

- *Wetlands – Land reclamation – Agricultural use – Water management – Strategic options*

Joachim Quast

Towards an Integrated Land and Water Resources Management in Brandenburg's Oderbruch-Havelland Wetland Belt: History and Strategies for the Future

*Wege zu einem integrierten Land- und Wasserressourcenmanagement im
brandenburgischen Feuchtgebietsgürtel Oderbruch-Havelland:
Historische Entwicklungen und Strategien für die Zukunft*

With 10 Figures

The article informs about historical developments and recent problems in the former wetlands of the Oderbruch, which has been cultivated for agricultural use for 300 years, and in the fen region of the Rhin-Havel-Luch. The periodically inundated floodplains of Oderbruch are characterised by rich-in-clay sedimentation soils, while Rhin-Havel-Luch is a year-round wet fen region with peat soils. In both areas land use necessarily requires an adequate regional water management, employing measures and system solutions for river training, dike construction, drainage and soil cultivation. Options for action and adaptation strategies for the next 20 to 40 years, based on many years of own analyses and case studies, are presented and discussed. The article also considers an aggravation of the problems to be expected from climate change.

1. Problem Situation

1.1 General physical and hydrological features of the study area

In terms of its geomorphology the Berlin-Brandenburg region is characterised by sandy and loamy-sandy ground moraines. From east to west, the area is crossed by wetland depressions, following the course of the Torun-

Eberswalde glacial valley and the Warsaw-Berlin glacial valley (*Fig. 1, Neef 1970*). These depressions experienced different processes of soil formation depending on the post-glacially affected regional hydrological regimes.

In the floodplains of the Oder River, which, after deglaciation, flowed northward into the Baltic Sea, formation of Eutric Fluvisols and Eutric Gleysols occurred during flooding in the inundated areas

due to sedimentation of erosion loads transported from the runoff-forming regions upstream. In the Oderbruch, a lowland area of about 1000 km² along the lower middle reaches of the Oder (Fig. 2), this top layer has a thickness of 0.5 to 3 m. In the underlying stratum there is a sandy to gravelly aquifer with a thickness of 10 to 30 m (Fig. 3).

In the other regions of the glacial valleys mentioned above, which drain from east to west, year-round water loggings resulting from very low gradients have led to the formation of fens and peat soils (Noteć and Warta marshes, Rhinluch and Havelland Luch, Drömling, and, in the Berlin glacial valley, the Spree wetland).

The fen wetlands and also many lakes are fed by the groundwater evolving below the sandy infiltration sites within the catchment area. With

comparatively low annual rainfall totals of 500 to 600 mm, a groundwater recharge of 100 to 110 mm occurs at these sites (BMU 2003). The low topographic energy of the sandy basin causes a severely retarded baseflow. These conditions form the cause for the apparent paradox of an abundance of water in a region of low rainfall. Brandenburg is “poor in water” but “rich in waterbodies” (Quast 1994, 1995, 1997)! This fact also elucidates the vulnerability of the wetlands and lakes. The actual summerly water balance deficit of the wetlands is 300 to 400 mm, which can only be compensated by wintery flooding (Quast et al. 2001, Dietrich and Quast 2004, Dietrich 2008). If, according to existing climate change scenarios, less rainfall and increased evaporation (through temperature rise) have to be expected, even less groundwater recharge and less feeder flows towards the wet-

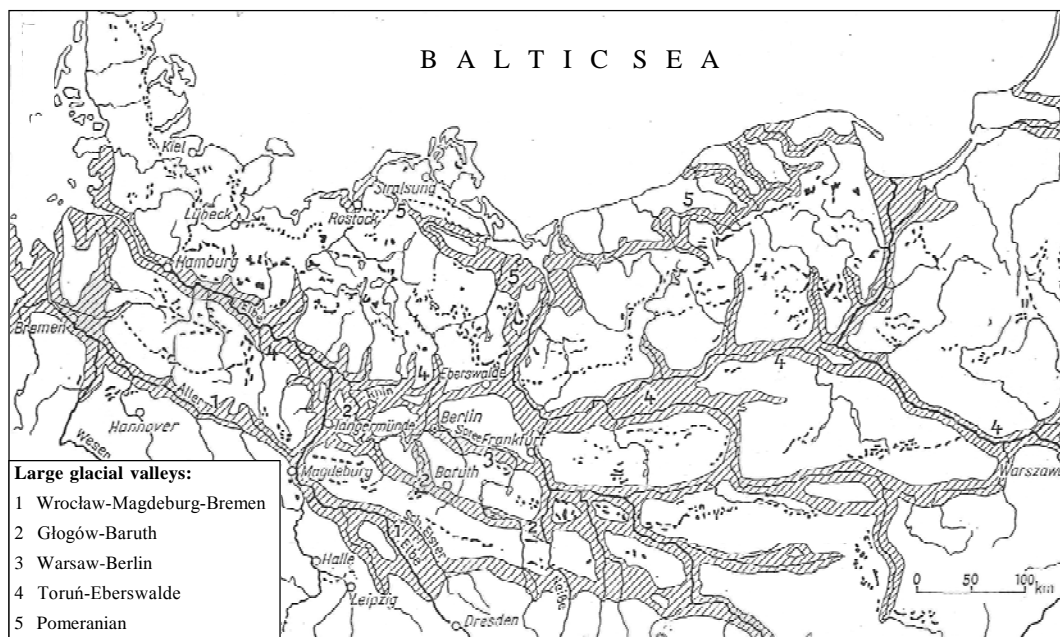


Fig. 1 Large glacial valleys in north-central Europe (Source: Neef 1970)
 Urstromtäler in Nordmitteleuropa (Quelle: Neef 1970)

