Managing Common Groundwater Resources
The Case of the Netherlands

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Introduction

When people talk about the loss of biodiversity, they usually associate this phenomenon with the tropics in general and with the tropical rainforest in particular. However, highly industrialized societies may be affected as well. The Netherlands is a case in point.
The Netherlands has an abundance of water. Wide rivers, lakes, canals, and streams are found throughout the country. Indeed, there does not seem to be any obvious lack of water. Yet appearances can be deceptive. The land is under threat of desiccation. In numerous places, the water table is falling. And this has been going on for decades.
Due to this process of desiccation, fewer water-dependent ecosystems are able to survive, while the quality of those that remain is steadily declining. Of more than 1400 plant species native to the Netherlands, 400 have disappeared or been drastically diminished in this century alone. The country's characteristic ecosystems such as heath, peat bogs, artesian woodlands, and stream valleys are declining rapidly.
The country's wildlife is also subject to the negative effects of a lower water table. Various species of fish, reptiles, amphibians, and water-borne invertebrates are threatened when bogs, ponds, and streams dry up. Many insects, such as butterflies, depend upon plant species that are susceptible to dehydration. These insects are thus also threatened with extinction.

The loss of biodiversity through desiccation is a relatively recent phenomenon in the Netherlands. The process got started in the early 1950s. Since then, the water table has dropped by an average of 25 to 30 cm. In some places where groundwater has been withdrawn, the water table is now a meter or more deeper below the surface than previously.

The falling water table in the Netherlands has nothing to do with an incidental dry spell, which is often the case in other countries. Rather, we are looking at a structural lowering of the water table due to human intervention.

This article explores the loss of biodiversity in terms of human interventions. We highlight how this process is related to human activities that affect the water table. At the same time, we suggest ways to approach this problem and perhaps to solve it.

We perceive the problem as one of "common pool resources" (CPR). This perspective seems appropriate, since groundwater can be classified as a renewable common natural resource. In view of its limited capacity for regeneration, groundwater is a natural resource for which the exploitation should be regulated.

The capacity for regeneration of this resource has been stretched to its limits for decades. The natural recharge of groundwater in the Netherlands is smaller than the amount used. This does not pose an immediate problem to the active interests such as the water supply companies, industry, and agriculture. For these users, the shortage is not acute.

We are dealing with a special CPR problem. It is special in the sense that exploitation of this resource is considered detrimental to the passive interests. In other words, the problem lies in the negative impact on nature.

In order to preserve and restore biodiversity, a policy has been formulated with reference to the CPR groundwater. Groundwater is considered to be a scarce commodity because of its critical role in conservation. Recognition of this passive, immaterial interest prompts the active interests to adapt their behavior.

The groundwater situation

There is groundwater everywhere in the Netherlands. Of course, we must differentiate between shallow and deep groundwater.

The shallow (or phreatic) groundwater lies close to the surface. It creates the conditions for the development of crops and ecosystems. It also determines the rigidity of the soil.

The deeper groundwater provides households, industry, and agriculture with most of its water. Deep groundwater occurs in systems. Depending on their size, these may be called local, sub-regional, or regional groundwater systems. Such systems are mostly nested within each other underground.

