Understanding stream incision, riparian function, and Indigenous knowledge to evaluate land management on the Prairie Band Potawatomi Nation

by

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B.S., University of Kansas, 2005
M.A., University of Kansas, 2009

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

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Abstract

One of the critical challenges facing our world today, is managing our intensive use of land to support a growing population, while also ensuring the continued provision of ecosystem services that have supported human civilization thus far. The Great Plains region is representative of this complex global challenge because it supports some of the most productive agriculture in the world, yet is also degraded by land cover change, habitat loss, and nonpoint source pollution from nutrients, sediment, and pesticides. In the absence of regulatory remedies, nonpoint source pollution is typically addressed through voluntary adoption of Best Management Practices (BMPs). However, meaningful reductions in nonpoint source pollutants are too often elusive. This is due to two overarching factors: variable rates of effectiveness based on site-specific, geographic factors; and variable rates of adoption due to social, economic, and policy pressures. Therefore, to address the problem of nonpoint source pollution, we must better understand the interacting physical processes behind nonpoint source pollution, and the cultural processes driving land management choices. The unifying variable between rates of effectiveness and rates of adoption, is land use/land cover (LULC) driven by land management practices. This dissertation seeks to integrate an advanced understanding of the interactions between the physical impacts of LULC on nonpoint source pollution removal in stream riparian zones, with an evaluation of Indigenous cultural frameworks to better inform land management paradigms. This dissertation explores the relationship between fluvial geomorphology, hydrology, and nutrient dynamics in riparian areas of incised stream channels. To add to this understanding, I utilize a transect of nested piezometers to observe riparian zone hydrology under both forested and row-crop land cover along an incised stream, James Creek in northeast Kansas. The investigation of coupled hydrologic/biogeochemical relationships addresses whether precipitation interflow to incised channels is interacting with the soil in such a way that denitrification processes are facilitated, or inhibited. These issues may be better addressed through multiple BMPs and management for whole ecosystems – a view that is contained within the Traditional Ecological Knowledge (TEK) framework. Understanding Indigenous values and land management preferences may provide an alternative cultural framework for valuing native land cover, and help government agencies and NGOs promote

increased adoption of BMPs. A greater understanding of these Indigenous cultural frameworks will also help to bridge gaps in understanding between government agencies and Indigenous tribes in questions of resource management. Therefore, this dissertation examines Indigenous governance of natural resources, and historical barriers that have led to the unique situations that exist today. Utilizing mixed-methods research, the overarching goal of this dissertation is to apply advanced understandings of riparian hydrology and water quality function in the Great Plains to best management practice recommendations based on a sound understanding of Indigenous nature-society value systems.

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List of Abbreviations

BMP – Best Management Practice

LEK – Local Ecological Knowledge

LULC – Land use/land cover

NGO – Non-governmental organization

PBPN – Prairie Band Potawatomi Nation

TEK – Traditional Ecological Knowledge

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Dedication

To Martin, for standing by my side through this experience, for always encouraging me to pursue my dreams and goals, and for always reminding me that family, friends, and time for relaxation are important too, and that I have to shut my laptop once in a while. Asante kwa ukarimu wako, nakupenda sana.

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Chapter 1: Introduction

One of the critical challenges facing our world today is managing our intensive use of land to support a growing population, while also ensuring the continued provision of ecosystem services that have supported human civilization thus far. The Great Plains region is representative of this complex global challenge because it supports some of the most productive agriculture in the world, yet is also degraded by land cover change, habitat loss, and nonpoint source pollution from nutrients, sediment, and pesticides. The EPA reports in their National Water Quality Assessment, that nonpoint source pollution is the leading cause of water quality impairments today (U.S. Environmental Protection Agency, 2017). Communities from rural populations to large cities such as Des Moines, IA, are struggling to deal with these issues stemming from land use, including degraded surface and ground water quality and increased water treatment costs; limited recreational opportunities and loss of revenues; reduced reservoir storage capacity; uncertainties over future water supply; and degraded aquatic habitats and loss of biodiversity (Chesters and Schierow, 1985; Clark, 1985; U.S. Environmental Protection Agency, 1998). The cumulative impact of this degradation is represented by the "Dead Zone" in the Gulf of Mexico, which continues to increase in size (NOAA, 2017; Dybas, 2005).

Nonpoint source pollution presents a difficult challenge to agencies charged with protecting the nation's shared natural resources. The Clean Water Act provided a structure for regulating point source water pollution, as these discharges come from discrete, testable sources. Nonpoint source pollution comes from many diffuse sources, and it is often difficult or impossible to quantify the contribution from a single landowner. In the absence of regulatory remedies, nonpoint source pollution is typically addressed through voluntary adoption of Best Management Practices (BMPs). However, meaningful reductions in nonpoint source pollutants are often elusive (e.g. Jones et al., 2018). This is due to two overarching factors: variable rates of effectiveness based on site-specific, geographic factors; and variable rates of adoption due to social, economic, and policy pressures. Therefore, to address the problem of nonpoint source pollution, we must better understand the interacting physical processes behind nonpoint source pollution, and the cultural processes driving land management choices. The unifying variable between rates of effectiveness and rates of adoption, is land use/land cover (LULC) driven by land management practices. This dissertation seeks to integrate an advanced understanding of the interactions between the physical impacts of LULC on nonpoint source pollution removal in stream riparian zones, with an evaluation of Indigenous cultural frameworks to better inform land management paradigms. This is accomplished through a focus on nitrogen cycling in the riparian zone of an incised stream; coupled with a case study of land management on the Prairie Band Potawatomi Nation (PBPN).

Nutrients such as nitrogen are often the focus of nonpoint source pollution studies, due to their widespread excessive presence and deleterious effects. “Nutrients” refer to major elements (primarily nitrogen [N], phosphorus [P], and Potassium [K], as well as calcium [Ca], magnesium [Mg], and Sulfur [S]) and trace elements (including iron [Fe], manganese [Mn], copper [Cu], and zinc [Zn]) that are needed in small quantities for normal plant growth (U.S. Environmental Protection Agency, 2009). However, large inputs of nutrients into aquatic systems result in undesirable consequences such as algal blooms, taste and odor problems in finished drinking water, depleted dissolved oxygen, fish kills, reduced recreational and commercial value, and reduced aesthetics (Anderson et al., 2002). Common sources of excess nutrients are crop and lawn fertilizers, manure, and improperly-processed sewage. During runoff events, these elements are transported by overland flow and subsurface flow into nearby streams, rivers, wetlands, lakes, and reservoirs, where harmful effects occur (Timmons, 1970). Destruction of native land cover, followed by intensive grazing and cultivation of the land, alters surface hydrology and results in increased nonpoint source pollution as well as widespread incision of stream systems, substantial increases in sediment loads, and lowered groundwater tables (Thorne, 1991).

Many BMPs are promoted as solutions to mitigate the water-quality impacts of intensive agriculture. In-field practices like conservation tillage, nutrient management and cover crops may reduce nutrient and sediment loss, and practices like riparian buffers and restored wetlands may filter and mitigate runoff from agricultural fields. However, as we continue to modify land cover and intensify agricultural production around the world, the effectiveness of BMPs becomes dependent on a number of variables, including whole watershed management, modified hydrology, and overall water balance in the watershed (Angier et al., 2005). Watershed hydrology, affected by changes in the amount of water infiltrating vs the amount evaporating or running off the surface, impacts the flow regime and channel geometry of a stream, and may lead to unstable channels (Thorne, 1991). These hydrological changes may also impact nutrient transport pathways and BMP effectiveness in mitigating pollution (Mayer et al., 2007). There is a need for research on the impacts of land use on riparian hydrology and stream channel function, and for these impacts to be coupled with an understanding of nutrient transport and mitigation potential.

In addition to potential variable levels of effectiveness, we also face the problem of adoption of BMPs at scales adequate to mitigate large-scale impacts. Widespread adoption is proceeding slowly, and many government agencies and non-profits are investing in research to understand land use decisions and barriers to BMP adoption. An important aspect of this research is understanding the cultural frameworks from within which these decisions are made (Bryant, 1998). In the Americas, land was managed according to Indigenous cultural standards and traditions for thousands of years, including landscape manipulation by fire (Kimmerer & Lake, 2001). The arrival of European settlers in the Americas, bringing with them their own cultural standards and ideas, signaled the beginning of a large-scale conversion in land cover that would eventually transform large areas of land on both continents (Turner et al., 1998). In many areas of the United States today, Western cultural frameworks exist alongside non-Western, Native American (Indigenous) cultural frameworks. Each have their own values, priorities, and cultural definitions of success. However, many Indigenous communities struggle to enact their own values and priorities due to the history of government policies, and cultural differences influencing the application of the federal trust doctrine. A greater understanding of these Indigenous cultural frameworks will help to bridge gaps in understanding between government agencies and Indigenous tribes in questions of resource management. Understanding Indigenous cultural frameworks and land management preferences may also provide an alternative framework for valuing native land cover, and help government agencies and non-profits promote increased adoption of BMPs.

1.1 Problem Statement and Research Goal

In the Great Plains region, land management and LULC have led to severe impacts from nonpoint source pollution. Despite many sincere and large-scale efforts to address it, there has been little to no gain made in many areas. Even more concerning, some regions are exporting even more pollutants than ever before. In a recent evaluation, Jones et al. (2018) reported that, despite hundreds of millions of dollars spent in Iowa to address nutrient runoff over the last two decades, nitrate loads have increased by 47 percent. The impacts of this type of pollution are felt disproportionately by smaller communities who may not be able to afford advanced water treatment (e.g. Pretty Prairie, KS) (U.S. Environmental Protection Agency, 1994), and by Indigenous cultures whose use of natural resources may bring them into closer contact with pollutants (Hoover et al., 2012). There is a need to achieve a paradigm shift in both the science and the culture of land management.

This dissertation seeks to provide a step toward that paradigm shift, using a mixed-methods approach. The purpose of this research is two-fold: to determine how LULC and associated flow regime impacts may change the effectiveness of riparian zones to remove nitrogen; and to examine how government policies affect the agency of an Indigenous community to interpret their cultural values onto the landscape, affecting LULC patterns. **The overarching goal of this research is to apply advanced understandings of riparian hydrology and water quality function in the Great Plains to best management practice recommendations based on a sound understanding of Indigenous nature-society value systems. Specific objectives include:**

1. **Investigate the influence of stream incision on riparian soil moisture and groundwater recharge pathways.**

2. **Develop a framework to investigate the effectiveness of Great Plains riparian forests to remove nutrients from overland and subsurface flow based on preferential flow paths.**
3. **Investigate how Indigenous knowledge of riparian and stream ecosystem services is translated into land and water management on the Prairie Band Potawatomi Nation.**

Chapter 2: Riparian Buffers, Land Use Change, and Associated Physical Impacts

A diverse suite of efforts to reduce nutrient pollution is ongoing, including smart application techniques, in-field practices such as conservation tillage, edge-of-field practices, and stream corridor protections like riparian buffers. More recently, consideration has been given to the function of BMPs under different geographic and hydrogeologic settings (Rittenburg et al., 2015). A number of interacting factors determine the effectiveness of BMPs to trap pollutants such as nutrients and sediment, including soil composition, hillslope, the type of vegetation present, width of the buffer zone, and elevation of the groundwater table (Vought et al., 1994; Vidon et al., 2010). It is possible for agricultural land use to impact any or all of these factors, depending on management choices by the landowner. One of the more significant choices in terms of stream health, is whether the landowner retains or removes deep-rooted riparian vegetation between their field and the stream channel. Retaining this vegetation can benefit the soil moisture profile, by increasing soil infiltration and facilitating recharge of groundwater (Burgess et al., 2001; Hultine et al., 2004). Increased soil moisture can help facilitate the conditions needed for nutrient removal processes to occur, including uptake and denitrification (Weier et al., 1993). Infiltration in forested riparian zones may also augment baseflows within the channel, providing a more stable stream channel and healthier aquatic habitat (Wine and Zou, 2012).

When infiltration rates change relative to overland flow rates, the impacts can be seen in stream channel structure and stability. Unstable and incising channels can be a symptom of changing hydrology in a watershed, typically caused by urbanization or conversion to agriculture, although other factors such as reduction in sediment load can also lead to incising channels (Thorne, 1991). Changing hydrology caused by land use is also understood to change groundwater table interactions and soil moisture dynamics in the near-stream riparian zone (Schilling et al., 2004). Because riparian buffers are often relied upon to treat nitrogen pollution in runoff from surrounding agricultural land, there is a need to better understand riparian zone hydrology and runoff flowpaths, and the implications for potential delivery of nitrate to an incised stream channel. In the following sections, I expand on these concepts and discuss the perceived benefits of riparian buffers as a conservation practice; causes of channel incision; nitrogen processes in soil; and hydrologic controls on nitrogen removal.

2.1 Riparian Buffers as a Best Management Practice

A riparian ecosystem forms the transition between an aquatic environment and the upslope terrestrial environment. The U.S. Forest Service defines the riparian buffer as: "The aquatic ecosystem and the portions of the adjacent terrestrial ecosystem that directly affect or are affected by the aquatic environment" (U.S. Forest Service, 1997). This definition includes streams, rivers, lakes, and bays and their adjacent side channels, floodplain, and wetlands. A similar definition is offered by leading riparian experts Lowrance, Leonard, and Sheridan (1985) as: "A complex assemblage of plants and other organisms in an environment adjacent to water. Without definitive boundaries, it may include stream banks, floodplain, and wetlands, as well as sub-irrigated sites forming a transitional zone between upland and aquatic habitat. Mainly linear in shape and extent, they are characterized by laterally flowing water that rises and falls at least once within a growing season." Healthy riparian areas provide many important functions, including aquatic habitat services; geomorphic functions such as bank stabilization; and water quality improvements. Riparian buffers also perform key services for terrestrial habitats, such as providing shelter and movement corridors for terrestrial animals (Naiman et al., 1997; Cunningham et al., 2009). These functions are discussed below.

In watersheds dominated by agricultural land use, healthy riparian zones consisting of trees, grasses, and other native vegetation have been shown to reduce the amount of agricultural pollutants reaching surface water channels (Schlosser and Karr, 1981a; Daniels and Gilliam, 1996; Liu, 2006). The U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) includes riparian forest buffers (code 391) in its National Handbook of Conservation Practices as an effective strategy to prevent erosion and reduce the total loads of agricultural pollutants reaching surface water channels (USDA-NRCS, 2005). There are numerous studies providing empirical evidence for this claim (e.g. Schlosser and Karr, 1981; Daniels and Gilliam, 1996; Liu, 2006). USDA-NRCS provides funding through numerous Farm Bill Programs to install buffers, typically between 30 to 150 feet in lateral width. Farm bill conservation programs providing cost-share funding for riparian buffer installation and maintenance include the Conservation Reserve Program (CRP); Environmental Quality Incentives Program (EQIP); and the Emergency Watershed Protection Program (EWP). Other programs that formerly provided funding were the Wildlife Habitat Incentives Program (WHIP); Wetlands Reserve Program (WRP); Stewardship Incentives Program (SIP); these programs have since been eliminated from the Farm Bill.

2.1.1 Aquatic Habitat

The health and diversity of aquatic species such as fish and mussels are important to river management and restoration, to river communities and subsistence and commercial fishers, and as an evaluation of overall stream health. The quality of habitat is affected by several factors, and can generally be improved by healthy riparian buffer areas (Schiemer and Zalewski, 1992). Roots and branches of riparian vegetation trailing into streams are an important habitat for many macroinvertebrate taxa (Milner et al., 2005).

Macroinvertebrates are important indicators of stream health, as well as a food source for many freshwater fish. Forested riparian areas contribute large woody debris (LWD) to the stream channel, which traps sediment from the water column (USACE, 1991); and provides crucial fish habitat and refugia (May et al., 1997). Snyder et al. (2004) found in West Virginia that urban and agricultural land uses have deleterious effects on stream biotic integrity, and that riparian forests can potentially mitigate these effects. In a comprehensive review for the U.S. Geological Survey’s National Water Quality Assessment (NAWQA), Meador (2003) found that decreased fish community condition was associated with degraded riparian condition and increases in total dissolved solids.

Riparian forests keep headwater streams cool and mitigate temperature fluxes by shading the surface water and reducing the temperature of shallow groundwater inputs into the stream. Removal of riparian vegetation results in an increase in stream temperature, which may put stress on fish communities and other aquatic organisms, possibly resulting in a change in community structure (Baltz and Moyle, 1984). Many species, including commercial species such as trout, are only able to survive within a specific temperature range (Allan, 1995). Warming temperatures also decrease the amount of dissolved oxygen the water is able to hold, potentially past the point that certain aquatic species are able to survive (Karr and Schlosser, 1978). Stream corridors from which all woody riparian vegetation has been removed are more susceptible to loss of land by bank erosion, while the affected stream will likely be warmer, and thus have lower dissolved oxygen, due to lack of shade, less suitable habitat and woody debris for fishes and other aquatic species (Gregory et al., 1991; Schlosser and Karr, 1981b).

Leaf litter and other organic matter from riparian forests are an important source of food and energy to stream systems. Relatively low levels of riparian deforestation along headwater streams can lead to reductions in stream food web dependence on terrestrial subsidies, representing a fundamental shift in stream energy dynamics. England et al. (2004) found in Georgia that both allochthonous course particulate organic matter (CPOM) and autochthonous production are important basal resources for crayfish and fish populations. The degree of consumer dependence on CPOM decreased with reductions in riparian canopy cover. Some studies suggest that planting riparian buffers with native vegetation is crucial for aquatic species, because the organisms may not be adapted to the leaf fall patterns or the chemical characteristics of leaves from non-native trees (Abelho and Graça, 1996).

2.1.2 Geomorphic Functions

Streambank erosion can be a major source of sediment to streams, with deleterious downstream effects (Trimble, 1997a; Rabeni and Smale, 1995; Cooper et al., 1993; Lowrance et al., 1985). Riparian buffers are promoted as a conservation practice to stabilize streambanks and resist erosion of the bank. Root reinforcement provided by riparian vegetation reduces soil erodibility (Wynn and Mostaghimi, 2006). Research conducted in Iowa found that riparian buffers can reduce streambank erosion up to 72 percent (Zaimes et al., 2004). Streambank erosion rates are greatest on the outside banks of meander bends, where flow velocities are greatest (Malanson, 1993). Studies have found that these outside banks benefit greatly from riparian vegetation. A study of four stream reaches in British Columbia found that 67 percent of bends without vegetation experienced detectable erosion during flood events, compared with only 14 percent of bends with riparian vegetation (Beeson and Doyle, 1995). Erosion on semi-vegetated bends occurred at rates between that of vegetated and non-vegetated bends. They concluded that “the denser and more complete the vegetation around a bend, generally the more effective it is at reducing erosion” (Beeson and Doyle, 1995). Similarly, Geyer et al. (2000) found that, during the historic 1993 flood on the Kansas River, forested river bends experienced significantly less erosion than river bends with no woody vegetation. River bends with cultivated crops planted to the edge of the bank with no buffer experienced the greatest lateral migration during the flood event (Geyer et al., 2000). Studies also suggest that riparian grasses, compared with trees, allow greater storage of sediment along streambanks (Trimble, 1997b). Woody vegetation has also been demonstrated to prevent the formation of rills and gullies in riparian areas (Barling and Moore, 1994).

Where streams are connected to their floodplains, riparian vegetation will slow floodwaters, allowing some of the sediment load to deposit on the floodplain, building the streambank (Hughes, 1997, USACE, 1991). Large woody debris that enters the channel from riparian forests also functions to slow in-stream flow and trap sediment, at least temporarily (USACE, 1991). These areas are also important refugia for stream fish and other aquatic biota. However, certain processes such as channel incision can disconnect streams from their floodplains (Schumm et al., 1984). This disconnection may cause the deterioration of the floodplain and associated wetlands; loss of spawning refugia for many fish species; loss of wetland habitat for many amphibians, insects, and migratory birds; and loss of flood storage benefits for riparian landowners (Fischenich and Morrow, 2000).

2.1.3 Water Quality

Primary removal pathways of pollutants by riparian buffers are generally through uptake of dissolved nutrients (nitrogen, phosphorus) by plants; retention of sediment and sediment-adsorbed pollutants (phosphorus, pesticides); or denitrification – chemical conversion of nitrate to nitrogen gas. Riparian buffers can be very effective at removing excess nutrients, sediment, and other pollutants from overland runoff (Gilliam, 1994). Fennessy and Cronk (1997) found in a review of riparian buffer literature that riparian buffers of 20-30m (66-98 ft) can remove nearly 100 percent of nitrate (NO_3^-). However, this removal rate is dependent on a number of geographic, geohydrologic, and design variables. The most important factor controlling the effectiveness of riparian buffers is hydrology, or how the water moves through or over the buffer (Dillaha et al., 1989). Buffers are optimized where shallow groundwater flow channels water through the riparian zone at optimal velocities (Simpkins et al., 2002). When surface or subsurface flow interacts with the root zone in the crop field or riparian buffer, plants can take up dissolved nutrients from the water (Hill, 1995). The nutrients must be present in an inorganic form in order to be taken up by plants (nitrate [NO_3^-]; ammonium [NH_4^+]; orthophosphates [$H_2PO_4^-$ or HPO_4^{2-}]). Removal through uptake is typically more effective for nitrogen, which is more soluble than phosphorus and thus more likely to be in dissolved form (Lowrence et al., 1985). Where there is insufficient vegetation for uptake, riparian zones of incised streams can be sources of nitrates to streams (Shilling et al., 2006).

Nutrients are needed in small quantities for normal plant growth and are present naturally (U.S. Environmental Protection Agency, 2009). Nitrogen is commonly applied as anhydrous ammonia fertilizer (NH_3) to cropland in the Great Plains, which has enabled greater crop yields and a more stable food supply. However, during runoff events, excess fertilizer that has been converted to the nitrate form can be transported by overland and subsurface flow into nearby streams, rivers, wetlands, lakes, and reservoirs, where harmful effects such as eutrophication occur (Timmons, 1970). Nitrate is also subject to leaching and may contaminate groundwater, especially where soils are more permeable (Nolan et al., 2002). Large inputs of nutrients into aquatic systems result in undesirable consequences such as algal blooms, depleted dissolved oxygen and fish kills, reduced recreational value, taste and odor problems in finished drinking water, increased water treatment costs, and reduced aesthetics (Anderson et al., 2002). Cropland is not the only source of these issues - other common sources of excess nutrients to streams include fertilizers from lawns and golf courses; manure from animal feeding operations; and improperly-processed sewage, especially from failing rural septic systems. This type of nonpoint source pollution from agricultural and pastoral operations is considered a major threat to in-stream water quality, groundwater quality, reservoir water quality and storage capacity, recreational resources, and aquatic habitats and can severely impact drinking water treatment costs (Chesters and Schierow, 1985; Clark, 1985; U.S. Environmental Protection Agency, 1998). Most infamously, the negative effects of nutrient loading from the Great Plains and the entire Mississippi River basin have culminated in the Gulf of Mexico "Dead Zone" – a large area near the mouth of the Mississippi River with oxygen levels so depleted from algal blooms that most aquatic life cannot survive there for portions of the year (Malakoff, 1998; Rabalais et al., 2002).

2.2 Land Use Change and Channel Incision

Riparian buffers have been demonstrated to mitigate many of the negative impacts of agricultural land use. However, agricultural land use may also alter watershed hydrology, leading to incision of stream channels that may in turn impact riparian buffer functions through lowered water tables and changes in near-stream riparian hydrology (Schilling et al., 2004). Channel incision refers to the deepening and widening of a stream channel caused by some disturbance. Incision usually originates at the point of a disturbance and migrates upstream throughout the stream and its tributaries. The disturbance may be increased flow velocity, or a decrease in sediment load. Both of these conditions can cause the stream to scour material from the bed and banks of the channel, lowering the bed of the river. The lowered bed and increased velocity also increase erosion at the toe of the bank, carrying away the bottom portion of bank sediment. Scour will continue over time, increasing bank height and bank angle until mass failure is imminent (Simon & Hupp, 1986). Once a critical mass threshold is achieved, failure of the bank will occur, usually caused by additional weight on the bank profile from rain or snow. The precise timing of failure and the characteristic mode of collapse are controlled by bank geometry, bank stratigraphy, bank material properties and catchment hydrology (Thorne, 1991). Upon failure, the destabilized portion of the bank slumps into the river and is carried downstream, leaving a deeper and wider channel. The downstream section of the stream will experience aggradation where this excess sediment is deposited. At some point, depending on flows in the channel, the stream will reach a new equilibrium, lower and wider than before, with vegetation established on the slump banks in the channel (Simon & Hupp, 1986; Schumm et al., 1984; Thorne, 1991). Three primary causes of channel instability common in the Great Plains region can result in channel incision: regulation of flows by dams and reservoirs; channelization of a portion of the river; and changes in land use and erosion management.

Dams have been installed on many Midwestern tributary streams to control flooding on major rivers downstream, and to provide water supply and recreation benefits. However, dams interrupt the hydrologic connectivity of flowing systems, disrupting flows of sediment and organic matter, and fragmenting aquatic habitat (Graf, 2006; Freeman et al., 2007). Reservoirs often accumulate sediment in their upper reaches where streamflow first slows enough for the sediment to settle out of the water column. When water is released from the dam to the downstream reach of the river, it is sediment starved – in other words, it has the capacity to carry much more sediment than it is carrying when released. This causes rapid scour downstream from the dam (Kondolf, 1997). The scour of the downstream portion may also cause scour in downstream tributaries by increasing the bed angle and thus the flow velocity and sediment transport capacity (Thorne, 1991). The interruption of sediment transport and downstream scour is also seen below small headwater impoundments, common in agricultural regions of the Great Plains (Petts & Gurnell, 2005).

Channelization, the process of clearing and straightening a stream channel, was common practice in the United States in the 1950s and 60s, and was based on the idea that floodwaters should be moved out of urban areas as quickly as possible. It was also common in many agricultural areas to facilitate agricultural machinery and make it possible to plant straight rows. It has now become clear that channelization has disastrous consequences for channel morphology, water quality, and flooding of communities downstream from channelized areas. Channelizing a river involves a reduction of sinuosity and usually an increase in bed slope, causing increased water velocity and a higher sediment transport capacity in the stream. The bed scours in response, and the scoured area or knickpoint rapidly migrates upstream from the channelized area. Absent any grade controls, the entire system upstream from the original knickpoint may experience lowered beds and wider channels. Channelization also eliminates habitat for many fish and other aquatic life (Gordon et al., 2004; Schumm et al., 1984; Thorne, 1991).