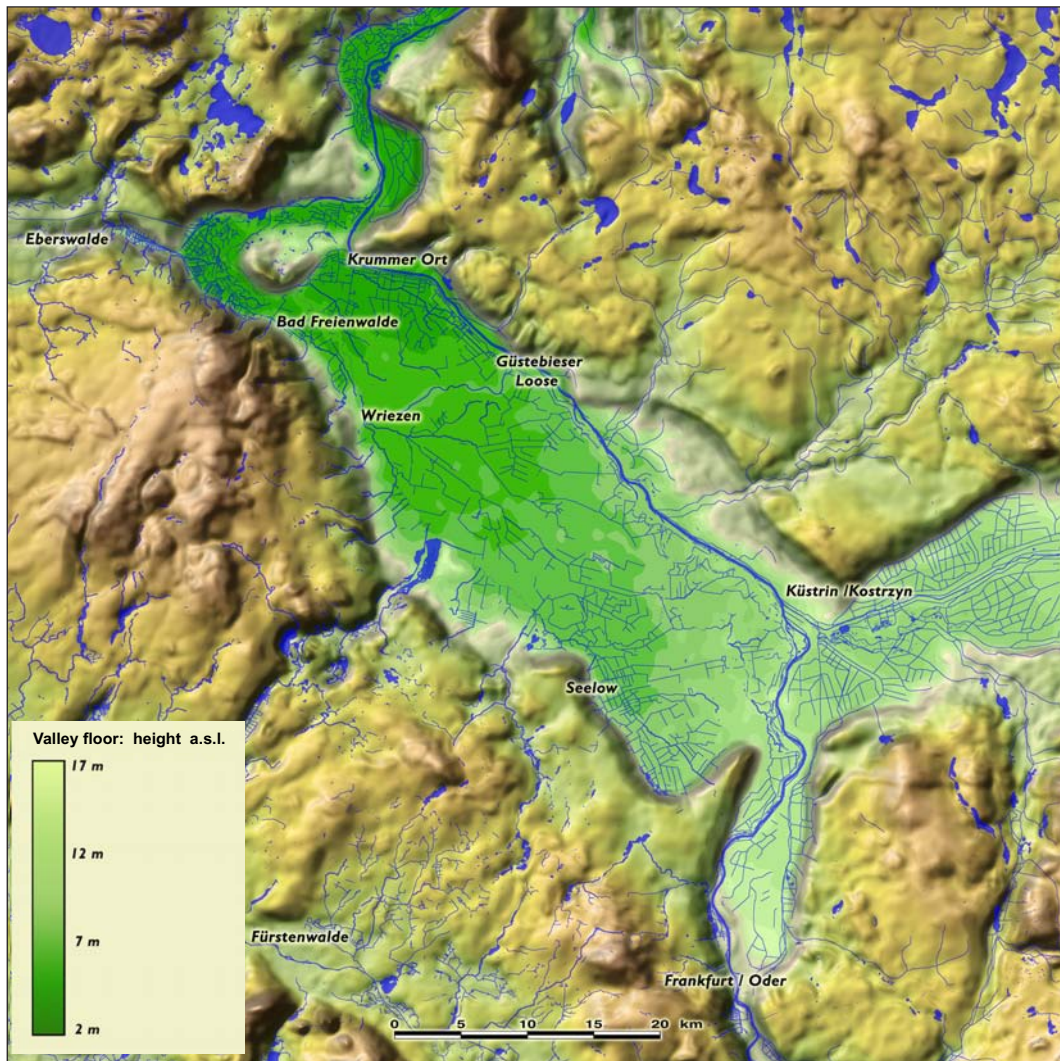


Fig. 2 Map of the Oderbruch region with waterbodies (Dalchow et al. 2009)
 Karte des Oderbruchs mit Gewässern (Dalchow et al. 2009)

lands will be the result, as well as an increasing water withdrawal from the wetlands, thus jeopardising their future existence.

For approximately 300 years, the areas of the "Brandenburg wetland belt" have been reclaimed for agriculture (Berghaus 1854). After the dev-

astation during the Thirty Years' War (1618-1648), the electoral princes of Brandenburg (who were kings of Prussia from 1701 onward) spurred the development of agriculture and the colonisation of the country. Since the fertility of the sandy sites was low, it was reasonable to include the potentially fertile wetland sites into the de-

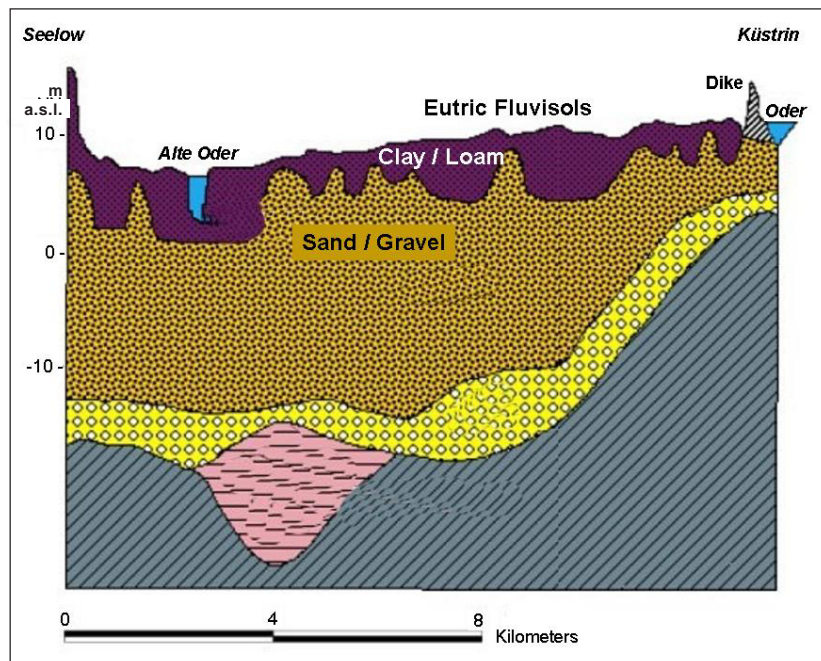


Fig. 3 Geological cross-section between Seelow and Küstrin (Oderbruch) (based on data of various geological investigations) / *Geologischer Schnitt zwischen Seelow und Küstrin (Oderbruch) (nach Daten aus verschiedenen geologischen Gutachten)*

velopment programmes. Subsequently, it became necessary to drain the wetlands (by means of ditches and diversion channels), to protect them against further flooding (by means of dikes), to clear the land from trees and to cultivate it. The extremely high costs of these measures were disbursed by the Treasury. The land was parcelled and allocated to the recruited colonists. During the 18th and 19th century, both Oderbruch and the ameliorated fen sites of Rhin-Havel-Luch rapidly evolved into prospering agricultural landscapes, giving an example for the later reclamation of many similar wetlands (Blackbourn 2006).

The agricultural use and the development of cultivated lowland sites have always been and still are indispensably bound to a specific water management adapted to the production targets. These

close interactions may explain why, in terms of hydrology, the groundwater-affected lowlands are in a very special position compared to other areas. In the past, new concepts for the advancement and “perfecting” of the hydro-technical facilities and the water management methods came up about every 50 years, until the 1970s, with intensifying agricultural production always being the driving force for these activities.

1.2 Oderbruch

In the Oderbruch, the river, which once oscillated over the entire lowland (65 km in length, 12 to 15 km in width), has systematically been fixed by dikes to the eastern edge of the valley since the 16th century. The construction of the Neue Oder

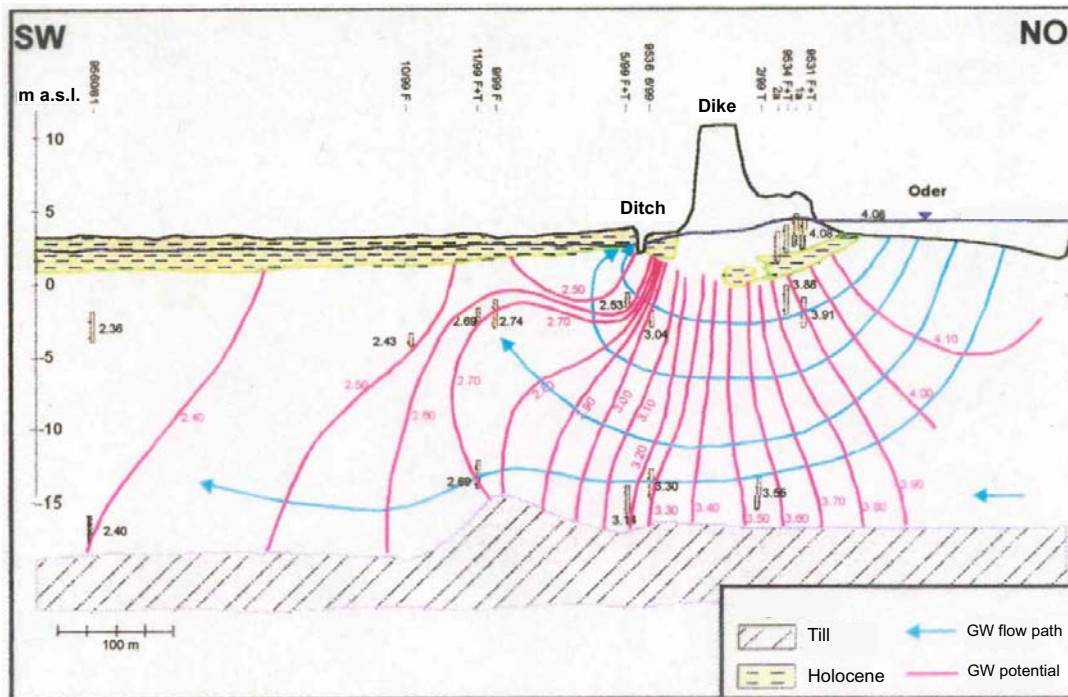


Fig. 4 Seepage under dikes, cross-section of groundwater equipotentials (Massmann 2002)
Drängewasserströmung unter Deichen, Äquipotenziallinien (Massmann 2002)

Canal between Güstebiese and Hohensaaten in the years from 1747 to 1753 and the completion of diking created the Oderbruch polders which have remained substantially unchanged until today (Fig. 2, Fig. 3, Berghaus 1854, Mengel and Eckstein 1930). The polders were flood-free, which means that there were no longer any further soil-forming deposits. Drainage systems to divert seepage waters, which flowed in from the now higher Oder via the aquifer (Fig. 4, Fig. 5), were imperative as a precondition for the cultivation of the land and the settlement of the polders.

