May2021

Groundwater and the Beaver Creek Wetlands

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Introduction

The Beaver Creek wetland corridor contains many types of wetland and related upland habitat. One feature of this geographic setting is that it is rich in gravelly soils deposited as the Wisconsin Age glaciers receded about 10,000 to 12,000 years ago. Much of it was deposited in a deep preglacial valley forming what geologists call an outwash plain. Beaver Creek runs through the center of the valley with more glacial gravel deposits on either side. When it rains, a high percentage of the water enters the soil instead of forming creeks that join the Beaver Creek. The water absorbed by the gravel rich soil continues on a downward path eventually forming an aquifer in the deepest parts of the former valley. At the surface of the present valley, the creek is flanked by rich soils indicating that they were once wetland. Farms there must use drainage ditches or tiles to carry the excess water off fields to Beaver Creek so fields can be planted. In many places, the water table (the top of the aquifer) is so close to the surface that effective drainage could never be achieved and those remained as wetlands. Many of those wetlands are the type called *fens.* These are wetlands fed by groundwater – further defined later. The fens between New Germany Trebein and Fairground roads are good examples. In other areas the water table is high enough to cause difficulty achieving tillable conditions most years. Those are good places to consider being returned to functional wetlands. The Beaver Creek Wetlands Association formed in 1988. BCWA recognized that many of these wetlands were rare fens and most of these wetlands could provide ecosystem functions of value to all who live in the region. The BCWA decided, with great community support, that they would work to protect and manage the ecosystem of these wetlands for the good of the community.

About the Beaver Creek Wetlands Association (BCWA)

BCWA was founded as a 501(c)3 charitable organization by volunteers who wanted to save the high quality fen-based ecosystem found along either side of Beaver Creek. Their objective is met by working with partners such as local park systems, by memberships and by funding assistance from local, state and federal grant sources. Most of the work on the day-to-day conservation is carried out by volunteers. BCWA works with local officials to help them make decisions that are protective of the wetlands in any developments in the watersheds of Beaver Creek and Little Beaver Creek. BCWA prefers to work *with* developers and regulators to solve issues that could do harm to wetlands or make development impossible.

Definition of and Protection of Wetlands

Under the Clean Water Act, regulations of US and local EPA and the US Army Corps of Engineers are used to determine impacts to wetlands. Impacts to wetlands can be permitted but the permits are issued only if an approved plan is made to mitigate those impacts. Wetlands are defined by three essential characteristics. 1) They contain soils that were formed in anaerobic, water saturated conditions, 2) Over 50% of the plants that grow there are specially adapted to grow in water saturated soils, 3) The soils are saturated with water during the growing season for about 3 weeks minimum (varying with geographic location).

Ohio EPA uses the Ohio Rapid Assessment Method (ORAM) to numerically evaluate the quality of wetlands in the state. Three quality levels are recognized, (1, 2, and 3) with three being the highest quality. Mitigation of impacts always strives to improve a site to a higher quality level.

There are many kinds of wetlands, but the four major categories are Swamps, Marshes, Bogs and Fens. The first three are generally fed by surface water and fens are fed by groundwater. Swamps have trees and some period of standing water and Marshes have non-woody vegetation and shallow standing water for some part of the year. Bogs are fed solely by rainfall and snow melt and tend to be more acid than the others. Fens are defined below because of their unique characteristics and their high ecologic value.

Definition of Fens

Fens are peat accumulating (producing) wetlands that are fed by groundwater, have a circumneutral pH (not acid or alkaline) and are dominated by sedges and other grass-like plants. The water, usually having travelled through limestone rich glacial deposits in the Midwest has a high mineral content (mostly due to calcium and magnesium). Those minerals are needed by some fen plants and under the right conditions the water coming to the surface encounters conditions that cause the minerals to precipitate (form solid deposits from those dissolved in the groundwater) into deposits called marl, tufa and travertine. Such fens are often referred to as calcareous fens and because of the rare plants that require these minerals, calcareous fens are usually more highly protected. All fens in the Beaver Creek Wetlands system are calcareous. With groundwater as the source of water, the temperature of soils in the fen is nearly constant throughout the year in the deep root zone. Roots are known to penetrate very deeply in fens and are specially adapted to receive oxygen from the leaves that is then transported all the way to the deepest roots.