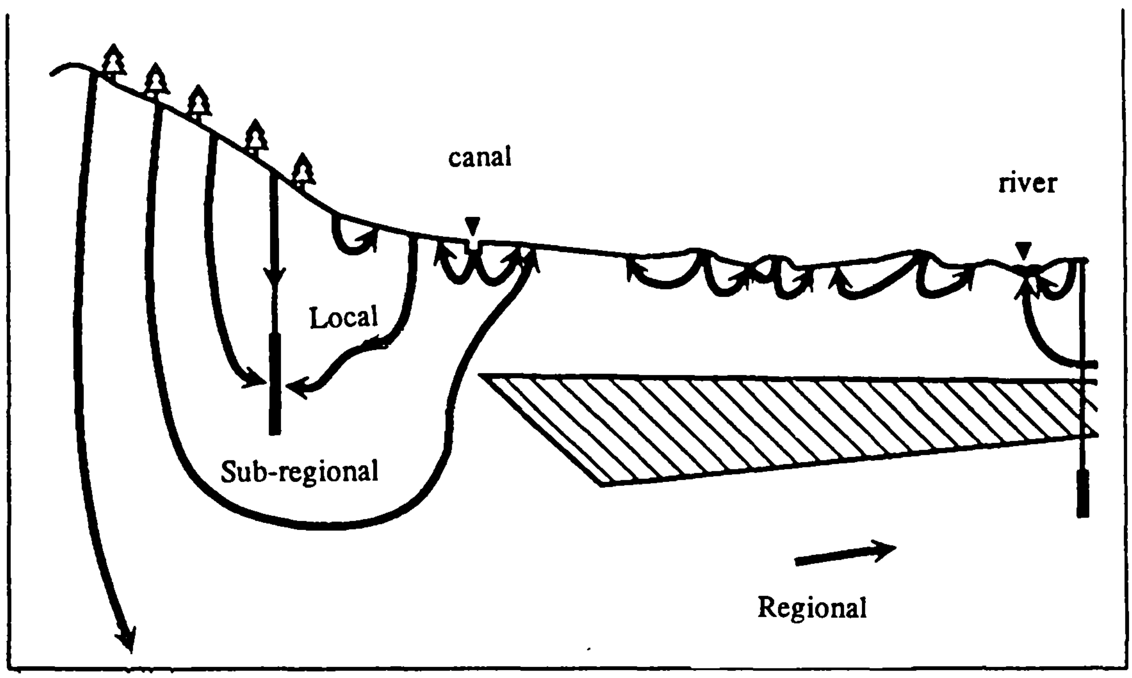


Figure 1. Model of groundwater systems

In many areas, a reciprocal relationship exists between deep and phreatic groundwater. The interaction consists of upward seepage or infiltration/lateral filtration. Groundwater also interacts with surface water. Excess water can be removed in the form of surface water, while a supply of surface water can replenish a water shortage.

Intervention in the water balance also has another effect. For instance, a change in the deep groundwater often influences the water balance of phreatic groundwater and surface water. Vice versa, a change in the water balance at or just below the surface affects the deep groundwater.

The total supply of fresh groundwater in the Netherlands is relatively large. Estimates range from 500 to 1000 billion cu.m. The annual recharge of groundwater ranges from three to ten billion cu.m., depending on meterological conditions. The average is 5.8 billion cu.m. per year.

Considerably less groundwater is available for exploitation. For instance, the geohydrological characteristics of the groundwater reservoirs may not be optimal for extraction. Furthermore, the quality may not match the intended use. Extraction may also have undesirable effects on the water table, on its flow, and/or on its quality.

The amount that can be extracted is thus related to the groundwater reservoir, the location of the pumping station, and the surroundings of the installation. Several variables are taken into account to determine the feasibility of exploitation. These include the geohydrological conditions, the risk of silting, and the chance of damage to other interests. On the basis of these variables, the total extractable amount of groundwater is estimated to be 1940 cu.m. per year. This is a very rough estimate, however.

In relation to the groundwater, the main threat to the ecosystems and the landscape is desiccation. An area is considered to be desiccated when the water table is too low to perform its function in nature.

The phenomenon of desiccation

When can we actually say that desiccation is taking place? Various definitions are possible. Here, we use the definition that is relevant from a policy standpoint, one that is also used in Dutch government policy.

In this definition, desiccation includes "all effects of a lowering of the water table, not only those that occur as a consequence of a lack of moisture but also those that are due to mineralization, change in the upward seepage, or change in precipitation." A further differentiation can be made between hydrological desiccation and ecological desiccation.

Hydrological desiccation refers to the abiotic effects of intervention in the water balance. These may be divided into direct and indirect effects. The direct effect of desiccation is insufficient moisture, due to a structurally lower water table. For this reason, less water is available for the vegetation. This shortage makes plants amenable to growth disorders. Moreover, surface waters can dry up, leading to major changes in the landscape.

The lowering of the water table causes a number of side effects. First of all, it may reduce the upward seepage in an area or even reverse the process, turning it into lateral filtration. In this way, the moisture balance is disrupted. This, in turn, may lead to critical changes in water quality. Thus, ecosystems that are dependent upon nutrient-poor water from upward seepage might disappear.

Secondly, the oxygen content in the soil could rise. This accelerates the decomposition of organic matter, causing the nutrient content of the soil to increase (mineralization). Moreover, both the acidity and the temperature of the soil would change. In this way, lowering the water table affects the quality of the groundwater.

The phenomenon of hydrological desiccation also encompasses supplementation by water from elsewhere in an attempt to compensate for moisture deficits. The quality of such exogenous water is often so poor that an area's characteristic vegetation suffers under this measure.

Box 1. *Desiccation of the Naardermeer*

We can say that desiccation is taking place when the water table can only be sustained by supplementing the groundwater with exogenous water that is detrimental to the vegetation. This has occurred in the Netherlands' first protected nature area: the Naardermeer.

The Naardermeer nature preserve is surrounded by polders. Beyond these low-lying polders, the land is higher and sandy. Originally, the water in the nature preserve came from these higher sandy soils. There, the rainwater seeps directly into the soil. Then, the water flows underground and filters laterally toward the nature preserve. At that point, this water comes to the surface.

Over the years, more and more groundwater has been extracted from the higher area to provide drinking water. In the meantime, local industries used increasing amounts of groundwater. Furthermore, the water level in the polders surrounding the Naardermeer was lowered to serve the needs of agriculture.

Because of these human interventions in the system, the flow of groundwater in the direction of the nature preserve -- the artesian flow -- ceased. Now, in order to maintain the water level in the nature preserve, exogenous water is introduced, diverted from a river in the vicinity. However, this water is highly contaminated. Among other pollutants, it contains an overabundance of phosphorous and nitrogen. This causes a prolific algal bloom. Sunlight does not penetrate deeply enough anymore, so the water plants die off.