The largest extensions of the water management system occurred from 1890 to 1930 by setting up steam engine driven and later electrically operated pumping stations. Large grassland areas, which until then had remained wet, were drained

and turned into arable land. By 1980, the wetland portion diminished to less than 5 %.

From 1970 to 1980, the entire drainage system was restructured and supplemented by many new pumping stations in the course of a so-called "complex melioration". At the same time 20 % of arable lands were equipped with sprinkling irrigation systems to provide sufficient water for the crops during the recurrent summer drought periods. With an average annual precipitation of 470 mm, Oderbruch, lying about 50 m beneath the surrounding moraine, ranges among the regions of lowest precipitation in Germany. Accordingly, despite a good water storage in the clayey soils and a certain capillary rise of water from the groundwater, summerly drought stress occurs, and irrigation is crucial.

Another latent risk of extreme flood events is the danger of dikes being overtopped. After the flood of 1997, the Oder dikes were reinforced to withstand a 200-year flood (HQ_{200}), i.e. a probability of occurrence of 0.5 %. Further precautions are required to protect the area from a flood of an even more extreme dimension.

1.3 Brandenburg fens

For a long time the utilisation of the fens was dominated by extensive grassland and pasture farming with relatively shallow drainage and wintery flooding of the grassland. The topographic conditions with nearly horizontal surfaces without a noticeable gradient did not allow intensive

drainage by means of common open ditch drainage and water diversion by channels. Nevertheless, even with this drainage regime, consolidation of peat soils and diminishing of fens by mineralisation of the upper soil layers could be observed (Kratz and Pfadenhauer 2001). In addition, there was the extraction of peat, essentially to supply Berlin with fuel (Berghaus 1854).

A period of deeper drainage for the fen regions began in about 1925 with the introduction of drainage pumping stations targeted at higher grassland yields and better trafficability for harvesting and transport devices. This intention in mind, in many subregions of the area the water management system was completely redesigned in the 1960s and 1970s and extended to a com-

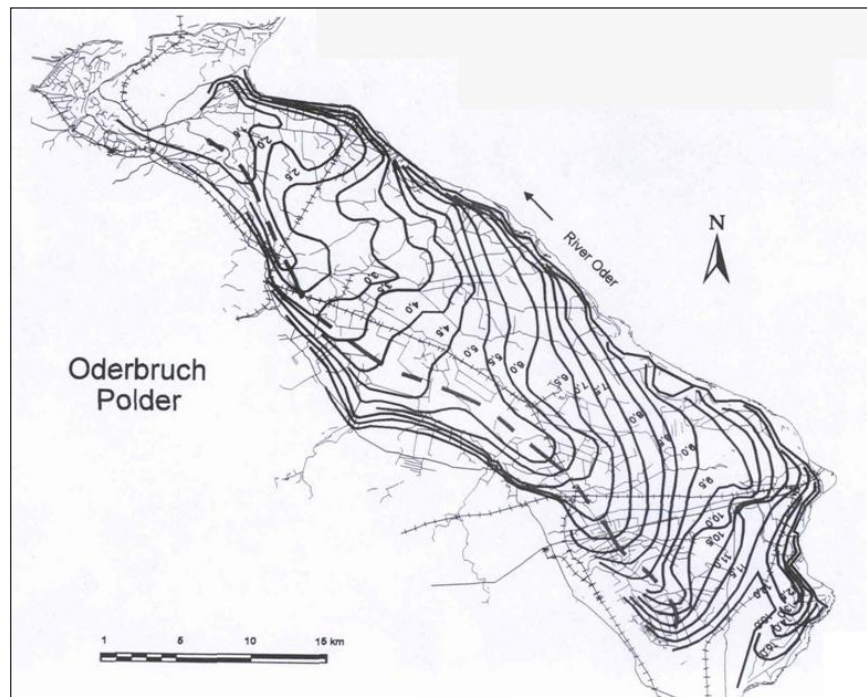


Fig. 5 Hydroisohypses in the Oderbruch polder, calculated from groundwater level data acquired in spring 1971
Hydroisohypsen im Oderbruch, berechnet aus Grundwasserstandsmessungen im Frühjahr 1971

bined alternating drainage and subsurface irrigation (Fig. 6). An early and deep drainage in spring-time was followed by back-up irrigation by means of high ditch water levels in summer; for this purpose the water was diverted from lakes further upstream. The agricultural use consisted primarily of sowed grassland and maize monoculture for silage production (Leue et al. 1981).

The regulation of groundwater levels, accomplished under the responsibility of regional "amelioration cooperatives", worked well. Overall, farming practices were nevertheless marked by severe negative impacts since about 1970.

The degradation of the peat soils accelerated, soil fertility decreased, and the soil hydrological parameters (permeability, storage capacity) deteriorated. Frequent ploughing and new seeding of grass, necessary for weed control, accelerated these processes even further. Monoculture and the technologies applied reduced the biodiversity, and the withdrawal of irrigation water from lakes damaged the ecosystems along their shorelines – the necessity of a change was evident. After 1990, concepts were elaborated; none of them, however, have been implemented so far (Kretschmer 2000). With the privatisation of the fenland and of the associated hydro-technical

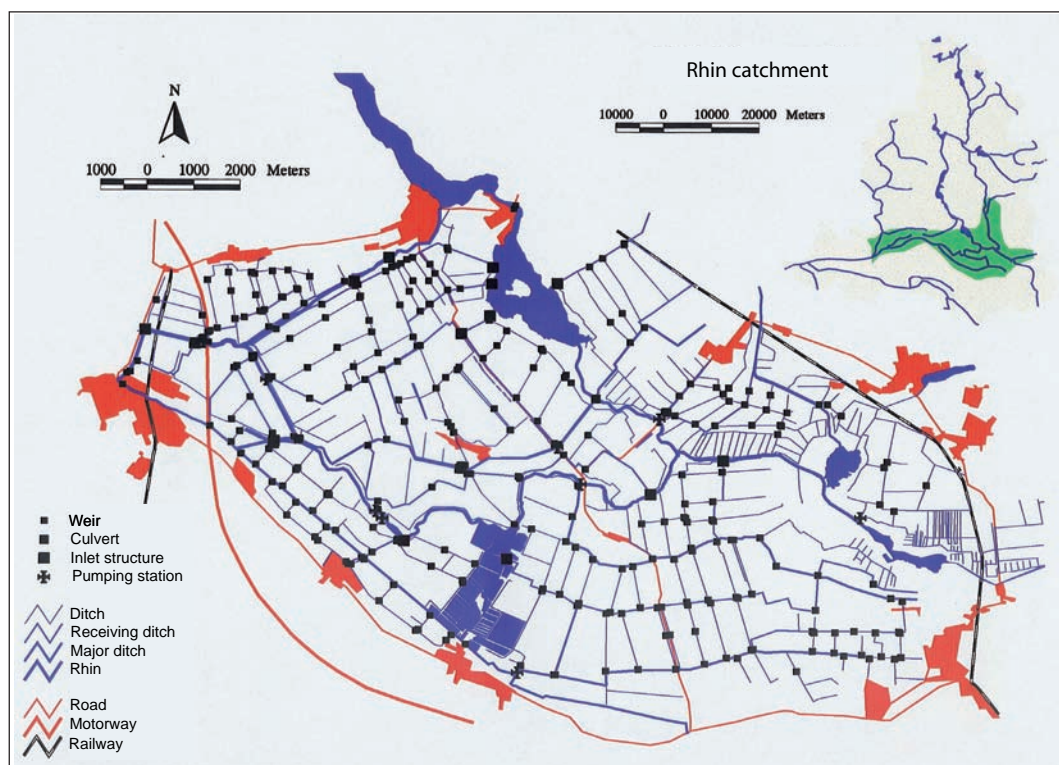


Fig. 6 Network of ditches with control structures in the fen region Oberes Rhinluch (source: Dietrich and Dannowski, ZALF) / Grabennetz mit Staueinrichtungen im Niedermoorgebiet Oberes Rhinluch (Quelle: Dietrich und Dannowski, ZALF)

systems such as ditches, back-up structures and minor pumping stations, the situation became even more complicated. At present, no coordinated water management is installed, mainly because of the large efforts which are associated with it. Because of the feedback effects in the regulation system, a separate control of individual sections is not possible, which requires again a complex control system for an entire area, as depicted e.g. in *Figure 6*. Currently, the hydro-technical systems are no longer sufficiently functional and there are no authorised institutions for a coordinated water management in the area; the ecological deficits have worsened since 1990.