Another common driver of unstable and incising channels is large-scale change in land use over a majority of the watershed, which alters watershed hydrology and water balance. For example, modification of hillslope runoff generation dynamics through land use change, such as the conversion of forest and grassland to cropland, can reduce hillslope infiltration, increase runoff and sediment production, and increase the "flashiness" of the stream (Knox, 2006). Increasing flood peaks and stormflow discharge magnitudes coupled with decreased flow durations causes increased bank erosion, channel incision and widening, reduced baseflows between precipitation events, and increased periods of intermittency (dry channels) (Poff, 2006). Riparian vegetation is important in these areas to help trap pollutants and sediment from overland runoff, and to hold the bank in place. If there is absent or insufficient riparian vegetation to filter the runoff, the nutrients and sediment will flow into surface water sources, and banks are more likely to fail (Schlosser and Karr, 1981a).

The prevalence of small and large dams, channelization of streams, and land cover changes in the Great Plains, have resulted in incised channels becoming a ubiquitous problem in many regions. As bed elevations lower, water tables typically lower with them, causing large areas of the floodplain to become unsaturated for longer periods of times (Schilling et al., 2004). Water tables naturally fluctuate in forested riparian corridors (e.g. Schilling, 2007), but the net lowering of the riparian water table caused by the lowered elevation of incised stream channels reduces baseflows and limits riparian forest growth and/or restoration (Schmalz et al., 2009). Along channelized streams, vegetation distribution is largely controlled by cycles of degradation and aggradation in response to the increased channel gradient (Hupp and Osterkamp, 1996). At least one study found that riparian water tables lowered by a meter or more by channel incision caused the death of important riparian woody species, thus changing the succession of riparian vegetation (Scott et al., 1999).

In areas with lowered water tables, deep groundwater flow paths may cause drainage to bypass the riparian zone, reducing the effectiveness of riparian buffers (Sabater et al., 2003; Hefting et al., 2004; Schilling, 2007). There is also evidence that lowered water tables impair the ability of riparian areas to filter nutrients (Sabater et al., 2003; Hefting et al., 2004). To understand why, we must first understand nitrogen processes in soil and how a functioning riparian buffer would remove different forms of nitrogen.

2.3 Nitrogen processes in soil

Nitrogen is needed by plant life to grow and function. It is the most abundant element in our atmosphere, but must be “fixed” through chemical processes to become a form that is available to plant life (nitrate [NO_3^-]; ammonium [NH_4^+]). This process occurs naturally, but is commonly augmented by humans through the production and application of fertilizers to crops, lawns, golf courses, and decorative vegetation. Over-application and subsequent runoff of fertilizers has resulted in nitrate pollution becoming a serious problem around the world. This problem is made even worse by increasing stocking rates for livestock (Carpenter et al., 1998).

Nitrogen will change forms as it moves throughout the soil profile and encounters certain biological and physical conditions. Fixed, organic forms of nitrogen will undergo mineralization when they encounter particular soil microorganisms. Mineralization is a two-step process. Aminization (step 1) requires heterotrophic microorganisms to break down complex proteins into amino groups. Ammonification (step 2) follows, in which autotrophic microorganisms convert amino groups to ammonium (NH_4^+) (Lamb et al., 2014). Ammonium may be taken up by plants, or immobilized back to organic nitrogen by soil microorganisms. Immobilized (organic) nitrogen will be unavailable to plants for a time, but will eventually be mineralized into inorganic forms as decomposition proceeds. The duration of time that nitrogen is immobilized will depend on temperature, moisture, and carbon to nitrogen (C:N) ratio of the soil (Hoorman & Islam, 2010). As decomposition proceeds, microbe respiration will increase and CO_2 will leave the soil, until the C:N ratio narrows to about 17:1. At this point, mineralization rates will increase (Lamb et al., 2014).

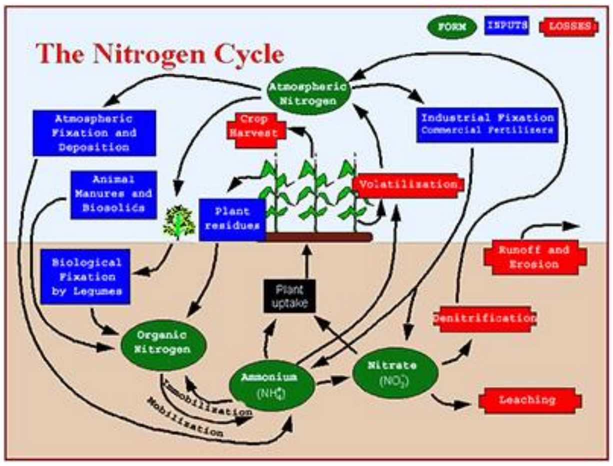

FIGURE 1 THE NITROGEN CYCLE, COURTESY OF THE INTERNATIONAL PLANT NUTRITION INSTITUTE (IPNI).

Ammonium (NH_4^+) is converted to nitrate (NO_3^-), the other plant-available form of nitrogen, through the two-step process of nitrification. In the first step, *Nitrosomonas* spp. bacteria convert ammonium to nitrite (NO_2^-). Nitrite is actually toxic to many plants (Cleemput & Samater, 1995), but it is not common for large amounts of nitrite to accumulate in the soil under normal conditions. Nitrite undergoes a quick conversion to nitrate (NO_3^-) in the second step of nitrification, which is accomplished by *Nitrobacter* spp. (Lamb et al., 2014). Nitrate is the most abundant soluble form of nitrogen. It can easily be taken up by plants when it is moved with water to plant roots through the mass flow process. This process requires adequate moisture in the soil profile. Similarly, the processes of mineralization and nitrification are dependent on temperature, soil moisture, and aeration (oxygen) to support microbial activity (Hoorman & Islam, 2010). Excessive soil moisture (saturation) will limit oxygen availability and reduce rates of mineralization and nitrification. Persistent saturation, as seen in wetland environments, will create an anaerobic soil condition (Reddy et al., 2000).

Shortly after flooding, the limited supply of oxygen in soil pore spaces is depleted rapidly by roots, microorganisms, and soil reductants. Oxygen depletion is associated with a reduction in soil oxidation-reduction potential (Eh) (Pezeshki & DeLaune, 2012). Although nitrification cannot occur in saturated, anaerobic soils, nitrate that is already present can be removed through the process of denitrification. This process requires the presence of carbon (organic matter) and denitrifying bacteria, and the lack of oxygen (Schipper et al., 1993). Denitrifying, anaerobic bacteria in the presence of organic carbon will use nitrate as the electron acceptor for respiration, and the nitrate will be lost to the atmosphere as nitric oxide (NO), nitrous oxide (N_2O), or dinitrogen (N_2). Carbon supply as organic matter or nitrate supply as the electron acceptor are the major limiting variables on this reaction (Burford & Bremner, 1975). Physical factors such as temperature and pH will influence the rates of denitrification. The efficiency of denitrification may be partially dependent on season. Pinay et al. (1993) found in a study in southwest France that the highest rates of denitrification were measured in riparian forest soils in the late winter and early spring, while the lowest rates occurred in the summer and autumn. For the purposes of the nitrogen cycle, denitrification represents a complete removal of nitrogen from the riparian ecosystem (Fennessy and Cronk, 1997).

There are key differences between nitrate (NO_3^-) and ammonium (NH_4^+), although both are plant-available inorganic forms of nitrogen. Ammonium ions have a positive charge, and are therefore held in place by negatively charged soil. Nitrate is very soluble and negatively charged and is therefore subject to leaching to groundwater or being carried in runoff to surface water (Nolan et al., 2002; Lamb et al., 2014). Depending on soil moisture and geologic conditions, nitrate may leach beyond the root zone and move to the water table/saturated zone. This can cause contamination of local aquifers, or the nitrate may move with groundwater toward a stream and discharge into the channel. In certain geologic settings, riparian buffers have been demonstrated to interact with groundwater in such a way that the nitrate is removed through uptake or denitrification (e.g. Hill, 1995; Fennessy & Cronk, 1997). However, local hydrological conditions may also inhibit these functions of riparian buffers.

2.4 Hydrologic controls on nitrogen removal in riparian zones

Riparian buffer lateral width is often cited as one of the most important design considerations for a riparian BMP, with wider buffers considered to provide more efficient pollutant removal and greater soil stability (Wenger, 1999). Width is an important variable, but it is not the sole factor determining nitrogen removal efficiency. Even in buffers deemed sufficiently wide according to site specifics (slope, channel order and width), the capacity to filter agricultural pollutants may be affected by riparian zone hydrology and soil structure (Angier et al., 2005; Duval and Hill, 2006). Soil type, subsurface biochemistry, and subsurface hydrology (including preferential flow paths) are controlling variables on nutrient cycling rates (Dillaha et al., 1989; Mayer et al., 2007). Vegetation type may be less important, as both grass and forested buffers have been shown to remove nitrogen effectively (Groffman et al., 1991; Schnabel et al., 1997; Haycock and Pinay, 1993; Osborne and Kovacic, 1993). However, there may be site specifics such as ecoregion, stream order, slope, and flow regime and stream erosion potential that would necessitate planting of either trees or grasses. Sabater et al. (2003) found that the removal of nitrate by biological mechanisms (denitrification, plant uptake) in riparian areas is related more closely to nitrate load and hydraulic gradient than to climatic parameters. This suggests that there are also no geographical limitations on the ability of riparian vegetation to remove nutrients.

Buffers are optimized where shallow groundwater flow channels water through the riparian zone at optimal velocities (Simpkins et al., 2002), and optimal elevations in the soil profile to intersect the root zone (uptake) or organic carbon supplies (denitrification) (Hill et al. 2000). Hydrologic conditions in the riparian buffer are controlled primarily by slope, rainfall, vegetation, soil characteristics, and elevation of the water table (Phillips 1989a,b). These same controls will determine the length of time water is retained in the buffer zone, which influences the rate of nitrate conversion and denitrification (Fennessy and Cronk, 1997). Local conditions will determine whether nitrate removal is dominated by uptake or denitrification (Gilliam, 1994).

Studies have demonstrated that the best opportunity for nitrogen removal lies in the upper soil layers where the root zone is most dense, and where denitrifying microbes are likely to be present in organic material (Rassam et al., 2009). Tree roots, contrary to popular belief, grow primarily near the soil surface and spread radially. Over 90 percent of all roots occur in the upper 60cm (~2 feet) of the soil profile (Dobson, 1995). Some tree roots, and roots of other plants such as grasses, may extend deeper than this; however, water flowing in shallow subsurface pathways will intersect a much greater density of roots.

Denitrification is both an anaerobic and a C-limited process, and nitrate-enriched water must intercept organic-rich soils that typically occur near the surface of riparian zones (Cooper 1990; Pinay et al. 1993; Schipper et al. 1993). For example, local soil permeability and the presence or absence of a shallow aquaclude layer will affect the subsurface flow path through which water travels from the uplands to the stream channel (Heinen et al., 2012). Puckett (2004) found that, as long as flow paths intersect a reducing (saturated, anaerobic) environment, denitrification will occur in virtually any setting. Interestingly, highly reducing conditions which favor denitrification also favor reduction of iron oxyhydroxides, which can release bound phosphorus from sediment and increase the amount of phosphorus that is exported from the buffer (Jordan et al., 1993).

Preferential subsurface flow paths through riparian areas can have a significant impact on the quality of water delivered to stream channels (Hill et al., 2000; Angier et al., 2005; McCarty and Angier, 2001). Discharge to a stream channel will be comprised of overland flow, interflow (water percolating through the unsaturated zone of the soil matrix), and groundwater flow (water from the saturated zone, below the phreatic surface) (Gormally, 2009). Deeply permeable soils may cause subsurface flow to bypass the zone of active denitrification (Heinen et al., 2012). Denitrification will not occur in groundwater moving through permeable riparian sediments below the organic horizon, unless groundwater flow paths intersect localized deposits of organic matter (Hill et al., 2000). Carbon deposits may occur in buried river channel deposits in the alluvium, or where dissolved organic carbon (DOC) is carried from overlying organic soils to deeper sedimentary layers (Hill et al., 2000).

Hyporheic zones could be hot spots for mixing and biogeochemical processing (Cardenas 2009). Lateral flows stored in the riparian zone of connected floodplains during high channel flows (bank storage) may experience denitrification before they return to the channel. This phenomenon has been observed on both ephemeral and perennial streams (Rassam et al., 2006). In semi-arid regions such as the Great Plains, most surface streams lose water to riparian bank and floodplain soil moisture storage as well as near-surface ground water during times of active streamflow. Return flow from stored bank and floodplain soil moisture storage along with hillslope return flow then feeds baseflow for a time period after precipitation ceases (Rassam et al., 2006). Baseflows in particular are thought to be critical to nitrate removal where baseflow seepage interacts with organic riparian sediments.

Previous research has demonstrated that hydrologic changes associated with agriculture can cause stream channel incision, and that stream channel incision impacts water tables and riparian soil moisture. We also know that subsurface biochemistry, and subsurface hydrology (including preferential flow paths) are controlling variables on nutrient cycling rates (Mayer et al., 2007). A more detailed understanding of hydrologic setting is needed to determine how channel incision affects riparian soil moisture and subsurface flow pathways, and how those pathways may affect the ability of Great Plains riparian forests to remove nitrogen pollution from overland and subsurface flow.

Chapter 3: A Political Ecology of Resource Governance on the Prairie Band Potawatomi Nation

The physical geography framework presented in the previous chapter is important for understanding and addressing problems of environmental degradation. We must understand links between complex processes across different scales to know that conservation practices are going to deliver the services that we expect them to, or whether we must make other changes on the landscape to achieve the desired results. However, we face another problem in addressing environmental degradation - the rate of adoption of land management practices that will support healthy ecosystems and ecosystem services. In a nation that typically relies on voluntary adoption of practices and gives deference in many cases to landowner rights and autonomy, progress in addressing these practices is often slow, and sometimes no progress is made at all. Increasing rates of adoption requires understanding barriers, whether those are cultural, economic, or political. Sometimes, our challenges may be overcome by identifying an area that is demonstrating the type of success that we hope to replicate.

In my past work with the Prairie Band Potawatomi Nation, first as an employee of the U.S. Geological Survey, and then as a graduate student at the University of Kansas and Kansas State University, I have been fortunate to interact and have many conversations with PBPN citizens and environmental professionals. Through these interactions, I observed a different way of valuing the landscape and thinking about a community. I witnessed a strong cultural attachment to native ecology (forests, grasslands, bison, catfish) that is not always seen in other communities in Kansas. Understanding how Indigenous cultures place value on a landscape, and the land management practices they enact to benefit their community (broadly defined, see discussion below), could help to inform the challenges faced by the non-Indigenous communities in Kansas and across the nation.

3.1 Roots of Political Ecology

Political ecology is a broadly defined field, drawing from theories in a number of different disciplines. Political ecology deals primarily with interactions between society and nature, and seeks to answer questions regarding how these interactions translate into management of natural resources (Blaikie and Brookfield, 1987). Specifically, Political Ecology examines how laws, politics, and economy are translated onto a landscape in the form of agricultural practices, natural resource management, urban design, traditional practices, and other features of human existence. Most studies in Political Ecology focus on problems of environmental degradation; however, Political Ecology may also seek to explain how an ecological problem was improved by a society (ie. through passage of new laws, valuation of a commodity, or a change in the general attitude of a community) (Folke & Berkes, 1998). Two important features of Political Ecology are the disproportionate effect of environmental degradation on different segments of a society (ie. poor vs. wealthy; Western vs. Indigenous) (Bryant, 1997); and the importance of analyzing environmental problems on varying scales (Rangan & Kull, 2009).

A precursor to Political Ecology is the field of Cultural Ecology. Cultural Ecology emerged as a field in the 1960s and 1970s to examine linkages between nature and culture (Gunn, 1980). The field of Cultural Ecology deals less with how a society influences natural systems, instead focusing on how nature may influence human behavior, and how local environments may be a determining factor in expressions of culture (Steward, 1955).

Two criticisms of this field led directly to the development of Political Ecology. First, Cultural Ecology tends to operate only at local scales. Researchers realized a need to examine local environmental problems in a regional or even global context. Secondly, Cultural Ecology does not consider the wider political and economic influences (especially outside influences) that may be affecting nature-culture linkages. The call to "put the political first" resulted in the emergence of Political Ecology as a defined field. Despite criticism, Cultural Ecology continues to persist as a field and may lend itself to analyses in Political Ecology, especially when attempting to understand nature-society value systems and how these may be disrupted by politics or economics. For example, in the book "Water, Culture, and Power," edited by Donahue and Johnston (1997), a case study of the effects on the Cree people of the James Bay hydrologic project is largely focused on their culture, and the ways in which it was disrupted by the diversion of the East River.

An important feature of Political Ecology analysis is the assertion that the effects of environmental degradation are felt unevenly across different segments of society. For this reason, many analyses in Political Ecology focus on unequal power relations and unequal segments of society. This theme is especially prominent when considering Indigenous people who are often controlled in some way by a colonizing force, or the effects of degradation on poor or landless people. For an example, we may look to the Hopi and the Black Mesa coal mine (Donahue and Johnston, 1997). Black Mesa reaps the financial rewards of coal mining while using local groundwater resources for their coal slurry. The Hopi have received much less compensation (financial or otherwise) than originally promised, and have seen springs dry up that have served as sources of drinking water, irrigation water, and traditional sacred sites for generations. For the Hopi, this not only represents the loss of a resource, but also a loss of cultural practices and tradition.

There is a tendency in some fields to focus exclusively at the local scale, analyzing local problems and local cultures in a single context. Political ecologists, especially since 2000, have argued that a local focus is important, but may miss other important influences such as state laws and national trade agreements. Therefore, it is important to consider a study from a variety of scales, from local to regional to even global. For example, Barbara Rose Johnston in her analysis of control of water resources in the United States, notes the problems associated with privatization of local water utilities. International companies who buy private water utilities are not subject to the same laws determining fair and equitable use of a water resource as a public utility would be. There are also fears regarding increasing prices for local consumers, and apprehension that their utility payments will fund commercial operations to bottle and sell local water (Johnston, 2002). Johnston couches local concerns over privatization in Federal law that rewards local utilities for selling their resource to private companies (Water Resources Development Act of 2002); as well as international laws that define water as a commodity (North American Free Trade Act, General Act on Trade and Tariffs). In general, Political Ecology is an important field for understanding environmental change, the interactions of human cultures and their effects on the environment, and the future of resource management.

Political Ecology examines how laws, politics, and economy are translated onto a landscape, and thus informs various aspects of this study. I examine the interactions between the laws, politics, history, cultures, and values of two societies – Western society (Federal and state laws, Kansas agricultural tradition, Topeka urban planning) and an Indigenous culture (the Prairie Band Potawatomi Nation) – and the effects of these interactions on natural systems (Soldier Creek, riparian areas, land use). Understanding power relations between cultures is crucial to understanding how land and water resources are managed.

3.2 Indigenous Political Ecology – History of Indian policy and legacies of colonialism

As sovereign nations inside the United States, Native American tribes have their own governing bodies and create their own laws regarding natural resources. However, they are also subject to the laws of the United States and must operate within them, and exist under a federal trust relationship. Regarding the policies of the U.S. government toward tribes, David Getches (professor of Indian and Water Law at University of Colorado – Boulder) quoted "It is Indian Law, but it is not the Indian's Law." Therefore, understanding how politics affects natural resource management in Indian country requires an understanding of the complex history of Indian law, tribal land tenure, cultural values, and the extent to which the tribe may use the laws of the U.S. government to fulfill their own culturally-defined versions of success.

Beginning in the early 19th century, Indigenous Nations in the United States faced a set of government policies that attempted to terminate their cultures, first by forcing removal from their homelands to reservations, and subsequently by chipping away title to those reservation lands (Royster et al., 2002). These policies resulted in the deaths of thousands of Native people, and greatly tested the overall resilience of Native communities (Glauner, 2002). Although many of these policies were repealed or reversed starting in the mid-20th century, Indigenous Nations in America have been left to deal with their lasting effects, including lack of access to historical homelands and sacred areas, and fractionated land title within reservation boundaries.

Perhaps no policy was more damaging or had more permanent impacts, than the General Allotment Law, or "Dawes Act," of 1887. The Dawes Act was in a category of legislation enacted in the late 19th century with the purpose of reducing tribally-owned lands, extinguishing cultural practices, and turning the colonized American Indians into commercial farmers, with the ultimate goal of complete assimilation of Indigenous people into the colonizer's culture, economy, and religion (Prucha, 1984; Washburn, 1975). At the time of the passage of the Dawes Act, it was widely believed that communal land tenure traditions practiced by many tribes were the largest hurdle to assimilation, and that once an Indigenous person owned his own land and was in charge of his own economic fate, he would "advance" to the dominant (colonizer) culture and the tribes would disappear (Royster et al., 2002). To achieve this, the Act forcibly partitioned communally held tribal land into individual landholdings or "allotments," with each man or head-of-household allotted either 80 or 160 acres. After the allotments were assigned, the remainder of reservation territories were declared "surplus land" and sold to private interests, resulting in a drastic loss of territory for the tribes.

The allotment lands were held in trust by the government for a period of 25 years, during which time the individual was expected to assimilate to Western cultural practices, including farming and Christianity (Royster, 1995). At the end of the 25-year period, the individual would receive absolute title to the land, free from any other claims against the title, known in legal parlance as "fee simple absolute" (Royster et al., 2002). The desired result of this legislation was the complete privatization of land and subsequent abolishment of reservations.

The effect of the Dawes Act on the tribes was devastating. For many tribes, the concept of private land ownership and a commercial farming lifestyle were culturally unacceptable. Even for tribes with established agricultural traditions, the abolishment of traditional land tenure and establishment of allotments greatly diminished their agricultural productivity (Carlson, 1992). The allotments assigned to tribal members were predominantly marginal lands, while the most desirable lands were sold in the "surplus" auctions. Subsequently, even if they were willing to put the land into production, they were often unable to do so successfully (Linton, 1942). Once an allottee received the deed to the land (sometimes before the 25-year trust period had passed) it became subject to taxation and other potential financial obligations. Many owners were unable to pay the taxes and fees, and saw their allotments sold in sheriffs' auctions (Royster, 1995). Some individuals managed to retain ownership of their land, only for it to be lost or fractionated (divided into smaller parcels) after their death. Multiple heirs inherited equal divisions of the original allotment, causing land tenure to become increasingly fractionated with each generation. Allotment owners who died with no legitimate heirs could lose their entire land parcel to the state in a stipulation known as an "escheat" provision (Royster et al., 2002). Lost lands were sold to private interests, even when located within the formal boundaries of reservation territories. Through taxation, fractionation and government sale of "surplus" trust lands, approximately 90 million acres across the U.S. - nearly two-thirds of all land originally allotted to the tribes - was lost by 1934 (Washburn 1975).

Allotment policies and government sale of tribal lands were ended by passage of the Indian Reorganization Act (IRA) of 1934. This Act also established tribal trust land, the third (and today, the largest) category of reservation land tenure. The United States holds the legal title in trust, and the tribe holds the beneficial interest. The tribal government decides how tribal trust land is managed, though it is subject to certain federal restrictions. When tribes acquire additional land, they have the option to place it in trust, with the approval of the federal government (Royster et al., 2002). As a direct result of these policies, land within reservations today is generally classified as allotment land, tribal trust land, or private (fee) land (typically owned by non-tribal members).

Although the IRA was positive in terms of ending the continual loss of reservation territories, the previously lost allotments and "surplus" lands were never restored to tribal ownership and control (Royster et al., 2002). Therefore, private (non-Native) lands still exist within the boundaries of many reservations. The Indian Lands Consolidation Act of 1983 found the escheat provision unconstitutional, and has been marginally successful in preventing further losses from fractionation. But the legacy of the Dawes Act has left many reservations with a "checkerboard" pattern of Native and non-Native ownership of reservation land parcels (Cohen, 1945), as well as fractionated land tenure in which ownership interests are represented as fractional shares of a whole parcel (Shoemaker, 2003). Many fractionated allotments have hundreds or even thousands of individual owners, greatly inhibiting beneficial use of the land. This situation has created a complicated jurisdictional burden within reservations. Generally, tribal power is strongest over tribally owned trust land and allotment land within the formal boundaries of the reservation. Tribal power will be weaker to nonexistent, and state power correspondingly stronger, over private lands within the reservation and Indian lands outside reservation boundaries (Slade and Stern, 1995). This jurisdictional burden has created difficult geographic relationships in which Indigenous people have varying levels of governance over certain reservation lands (Sutton, 1991).

These land tenure issues present a difficult jurisdictional problem when tribes are attempting to manage natural resources according to their own value systems. According to the Clean Water Act (1972), and the subsequent Treatment as a State amendment (1987), a tribe may be awarded the same powers as a state to set guidelines regarding water quality on their reservation. The tribe (or the state) must meet the minimum requirements set by the U.S. EPA, but they are able to set more stringent guidelines or manage for wildlife if they so choose. Any guidelines set by a tribe may apply to upstream private landowners, who must ensure that water flowing onto the reservation meets the tribe's established standards. However, the decision "Montana v. United

States" (1981) stipulated that a tribe does not have authority to regulate activities on private land, even within their reservation. The Montana decision included a two-part test to determine exceptions to this rule. First, if the private landowner has entered a consensual relationship with the tribe, the tribe may regulate the landowner's activities on his land. Secondly, if the tribe can demonstrate that the landowner's actions are having a direct effect on the health and well-being of the tribe, they may win the ability to regulate the landowner's activity. A decision in the 1989 case "Brendale v. Confederated Tribes & Bands of Yakima Indian Nation" upheld the Montana ruling, establishing that an American Indian tribe does not have the authority to zone non-Indian fee land within the reservation (Brendale v. Confederated Tribes, 492 U.S. 408 (1989)). Decisions regarding a tribe's powers over private landowners often comes down to a court's individual interpretation of the Clean Water Act, Treatment as a State provision, Montana vs. United States and its "direct effects" test, Brendale vs. Yakima, and the Winters Doctrine (a court ruling that reservation land must also include water rights). Therefore, in the absence of a court judgment, the tribe must determine what management goals may be met without the cooperation of private landowners, or attempt to elicit their cooperation. This presents problems if the tribe's values and culturally defined management goals are in opposition to those of the private landowner.

This limits the options for tribes wishing to manage their natural resources for certain outcomes. Indigenous land management systems tend to emphasize cultural resilience and foster biodiversity and sustainability of resources (Pierotti, 2011). However, the complicated land tenure system has prevented widespread application of traditional land management practices and full recognition of sovereignty over many important natural resources (La Duke, 1994). Because access to land and natural resources is central to the maintenance of Indigenous cultures and traditions (Pierotti and Wildcat, 2000; Berkes et al., 1995), this lack of governance has important implications for traditional practices and cultural resilience (Gregory and Trousdale, 2009).

