60 percent allowed groundwater production share. This amount is then transferred to another water user who has facilities to take surface water in excess of 40 percent of the user's total capacity in order to provide an inducement to take the 60 percent fair share from a surface water source rather than pumping it from the underground water system. As such, the assessment is used as a rebate. Moreover, the assessment can be used to subsidize a water user with reasonable or potential access to surface water supply facilities to convert to this source. This operation constitutes the District's water exchange: what is being exchanged in effect are economic values represented by surface water/ groundwater cost differentials.

In effect, the management scheme provides individuals who demand water access to a water supply rather than to a particular source. All groundwater pumpers equitably share in the costs of reducing subsidence by conjunctive use of surface water, even though they actually might not use surface water. No groundwater users are forced out of the field, indeed, this system permits all to survive.

The central aspect of the water exchange is the use of a price mechanism to equalize costs of surface water and groundwater. A new structure of incentives and deterrents among water users is established by the Water District through the imposition of the economic deterrent of assessment

against those who overpump, and economic incentive of rebate to those who underpump. The objective of using economic measures is to provide the same structure of incentive and deterrents found in a workable market, such that all groundwater users recognize the full cost of their activities.

The key to the water exchange is, of course, an adequate amount of surface water use facilities in the short run, and in the long run, water users with both ground and surface water facilities. In the implementation of the system, it would be necessary for the Water District to encourage the capital investment in surface water facilities, as the region has primarily relied on groundwater to satisfy water demand. To further this end, the Water District can vary the level of the assessment, such that revenues are provided for the District to subsidize those who, at the request of the District, build capital facilities for and use more water from alternative surface water sources. Alternatively, after adjustment to the new structure of incentives and deterrents, those who can most efficiently convert to surface water, conversely, those who obtain a greater value in use from pumping groundwater, may notify the District, which would distribute the collected assessments appropriately and in relation to its management objectives. In any case, the exchange permits saving the cost of distribution facilities in the long run under this management scheme. Water is largely allocated to its highest valued uses.

The Water District acts in a fiduciary entrepreneur capacity for all groundwater pumpers within its jurisdiction, as an agent to ensure the availability of water supplies through coordination of surface water suppliers, and when necessary, cooperation or direct investment in development and

delivery. In addition, the Water District functions to assure water users within its boundaries that surface water is priced reasonably, fairly and economically, according to applied economic principals which facilitate efficiency in water use and allocation.

IV. A Coastal Water Service Enterprise: Total Water Resources Pooling and Price Allocation

The ultimate extension of the contemporary concept of a collective enterprise for conjunctive management and operation of ground and surface water supplies is compatible with the modern trend of increased public ownership and control of natural resources: vesting in a collective enterprise all groundwater rights, thereby treating groundwater in law what the resource is in fact - the common property of those who own land overlying the aquifers.

The central feature of the following institutional arrangement is total water resources pooling: the merging of community interests into a collective management enterprise for unified control and pooling of regional water resources to control and prevent the common problem of land surface subsidence and to provide an expanding level of water services. Legal problems are foregone in the operation of the enterprise, instead economics is the controlling force. The single owner and seller knows its water supply, and has adequate scope to compute the relevant costs and benefits. As such, the "sole owner" would ensure that groundwater is produced at the socially optimum rate so as to maximize income and forego any external costs associated with inefficient water resource use.[37]

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[37]Sole ownership is rarely encountered in practice, but as a goal for groundwater management and mitigation of commonality problems, it is advocated in contemporary literature (Corker, et al., 1971, 201-211; Murphy, 1970; Swanson, et al., 1976; Johnson, 1971; Renshaw, 1963; see also Scott, 1955). The concept is innovative in its contemporary application to groundwater management, but actually not new: water consumers in metropolitan areas, for example, Houston, take their water from a common water works system, being guaranteed a supply of water, but having no control regarding the source of the water.

It is interesting to note that this contemporary style of groundwater management (collective economic enterprise providing management and water services) is proposed not only for areas where water supply is the immediate

continued

management problem (semi-arid areas, especially California) but where complex spillovers are the greater management concern as well (humid areas). For the forme, see Schiff, ed., 1963 and 1966; for the latter, see Murphy, 1970. The common problem in both cases, however, is maximization of benefits and minimization of costs, both internal and external, in the development and use of groundwater resources through centralized decision making.

The rationale of centralized ownership in natural resources development is also a conservation practice used in the oil and gas industry. Here the common pool problem is presented at its "best". To destroy destructive and inefficient competitive pumping from an oil and gas pool, pumpers unitize, surrendering individual competitive withdrawal rights to a management committee for a fractional share of the ownership of the common oil pool. The pool is then beneficially managed for the owners (see Hirschleifer, et al., 1969, 59-66).

In practice, this management scheme has been used in southern California to halt a serious land subsidence problem due to withdrawal of oil and gas (Steelhammer, 1970, 211; see Poland, et al., 1969).

Organization

A public Water Authority would be created for the dual purposes of conjunctively managing regional groundwater and surface water resources to control and prevent land subsidence, sea water intrusion and other problems, and for providing water service. Its geographical boundaries would encompass those land areas of Harris and Galveston counties, and any other contiguous land areas which may wish to participate or which the Authority, upon petition of the State, deems necessary to effectively accomplish its management objectives.