The notion of ecological desiccation refers to the degradation of an ecosystem as a result of hydrological desiccation. In other words, when the abiotic conditions are altered, the result is a series of biotic changes. A policy has been formulated to tackle the problem of desiccation. In order to prevent these biotic changes, this policy focuses on creating favorable abiotic conditions.

Interests related to groundwater

After the Second World War, the nation's energies were funnelled into the reconstruction of the economy. The productivity of industry and agriculture had to be raised drastically. For decades, this goal was pursued through large-scale hydraulic engineering projects to improve run-off and drainage.

These measures were successful in increasing agricultural production. The precipitation that falls in the winter could be pumped away in the spring much more quickly. Consequently, the livestock could be put out to pasture sooner, the land would warm up faster, the crops could start to grow earlier, and the farmer could get heavy equipment out on the fields earlier in the year.

The harvests then became more abundant, raising agricultural productivity. However, this was accompanied by a decline in the water table. Meanwhile, farmers have also used groundwater to irrigate and inundate their land. The amount of groundwater that is extracted each year for this purpose is estimated at 150 to 200 million cu.m.

It is not only agricultural activities that have led to a lower water table. Industry and households also exert an increasing demand for water as a coolant and for drinking water. Because this is largely derived from groundwater, both industry and residential use have contributed to the lowering of the table, and continue to do so.

Industry has carried out its own groundwater extraction. After a peak in the early 1970s, withdrawals declined to cover 27% of their needs. From 433 million cu.m. in 1976, their production had dropped to 318 cu.m. ten years later.

Industry also uses piped water (which is provided by the public waterworks). This use has also declined. From 200 million cu.m. in 1976, it had dropped to 190 million cu.m. in a decade. The percentage of that water that was used exclusively or partially as a coolant remained the same at 27%.

Groundwater is mainly extracted for the provision of drinking water. Two-thirds of the content of drinking water in the Netherlands is derived from groundwater.

According to the figures for 1990, the Netherlands uses over 1200 million cu.m. of piped water annually. In 1950, only half that amount was used. If no measures are taken, the use of piped water will probably increase by at least 60% between now and the year 2020.

Figure 2 gives an overview of the amount and location of groundwater extraction in the Netherlands. This diagram shows that these activities are spread throughout the entire country.

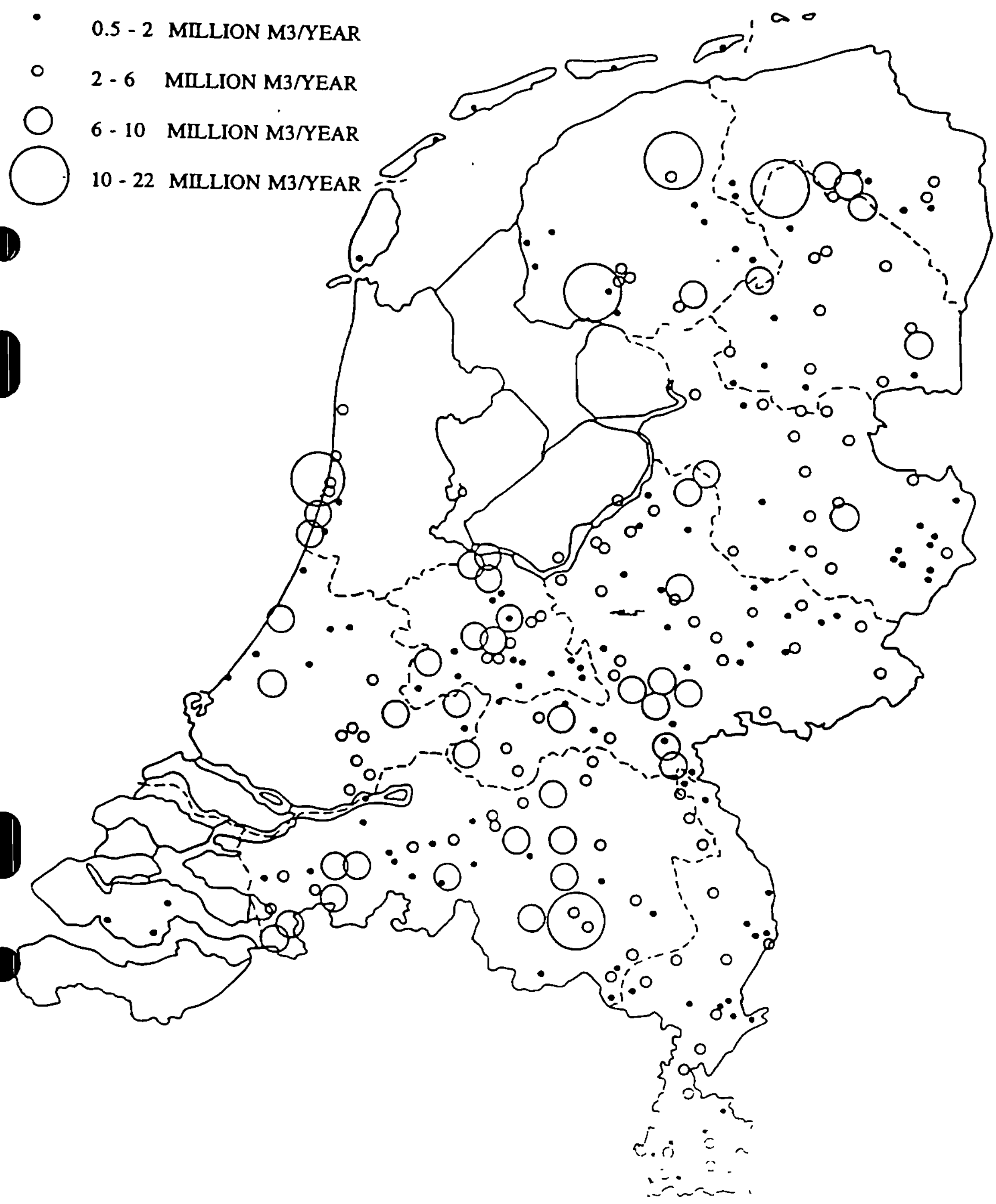
Besides the high volume of groundwater used by industry, households, and agriculture, urban growth has also exacerbated the process of desiccation. To prevent dampness in dwellings, a drainage system is usually installed when the land is prepared for building. However, this lowers the water table significantly.

