Chapter 10

Wetlands and Agriculture

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The values of wetlands are commonly known among the general population—waterfowl habitat, sport fisheries, timber, recreation, and so forth. More importantly, ecological wetland functions such as nutrient cycling and mitigation (filtering) of pollutants are becoming more widely recognized, especially in the agricultural community. So then what is the importance of agriculture and wetlands? Although their affiliation may seem antagonistic at first glance, it is more closely related to one of mutualism. Certain agricultural crops thrive in the moist, rich wetland soils, while wetlands near agricultural lands receive nutrient inputs to maintain an ecosystem balance. More importantly, this relationship shows the intricate balance between viable food and fiber production and preservation of natural resources. Wetlands, both natural and constructed, serve as important habitats for a variety of plants and animals. They also serve as natural buffers for rivers, lakes, and streams. By maintaining these wetlands around production agriculture landscapes, significant improvements in water quality may be achieved. This will have a direct effect upon the preservation of our aquatic resources. Therefore it is imperative to not only discuss the historical relationship of agriculture and wetlands, but to also focus on future symbiotic relationships resulting in sustained food and fiber production, while not compromising the ecological integrity of the surrounding watershed. After a brief discussion of the historical relationship between agriculture and wetlands, this chapter will address research results of wetland mitigation of specific agricultural pollutants—sediments, bacteria, pesticides, and nutrients. Further evaluation of the success of riparian wetland habitat will be presented, as well as new discoveries of drainage ditch wetlands for pesticide mitigation. Conclusions and recommendations for future research needs will conclude the chapter.

Background

Agriculture had its beginnings in the fertile floodplains of the large river valleys of the world where fresh silt was deposited annually and seeds were sown in wet soils enriched with new sediment. Today, subsistence cultures still grow plants in the wet areas along wetland fringes, with the most common wetland agriculture being rice paddy cultivation (Hook 1993). Some seasonal marshes and wet floodplains around the world are now human-managed wetlands. The most common example is the rice field; however, freshwater and brackish aquaculture are also common practices.

Until recently, wetlands not directly used for agriculture have been treated by many with contempt as wastelands. This contempt has resulted in the loss of many areas of wetlands over the years. In tropical regions, it is estimated that recent losses of mangroves have been 6 percent in Indonesia, 8 percent in Malaysia, 20 percent in Thailand, and 50 percent in the Philippines (Gosselink and Maltby 1990). In temperate zones, most wetlands have been drained and converted to agricultural systems. It is estimated that over 1.6 million square kilometers of wetlands had been drained prior to 1985 (L'vovich and White 1990), of which three-fourths were in the temperate regions. Williams (1990) and Gosselink and Maltby (1990) have thoroughly discussed wetland drainage for agriculture with detailed examples from the United States, Europe, and Australia. According to the U.S. Department of Agriculture, Natural Resources Conservation Service (USDA NRCS), until the mid-1950s, agriculture was responsible for an estimated 87 percent of wetland conversion. For the period of 1982–1992, only 20 percent of the total wetland losses were attributed to agriculture, while 57 percent were attributed to urban development (USDA NRCS 1999).

Wetland losses generally result in major hydrologic changes and species declines. Impacts from agriculture involve additional complications, including inputs of nutrients (primarily nitrogen and phosphorus), addition of pesticides, and lack of fertility replacement with reduced flooding cycles. At some point, the sustainability of wetland ecosystems becomes intertwined with the sustainability of agro-ecosystems.

Natural wetlands, at the interface of upland or floodplain agriculture, have served as the interface and buffer between agriculture and other ecosystems. However, many natural wetlands are at or beyond their carrying capacity. Constructed wetlands, therefore, are being developed to provide the filtering and processing component of the landscape previously provided by natural wetlands. Constructed wetlands are areas of designed hydrology (water), hydrosoils (soils), and hydrophytes (plants). They may be constructed in former wetland areas or other suitable locations. Thus, constructed wetlands will more and more become partners with agriculture in water-quality improvement and protection.

Nonpoint Source Agricultural Pollutants

Excessive sediments, nutrients, pesticides, and bacteria are the most common potential agricultural contaminants. Fowler and Heady (1981) considered sediments to be the single largest pollutant affecting aquatic systems, and according to the U.S. Environmental Protection Agency (U.S. EPA), sediment is the primary impairment cause listed on individual states' 303(d) lists (U.S. EPA 2001). These lists identify bodies of water targeted for development of total maximum daily loads (TMDLs) for specified pollutants. Sediments were listed as the top cause of impairment, responsible for 6,133 of 37,428 identifiable, reported impairments (16 percent), followed by pathogens (14 percent), and nutrients (13 percent). Pesticides were identified for approximately 4 percent of listed impairments (U.S. EPA 2001).