Peat accumulation can also be described as carbon accumulation and in a time when carbon sequestration is highly important, peat is a good example of how nature can store carbon, keeping it out of our atmosphere. Fens have an extremely diverse flora and fauna. Studies done locally have never fully cataloged all the plant life, but well over 500 species can be found in fens of the entire wetland corridor. Fen and Bog definitions are often confusing. Bogs are peat accumulating, but have acid pH, and their plant life is dominated by *Sphagnum* mosses and, most importantly, they get their water from rainfall or snowmelt, and thus bogs are not mineral rich. Generally speaking, bogs are far less diverse than fens, but do, like fens, contain many rare species of plants.

Function and Values of the Wetlands

Wetlands serve many important functions and opportunities such as:

- Flood control
- Cleansing of air and water including detoxification of many human made chemicals
- Moderation of climate
- Sequestration of carbon
- Preservation of biotic diversity
- Recreation
- Education
- Research
- A storehouse of genetic elements we don’t fully know about, but that may be the basis for discoveries yet to come.

Relation of Fens to Geological Features

In much of the Midwest, glacial activity thousands of years ago set the stage for fens to form. Glaciers moved over a river where the Beaver Creek Valley now lies. As the glacier melted back at the end of ice age, around 10,000 to 12,000 years ago, it filled the preexisting valley with deposits. The melt waters filled existing valleys with deposits of sand, gravel, clays and to the East and West deposited piles of similar materials between lobes of the glacier and even under the melting ice. Sometimes piles of glacial material accumulated at the place where the glacier stalled before it began to melt back north or in valleys between lobes of the glaciers. These deposits can still be recognized today as the ridges, humps and bumps in topography of Greene County and surrounding areas. What is most important is that these sandy/gravelly soils allow rainfall to seep into the ground and form aquifers, deposits that hold and carry slowly moving groundwater. Water always has a tendency to move down, where it can, to the lowest place that allows movement (or would do so very much more slowly). In the Beaver Creek system, the hills to the East and West of the valley are rich in sand and gravel. Soil occasionally has impervious layers of clay, likely wind-blown deposits, but, overall, those hills provide a gravel rich path for water to the lower elevations below the surface. Water flows into gravels that were deposited from the melting glaciers and now rest in a very wide buried river valley. This ancient river valley now contains the aquifer that is tapped by Greene County to provide drinking water. It just so happens that when the geologic deposits are in just the right location water can return to the surface sometimes as springs that form creeks, and at times the discharge over thousands of years forms fens.

Fens form where water from the aquifer spills out at the ground surface. Since water likes to run downhill this is not intuitive, but there is an explanation.

The recharge area (Figure 1) is a place where rainfall can enter the ground and travel through the gravel rich deposit beneath. The impermeable deposits are clay rich and water does not travel well through it. Where the gravel rich deposit comes to the small opening at the valley bottom water seeps out. At first, not long after the glaciers had disappeared, springs at this discharge point began to form a deposit of peat composed of the poorly decomposed leaves, stems and rots of the plants growing there. Decomposition is incomplete because the site is always water saturated allowing almost no oxygen, needed for decomposition, to enter. Over thousands of years this deposit grew in height and spread laterally forming a mound fen. The apparent up-flow of water at the fen might better be called discharge to the surface, but as the mound grew in height an up-flow developed due to the pressure behind the water allowing water to rise to the top of the mound.

Because the recharge area is large compared to the discharge area, the outflow is slow enough that rainfall is sufficient to maintain the pressure supporting the water flow. The pressure is proportional to the height of land at the recharge area. One might compare this system to the way a water tower maintains pressure in a water supply to homes. The size of the recharge area is important and the larger its area the better the system is at supplying water to the fen that has formed. Water goes into the aquifer faster than it goes out. Whether or not a fen can form depends on the geological history of the site.

