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THE EFFECTS OF LAND DRAINAGE ON GROUNDWATER RESOURCES IN KARSTIC AREAS OF IRELAND

David P. Drew* Catherine E. Coxon**

*Department of Geography, **Environmental Sciences Unit,
Trinity College, Dublin 2, Ireland.

ABSTRACT

The impact of land drainage on groundwater resources is particularly acute in karst areas because of the unique characteristics of karstic aquifers. Arterial drainage of karst lowlands in Ireland, involving the construction of artificial river channels, has resulted in losses of recharge, lowering of water tables, drying up of seasonal lakes (turloughs), alteration of underground flow routes, and periodic groundwater contamination.

INTRODUCTION

The general awareness of the magnitude and significance of human impact on the natural environment, characteristic of recent years, has found particular expression in relation to karstic terrains. The distinctive nature of karsts has long been recognised in terms of their morphology, ecology and hydrology and more recently (for example LeGrand 1977, 1984), their high degree of sensitivity and vulnerability to imposed change has been remarked upon.

Historically, human impact in karstic areas has been most profound in relation to the soils (often inadvertent change) and to water, the two primary resource bases in rural economies. The restricted occurrence of water both temporally and spatially in karsts has made its management an imperative for economic development. Such modifications of karst waters may be rendered easier by the fact that concentrated groundwater flow occurs in many karsts, flow in caverns and discharges from springs for example, but successful exploitation of this and other aspects of karst areas requires an adequate perceptual understanding of the character of the karst and its dynamics. The particular aspect of hydrological modification with which this paper is concerned is that of land drainage.

LAND DRAINAGE AND GROUNDWATER RESOURCES

The purpose of land drainage is to remove excess soil water

from the land in order to improve its agricultural potential. The works carried out to achieve this aim span a wide scale, from field drainage involving subsurface drains and small ditches to major works, usually termed arterial drainage, involving the alteration of main river channels, in order to increase their effectiveness in draining whole catchments (Baldock, 1984). Hill (1976) has reviewed the environmental impacts of drainage schemes, including changes to water tables, and he notes that impacts on groundwater will be greatest where the level of excess water in the soil corresponds to the regional water table. In this situation, drainage can bring about a permanent lowering of the water table - Hill cites falls of 1-2m in parts of the U.S.A. - and as a result, shallow wells and farm ponds may dry up, and dry season stream flows may be reduced. Muzikar (1986) and Rodionova (1986) also record declines in groundwater levels, and changes in groundwater quality brought about by land drainage.

THE IMPACT OF DRAINAGE IN KARSTIC AREAS

Land drainage is usually associated with the lowering of an overly high water table. This may be perched on superficial deposits of low permeability, and in this case the underlying rock, whether karstic or not, may be irrelevant (unless the water can be drained into the highly permeable karst aquifer beneath). However, if the high water table is the actual groundwater table, drainage of karst areas can be expected to differ because of the unique characteristics of karst aquifers:

1. As groundwater flow networks are commonly well-integrated, the effects of drainage, for example lowering of water table levels and drying of wells and springs, may be experienced at a considerable distance from the point of interference.
2. Given the low storage coefficients of most karst aquifers, the lessening of recharge water may cause very considerable falls in water table levels although such changes may exhibit marked areal variation if the aquifer has great spatial variability with respect to storativity and permeability.
3. The development of saline intrusions may be facilitated by drainage in some coastal areas whilst the construction of artificial conduits or the opening up of sinkholes may allow polluted surface waters easier ingress to the aquifer.
4. Flooding may be of an unconventional type, for example the backing up of sinking rivers with inadequate underground channel capacity or the flooding of closed depressions by rising groundwater (perhaps via estavelles), thus rendering the usual techniques of land drainage less than satisfactory.
5. Wetlands are uncommon in karsts and thus their removal may be of more significance, particularly in ecological terms, than in other terrains.

Relatively little has been written about land drainage in karstic areas, presumably because many karstic areas are associated with a lack of surface water. Flooding problems associated with

sinking rivers are documented by Medardo & McDonald (1987) in Jamaica, where poor land management has led to flooding due to the clogging of river sinks with vegetable debris. In this area, however, the solution proposed is not one of drainage, but rather of debris traps to keep sinks open, and better watershed management and flood warning systems.

In areas of the U.S.A. where there is an excess of surface water above a karst limestone aquifer, one solution has been the installation of drainage wells, usually in the bottom of sinkholes (dolines), to remove not only land drainage water, but also storm water associated with urban developments. These are used for example in north Florida and south Georgia (Stringfield, 1966) and in Kentucky (Crawford, 1984).