In addition, the construction of roads and industrial sites in urban areas also affects the groundwater reserves. Rain water runs off the roads and is collected in the storm sewers. Rain water that falls on industrial estates is collected in separate drainage systems. In both instances, that water flows directly into the sewers instead of seeping into the soil.

Box 2. Relative contributions to desiccation

The contribution made by each of the variables to the problem of desiccation is only partially understood. It is estimated that 17 to 25% of the ecological degradation is caused by the increased extraction of groundwater for the provision of drinking water and for industrial purposes. The drainage and irrigation of arable land probably account for most of the remainder. These estimates represent average amounts. In individual places, the situation may be quite different, particularly where large-scale extraction occurs for the provision of drinking water.

Figure 2. Amount and location of groundwater extractions in the Netherlands



Source: Project team dessication (1989). Dessication of nature and landscape in the Netherlands.

The users described above may be counted among the active interests. Alongside these, we can also distinguish passive interests. Agriculture, for instance, is a passive interest to the extent that it suffers from desiccation. The total surface of arable land that has incurred damage due to desiccation is estimated at 40,000 to 50,000 ha. The average loss of income varies from a few percent to a maximum of ten percent.

Forestry also incurs damage due to desiccation. Most of the Dutch forests are managed to serve multiple aims: timber production, recreation, and nature. The vitality of the forests is declining rapidly. During the period 1984-1988, the percentage of deteriorating and degraded forests rose from five to thirty percent. Of course, other factors are at play too, particularly acid rain.

The most damage is incurred in the nature, however. There, plant species are disappearing and aquatic biotopes are being destroyed. The scope of the problem is demonstrated by the types of vegetation that depend upon humid or wet conditions. Of these types, 80% are currently in moderate to acute jeopardy. The total surface of nature preserve land that has become desiccated is about 424,000 ha.

Figure 3 gives an overview of desiccated areas.

Besides the active and passive interests, we may also distinguish a strategic interest in groundwater systems. A crucial characteristic of groundwater is that it is not highly sensitive to contamination. Groundwater has a fairly consistent quality, which is hardly affected by environmental disasters or accidents. Whereas groundwater can still be used under such conditions, surface water may become unsuitable for the preparation of drinking water. It is thus imperative to protect strategic reserves of groundwater.

Groundwater management as a distributive issue

The above discussion leads us to conclude that groundwater is rapidly becoming a scarce commodity in the Netherlands. On the one hand, nature has a greater need for groundwater (to ameliorate desiccation), while agriculture, industry, and the waterworks exert an increasing demand too. On the other hand, the supply is limited.

There are no possibilities to expand the supply of groundwater. This implies that for each area, a maximum must be set on the amount of groundwater that may be withdrawn. This ceiling should take into account the ecological value of the area.