Nonpoint Source Agricultural Pollutants and Wetlands

With increased concern over water-quality issues across the globe, more emphasis is being placed on best management practices (BMPs) designed to decrease deleterious effects of potential agricultural pollutants to downstream receiving systems. One suggestion involves using constructed wetlands as a buffer between agricultural fields and aquatic receiving systems. This is an approved practice, with standards already put into place by the Natural Resources Conservation Service (USDA NRCS 2000). Mitsch (1993) outlined some preliminary principles regarding ecological engineering of constructed wetlands that minimize nonpoint source pollution. Among his suggestions:

- Constructed wetlands should be designed for minimal maintenance
- Constructed wetlands should mimic natural systems
- Utilization of natural energies should be incorporated in the design
- Wetland systems must be designed with the landscape in mind
- Multiple objectives should be incorporated in the design, with at least one identified major objective and several secondary objectives
- Sufficient time must be allowed for the system to operate properly.

Sediments and Wetlands

Sediments are unique contaminants, since other potential pollutants (such as pesticides, phosphorus, and metals) often piggyback on sediment particles. Therefore, efforts to decrease the amount of sediment entering receiving waterbodies often lead to concomitant decreases in potential pollutants such as phosphorus and pesticides. Several studies have reported on the use of constructed wetlands to reduce sediment outflow into receiving waterbodies. Higgins et al.

(1993) reported on the use of a constructed wetland to control agricultural runoff. Performed on the Long Lake watershed in northern Maine, this study focused on combining several best management practices for optimum nonpoint source runoff mitigation. Utilizing the combination of sedimentation basin, level lip spreader, grass filter strip, constructed wetland, and detention pond, researchers documented that annual removal efficiencies of total suspended solids were 96–97 percent, but that seasonal removal rates were quite variable. Spring outflow of suspended sediment was actually higher than the inflow due to the high groundwater table that surfaced in the system during April and May (Higgins et al. 1993).

In their classic text *Wetlands*, Mitsch and Gosselink (1993) reviewed works reported by Knight (1990) and Mitsch (1992) regarding comparisons of sediment retention by natural, nonpoint source (wetlands receiving nonpoint source effluent) and wastewater constructed wetlands (both surface and subsurface flow wetlands). The only data for a natural wetland indicated approximately 3 percent sediment retention, while nonpoint source wetlands retained between 88 and 98 percent of sediment input. Surface and subsurface flow constructed wastewater wetlands retained between 61and 98 percent and 49 and 89 percent, respectively.

Elder and Goddard (1996) reported mean suspended sediment retention of 48 percent in the Jackson Creek Wetland. This wetland area is actually a 95-acre shallow prairie marsh housing three sediment retention ponds. The project goals were to decrease the amount of sediment and nutrient inflow into Delavan Lake. Other results indicated that there was consistent sediment retention throughout the year, including periods where retention was up to 80 percent.

Bacteria and Wetlands

Although bacteria are not typically considered agricultural contaminants, with increased poultry, hog, and dairy production, bacteria are becoming more prevalent as nonpoint source pollutants within waterbodies. Much work has been published in the literature regarding the efficiency of constructed wetlands in mitigating potential effects of dairy farm effluent. Going beyond typical reductions in fecal coliforms, most constructed wetland and dairy wastewater research has also examined changes in nutrient concentrations, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and suspended solids.

Cooper and Testa (1997) examined efficiency of three constructed wetland cells located on a dairy farm in northern Mississippi, which housed an average of eighty Holstein cattle (ranging from sixty to one hundred head). The three parallel, non-sloped cells were 6 meters in width and 24 meters in length and were dominated by *Scirpus* (bulrush). Results of nonpoint source pollutant reduction were grouped according to weather patterns—warm and cool—with warm representing spring and summer, and cool representing fall and winter. Warm season results indicated decreases in COD, BOD, and fecal coliforms of 50 percent, 68 percent, and 89 percent, respectively. Cool season results revealed decreases in COD, BOD, and fecal coliforms of 79 percent, 84 percent, and 97 percent, respectively.