Figure 1

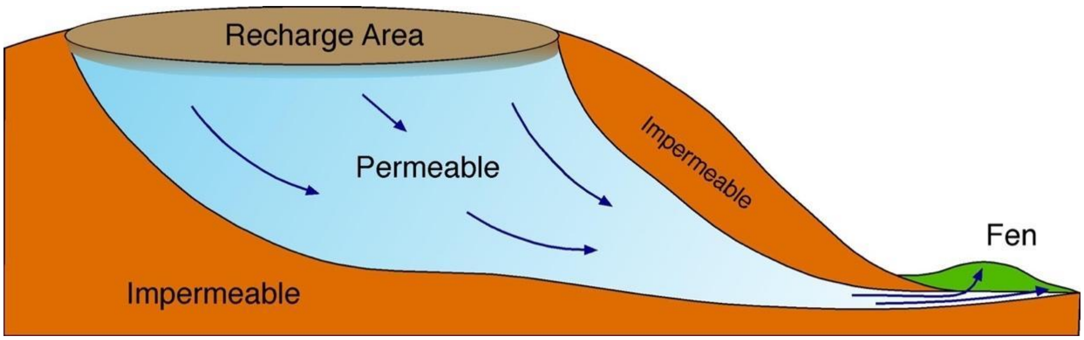
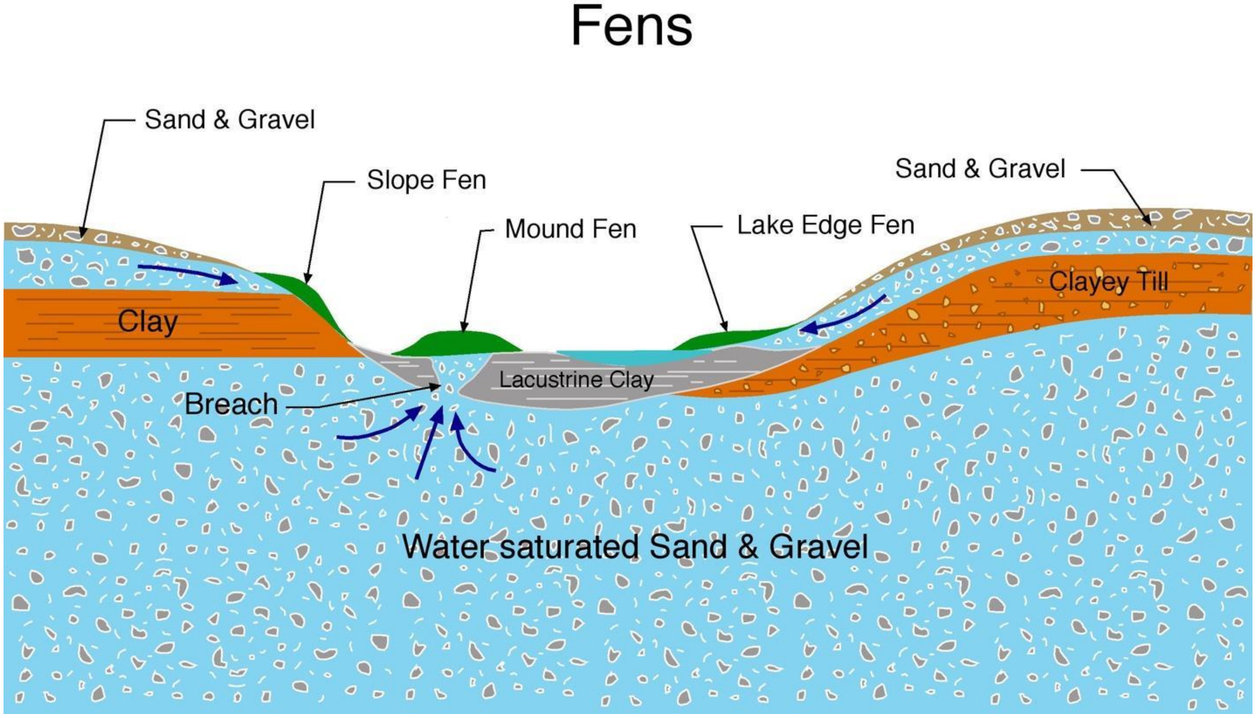


Figure 2



In figure 2, you can see that fens can form wherever water continuously comes to the surface. In this illustration the recharge area can be anywhere the deposits allow water to enter the ground. Water (blue) can travel for miles in the sand and gravel (the aquifer). Arrows indicate the flow pattern that is generally downhill. Where water in the aquifer meets impermeable layers like clay, the water can be directed to discharge points at the surface. In the middle of the diagram, water is shown flowing up through a breach in a lake clay deposit (lacustrine clay). This water is rising because it is under pressure and that must be because the recharge point is out of the illustration, but at some higher elevation as shown in figure 1. All of these fen types can be found in Ohio and throughout places in the Midwest where glaciers left similar deposits.