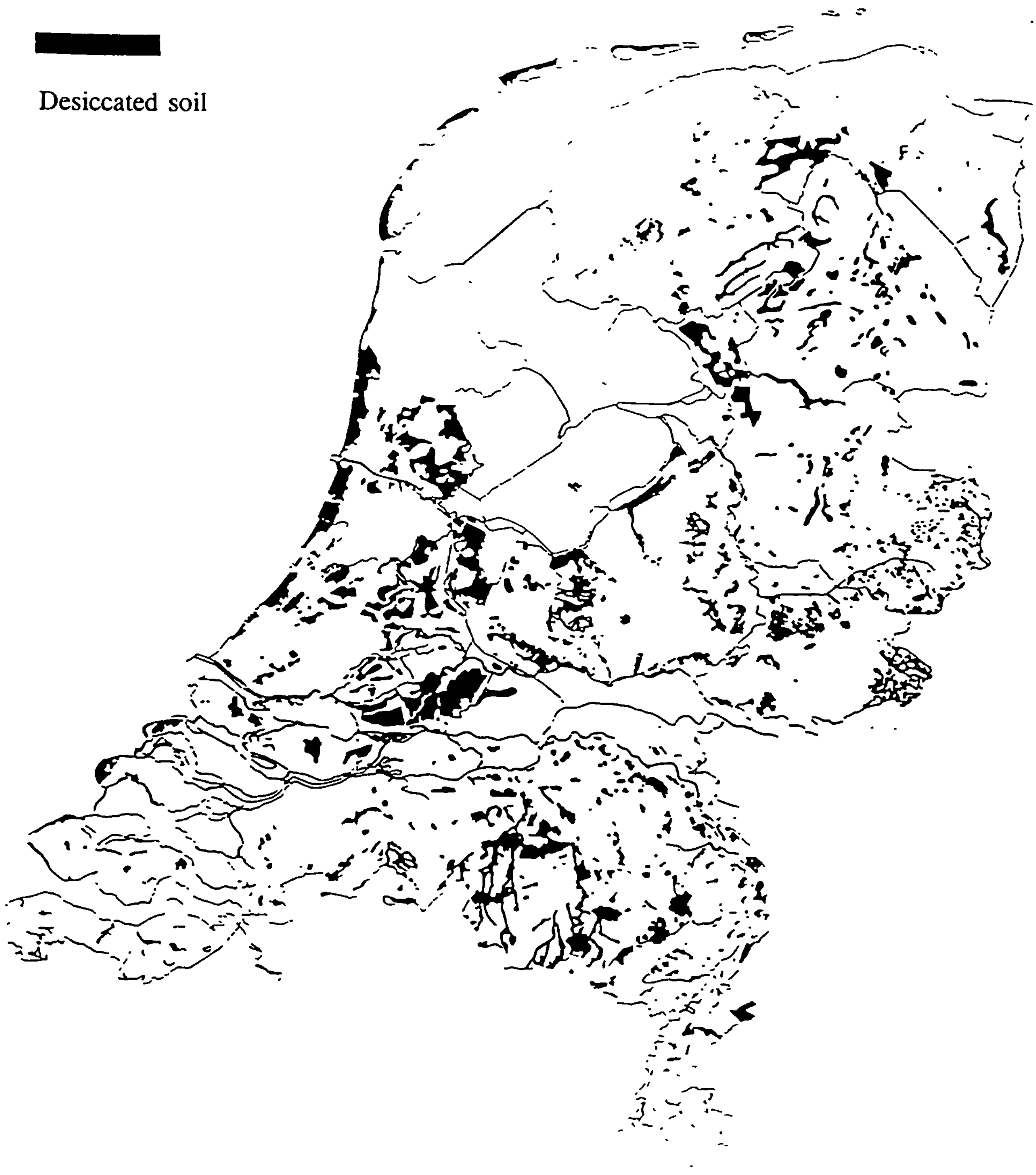
We are dealing with a distributive issue. Classical management systems such as private control or self-organization are not suitable ways to achieve the desired distribution.

Private control, in the sense of the freedom of an individual to utilize a resource, lies at the core of the present problems. Its role in creating the problem indicates that it is futile to seek a solution in this direction.

But there are technical problems as well. These are related to the characteristics of the resource. Groundwater reserves are connected underground. Thus, it is difficult to assign ownership rights to this resource.

In principle, each landowner can tap into the same supply from his/her own property. Thus, the number of potential users of the resource is extremely high. They will surely compete with each other for its exploitation.

Figure 3. Desiccated nature preserves



Source: Project team desiccation (1989) Desiccation of nature and landscape in the Netherlands.

Piped water is more expensive than groundwater. Therefore, all these users, driven by economic motives, might feel compelled to use a high volume of groundwater. This will certainly occur unless the costs of compensation for ecological degradation are factored into the price of groundwater. Of course, to do so would presume a form of government intervention.

Furthermore, a system of private ownership can have undesirable social repercussions. This occurs when the owners of the groundwater supply exploit the resource for their own commercial interests. But a system of self-organized management is not ideal either to accomplish an equitable distribution of the resource.

Certain characteristics of the resource must be present if a system of self-organized management is to be successful. First of all, the resource must be small and it must be possible to delimit it clearly. Secondly, the number of users must not be too large. In fact, these characteristics do not apply to the resource of groundwater. The boundaries of the resource are vague and widespread, and the number of users is large.

In principle, the passive interest of nature conservation can be served either locally or regionally. But a national effort will always be necessary too. At an even higher level, it should be determined where it is necessary to protect nature, in view of the ecological significance of nature from an (inter)national perspective.

In the Netherlands, the limitations of each of these management systems have been recognized. The system that has been developed for the distribution of groundwater is based on intervention by the state. The foundations of that management system may be described as follows.

Groundwater that lies underground is common property. As soon as that groundwater is pumped out by a landowner, it becomes his/her property. However, the state is increasingly restricting the use of that property.

The regime of groundwater management

By the end of the 1970s, nature organizations started to draw attention to the problem of desiccation. Research was conducted here and there. The results were disturbing. In the 1980s, the government acknowledged that desiccation was a problem. Since then, the systematic research effort has been intensified. Tentative policy aims were formulated in the Third Memorandum on Water Management. These aims were further specified in 1994.