2. Methodology

Around 1970, field measurements, modelling and case studies began in both Oderbruch and Rhin-Havel-Luch in the framework of the measures which were envisaged for the complex melioration. Since then, manifold investigations were started by the author himself and in cooperation with other scientists. For these investigations, new approaches for the study of geo-hydraulics of drainage systems and the seepage through and under dikes as well as for soil water movement and infiltration were applied (*Luckner et al. 1969, Quast 1973, Quast 1983, Quast et al. 1993*).

For Oderbruch, an electro-analogue resistance network model was developed allowing the analysis of groundwater dynamics for the first time in an area of such an extent (*Fig. 7, Quast 1973, Quast and Müller 1973*). The model had a triangle discretisation of about 100 network nodes. The resistance elements were assigned to the polygons at these nodes. The calibration of the model resistances was done by section, by trial and error, using field measurements of groundwater levels (see *Fig. 5*) and discharge in ditches from the flood period of 1971. As a result, groundwater levels for the entire Oderbruch,

seepage water inflow into the Oderbruch for each node along the Oder and inflow from the western slope were obtained, each was determined for different water levels of the Oder. The model results of 1971 were confirmed in full extent by later field measurements and model applications (*WASY 1999*). *Dybek (1977)* investigated possibilities for operational groundwater control measures by an advanced electro-analogue resistance model.

Computer-based control methods for groundwater regulation in Rhin-Havel-Luch (*Fig. 6*) were designed and tested successfully (*Leue et al. 1981, Quast 1983*). In the 1990s, a large interdisciplinary research project focused on objectives of ecosystem management (*Kratz and Pfadenhauer 2001, Balla and Quast 2001, Quast et al. 2001*). Micro-meteorological stations were established and comprehensive field measurements were taken for hydrological regional process studies and water management methods (*Quast et al. 1993, Quast and Böhm 1998, Dietrich and Quast 2004, Dietrich 2008*). Within the framework of a Germany-wide project on anthropogenically affected geochemical processes in soil water and groundwater, comprehensive field studies were carried out in the Oderbruch (*Massmann 2002, Massmann et al. 2003*).

Findings and concepts could be derived from numerous studies, cooperations and conceptual approaches. After the extreme flood of 1997, multiple activities and discussions on sustainable adaptation solutions for the Oder polders emerged (*Quast 1999, Quast and Lukianas 1999, Quast and Wenkel 2004, Quast 2005a, Quast 2005b, Quast and Ehlert 2005, Quast 2006*).

For sandy moraine sites near the lowlands in need of sprinkler irrigation, options for the alternating use of aquifers for the withdrawal of water by wells during the growing season and the subsequent recharge of the extraction funnel through artificial infiltration with winterly excess runoff or with treated wastewater were in-

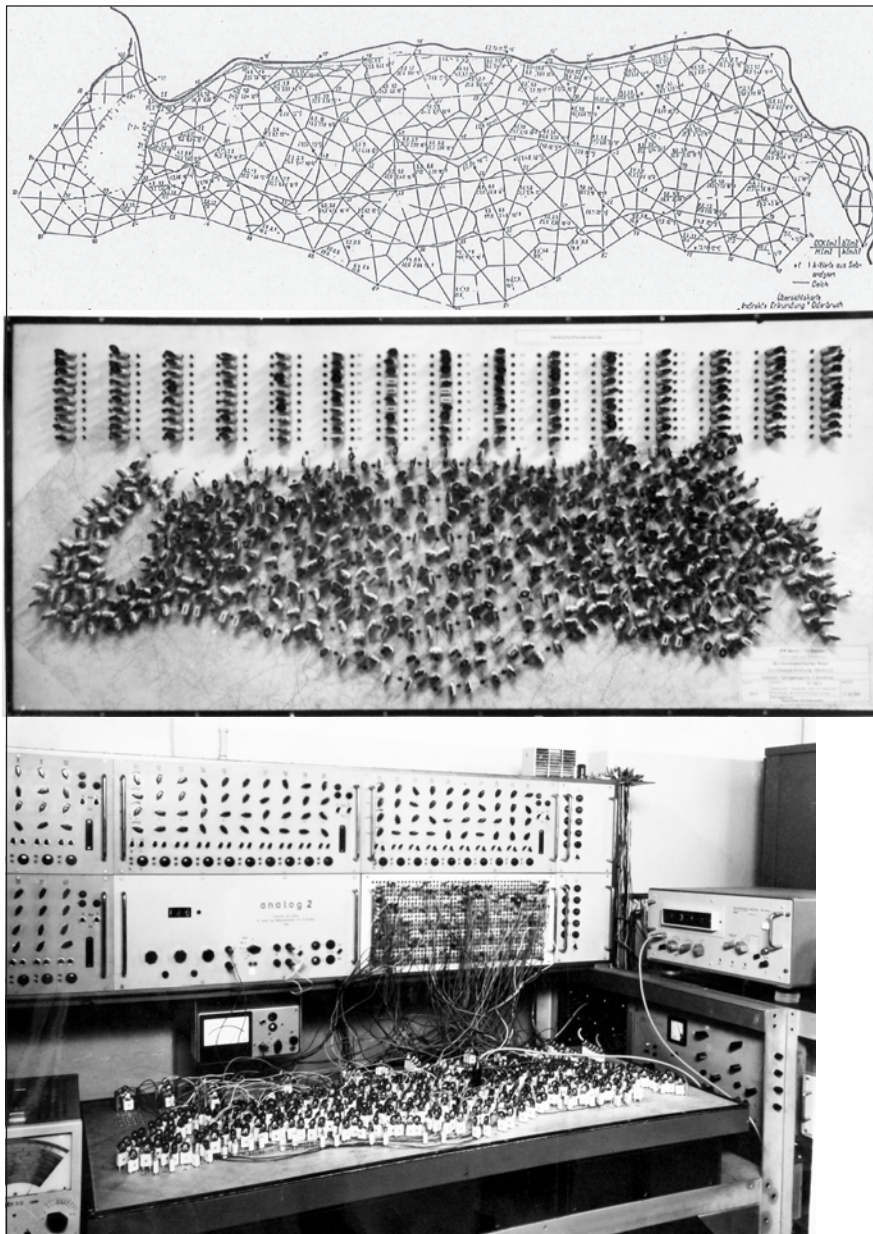


Fig. 7 Pattern of discretisation (top), electric resistance network of the regional specific electro-analogue geo-hydrological network model Oderbruch (middle), and network model Oderbruch with analog2 boundary condition and measurement unit (below) (Quast 1973) / Diskretisierungsschema (oben), Widerstandsnetzwerk des regionalspezifischen elektro-analogen Netzwerkmodell Oderbruch (Mitte) und Netzwerkmodell Oderbruch mit analog2-Randbedingungsgeber und Messeinheit (unten) (Quast 1973)

