RIPPLES IN CLIO'S POND

Holland Against the Sea

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Dutch artists used mythological imagery to express the need to control water to defend their country, much of which was and is below sea level. In a chamber of the Water Board of Rhineland in Leiden, a huge painting by Caesar van Everdingen and Pieter Post dating from 1655 shows Pallas, goddess of technology, and Mercury, god of commerce, holding the sea gate against Neptune's onslaught. At the time, the Dutch led the world in seaborne trade, providing the financial resources for infrastructure such as dikes and the hydraulic windmills that protected the Netherlands against drowning.

The long historical experience of the Dutch in their struggle against rising sea levels and storm surges has attracted new interest in the 21st century in view of concerns about global warming and events such as the flooding of New Orleans by hurricanes Katrina and Rita. Indeed, communities facing possible inundation in places like the Gulf Coast and Bangladesh now seek the advice of Dutch water management experts. Two major aspects of the Dutch experience may be symbolized by gods in the painting just mentioned: Pallas, standing for the technological advances necessary to control water, and Hermes, standing for the economic and political integration necessary to put a technological infrastructure into place.

No one really knows who first said, "God made the world, but the Dutch made Holland." It has been repeated, however, in numerous books about water management in the Netherlands, where virtually every square kilometer of the landscape bears evidence of human effort. Without constant exertion by its inhabitants, most of the Netherlands would be covered by the North Sea. But it is just as true to say that the precarious nature of the Dutch environment in many ways is a result of actions taken by people in the past.

In the centuries before it had many human inhabitants, the major part of what is today the Netherlands was a flat coastal plain protected by a line of sand hills covered with grass and trees, just inland from the seashore. In the south was the delta where the great rivers Rhine, Meuse, and Scheldt poured into the North Sea through shifting channels as they dropped their silty loads eroded from the continent, forming fluvial deposits.

The lowland area had a high freshwater table, and peat-forming ecosystems dominated the landscape. Peat is created by the accumulation of plant material that does not completely decay because it is soaked in water, and there is too little oxygen for the plant material to break down. Peat moss (sphagnum) and other plants continued to grow and accumulate, so that peat bogs rose above the surrounding fens in extensive pillow-like formations. Capillary action within the peat often raised the water table 4 meters (13 feet) or more above the fens. Because peat is rich in carbon, it makes useful fuel when dried. In the forest-poor Netherlands, it became the basis of an open fuel market. Huge volumes of the peat-covered surface of the land were removed and used to generate heat—a colossal human-caused alteration of the landscape.

Meanwhile, people dug ditches to drain the peat bogs, transforming them into land for agriculture and dwellings. As peat dried it decreased in volume, lowering the elevation of the land surface, interfering with drainage, and increasing the frequency and depth of floods. The land sunk on average a meter per century, so that eventually much of the central lowlands was at or below sea level. As miners cut into peat bogs, sections of the land became freshwater lakes that became ever larger. The so-called "water-wolf" eating away the land was actually peat digging rather than natural sea flooding.

In the Middle Ages, the Dutch built dikes and dams to exclude floodwaters and keep the farm fields dry. At first these efforts were local, but it became obvious that coordination was necessary to keep one village's dikes from causing flooding in another's farmlands., So in the 12th and 13th centuries, water boards were organized to supervise the management of water in certain regions and maintain dikes, canals, dams, locks, and sluices. These were among the first institutions requiring local participation, and they provided a base for the later Dutch republic and the gradual development of democracy. The first to be established were the water boards of Lekdijk Bovendams (in 1122), Rhineland (in 1170), and Groote Waard (in 1230), and many followed. The system still functions today, after some modification.

As it became evident that ditch drainage using gravity was no longer working, landowners began to surround units of land with dikes, creating enclosures called polders. Rainwater and seepage entering a polder made drainage necessary, so sluices were installed at low points, allowing water to empty at low tides, but closed at other times to prevent water from flowing back in. Emptying water from a polder—especially one below sea level—could only be accomplished by pumping.