The ultimate goal of government policy is conservation. The groundwater situation should be managed in such a way that a sustainable use of groundwater by sectors with an interest in this resource will be guaranteed. At the same time, a sustainable development of nature, forest, and landscape must be ensured as well.

An interim goal of the government policy concerns the targets to be met by the year 2000. By then, the surface of desiccated land has to be 25% less than in 1985.

In order to achieve these goals, a regime has been developed. In this section, we will analyze that regime in terms of the opportunities it creates for management of the variables that are crucial to the desiccation process. In this analysis, we focus our attention on the legal options that are available.

Many of the legal options are actually instruments of the central government that are implemented at the regional level. But the regime also includes a regionally oriented project approach. This was developed later, to supplement the legal approach. These rehabilitation projects will be discussed in the next section.

With regard to the crucial variables that affect the efforts to combat desiccation, we should distinguish between deep and shallow (phreatic) groundwater. This distinction corresponds with a different use of these resources. Deep groundwater is pumped out and put to commercial use. Shallow groundwater, in contrast, forms an obstacle to commercial activities. In order to raise the productivity of the lands, the shallow groundwater will have to be removed from many places.

Box 3. Relevant fields of policy

The complexity of the management issue can also be expressed in a typology of the fields of policy that affect the development of the regime.

a) *The water management policy. This affects the regime because attempts to combat desiccation require interventions in water systems.*

b) *The nature policy. This policy formulates the framework for the (negative) evaluation of the observed effects.*

c) *The physical planning policy. This is significant because amelioration of desiccation is often accompanied by redistribution of the use of space.*

d) *The environmental policy. This is significant because attempts to restore ecosystems presume the creation of favorable environmental conditions.*

e) *The physical structuring of an area. In this framework, a substantial contribution can be made to reversing the process of desiccation.*

f) *The provision of drinking water and industrial water. The plans for this sector will have to harmonize the deployment of means of production with the aim of curtailing the progress of desiccation.*

g) *The agricultural policy. Attempts to redress the effects of desiccation require raising the water level. This, in turn, has effects on productivity.*

Deep groundwater

Deep groundwater is a valuable natural resource that people withdraw from the soil. This water can be used for many purposes because it is pure and has a constant, low temperature. The main users are the waterworks, where drinking water is prepared, and industry. These users will have to compete for exploitation of this resource as it becomes more scarce.

This competition provided groundwater management with a lever to intervene in the process of desiccation. The most important instrument is the Groundwater Act (1981). For a long time, this was the only instrument that offered any hope of dealing with the problem. The law provides a framework for weighing the interests that are involved in groundwater extraction. The law prohibits the withdrawal of deep groundwater without a permit.

Groundwater management as outlined in the Groundwater Act is delegated to the provincial authorities. Any conflicts of interest that arise will be manifest at the regional level. Therefore, such conflicts should be resolved at that level as well. The provinces grant extraction permits on the basis of groundwater plans in which the interests (including ecological interests) are in principle taken into account. In practice, however, this proves to be difficult. More attention for desiccation would have repercussions on local policy. It would lead to the reduction, cessation, or compensation of groundwater withdrawals.

With reference to groundwater extraction for the provision of drinking water, this is not a realistic option in the short term. Various fundamental factors make it unfeasible.

For one thing, the use of drinking water is virtually impossible to influence. Water-saving behavior can only be influenced through information campaigns and financial incentives. Even then, the effect is minimal. In light of the social value of a secure provision of drinking water, it not feasible to reduce or stop withdrawals.

One option remains. That is to develop alternatives for groundwater as a source of drinking water. Conceivably, surface water could serve the purpose. However, the surface water is so polluted that it would be very expensive to purify. Moreover, solutions along these lines would only be possible in the long term. At present, the possibility of deep infiltration is being considered.

The Groundwater Act does create the formal provisions for reducing extraction of groundwater to prepare drinking water. However, these provisions cannot actually be implemented for material reasons. At this point, the situation is as follows. Because of increasing demand for drinking water, the consumption of groundwater will continue to rise until the year 2000. By then, at the latest, the volume of extraction of groundwater for the provision of drinking water should have stabilized for the country as a whole. In the meantime, groundwater extraction within or nearby fragile ecological areas should not be allowed to expand at the local level. Early in the next century, the use of surface water will have to serve more as a replacement.

Box 4. Amendments to the Groundwater Act

Another problem in connection with the Groundwater Act is legalistic. Once a permit has been granted to withdraw groundwater, it cannot be revoked, even if the withdrawals cause severe ecological damage. At present, an amendment to this act is being drafted, which would allow permits to be revoked. Furthermore, it would make it possible to grant permission to withdraw groundwater for a limited time only.

There is a need to gain more insight into the consequences of granting new permits and the effects of expanding the rights entailed by current permits. To shed light on these repercussions, the amendment will also stipulate the need for environmental impact analyses. These must be conducted for groundwater extraction and infiltration activities with a volume greater than three million cu.m. per year.