For an example, we may look to the Wind River basin in Wyoming. Wind River is part of the Eastern Shoshone/Arapaho reservation. However, like many reservations, non-Native farmers privately own a majority of the arable land. The non-Native farmers, many of who have been on the land for generations, believe deeply in the Western cultural ethic that land should be developed and put into production to be useful. When the land was sold at auction beginning in the late 1800s, the farmers were promised irrigation ditches to deliver water from the Wind River to make their land productive. Almost 100 years later, the tribe began to reassert their rights under the Winters Doctrine, which stated that when Congress reserves land for a reservation, it also reserves sufficient water to support the reservation. Tribal lawyers interpret this as a senior water right, and have gone to court many times to argue that the tribes have the right to their fair share of the water and can use that right to support in-stream flows to restore trout habitat. By the time the Eastern Shoshone and Arapaho went to court, so much of the Wind River was being diverted for agriculture that the river no longer flowed on the reservation for most of the year. A contentious conflict resulted based on one culture's values and priorities (irrigation) over another (fish habitat and subsistence resources) (O'Gara, 2000). This case study is a vivid illustration of the need to understand cultural values and environmental-social dynamics in environmental management, and the need to find some sort of effective compromise over shared resources.

Chapter 4: Environmental-Social Dynamics in Land Management and LULC patterns

Private property generally prevails in the Great Plains. In Kansas, some 94 percent of land is privately owned, with private landowners making relatively independent land management decisions (Vesterby, 2003). In most of the region, there are few enforceable environmental regulations on private land, especially regarding nonpoint source pollution. Instead, natural resource management relies heavily on voluntary participation in conservation programs (ELI, 1997). Voluntary implementation of best management practices (BMPs) and enrollment in the conservation reserve program (CRP) varies widely among landowners and lessees, with some fully embracing conservation practices and others resisting implementation for various reasons (Pannell et al., 2006; Dosskey, 1998).

The Great Plains region is also home to numerous Indigenous (American Indian) Nations. Indigenous communities have their own unique land management preferences based on their traditional ecological knowledge systems (TEK) that were developed to support cultural practices and resilience, and may differ from preferences of private landowners (Gregory and Trousdale, 2009). However, land tenure within American Indian reservations is characterized by complicated and sometimes overlapping jurisdictions and complex political relationships, which may hinder a tribe's agency over natural resource management and environmental goals.

4.1 Environmental-Social Dynamics

To provide context for an examination of Indigenous attitudes toward land management, we first review previous studies examining the attitudes and motivations of rural (Western; non-Indigenous) agricultural producers, who represent the dominant social group in the study area. Because the majority (~99%) of land in Kansas is privately owned, and because prevailing opinion among landowners and state agencies strongly favors voluntary programs over regulation (Sorice et al., 2013), it is critical to understand perceptions and drivers of land management choices, and how these may be influenced for better overall management of shared natural resources such as water.

Landowner motivations for breaking out new cropland or retaining or restoring native vegetation are typically viewed in economic terms, with major deciding factors typically being crop prices, input prices, and comparative payments for conservation programs such as the Conservation Reserve Program (CRP) (Kraft et al., 2003). Underlying these analyses is an assumption that land is primarily valued in monetary terms, and that native vegetation only has value when the government or another entity is willing to pay for its conservation. Farm decision-making models are based on economic production, with models maximizing net expected farm profit. Prices of inputs (water, fertilizers, pesticides) and outputs (crop yield and price) are primary factors in land use decisions (Marques et al. 2005; Kantanantha et al., 2010). Commodity prices also influence enrollment in and benefits from environmental conservation programs, such as the Conservation Reserve Program (CRP). (Hellerstein & Malcom, 2010). Decisions by farmers were categorized as either business-oriented or environmentally-oriented; never in the studies reviewed were these categories characterized as complementary (Willock et al., 1999).

Private property rights and the right to make independent land management decisions are paramount in rural America (Schrader, 1993). Most of the studies reviewed placed a major emphasis on individual, independent decision making, as well as economic productivity and risk mitigation. Even where a landowner is making land use decisions motivated by nonmonetary or environmental benefits instead of financial returns, the decisions are still based on that landowner's individual land use ethic, knowledge, or values, as well as their perception of the benefit of the practice (Koontz, 2001). In fact, private property rights are often seen as juxtaposed with stewardship responsibilities (Daley, 2002). Successful conservation activities in agricultural areas, such as wetland restoration, largely depend on the individual landowner (Schrader, 1993).

Philosophies and values of individual landowners are often studied, yet very few of the papers reviewed mentioned community values or community well-being as a driver for private land management decisions. Karp (1996) identifies environmental protection as a conflict between individual and collective preferences. Ahnström et al. (2009) explicitly make the point that conservation practice adoption must be understood in the context of the individual farm. They point out that farmer attitudes are complex, however, circumstances are individual. Greiner et al. (2009) similarly points out, "[conservation practice] adoption depends on individual goals, motivations, and risk perceptions." Kabii & Horowitz (2006) also found that individual landowner philosophies and values underpin decision-making. These values were categorized into five constructs, including economic dependence on property and private property rights, as well as (individual) conservation ethic (Kabii & Horowitz, 2006). Perhaps the most vibrant illustration of this attitude comes from a quote in a paper published by Virginia Tech Extension:

> "Farmers must make a living farming, maintain stability in their business, and respond to needs in the market. They have no economic incentive to bear the cost of producing benefits for others (for example, improved water quality), particularly if they feel that their actions will make little difference in solving problems on a regional scale" (Klapproth & Johnson, 2009).

This is not to suggest that landowners never consider community or collective concerns. A survey carried out in Dickinson County, Kansas, found that 1 in 5 landowners felt that non-landowner (public) concerns about water quality should be included in local land-use decisions. However, a slightly greater percentage (1.5 in 5) expressed extreme disagreement with this idea (Schrader, 1993). Many landowners are at least somewhat responsive to public concerns and "the greater good," but are not willing to accept any mandated changes to land management. Voluntary solutions are typically viewed more positively, though participation rates vary and have been found to be negatively correlated with economic factors such as crop prices (Hellerstein and Malcolm, 2010).

While landowner attitudes are complex, individual decisions to adopt conservation practices are often rooted in land and resource stewardship and long-term concerns about health of the farm and the soil (Ahnström et al., 2009). Some studies found that landowner awareness of environmental issues influenced their willingness to participate in conservation activities and programs. Beedell & Rehman (2000) found that farmers with greater environmental awareness, and those belonging to farming and wildlife advisory groups, tended to be more influenced by conservation-related concerns and less by farm management concerns. Enhanced awareness increased participation in conservation programs, and the most successful conservation programs include the participation of the local farming community (Schrader, 1993). Conversely, Johnson (1996) found that many riparian landowners were "conservation-minded," but often lacked access to understandable and reliable information, leading them to believe that nonpoint source water pollution was not a serious issue. Similarly, Hairston-Strang and Adams (1997) found that factors affecting support for conservation measures in stream corridors included "financial costs, the ability to control management, and the confidence that the measures are based on good science." This is reinforced by the authors' personal observations, including a conversation between PI Mehl and a soybean farmer in central Iowa (2016), who admitted that he did not believe his fields were contributing to the eutrophication problem in local streams. He agreed to allow researchers to test streams at the outlets of his fields, and once he was shown the elevated nutrient levels running off his fields, became a champion of multiple conservation practices including bioreactors and prairie strips.

Major factors identified as preferred policy options for influencing conservation in land management are tax relief, compensation (payments), cooperative agreements, and participation in program development (Schrader, 1994; Hairston, 1996). Although it is difficult to isolate a single factor determining participation in conservation activities for the majority of landowners, there is an unavoidable consideration of personal financial risk and reward (Kabii & Horowitz, 2006). For example, reductions in property taxes were reported as one of the most favorable aspects of conservation programs such as CRP (Schrader, 1993). Economic valuations also factored into perceived positive or negative impacts of land use practices. For example, landowners who derive a higher percentage of their income from crops planted on riparian lands perceive runoff pollution to be less of a problem, and stream corridor protection less important (Schrader, 1994).

In summary, environmental awareness and concern exists in rural communities. However, there are barriers that impact the ability or willingness of landowners to turn that concern into action. Barriers may be structural constraints, economic forces, or inaccessible technology (Stern, 1992). Other issues are financial risks associated with changing land operations, lack of access to reliable information (real or perceived), and societal expectations (for example, community expectations on certain tillage practices) (Stern 1992; Vanclay & Lawrence, 1995). While these studies provide a good understanding of the values and motivators of Western, non-Indigenous landowners, there are very few studies that take a pluralistic viewpoint across different cultures. Next, we examine land management priorities in Indigenous cultures.

4.2 Indigenous Land Management

> "I wish all to know that I do not propose to sell any part of my country, nor will I have whites cutting our timber along the rivers, more especially the bark. I am particularly fond of the little groves of oak trees. I love to look at them, because they endure the wintry storm and the summer's heat, and--not unlike ourselves--seem to flourish by them." ~Sitting Bull, Hunkpapa Lakota leader, quoted in 1932.

For Indigenous communities, land management according to traditional cultural frameworks is crucial to their sovereignty as self-governing nation states (The Kimberley Declaration, 2002). Many Indigenous people also assert that traditional land management is critical to the health of their people, as they seek to return to more traditional diets based on fresh, nonprocessed, locally grown food (Baldes, 2016). Specific Indigenous land management preferences and environmental values vary among Native American nations, reflecting cultural and geographical differences, and their unique histories and experiences with colonial policies (Cornell & Jorgenson, 2011). However, there are some core similarities, such as respect for the earth and natural processes, and the inclusion of non-humans in the concept of a social community (Pierotti, 2010, pg. 26; Fixico, 2013). The literature often frames Indigenous environmental values within the framework of Traditional Ecological Knowledge, or TEK. TEK has been defined as "the cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down in generations by cultural transmission, about relationships of living beings (including humans) with one another and with their environment" (Berkes et al. 2000). From within TEK frameworks, the "ecosystem" is defined as a community, with humans and nonhumans as integral parts of the same community who interact and cooperate (Pierotti and Wildcat 2000; La Duke 1994). Cultural and social cohesion are reinforced through activities that depend on access to healthy, diverse ecosystems, including hunting, fishing, and cultural ceremonies (McGregor et al., 1998; McGregor, 2003). Therefore, it is not uncommon for Indigenous communities to put greater emphasis on group well-being and community (in the TEK sense) success, than on individual outcomes. This framework is discussed in greater detail below.

It is important then, to recognize that this more holistic view of a "community" and integration of culture with biodiversity will shape Indigenous land use preferences and values. In an illustration of this idea, Stuart Harris (Confederated Tribes of the Umatilla Indian Reservation) writes,

> "The role of infrastructure is, or should be, to protect values, biodiversity, cultural diversity, and land use options of future generations…. The European dream of conquering the wilderness, manicuring the forests, improving on nature, making the world look like England, and fulfilling the American dream of material possessions and white picket fences must be realigned. We must look at infrastructure within a larger context of long-term interwoven multi-species survival….A traditional person is responsible to the family (human and nonhuman), which is emphasized more than in American society, and our traditional economies and status systems still reward generosity and responsibility."

This quote illustrates differences in values and priorities (especially relationships with non-humans) in land development, and differences in definitions of success and reward. However, Indigenous people continue to struggle for control over the land and natural resources that are so integral to their cultural identities and their own definitions of wealth and success (Schmidt & Peterson, 2009). The ability of Indigenous Nations to manage land in accordance with their values depends on their specific situation of land tenure and status of self-determination, as discussed in previous chapters. They are most successful when they possess the technical, administrative, and financial capacity for governance, which again depends on the history of colonial policies and their status of self-determination. They also must possess a land base, including the rights to water, minerals and other resources that are necessary to control land use. Following destructive Termination Era policies, however, many tribes in the U.S. were left with greatly reduced land bases or completely landless (Carlson, 1992; Royster et al., 1995).

Many tribes in the United States have made some progress in their efforts to reassert their resource management authority and expand their land bases as a method of cultural preservation and sovereignty (Cornell & Jorgenson, 2011). However, the collective impact of historical policies toward Indigenous people have created complicated jurisdictional situations in terms of self-governance and management of natural resources (Anaya, 2012). American Indian and Alaska Native tribes are defined as sovereign nations, with the power to engage in relations with the Executive and Judicial branches of the United States government. Their sovereignty may not be encroached upon by other sovereigns, including state governments. However, this sovereignty is limited to some extent by treaties, acts of Congress, and other federal actions. What remains of their sovereignty must be protected by the federal trust responsibility, which is defined as "a legally enforceable fiduciary obligation on the part of the United States to protect tribal treaty rights, lands, assets, and resources, as well as a duty to carry out the mandates of federal law with respect to American Indian and Alaska Native tribes and villages" (Bureau of Indian Affairs, undated). For much of the history of the relationship between the United States and American Indian nations, natural resource management fell under this trust responsibility.

However, federal management historically did not adequately account for Indigenous values and priorities. Numerous Supreme Court rulings illustrate the divide between Western and Indigenous environmental values. For example, the decision in Lyng v. Northwest Indian Cemetery Protective Association allowed the construction of a logging road (known as the G-O road) through a section of the Six Rivers National Forest, in northern California (Royster et al., 2002). The area was sacred and used for religious services by three local tribes: Pohlik-lah, Karuk and Tolowa. Although the anthropologist hired by the U.S. Forest Service concluded that there would be no way to mitigate the damage to the sacredness of the site, the Forest Service disregarded the report and continued to pursue construction of the road, resulting in a lawsuit being brought by the tribes. Two lower courts ruled that construction of the road would violate the American Indian Religious Freedom Act (AIRFA). However, the Supreme Court overturned these rulings, writing in their decision that, because they are not outlawing their beliefs nor coercing them to violate their beliefs, there is no violation of the tribes' Constitutional rights (Lyng v. Northwest Indian Cemetery Protective Association, 1987). What the court seemingly failed to understand, is that the concept of a "sacred landscape" is central to Native American religious belief, and allowing destruction of that landscape is akin to a legal action against their beliefs. Even legislation that is meant to protect Indigenous religious practice (AIRFA), was found to be insufficient to avoid the destruction of a place of religious significance.

In a similar case, the Navajo (Diné) Nation sued the U.S. Forest Service to prevent the use of recycled wastewater for artificial snow at the Snow Bowl ski area in Arizona. Snow Bowl is located on the San Francisco Peaks (Dook'o'ooslííd in the Diné language), sacred ground to thirteen Native American tribes, including the Hopi Tribe, Navajo Nation, Havasupai Tribe, White Mountain Apache Nation, Yavapai Apache Nation, and the Hualapai Tribe. The tribes argued against the use of recycled wastewater, citing potential impacts to the environment, social justice, and their religious practices. However, a 9th Circuit ruling sided with the Snow Bowl ski resort, stating that the snowmaking would not be a "substantial burden" on the practice of religion (Mahoney, 2011). Notably though, the author of the dissenting opinion (Judge Fletcher) admonished the court for misconstruing the meaning of "substantial burden," asking whether a government rule requiring a Christian church to use treated sewage effluent in their baptismal rites would impose a substantial burden on the exercise of religion (Klein et al., 2018, pg. 657). These cases illustrate how Western environmental standards are still often insufficient for Indigenous environmental uses. Total maximum daily load (TMDL) standards establish the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards. However, these standards typically do not consider the traditional uses of water by the tribe as they use the resource for recreation, ceremonies, and human consumption (Mo'Ko'Quah Jones, PBPN Department of Planning and Environmental Protection, Tribal Ethics Workshop).

Despite this divide, there have been some important efforts by the federal government to recognize tribal values and priorities in natural resource management. The Environmental Protection Agency (EPA) adopted provisions in 1987 amendments to the Clean Water Act and Clean Air Act to allow tribes to administer regulatory programs under these laws on their own lands (Royster et al., 2002). This delegated authority includes Section 303 for Water Quality Standards (WQSs). Under this program, tribes may set standards that will meet the requirements for cultural or ceremonial uses. These may be more stringent than federal standards, and consequently will impact upstream off-reservation users (Grijalva 2006; Anderson 2015). However, tribes must meet certain criteria for administrative and technical capacity before they are given authority to administer these programs, and fewer than 10% of eligible tribes have had their WQSs approved by the EPA (Slade and Stern, 1995; Diver, 2018). Other regulatory programs (e.g. Section 106-federal grants for water pollution control) have seen greater participation, but these programs do not carry the same regulatory authority as Section 303.

The EPA is also developing new tools for tribes to access important information for decision-making, such as the Tribal-Focused Environmental Risk and Sustainability Tool (Tribal-FERST), described as "an online information and GIS mapping tool designed to provide tribes with easy access to the best available human health and ecological science"

(EPA, 2017). The tool is being developed in consultation with Tribes and partners throughout the United States. While there are still gaps between federal environmental regulation and tribal values and priorities, notable progress has been made. For example, a 1993 survey by the Intertribal Timber Council found a major gap between the goals of Bureau of Indian Affairs (BIA) forestry officials, and those of tribal citizens. The survey found that BIA forestry employees emphasized the forest's economic benefits through commercial timber production, while tribal members emphasized holistic management and resource protection for a multiplicity of use and values (Indian Forest Management Assessment Team 1993, p. ES-4). A follow-up survey a decade later showed that there had been an improvement in the relationship and a greater alignment in management strategies between the tribe and the BIA, due to increased tribal participation and agency in management of the forests (Indian Forest Management Assessment Team 2003, p. 4).

Efforts to reorganize fractionated land interest (discussed in Chapter Two) were accelerated by the judgement in Cobell v. Salazar (2009). The majority opinion found that the Department of Interior and Department of the Treasury had mismanaged the income from Indian trust lands, and awarded $1.9 billion for tribes to buy back fractionated land interests, in addition to pots of money for individual settlements and for a scholarship fund for American Indians/Alaskan Natives. Buying back fractionated land interests and placing them in trust will make it easier for the land to be used for a beneficial purpose, as defined by the tribe. However, some estimated that it would take over $20 billion to completely address this issue and make the tribes whole. Now that the majority of funds have been spent, there is some debate over what the next steps should be.

These steps towards recognizing Indigenous value systems and sovereignty over natural resource management are important advances away from the attitudes of the past that were so devastating for the tribes. Historically, patterns of land tenure and the ability to manage land have been used to control and undermine the sovereignty of Indigenous Nations within the colonial structure (Rotz, 2017). There was a colonial mentality that Indigenous people did not actively manage the land, that they simply allowed it to be wild and “unproductive.” Therefore, it was believed that they could not be trusted to manage it according to their traditions. In reality, Indigenous people do (and always have) manage for specific outcomes in the environment. Some regions were so carefully managed, that the removal of Indigenous people caused an ecological vacuum resulting in a loss in biodiversity and an increase in natural disasters such as fire (Anderson & Moratto, 1996). Today, there is a danger in only focusing on overarching values, that people from outside the tribe may misinterpret these values as a “hands-off” approach, with tribes lacking a desire to “develop” the land and “become prosperous” (as defined by Western culture) (see: Riley, 2016; Mosteller, 2016). This can lead to reinforcement of colonial attitudes of the western tradition leading to productive, developed land, while Native people are passive and “lazy.” It is important for government agencies, conservation practitioners, and private landowners from outside the tribe to better understand the tribe’s values, community concerns, and cultural definitions of success.

It is important for federal and state agencies, and other natural resource managers, to understand how Native people define beneficial uses and their own definitions of wealth and success. Gaining this understanding will help to continue closing the gap between the goals of those agencies and the goals of Indigenous communities. It is also important for these agencies, and landowners from the Western tradition, to learn from these traditions and look for opportunities to incorporate their lessons on managing for biodiversity. Indigenous people carry the “intellectual heritage for ecological survival” that we will need to draw upon as we address increasingly dire environmental challenges (Hall et al., 2000). In service of those two goals, this chapter analyzes the perception of a local Indigenous community, the Prairie Band Potawatomi Nation, toward land management issues and desired changes or outcomes, and seeks to better understand community values and priorities. Tribal self-determination depends on strategic thinking and long-term planning by tribal governments and administrators, and careful evaluation of these strategies against long-term community goals (Cornell & Jorgenson, 2011). Understanding Indigenous community values will help to build a bridge between natural resource management agencies, private landowners, and the tribe for land management planning and natural resource protection.

Chapter 5: Defining Traditional Ecological Knowledge as a complementary framework for Understanding Land Management

Ecosystem services are defined as the ecosystem goods and processes from which people benefit, which contribute to social and economic well-being (MA, 2005). It is important to keep in mind that human activities change and shape ecosystems, and human cultures and societies are shaped by the ecosystems in which they live (Schnegg et al., 2014). Inevitably, social processes and values will shape the production, consumption, and valuation of ecosystem services (Raudsepp-Hearne, 2010). People seek multiple and different services from ecosystems and thus will perceive the condition of an ecosystem in relation to its ability to provide the services desired (MA, 2003).

The ecosystem service concept seeks to define these various benefits, generally operating under the assumption that ecosystems are degraded because the contribution of the natural world to human well-being in modern societies is unrecognized or undervalued (Lele et al., 2015). In most industrialized societies, "value" is often thought of in terms of monetary value; therefore placing a monetary value on ecosystem services such as intact forest habitat or carbon sequestration gives the average citizen in a market-based society a common denominator from which to realize the importance of supporting healthy ecosystem function, and represents a tool for environmentally-focused organizations and individuals to lobby support from anthropocentric policy makers (Lele et al., 2015; De Groot et al., 2012; De Groot et al., 2010). This idea of placing economic value on ecosystem services has gained traction in many places in today's globalized world (IIED, 2012). In certain contexts, monetary valuation can help to guide policies and decisions by governments, businesses, and non-governmental organizations for better ecological management (Boyd, 2011).

The goal of valuing ecosystem services is ultimately to improve natural resource management for better ecological and human well-being by providing a common communication tool (Lele et al., 2015). However, critics have noted that monetary ecosystem service valuation may not be appropriate in some cultures, particularly for cultural ecosystem services, and may ultimately do more harm than good (e.g. Daniel, 2012; Boyd, 2011; De Groot, 2010; Gómez-Baggethun et al., 2009). This is especially true for many traditional or Indigenous societies (Gregory and Trousdale, 2009). In this dissertation, I suggest that Traditional Ecological Knowledge (TEK) may provide an additional viewpoint to help bridge this gap. I do not seek to replace existing valuation schemes where they have utility, simply to expand the framework with alternative viewpoints on what makes an ecosystem valuable.

5.1 An Examination of Ecosystem Services

The Millennium Ecosystem Assessment (MA, 2005) recognizes four categories of ecosystem services: provisioning, regulating, supporting, and cultural. Of these categories, cultural services, defined as the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences (MA, 2005), have proved the most problematic to represent in valuation schemes. If they have been considered at all, valuation of cultural ecosystem services (CES) have been restricted to easier-to-quantify services like recreation and ecotourism, educational values, aesthetic values (which can be reflected in property values), and inspiration for art, architecture, advertising, and national symbols (Lele et al., 2015; Daniel et al., 2012). Often omitted are services such as the social relations influenced by particular ecosystems; the "sense of place" people associate with recognized features in their environments; cultural heritage values and maintenance of historically important landscapes or species; cultural diversity as a reflection of diverse landscapes; spiritual or religious values attached to ecosystems or their components; and knowledge systems developed by different cultures (including Traditional Ecological Knowledge, or TEK) (Daniel et al., 2012).

Thus, although the importance of CES is recognized nearly universally in the literature, they are often brushed aside in economic studies as "intangible," "subjective," "generic," or "unmeasurable" (Daniel et al., 2012; Boyd and Banzhaff, 2007). This presents a problem if the goal is to define "value," as CES are often the driver for why people value certain landscapes. Western, industrialized societies more readily find value in the aforementioned “tangible” ecosystem services, reflected in increasing budget shares for recreation (Vandewalle et al., 2008) and the increased value given to ecosystems that attract tourists (De Groot et al., 2012). However, this overlooks the fact that in traditional communities, both tangible and intangible CES are essential for cultural identity and survival (Milcu et al., 2013; Gregory and Trousdale, 2009; Le Maitre et al., 2007).

The fact that these “intangible” CES play such a central role for traditional communities creates problems when trying to apply a monetization framework such as payments for ecosystem services, or PES (Gregory and Trousdale, 2009). It is often impossible to develop a common definition across different societies, as a landscape feature that holds significance in one community may not hold the same value in another. Even if such a valuation were possible, it may be seen as inappropriate or even insulting to attempt to place an “economic value” on cultural practices, which inevitably facilitates the logic that communities can be monetarily compensated or “paid off” for the loss of certain ecosystem components (Gregory and Trousdale, 2009). The inability to work cultural or non-material ecosystem services into valuation schemes often restricts their incorporation into broader ecosystem assessments (Chan et al., 2001).

Valuation assessments that require ecosystem services to be broken down into individual components may also be problematic in communities that value whole ecosystems above their component parts. In economic assessments, for example, component features such as individual wetlands or tracts of forest will be assigned a particular market value, which will then guide development, mitigation, and conservation decisions (Boyd, 2011). This may yield useful results in certain situations; for example, in incentivizing agricultural operators to take tracts of their land out of production and allow native grasses and trees to grow, in exchange for payments. One such program operating within this framework in the United States is the Conservation Reserve Program (CRP), which gives landowners financial assistance and payments for planting and developing native tracts, especially on highly erodible lands, and keeping these tracts out of agricultural development for certain periods of time (typically 10-15 years) (Heimlich, 2010). However, in CRP and similar monetary valuation programs, the material and nonmaterial are consistently treated as separate domains, with non-material services seen as less important or, at best, a residual category (Daniel et al., 2012). Monetization (which represents an extreme case of contemporary ecosystem service valuation) calculates value based only on the end product, typically a provisioning or regulating service (Lele et al., 2015), and places no value on the sense of community or aesthetic benefits gained from engaging in the procurement of provisioning services, or on the activity itself, which are often central to cultural survival in traditional communities (Gregory and Trousdale, 2009; Schnegg et al., 2014). Therefore, any compensation for losses based on a monetization model only considers the value of the end product to the individual, and not the cultural loss to the community of engaging in the activity and passing down knowledge. These criticisms represent major roadblocks for traditional communities, who view ecosystems from a holistic worldview that does not allow separation of these components into parts that can be sacrificed or conserved (Kawagley and Barnhardt, 1998).

5.2 Traditional Ecological Knowledge

Traditional Ecological Knowledge (TEK) provides alternative frameworks from which to view and value natural landscapes, and possibly from which to assess the value of ecosystem services. TEK has been defined as "the cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down in generations by cultural transmission, about relationships of living beings (including humans) with one another and with their environment" (Berkes et al., 2000). We refer to "TEK frameworks" in the plural tense because Indigenous groups and systems of TEK are not homogenous, though certain shared themes do exist (i.e. careful long-term observation of natural phenomena, precise focus on local environments and "places," shared understanding of relatedness; Pierotti 2011, pg. 9-10). Because TEK emphasizes local phenomena, multiple frameworks with sometimes competing observations can coexist without displacing each other. This further emphasizes the difficulty in assigning value to cultural ecosystem services, as the same landscape feature may be valued differently from within different frameworks. It is important to allow for the plurality of voices that exist both within and among Indigenous groups.