Seasonal flooding occurs in many of the Yugoslavian poljes; in some instances the flooding is similar to that discussed above, i.e. ponding up of surface water, while in other instances groundwater inflow is involved (Mijatovic, 1987). Because of their importance as flat, fertile lands in a bare, rocky area, many of the Dinaric karst poljes have been subjected to drainage schemes, sometimes involving the construction of subsurface tunnels. Such schemes have not always been successful: Bonacci (1985) observed that in some instances, outflow tunnels constructed from poljes resulted in an increase in droughts but did not eliminate floods. An attempt to prevent flooding in Fatnicko Polje by constructing a concrete plug in the ponor led to water rising at new locations, causing localised seismic shocks (Milanovic, 1984). However, increasingly sophisticated polje regulation schemes are being developed, and such schemes are often multi-purpose, concerned with hydro-electric power generation, water supply and recreation as well as agricultural uses (including both summer irrigation and winter drainage) (Habic, 1987).

LAND DRAINAGE IN KARSTIC AREAS OF IRELAND

Limestones of Carboniferous age underlie almost all of the central lowland of Ireland, and comprise the prime agricultural land in the country, yet the subdued topography and high effective rainfall (c.550mm) mean that river flooding and poor land drainage are acute problems over large areas. Deposits of glacial drift mantle the bedrock over most of the lowland, the thicknesses generally being less in the west of the country where bedrock is commonly exposed in river channels. Arterial drainage schemes conducted on a basin basis, have involved deepening, straightening, embanking and creating a uniform gradient in river channels together with the excavation of tributary drainage channels where necessary.

As arterial drainage have been the responsibility solely of civil engineers, awareness of the wider environmental implications of drainage or of the peculiarities of karstic or semi-karstic terrains has been largely absent. The reports of nineteenth century drainage works often refer to problems encountered during channel

excavations, for example: "...it was with great difficulty the work was proceeded with in consequence of the cavernous nature of the rock and the difficulty of unwatering it" (Roberts, 1854). Characteristic features of karst such as swallow holes have been widely used as convenient sinks for drainage channels, though with varying degrees of success. Only rarely have drainage schemes researched the groundwater:surface water relationships in an area in sufficient depth to allow for the development of an optimal drainage strategy. Such an exception, documented by Jones and Gunn (1982) was the construction of a 220m tunnel between a flood-prone sink and its rising to allow flood waters to be conduited rapidly away and thus prevent seasonal inundation of farmland and damage to property in an area of Co. Tipperary.

Although there have been few before-and-after studies of the impacts on groundwater of land drainage in karstic regions of Ireland, some reliable data are available indicating the nature and scale of imposed changes. Three types of hydrological modification are described from the lowland limestone areas of counties Galway and Mayo in western Ireland.

1. In areas formerly characterised by karstic internal drainage, artificial channels have been constructed leading to the sea, for example the 780km^2 River Clare basin was engineered from an ill-drained region of closed depressions and swallow holes. To the south the Kilcolgan-Lavally catchment, some 500km^2 in extent, is similarly artificial. It is estimated that in the latter catchment recharge to the limestone aquifer has been diminished by c.93x10^6 m^3/y as water which formerly sank underground is now channelled to the sea. In the same catchment summer water table levels have fallen by 2-3m causing a higher proportion of the springs of the area to be seasonal rather than perennial.
2. Although overall recharge is lessened by arterial drainage, localized point or strip recharge is enhanced by the construction of river channels and the enlargement of sinks. Such localised inputs to groundwater cause diversions of underground flow routes and also allow any pollutants present in surface waters to enter the aquifer more readily. In the river basins described above, agriculture-based industries located close to the river channels cause periodic severe pollution of the surface waters and hence of the groundwater, for example as documented by Drew (1984).
3. The draining of turloughs is an important aspect of the drainage of the western limestone lowlands of Ireland. Turloughs are seasonal lakes, varying in area from a few hectares to a few sq.km, formed by a combination of karstic and glacial processes, and having a karstic function similar to poljes. They generally flood in the autumn from springs, estavelles, or sometimes surface streams, and form a lake for several months in the winter, emptying underground in the late spring to leave a vegetated depression used as summer pasture. It has been estimated that at least a third of all turloughs have now been drained: of ninety sites with an area of at least 10 hectares, thirty were found to have been drained

since the mid-nineteenth century, and several other sites are likely to have been affected to some extent (Coxon, 1987).

The drainage of turloughs has ecological implications, because their hydrologic behaviour provides an unusual habitat. The turlough vegetation is very distinctive, consisting of flood-tolerant grassland communities (O'Connell et al., 1984). Turloughs are also very important wildfowl sites; many ducks, geese and waders depend on turloughs and callows (river flood meadows) as winter feeding areas, and turlough drainage has resulted in the near-extinction of at least one breeding species (Hutchinson, 1979; Merne, 1980). The largest remaining turlough, at present being considered for drainage, is ranked as of international importance for several wildfowl species, and it also contains a rare invertebrate, Tanymastix stagnalis (Young, 1976). Thus the cessation of winter flooding results in the destruction of a unique ecosystem.

CONCLUSIONS

Although the topic of land drainage in karst areas is comparatively poorly documented it may be of considerable importance in specific karstic environments such as lowland karsts in regions having high levels of excess precipitation. The intimate and direct character of the interconnections between surface water and groundwater in karst means that it is highly unlikely that modifications can be made to surface waters without markedly affecting groundwater. The investigations carried out on the lowland karst of western Ireland illustrate these principles.

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