The Authority would be constituted as a self-governing coporate body politic of the State. A management committee would be established for the purpose of administration and policy making. The making of the committee would be determined by election of representatives of the community under an equitable representative scheme, and likewise by appointment.

In order to reduce the functional fragmentation of surface and groundwater development, supply and use decisions, and to accomplish control of subsidence, the Authority is granted absolute control over all management practices and decisions of all public, water related organizations constituted under the laws of the State. Control may be exercised as joint powers only insofar as it is necessary for fashioning of a conjunctive management and subsidence control program; for purposes of planning, investing and financing surface water works and supply to provide for the satisfaction of water demands of the Authority; and for purposes of effecting efficient groundwater use and for purposes of groundwater management in general.

The Authority would be directly accountable to the water users for which it is supplier, users supplied water service from the Authority would have

legal recourse for failure of the Authority to provide water under the water service contracts.

Property rules

The contemporary management concept of water resources pooling will be conceptually based on the property rule of communal ownership of regional groundwater resources, as adapted to permit commercial water resources operation. As was explained in detail earlier, the communal title is a right of and in common to pump water from the ground without limit as to number of users, subject of course to practical considerations. The title is collective, not individual; incorporeal, not fee simple or absolute. Such a title automatically calls for supervision and control of the common by a public unit of the common in order that the benefits which the right seeks to confer may be equitably enjoyed. Under the communal title, groundwater resources within the subsiding region are legally the common property of the overlying landowners.

A communal title to and public trusteeship of groundwater is of course directly opposed to the present title of absolute ownership. To become operational, to bridge the gap between concept and reality, absolute ownership would be abolished in favor of conveying to a management committee appointed by the collectivity groundwater users legal title to all interests in groundwater resources of the subsiding region (Murphy, 1970). In a sense, ownership would still lie with the collectivity of groundwater users, such that each would be given equitable recognition of what was a valuable contribution to the committee. However, absolute disposition of the resource would be in the hands of the management committee (the community) which would have

absolute control. Upon reception of all property interests in groundwater, the committee would proceed to operate as a collective economics enterprise to manage the common and equitably satisfy the water needs of the community of water users which it represents and acts in behalf of.

Murphy (1970) argues that without such a functional concept of groundwater ownership, "limitations on the use of such property interests (absolute ownership) induces violations, increases costs of enforcement, puts too great a reliance on governmental regulation, and tends to institutionalize a problem without solving it" (68). He argues (65-67) that the new property rule would be beneficial to both the community of interests and management. It would promote "user predictability", "planner flexibility", and would be "sufficiently general to afford common coverage and sufficiently particular in economic usage to make computation of costs and benefits analytically possible." For the collectivity of groundwater users, a limited communal title "would create investment reliability" and "that degree of certainty associated with a well conceived legal title."

While a limited communal title provides the conceptual property rule for "sole ownership", the arrangement can only become functional upon creation of a public water district, to be called Water Authority, in which is vested legal title to all groundwater resources within its boundaries. The legal technique for recognizing valuable contributions of groundwater rights to a central Authority would be the service contract (Corker, et al., 1971, 211) which, in effect, provides to each contributor a legally enforceable right to a supply of water, rather than, and regardless of, a right to a specific source, the contributor being responsible for bearing his fair share of the costs of the water service (Buchwalter, 1970, 43-44; Gindler, 1963, 5; Murphy, 1970; Warne, 1963, 7-8; Dalcini, 1965, 0-5; Ries, 1967).

Ostrom, et al. (1972, 4) explains that "under contractual arrangements, persons may participate in a mutually agreeable arrangement in redefining and altering legal relationships in order to accomplish objectives of mutual interest.

Hence, it is clear that there must be substantial consensus as to the terms of the service contract (see Corker, et al., 1971, 210). The contract must provide for legal and physical access to water, water quality, and water quantity no less than (ideally, greater than) that available under an absolute ownership right. As to quantity, an expanding level of water service must be guaranteed, and therefore the Authority must have the inherent and explicit capacity to meet water demands.

All other factors being satisfactorily negotiated, which seems to be easily accomplished, price or water costs would become the important term of the service contract. Water costs would in most cases increase as externalities are internalized. The Authority must balance its management objectives (no subsidence) against assuring a coincidence of benefits with beneficiaries, again using subsidies and rebates where necessary. Price setting policy must be equitable and clearly defined as it relates to present water supply and cost conditions, and under changing conditions.

Participation in the Authority must be mandatory, in order to reinforce the property rule of a single collective groundwater right and the management concept of "single owner". Dual techniques of condemnation and voluntarism can make "membership" mandatory and complete, the service contract being common in both cases (Murphy, 1970; Hershleifer, et al., 1969, 61).

As related to voluntary conveyance of groundwater rights to the Authority, rights can be acquired by voluntary agreement, or leased by contractual

arrangement (hutchins, 1968, 439). As Murphy (1970) conceives the water management program, coercion, while in some cases necessary, remains the exception. The likelihood of the collectivity of groundwater right holders making voluntary conveyances of their rights to the Authority would depend upon the "political persuasiveness" of the arguments put forth in their favor (Murphy, 1970, 69). In any case, the Authority must convince each that transfer of title would ultimately be beneficial to them, that benefits would ultimately exceed the costs of the transaction. It must be demonstrated that a carefully managed regional water system would provide absolute certainty of water supply which is not available under the present institutional arrangement, or under absolute groundwater rights in particular. It is reasonable to assume that those landowners in shoreland areas throughout the region would readily convey their title as benefits would substantially exceed costs, in the face of reduced groundwater pumpage.