TEK frameworks represent a body of empirical knowledge developed through close observation of nature and natural phenomena, combined with concepts of spirituality and community membership (Pierotti and Wildcat, 2000; La Duke, 1994). From within TEK frameworks, the “ecosystem” is defined as a community, with humans and nonhumans as integral parts of the same community who interact and cooperate. These frameworks fit within the larger concept of “relational values,” which stresses a perception of nature that goes beyond purely intrinsic values (nature has inherent value independent of people) or utilitarian values (nature’s value is based on how well it satisfies the preferences of people). The concept of relational value moves beyond these two extremes to the understanding that people value the “preferences, principles, and virtues associated with relationships, both interpersonal and as articulated by policies and social norms” (Chan et al., 2016). Relational values are not inherent in nature, but instead stem from the relationships and responsibilities perceived by different cultures or communities (Chan et al., 2016). TEK embodies this concept through the close association of individual and cultural identity with “place” (Pierotti, 2011). The relationship with place and the social cohesion provided by interaction with certain environments through hunting, fishing, cultural ceremonies, etc., provides the basis for value within TEK frameworks. For this reason, systems managed from TEK frameworks have been increasingly touted as examples for sustainable resource use and long-term resource conservation (Menzies and Butler 2006).

Schnegg et al. (2014) recognized this alternative way of conceptualizing nature, and pointed out that culture should not be restricted to a non-material category. For many Indigenous people, cultural services are inextricably linked to provisioning and other services. The loss of a food source such as a population of fish or game animal may be replaceable with other food provisions, but the act of collecting that game animal and the social and aesthetic services that accompany it will be lost, as well as the transmission of both practical and cultural knowledge between group members and across generations, representing a major cultural loss to the society. Schnegg et al. argue that we should not think of “nature” vs. “culture” and “material” vs. “non-material” as individual, competing categories. Restricting cultural services to "non-material" categories is too narrow, as some studies showing the inextricable link between culture and nature have demonstrated (e.g. Schnegg et al., 2014; Cocks, 2006; Posey, 1999).

From within TEK frameworks, ecosystems are valued at the landscape level and seen as worth more than the sum of their parts (Pierotti, 2011). TEK frameworks recognize the interconnectedness and interrelatedness of all living things; therefore a "biocentric" view of an ecosystem is valued above an "anthropocentric" view that may preferentially target ecosystem services that directly support human health and economies. TEK frameworks generally place more value on an overall functioning ecosystem, rather than on preservation of a single wetland or animal population. For this reason, the very act of breaking down an ecosystem into its component parts, as is often done as part of ecosystem service assessments, proves problematic. The notion that certain components of the ecosystem will be "conserved" while other components will be "sacrificed" does not meet the TEK concept of caring for the entire community (Kawagley and Barnhardt, 1998). Designating some resources as less special, and thereby placing them at greater risk, can be felt as a violation of the sacredness of the land and of responsibilities toward nature (Gregory and Trousdale, 2009).

The vast majority of Indigenous societies across the globe have experienced some degree of displacement, and for many the separation from lands and resources is ongoing (UN, 2010). Many Indigenous people lack access to historical homelands and sacred areas, and may have limited or no jurisdiction over resources where they now live. This has profound impacts on knowledge systems based on TEK, as the deep traditional knowledge becomes disconnected from its landscape of origin and from its integral place in the management of the natural landscape (Pierotti, 2011, pg. 48). However, TEK can provide a basis for displaced populations to develop adaptive knowledge, which may incorporate both traditional and "non-traditional" sources of knowledge (Sydneysmith et al., 2010), and can be termed local ecological knowledge or LEK (Berkes, 1999). Lessons from TEK can be used to frame and implement LEK, and various paradigms based on LEK may exist in different populations who interact with a certain landscape (for example, Indigenous populations and farmers may rely on the same landscape and have their own versions of LEK shaped by their cultural values). Displacement and development of LEK can inherently affect landscape values. For example, a population may retain values shaped by their TEK of their original homelands, and may value and manage for similar features after displacement. The combination of TEK and LEK can provide valuable insights into management for overall ecosystem function. However, the degree to which TEK/LEK are used to manage the landscape depends on the degree of agency possessed by the Indigenous population. Where Indigenous people lack agency, both TEK and LEK are often ignored by resource managers in discussions of landscape management (Pierotti, 2011).

Operating from within TEK, which views culture as shared knowledge, practices, and beliefs, provides a framework for overcoming the divide between nature and culture. Both material and nonmaterial benefits play an important role in livelihoods and the quality of life of all people. In contrast to seeking exact ecological and monetary measurements of ecosystem services, some ecosystem service assessments use methods such as semi-structured interviews and participatory mapping to understand landscape values (e.g. Raymond et al., 2009; Schnegg et al., 2014).

5.3 The Conceptual Framework

Drawing on this methodology and using the Prairie Band Potawatomi Nation as a case study, this dissertation examines the way in which Indigenous people who experience varying degrees of agency in managing resources value the landscapes in which they now live through a TEK lens, and how those views contribute to land management and overall LULC patterns that influence nonpoint source pollution impacts. I argue here that, in order to address the serious nonpoint source pollution issues faced by society, we must achieve a paradigm shift in both science and culture. TEK can provide a framework to better understand what is needed to achieve these shifts, through a focus on whole ecosystem functioning and valuation of non-monetary benefits of a landscape for the multiple ecosystem service benefits they provide.

The overarching goal of this study is to apply advanced understandings of riparian hydrology and water quality function in the Great Plains to best management practice recommendations based on a sound understanding of Indigenous nature-society value systems, requiring a better understanding of the cultural and structural drivers of land cover patterns and subsequent environmental impacts. The major unifying variable in these considerations is land management, and subsequent land use/land cover (LULC). Other variables addressed in this dissertation, and their linkages, are discussed below (fig. 2).

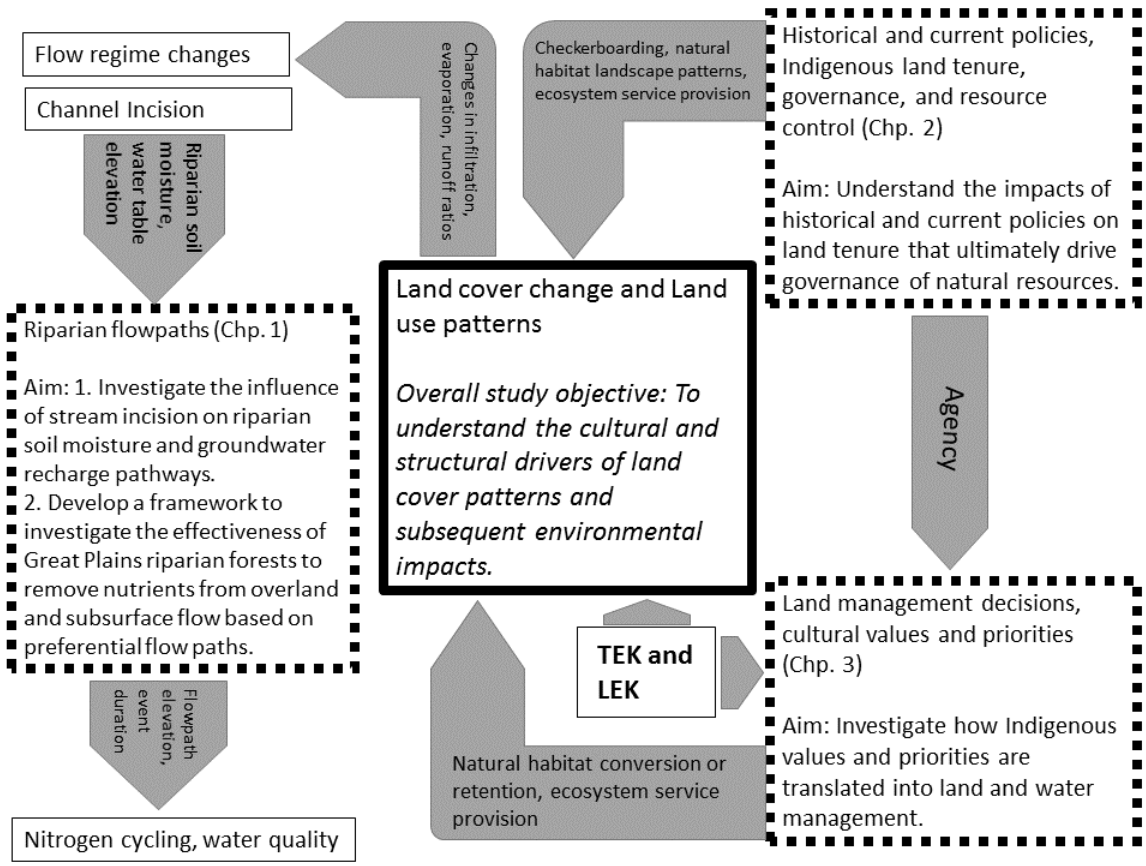

FIGURE 2 THE CONCEPTUAL FRAMEWORK OF LAND USE/LAND COVER CHANGE AND TRADITIONAL ECOLOGICAL KNOWLEDGE

5.3.1 Investigate Preferential Interflow and Groundwater Recharge Pathways Under an Incised Channel Condition; And Develop A Framework To Investigate The Effectiveness Of Great Plains Riparian Forests To Remove Nutrients From Overland And Subsurface Flow Based On Preferential Flow Paths.

Understanding and mitigating environmental degradation requires an understanding of different complex earth processes and interactions across different spatial scales. To achieve this, I utilize principles of the subfields of Fluvial Geomorphology and Hydrology to examine links between fluvial geomorphic processes in streams, near-stream riparian hydrology, and biogeochemical cycles.

Fluvial geomorphology is an interdisciplinary science that examines river channels and their forms, and the relationship to prevailing conditions in its watershed. Special attention is given to how water and sediment are delivered to the channel, and how erosional and depositional processes form the land surface at various scales (Leopold, 1964; Leopold et al., 1994). Fluvial geomorphologists seek a process-based understanding of streams and their connected systems (ie. Riparian corridors, floodplains, watersheds, groundwater connections) (Wohl, 2014). This fundamental basis allows multidisciplinary collaborations with stream ecologists, landscape engineers, and other fields addressing stream and river management (Gordon et al., 2004).

Prevailing watershed conditions during the current age, the Anthropocene, are almost always affected to some degree by human-environment interactions and human land cover modifications. There is a need to incorporate the effects of these impacts on fluvial processes and biogeochemical cycles into our understanding of surface water management. We are dealing with the legacy of large-scale alterations to the hydrologic cycle, and only relatively recently have begun to understand the impacts on issues like pollutant transport (e.g. Böhlke et al., 2007; McCarty et al., 2001). These types of studies provide a framework for more holistic watershed management that focuses on hydrology and sediment regimes, incorporating principles of fluvial geomorphology into our understanding of maintenance of ecosystem services. From the TEK framework, we can draw a broader definition of ecosystem service value, and ecosystem functioning at the landscape level. This dissertation uses this framework to examine linkages between land use modifications, fluvial geomorphology and hydrologic alterations, and impacts on biogeochemical cycles in stream riparian zones.

LULC is a major driver of water balance in a watershed. Along with variables such as rainfall intensity and slope, LULC determines what percentage of a precipitation event evaporates, infiltrates, or is discharged to surface water (Gerten et al., 2004). These patterns impact flow regime and subsequent stream channel morphology, and may cause impacts such as bed degradation and channel incision (Poff et al., 1997). Channel incision has been shown to affect riparian soil moisture and water table elevation (Schilling et al., 2004). What is not known from the literature, is how these changes in soil moisture and water table elevation may affect dominant flow paths of water through the riparian zone. Therefore, the aim of Chapter 7 is to understand the impacts of land use/land cover on fluvial processes and riparian flowpaths. This is important, because flow path elevation and duration control the processes that remove nitrogen from the stream riparian zone and ultimately affect water quality (fig. 1). Riparian buffers are often promoted as effective land management practice to improve water quality (USDA-NRCS, 2005); therefore, it is important to understand site-specific factors that may impact their effectiveness.

5.3.2 Understand the impacts of historical and current policies on land tenure that ultimately drive governance of natural resources.

Because LULC can be a major driver of the processes that determine effectiveness of best management practices to remove nonpoint source pollution, it is also important to understand political and cultural drivers that determine adoption of certain land management practices, and subsequent land cover patterns. Chapter 8 seeks to understand the impact of historical and current government policies on Indigenous land tenure, governance, and natural resource control on the Prairie Band Potawatomi Nation. These variables help to explain checkerboarding (a common situation on reservations where native land is intermingled with non-native, privately owned land); natural habitat landscape patterns; and ecosystem service provision that drive land use patterns. Land tenure and governance will also determine the amount of agency that Indigenous tribes possess to apply their own values and priorities to land management (see: Montana v. United States, 1981; Brendale v. Confederated Tribes & Bands of Yakima Indian Nation, 1989). Political Ecology lends itself to an understanding of the impact of historical laws and policies on current landscape patterns.

5.3.3 Investigate how Indigenous values and priorities toward riparian and stream ecosystem services is translated into land and water management on the Prairie Band Potawatomi Nation.

Where a tribe has agency, they will apply land management strategies according to their cultural values, priorities, and their own definitions of success (Schrader, 1993; Berkes et al. 2000). This ability is crucial to their sovereignty as self-governing nation states (The Kimberley Declaration, 2002). Understanding Indigenous values and priorities is important for government agencies and conservation managers who work in areas controlled by tribes. It also may provide an alternative framework for understanding the drivers behind land management strategies and ecosystem service provision. Chapter 9 examines the cultural drivers of land management decisions on the Prairie Band Potawatomi Nation, including Traditional Ecological Knowledge (TEK) and Local Ecological Knowledge (LEK). These values, where a tribe has agency, will determine natural habitat conversion or retention, and ecosystem service provision. These variables feed back into overall LULC in a watershed.

In summary, this dissertation examines relationships between LULC, riparian flowpaths and riparian buffer effectiveness, and Indigenous governance and cultural values that interact to determine overall LULC patterns. Understanding both the physical and the cultural variables in this study are important for achieving the management shifts needed for real change. Our current standard approaches are not being effective, despite millions of dollars spent (eg. Jones et al., 2018). Real progress toward addressing nonpoint source pollution requires a paradigm shift in both science and culture. This dissertation provides a framework to move closer to that shift.

Chapter 6: Study Area – the Prairie Band Potawatomi Nation

6.1 Study Site – Physical Characteristics

This study was conducted on the Prairie Band Potawatomi Nation, at a private property site on James Creek (fig. 3). James Creek is a deeply incised second-order (Strahler, 1952) tributary to Soldier Creek. Soldier Creek flows from Nemaha County in northeastern Kansas, across the length of the Prairie Band Potawatomi Reservation in Jackson County, and south to Topeka in Shawnee County where it converges with the Kansas River (fig. 3). The watershed of Soldier Creek drains about 334 mi^2 of mostly agricultural land (Juracek, 2002) and is located within the Dissected Till Plains Section of the Central Lowland Province, characterized by dissected deposits of Pleistocene glacial till that consist of silt, clay, sand, gravel, and boulders overlying bedrock (Fenneman, 1946). Bedrock in the basin is primarily Pennsylvanian and Permian limestone and shale that dips gently northwestward (U.S. Army Corps of Engineers, 1974; Carswell, 1981). Flood plains in the basin consist of Pleistocene and Holocene alluvium ranging in thickness up to 65 feet (~20 meters), and generally consist of clayey silt in the upper 30 to 40 feet (9.1 to 12.2 meters) underlain by as much as 30 feet (9.1 meters) of silty sand and gravel (Walters, 1953; Carswell, 1981). Soils within the basin are classified as silt loam (soil group B), clay loam, or silty clay loam (soil group C). The basin has a rolling land surface with gentle slopes of generally less than 10 percent (U.S. Department of Agriculture, Soil Conservation Service, 1979).

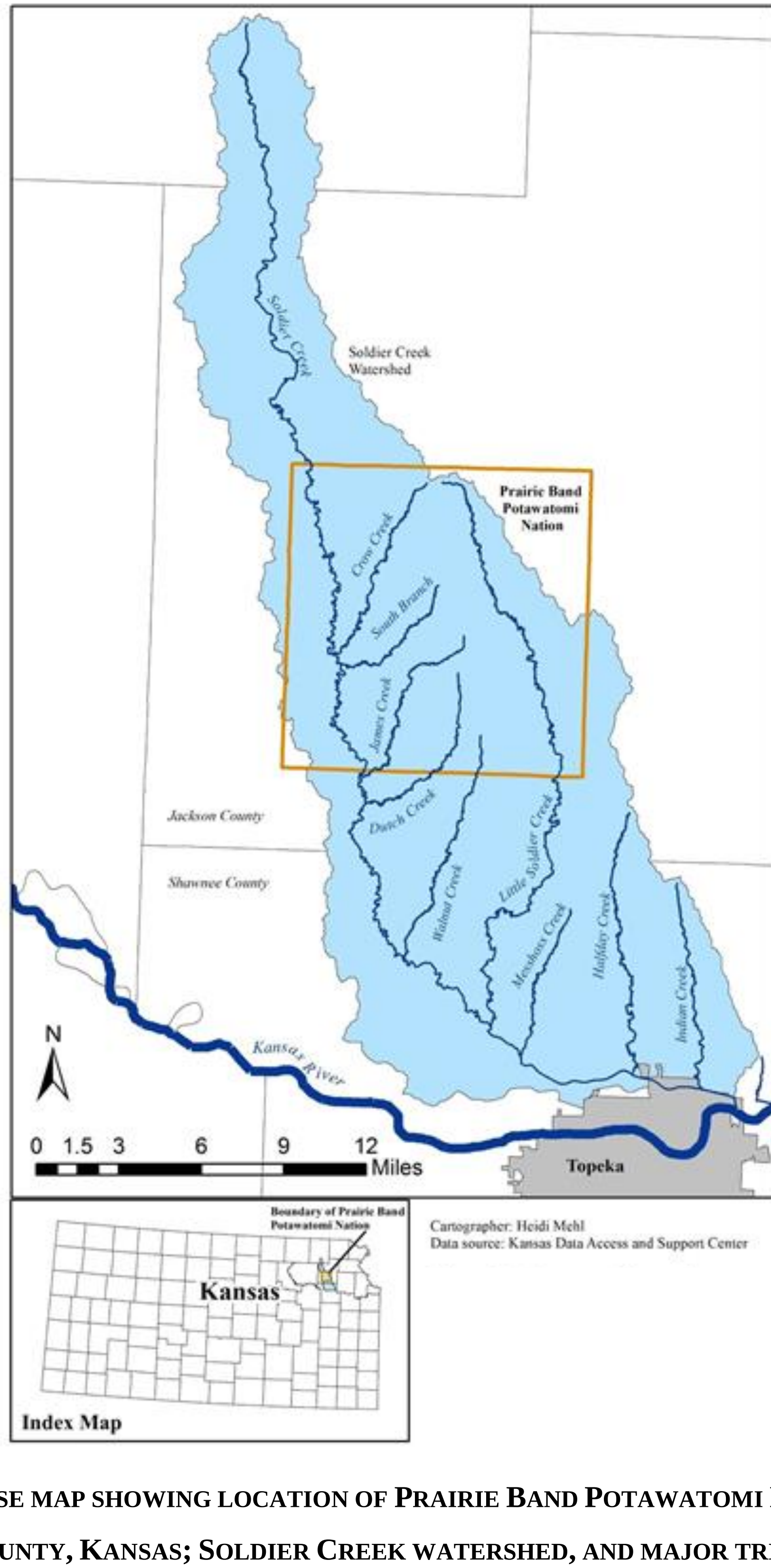

FIGURE 3 BASE MAP SHOWING LOCATION OF PRAIRIE BAND POTAWATOMI NATION IN JACKSON COUNTY, KANSAS; SOLDIER CREEK WATERSHED, AND MAJOR TRIBUTARIES

The Soldier Creek watershed includes approximately 339 mi2 (216,898 acres) of land. Annual average precipitation in the Soldier Creek basin is 34-37 inches per year (86-94 cm/year) (1981-2010 average). Depth-weighted, mean soil permeability in the basin ranges from 0 to 2.2 in/hr (0 to 5.6 cm/hr) with a mean of about 0.5 in/hr (1.27 cm/hr). In general, soil permeability is less in the uplands (typically less than 0.7 in/hr [1.8 cm/hr]) and higher in the flood plains (typically between 1.0 and 1.3 in/hr [2.54 – 3.302 cm/hr]) (Juracek, 2000). Land use in the basin is predominantly agricultural. Major categories are grassland (63 percent), cropland (30 percent), and woodland (6 percent). Cropland is generally concentrated in the flood plains of Soldier and Little Soldier Creeks. Urban land use accounts for less than 1 percent of the basin (Kansas Applied Remote Sensing Program, 1993).

The water resources on the Prairie Band Potawatomi Nation (PBPN) reservation are affected by many of the same issues facing surface and groundwater systems throughout the Great Plains. Soldier Creek and its major tributary, Little Soldier Creek, are major resources for the Prairie Band Potawatomi Nation, and provide valuable fishing, hunting, and recreational resources for the tribe, as well as potential water supply (Mehl, 2009). Major streams on the reservation are deeply incised and have been shown to be affected by elevated levels of nutrients, sediment, bacteria, pesticides, and other water quality problems common in the Great Plains region (Schmidt and Mehl et al., 2007). Soldier Creek, the main stem of the stream system draining the reservation, was channelized on its lower reaches more than 50 years ago. A knickpoint resulting from channelization has migrated upstream to at least the southern boundary of the reservation, where a natural limestone bedrock outcropping seems to be preventing further upstream incision, at least temporarily (fig. 3) (Juracek, 2002).

The downstream reaches of Soldier Creek were channelized in and near Topeka during at least two projects. In 1933, the Northeast Drainage District of Topeka channelized the portion of Soldier Creek flowing through the city, in an effort to minimize flooding. The affected channel was reduced in length by about 27 percent. The second project was conducted by the U.S. Army Corps of Engineers (USACE) between March 1957 and

November 1961. The resulting project realigned several miles of Soldier Creek and reduced the length of the channelized reach an additional 20 percent. This project also relocated the Soldier Creek confluence with the Kansas River 1.6 mi farther downstream (U.S. Army Corps of Engineers, 1988; Juracek, 2002). The channelized portion of Soldier Creek extends approximately 10 stream miles upstream from its confluence with the Kansas River (fig. 3).

Studies subsequent to the channelization project indicated that the channel bed upstream had degraded and widened substantially, and aggraded downstream from the channelized area (U.S. Army Corps of Engineers, 1988). In 2002, the U.S. Geological Survey published an assessment of spatial and temporal channel change on Soldier Creek (Juracek, 2002). The study used data from seven stream gauges presently or formerly located on Soldier Creek, and one gage located on the Kansas River just downstream of the confluence.

The USGS study found that significant incision had occurred on the lower reaches of Soldier Creek. The channel-bed degradation resulting from the channelization traveled as far upstream as the gauging station near Delia, 12 miles upstream from the upstream end of the channelized section. The degradation had not yet reached this site in 1971, when a low-water bridge was installed just downstream from the gauging site. The bridge was undermined by bed scour and washed out in 1978, which allowed the bed to continue incising upstream until at least 1999. The channel degradation is estimated to have reached the southern boundary of the Prairie Band Potawatomi reservation between 1983 and 1987 (Juracek, 2002).

There is a natural limestone outcropping just within the southern boundary of the reservation on the main stem of Soldier Creek. This outcropping forms a short waterfall at low flows, referred to locally as “Rocky Ford” (fig. 3). Channel degradation has been measured downstream of Rocky Ford, but has not yet affected the outcropping in any measurable way. There are several theories for why the degradation has failed to migrate past Rocky Ford. It is possible that channel degradation has been inhibited by weirs and other grade-control structures that have been installed in the channel. It is also theorized that natural channel features and geologic conditions may be inhibiting further degradation of the channel. The channel immediately downstream from Rocky Ford may also be armored, preventing rapid incision of the channel (Juracek, 2002).

Though the severe incision caused by the channelization disturbance on the lower reaches has not proliferated beyond Rocky Ford, there have been periods of measurable stream degradation and aggradation in the upper reaches of Soldier Creek. Gauging sites near Circleville, Soldier, and Bancroft degraded during certain periods between 1961 and 1983. The gauging site just upstream from Rocky Ford (near Saint Clere) was aggrading between 1964 and 1978, with no trend in the years since then (Juracek, 2002). Because there are no dams or reservoirs in the Soldier Creek watershed (other than small farm ponds in the headwaters), and because the Rocky Ford outcropping seems to be providing a geologic control for channel incision migrating upstream from Topeka, channel incision observed on the main stem of Soldier Creek and tributaries above Rocky Ford is likely being influenced by changes in land use practices.

6.2 History of the Prairie Band Potawatomi Nation

The name “Potawatomi” means “People of the Place of the Fire,” as reflected on their tribal seal. The Potawatomi tribe originated in the Great Lakes Region of North America, originally part of a wider community that included the Odawa and Ojibwa People (known as the “Three Fires). These related tribes were quite successful in the Great Lakes region both as hunters and fishers, and later as traders with French settler communities (Mitchell, 2009).

In 1830, President Andrew Jackson signed the Indian Removal Act into law, giving the president power to negotiate removal treaties with Indian tribes living east of the Mississippi River. The wording of the Indian Removal Act was that of negotiated voluntary relocation; in practice the removal was often forceful and violent, and resulted in the deaths of thousands of native people (Cave 2003). Despite the best efforts of Potawatomi leaders to legally stay in their homelands, the Potawatomi tribe was forcibly removed under the Indian Removal Act, eventually ending up in present-day Kansas in 1846. Their original reservation territory was bordered on the south by the Kansas River, and included part of present-day Topeka (fig. 3). Less than ten years later, the Kansas-Nebraska act of 1854 opened this territory to settlement. Settlers were squatting on the land even before it was officially taken from the Potawatomi by treaty (Nichols 1956). Much of what remained of the original Potawatomi reservation was given to the railroad and religious interests by two treaties in 1861 and 1867 (Royster et al. 2002; Prairie Potawatomi Resistance, 1976).

During the period from 1871 to 1934, there were continuous efforts by the U.S. government to abolish tribes, reservation land holdings, and Indigenous ways of life. Known as the "Allotment and Assimilation Era," many policymakers during this time were driven by the notion that assimilation to Western culture was the key to prosperity for Indigenous people (Royster et al. 2002). As this idea gained traction, Indigenous people were encouraged and incentivized to abandon communal ownership of land, take individual land allotments and pursue agriculture as a career. According to PBPN historian Gary Mitchell (2009), it was around this time that the Potawatomi Nation experienced an internal divide. A majority of the members, desiring some type of stability amid the chaos of forced removals and land grabs, signed a treaty in 1861 to become citizens of the United States and to take the individual allotments. This group became the Citizen Band of the Potawatomi Nation (Mosteller 2011). A smaller group wished to remain true to their belief that the land belonged to everyone, not individual owners. This group of approximately 780 people became the Prairie Band of the Potawatomi Nation (PBPN) (Mitchell 2009). They remained on their communally-held land base, which by the 1880's had been reduced to 77,357 acres (Prairie Potawatomi Resistance, 1976).