Special Aspects and Values of Fens

Groundwater rising to the surface of a fen has traveled through gravel rich soil and then through the roots of plants and the bacteria associated with them. It picks up minerals from the glacial deposits, often calcium and some magnesium. During that journey water goes through nature's biogeochemical treatment. It has been shown that water contaminated with things like carcinogenic chlorinated ethenes can be degraded to harmless compounds as it moves through fens. The bacteria involved in these reactions are just beginning to be studied and many researchers have seen similar results with numerous compounds. Plants and bacteria work together to provide decontamination. There are 10s of thousands of bacteria in every gram of fen soil, and some kinds of bacteria there are functionally able to alter many different compounds. The deep roots of fen plants release oxygen, usually absent in deep soils, creating gradients of oxygen in the root zone that allow growth of thousands of kinds bacteria and carry out chemical reactions that can range from aerobic (oxygen requiring) to anaerobic (in absence of oxygen). In addition, roots extending deeply into the soil provide a tremendous surface area for these reactions. As water moves up through these roots and their associated bacteria the degradation of some compounds causes the environment to change, allowing yet other chemical reactions to take place, creating stepwise degradation using different bacteria and different microenvironments for each step.

Discharge of water to the surface through the roots all year long can keep bioremediation activity going in many plants. The temperature in the soil is stable because the temperature of the groundwater from deep sources is stable. This allows for stable ecosystems to establish as they encounter potentially toxic compounds in the incoming water. A constant groundwater temperature of around 54F is supportive of the bacteria found locally. Even though a plant looks dormant on the surface in winter, underground it is still alive and carrying out many activities. Thus, seasonal air temperature changes have little impact. Researchers from Wright State and the Air Force Institute of Technology have constructed fens showing many of these processes. Low nutrient conditions exist in groundwater because it has moved through many kinds of biological, physical and chemical filters. Water flowing out of the fens tends to take with it the degradation products of the chemicals and many like carbon dioxide are released to the air.

When too much of the stressing chemicals get into the aquifer there may not be time to degrade it all. So, there are limits to what a fen or fen-like bioremediation system can take. Fens can be damaged by high nutrient conditions (Nitrogen and Phosphorus) because their plants tend to grow slowly and high nutrient conditions favor fast growing invasive plants, often annuals, that do not function during winter months like the perennial fen native plants. Under these conditions, diversity among the plants and bacteria is lost and less degradation of pollutants can occur.

Fens are part of a water recycling system. Water emerging from fens has been cleansed as rainfall enters the ground and travels via the aquifer and then is cleansed again when it comes back to the surface of the fen. Water leaving the fen can reenter the groundwater as it pours out in sheet flow or in small streams that become part of the watershed's stream system. Those streams have places where they lose water to the aquifer below them when the stream geology is right, starting another recycling cycle.

The bacteria in fens are of so many kinds that many do not even have names. What we know is that different bacteria have different kinds of abilities packaged in their DNA. Fens are a library of unread sets of instructions. That DNA can be put to work for more things than most of us can even imagine. Those bacteria are intimately associated with the plants they live next to, on, and within. Disturbance of that microbial ecosystem can result in changes to the way fens behave, what they can do, or even if they survive. We need to protect this resource as we learn how it works and what it can do for us now and in the future.

Protection of Uplands Adjacent to the Wetlands

Because fens are rare and contain a great variety of rare and unusual wetland plants, they are some of the most highly protected and valued ecosystems in the world. Since they are uniquely linked to surface emerging groundwater, the quality of groundwater is of paramount importance in their protection. Until quite recently, our knowledge of groundwater, its behavior and origins has been limited. Scientists didn't understand how important groundwater was to the function and ecological stability of fens. Groundwater protection has been mainly aimed at our ability to provide our citizens with drinking water of suitable quality. Lately, some supplies of groundwater have come under scrutiny because we have found dangerous chemicals there and intense research is underway to understand how we can mitigate the presence of these substance in groundwater or, just as important, prevent them getting there in the first place.

The needs of fens are similar, but a bit different, than those of other habitats. They need groundwater supply to the roots of the plants on a year-round basis and the presence of things like fertilizer in the water, mainly nitrogen and phosphorus compounds, can promote the growth of plants that prevent the growth of the wide variety of typical fen plants, some found only in fens. Loss of groundwater flow to the surface of fens can likewise do the same thing. Rainwater or flooding from streams or rivers or any other surface derived source will not suffice to meet the needs of fens.