Notwithstanding this impetus, for voluntarism, Swanson, et al. (1976) makes a pervasive argument that a substantial number of landowners would welcome the chance to dispose of their groundwater rights if they are held legally liable for damages sustained by subsidence victims, those experiencing the disproportionate effects of regional groundwater pumping. As explained in an earlier section, two class action lawsuits have been filed and are pending within the subsiding region attempting, in effect, to shift disproportionate collective social costs from "victims" more proportionately to pumpers. If the courts do recognize tort liability,[38] then, for considerable numbers of groundwater users and landowners, it becomes economical to

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[38]The national trend is moving toward allowing recovery for subsidence caused by fluid withdrawals from the ground. See, for example, American Law Institute, Restatement (second) of Torte, Sec. 818 (Tentative draft,-----). See also Teutsch, 1975.

transfer groundwater rights to the Authority in return for immunity, as costs of damage liabilities outweigh the value of owning the groundwater right.

In any case, there will be holdouts, and if they are sufficient in number, or if there be few but large producers, the demise of an efficient and equitable groundwater management scheme is probable. Overt coercion, normally being the exception, becomes the rule in this situation. The Authority would initiate legal action to condemn and take groundwater rights of recalcitrant landowners, providing, of course, just compensation.[39] In essence, condemnation makes participation in the Water Authority among holdouts mandatory. Indeed, the threat of condemnation generally can be expected to be sufficient to indirectly coerce transfer of groundwater property interests to the Authority.

Regardless of whether landowners voluntarily transfer their legal interests in groundwater ownership or lease their rights to the Authority, or whether rights are condemned, all who convey must be given recognition for what is a valuable contribution (Corker, et al., 1971, 213); just compensation must be provided. It is suggested that compensation should be minimized because of the increased value of groundwater owing to a carefully managed and equitably distributed resource (Murphy, 1970). At time of transfer, each would be granted a right to a supply of water, guaranteed by a water service delivery contract, which presents a substantial benefit in itself (Buchwalter, 1970, 45).

For the right to a supply to become operational, Ries (1967) proposes the allowance of a transferable credit which would be used to offset the

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[39] Costs of litigation would vary with the number of rights to be condemned.

cost of water purchased from the Authority under the contract of delivery. The credit would be based on the average quantity of groundwater use (share) during a recent and specified period for each conveyor. The credit would be computed as an annually allowed dollar credit by multiplying the internal, user cost of groundwater per gallon by the amount of the share. This annual credit is charged against the price charged by the Authority for water service, that is, the water user is only required to pay the difference between the total water service charge from the Authority, and the annual credit. As the single seller and sole owner, the Authority can economically and efficiently allocate regional water resources such that costs are minimized and benefits maximized (Murphy, 1970; Ries, 1967).

The contemporary property rule is totally appropriate for urbanized regions, but constitutes a substantial departure from the common law of groundwater which attaches a corporeal property interest in groundwater. The property rules suggested under the previous alternative institutional arrangements are adequate for the institutional systems proposed and are substantially "better" than the absolute ownership property rule. However, they are adequate only insofar as they can be recognized under the present system of Texas law. Ideally they would represent only a limited constraint to the Water Districts' management program so long as the management schemes reasonably equate benefits with beneficiaries.

The problem, however, ultimately relates to the regulation of proprietary interests in groundwater; the Water Districts necessarily must pay careful and close attention to reasonably regulating groundwater rights, even under the exercise of police power. The new property rule, both conceptually as a limited communal title and empirically as a right to a water supply, lays to rest once and for all the precarious dilemma of disturbing private property interests.

Again, property becomes the bases for internalizing externalities for allocating groundwater and surface water resources according to the workings of market forces.

Powers

To control subsidence, conjunctively manage regional water resources, and to provide water service, the Authority would be granted the several powers. The Authority may purchase, lease contract for, and condemn with just compensation, all groundwater rights in order to hold all groundwater rights within or without its jurisdiction. For all water rights received, it would grant a water service credit of equal value. The Authority would provide water service to all who own an annual credit, and, if feasible, to any others within or without its jurisdiction who request it. Water service credits can be applied against water service charges of the Authority. Water service would be provided by guaranteed contracts of delivery. The level of water service would be met within practical means.

The Authority may buy and sell surface water and groundwater, and construct surface water works. It may prescribe, revise and collect fees and charges for its rendered water services, based on the costs of providing the water service. It may levy ad valorem taxes for general administrative expenses, and, in conjunction with its water service charge, for purposes of surface water supply and development finance.

The Authority may sue in its own name for the protection of its (community) property and may be sued for damages caused by its own operations.

It may store, reclaim, treat otherwise purify water in the ground.

The Authority may require the cooperation of all public corporations and authorities when necessary for purposes of subsidence control and conjunctive

water resource management.

Operation

The effect of the institutional arrangement would be creation of a public water service entity, equivalent to a public water utility, engaged in supplying and selling water from controlled water supply sources (Murphy, 1970). The management and subsidence control program would involve total pooling of regional water resources, both ground and surface supplies, stored in surface reservoirs and underground reservoir or both (Warne, 1963). Entitled to a right of supply, water users might be allocated water from surface supplies, groundwater supplies, or a combination of both. Each user might receive the service quantity by direct connection to surface water works whether owned by the Authority or not, or by allowing the water service quantity to be pumped from the ground (Ries, 1967, 85).