Despite continued resistance and skillful use of non-violent protest and legal tactics, passage of the Dawes Act in 1887 provided an avenue for the U.S. government to force them to take the individual allotments. By 1895 their remaining reservation territory had been divided into 80-160 acre parcels and allotted to each head of household (Prairie

Potawatomi Resistance, 1976). After allotments were designated, remaining reservation lands were sold in "surplus" auctions. Much of the allotted land too would be gradually lost, as it became subject to taxation and other financial obligations. Many owners, having been given marginal lands and finding an agricultural lifestyle not just unfeasible, but also culturally unacceptable, were unable to pay the taxes and fees and saw their allotments sold at sheriffs' auctions. Some individuals retained ownership of their land, only for it to be lost or fractionated (divided into smaller parcels) after their death. If the allottee had more than one legitimate heir, the land was divided evenly among them, resulting in the original allotment being fractionated into smaller and smaller pieces with each generation. Each fraction of the allotment was then again subject to taxation and other provisions. If an allottee died with no legitimate heirs, his land transferred to the state by the "escheat" provision (Royster et al. 2002). Many of these allotment parcels met the same fate as many others across the United States, chipped away through taxation, fractionation, and the escheat provision. The end result is the checkerboard pattern of land tenure seen today (fig. 17). The PBPN reservation today covers an area of 121 mi^2 (77,880 acres), about 20 miles north of Topeka, in Jackson County in northeastern Kansas (fig. 3).

Despite enduring forced relocation and the loss and fractionation of their reservation territory, the PBPN have shown incredible resilience and have been very successful in building infrastructure and creating community resources. They have built the governance structures necessary to extend their agency and apply land management preferences for cultural resilience and survival. They have tracts of recently purchased land, which will now fall under their jurisdiction for land management (fig. 17). Their land management preferences place emphasis on cultural resilience and survival. Natural resources, including streams, are highly valued as a resource for subsistence fishing and hunting. Many tribal members still engage in traditional hunting and fishing practices such as hand fishing, and consider them culturally important (Mehl, 2009).

Over the past ten years, I have worked closely with the PBPN on various water quality studies and stream improvement projects, and have had an opportunity to build relationships and conduct ethnographic fieldwork with members of the tribe. This dissertation is informed by my previous research on the reservation, which found that the primary streams on the reservation (Soldier Creek and Little Soldier Creek, fig. 3) are affected by water quality problems common to surface water in agricultural regions, including elevated levels of sediment, nutrients, bacteria, and pesticides (Schmidt and Mehl et al. 2007).

Chapter 7: Understanding Hydrologic Setting and Potential Delivery Or Remediation Of Nitrate In The Riparian Zone of an Incised Channel, Under Both Forested and Agricultural Land Use.

7.1 Research Objectives and hypothesis

This study investigates riparian zone hydrology on an incised stream, to better understand potential impacts on nitrogen removal processes. The investigation of coupled hydrologic/biogeochemical relationships under different land management regimes (forested vs. cropland) will address whether precipitation interflow to incised channels is interacting with the soil in such a way that denitrification processes are facilitated, or inhibited. I hypothesize that interflow will more often occur at a lower elevation due to incised stream beds and lowered water tables, thereby inhibiting denitrification processes.

7.2 Methodology

To determine how precipitation interflow is interacting with riparian zone soils, I installed a transect of nested piezometers in the riparian zone of James Creek (fig. 4). A site was chosen that had an intact forested buffer on one side of the creek, and a crop field with a thin (~40 feet) riparian buffer between the creek and a conventional-till row-crop field. The crop field was observed to be planted with corn during the growing season. No cover crops were used. James Creek is incised to a depth of 10.5 feet (3.2 meters) into the floodplain (fig. 5).

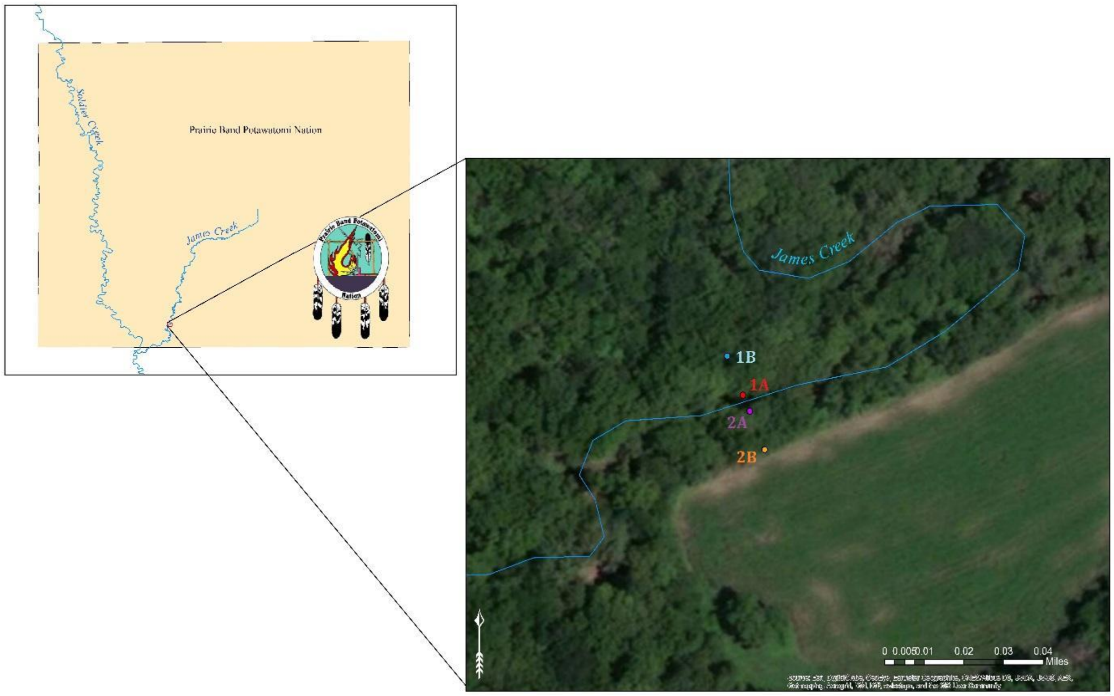

FIGURE 4 PLANFORM VIEW OF STUDY SITE ON JAMES CREEK, PRAIRIE BAND POTAWATOMI NATION

A total of 12 piezometers were installed at four sites along the transect. Each site contained three nested piezometers installed side-by-side at 2 feet, 6 feet, and 10 feet below the soil surface. The 2-foot (shallow) piezometer was intended to capture interflow interacting with the denitrification zone. The 10-foot (deep) piezometer was installed to approximately the bed elevation of the stream channel. The 6- foot (medium) piezometer was installed to capture any interflow that might occur between the shallow and deep flow paths. A nest was installed at the edge of the bank on both sides of the stream (nest 1A on the forest side; nest 2A on the crop field side, fig 5). Another nest was installed approximately 45 feet upslope from the near-bank nest on each side (nest 1B on the forest side, nest 2B on the crop field side, fig 5). This provided an array of sampling points, both laterally and vertically. This design also established a paired riparian study, so that preferential subsurface flow paths under an intact forested area could be compared to preferential subsurface flow paths from a crop field through a narrow riparian buffer on the other side of the stream corridor.

The piezometers were constructed of white 2-inch PVC, screened along the bottom 2 feet. The piezometers were installed using a hand auger with a 4-inch diameter bucket attachment. Holes were augered to the desired depth (2, 6, or 10 feet, described below). Soil samples were collected along the vertical transect as the holes were augered. Soils across the transect were dominated by an alluvial silt loam. After placement of the piezometer, the holes were refilled with sand along the screened portion of the PVC, then backfilled to the soil surface with the alluvium that had been removed when augering. Bentonite clay was used to create a seal over the top of the augered area and around the piezometer, to prevent vertical flow of water.

Each piezometer was instrumented with a CTD sensor, manufactured by Decagon Devices. The CTD sensors log water depth, electrical conductivity, and temperature. One sensor was placed in each piezometer, which was then capped with a U-shaped piece of PVC. This allowed the piezometer to stay open and equilibrated to ambient air pressure, but also kept rain from interfering with the readings inside the piezometer. A data logger was installed at each of the four nests, also from Decagon Devices. The sensors were programmed to take a reading every 5 minutes.

In addition to the piezometers, a WL16 Global Water Level Logger, manufactured by Xylem, was installed inside of a 2-inch PVC secured vertically to the bank. The site of the

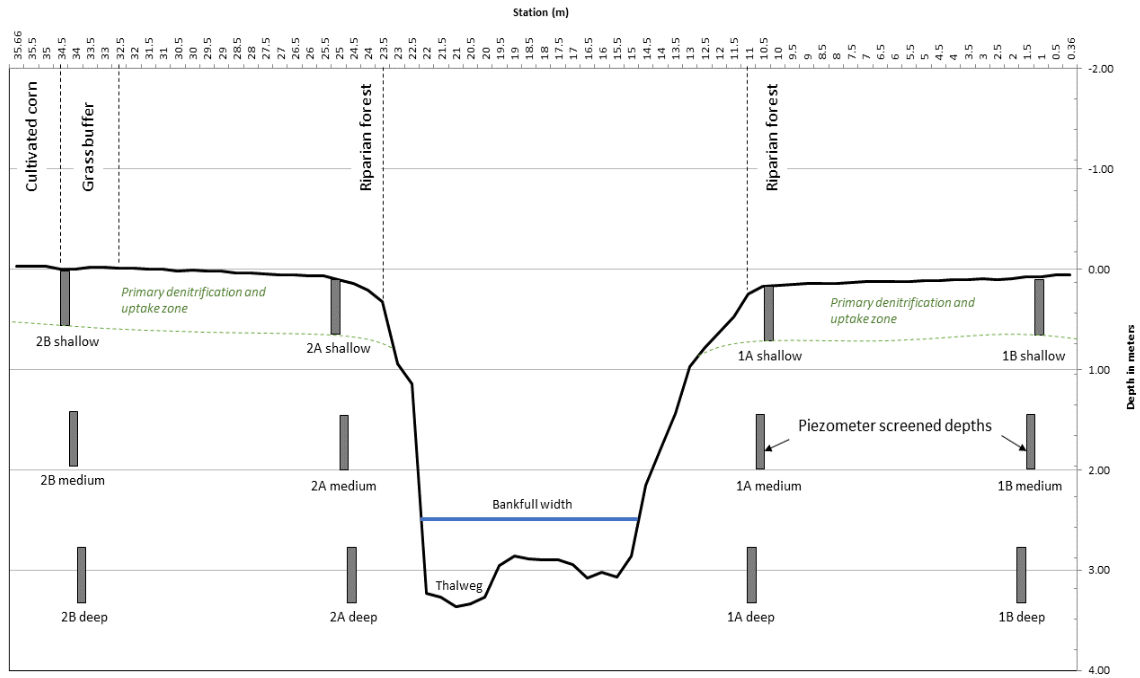

FIGURE 5 CROSS-SECTION VIEW OF STUDY SITE AND PIEZOMETER INSTALLATION

installation in the channel was directly in-line with the transect. The Global Water Level Logger logs internally, and was set to record in-stream water level measurements every 5 minutes. A tipping bucket rain gauge (Davis Model 7852M Metric Rain Collector) with an internal logger was installed just north of the site in an open field. The rain gauge bucket tips after collecting 0.2mm of water, and records each tip with the date and time.

Instrumentation was installed in the spring and summer of 2013. Unfortunately, there was an historic drought across Kansas for much of 2012 – 2014; therefore, the first year of this study did not yield much usable data (fig. 6). However, this did provide an opportunity to examine riparian zone hydrology under different antecedent moisture conditions (described below). This situation changed rapidly in the spring of 2015, when northeastern Kansas experienced above-average rainfall. This culminated in an overbank flood in June of 2015, which overtopped all 12 piezometers. This event compromised some of the equipment, and made future site measurements unreliable due to the amount of water that had entered the piezometers from the top. Therefore, the usable period of data evaluated was October 2013 – June 2015.

All instrumentation was tested and calibrated before deployment in the field. Sensors were checked and cleaned at every site visit, and calibration checks were done every 6 months in the field. The site was visited during every precipitation event, or at least once every four weeks in the absence of rain. When sufficient water was present in the piezometers during site visits, samples were extracted using a sanitized hand pump, and stored in sterile polypropylene sampling bottles. Sample bottles were stored on ice and transported to the K-State Research and Extension Soil Testing Laboratory (2308 Throckmorton Plant Sciences Center). Lab technicians analyzed the samples for nitrate (NO_3^-) and ammonium (NH_4^+).

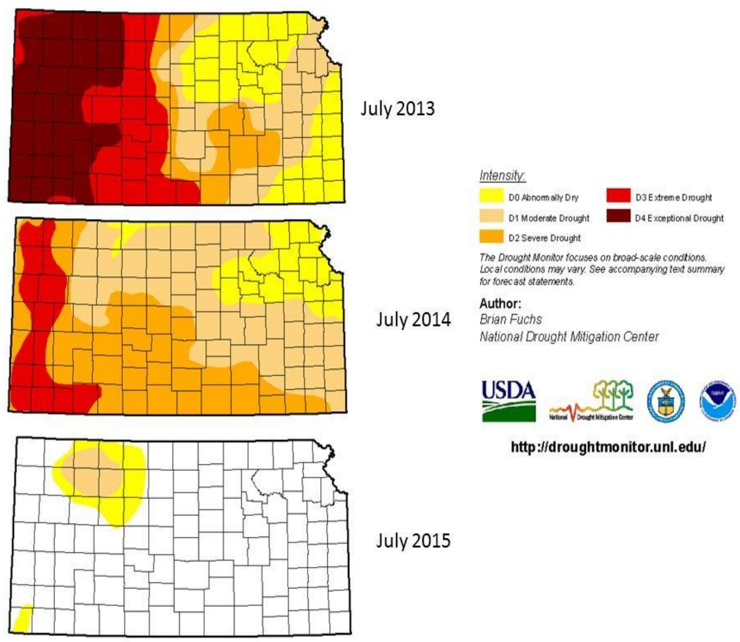

FIGURE 6 DROUGHT CONDITIONS DURING THE STUDY PERIOD

7.3 Results and Discussion

7.3.1 Frequency

Overall preferential flow paths through riparian soils indicated that piezometer 1B deep had the greatest number of event occurrences (32), followed by 2B shallow (30), and 2A medium (24) (fig. 7). Piezometer 1B medium did not register any events, and 1A medium only recorded two events, both during antecedent wet conditions in May 2015 (fig 7).

Comparing forest-side piezometers to crop-side piezometers, interflow on the forested side more often occurred in the deep wells in both nest 1A and 1B. On the crop side, both nests (2A and 2B) registered a greater number of events in the shallow wells than in the deep wells. The medium piezometers in 2A and 2B also registered a greater number of events than they did on the forested side, with piezometer 2A medium (near the stream) registering the greatest number of events in that nest (fig. 7). Flow occurrences from piezometers 1B deep and 2B shallow were greater than one standard deviation above the average. It would appear from these data that the greatest percentage of overall streamflow seems to be derived from deep interflow/groundwater under forested land cover, and from surface flow/shallow interflow from crop field runoff.

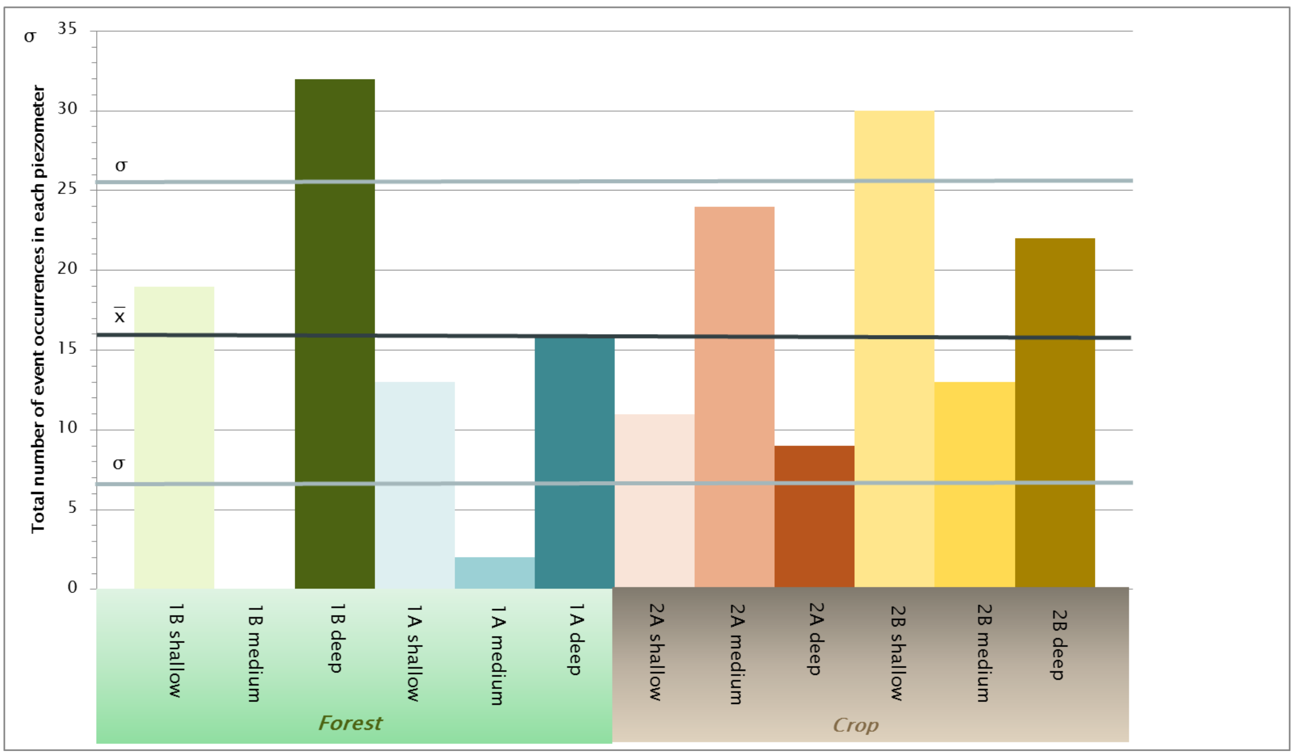

FIGURE 7 TOTAL EVENT OCCURRENCES IN EACH WELL. NESTS 1A AND 1B ARE ON THE FORESTED SIDE; NESTS 2A ND 2B ARE ON THE CROP FIELD SIDE

7.3.2 Duration

The duration of the flow events tells a different story than simply looking at number of event occurrences. Although 2B shallow had the greatest number of event occurrences, it has one of the shortest event durations. Flow events through the 2B wells were flashier (fig. 8), while flow events through the piezometers on the forested side took on a similar shape to a forested land cover stream hydrograph (longer events, more gradual, lower peaks) (fig. 8).

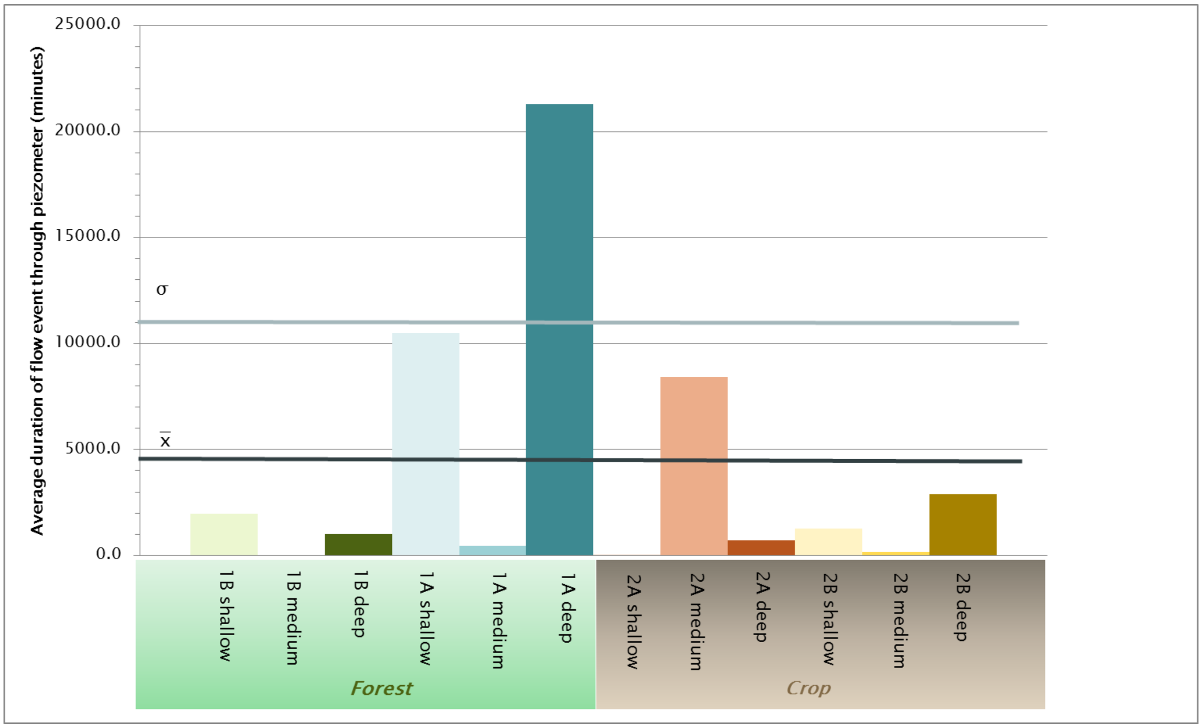

FIGURE 8 AVERAGE DURATION OF FLOW EVENTS THROUGH EACH WELL. NESTS 1A AND 1B ARE ON THE FORESTED SIDE; NESTS 2A ND 2B ARE ON THE CROP FIELD SIDE

It stands to reason that the deep wells under forested land cover would register a greater number of events. Forested land cover promotes infiltration (Yimer et al., 2008). The observations of deep preferential flow paths are likely due to the combination of infiltration of runoff, and the lowered elevation of the water table due to channel incision. The shallower preferential flow paths on the crop side could be due to reduced infiltration and the presence of a compacted soil layer caused by heavy agricultural machinery (observed when augering the wells for piezometer nest 2B).

It is interesting to observe that flow events in the 2B piezometers had larger storm peaks and shorter event durations, reflecting the appearance of in-channel stream hydrographs in highly modified watersheds (Tiller & Newell, 2009) (fig. 9, fig. 10). Flow events (defined as a distinct rise and fall of water level in the piezometer) through wells on the forested side occurred later after a precipitation event, had longer durations, and greatly reduced storm peaks (fig. 8, fig. 10). Larger storm peaks in streams are often assumed to be caused by increased overland flow. However, these data appear to show that water flowing through the soil profile from row-crop agriculture – even water flowing through deeper wells – behaves similarly (fig. 10).

There are interesting implications here for nitrogen removal processes. Buffers are optimized where shallow groundwater flow channels water through the riparian zone at

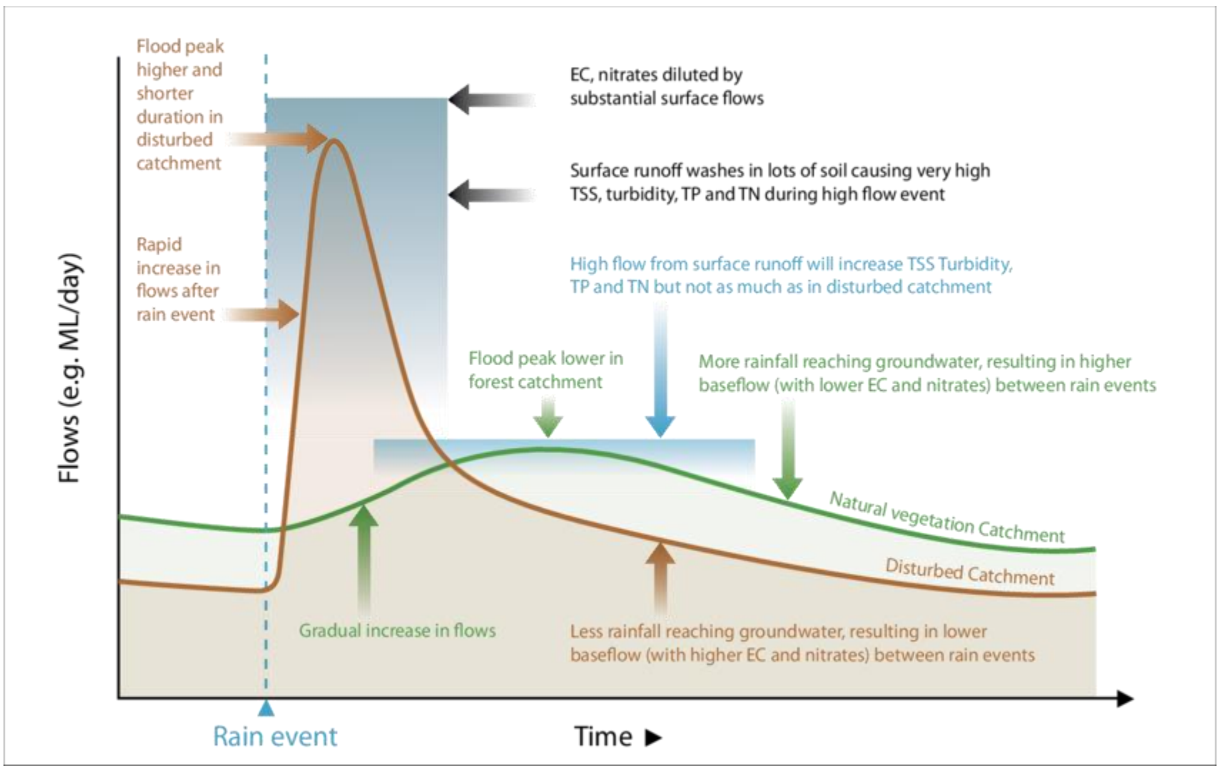

FIGURE 9 NATURAL VS. MODIFIED WATERSHED HYDROGRAPH. ADAPTED FROM TILLER & NEWELL, 2009

optimal velocities (Fennessy and Cronk, 1997; Simpkins et al., 2002), and optimal elevations in the soil profile to intersect the root zone (uptake) or organic carbon supplies (denitrification) (Hill et al. 2000). Under forested land cover on an incised channel, water seems to be flowing through the alluvial soils at favorable (slower) velocities (fig. 8, fig.