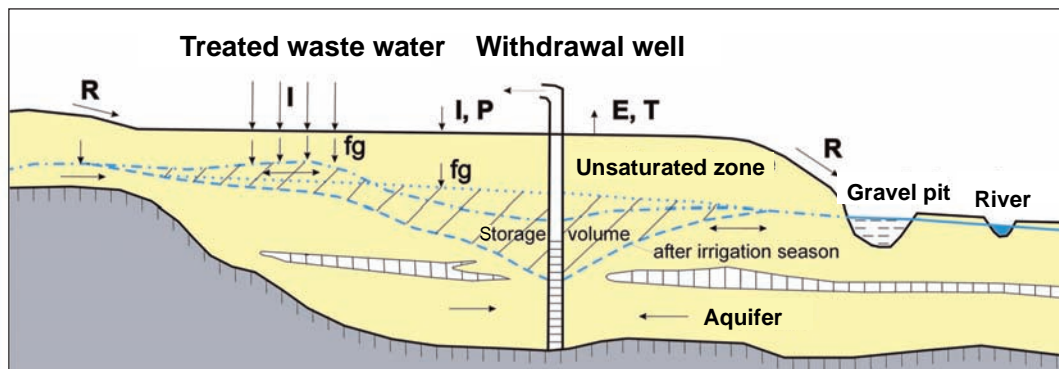


Fig. 8 Water storage in an aquifer for irrigation purposes, scheme of withdrawal cone and recharge (after Kluge et al. 1980, modified) / Grundwasserspeicher für Bewässerungszwecke, Entnahmetrichter und Wiederauffüllung (modifiziert nach Kluge et al. 1980)

vestigated (Kluge et al., 1980). These results are helpful nowadays for pilot projects using such storage technologies (see Figs. 9 and 10).

3. Options for Action and Adaptation Strategies

3.1 Polders

For polders, i.e. diked natural floodplains, it is generally to be examined whether they, once built in a different historical context of social objectives and economic conditions, can still adequately meet today's sustainability criteria (in terms of both environment and economics) and the anticipated challenges which global change imposes on regional adjustment. Two alternative options arise:

a) deconstruction of dikes and abandonment of further intensive agricultural use of the alluvial soils to enable the recovery of the natural floodplains with their high ecological potential and positive retardation and retention effects on floods (reduction of peak discharge and of flood levels in general). This option was advanced by its proponents using

ecological arguments but also a number of other considerations: A total protection against flooding was not feasible, the expenditures for structural flood protection were extremely high, and there was no demand for agricultural land given the existing large agricultural surpluses. Meanwhile, land requirements have drastically changed due to the growing bio-energy farming. Moreover, the dikes along the Oder and the Elbe rivers have already been upgraded effectively with state funds after the floods of 1997, 2002 and 2006.

b) preservation of the polders, in particular the populated ones, under the condition of i) flood risk management for potential, so far not predictable, extreme floods in the future, ii) improvement of the ecologically deficient situation in the polders, iii) means-tested and cost-efficient optimisation of the water management in the polders, iv) improvement of the socio-cultural infrastructure and preservation of the cultural heritage in the polder landscape.

Oderbruch belongs to the category of populated polders with remarkable cultural heritage

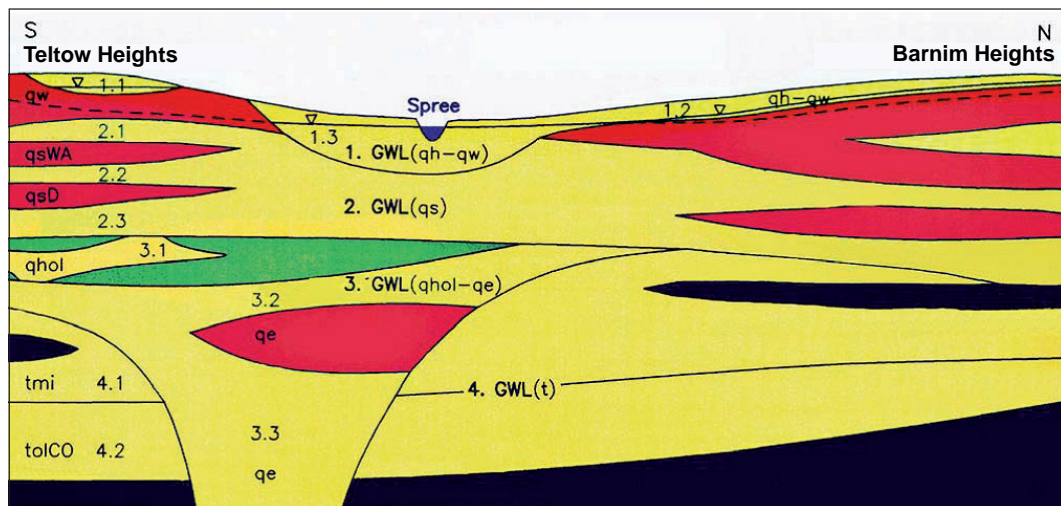


Fig. 9 Geological cross-section through a potential location in the Berlin glacial valley (Hannemann and Manhenke 1995) / Geologischer Schnitt durch einen potenziellen Standort im Berliner Urstromtal (Hannemann und Manhenke 1995)

and highly productive agriculture. Since the beginning of the 1990s, proposals for adaptation strategies have been brought forward and adjusted in the 'Concept Oderbruch 2010' (Quast 1994, 1997, 1999, Quast and Ehlert 2005). The concept was presented in the region through lectures and posters and discussed with stakeholders and the general public (see www.oderbruchpavillon.de):

- i) Risk management for extreme floods: In the case of more extreme floods (e.g. caused by climate change), which have not occurred so far, there is a high risk of dikes being overtopped, which also implies the risk of crevasses and disastrous flooding of the polders. For this worst-case scenario, overtoppable sections with lowered dike crests are to be established, permitting a controlled, delayed flooding of the polders without the destruction of the dike. Along the lowered spillover sections, movable flood barriers are to be installed which can be opened in case of emer-

gency. Within the polders, the buildings have to be reinforced to withstand temporary flooding, with regard to both the fabric of the building and, in particular, the electrical installations and other equipment (Quast 2005a, 2005b).

- ii) Improvement of the ecological situation: A 200 to 500 m wide wetland strip along the dike leads to ecological improvements. It reduces the geo-hydraulic gradient near the dike at high groundwater levels, thus decreasing seepage water flowing from the higher Oder via the aquifer into the polders. This subsurface inflow accounts for more than 90 % of the water regime in the polders (see Figs. 5, 8) and amounts to approximately $5 \text{ m}^3\text{s}^{-1}$ at medium water levels of the Oder and up to $20 \text{ m}^3\text{s}^{-1}$ at flood levels along the complete dike line in the Oderbruch (Quast 1973, Quast and Müller 1973).

The sluices in the dikes, which were proposed to revitalise the Oder bayous by re-