The Authority allocates regional water resources according to the workings of a price system. Since the Authority would not wish to produce its own groundwater inefficiently, it will promptly proceed to produce the groundwater resources such that land subsidence is halted, that is, the Authority would directly induce the socially optimum rate of groundwater production. It would therefore substitute that quantity of surface water for the groundwater such that the total value obtained from water resource use can not be increased.

Ideally, the Water Authority would set its water service charge or water price on the basis of the most efficient production mix of surface and groundwater. On the basis of aggregated water supply, its price would be an average of the costs of the most efficient quantity of surface water and

the most efficient quantity of groundwater. Price would be uniform and based on metered sales.

In practice, the Water Authority would need to take account of the substantial disparities among the collectivity of groundwater users in benefits of a no subsidence condition and costs of reducing subsidence. Therefore, the Water Authority must set its water service charge on the basis of its cost of providing service to various areas within its jurisdiction.

In remote areas of the region, the Water Authority's service charge will be largely the same as the customers' credit. In seriously subsiding areas, the service charge will be set so as to generate sufficient revenues to build the necessary surface water works to reduce reliance on groundwater pumping and halt subsidence. Where surface water is readily available, the Water Authority will finance construction of the necessary connections, buy surface water from the surface water seller, and charge users an appropriate price for this service. It can readily be seen that the Water Authority could recognize substantial economies of scale. Where the Water Authority builds centralized surface facilities, serving multiple users, service charges would be on amortized-cost basis, plus the normal, incremental cost to the Authority of providing the water.

To be equitable, however, the Water Authority must recognize that some customers will benefit more than others from an efficient (no subsidence) rate of groundwater production. The Water Authority has complete flexibility in determining who may pump groundwater and who will use surface water. Therefore, even though customers in seriously subsiding coastal areas are paying the costs of surface water use, they may be pumping groundwater, and indirectly "subsidizing" neighbors or others within the seriously subsiding areas for using surface water. In this manner, the Water Authority may recognize the

disparities in real costs and benefits, but these disparities are centrally internalized into the water service charge.

Within the seriously subsiding region, inland customers closest to surface water sources and facilities are largely the ones who normally could not justify converting by comparing total surface water costs with both internal, user costs and external costs of their groundwater pumpage. The water service charge would be computed precisely in the same manner as a pump tax, that is, by determining the quantity and price of surface water required to reduce groundwater pumpage in order to halt subsidence, and spreading this cost among users (customers) in a general area. However, instead of directly subsidizing these customers closest to the surface water source, the Water Authority internally "subsidizes itself" for providing this amount of surface water use, having collected sufficient revenues to do so.

This flexibility is the most important feature of the centralized pricing scheme. Essentially, the Water Authority sets its service charge uniformly within particular but very large areas to achieve management objectives. Surface and groundwater costs are effectively equalized, regardless of the water used. Those that are closest to available or potential surface water facilities are serviced by water from these faciltiies, simply because it is more economical and easier for the Authority to do so, but they are in effect subsidized. The Water District thus produces water conjunctively in the most economical manner while, at the same time, service charges are set in an equitable manner.

In all cases and in all areas, potential water users who do not have an annual credit are required to pay the full amount to the Water Authority for their water service deliveries (Ries, 1967, 85-86). Again, this service charge may or may not differ from the internal, user cost of groundwater

use, rather depending on the area of prospective use.

The Authority would initiate, coordinate, and in any case require cooperation, where necessary, in the development of surface water resources, water works facilities, including treatment plants and delivery systems, appropriate for the control of land subsidence, and in general, when user demands become high enough to pay the costs of the projects. Coordinated water resource investment planning is a requisite to efficient water resources allocation (Johnson, 1971). The Authority would require cooperation among all regional water related organizations in the fashioning of a subsidence control and conjunctive management program, and in standardizing pricing policies and management practices of water organizations.

With new emphasis on efficient water resources use, all public freshwater supply and control districts, as well as water authorities, will be encouraged to help conserve groundwater supplies so as to minimize the costs of dependence on surface water. Indeed, it would behoove all customers with annual credits who are pumping their water service quantity from the ground to conserve since the credit would be more valuable as internal, user pumping costs would decrease.

Since a comprehensive conjunctive management program will be hindered by the numerous independent water districts, the Authority will encourage and assist in the consolidation of special purpose water districts into master districts,[40] either to use groundwater more efficiently, or for pooling to receive and distribute surface water. Surface water could be supplied to nearby cities as well. Master districts would enhance the ability of the Authority to recognize greater economies of scale (see Solomon, 1973).

[40] Vernons Texas Code Annotated, Water Code, Sec. 51.047, provides water districts the opportunity to consolidate into Master Districts.

An overall comprehensive and efficient management program is accomplished by institutionalizing a pricing system developed in the water service arrangement, and by institutionalizing centralized policy making, planning and management. Functional fragmentation of ground and surface water development, supply and use decisions would be mitigated by providing the institutional framework for mutually beneficial planning and cooperation for solving a common problem of subsidence.