10). However, the events are more often occurring deeper in the profile, implying that the majority of the runoff is not intersecting the root zone or areas of (likely) organic carbon supplies needed for denitrification to occur. This may not be a concern if there are not high nitrate loads in runoff from forested land cover to begin with. However, if nitrate is being carried in streamflow from upstream agricultural or urban land uses, there could be reduced opportunities for denitrification on the floodplain or in bank storage during high flow events. Bank storage occurring at lower elevations in the soil profile would likely not interact with the root zone or areas of organic carbon supplies. Overbank floods may achieve this interaction; however these occur less often on an incised channel, which has effectively been disconnected from its floodplain (Fischenich et al., 2000).

Conversely, the thin (~45 feet) riparian buffer on the edge of a crop field seems to be experiencing interflow at shallower elevations, where water would intersect the root zone and organic carbon supplies more often. However, the majority of events in these piezometers were flashy, with quick event peaks and short durations. This implies that, although the water is intersecting favorable conditions, it may not be experiencing sufficient removal of nitrogen due to short event durations.

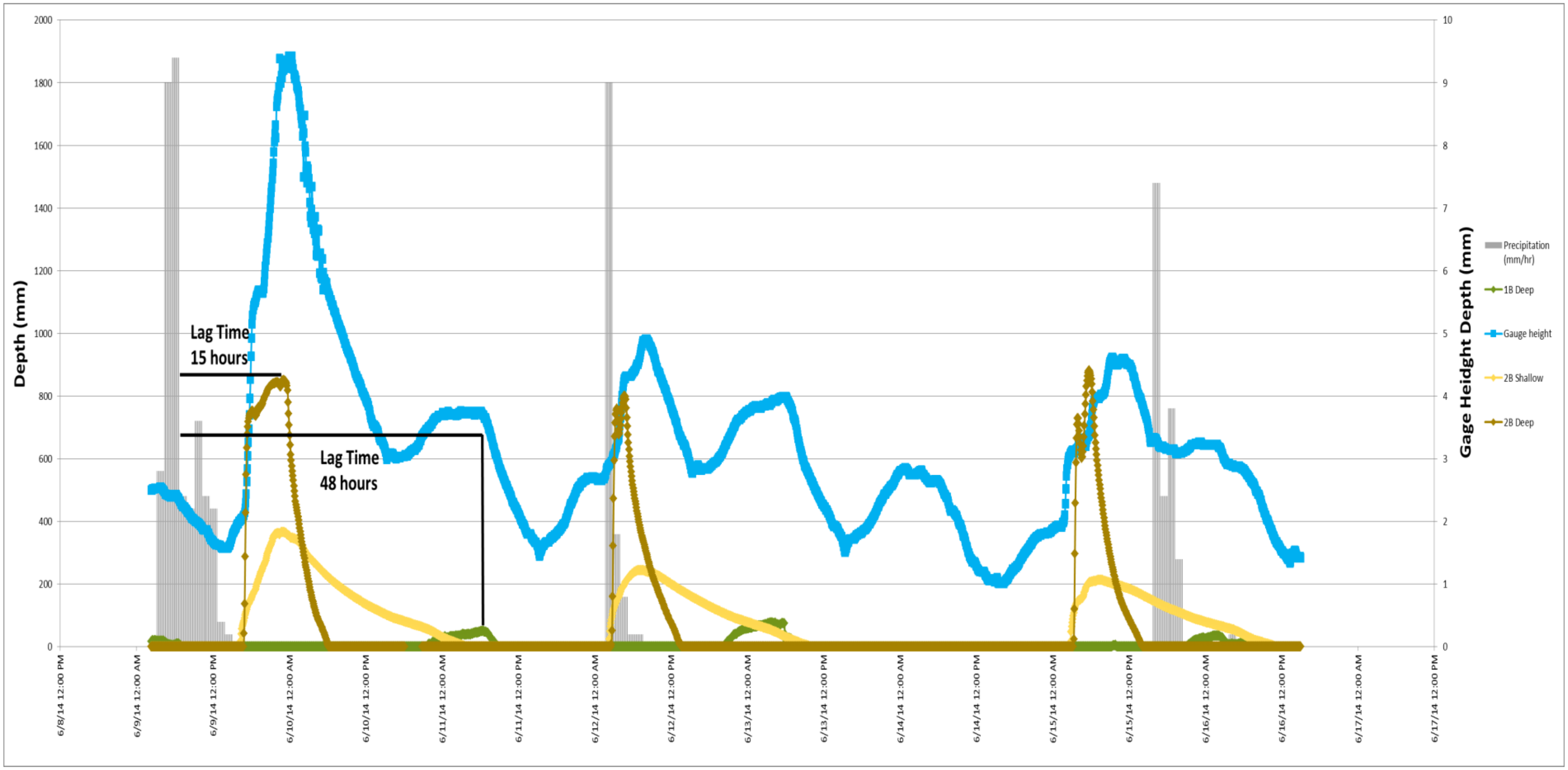

FIGURE 10 PIEZOMETER DATA FROM JUNE 2014, ILLUSTRATED WITH IN-STREAM GAGE HEIGHT (BLUE) AND PRECIPITATION EVENTS (GRAY). THE PIEZOMETERS AT THE EDGE OF THE CROP FIELD (2B SHALLOW, 2B DEEP) DEMONSTRATE SHORTER LAG TIMES AND QUICKER, FLASHIER FLOW PATTERN

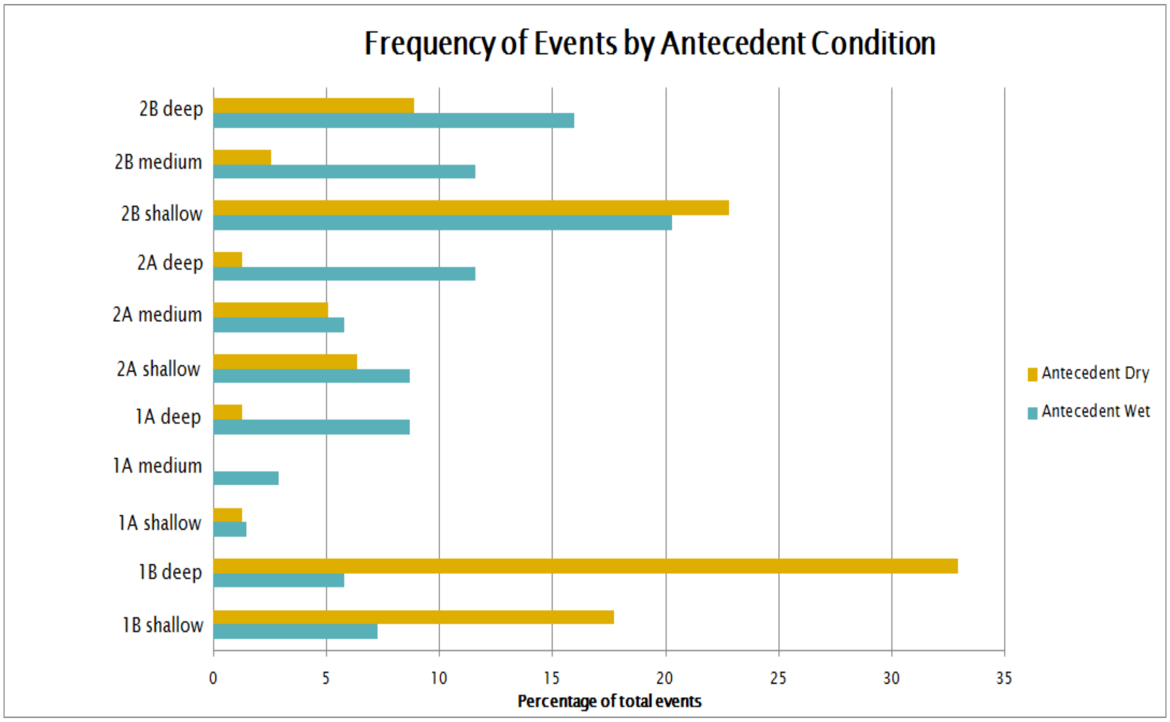

FIGURE 11 FREQUENCY OF EVENTS IN DRY VS WET CONDITIONS, CALCULATED AS A PERCENTAGE OF TOTAL EVENTS FOR THAT CATEGORY

7.3.3 Drought vs. Wet Years

The study period was marked by a long-term drought, lasting from 2012 - 2014. Rainfall began to increase in September of 2014, with much of northeastern Kansas experiencing flooding by June of 2015. This provided an opportunity to examine subsurface flow under different extreme conditions. During drought years and under dry conditions (fig. 11, fig. 12), streamflow appears to be dominated by deep interflow. The greatest overall frequency of interflow events occurred through 1B deep (fig. 11). However, the largest magnitude (hydraulic head) of interflow events occurred through 2B deep (fig. 12). A significant number of events also occurred in 2B shallow.

During wet conditions, nearly all of the wells experienced a greater frequency of events (fig. 12). Interestingly, 1B deep experienced significantly less frequent events under wet conditions, but the events were of greater magnitude (fig. 10, fig. 12). The frequency and magnitude of events through 2B shallow remained relatively consistent between dry and wet conditions. During wet conditions, near bank deep wells (1A medium and deep, 2A deep) experienced a significant increase in event frequency, which likely indicates bank storage and return flows from higher stream flows.

The dominance of deep interflow during drought conditions is interesting. It is possible that, in the absence of sufficient soil moisture in the upper layers of the soil profile to generate runoff, precipitation is percolating through unconsolidated alluvial soils in the vadose zone to deeper layers of the soil, nearer the water table. This underscores the impact of incised channels and lowered water tables on riparian soil moisture (Schilling, 2004). As the upper layers of the soil experience more prolonged periods of drying between precipitation events, interflow is also hindered. This may be causing leaching of nitrate as water percolates to deeper layers in the soil instead of flowing along the surface/subsurface where nitrogen removal processes could occur. A hypothesis for future research may be examining nitrate levels in deep groundwater during prolonged droughts.

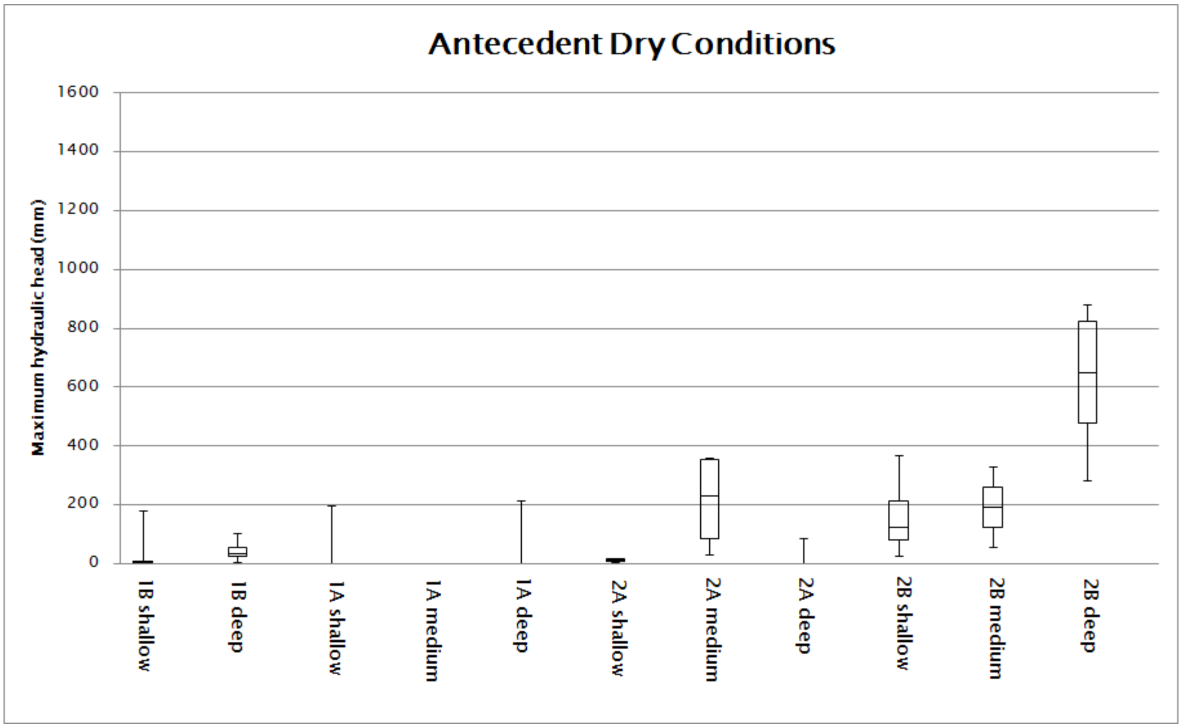

FIGURE 12 BOX PLOT OF HYDRAULIC HEAD MEASUREMENTS IN TRANSECT WELLS DURING DRY CONDITIONS. BOX PLOTS ILLUSTRATE THE 25TH, 50TH, AND 75TH PERCENTILES; THE WHISKERS INDICATE MAXIMUM AND MINIMUM VALUES

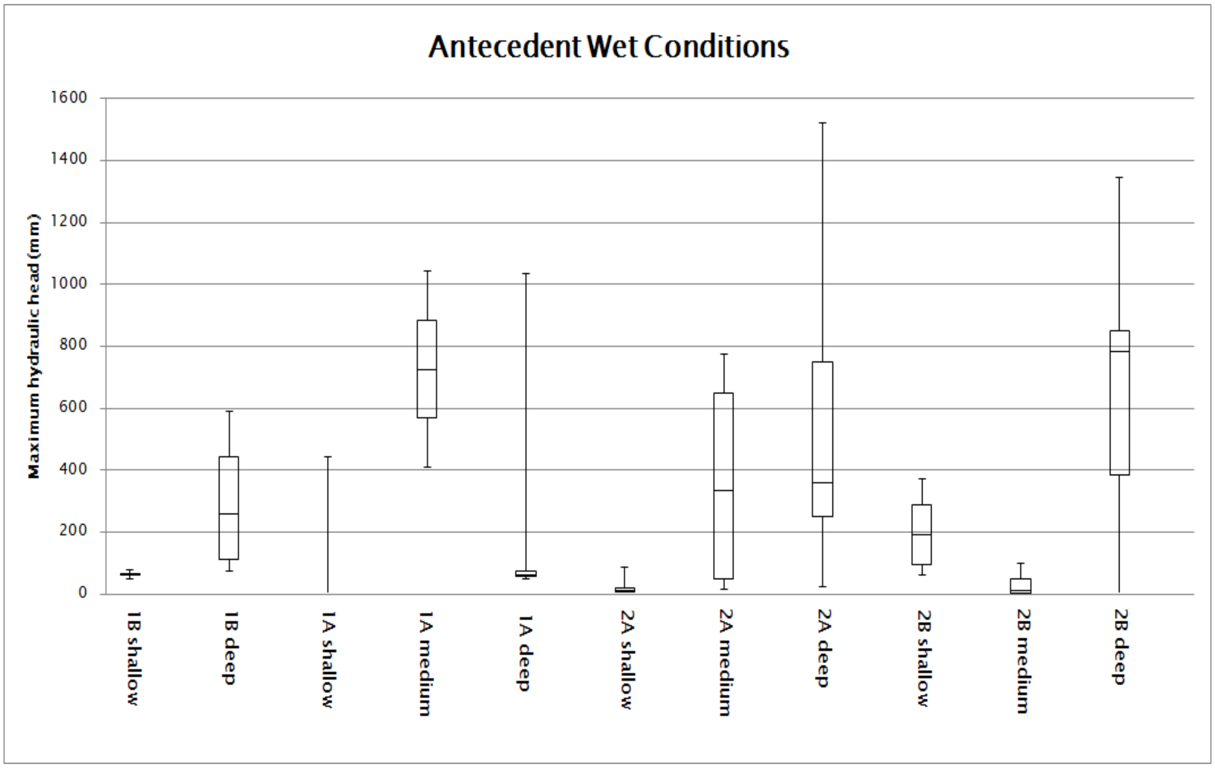

FIGURE 13 BOX PLOT OF HYDRAULIC HEAD MEASUREMENTS IN TRANSECT WELLS DURING WET CONDITIONS. BOX PLOTS ILLUSTRATE THE 25TH, 50TH, AND 75TH PERCENTILES; THE WHISKERS INDICATE MAXIMUM AND MINIMUM VALUES

It is intuitive that a greater number of wells would be active during antecedent wet conditions, when soil moisture is greater and would generate more runoff throughout the soil profile. Bank storage seen under these conditions could be providing an opportunity for denitrification and uptake, if the water is intersecting the root zone or organic carbon supplies in the soil (Rassam et al., 2006). These conditions would be more likely on the floodplain. Overbank floods are less frequent on incised channels (Fischenich et al., 2000), although it is worth noting that overbank flow that did occur in June 2015.

7.3.4 Ionic compounds

Due to the drought, short event durations, and other complicating factors, capturing samples from the piezometers by hand proved to be difficult except during very large rainfall events. However, sensors with the ability to record electrical conductivity (EC) and temperature were chosen to provide a proxy for concentrations of nitrate ions (Koumanov et al., 2001). Electrical conductivity measurements, because they are influenced by temperature, were standardized to 25^0C (Calles & Calles, 1990). With the samples that were captured and concurrent electrical conductivity readings from the piezometer, a regression equation was developed to estimate nitrate ion concentrations (*see*: Gali et al., 2012). However, the samples in this study showed a negative relationship with standard conductivity measurements. Therefore, this relationship cannot be used to directly estimate nitrate concentrations. However, EC readings do provide some information about overall concentrations of ionic compounds in riparian subsurface flow.

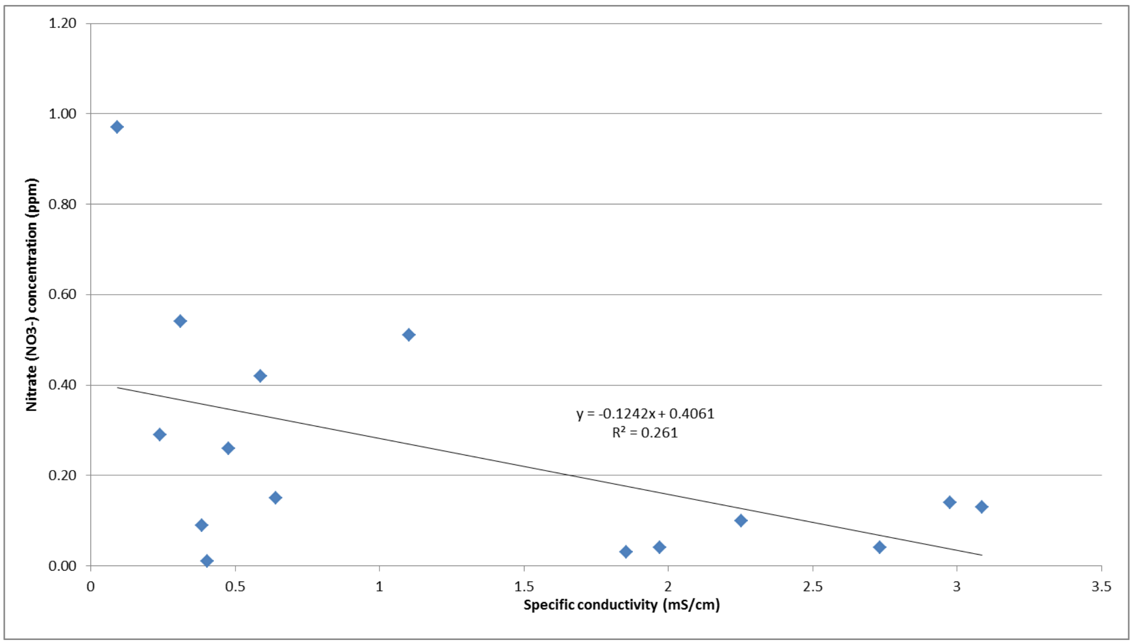

FIGURE 14 REGRESSION ANALYSIS OF MEASURED NITRATE (NO3-) CONCENTRATIONS AGAINST SPECIFIC CONDUCTIVITY

In both shallow and deep wells across the transect, we see a buildup of ionic compounds that is flushed out by subsequent precipitation events (fig. 15, fig. 16). This is especially pronounced in the deep wells (see 1A deep, figure 16). There is a slight increase under saturated conditions, presumably as compounds are carried from upland soils into the riparian area. These observations support the hypothesis that ionic compounds, potentially including nitrate, could build up in soils and be leached to deeper elevations in the soil profile during drought.

7.4 Conclusions

These data suggest that stream channel incision may be having an impact on runoff flow path elevation and duration in the stream riparian zone. This suggests that, as we disconnect water tables from surface soils and surface hydrology through our land use practices, we are also decreasing opportunities for nitrogen removal from our water resources. Runoff was found to be missing the best opportunities for removal of nitrogen and other pollutants, because of lower interflow paths under forested landcover, or because of short residence times in runoff from a conventional-till crop field. Drought conditions may be exacerbating the problem, as interflow through the shallow vadose zone was greatly reduced. On a larger scale, lowered water tables and reduced soil moisture may have profound large-scale impacts on biogeochemical cycles and nitrogen

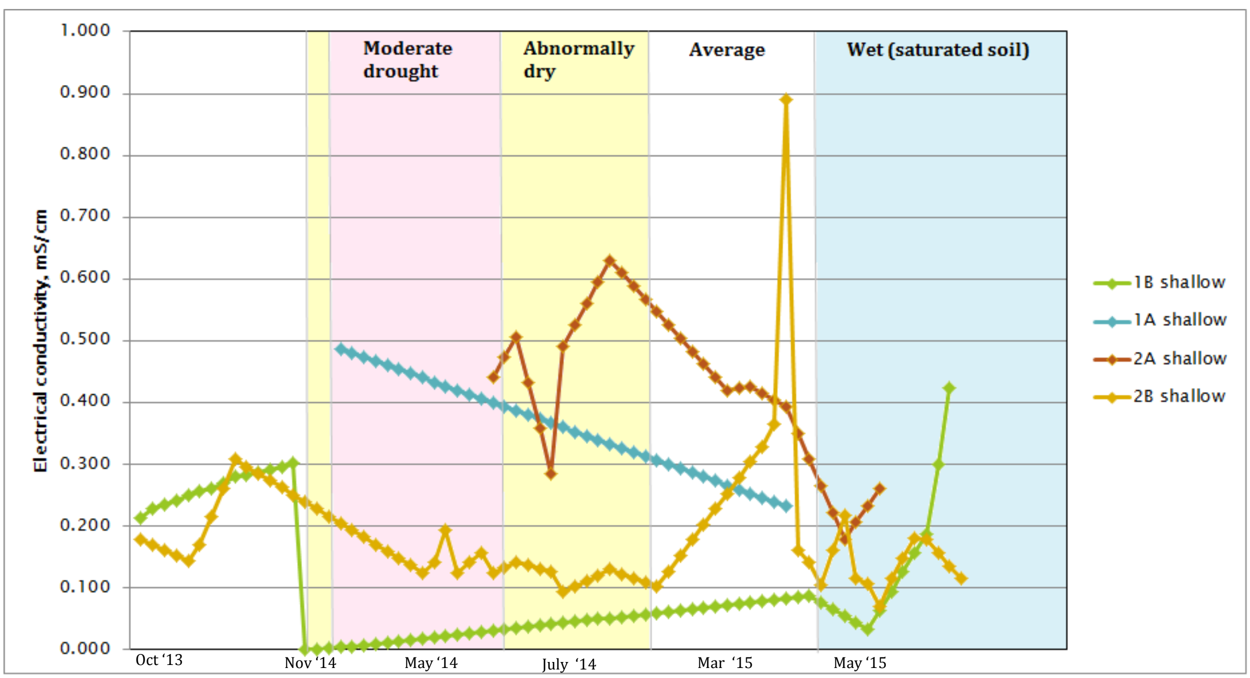

FIGURE 15 ELECTRICAL CONDUCTIVITY IN SHALLOW PIEZOMETERS

removal as climate change causes droughts to be more frequent and prolonged (IPCC, 2007).

These data suggest that in regions where incised channels exist, riparian buffers alone may not be sufficient to remove nitrogen from runoff before it enters a stream channel. This is not to suggest that riparian buffers are not helpful at all. They still provide myriad benefits to water quality, bank stability, and wildlife habitat as described above. However, when looking for solutions to large scale problems such as the hypoxic zone in the Gulf of Mexico, it is important to understand whether preventative practices are achieving the reductions that are expected, and where those practices should be layered with other practices to improve results. Increasing the effectiveness of riparian buffers to remove nitrogen is possible if upslope hydrology is better managed through in-field BMPs. For example, if the velocity of runoff from crop fields is slowed, the water entering the riparian buffer would experience a longer residence time, facilitating greater removal of nitrogen. This can be achieved through in-field practices, such as cover crops (EPA, 2003), and conservation tillage systems such as no-till (Lal et al., 2007). If these practices are not in place, a much greater width of riparian buffer would be needed to slow runoff and allow nitrogen to be removed from runoff (Snyder et al., 2004). These

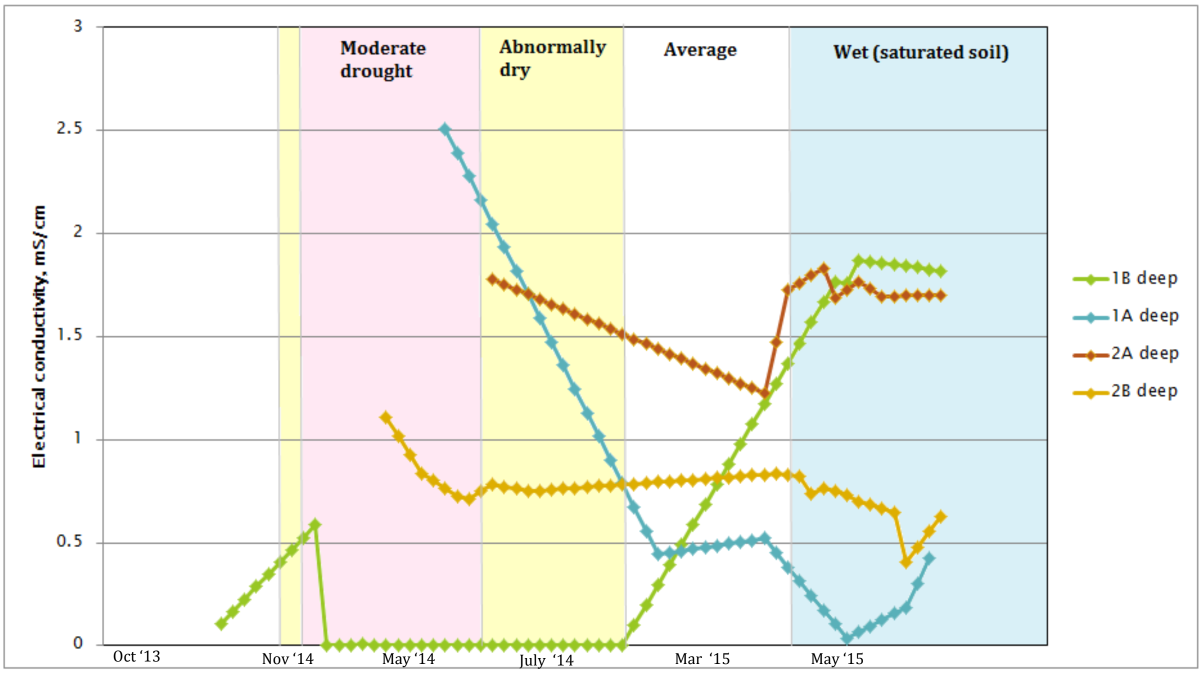

FIGURE 16 ELECTRICAL CONDUCTIVITY IN DEEP PIEZOMETERS

findings highlight the importance of whole-watershed management of hydrology for nutrient management. Whole-watershed management also provides greater opportunity for nitrogen removal throughout the landscape, instead of only relying on the stream corridor (Böhlke et al., 2007).