Reaves and DuBowy (1997) reported results from constructed wetlands on a similar-sized dairy operation (seventy cows) in Kosciusko County, Indiana. In this system, two wetland cells in series were used, one rectangular-shaped (64.6 × 14 meters) and the other horseshoe-shaped, with the two arms measuring 32.3 × 14 meters each and the upper end measuring 9 × 6.1 meters. Outflow from the second cell indicated an 83–93 percent decrease in COD.

Using a combination of constructed wetland cells, a settling basin, and a vegetative filter strip, Schaafsma et al. (2000) assessed effects of BMPs on dairy wastewater. The system under investigation had been designed to treat waste for 170 cows, basically double that of the above described studies. Several parameters were examined for reduction, including total nitrogen, ammonia, total phosphorus, ortho-phosphate, suspended solids, and BOD. In particular, BOD was decreased by 97 percent following treatment in the settling basin and wetland cell.

Pesticides and Wetlands

Using constructed wetlands to mitigate agricultural pesticide runoff is of increasing research importance. Because of the proximity of agricultural production to aquatic systems such as reservoirs, lakes, rivers, and streams, there is a potential for contamination by a variety of pollutants, especially pesticides (Moore 1999). Rodgers and Dunn (1993) suggested general modeling and design guidelines for using constructed wetlands as buffers between agricultural fields and their receiving aquatic systems (rivers, lakes, streams, etc.). Their model is based on a combination of wetland physical, chemical, and biological characteristics that guide the fate and persistence of pesticides targeted for remediation. To be mitigated, pesticides can only be either transferred or transformed. Transfer of pesticides refers to processes including, but not limited to, volatilization, solubility, flow, retention, sorption, and infiltration. Pesticide transformations refer to, but again are not limited to, photolysis, oxidation, hydrolysis, and biotransformation. In order for the effects of the targeted pesticide to be mitigated, it must be capable of being held within the wetland for a determined amount of time (*pesticide retention time*, or PRT). If pesticides cannot be held within the wetland, then they are not appropriate targets for constructed wetland mitigation. Even though there are several explicit assumptions incorporated in their model, initial efforts by Rodgers and Dunn (1993) have benefited later pesticide studies, discussed below.

Darby (1995) first used the suggested modeling parameters for examining the fate of the organophosphate insecticide chlorpyrifos (sold under the trade names Lorsban and Dursban) in constructed wetlands. She determined that the majority of chlorpyrifos was rapidly bound to the sediment and plant material in the inflow area of the wetland cells. Moore et al. (2000, 2001b, 2002) expanded Darby's original study to also include the herbicides atrazine and metolachlor, and reevaluated chlorpyrifos at worst-case scenario storm runoff concentrations. Targeted inflow chlorpyrifos concentrations were 73 micrograms/L, 147 micrograms/L, and 733 micrograms/L, representing 0.5, 1, and 5 percent estimated chlorpyrifos runoff. Based on water, sediment, and plant data collected weekly for twelve weeks following a simulated storm runoff event, 47–65 percent of the measured chlorpyrifos was located within the first 30–36 meters of wetland mesocosms. Of the measured chlorpyrifos, 55 percent was in sediments and 25 percent was in plant material. Based on models and equations provided by Rodgers and Dunn (1993), wetland travel distances of approximately 184–230 meters would be needed to mitigate chlorpyrifos runoff of the magnitude described above (Moore et al. 2002).

Similar studies were conducted by Moore et al. (2000, 2001b) evaluating the use and efficiency of constructed wetlands in mitigating atrazine and metolachlor. Target concentrations of 73 micrograms/L and 147 micrograms/L atrazine were amended to the wetlands. Mitigation was much less than that observed for chlorpyrifos, with no detectable atrazine measured in either plant or sediment samples collected throughout the five-week exposure period. These results were similar to those obtained by Glotfelty et al. (1984), who reported no detectable atrazine residues in bottom sediments of an estuary from edge-of-field runoff. Between 17 and 42 percent of measured atrazine mass was located within the first 30–36 meters of the wetlands. Based on field data and equations from Rodgers and Dunn (1993), 100–280 meters of wetland travel distances would be needed to mitigate runoff episodes of this magnitude. While this is somewhat lower than distances needed for chlorpyrifos, one must remember that chlorpyrifos is much more potent to nontarget organisms such as fish and aquatic invertebrates than is atrazine (Moore et al. 2000). Identical concentrations of metolachlor were also amended into the constructed wetlands and evaluated for a five-week period. Only 7–25 percent of the measured metolachlor mass was within the first 30–36 meters of the wetlands, and only 10 percent of the total metolachlor was measured in plant material. The range of wetland buffer travel distance needed to mitigate this size event was 100–400 meters (Moore et al. 2001b).