V. A Coastal Water District: Water Exchange in a Quasi-Market

Economists argue that groundwater resources are more likely to be allocated to their most valuable use when the right to use is exclusive and that institutional settlements are more likely to result when property rights in groundwater are made definite (Milliman, 1969 and 1965; Meyers, et al., 1971-A).

Previous institutional arrangements were based on property rules of exclusive centralized groundwater ownership, either actual or effective. Such a property rule mitigates the commonality problem of nonexclusive property rights and resulting externalities. Nonexclusivity established an incentive for social cost creation. Collective enterprises were established either to simulate workable market allocation conditions or for directly providing the water at appropriate prices.

The following institutional arrangement is also based on the concept of a property rule of exclusivity, however, it is decentralized rather than centralized. Quotas or proportionate shares of the safe yield of the underground water system are parcelled out to the collectivity of groundwater users, thereby physically internalizing the externality in proportion to contribution to the subsidence problem. An institutional system is structured around the framework provided by the decentralized property rule such that the ordinary, workable mechanism of the market allocates ground and surface water resources. The market is simulated as a water exchange is provided for transfer of shares.

It is argued that the advantages of assignment of quotas are "simplicity and directness"; "commonality of rights" are replaced with "specificity of

shares" (Milliman, 1965, 431; Hirschleifer, 1969, 62).[41]

The organizational arrangement, boundaries, and functional political relationship of this Water District are largely the same as the Water Districts' in institutional arrangements II and III. It is properly conceived of as an enterprise allocating pooled water resources, however the "scale" of enterprise is slightly reduced by the very nature of its arrangement. It is relatively more involved with administrative operation of the management program, and less involved with purposeful economic activity, such as surface water works construction. However, it properly acts as an agent for the collectivity of groundwater users to ensure an expanding level of water supplies to meet water demands of the users within its geographical boundaries.

Powers are also largely the scene as institutional arrangements III, as it may provide for the exchange of water. However, in addition, the Water District may provide for an equitable administrative determination of water shares and quotas, as rights to use groundwater resources within its jurisdiction, to be granted initially on an applicant by applicant basis. It may provide procedures for the transfer of these shares and quotas among persons, public entities and corporations including the establishment of a

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[41] The following institutional arrangement can be recognized as containing elements of theoretical principles, advocated by noted economists and legal scholars, and institutional schemes used in practice for groundwater management. The Raymond, Central, and West groundwater basins in California, for example, have been brought under management systems which are characterized by definite property rights and various market mechanisms which both provide for the transfer of water rights in some manner and ideally limit groundwater production although allowing a certain degree of autonomy and flexibility to users (see Ries, 1967; Buchwalter, 1970; Ostrom, 1965; Krieger, et al., 1962). In any case, this institutional arrangement is based on principles inherent in the market model.

Quotas have been recommended for solving common pool problems characterized by a physical system able to naturally renew its supplies, and where there is an incidence of large spillover costs (Milliman, 1965, 431-2).

centralized water exchange pool where buying and selling of quotas and shares can be facilitated and coordinated. The Water District may also levy pump taxes within the District, and in outlying areas where it can reasonably be demonstrated that such pumping is damaging or causing subsidence of the land surface within the District. Ad valorem taxes on all property within the District are levied to generate revenues sufficient to cover the general administrative and operating expenses of the Water District. Again, it is recognized that the management program benefits all groundwater users, directly or indirectly, within the District.

Property rules

The logical extension of the common law rule recognizing proprietary property interests in groundwater resources underlying the surface of regional land tracts is to make these water rights definite and exclusive. However, a clear definition of the extent of property rights must be particularly adapted to eliminate the common pool problem evidenced by subsidence. To provide a basis for the operation of a workable market mechanism, specification of property rights must provide certainty of tenure, procedures whereby individuals, private and public entities, may secure groundwater rights in areas where groundwater is still available or unowned, and a mechanism for groundwater rights transfer among the collectivity of groundwater users under contractual arrangements of purchase and sale (Milliman, 1965, 287).

To provide for the establishment of these conditions, and at the same time avoiding protracted legal battles of formally adjudicating groundwater rights, an administrative procedure can be initiated to parcel out quotas or pro rata shares, as rights to use a specified annual quantity of groundwater,

rather than rights to own, on an applicant by applicant basis (Clark, 1972, 450). Such an administrative procedure will bring groundwater into the realm of concrete property that could be subject to barter and sale, and will constitute a substantial step toward actually defining groundwater rights and at the same time mitigating commonality problems of nonexclusive ownership (Snyder, 1973, 310).

Conceivably, assignment of shares of current, collective groundwater production can be accomplished on the basis of recent beneficial use or on the basis of overlying acreage (Meyers, et al., 1971-B, 594). In any case, the rule must be that individual holders of groundwater rights must be recognized as interested parties entitled to equitable consideration of their beneficial interests in groundwater. Assignment of shares based on overlying acreage is compatible with the present system of groundwater law which recognizes ownership of the groundwater underlying private or corporate property. However, since the cause of subsidence is collective overuse of groundwater, there must be reasonable relationship between overlying acreage and amount of water used. It is also apparent that the quantity used is determined by the amount captured from the underground water pool. Whether amount captured is related to overlying acreage is difficult to determine, if there is any relationship at all. Assignment of shares inthis manner might result in a disproportionate relationship between amount captured and amount underlying an overlying tract of land. Actually, the relationship between what is used above the surface and what is "owned" below the surface is tenuous at best because of the "fugitive" nature of groundwater.