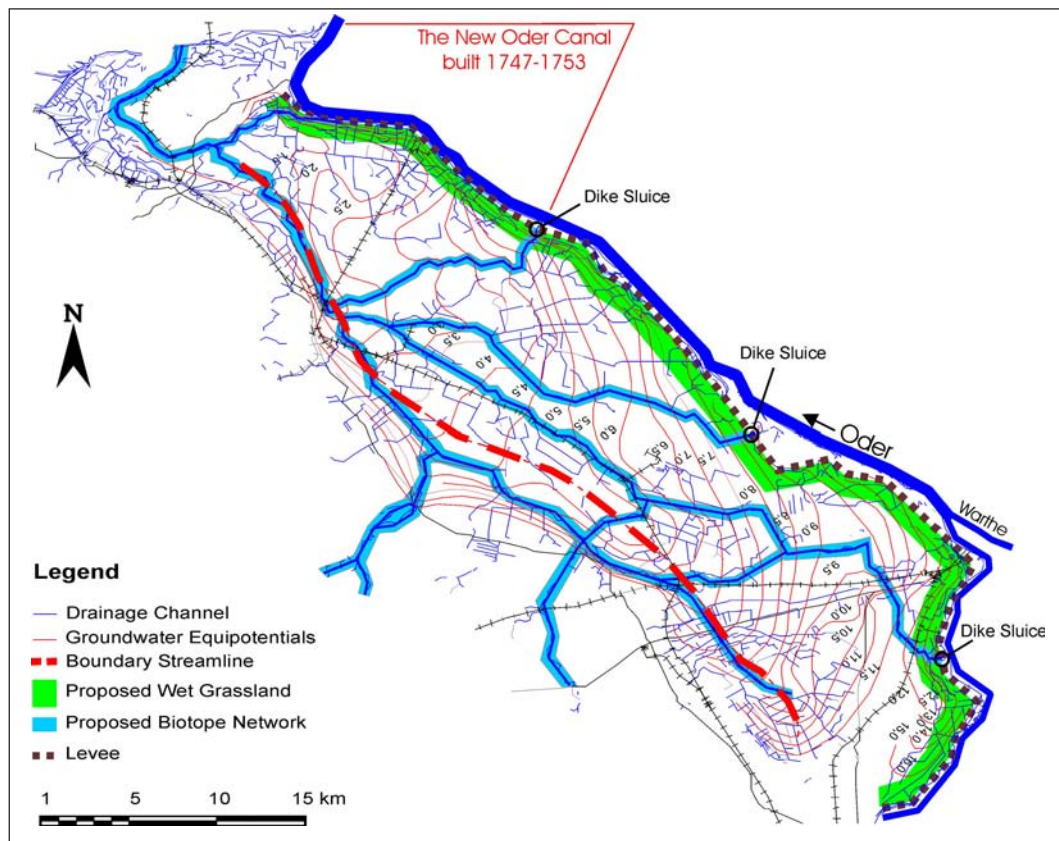


Fig. 10 Scheme of the KONZEPT ODERBRUCH 2010
Übersicht zum KONZEPT ODERBRUCH 2010

connecting them to the Oder river and thus turning them into running waters again, have already been built and are in operation near Reitwein (2004) and near Güstebieser Loose (2009) in the north. Thereby and by some already installed fish ladders the ecological passability of the bayous in the polders has already been improved significantly. The planned ecological corridors reaching from the Oder and the dike-near wetland strips along the main watercourses to the western slopes of the Oderbruch are being constructed step by step.

iii) Drainage system management and arable land use: The drainage ditches in the Oderbruch collect water seeping in from the Oder river and convey it northward through larger ditches and pumping stations into the Old Oder and the Oderberg waters. For a rapid drainage of surface-water logging (due to heavy rainfall or snowmelt), however, the ditch system is not effective as the topsoil layer of the alluvial clay possesses a very low hydraulic conductivity and surface water can infiltrate only at a very moderate rate over a long period of time (see Müller 1988). The top layer is to be considered as a so-called “leaky aquifer”.

So far, these long-known system properties have insufficiently been taken into account in water management practices. In the case of surface water logging, farmers demand drainage by deep open ditches and the operation of pumping stations – although experience has shown that this does not result in any drainage effect. As a result of the present practice, groundwater tables in most areas are significantly lower than the optimum of 1.2 to 1.5 m below surface level (data from the State Environment Agency). In general, it is important that the groundwater table is high enough to produce a confined aquifer to avoid aeration, removal of substances and oxidation (Massmann 2002, Massmann et al. 2003). Therefore, Concept Oderbruch 2010 envisages to set groundwater tables area-wide to optimum levels by reduced drainage and to accept that some depression sites (e. g. the locations of pumping stations) turn to wetlands again because of the flow patterns in the aquifer. In future, the groundwater levels should be regulated by modern speed-controlled pumps, directly in the pumping stations, by means of telemetric coupling of sensors in the areas. This technique promises improved control compared to the currently used regulation of ditch water levels at the pumping stations. In addition, significant savings are to be expected.

The state of geo-hydrological knowledge permits the conclusion that some drainage ditches and also some pumping stations are dispensable for a target-oriented effective water management. Reappearing wet sites cover only small areas and will reduce the available cultivable acreage only negligibly; they have, however, positive ecological effects.

iv) Socio-cultural and touristic activities: The historical farming villages, which were established systematically for immigrating

colonists, and the individual farmsteads (*Loose*) built in later centuries have experienced a steady decline and decay since East German collectivisation of agriculture (1960ff.). This is especially the case with regard to farm buildings which are no longer required, such as stables and barns. Even with collective management, land ownership remained with the former proprietors. And under the new market-economy conditions, predominantly the large farms of socialist times (with a farm size of 1000 to 7000 ha) remained intact. Reestablishment of former family farms was limited to individual cases only. In addition, new agricultural enterprises of several 100 ha to 1000 ha were founded. Leased land is used for production. For the mostly elderly landowners the rent constitutes an important part of their income.

All these processes are accompanied by a declining population. Most notably, it is the young people who leave the region because career prospects are lacking. Labour requirements of the highly productive large-area agriculture are low. To a certain degree, this deficit is now beginning to be compensated by in-migrating people – artists, writers, traditional craftsmen, retirees, organic farmers and others. These new migrants – “new colonists” – have already contributed effectively to the maintenance and preservation of the cultural heritage and also to the fact that this unique cultural landscape, which permanently depends on state subsidies (e.g. for flood control), is more widely known and increasingly accepted by the general public beyond the region and especially in the capital city of Berlin.

This process must continue to form an important component of future adaptation strategies combined with the rejection of planning permission to any kind of non-local trade.

3.2 Fen landscapes in the Rhin-Havel-Luch

Any use of fen soils based on drainage results in aeration of the organic soils and, consequently, leads to their mineralisation combined with a degradation of the hydrological permeability and storage properties and also to a decline of soil fertility. Considering the already critical degree of degradation, there are essentially two alternatives for action for the shallow fens in Rhin-Havel-Luch, with their soil cover of 0.5 to 3 m above the sandy aquifer:

- a) continuation of the existing traditional land use with drainage in springtime and subsequent water retention by control mechanisms in the ditches, accepting further fen degradation. When the fen cover is reduced to less than 0.3 m, ploughing will mix the fen soil with the underlying sand. These mixed soils have good soil-hydrological properties and are suitable for the use as arable land;
- b) rewetting of degraded fen soils and re-establishing of peat-forming vegetation to achieve conservational objectives or for the production of renewable resources.

Designing regional adaptation strategies, combinations of both options are possible, which has already been proposed for the Upper Rhinluch in the ecological development concept by *Kretschmer* of 2000. The bog areas in depression sites, which have been drained only very recently, and with particularly great effort, are favourable areas for rewetting. They can be supplied best with the necessary water – even in the event of decreased water availability due to climate change, when there is not enough water for the entire region. The positive ecological effects and the savings from no longer needed drainage are evident. This land for rewetting has to be acquired by the state, though.

In any case, a functional hydro-technical control system and regional water management under the central responsibility of a water user association are indispensable. This concerns explicitly the water supply of the rewetting areas.

Because the preservation of wetlands in the sandy catchment depends on water availability and, therefore, on groundwater recharge, good infiltration properties in the catchment have to be secured. This can be achieved by continuing cultivation of such sites (e.g. with potatoes or rye) – despite their low productivity.

3.3 Storage of irrigation water in aquifers

With summer precipitation further decreasing in the Berlin-Brandenburg region, there will be an increased need for agricultural irrigation. Beside the necessary cost-benefit calculation, water availability in dry periods during summer will become the decisive criterion for the feasibility of irrigation. Already today withdrawals from low-water discharges of streams and from lakes are no longer allowed due to ecological restrictions. The usual practice of withdrawal of groundwater for irrigation purposes must neither interfere with the abstraction of drinking water nor drain groundwater resources. An appropriate solution would be to compensate summerly deficits in the aquifer by artificial infiltration of water from winterly runoff surpluses or from treated effluent of sewage plants and to refill the depression cones (*Fig. 9*). In sandy-gravelly aquifers the pore volume available for withdrawal or recharge, respectively, is about 25 to 30 % of the overall volume. In the Pleistocene lowland, there are no other options for storage of a comparable capacity.

The storage technology can be controlled easily, given the very slow flow processes in the aquifer. The depression cone, generated by withdrawal during summer, will be refilled by the in-

teraction of natural inflow and artificial infiltration. The depressions are not refilled entirely so that a basin is sustained and no lateral groundwater flow-off occurs. Thereby, potential contamination of areas outside the depression cone can be avoided (*Quast and Messal 2010*).