Runes et al. (2001) examined the remediation potential of atrazine in small, 265 liter wetland microcosms. According to their results, less than 12 percent of the applied atrazine was present in the water column after fifty-six days. They also reported that 67 percent of atrazine and hydroxyatrazine residues were detected in the sediments of the wetland microcosms.

Even though the majority of research regarding atrazine and wetlands has been conducted on constructed or artificial systems, some literature exists on use of natural wetland systems. Alvord and Kadlec (1996) reported on atrazine fate and transport within the Des Plaines natural wetlands in northeastern Illinois. Their results indicated that wetlands decreased spikes of atrazine, as well as decreased atrazine concentration, by 26–64 percent from inflow to outflow.

Other studies have examined the effectiveness of small constructed wetlands to buffer against the effects of pesticide runoff and spray drift. Water quality within the Lourens River (South Africa) has been declining over the last few decades because of intensive agriculture, sediment input, and loss of indigenous vegetation (Tharme et al. 1997; Schulz 2000). A study was conducted to determine the capability of a previously constructed wetland (originally designed to decrease sediment input into the Lourens River) to buffer against pesticides associated with particles from runoff, as well as input from spray drift (Schulz 2000). Sediment and nutrient retention, as well as in situ exposures, were examined within the wetland. Little information exists regarding toxicity assessments within constructed wetlands for pesticide or nutrient retention. This information is important, however, since sublethal concentrations of these contaminants may affect growth, reproduction, behavior, and physiology of aquatic organisms (Anderson and Zeeman 1995; Rice et al. 1997). It was determined that 75–84 percent of suspended sediment, orthophosphorus, and nitrate were sequestered within the wetland. Bioassay results indicated decreased *Chironomus* toxicity from wetland inflow to outflow, demonstrating the ability of constructed wetlands in decreasing possible effects from potential agricultural contaminants.

Nutrients and Wetlands

While many other studies combine evaluations of pollutant-trapping efficiencies (e.g., bacteria and nutrients), some have focused primarily on nutrient trapping efficiencies of constructed wetlands. Hey et al. (1994) studied four wetlands at the Des Plaines River Wetlands Demonstration Area in Illinois. Wetlands ranged in size from 2 to 3.5 hectares, and they had trapping efficiencies of 39–99 percent and 52–99 percent for nitrate-nitrogen and total phosphorus, respectively. In another Illinois study, Kovacic et al. (2000) evaluated three wetlands (0.3–0.8 hectares in surface area; 1,200–5,400 cubic meters in volume) for mitigation of nitrate-nitrogen and total phosphorus. Although 37 percent of the total nitrogen inputs were trapped in the wetlands, nitrate-nitrogen concentrations were decreased by 28 percent compared to inflow concentrations. Total phosphorus trapping was only 2 percent for treatment wetlands (Kovacic et al. 2000). Rehabilitated wetlands along the Maryland coastal plain were studied by Whigham et al. (1999). Wetlands ranged in size from 0.4 to 7.3 hectares and were capable of mitigating 50 percent of dissolved phosphate and 70 percent of dissolved nitrate. Likewise, 30–40 percent of dissolved organic nitrogen, phosphorus, and carbon was trapped in the treatment wetlands (Whigham et al. 1999). Smaller-scale (microcosm) wetland studies were conducted by Rogers et al. (1991) and Ingersoll and Kasperek (1998). Plants were responsible for 90 percent of the nitrogen removal in gravel bed wetland microcosms, with total nitrogen removal ranging from 91 to 98 percent (Rogers et al. 1991). Ingersoll and Baker (1998) used eighteen flow-through sediment-water wetland microcosms and reported varied nitrate trapping efficiency between 8 and 95 percent. This was believed to be caused by fluctuating hydraulic loading and carbon addition rates.