It is argued that in an industrial or urbanized environment, no necessary distinction can exist between the area of overlying acreage and the amount

of water which may be put to beneficial use on or off the land (Hanks, et al., 1970, 638, Note 73). It is therefore argued that assignment of shares should be based on recent beneficial use rather than acreage (Ibid., and Meyers, et al., 1971-B, 594; Corker, et al., 1971, xxxiii). This rule is realistic because it recognizes that a groundwater right is no more than a right to use underground water.

The result of assignment of shares based on recent use is that each property owner obtains a percentage of aggregated groundwater production within the District's boundaries.[42] In order to physically allocate the externality, that is, reduce aggregate groundwater production to the maximum acceptable withdrawal quantity, production quotas must be allocated among the collectivity of groundwater producers within the District's boundaries, so as to balance use with safe supply.

A proportionality rule operates under a systme of assigning shares of groundwater pumpage based on recent beneficial use (Hirshleifer, et al., 64; Meyers, et al., 1971, 594), such that the avialable or allowed maximum acceptable annual groundwater withdrawal quantity is divided among groundwater users on a pro rata basis.[43] In practice, the Water District computes the maximum acceptable annual groundwater withdrawal quantity for the portions of the underground water system under its geographical jurisdiction.

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[42]Undoubtedly, groundwater users who recently converted to surface water would probably have to be given credit, in the form of a share, for what was a valuable right voluntarily "given up." Indeed, those overlying landowners who have stopped, or are about to stop groundwater pumpage would be glad to find a market for their shares.

[43]If water rights were formally adjudicated in a court of law, the doctrine of "prescription" would probably be applied. "Prescription" means that each party claiming a groundwater right has actually pumped water from beneath other's land tracts openly and adversely. The net effect of "prescription" would be the assignment of shares proportionately (See Ries, 1967).

The basis for allocating this quantity among that collectivity of groundwater users is each groundwater user's percentage share of current collective annual pumpage. Each groundwater user's percentage is applied against this quantity differential resulting in the allocation of the "safe" pumpage quantity proportionately. Thus, shares are reduced to quota rights to use groundwater; overdraft is eliminated; subsidence will be halted in a short period to time. All groundwater users share the costs of reducing land subsidence in proportion to their contribution to the problem.[44]

The prerequisite for an effective allocation of quotas is a complete knowledge of the hydrology of the underground water system, including the maximum acceptable withdrawal rate (Krieger, et al., 1962, 61). Matters would be greatly simplified if the entire groundwater system was overdrawn. However, hydrological studies have indicated that only localized areas of the aquifers are overdrawn, while others are relatively full (Jorgensen, 1975). Since subsidence is a localized problem, quotas must be allocated equitably, in proportion to the contribution to the problem, based on best, although somewhat arbitrary, approximations.

Thus, a property rule of exclusive quota rights to use groundwater provides a simple and direct institutional method for destroying a central aspect of the commonality problem evidenced by subsidence and subsidence related costs--non-exclusive ownership of groundwater. However, such a

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[44]Assigning quota rights is analogous to levying a pump tax on groundwater withdrawals based on proportionate contribution to external costs associated with subsidence. While the pump tax operates on the "demand" side, the quota rights operate on the "supply" side based on proportionate contribution to the physical overdraft of the underground water system. However, both physical rationing and economic value rationing are alternative institutional methods for allocating the subsidence externality.

property rule only answers how the resource is divided and allocated among users and claimants. It does not indicate how owners of quota shares may meet displaced demands for water. Therefore, quotas will be allowed to be exchanged, and ground and surface water resources will be efficiently allocated through a centralized water exchange operated by the Water District. The exchange presents an opportunity for both public control and simulation of a workable economic market.

Decision Rules and Operation

Exclusive property rights, economic forces and public regulation are the idealized and essential elements for institutionalizing a quasi market system for efficient water resource allocation (Trelease, 1965). Property rights in groundwater are important because they enable groundwater to be valued as a commodity responsive and subject to economic forces (Harrison, et al., 1971, 20; Flint, 1968, 569). Without a basis for transfer or exchange, "water becomes literally frozen to a particular price of land and to a particular use of water, even though the value of water on alternative lands and in alternative uses might be greater" (Milliman, 1969, 51; also Trelease, 1965). Specifying property rights and providing a means for their transfer, however, is not sufficient because persons are still at liberty to impose costs on third parties without compensation. External decision-making structures are necessary to prevent damaging effects to third parties who are not involved in an exchange transaction (Trelease, 1965).

Ideally, property rights in groundwater would be made definite by parceling out freely transferable quotas, subject to free exchange according to economic forces of supply and demand. Public regulation would operate

on the fringes of the system to protect and preserve the public interest.

While the idealized institutional system is simple, direct and efficient in theory, it must be adapted to the contemporary conditions and problems of a largely urbanized and industrialized environment using scarce water resources from a complex hydrological system. The prerequisites for contemporary adaptation of the transferable quota system requires greater public management: to provide for an expanding level of water supplies to those whose demands are partially displaced from groundwater resources; and generally for continuing public management interest to ensure effective and equitable solutions to contemporary water resource problems (Krieger, et al., 1962, 61; Buchwalter, 1970, 29). Therefore, the Water District will engage in the necessary entrepreneurial economic activity, acting as an agent in behalf of the collectivity of water users, planning for and providing when necessary an expanding level of water supply while controlling land subsidence.