An answer to the question of polder drainage appeared in the 15th century when the windmill, previously used to grind grain, was adapted to lift water. The first recorded drainage mill was built at Alkmaar by Floris van Alcmade and Jan Grietensoen in 1408. The energy from its sail arms turned a "scoop-wheel" lined with wooden blades that dipped into the water and lifted it a meter or so before discharging it. This came to the notice of Willem VI of Holland, who urged its use throughout his domain. Hundreds were built in the following three centuries.

The major rivers of the southern Netherlands, with shifting channels, presented a complicated challenge. Communities began to line their banks with dikes, and after 1300 these extended from the river mouths far upstream. But over time, it became evident that the more a river is channeled, the higher it rises and the worse floods become if dikes are breached. Though polders were built on the land between the rivers and on the islands in the delta, they remained vulnerable to flooding from rivers and the sea. A constantly shifting environment required the inhabitants to carefully watch the rivers and perform constant labor on dikes and dams.

Also constantly threatening were storm surges sweeping in from the North Sea, impelled by gale winds and intensified by high tides. They usually came years apart, and the Dutch had to guard against complacency in the years between, because the surges could swallow polders and villages, drowning crops, animals, and people in salt water. The natural line of hills and sand dunes along the coast offered a degree of protection, but the line was sometimes breached. In the delta region tidal streams had almost free access. Dikes were built along the North Sea coast to supplement the sand dunes and to protect them against wave erosion. Nevertheless, surges in the 12th and 13th centuries broke through between North Holland and Friesland, forming and enlarging a brackish arm of the sea in the heart of the lowlands called the Zuider Zee, a mixed blessing that offered access to the

world for the merchant fleet but provided a dangerous portal for the North Sea with its surges and constantly gnawing tides and waves. Only the persistent lengthening and strengthening of dikes and dams, along with the multiplication of windmills that pumped drainage water, averted the immersion of the lowland district. As Petra van Dam noted, "The innovations in hydraulic technology of the period 1300-1600 must be understood as [a] response to the rapidly changing conditions in Holland's wetland environment." Defenses were inadequate against strong storm surges, one of which hit the delta and the Zuider Zee in 1421, inundating scores of villages and killing thousands of people. Many square kilometers of polder land were never reclaimed.

The accomplishments of the Dutch in the "Golden Age" of trade, prosperity, empire, and intellectual and artistic flowering included the reclamation of large areas of land and the installation of hydraulic infrastructure. As Simon Schama wrote, "The period between 1550 and 1650, when the political identity of an independent Netherlands nation was being established, was also a time of dramatic physical alteration of its landscape." Financial resources came from the profits of the largest merchant fleet in the world, dominating trade in the North Sea and Baltic, and the acquisition of a colonial empire stretching from the West Indies by the Cape of Good Hope, to Sri Lanka, the East Indies, and Taiwan; for a time, the Dutch also had exclusive access to trade with Japan. A proportion of these resources was invested at home in land reclamation. It is astounding to remember that these developments occurred while the Netherlands was fighting its war of independence (1568-1648) against the Spanish Empire under Philip II, the most powerful monarch in Europe, and his successors. The war had its environmental aspects, since the Dutch at times breached dikes, flooding the land to impede the Spanish armies. In January 1648, the Treaty of Münster ended the war and recognized Dutch self-government.

A major reclamation activity in this period was the draining of a number of lakes and small arms of the sea. This was accomplished by "empolderment," which began by encircling a lake with a dike and an outer drainage canal. Windmills were set up on the dike to pump the water from the lake into the canal. In the case of deeper lakes, it became necessary to put two or more windmills in series. When the polder was dry, the former lakebed could be provided with drainage ditches and parceled out for farms. The area of arable land added by lake reclamation between 1500 and 1800 amounted to an increase of one-third, some 250,000 hectares.