There are some caveats to this research that should be considered when interpreting the results. First, this study relied on data from only a single transect. There may be local characteristics in soils and soil texture, flow paths, or macropores (wormholes, fauna tunnels, voids from decayed roots) that could have influenced the data. Future studies should utilize an expanded monitoring area to control for these influences. Future site design may benefit from taller “snorkels” on the piezometers, to avoid the issue of overtopping during overbank floods. Future research may also analyze a comparison of runoff flow paths from conventional-till fields; vs. crop fields utilizing conservation tillage, to understand how layered BMPs may improve pollutant mitigation. Also, in areas where tile drains or other conduits are common, the majority of runoff may be delivered to the stream without passing through a riparian buffer or other area where nutrient uptake could occur. In these areas, it is even more important to consider land use and whole watershed management, and reduce nutrients and other pollutants before they are carried toward streams by runoff.

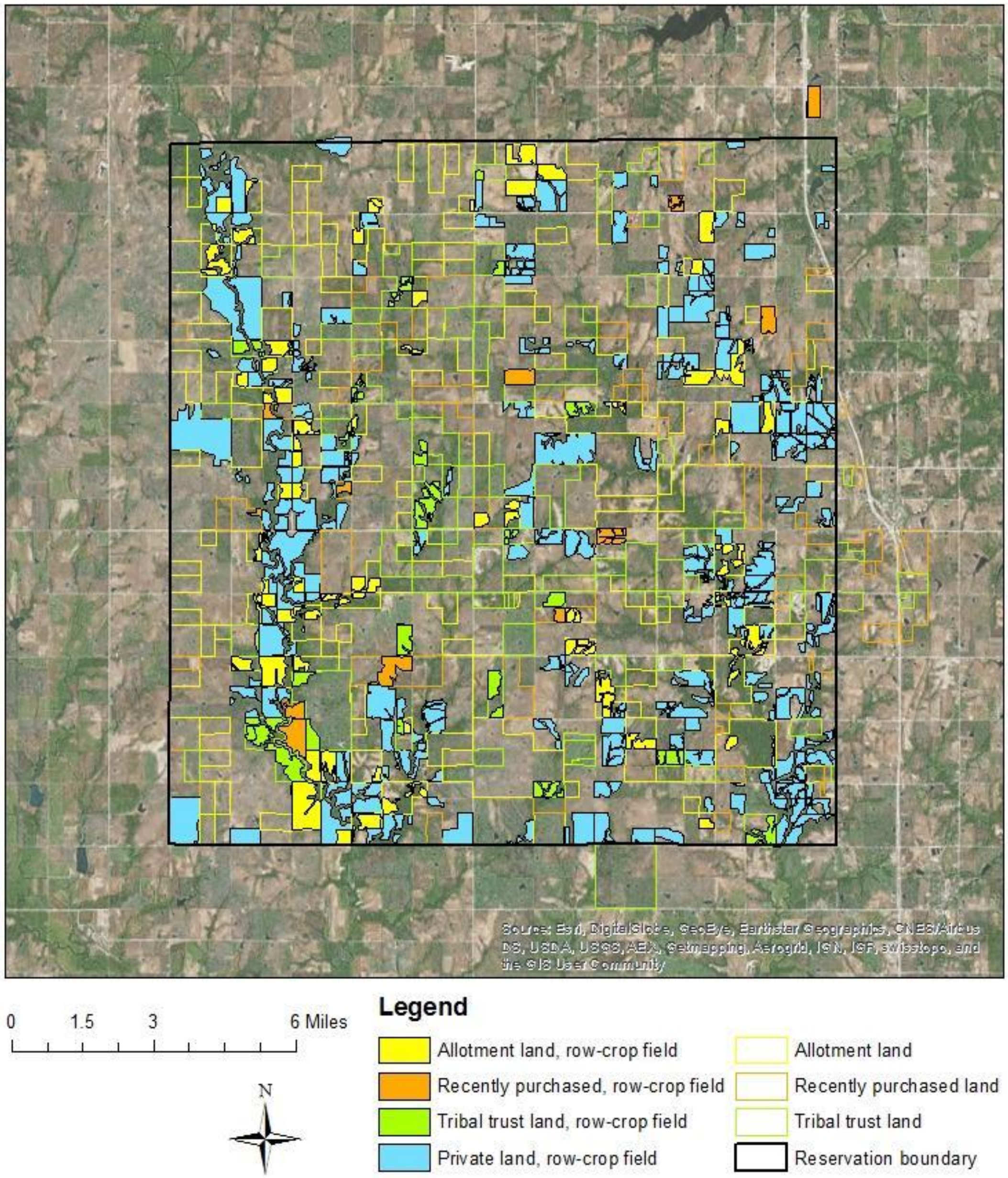

FIGURE 17 PARCELS ON THE PRAIRIE BAND POTAWTOMI NATION, SHOWING TRIBAL LAND TENURE AND OVERLAPPING ROW-CROP FIELDS

Chapter 8: Land Tenure on a Checkerboard Reservation as it impacts stream quality: Patterns of Land Use/Land Cover on the Prairie Band Potawatomi Reservation

Considering the impacts of historical policies toward Indigenous people, this study attempts to fill a gap in the literature by examining the role that reservation land tenure plays in LULC patterns that drive natural resource production and stream condition. This has direct implications for the ability of the PBPN to maintain their natural environment in a way that supports their culture and traditions. The overall objective for this study is to better understand patterns of land tenure on the PBPN reservation, and to understand how ownership drives LULC patterns. To achieve this, we use GIS mapping techniques to quantify important land management choices, specifically areas of row-crop agriculture and forested riparian buffers, by land ownership category within the boundaries of the Prairie Band Potawatomi Nation (PBPN) reservation in northeastern Kansas. The focus is placed on row-crop farming due to its prevalence in the Great Plains (USDA, 2011), as well as its drastic effects on biodiversity and stream condition (Allan, 2004; Puckett, 1995). Riparian buffers confer benefits to both biodiversity and stream condition in agricultural areas (Black, 2004), and are an important best management practice (BMP) (USDA-NRCS, 2005). Defining these patterns will inform development of a comprehensive management plan to meet tribal management goals to improve biodiversity and stream function.

While many authors have explored issues of environmental justice, pollution, and exploitation of reservation lands, no published studies to our knowledge have attempted to quantify the effects of fractionated land tenure on overall land use/land cover (LULC) patterns. Because LULC patterns largely govern biodiversity and stream condition (Allan, 2004), this is an important consideration to determine the ability of the tribe to implement management practices to support lifestyles and cultural traditions. This is especially significant in the Great Plains region, where a majority of land cover has been altered from native prairie grasses and lowland forests to row-crop agriculture and rangeland, with profound effects on natural resources and stream condition (Drummond and Auch, 2012).

Previous chapters explained the history and current social reality regarding Indigenous governance over reservation lands and how it impacts their ability to meet important ecosystem service goals. The current chapter presents findings on the impact of land tenure on land use/land cover. This is followed by a discussion of policy implications for Indigenous land management, including critical theory analysis identifying the actors to change the current reality, and an outline achievable practical goals for social transformation.

8.1 Data analysis

The overall objective for this study is to better understand patterns of land tenure on the PBPN reservation, and to understand how those patterns drive the LULC patterns that govern biodiversity and stream condition. To quantify these patterns, we asked:

1. What area of reservation land falls into each of four land tenure categories (tribal trust land, allotment land, recently purchased, or privately owned)?
2. Does land tenure category predict presence or absence of row-crop agriculture?
3. How many stream miles within the reservation (major creeks only) have intact riparian buffers, and how does land tenure relate to the presence or absence of riparian vegetation?

To achieve these objectives, I used the most recent tribal tract map (2011) produced by the Prairie Band Potawatomi office of Planning and Environmental Protection. The map shows how the reservation is divided among each land tenure category. The map was imported and georectified in ArcMap 10, and parcels were digitized according to land tenure category. Four categories of land tenure were considered: tribal trust land, allotment land, recently purchased land, and privately-owned land. Recently purchased land indicates land that has been purchased by the tribe from private owners. This land is typically placed into trust; however, it was considered as a category separate from tribal trust land, because recently purchased land may still reflect the land management choices of the previous private owner and not the tribe. Including it in the tribal trust category could skew those results.

The next step involved the overlay of the digitized map on aerial photography obtained for 2012 from the U.S. Geological Survey (USGS, 2012). The overlay allowed the identification and digitalization of row-crop field areas to determine total acreage devoted to row-crop agriculture on reservation lands (fig. 17). The National Land Cover Database (NLCD) (Homer et al., 2015) was used as reference, but manual digitizing provided a more accurate measure of total row-crop field area, and was feasible for this relatively small area. Fields with obvious signs of recent production (e.g., recent tillage, planted row crops, terraces, closed gullies) were marked as being in production. It is important to note that some agricultural lands in the watershed have been taken out of production in recent years due to many factors, especially enrollment in the Conservation Reserve Program (CRP). Therefore, fields with remnants of production (e.g., terraces), but displaying successional growth (shrubs, trees, dense grasses) were not marked as currently in production. Ground-truthing and Google Earth street view were used to confirm these designations. ArcMap geoprocessing tools were used to calculate the area where digitized row-crop agriculture parcels intersected each category of land tenure.

Statistical analysis was performed on the previous area-designation results, to determine whether land tenure is a statistically-significant variable in predicting presence or absence of row-crop agriculture. A chi-square test was used to test the null hypothesis: “Row crop agriculture will be distributed equally among land tenure type.” The expected null hypothesis value was calculated using the total percentage of row-crop area within reservation boundaries (18.59%, Table 1), multiplied by the total reservation acres in each land tenure category. This calculation provides the expected acreage for row-crop agriculture in each land tenure category if it was distributed equally among them. The chi-square test was carried out using these “expected” values against the observed values obtained from the GIS analysis.

Areas of intact riparian vegetation along major streams within the reservation boundaries were digitized using aerial photography from 2012 (USGS, 2012). Intact riparian vegetation was defined as any lateral width of continuous dense vegetation along the stream corridor. Intact riparian vegetation was most often characterized by deciduous trees; however shrubby grassland, especially along headwater streams, was also included. Riparian meadows and shrubby grassland are common native land cover for small headwater streams in northeast Kansas (Balch, 2001). Areas excluded from the “intact riparian vegetation” designation were those areas with obvious deliberate removal of dense vegetation, and/or crop fields planted to the edge of the stream channel. Major streams analyzed were: Soldier Creek, Little Soldier Creek, Crow Creek, South Branch, James Creek, and Dutch Creek (fig. 3). Surface water miles for the major streams were extracted from the National Hydrology Dataset (USGS, 2000), and clipped to the reservation boundaries using ArcMap geoprocessing tools, to give total major stream miles within the reservation. This file was then clipped where stream area intersected the digitized layer of intact riparian vegetation, giving the total stream miles with intact riparian vegetation on the reservation. These stream miles were then clipped by land tenure category, to give the total stream miles within each category with intact riparian vegetation. Total stream miles without intact riparian vegetation were calculated by subtracting stream miles with intact riparian from total stream miles for each land tenure category.

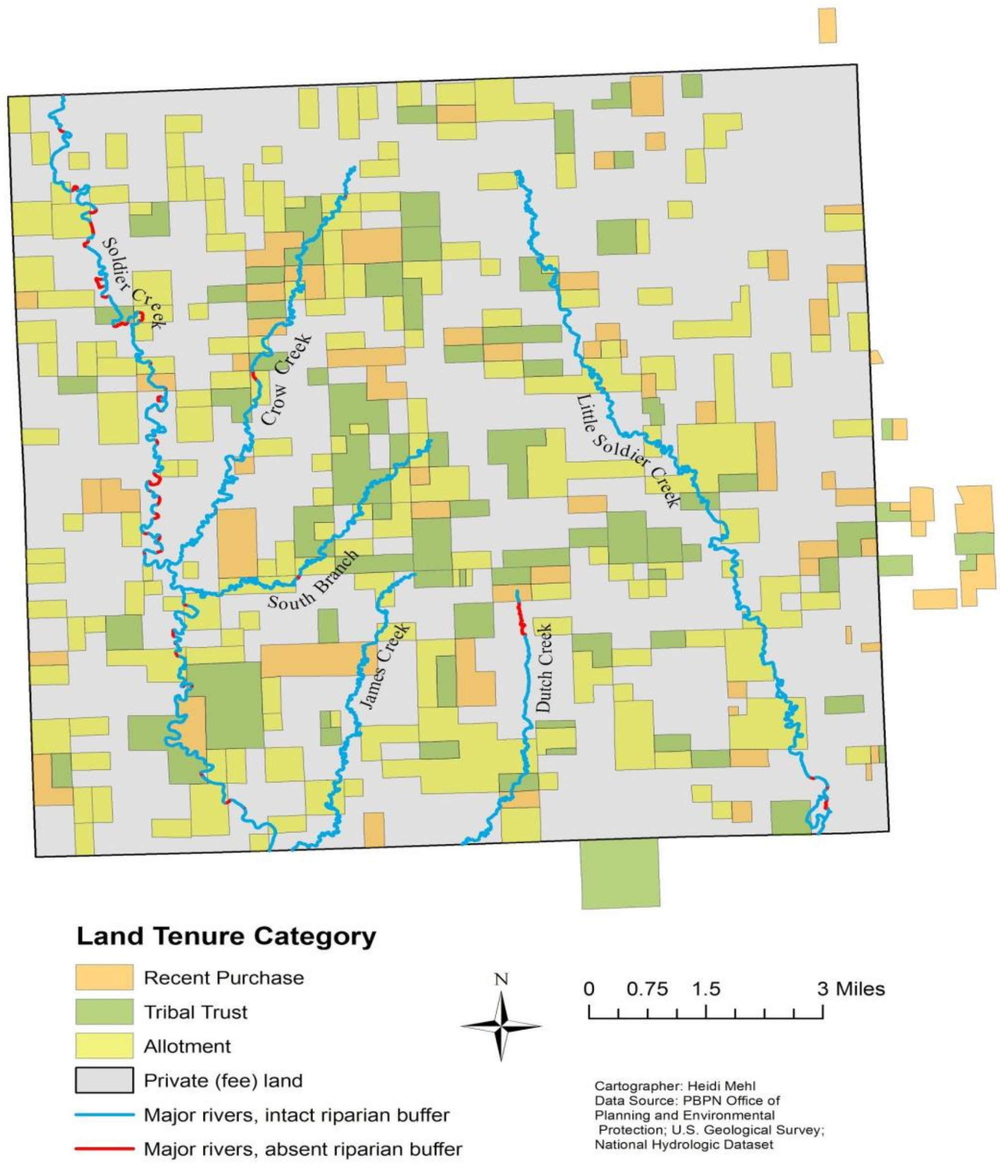

FIGURE 18 MAP SHOWING ANALYSIS OF RIPARIAN VEGETATION ON MAJOR CREEKS WITHIN THE PBPN RESERVATION. MAJOR CREEKS ANALYZED WERE SOLDIER CREEK, CROW CREEK, SOUTH BRANCH, JAMES CREEK, DUTCH CREEK, AND LITTLE SOLDIER CREEK.

8.2 Results

The analysis of the study area revealed a spatially fragmented landscape, both in terms of land tenure and LULC. Analysis of land tenure showed that 58.5 percent of the land within the reservation is privately owned (table 1). The remaining land is divided nearly equally between allotment land (22.5 percent) and tribal trust/recently purchased land (11.7 and 7.4 percent, respectively).

Table 1 Results of GIS analysis

	Total Reservation area (acres	Percent of Total Reservation area (%)	Row-crop area (acres)	Total Stream Miles	Total stream miles without riparian vegetation (mi)
Allotment Land	17522	22.5	2685	20.30	0.91
Tribal Trust	9083	11.7	1064	6.87	0.13
Recent Purchase	5730	7.4	655	3.90	0.05
Private Land	45545	58.5	10071	42.70	5.56
Total Area	77880	100.0	14475	73.77	6.65

Analysis of row-crop field area revealed that 18.6 percent of total reservation area (77,880 acres) is devoted to row-crop farming (14,475 acres), compared to approximately 30 percent of land in the entire Soldier Creek watershed (Kansas Applied Remote Sensing Program, 1993), and 38 percent of land in the state of Kansas (USDA, 2011). Cropland in the basin tends to be concentrated along the streams and floodplains of Soldier Creek and its tributaries.

Analysis of row-crop field area by land tenure category determined that the majority of row crops on the reservation are located on private land (table 1). Of a total 14,475 acres of row-crop agricultural land, 10,071 acres (70 percent) of row crops are on privately owned land. The remainder is split between tribal trust land (1064 acres; 7.4 percent), allotment land (2685 acres; 18.5 percent), and recently purchased land (655 acres; 4.5 percent) (fig. 17, table 1).

A chi-square test analyzing these results produced a p-value of < 0.00001. This indicates a vanishingly small chance that the null hypothesis is correct. The null hypothesis was therefore rejected, supporting the hypothesis that land tenure is a predictor of presence or absence of row-crop agriculture.

The majority of analyzed stream miles on the reservation have at least some intact riparian vegetation (fig. 19); only 6.7 miles (9 percent) of 73.8 total stream miles completely lack riparian vegetation (table 1). However, the majority (84 percent) of the stream miles lacking intact riparian vegetation were on private land. It was also found that more major stream miles cross private land than the three categories of tribally owned land combined (nearly 43 vs. 31 miles).

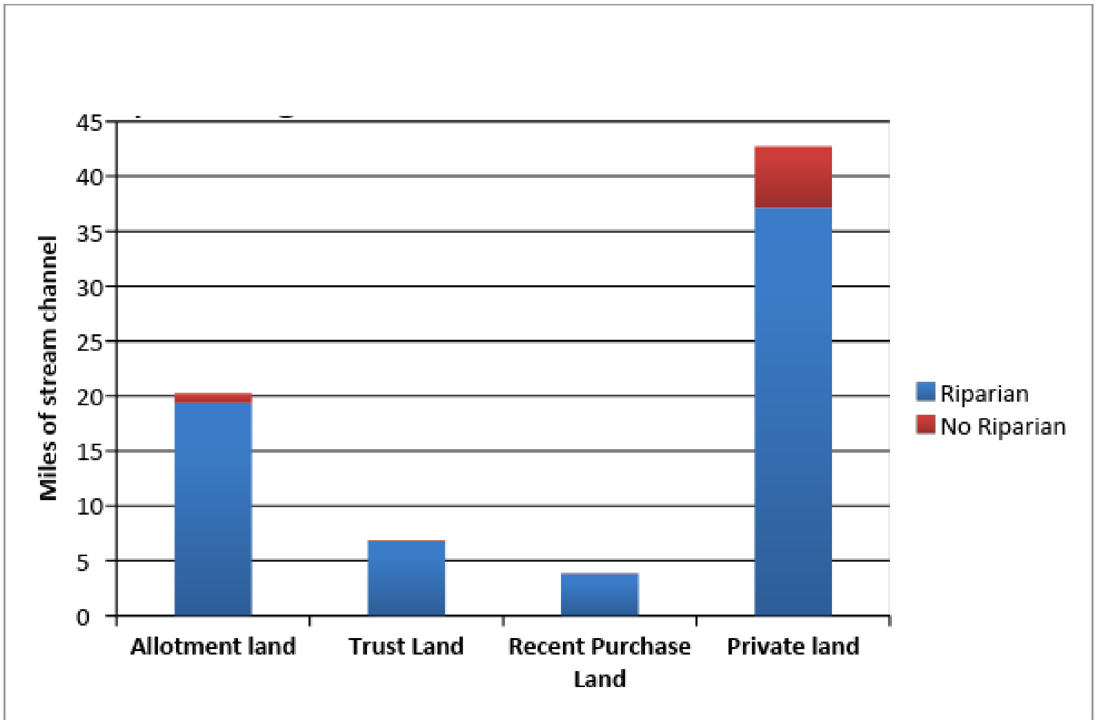

FIGURE 19 TOTAL STREAM MILES WITH AND WITHOUT INTACT RIPARIAN VEGETATION

8.3 Discussion

This study provides insights into important considerations of land tenure and associated management patterns, which drive biodiversity and stream condition and impact natural resources important to human livelihoods. The prevalence of private (non-tribal) land within reservation boundaries is a direct result of the Dawes Act and other government policies intended to abolish reservations. The analysis showed a clear preference for row-crop agriculture on private land, contrasted with a preference for native vegetation and management for optimal wildlife habitat on lands under tribal control (see fig. 20). However, there are relatively small areas of row-crop agriculture present on tribally-controlled lands (table 1). This could be explained by the observation that some allotment owners lease their land to non-Native farmers. Very few PBPN members farm their allotment land themselves (Barden, 2011). These observations are compatible with the history of the PBPN and stated preferences to continue subsistence traditions rather than engage in large-scale commercial agriculture. This also fits into the larger theme of land management according to traditional ecological knowledge (TEK), which places value

FIGURE 20 AERIAL PHOTOGRAPH OF A SECTION OF PBPN RESERVATION ILLUSTRATING DIFFERENCES IN LAND MANAGEMENT STRATEGIES BETWEEN ALLOTMENT LAND (AREAS CONTAINED WITHIN YELLOW SQUARES), AND PRIVATELY OWNED LAND (REMAINDER OF PHOTOGRAPH).

and priority on ecological processes, habitat, and biological conservation (Pierotti and Wildcat, 2000).

The finding that the majority of stream miles cross private land is likely also a legacy of the Dawes Act and other government policies during that time, as the most desirable lands were often the first to be declared “surplus” and sold to private owners. In this area of the state where lowland farming dominates, stream-adjacent lands and their associated riparian water rights certainly would have been the most desired.

This study highlights important consequences of the impact of fragmented land tenure on LULC patterns, and has implications for tribal sovereignty. Land management priorities often differ greatly from one land parcel to the next, creating a heterogeneous landscape of varying degrees of disturbance. The legacy of Dawes Act-era policies has left many Native communities with relatively small, disconnected parcels of land through which to fulfill cultural priorities and practices (if they were left with any land at all). The location of the majority of row-crop agriculture on private land underpins the notion that different land management priorities exist between private and tribally owned land, and these different priorities are determining LULC patterns accordingly. We can conclude that land management preferences and cultural attachments vary significantly between tribally-controlled land and private land parcels located adjacent to each other.

Regarding reservation ecosystems, the preference for row-crop monocultures and removal of riparian vegetation on private land may negatively impact biodiversity and stream condition throughout the watershed. Conversely, the presence of tribal trust and allotment lands with dense land cover (grassland, shrubland, deciduous forest), as well as intact riparian vegetation and wetlands, effectively increases landscape heterogeneity and creates “sinks” for nonpoint source pollution (Mankin et al., 2007; Black, 2004). Fragmented land tenure combined with different land management priorities has created distinct habitat patches within the reservation (see fig. 20). These dense vegetation patches benefit both biodiversity and stream condition in the agricultural landscape (Gergel, 2005; Pickett, 1978), helping to support important cultural traditions such as hunting and hand fishing.

It is important to point out that there are many non-Native landowners across the United States who manage their land from a strong conservation ethic, and whose efforts may be impacted by factors beyond their control, from pollution to climate change. However, as this paper has explained, the situation on reservations was created by systematic attempts to strip Native people of their land and cultures. Had Native tribes been allowed to remain in their homelands, or even retained their original reservation allotments, there would be more continuous land under their control to manage according to their specific ethics and fulfill cultural priorities. However, because we are left with the checkerboard and fractionated situation seen today, we must seek achievable practical goals for social transformation (*sensu* Frankfurt school).

8.3.1 Policy implications

Because the PBPN do not have jurisdiction over a majority of land within their boundaries or within the Soldier Creek watershed, it will be difficult for them to successfully implement projects to conserve natural resources and improve stream channel condition without the participation of private landowners on the reservation and throughout the watershed. The finding that that the majority of stream miles on the reservation are located on private land, as are the majority of row crops and nearly all of the stream miles that lack a riparian buffer, poises private landowners in an especially influential position to affect stream water quality and channel condition. Because the effects of agricultural runoff and unstable streambanks can proliferate throughout the stream system (Harding et al., 1999; Simon and Hupp, 1987), it will be necessary to include these private landowners in conservation plans to improve biodiversity and stream condition.

However, different land management priorities may create obstacles to reaching common natural resource goals. The emphasis placed by the PBPN on long-term ecological health and maintenance of traditional practices leads them to favor practices such as extending riparian forests and restoring or conserving wetlands. These practices represent long-term commitments to the landscape. Conversely, many private landowners may value natural resource conservation, but ultimately make land management decisions based on a financial risk/benefit assessment (Greiner et al., 2009; Kabii and Horwitz, 2006). Operating from this model may incentivize them to cut back riparian buffers or remove land from CRP to extend row-crop land when commodity prices are high (Hellerstein and Malcolm, 2011). So, while conservation practices on private and tribal lands may be superficially similar, those on private lands that are based on monetary incentive may be more vulnerable to economic fluctuations (Hellerstein and Malcolm, 2011; Pannell et al., 2006). Changing monetary incentives may also encourage landowners to favor practices such as grass swales that can be more easily removed, over long-term commitments like riparian forests and wetlands (Klapproth and Johnson, 2009).

Tribal power over non-Native activity on private lands within a reservation generally has been limited to that necessary to protect tribal members' health and safety (Slade and Stern, 1995). It can be difficult to impossible to impose upon private landowners to meet water quality standards or other natural resource goals, even if those private landowners are within reservation boundaries. However, the PBPN do have three options for influencing the actions of non-tribal members on private land. First, they can apply to the USEPA to be granted the authority to administer programs under the federal Clean Water Act (CWA). Under this Act, any federally recognized Indian tribe may be delegated the authority to regulate water within reservation boundaries, including setting and implementing a nonpoint source pollution management plan (CWA section 319); designating impaired waters and setting total maximum daily loads (CWA section 303); and issuing permits under the National Pollution Discharge Elimination System (NPDES) (CWA section 402). However, before this authority is delegated to a tribe, they must qualify to administer the program (sometimes referred to as “Treatment in a similar manner as a State” or TAS status), and develop a set of water quality standards that will be applicable under the CWA (USEPA, 2015). To qualify, the tribe must demonstrate that they have the resources to set and implement these standards, and to monitor environmental quality. A tribe who is granted this authority is allowed to set standards that are more stringent than those set by the U.S. Environmental Protection Agency

(USEPA) and the state (see: Albuquerque v. Browner, 522 U.S. 965 (1997)). Any standards set by the tribe apply to water flowing onto reservation lands as well as stream channels on the reservation; meaning private landowners both upstream and on the reservation would have to ensure that streams running through their land are able to meet the standards set by the tribe.