The development of viable adaptation strategies implies solutions to the following problems: water transport in frost-free pipelines into the area of demand (over distances of 20 to 70 km), high-capacity infiltration basins and associated regeneration / purification technologies. Pilot studies and reference installations are required envisaging practical and economically applicable solutions by 2020.

4. Discussion

Given the extreme floods of the Oder River in 1997 and of the Elbe River in 2002 and 2006, it was advocated by many to abandon the present practice of an economic use of the polders protected by dikes against flooding altogether. The presented arguments concerned mainly the ecological deficits in the no longer flooded areas of the former floodplains and the loss of retention areas. It was also asserted that an absolute flood protection could not be guaranteed, necessary hydro-technical systems caused high costs, a high residual risk remained in case of even more extreme flood levels not experienced so far. In addition, the population in those peripheral rural areas was declining already, and the fertile alluvial soils might be set aside in times of agricultural overproduction. With the preservation of the polders as agricultural land, benefits for a relatively small group of the local population contrast sharply with high governmental expenditures for the preservation of the polders and for water management. This raises the following questions: "How many polders can the state afford in the future?" and "How many polders are still appropriate?" These are definitely

not simply recent issues arising from the present societal importance of ecological goals. It was *Franzius* who already in 1890 compared advantages and disadvantages of dikes very critically in his book "Wasserbau" (*Franzius 1890: 129f.*): Advantages of an agricultural use of entirely diked lands (polders) were not only effective for local residential farmers, but contributed also to the economic strength of the state. On the other hand, there were the disadvantages of faster and unchecked flood flows within profiles reduced by dikes and of higher flood levels between the dikes. Another negative effect was the absence of sludge deposits supporting soil fertility. Since the dikes had been in existence for almost 200 years (so written in 1890!), there would be little sense in making them completely ineffective again. It seemed to be recommendable to lower the dike crest down to the level of the summer dikes or to provide large flooding areas to allow winter flooding of the polder areas, in connection with allowing the input of suspended matter. Populated polders, of course, were to be excluded from such dismantling solutions.

The Oderbruch has always belonged to this category of polders. Despite controversial discussions on its future role after the flood of 1997, Oderbruch has actually never been open to debate, but was immediately secured in its existence by generous federal and EU support for upgrading and reconstruction of the dikes. The district parliament of the district of Märkisch Oderland titled its programme "Oderbruch – land to live on!"

Dismantling and transformation into a summer polder would hardly be a solution today, even for the non-populated polders, exclusively used for agriculture, as summer floods are temporarily linked to particularly high risks after extreme precipitation events (Vb weather situation). The installation of flooding mechanisms and the controlled flooding of polders in certain severe flood situations in accordance with land use could definitely be one option in flood risk management.

The dike constructions along Oder and Elbe have meanwhile been solidly improved, except for the not yet implemented overtoppable crest segments for a controlled flooding of polders in case of an extreme flood, not experienced so far. In the Oderbruch, citizens are rather reluctant with the regard to accepting such scenarios. They fear another devaluation of their estates since the mandatory classification of all polders as “flood-prone areas” according to the EU-Directive of 2007 on flood risk management. In addition, they are very prejudiced towards measures considered necessary to reduce flood risk damage of buildings. The majority of the population simply expect a governmental guarantee of safe technical protection against flooding. Here, compromises are required with personal contributions rendered stepwise by the beneficiaries in the polders. Examples of tailor-made risk management are available from the Mosel River. Critical damage situations occurred during the Thames floods in recent years with the flooding of settlements (damaging electric power supply or drinking water and pollution by faeces).

Basically, the polder areas with their fertile soils have important production potentials for agriculture and are likely to gain even more importance in the future. This is especially true, given the situation in the Berlin-Brandenburg region, where only the subregions of Prignitz in the north-west and Uckermark in the north-east offer similar fertile sites comparable to the polders along the Oder and the Elbe.

For the fen regions of Berlin-Brandenburg, the options mentioned in Section 3.2 allow only either of the two strategic lines of “fen preservation by rewetting with abandonment of previous utilisation” or “fen exploitation on shallow peat land or groundwater sand”. The essential present-day problems here are the obsolete, no longer sufficiently functional hydro-technical control systems, their necessary replacement, the establishment of a regionally responsible water management board, and, above all, the financing of these

necessary measures. It is not to be expected that the users of leased farmland, operating at low economic gross margins, will be able to contribute much to the financing. Therefore, the necessary adaptation solutions for the fen regions require governmental interference, starting with the acquisition of potential rewetting areas and taking them out of utilisation.

The expansion of irrigated farming will only be possible in the future if the necessary water availability will be ensured – even in the case of a climate change caused increase of demand – by means of anticyclical storage during wintery surplus periods, and by the use of the treated effluents from treatment plants. The hydro-geological conditions for water storage in aquifers are favourable in the Berlin-Brandenburg region (*Fig. 10*). And there are no other storage options available, in the magnitude needed.

Storage of water in aquifers as well as use of treated wastewater is being developed in water-scarce regions all over the world (*Huibers and Terwisscha 2007*). The prevention of evaporation losses associated with these measures is considered a further advantage. The present technological know-how can already ensure a safe separation of the storage-affected aquifer sections. This containment of the managed aquifer sections leaves restrictions, still effective in Germany, dispensable. Furthermore, this may help to counteract existing prejudices towards an underground storage of treated wastewater. The amount of 600,000 m³ of treated effluent accumulating every day at the six treatment plants of the city of Berlin illustrates the quantity previously diverted unused into the rivers. Compared with the present annual need for supplemental water, this amount would be sufficient for the irrigation of 100 000 ha of cropland or grassland. The expenses for such a securing of the required water availability have to be added to the total cost of irrigation. On the occasion of the “irrigation days”, held for the three east German

states of Brandenburg, Mecklenburg-Western Pomerania and Saxony-Anhalt, this was accepted by the farmers as an adaptation strategy with regard to their production of special crops.

5. Conclusions

The reclamation of floodplain areas and fen lands for cropland and pasture utilisation in the Berlin-Brandenburg region, performed for more than 300 years, requires a water management adjusted to the production goals and the regional hydrological characteristics. Land and water management are to be adapted to the varying production and land-use objectives and, if necessary, also to changing hydro-climatic conditions using the achieved scientific-technical progress. In the man-made landscapes of the Brandenburg wetland belt, shaped by water-control measures and agronomic progress, an extensive modernisation of the regulation systems and of the water management practices was performed last in the period from 1960 to 1985. Priority was given to the intensification of crop production. Other objectives included environmental aspects and the avoidance of further deficits. Since 1990, again fundamental and drastic changes occurred with the introduction of free-market conditions and with the far higher social status of ecological targets. In addition, there are clear indications of regional impacts of a beginning climate change, particularly increasing summer drought as well as hitherto unusual heavy rainfall and flood events. This situation is met only to a limited extent by the existing hydro-technical system and present water management practices. Innovative future-oriented action and adaptation options and their successive implementation are required. Sustainable integrated land and water resources management is achievable if the desired landscape structures are developed carefully by conscious acting in a regional landscape context. Options for a corrective turn-around have been

kept open, mistakes are recognised and spelled out, and irreversible damage to the landscape functionality has been avoided by preventive action (*Quast and Wenkel 2004*). The adaptation solutions should be focussed on a period up to 2030/2040, during which general regional feedbacks of global change on the land-use sector as well as on critical water balance changes, specifically for the Berlin-Brandenburg region, are to be expected from climate change.

With regard to the Brandenburg wetland belt, good development potentials are seen for the Oderbruch (and other polders located further upstream) as a fertile agricultural area. In the fenland areas agricultural use should be abandoned; these lands should be retained as wetland refuges, wherever there is sufficient water availability for the preservation of wetland.

As for the increasing need for irrigation of agricultural crops on moraine sites, sufficient water availability can only be met by anticyclical storage of winterly water surplus and/or the use of treated wastewater.