With reference to the extraction of groundwater for industrial use, the picture is not fundamentally different. In fact, it is quite similar to that of drinking water provision. In both situations, the Groundwater Act provides ample opportunity to deny requests for new permits. However, this can be physically just as difficult as in the case of drinking water provision. These requests may pertain to vital industrial processes that are dependent upon access to groundwater. The volume of water withdrawn is lower, though. And there are signs of a further decline. Attention is now focused on cutting back the extraction of groundwater for purposes that are not of high value (for example, to use as a coolant). This too takes time.

Recently, a relatively low tax has been levied on all groundwater extractions. It is not yet clear what effects this tax will have. The money that this measure will generate will be applied to the development of alternatives for the provision of drinking water and industrial water.

Shallow groundwater

Phreatic groundwater tends to be a burden rather than a blessing. This groundwater has to be removed for farming. In this case, a negative value has been ascribed to groundwater. Accordingly, there are no conflicts of interest between parties trying to get as big a share in the resource as possible. Damages may result in the form of a lower productivity of the soil. Such damages may occur if water management measures are not carried out. Damage of this type can be expressed in monetary terms. But that is not true of damage of another type: the harm done to nature.

With regard to phreatic groundwater, agricultural interests have always had absolute priority. Only recently has this started to change. The standpoint behind national policy is that groundwater management should no longer be focused on the needs of agriculture. At the provincial level, this is specified further by designating certain areas as fragile areas. These ecological functions should be indicative for water management.

Furthermore, steps have been taken to develop a body of legal instruments that deal with the following crucial variables:

a) General rules will be formulated to restrict the irrigation of crops with groundwater in fragile areas.
b) In the future, the supply of exogenous water for farming will only be allowed in new situations when this practice has no detrimental side effects.
c) From now on, permits will be required for drainage works in the vicinity of fragile ecosystems.
d) When a project to structure the region reaches a certain size, environmental impact analyses will be required.

The above analysis of possible ways to manage the crucial variables suggests that desiccation can only be addressed to a limited degree with the existing legal apparatus. The instruments are only effective in the long term, while the outcomes are uncertain. It is (partly) for these reasons that the policy has been focused on carrying out the so-called rehabilitation projects.

Expansion of the management regime: the projects

The laws to redress desiccation are very general. They are not formulated precisely enough to restore the water balance. This body of laws must be supplemented by area-specific rehabilitation projects. Various restoration projects have already been initiated. These are financed by the central government.

Box 5. Some data on the projects

In 1991, the central government subsidized 19 regional projects. Altogether, the subsidies *amounted to Dfl. 2.1 million. This generation of pilot projects was focused primarily on research, not yet on implementation. In 1992, there were 27 projects that shared in Dfl. 3.0 million in subsidy. Then in 1993, there were 33 projects that received Dfl. 5.7 million in subsidy. As of 1992, these projects were for the most part designed to be implemented, though the effects would only be manifest after some time.*

One example of the project approach involves the nature preserve described in Box 1, the Naardermeer. The measures for this nature preserve include the following:
- to build a special purification plant, which filters phosphates out of the river before this water flows into the Naardermeer;
- to raise the water level in the polders surrounding the Naardermeer;
- to restore the artesian springs that flow into the Naardermeer by restricting the extraction of groundwater on higher grounds;
- to seek alternative ways to provide drinking water.

Box 6 gives another example. This case illustrates the kind of problems that can emerge in the course of a project.

Box 6. Desiccation in the Province of Groningen; the case of the Westerkwartier

Originally, this was an area where artesian springs brought deep groundwater to the surface. Drainage works for the benefit of agriculture, such as trenching, the digging of canals, and the straightening of stream beds, diminished their flow. The water table now stands approximately one meter lower than before. Tapping the groundwater has also contributed to the gradual decrease of the water table.

Several nature preserves that depend on the artesian flow are scattered throughout this predominantly agricultural region. The preserves are the property of the state. Attempts are underway to stop desiccation by local measures within the nature preserves.

One option is to try to catch and retain the precipitation, but this entails the risk of acidification. Piping in water from elsewhere to raise the water table is no panacea either, since it may disturb the local water balance. Such a measure only increases the risk of eutrophication. Conserving water and replenishing the local supply carry the additional risk of suppressing the remaining artesian flows.

Obviously, regenerative measures can not solve the entire problem. Ideally, the original artesian flows should be fully restored. However, this is not a realistic policy option. Consequently, the actual policy for the Westerkwartier focuses on water conservation and limited replenishment of the water. These measures are taken at a small scale, within the affected areas. Large-scale measures of which the effects will be felt outside the nature will generate opposition in agricultural circles.

This case shows that the implementation of effective measures to combat desiccation demands a long-term commitment. Effective measures can only be taken when surrounding areas are purchased by the state. These agricultural properties must be acquired to be converted into a nature preserve. In reality, it proves to be difficult to obtain such areas, even apart from the financial considerations.

Box 7 presents another example of the project approach. It demonstrates the complexity of a project from a technical point of view.