The basic feature of this institutional arrangement is the simulation of a workable market so that groundwater is allocated to those who need it. The collectivity of groundwater users will be allowed to adjust to a pattern of regional water resources use which is efficient and able to reflect the most valuable use of groundwater resources (Burt, 1966).

A water exchange is institutionalized to assist in the transfer of quaotas. Normally, if the system were to operate under free market conditions, quotas would be transferred in such a manner that those who could not afford to convert to surface water to meet their displaced demand for water would seek to buy or otherwise acquire quotas from others who could

convert to surface water more easily. However, exchanging quotas in this manner "would involve costs for both buyers and sellers of searching out, negotiating and enforcing mutually beneficial exchange opportunities." It is anticipated that these costs would be high, as a market for water rights has heretofore been nonexistent. In any case, exchange would not result unless the difference between the value of the exchange exceeded the costs involved in making the exchange (Meyers, et al., 1971-B, 50).

A water exchange provides a centralized forum for buying and selling quotas, that is, for efficiently allocating ground and surface water resources.[45] It provides a procedure whereby demand for water in excess of quota rights can be met by each groundwater pumper, by allowing pumpers without access or direct connections to surface water works to annually purchase the additional water they need to meet their demands from those with surface water facilities or who can switch to surface water supplies more economically.

On an annual basis, each groundwater user without easy access to surface water or without surface water connections registers his demand for water beyond his quota right with the Water District, which operates the water exchange. Users having alternative surface water supplies available to them release all or part of their quota right, which includes their asking price, to the Water District.[46] The upper most limit on such an asking price

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[45] A very detailed description of a water exchange pool in operation is found in Sax, 1968, 477-489. For an excellent analysis and account of the political and economic forces leading that particular community to adapt and formulate such a groundwater management syste, see Ostrom, 1965; also Ostrom, et al., 1972.

[46] It might be necessary for the Water District to remind individuals that a surface water supply is available to them, especially when demand for exchange water exceeds that offered as supply.

would be set by the alternative cost of surface water plus construction of surface water facilities, which will involve either connections to a potable surface supply, or connections plus treatment facilities for raw surface water. The price in any case will be a function of the quantity and quality of surface water needed.

A market like structure is developed within the exchange pool as the Water District matches supply and demand by leasing quota rights to pump from suppliers to those who demand water beyond their allowed quota right. An economic market is simulated as follows:

> "The (Water) District releases water to the exchange pool starting with the lowest price asked and proceeding upward until the requests for water are fulfilled. Purchasers of exchange pool water pay a uniform price established by computing a weighted average for the water received. The revenues received by the (Water) District are then paid to the offering parties in an amount equal to the quantity of water released multiplied by their asking price. Buyers thus pay a uniform price, while sellers received their asking price up to the quantity of water purchased" (Ostrom, 1965, 339-340; see also Valentine, 1964, 102).

It thus can be seen that users who convert to surface water are subsidized by those who cannot. Also, those without access to surface water supplies can withdraw groundwater in excess of their quotas, not only permitting every groundwater user to survive such that economic growth is sustained but also permitting the costs and benefits of a conjunctive use system to be allocated equitably; the question of who should bear the costs of using the alternative surface supply is resolved (Buchwalter, 1970, 24-25). In addition, individuals with quotas are allowed to pump a "safe" amount of groundwater at the cheap price up to the allowed limit set by the quantity of the quota.

Potential users who do not have quotas have three alternatives: (1) a quota may be granted to an applicant if the applicant purchases and

retires existing quotas of equal quantity to compensate for the effects a new use would have on groundwater and land elevation levels; (2) a quota may simply be bought either directly through outright annual purchase or indirectly through renting annually from the exchange pool; and (3) he may bear the burden of purchasing surface water outright and directly if no quotas are available. The latter approach recognizes that there is some equity in allowing those who own quotas in over drafted areas to obtain the right to possess the property first (Buchwalter, 1970, 38). In areas of the District not overdrafted, quotas can be parceled out on an applicant by applicant basis, until the safe groundwater pumpage quantity is reached. Thereafter, resort would have to be made to the three alternatives listed above.

The exchange pool would necessarily be used only by these water users whose shares have been reduced to quotas or who do not have quotas but who wish to extract groundwater in an "overdrafted" area. Those whose shares and quota quantities are equal would look to the exchange pool for future "excess" demand, or would find more economical methods of obtaining water, such as by recycling or curtailing waste by increasing efficiency.

However, there are some areas within the District where the aquifer is relatively full, and where groundwater supply is in excess of aggregated shares. While it would seem at first glance to be equitable to allow owners of shares to increase pumpage beyond their shares in these areas, conceivably a situation would be created such that these users would pump more water than was needed to increase their share quantity, and eventually, when the groundwater resources become fully committed, their share would represent a higher quantity than would normally be the case. This situation could

be dealt with by a number of methods, such as prescribing prohibitions against pumping more than is needed, by attaching an "escalator clause" on the share to provide for conservative annual incremental pumpage increases, or, most effectively and equitably, by the imposition of a tax on groundwater pumped in excess of the quantity specified in the original computation of the share, to be discontinued when the "safe" supply quantity is reached. Revenues from such a tax, which would be set equal to the cost of surface water, could be held in a general fund to be used to finance surface water if and where it is needed in that area, or for other purposes. Gradually, as the safe supply of groundwater resources becomes committed, demand would be met through the exchange pool.