The search for more efficient pumps led to technological improvements. One of these was the Archimedes screw pump. In 1634 a patent was granted to Simon Hulsbos of Leiden for an Archimedean screw used in conjunction with a windmill. Several were installed and partially replaced the older scoop-wheels. Their advantage was that they raised the water 4-5 meters—much higher than scoop-wheels—so a single windmill could replace several older ones, since a screw could lift water faster than the scoop-wheel, with less spilling out.

The water control system as it was improved and expanded during the Golden Age resulted from both the prosperity of that period and planning on a regional scale. Unfortunately the 18th century brought economic decline due to war, competition with England, and depression in the agricultural sector. As a result, land reclamation along with the installation of new pumping mills slowed. There was an increase in floods from the rivers, possibly because dike maintenance was neglected.

River floods were also caused by a combination of the impact of the Little Ice Age (1400-1800) and human interference with the riverbeds. In springtime, as river ice began to break, huge ice mountains up to 30 meters (100 feet) would form. During that time even large rivers got entirely

blocked and shipping stopped. After 1600, the Dutch took measures to streamline and direct the flow. One of the constructions was "groynes," small dikes built into the water to slow down the water at the shores and prevent erosion. Exactly at the points where these obstructions occurred, ice mountains would form and water would flood the dikes, undermining them and causing them to break. People observed this, so why did they continue such practices? Erosion occurred everywhere and led to costs to adjoining Water Boards, whereas dike breaking only occurred at certain places, hopefully in a neighbor's dike. No integrated management of the big rivers yet existed.

In 1731 a disaster struck dikes along the North Sea coast, which were supported and covered with piles and other wooden structures. An organism called the pileworm, which is a mollusk with an awesome ability to bore into wood and rapidly turn it into a structure resembling Swiss cheese, was discovered in the millions infesting the dikes. It is not known why the pileworm, also called teredo, appeared so suddenly, although an increase in the salinity of the seawater in the area is suggested, since the organism prefers highly saline water. Sailors knew the teredo as shipworm—wooden ships were sheathed in copper to keep it from riddling their hulls—and perhaps a ship brought a new variety to the Dutch coast. The only way to save the dikes was to provide them with stone facing, an expensive undertaking, because stone had to be imported from Norway and Belgium.

After the French Revolution, French armies invaded the Netherlands and set up a Batavian Republic with a number of innovations. In regard to the environment, one of the centralizing reforms was the founding of the Rijkswaterstaat, a national water administration that undertook large water management projects and established a professional school for hydraulic engineers. The Rijkswaterstaat met with resistance from the water boards, who jealously guarded their regional authority and were unwilling to cede power to the center. Working out cooperation between the national agency and the water boards took half a century. The Rijkswaterstaat proved to be a permanent institution, lasting through the Napoleonic period and the establishment of the Kingdom of the Netherlands in 1813. Weathering stormy periods, both literally and metaphorically, it exists today because historic experience has shown that a national policy on landscape and water management is necessary for the survival of the Netherlands. Water boards still exist with responsibility for local water control and quality.

As the Industrial Revolution got under way, Dutch engineers saw the potential of steam engines to drive drainage pumps. One advantage over windmills was that steam engines could operate continuously, not just when the wind was blowing at the right speed. When driving scoop-wheels, however, steam engines proved uneconomical because they used too much coal. In 1837, two steam engines turning Archimedean screw pumps were used in draining a polder in South Holland and proved more economical. The centrifugal pump was also introduced and demonstrated superior efficiency. In the second half of the 19th century, steam engines were commonly employed for pumping, and by 1896 they were responsible for three-fifths of total mechanized land drainage. In the 20th century, experiments were made with internal combustion engines to drive several types of pump, but the source of energy that became dominant was electricity. These technological improvements rendered the windmill obsolete, and hundreds were demolished until it seemed that a typical element of the Dutch cultural landscape might disappear. A large number of them, however, were preserved as museums and landmarks, prized by both the Dutch and tourists.