Box 7 The Dwingelderveld

The nature preserve in question consists of approximately 3500 hectares of heath, which is surrounded by stream valleys. During the 1960s, the area was dedicated as a national park. Until then, the area was being reclaimed and its peat bogs were excavated. This entailed the digging of drainage ditches. Draining the area caused a severe drop of the water table, resulting in the desiccation of the remaining natural areas.

Since the early 1990s, a substantial package of measures has been put into effect to combat the desiccation and to restore the pristine state of the area.

First of all, the water table in the stream valleys was raised. This was brought about through an ingenious system of water management. Sluices were constructed, opening and closing in response to automatically recorded changes in the water table. The water table in the stream valleys has indeed increased, but without negative effects on agriculture. Furthermore, wherever agricultural interests will be damaged, properties will be purchased to be added to the national park.

A second measure consisted of the construction of numerous dams. These serve to separate the nature area from a stream polluted by fertilizer. The dams also cause the water table to rise because they promote the retention of the water within the area.

Thirdly, various water-management strategies may boost the restoration of the peat bogs. Their aim is to retain the groundwater in the peat bogs and to decrease surface run-off. If successful, peat-forming plants may recapture the area, and over time this will result in the growth of new peat layers.

A final measure is the digging of sod. This removes the top layer of the peat, which is rich in nutrients and minerals. This is a precondition for the restoration of the original vegetation, which flourishes only on wet, nutrient-poor soils.

The analysis of these pilot projects shows that, so far, little progress has been made toward the rehabilitation of desiccated nature. Although many projects have been initiated, they cover only a small area. A very rough estimate of the total acreage where desiccation is currently being tackled by such projects is at most 8,000 hectares. Of course, even a small area requires technically difficult and expensive provisions. In spite of all these efforts, these projects may not yield the anticipated results. Nevertheless, these projects are necessary to make progress toward the national environmental goals.

Irrespective of all the measures that have been implemented, desiccation is still proceeding. The goal to decrease the desiccated area by 25 percent in the year 2000 compared to its extent in 1985 remains elusive. The most recent forecast anticipates that only three percent of the desiccated surface can be restored (that is, 12,000 hectares). And even this estimate may prove to be overly optimistic. This figure is based on the assumption that the desiccation has not increased as a result of regular policy (that is, the preparation of drinking water).

Discussion

In the introduction to this paper, we indicated that the groundwater problem in the Netherlands must be seen as a special CPR problem. The Netherlands is an affluent society, which owes its well-being in part to the way it has dealt with its groundwater.

Groundwater is used for many purposes. As far as direct use is concerned, human consumption and industrial applications are the most important. The amount of water used is partly determined by the growing rate of pollution of surface water as a result of the increased prosperity. Although surface water is plentiful, its use entails high costs.

To make the country habitable, especially to be able to practice agriculture, it is necessary to remove "superfluous" groundwater. This has become feasible through a very advanced technical infrastructure.

The way in which groundwater has been dealt with has contributed in various ways to the development of Dutch society. The negative side effects of these practices have only recently become clear. Because of the normal practice of dealing with groundwater, nature has been seriously damaged, and these effects continue unabated.

In principle, groundwater is not a scarce resource. Yet the acknowledgement of the problem of desiccation has resulted in defining it as such. New policy goals have been accepted, which aim to restore the loss of biodiversity. Thus, the definition of scarcity results from the acknowledgement of an immaterial interest.

In the past, the negative effects of the use of the resource were shifted to the entire society. Now, society at large is being held accountable for the repair of the damage.

We have defined this problem as a redistributive issue. To solve it, a regime has been developed. The experiences gained through this regime show which kinds of policy problems need to be resolved by the management of CPR groundwater if a re-active approach is pursued.

Initially, all attention was focused on posing restrictions on the use of groundwater by means of legal instruments. But given the multitude of social activities that exert an impact on groundwater, the result is an increasingly complex legal system. More and more social activities must be kept in check. Yet, even when such an extensive regime is adopted, such a restrictive approach proves to be largely ineffective.

In the first place, this approach has to deal with largely autonomous social developments (e.g., the use of groundwater for consumption), which are barely amenable to control. Secondly, lack of alternatives (e.g., pure surface water) limits the options for a restrictive policy.

In response to these constraints, the regime has been expanded to include regional restoration projects. This signifies a major policy reversal, in the sense that the economic interests of agriculture have now been made secondary to nature's interests in some regions. But the implementation of this policy remains problematic. The financial compensation for farmers and the purchase of properties require large budgets. Likewise, the necessary technical infrastructure is expensive. It will only show its benefits in the long term.

In this case study, we encountered a highly industrialized society that became aware of the limits put on the use of a vital resource. Restricting the use of the resource is only feasible in the long term. But even if restrictions can be applied, these will not be adequate. It will also be necessary to adopt a restoration policy. However, again the problem is compounded because of the need for a long-term policy perspective. Both approaches carry a lot of uncertainty. This demonstrates that the management of a CPR, instigated by immaterial motives, remains vulnerable. Such management is only feasible if alternatives can be offered for the material interests involved, and if their losses can be compensated. Over and above that, such a policy mix requires of a society the commitment of a substantial financial investment.