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Summary: Towards an Integrated Land and Water Resources Management in Brandenburg's Oderbruch-Havelland Wetland Belt: History and Strategies for the Future

For about 300 years, both the floodplains of the middle Oder, with their rich-in-clay sedimentation soils, and the fen regions of the Rhin-Havel-Luch with their peat soils, have been developed for agricultural use. This required river training, dike construction, drainage systems, cultivation and an operational water management. The costly land reclamation and the later periodic adjustments to the various intensification targets were realized as state projects in order to gain fertile sites with good water availability in sandy and low-in-rainfall Brandenburg. The previous land use resulted in a drastic degradation of the peat soils. The flood-prone polders along the Oder require a very expensive flood risk management. Generally, there are major ecological deficits. Based on many years of own analyses and case studies, options for action and adaptation strategies for the next 20 to 40 years are developed. An expected aggravation of problems resulting from climate change is considered. The Concept Oderbruch 2010 focusses on i) risk mitigation in populated polders in case of overtopping of dikes at extraordinarily extreme flood levels, ii) ecological upgrading by rewetting dike-near zones and depression sites as well as by revitalisation of waters, iii) optimisation of drainage and pumping station operations for agricultural and environmental goals while significantly reducing costs, iv) promotion of broad social acceptance

of the state alimentation permanently needed for securing the polder landscape with its efficient agriculture, including the restoration of cultural heritage of national significance, and a positive socio-cultural change by immigration from the cultural sector. In fen regions, the current land use of the drained land, leading to further degradation, must be given up in favour of ecologically demanded rewetting, wherever water availability is foreseeable. Grassland and cropland use on peat soils and groundwater-sand sites are reasonable compromises. Water availability for the expansion of irrigated agriculture can only be realized by anti-cyclical groundwater withdrawal during the irrigation season and subsequent recharge of the depression cone by artificial infiltration of winterly surplus runoff and treated wastewater.

Zusammenfassung: Wege zu einem integrierten Land- und Wasserressourcenmanagement im brandenburgischen Feuchtgebietsgürtel Oderbruch-Havelland: Historische Entwicklungen und Strategien für die Zukunft

Seit 300 Jahren sind die Auen an der Mittleren Oder mit ihren tonreichen Sedimentböden und auch die Niedermoorregionen im Rhin-Havel-Luch mit ihren Torfböden für die landwirtschaftliche Nutzung erschlossen. Das erforderte Flussregulierungen, Deichbau, Entwässerungssysteme, Kultivierungsarbeiten und ein operatives Wassermanagement. Die aufwendige Landgewinnung und die späteren periodischen Anpassungen an die jeweiligen Intensivierungsziele wurden als Staatsprojekte realisiert, um im sandigen und niederschlagsarmen Brandenburg fruchtbare Standorte mit guter Wasserverfügbarkeit zu gewinnen. Die bisherige Nutzung hat bei den Torfböden zu drastischer Degradierung geführt. Die überschwemmungsgefährdeten Polder an der Oder erfordern ein sehr teures Hochwasserrisikomanagement. Generell gibt es große ökologische Defizite. Auf der Basis langjähriger eigener Analysen und Fallstudien sind Handlungsoptionen und Anpassungsstrategien für die nächsten 20 bis 40 Jahre erarbeitet worden. Zu erwartende Problemverschärfungen aus dem Klimawandel sind dabei berücksichtigt. Das KONZEPT ODERBRUCH 2010 ist fokussiert auf

i) Risikominderung im besiedelten Polder für den Fall des Überströmens der Deiche bei außerordentlich extremen Hochwasserständen, ii) ökologische Aufwertung durch Wiedervernässung in Deichnähe und in Depressionslagen sowie durch Gewässerrevitalisierung, iii) Optimierung von Entwässerung und Schöpfwerksbetrieb für landwirtschaftliche und ökologische Ziele bei gleichzeitiger deutlicher Kostensenkung, iv) Förderung einer breiten gesellschaftlichen Akzeptanz der dauerhaft benötigten staatlichen Alimentation für die Bestandsicherung der Kulturlandschaft im Polder mit effizienter Agrarwirtschaft, Pflege des Kulturerbes von nationaler Bedeutung und einem positiven sozio-kulturellen Wandel durch Immigration von Kulturschaffenden. In den Niedermoorregionen muss die zu weiterer Degradierung führende bisherige Landnutzung entwässerter Flächen zu Gunsten einer ökologisch gebotenen Wiedervernässung aufgegeben werden, soweit Wasserverfügbarkeit dafür absehbar ist. Grünland- und Ackernutzung auf Anmoor- und Grundwassersandstandorten ist ein vertretbarer Kompromiss. Die notwendige Wasserverfügbarkeit für die Erweiterung von bewässerter Landwirtschaft ist nur durch antizyklische Grundwasserentnahme in der Bewässerungssaison mit nachfolgender Wiederauffüllung der Entnahmetrichter über künstliche Infiltration von winterlichen Abflussüberschüssen bzw. gereinigtem Abwasser realisierbar.

Résumé: Vers une gestion intégrée des ressources en terre et en eau dans la ceinture de plaines humides d'Oderbruch-Havelland (Brandebourg, Allemagne): Histoire et stratégies pour l'avenir

Depuis environ 300 ans, les plaines d'inondation de l'Oder centrale, avec des sols riches en argile et de sédimentation, ainsi que les régions de la zone humide Rhin-Havel-Luch avec leurs sols tourbeux ont été développées pour l'utilisation agricole. Avec cela mesures différentes devenaient nécessaires comme la régulation de fleuves, la construction des digues, des systèmes de drainage, des travaux de la culture, et une gestion opérationnelle de l'eau. La culture coûteuse et aussi les suivants ajustements périodiques vers des objectifs d'intensification ont été réalisés comme projets de l'État pour gagner des

sites fertiles avec une bonne disponibilité de l'eau en Brandebourg avec ses sols sableux et sa précipitation faible. L'utilisation du sol antérieure conduit à une dégradation drastique de sols tourbeux. Les polders soumis aux inondations le long de la rivière de l'Oder nécessitent une gestion très coûteuse contre les risques d'inondation. Généralement, d'importants déficits écologiques existent. Basé sur de nombreuses années d'analyses et d'études de cas, des possibilités d'action et des stratégies d'adaptation pour les 20 à 40 années ont été développés. Des durcissements possibles des problèmes résultant du changement climatique sont ainsi envisagés. Le Concept Oderbruch 2010 est axé sur: i) la mitigation des risques dans un polder peuplé en cas de débordement de digues aux niveaux de crues extrêmes, ii) l'amélioration écologique par remouillage près des digues et en sites de dépression et ainsi que par la revitalisation des eaux, iii) l'optimisation du drainage et de l'opération de stations de pompage vers des objectifs agricoles et environnementaux réduisant les coûts en même temps, iv) le renforcement de l'acceptation sociale de l'alimentation par l'État nécessitée en permanence pour la sécurisation du paysage dans les polders avec son agriculture efficace, pour la préservation du patrimoine culturel d'importance nationale, et par un changement socio-

culturel positif par l'immigration continuelle. Dans les régions de tourbières basses, l'utilisation des terres drainées, entraînant une dégradation continue, doit être abandonnée en faveur de remouillage écologique, pourvu que la disponibilité en eau soit prévisible. Exploitation des prairies et des cultures arables sont des compromis raisonnables sur les sites des sols tourbeux et des eaux souterraines-sables. La disponibilité d'eau requise pour l'expansion de l'agriculture irriguée peut être réalisée seulement par un prélèvement des eaux souterraines anticyclique durant la saison d'irrigation et une recharge suivante du cône de dépression par l'infiltration artificielle de surplus de ruissellement hivernal ou des eaux usées traitées.

Prof. Dr.-Ing. habil. Joachim Quast, c/o Leibniz-Centre of Agricultural Landscape Research ZALF, Eberswalder Str. 84, 15374 Müncheberg, Germany, jquast@zalf.de

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