The 20th century brought both human-caused and natural destruction. But it also saw the construction of works of unprecedented size in attempts to control the sea and rivers. The first of these was the separation of the Zuider Zee from the North Sea by a dam 32 kilometers long

between North Holland and Friesland, which was built between 1927 and 1932. The barrier was 3.5 meters higher than the highest storm surge then known. The enclosed area became a freshwater lake renamed the IJsselmeer, providing a major resource to counter salinization. The saltwater fish that had inhabited it were replaced by freshwater species, and the fishing fleet switched from catching herring and anchovy to eel and pike-perch. Several huge polders were enclosed and drained inside the new lake, creating enough arable land to add a new province to the Netherlands.

In addition to the terrible cost in human lives of the Second World War and the German occupation, there were also environmental costs. Deliberate breaching of dikes was done by the Dutch and their allies, and by the Germans. Maintenance lagged due to the unavailability of materials, equipment, and fuel.

After the war, gaps in the dikes were sealed and reinforced, and polder lands were drained, while plans were drafted to dam the Meuse River Delta against salt seepage and storms. Any doubt that existed of the necessity to shore up defenses against the sea came to an end with the devastating storm surge of February 1953, which made scores of breaches in the dikes, inundated 200,000 hectares (770 square miles) of land, drowned 1,835 people, and forced the evacuation of 72,000. The brunt of the surge hit the Delta, so the Rijkswaterstaat concentrated its efforts after the flood on a large-scale project to realign river dikes and construct barriers against storm surges in the river mouths. But by 1970 many leaders of public opinion—writers, artists, and academics, including scientists—raised environmental objections to some aspects of the plan and received wide support. Not only safety, they argued, but values such as the diversity of wildlife, the beauty of the landscape, and preservation of objects of cultural history should also receive consideration. They also pointed out that if dams blocked the river mouths from the sea, the resulting lakes would be dead water where pollution would accumulate.

Bureaucrats and engineers were initially outraged at these criticisms, but the design that emerged after the political struggle showed the Dutch genius for compromise and action as a community. The new plans integrated environmental concerns with technological innovation. For example, the centerpiece of the project, the 9-kilometer storm surge barrier that protects the Oosterschelde estuary, has a 4-kilometer section of vertical sluice gates with steel doors 42 meters wide. The gates are ordinarily open to allow the tides to pass through, but they are closed when a storm surge is predicted more than 3 meters above normal high tide, an event that happened on average about once a year between 1986 (the year it was completed) and 2007. The Oosterschelde, with its rich variety of sea life, was designated the Netherlands' largest national park in 2002. This barrier is the largest of thirteen connecting islands and peninsulas in the Delta; in addition 300 other structures and 16,500 kilometers of dikes are part of the Delta Works.

At one end of the Oosterschelde barrier, an inscription announces, "Here the tide is ruled by the wind, the moon, and us." Most Dutch experts would not express that much hubris, though the project has been declared one of the world's seven engineering wonders. The sea and the rivers are ever changing, and the battle to safeguard the land is never finally won. The Netherlands is understandably one of the nations most concerned about global warming, rising sea levels, and potential increases in the energy of storm surges. The Dutch have begun to take steps to fortify coastal defenses. The Rijkswaterstaat is dredging up sand from the North Sea and dumping it in the water in front of the beaches to build them up. They have also built artificial dunes planted with grass to counter wind erosion in the weakest spots.

One proposal for the future includes a higher vanguard dike along the entire North Sea coast from border to border, storage basins for river water, and new "super pumping stations" to empty river water into the sea. Such a plan would continue the historical trajectory of water control works and would represent an escalation of human attempts to control nature by orders of magnitude.

The success of Dutch efforts to sustain the land was and is possible only because the country's unique environmental circumstances led to the gradual ascent of the public realm over localism and the privatistic aspects of the market economy. Civic freedom in the Netherlands allows environmental concerns to weigh in the social choices that must continue to be made for the survival of land and community.