Riparian and Other Natural Buffers as Wetlands

In some agricultural situations, construction of wetlands may not be a viable option due to constraints such as cost and available land. In such cases, we must look to natural wetland–related buffer systems already in place in the agricultural landscape. In 1997, the U.S. Department of Agriculture established the National Conservation Buffer Initiative, whose goal was to install 3.2 million kilometers of conservation buffers by the year 2002 (USDA NRCS 1998). These buffers are small fringe areas left in permanent vegetation designed to retain potential agricultural contaminants. Buffers may be in many forms, including herbaceous wind barriers, grass filter strips, or the more traditional riparian zone.

Vegetated (grass) filter strips are effective at decreasing concentrations of sediment, as well as nitrogen, phosphorus, and pesticides bound to soil. Research has indicated that a 7.6-meter-wide strip of land with a 6–7 percent slope was capable of decreasing movement of total nitrogen and the herbicides atrazine and alachlor by 70 percent, with total phosphorus being decreased by almost 85 percent (Leeds et al. 1993). Research on fields in Iowa, Virginia, Maryland, and Indiana with slopes of 3–12 percent indicated a decrease in sediment between 56 and 97 percent, depending upon the filter strip width and contributing drainage area (Franti 1997). Trapping efficiencies from vegetated filter strips (4.5–13.7 meters) in Kentucky fields with 9 percent slope ranged from 96 to 99 percent for sediment; 94 to 98 percent for nitrate-nitrogen; and 93 to 99 percent for atrazine (Snyder 1998). Fields in northwest Arkansas (3 percent slope) containing vegetated filter strips exhibited marked reduction in contaminant loss with a 6-meter strip (54 percent decrease in total nitrogen; 70 percent decrease in ammonium-nitrogen; 58 percent decrease in total phosphorus; and 55 percent decrease in orthophosphate-phosphorus). These same studies utilized a 21-meter filter strip, and trapping efficiency rose to 81 percent for total nitrogen, 98 percent for ammonium-nitrogen, 91 percent for total phosphorus, and 90 percent for orthophosphate-phosphorus (Snyder 1998).

The value of riparian zones has been well documented since the early 1980s. According to Henry et al. (1999), riparian corridors and associated wetlands provide flood velocity control and storage, as well as stream-flow maintenance in the dry season. Riparian zones also serve as a source of woody debris within the stream, while helping to maintain a moderate surface water temperature through vegetative shade. Both surface and subsurface water quality are better maintained with a continuously vegetated riparian corridor. Such stable vegetation will also decrease the likelihood of streambank erosion (Henry et al. 1999). As previously stated, there is abundant literature concerning riparian forest and wetland capacity to intercept and remediate nutrient- and sediment-associated waters (Lowrance et al. 1984; Jacobs and Gilliam 1985; Peterjohn and Correll 1986; Pinay and Decamps 1988; Chescheir et al. 1991; Brinson 1993; Haycock and Pinay 1993; Barling and Moore 1994).

Smith et al. (2000) reported on water quality of a forested riparian and wetland area in the Mississippi Delta. As part of the Management Systems Evaluation Area study located in the Mississippi Delta, characterization of water quality in shallow groundwater wells and a pesticide-controlled release experiment were conducted on the Beasley Lake watershed. Evaluation of nutrient analyses from the riparian zone shallow groundwater wells indicated mean concentrations of orthophosphate-phosphorus, ammonium-nitrogen, nitrate-nitrogen, and total organic carbon of 0.02, 0.27, 0.20, and 145 milligrams/L, respectively. Mean concentrations for the entire Beasley Lake watershed (at all sites and shallow groundwater depths) for orthophosphate-phosphorus, ammonium-nitrogen, nitrate-nitrogen, and total organic carbon were 0.16, 1.82, 0.72, and 61 mg/L, respectively. Data from the controlled-release experiment (with two pyrethroid insecticides) indicated rapidly decreasing insecticide concentrations both spatially and temporally with no detection of pyrethroids in the receiving water body, Beasley Lake (Smith et al. 2000).