In any case, one can envision special cases where the Water District may have to allow certain users to pump groundwater in excess of their quota when undue hardship would result if pumpage were to be required to be held at the quantity specified by the quota. These cases might best be dealt with by the imposition of a nominal pump tax on water pumped in excess of quotas. This revenue could be used to finance surface water facilities, such as treatment plants, to be constructed by the Water District itself, or, ideally, could be used to pay subsidence victims for past damages sustained.

The Water District functions to grant quota rights, operate the Water exchange in such a manner to equate demand with "safe" supply, and as an entrepreneur, an agent for the collectivity of groundwater users to ensure an expanding level of water supplies for the region. It thus fashions a subsidence control and surface water delivery program by requiring coordination and cooperation, when necessary, among other regional water organizations

in the planning of water deliveries to meet future demand. Most importantly, it would seek to standardize the prices charged for surface water where possible and justified, to guard against price discrimination and to ensure that conjunctive management does not become a vehicle for surface water suppliers to reduce incurred financial burdens by selling or providing more surface water than is absolutely necessary to halt subsidence and meet demand.

Comparison of Alternative Institutional Arrangements

This study has developed and examined alternative institutional arrangements for effective groundwater management to halt land subsidence. These arrangements have combined basic institutional techniques for eliminating commonality problems in the use of groundwater resources. Conceivably, other arrangements could be institutionalized, however, they would simply be slight modifications of the basic arrangements presented herein. For example, quota rights to use groundwater could be parceled out as in Arrangement V, and pump taxes (Arrangement II) could be levied on pumpage in excess of quota rights; revenues obtained could be used to subsidize surface water use. Other arrangements could be developed in a like manner. However, the arrangements suggested in this study can serve as analytical alternatives which decisionmakers within the subsiding region could consider and modify if deemed appropriate. Ideally, this study will stimulate thought among regional interests relevant to implementing institutional alternatives which were foregone.

To facilitate comparison of the alternative institutional arrangements developed herein, a summary evaluation matrix is presented in Figure 3. Each arrangement is described in terms of its organizational nature, property rules and nature and method of water resource allocation, respectively; each arrangement is evaluated in terms of criteria, which are strengths of institutional arrangements for subsidence control and conjunctive water resource management. Qualitative values are assigned to each criteria for each institutional arrangement, which indicate to what degree the arrangement is strong according to each criteria. That is, whether the inherent capability of each institutional arrangement to meet the criterion is

High (H), Moderate (M), Low (L) or unclear (U). These subjective evaluations are based on extensive arguments found in the literature cited and judgment of the authors.

The optimal institutional arrangement would display high capability in the entire set of 14 "strong points." The rule for using the matrix is that only those institutional arrangements are desirable and could be chosen where the costs associated with institutional failure or weakness are minimized. Institutional strengths and weaknesses are indicated by the degree to which criteria, in the aggregate, are maximized or minimized, respectively.

The implications of this report seem clear. Only when institutional arrangments are restrictured so as to modify or replace those basic institutional elements which allow a commonality problem evidenced by land subsidence to arise can costs associated with institutional weakness or failure be kept to a minimum. If these elements are not directly dealt with, the problem in effect becomes institutionalized without really solving it, and the social costs associated with institutional weakness can be expected to become increasingly evident in the future.

Figure 3. Summary, Evaluation and Comparison of Alternative Institutional Arrangements

Institutional Arrangement / Criteria	I	II	III	IV	V
	Subsidence Control District; preserves absolute but non-exclusive ownership of groundwater pumpage using conventional administrative decision rules	Water District Groundwater treated as common property of District: water rights being rights to use reasonably; water is conjunctively managed; Water use controlled according to economic incentives of taxation and subsidy.	Water District Groundwater treated as common property of District: water rights being rights to use reasonably; water is pooled and managed conjunctively: water use controlled by economic inducements, allocated by water exchange	Water Authority; control over surface water, sole owner of all groundwater; water right is right to a supply, provided by Authority; water use and allocation by price.	Water District water is conjunctively managed: water rights are exclusive, spedific and transferable; water allocated by a stimulated, centralized water, exchange market.
1. Technical Feasibility	M	M	M	M	M
2. Economic Feasibility	L	H	H	H	M
3. Financial Feasibility	H	H	H	H	H

Figure 3 (cont.) Summary, Evaluation and Comparison Matrix, cont.

Institutional Arrangement / Criteria	I	II	III	IV	V
4. Legal Feasibility	U	U	U	U	U
5. Political Feasibility	M	H	M	H	M
6. Capacity to Regulate Events	M	H	H	H	H
7. Capacity for Political Negotiation and Coordination	M	H	H	H	H
8. Accountability to Community of Interests	H	H	H	H	H
9. Flexibility	M	H	H	H	H
10. Police Cost Maximization	L	H	H	H	M
11. Social Welfare Maximization	M	H	M	H	M

Figure 3 (cont.) Summary, Evaluation and Comparison Matrix, cont.

Institutional Arrangement / Criteria	I	II	III	IV	V
12. Efficiency	L	H	H	H	H
13. Equity	L	H	M	H	M
14. Certainty	M	H	H	H	H

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