Because groundwater that supplies fens ultimately comes from rain falling on land at an equal or more often higher elevation than where it discharges to the fen surface, the activity of humans in those higher elevations is important. Application of fertilizers, pesticides, industrial chemicals, fire retardants and runoff from roads (combustion products, petroleum products and ice control products) eventually percolate into the groundwater and travel in aquifers to a point where they can be released at the surface. Travel through the soil, beds of roots, and filtration through sediments and glacial deposits can, with the help of microbes, degrade some of these compounds to harmless compounds. Like any system it can be overloaded to the point at which many of these compounds will be discharged in the root zone and over the surface of fens. Fens that have developed over millennia are not capable of tolerating many of these human-made chemicals and those chemicals may cause loss of many species of the plants that make fens so special. Likewise, the animals that are dependent on fens for sources of food, cover and a place to rear young are lost to these unseen or unrecognized compounds.

While fens can be very sensitive, we know they can deal successfully with many compounds. What we have learned by studying fens has allowed us to mimic their function in man-made bioremediation projects. As time goes on, we will learn more that can be applied to treatment and it is likely they can be made more resilient under controlled conditions. Already some success with this kind of constructed fen has been demonstrated (Amon et al 2007).

Primary Threats to the Fen Ecosystem

• Fens depend on a continuous supply of mineral rich groundwater that has low levels of nutrients like nitrogen and phosphorus.

• Nitrogen and phosphorus from farming operations and from lawn care activities have the potential to decrease diversity among the plants of the fen community. The Beaver Creek wetland system is showing signs of this. Fast growing (aggressive) plants such as cattails and Reed Canarygrass can overtake the fen plants by growing faster than the fen plants and the shading caused by their presence (they are much taller than fen plants) deprives the fen plants of the sunlight needed to grow.

• Pumping of water for water supplies can lower the amount of water available and the surface of the fens can dry out and many species will die. Some pumping used to build large housing areas has temporarily lowered water supply to local fens. The temporary nature of the water withdrawal was short of doing permanent damage, but care must be taken to not repeat such threats.

• Drainage through farm tiles and ditches has been used for hundreds of years and has caused the total loss of many fens.

• Ecosystem challenges such as loss of diversity when invasive non-native plants replace natural fen flora has wiped out the diversity and thus the function of many fens.

• Stormwater flooding of fens can reverse the flow patterns of water and introduce toxic materials to fens. It may also carry seeds of invasive species.

Ways to Protect the Wetlands

Ownership of the fen can't prevent contaminants from outside the fen from harming it. It can allow for restoration activities, and management that improves fen function. Organizations like the Beaver Creek Wetlands Association work with officials, conservation partners and member donors to carry out conservation best practices. BCWA as a land trust can own land or hold protective conservation easements on privately held lands, they also educate the public on the values of the land protected and provide places for recreation, education and relaxation.

How and Where to See the Beaver Creek Wetlands and its Fens

Siebenthaler Fen

All that is visible from the trail past the first patch of woods is fen. Water constantly comes to the surface and goes to the creek. Very few places have standing water more than a few inches unless beaver have caused ponding. This is likely a fen over a breach as is seen in Figure 2. It is likely that there are several breaches and that water comes from three high ground locations to the East and West providing strong hydrostatic pressure.

James Amon Biodiversity Reserve

From the prairie, take any of the trails down the slope and where land begins to level out. Springs are all along the base of the slope. The very gentle slope further toward open water is fen as well. At the water's edge the wetland begins to have lots of standing water and emergent vegetation like reeds and cattails. That part is called marsh and receives considerable surface runoff in addition to groundwater-fed springs. This fen is close to a lake edge fen as seen in Figure 2. It is somewhat like a slope fen as well.

Koogler Prairie and Wetland Reserve

Take the trail to the left from parking and go to first part of the boardwalk and look at the transition from Shrub-forest to wetland. Springs can be seen pouring from the base of the slope. The wet meadow without trees is fen as it bleeds out water year-round and that water moves to Beaver Creek, nearby. This is a slope fen (Figure 2) at the base of the slope, and it continues south for over hundreds of yards grading into a swamp that can be seen on the south part of the loop trail.

Pearl's Fen

This is a mound fen and the mound should be noticeable in every direction except toward the parking lot. At the bridge, the creek has cut down and reveals strong flow of water from the bottom of the creek. The whole mound over thousands of years has been built by this constant source of water that allows the growth and accumulation of peat. This fen appears to have a source of water just down-slope from its eastern edge. It is under study now (2021) to find the place where water is rising under the most pressure. Early results suggest that that place is on the north edge, but water is being drawn away by the deeply cut creek, probably human enhanced, in the middle of the fen.

References – all published in peer-reviewed research journals

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