Agricultural Drainage Ditches—The New Wetlands

Landscape features often overlooked for their contaminant mitigation potential are agricultural drainage ditches. A network of drainage ditches surrounds many agricultural fields for the primary purpose of promoting water removal following rainfall and controlled-release events (Moore et al. 2001a). Originally drainage ditches were constructed to remove water from land destined to serve as agricultural production acreage. Most often, these ditches ran from a wetland or marsh area to an aquatic receiving system. Now, ditches are commonplace, almost to the point of being innocuous, in the agricultural field setting. In today's litigious society, there is a battle over the right to "clean out" a drainage ditch—more specifically, to remove accumulated sediment, plant, and other organic material. Although this debate can better be addressed by legal experts, suffice it to say that drainage ditches are valuable yet controversial ecosystems. Ditches possess many of the same key characteristics that define wetlands: hydroperiod, hydrosoils, and hydrophytes. Many ditches maintain some level of water enabling flooded or waterlogged conditions throughout most, if not all, of the year. This in turn contributes to the presence of hydric soils in ditches. The presence of aquatic vegetation (hydrophytes) is variable depending upon many ditch parameters such as size and water depth—much like that of natural and constructed wetlands. Some of the same aquatic plants one may find in a natural or constructed wetland can also be found in an agricultural drainage ditch. It is for valid reasons then, we consider drainage ditches as a type of wetland ecosystem.

The ditch's ability to mitigate specific agricultural contaminants has been less studied, although Drent and Kersting (1992) briefly reported on the use of experimental ditches in the Netherlands for ecotoxicology research. Other studies in the Netherlands have focused more on ditch maintenance and vegetation (Van Strien et al. 1989, 1991). Little or no information is readily available concerning the ecology or classification of agricultural drainage ditches. Farris et al. (2000) reported initial efforts to categorize soils, water quality, vegetative conditions, and physical dimensions of agricultural drainage ditches in northeast Arkansas. The study also included preliminary information from macroinvertebrate surveys to serve as a possible biotic community index in future drainage ditch classification (Farris et al. 2000). As a result of this preliminary information, a classification of ditch ecosystems is currently under development. By further examining these systems, we can perhaps better define estimates of mitigation capacity. This will provide farmers and other conservationists with specific guidelines on the development, maintenance, and trapping efficiency of drainage ditches. By considering this type of wetland in conjunction with certain other BMPs, perhaps agriculture can better address issues concerning control of nonpoint source pollution.

Recommendations

The most important recommendation derived from this chapter is the need for improved and consistent technology transfer between wetland researchers and the general agricultural community. Historically, researchers interested in wetland functions were misperceived as enemies of agriculture. More participation and understanding on both sides (see Chap. 11) is needed to continue to progress in this area. Wetlands and agriculture, while historically having a less-than-agreeable relationship because of agriculture's past practice of draining wetlands, are intricately bound by commonality. Rice production, for instance, will always be related to wetland systems. As agriculture continues to grow and new production landscape is needed to sustain the world's food and fiber requirements, wetlands will serve an even greater role in water-quality enhancement for aquatic natural resources.

Research needs identified through efforts reported in this chapter include the following:

- Information on plant-specific uptake of agricultural contaminants (pesticides, nutrients, etc.).
- Close collaboration between farmers, resource conservationists, and plant scientists to ensure vegetation used for mitigation will not pose risks to surrounding crops.
- Vegetated drainage ditch research needs validation outside the Mississippi Delta region into other parts of the country, specifically the East and West coasts and the Midwest.
- Better communication between federal agencies responsible for wetlands and farmers. It is imperative that farmers understand their land rights but also have an increased understanding of the benefits of wetlands.
- Encouragement of wetland banking programs, such as those found in the Midwest, as alternatives to farmers.
- Continued practical research on the watershed level, such as reported by Smith et al. (2000) on a riparian zone in the Mississippi Delta.

Conclusions

There is an indelible link between agriculture and water quality. Due to historical conversion of wetlands into agricultural production acreage, nonpoint source pollution from cropland runoff has been identified as a significant source of surface water contamination. To decrease effects of such runoff, the agricultural research community has focused on ways to reduce the quantity and improve the quality of runoff water. These BMPs range from changes in tillage to construction of artificial wetlands. Where wetlands were once intentionally drained, many landowners are now constructing “artificial” wetlands in order to contain and remediate runoff. This chapter has examined the intricate relationship between agricultural pollutants and wetlands. Successful evidence of wetland remediation of sediment-, bacteria-, pesticide-, and nutrient-laden runoff has been documented. Additional consideration was given to riparian and other natural buffer wetland areas with successful remediation results. A final section peered into the future of wetland remediation, focusing on the idea and initial success of vegetated agricultural drainage ditches as small, constructed wetlands. By implementing successful constructed wetland remediation practices, agriculture can continue to decrease the effects of runoff contamination on rivers, streams, lakes, and reservoirs.

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