In the case of a problem with a single landowner negatively impacting water (or air) quality, the tribe may be granted regulatory authority under Montana v. United States. In Montana v. United States (450 U.S. 544, 547 (1981)), the Supreme Court ruled that a tribe does not have regulatory powers over nonmembers on private (fee) lands unless: the nonmembers have entered a consensual relationship with the tribe, such as a commercial contract or lease; or the nonmembers' conduct "threatens or has some direct effect on the political integrity, the economic security, or health and welfare of the tribe." In this context, a tribe must prove at least one of these conditions (known as the “Montana test”) to be granted regulatory authority over nonmember activities on private lands. However, this is the most costly and time-consuming option, and would generally only be successful in the case of a serious negative impact on the health and well-being of the tribe.

A third option is to develop a collaborative land management plan, with voluntary cooperation from private landowners and incorporating the knowledge and goals of both tribal members and private landowners (Stevenson, 1996). The degree to which this is successful depends heavily on the history of interactions between the tribe and private landowners, and the ability to agree on common environmental management goals.

To reduce impacts of agriculture and achieve greater improvements in biodiversity and stream quality, it will be necessary to increase the size and number of dense land cover patches. This can be achieved through a collaborative conservation plan between the PBPN and private landowners that includes enrollment of land into CRP and greater implementation of BMPs. There are promising indicators: many landowners have worked with the Kansas State University extension office and other conservation groups to implement BMPs and streambank stabilization projects (Barden, 2011; *and personal observation*). The finding that the majority of the major stream miles have some measure of intact riparian vegetation (fig. 19) may indicate an overall awareness of and concern for stream health by private landowners as well as tribal landowners. Many private landowners on the reservation have enrolled land in CRP, although overall enrollment in Jackson County declined from 21,890 acres in 2007 to 12,904 acres in 2013, a loss of 8,986 acres or 41 percent (FSA, 2013). Many landowners also participate in regular stakeholder meetings and BMP workshops organized by Kansas State extension, local nonprofit organizations, and other conservation agencies (e.g. Together Green meeting, Friends of the Kaw, November 15, 2012; Soldier Creek demo tour, March 28, 2013; Low-cost streambank erosion control workshop, Kansas Forest Service and Kansas State Extension, March 25, 2014). These observations suggest common goals and room for cooperation toward stream improvement and natural resource conservation.

8.4 Conclusions

Because checkerboarding as described here is a ubiquitous problem for Indian reservations, this study has implications for other tribes across the U.S. A tribe's ability to apply specific land management practices will vary depending on their land tenure situation and their capacity to administer programs under the Clean Water Act (CWA) and Clean Air Act (CAA) (USEPA, 2015). Control over land is a measure of the tribe's sovereignty, as it underpins their ability to manage natural resources central to maintenance of Indigenous cultures.

PBPN management goals, including improving stream quality and aquatic habitat, are not beyond reach under the current situation. The tribe has taken several important steps toward improving their water resources, including partnering with the U.S. Geological Survey for a 10-year project (1996-2006) to monitor surface and groundwater quality on the reservation (Schmidt and Mehl et al., 2007). In 2012, the tribe was awarded two grants by USEPA Region 7 to conduct further surface and groundwater monitoring, provide training and support to the tribe's environmental office, and build capacity for comprehensive planning and environmental protection programs (USEPA, 2012). The

PBPN has continued with many land improvement projects, streambank stabilization projects, and planting of riparian areas to protect and conserve water resources (Barden, 2011). The tribe is also the largest CRP subsidy recipient in Jackson County (EWG, 2013). As the PBPN continues to work toward natural resource and stream improvement goals, results from this study may be used to identify potential areas for restoration, and to help create a comprehensive, collaborative land management plan for the PBPN reservation.

Chapter 9: An analysis of cultural values driving land management on the Prairie Band Potawatomi Nation

Between 2007 and 2012 in the United States, 42 percent of the land that was converted to a developed use was previously in forest cover. Over that same time period, 91 percent of the land that was converted to cropland, was previously pasture or rangeland, reflecting the vulnerability of grasslands to conversion (Bigelow & Borchers, 2017). New modifications to native land cover are a concern, because converting ground from forest and grassland to cropland or other developed uses eliminates the ecosystem services provided by that native vegetation, such as water infiltration and pollutant removal, habitat provision, and air quality benefits (Scanlon et al., 2007; Stoate et al., 2009). Deforestation and plowing of grasslands is also associated with reduced sequestration benefits and increased carbon emissions (Schuman et al., 2002; Canadell & Raupach, 2008). Retaining native vegetation provides many valuable services to society that confer economic and health benefits in the long term (Netusil, 2006; Small et al., 2017). Therefore, a major challenge today is to improve the balance between private landowner rights and monetary incentives, and the retention of ecosystem services provided by native vegetation for long-term societal and ecological benefits. We will continue to witness large-scale conversion of intact native vegetation and loss of the ecosystem services provided by them, unless there is a paradigm shift toward society finding real value in retaining those types of land cover.

Often overlooked in addressing this challenge are pluralities in the definitions of “value” on landscapes, and differences in knowledge, environmental use, and values within and between social groups (Norton, 2000). The interactions between societal valuations and the environment are expressed as “cultural landscapes” (Davidson-Hunt, 2003). Acknowledging and understanding different cultural landscapes may inform and benefit new land management strategies that better protect our shared natural resources, such as water. This is an important topic at a time when population pressures on food, fiber, and fuel supplies are increasing, and related impacts on our water resources are growing

(Vörösmarty et al., 2000). Environmental sustainability depends on identifying paradigms that help inform alternative ways of valuing landscapes outside of exclusively monetary frameworks.

Understanding cultural landscapes and the drivers behind them can also provide a more common understanding for collaborative environmental plans and protections. Land management and adoption of conservation practices are directly affected by individual landowner actions and community attitudes and values (Schrader, 1993). Landowners invest time, labor, and capital into their land expecting certain returns and benefits. However, those expected benefits and valuations are determined by the landowner's history, cultural beliefs and values, as well as political, social, and economic pressures (O'Brien & Guerrier, 1995). Differences in expected benefits and valuations are expressed on the landscape in a variety of ways. For example, consider two neighboring landowners in the native grasslands of Kansas. One landowner considers row-cropping to be the most productive use of the land, shaped by their family history and the value placed on the monetary returns their land could provide. This landowner may till the soil and plant a monoculture of corn or soybeans. The neighboring landowner values the ability to hunt wild game, and feels that the landscape should have more trees for wildlife cover. This landowner may allow invasive trees to encroach on the native grasslands (a very common situation in the Red Hills of Kansas). Both landowners have eliminated native grassland habitat and changed the ecosystem service provision and hydrology of their lands, albeit in different ways and with different environmental consequences. As these types of modifications accumulate across entire landscapes, they have profound impacts on biodiversity and environmental condition (Foley, 2005).

Understanding these drivers and effects is especially important regarding water resources, particularly where competing or conflicting value systems exist (for example, a river crossing a political boundary). The dynamic interconnectedness of water and watersheds creates cultural and community linkages that cross traditional boundaries (Schrader, 1993). These "watershed communities" bear the cumulative impacts of individual land management decisions throughout the watershed. For example, downstream urban residents must pay increased costs to treat drinking water that has been polluted by upstream land practices. This was the basis of a recent lawsuit in Illinois, in which Des Moines Water Works alleged that increasing nitrate loads from agricultural pollution, and their concurrent increase in treatment costs, constituted violations of the Federal Clean Water Act (CWA) and Iowa state water pollution law (Coppess, 2017). Watershed communities can also see cumulative benefits from cultural shifts in management, such as in the Sheridan 6 LEMA (local enhanced management area) in Sheridan and Thomas counties, northwest Kansas. In this example, local landowners recognized that declining groundwater resources were going to prohibit crop production in the future, jeopardizing their desire to pass their farms to their children and grandchildren. The landowners agreed to a plan to voluntarily cut back their water usage by a certain percentage. Preliminary results have indicated that they have slowed the aquifer decline in their area without significantly impacting their crop yields (Golden, 2016). Identifying values and priorities of "watershed communities" as they are translated onto the landscape and waterscape is an important first step in conservation and source water protection.

The previous chapter identified differences in land use/land cover (LULC) between tribally-owned land and private (non-tribal) lands within the "watershed community" of the Prairie Band Potawatomi Nation (PBPN) reservation. The analysis found significant ($p= < 0.00001$) differences in land cover between the two land tenure categories. The majority (70%) of row-crop acres on the reservation are located on private land, while tribally-owned land showed a strong management preference for native grasslands and forest. Nearly all stream miles on tribally-owned lands have healthy riparian vegetation, with only a little over a mile of stream lacking a riparian buffer. By comparison, private lands on the reservation lack a riparian buffer on 5.6 miles of stream. The current chapter is a qualitative examination of the cultural values driving the land management choices of the PBPN, so that we may better understand the cultural landscape and drivers behind retention of native land cover. I hypothesize that the tribe's cultural priorities will reveal valuation of native land cover (forests and grasslands) and ecosystem services supported by native land cover (healthy streams, fish) over individual economic benefits, and that these priorities are driving land management choices.

9.1 Methodology

A questionnaire was developed and distributed to community members on the Prairie Band Potawatomi Nation (Jackson County, Kansas). An informed consent statement was signed by all participants before beginning the questionnaire. This statement detailed the purposes of the research, the voluntary nature of their participation, and the steps taken to ensure privacy of their data and protection of their cultural and intellectual property. The design of the questionnaire was meant to determine what features are valued by participants on local landscapes, how they use local streams, and what environmental issues they perceive to be affecting them. Questions were multiple choice, but also provided space to write qualitative responses or elaborate on the multiple-choice selection. The questionnaire is included in Appendix 1.

The questionnaires were distributed at two large community events, two smaller workshops (one of which was organized by co-author Mehl), and individually as the author made contacts within the community. The majority of respondents reported being a member of the Prairie Band Potawatomi Nation, Kickapoo Nation in Kansas, or another tribe. Questionnaire responses were coded and analyzed. For the purposes of this analysis, only responses from tribally-affiliated respondents were included (n=76). For an estimated tribally-affiliated population of 1000, this sample size provides a 90% confidence level.

To supplement the questionnaire results, a context analysis using qualitative coding (Saldana, 2015) was performed on “Rez Recycler” newsletters (available https://www.pbpindiantribe.com/pep/rez-recyclers/.). These newsletters are published approximately quarterly by the PBPN Planning and Environmental Protection department and contain articles about community events and environmental sustainability. We analyzed four newsletters per year from each quarterly newsletter published between 2008-2014, for a total sample size of 28 newsletters. We used open coding to distinguish distinct themes in the text and then applied axial coding to identify conceptual themes. Concepts and categories created through the coding process were analyzed in Google

Fusion Tables which served as the platform for code organization, filtering, and condensing. After code condensing, 19 major code categories emerged with corresponding frequencies as aided by the Fusion Table. This information allowed the determination of major themes highlighted in the newsletters. These codes were compared to the questionnaire that was distributed to tribal members. The questionnaire was also organized and filtered using Google Fusion Tables allowing us to derive the frequency of patterns in the responses for the participants. Newsletter codes and questionnaire responses were synthesized to give five major themes for analysis.

9.2 Results and Discussion

The overarching objective of this study is to better understand cultural drivers of land management choices for an Indigenous community. Given the observations from Chapter Two that land under tribal tenure was much more likely to retain native vegetation, the authors hypothesized that respondents would value native land cover (forests and grasslands) and ecosystem services supported by native land cover (healthy streams, fish) over individual economic benefits. Results from both the questionnaires and the newsletter analysis supported this hypothesis. Recurring themes include the value of streams as a fishing resource, and the use of streams and stream water for cultural purposes. Riparian forests were seen as important almost without exception.

Analyzing the questionnaire responses, the most frequently mentioned theme regarding streams was fish or fishing. A majority of questionnaire respondents (78%) indicated that they value the streams as a fishing resource. Other major themes mentioned are swimming/recreation (60%), drinking water (55%), and cultural uses (51%). Wildlife habitat was identified as an important issue by 45% of respondents, with 40% of total respondents specifically mentioning habitat for culturally-important plants and animals. Bank stabilization or erosion was mentioned as a concern by 43% of respondents. Only 13% of questionnaire respondents associated with a tribe indicated using streams for irrigation or livestock watering.

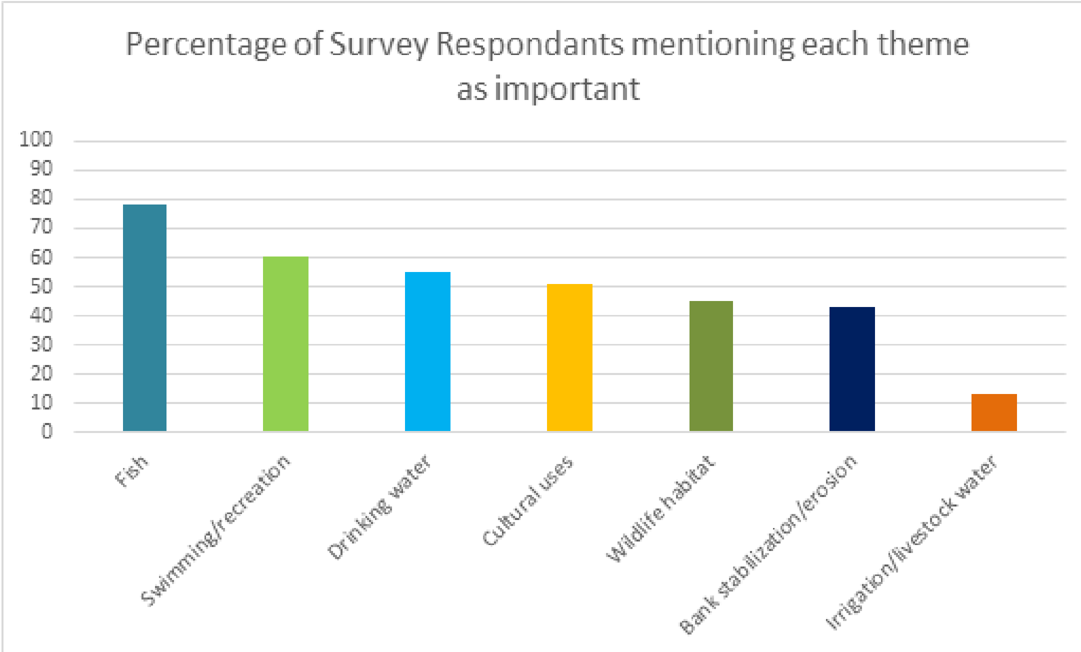

FIGURE 21 MAJOR THEMES EMERGING FROM TRIBAL MEMBERS' RESPONSES TO THE ORIGINAL QUESTIONNAIRES, REGARDING THE IMPORTANCE OF WATER QUALITY, QUANTITY AND STREAM CONDITION FOR PREFERRED USES

The "Rez Recycler" newsletter, published by the PBPN Department of Planning and Environmental Protection, had a number of overarching themes, including:

- Community-wide education of local environmental issues
- Describing department activities (monitoring, surveying, grants, etc.)
- Recycling and hazardous waste removal
- Water quality and water conservation
- Air quality
- Sharing community resources (who to call, available services)
- Promoting and advocating for community events
- Youth education (Boys and girls club)
- Earth day celebrations
- Hikes
- Community recognition
- Environmental heroes

- Recognizing others who are doing good in the community (recycling, environment, Earth day participants, etc.)

In addition, various attitudes and values were either implicitly or explicitly stated in the newsletter, including:

- Keeping reservation clean and litter free (aesthetics)
- Concern for human and environmental health
- Think of those "downstream"
- Do your part - ways you can help
- Elder knowledge and storytelling
- Community wellbeing and bonding

A synthesis of recurring codes between questionnaire responses and the newsletters resulted in the following overarching themes for analysis: stream condition, fish and fishing, culture and community, riparian knowledge, and restoration and education.

9.2.1 Stream Condition

Most questionnaire respondents perceive the quality of streams to be fair (57%), with only 15% viewing them as in good condition. Five respondents reported that they or someone in their community had become ill from primary contact recreation in local streams.

Water quality was cited most often as the most important issue regarding streams (54%). The most frequently mentioned concern was fertilizer runoff in streams (53%). Other frequently mentioned concerns were chemicals in drinking water (43%), livestock waste (40%) and pesticides (40%).

According to the newsletter analysis, the proper disposal of solid waste, medications, and hazardous waste, including backyard burns were listed as activities that need significant attention in order to improve water quality and quantity, and stream condition. This idea was also prevalent in the questionnaires, where participants classified the quality of streams in their area as fair and attributed this in part to the amount of trash derived from community members not picking up after themselves. Among the goals for streams and ponds in tribal land, questionnaire respondents highlighted the importance of improving water quality by “better cleanup”, “less trash”, “strict control over trash [...]”, “[making] sure everything is kept up clean for our environment”. The prevalence of these responses is likely reflective of awareness efforts by the PBPN Department of Planning and Environmental Protection for litter reduction and establishing places for trash disposal.

Aside from improper waste disposal, tribal members attribute the negative aspects of the streams in their area to nonpoint source pollutants such as “agricultural pollutants [that] drain into [the] water source”; “[water bodies being located] around a lot of farming”; “long term use of commercial fertilizer, herbicides, and pesticides”; “probably lots of runoff from fertilizers and pesticides”; and “runoff from farms because chemicals go into the water”. Questionnaire respondents also noted the “muddy” condition of streams, and stated that streambank erosion control was one of the desired goals for streams and ponds (although this was not the most commonly cited issue overall). There was a demonstrated awareness of the impacts of farming on surface water quality, again likely attributable to education efforts by the PBPN Department of Planning and Environmental Protection.

Questionnaire respondents tended to attribute positive attributes of reservation streams to the PBPN Department of Planning and Environmental Protection, known to the community as the “tribal EPA.” Many questionnaire respondents wrote comments such as “good EPA workers” and “our EPA is wonderful”. The “tribal EPA” is very active in numerous activities, including restoration projects, community education, and environmental testing and analysis. For example, the spring 2009 newsletter notes that they contracted with GIS Workshop from Lincoln, NE to develop an Agricultural Chemical (Pesticide) Assessment to seek and identify pesticide use patterns, activities and concerns that should be addressed by pesticide program activities. This is a direct response to community concerns over pesticide contamination in water resources. The success of the tribal EPA in furthering community goals becomes even more significant when considering that “research carried out over the last two decades shows that the success of Indigenous nations in achieving their goals—economic, political, social, cultural— depends to a substantial degree on their systems of governance" and institutional capacity (Cornell & Jorgenson, 2011).

When asked about the goals they would like to see achieved for streams, most respondents stated goals related to water quality, health and safety, and fishing access. Examples from questionnaire responses include: "less pollution," "get rid of all the pollution from factories," "strict control over trash/pesticides," "making sure they [water bodies] don't get exposed to chemicals, streambank erosion control," and "better methods of fertilizing and pest control." Respondents also commonly mentioned goals related to fish and fish habitat, such as "more stream bank projects," "more fishing spots," "safe drinking water and water for fish," and "more fish in ponds and more big rocks in big soldier for hand fishing." Overall, there was a frequently repeated desire for water bodies to "go back to their natural state." A handful of respondents mentioned observing declines in levels of water in streams over their lifetimes (water quantity), and stated that they would like to see a return of healthy streamflow. This is an interesting observation of the impacts of runoff regimes altered by land cover changes that were covered in Chapter One. These responses correlate to the most common preferred uses (fig. 21). The most frequently mentioned barrier to meeting these goals was lack of control over key areas. This response provides a direct connection to the fragmented land tenure and diminished land base illustrated in Chapter Two.

9.2.2 Fish and Fishing

Fish and aquatic life were by far the most frequently mentioned theme, as well as the most common stated use of reservation streams (78% of respondents). Tribal members highlighted the need for the provision of safe water to support fish populations. Over 1/3 of questionnaire respondents (38%) reported observations of declining populations of fish, frogs, crawfish, and mussels within the tribal community. Additionally, tribal goals for streams and ponds included "more fish in ponds and more big rocks in Big Soldier for hand fishing" and the need for "native plants" to improve water quality in the future.

In another example of the PBPN Department of Planning and Environmental Protection ("tribal EPA") conducting environmental analyses to address community concerns, newsletters detailed fish tissue sampling conducted by the U.S. Environmental Protection Agency. They tested fish tissue for four heavy metals: arsenic, cadmium, mercury, and lead, as well as pesticides. The tested fish were reported to have met the fish consumption portion of the fishable goal of the federal Clean Water Act. This is an important function of tribal governance, as many tribal members stated the importance of these fish as components of traditional diets.

In a notable newsletter article, tribal EPA scientist Verna Potts wrote about the importance of hand fishing to the community:

> "Hand fishing has always been a way of life for Potawatomi People. During this season, hand fishing provides us with nourishment, but also give us time to get together and enjoy the outdoors and make new memories with family and friends." (Spring 2012)

This quote emphasized many themes seen throughout the questionnaire responses and newsletters, including the cultural importance of hand fishing as a "way of life" that reinforces family and community bonds, as well as providing a dietary staple. Therefore, ensuring the health of streams for fish habitat moves beyond a recreational activity, and becomes central to the physical and cultural health of the community.

9.2.3 Culture and Community

One of the most common themes to emerge from this analysis was the idea of being embedded in a multi-generational community. Land decisions were not necessarily considered independent, autonomous decisions, because they could not be separated from the overall well-being of the community. When asked the most important reasons for preserving streams, the majority of questionnaire respondents (78%) mentioned future generations. Culture was second most important (55%), and economic reasons were third

(45%). Newsletter analysis reaffirmed these priorities, as reflected in their inclusion of the following quote in the Winter 2015 newsletter:

> "Water is constantly in motion, which means it cannot be the property of any one place. Water's circulation is a line between times past, present, & future. What we do with it now, will thus be of decisive importance to the future of us all." Terje Tvedt- professor at the Department of Geography, University of Bergen, and Professor in Global History, University of Oslo. (Winter 2015)

As reflected in the newsletters, tribal members hold ancestors, stories, spirits, and traditional practices like hand fishing as important reasons to improve and maintain stream water quality and quantity.

> "Part of protecting our environment as Native people has been through our story telling. Oral tradition has always been a part of Potawatomi's way of keeping their way of life alive for future generations." (Spring 2012)
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> *
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> "Elders say water is sacred. It has a spirit." (Spring 2010)
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> *
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> "Wetlands are a valuable resource culturally and environmentally. They provide medicines, cultural foods, and habitats for migrating birds, amphibians and other creatures." (Fall 2014)

Reflecting the emphasis on stories and respect for elders, the newsletter included an entire issue devoted to stories and memories of the local creeks (May 2010 "A Tribute to Our Water").

> "Reverend Vernon Potts relished in teaching youth the lifestyles of living off the land, like his dad & grandpa taught him. Big Soldier is a historical, cultural and traditional waterway within the PBPN Reservation. The fish weighed about 50-55 pounds!!!!" (Winter 2015)
>
> *

> "We all live downstream – every one of us. We need to keep that in mind and work together to restore and protect water quality. ~Billy Frank Jr. (March 9, 1931 – May 5, 2014) of the Nisqually Indian Tribe speaking as the long-time Chairman of the Northwest Indian Fisheries Commission." (Summer 2014)

Overarching themes of Indigenous Land Ethics were prevalent in both the questionnaires and the newsletters. For example, an article in the Fall 2010 Newsletter, "Honoring our Past with our Present Contributions", discusses honoring "our Grandmother (Earth)."

> "Love and respect our grandmother by reducing waste. Act in the best interest of the land."

The Winter 2012 newsletter extended those land ethics specifically to water resources:

> "It is wise for us to consider what we do to the land, and think upon this the next time we give a glass of water to our loved ones. Together we can collectively make a BIG difference in our local water supply. You've got the power!"

This seems to counter a purely utilitarian viewpoint common in Western societies that we should act in the best interest of ourselves and our economic bottom line. Other newsletters emphasized the rights of landowners and tribal members to hunt and fish on allotted lands, outside of state restrictions. However, the newsletter included a reminder that tribal landowners cannot transfer these rights to third parties, and reminds community members that their hunting and fishing rights serve a cultural purpose:

> "One thing to remember is that there are tribal members who hunt and fish to furnish these offering for tribal ceremonies." (Winter 2015)

The newsletters maintained an overall positive tone, but they didn't shy away from reinforcing cultural norms and standards. There was an occasional utilization of community shaming employed against those who were seen as acting against the good of the community or failing to do their part to keep the reservation clean and healthy (e.g. "Caught in the Act!", Spring 2013). This serves to reinforce tribal attitudes of what is "good" or "right," and puts pressure on those who do not comply by letting them know the community is keeping an eye on them.

Alternatively, the newsletters also served as a vehicle to acknowledge and celebrate members of the community who are working to improve the environmental state of the reservation. There was a large emphasis placed on recognizing anyone in the community performing good works, including children and teenagers. This was supported by the prevalence of the code "community member recognition" in the newsletter analysis. Frequently, these recognitions included mentions of saving water and protecting water. The newsletter regularly names "Environmental Heroes," including tribal youth, employees, volunteers, and citizens. There are special recognitions for the younger generation getting involved (Youth Environmental Council), as well as many educational events for children such as macroinvertebrate sampling and education about their function as indicators of water quality.

The recognition and education of tribal youth expanded into the recurring theme of intergenerational knowledge transfer. In both the questionnaire responses and newsletters, there was an expressed desire for the younger generation to gain cultural values. This is being accomplished through youth engagement and hands-on activities, including hikes with elders who share their knowledge. The importance of including children in activities such as hand-fishing, conservation, and restoration was stressed. There was also a desire for children to learn about the fluctuating environment (floods, droughts) from elders and how to survive and be resilient. For example, during the height of a multi-year drought, the newsletter included an article on the ongoing drought and education for drought resiliency. The article included stories from elders about historic droughts, detailing how they had to walk for miles to collect water from community wells (March 2013). An important part of Indigenous respect for elders is a desire to learn from their wisdom. They hold the keys to traditional lifestyles and cultural resiliency, and surviving extreme events (Ramphele, 2004; Magni, 2017).

Economic opportunities (through ranching and agriculture) were ranked as the last priority by tribal questionnaire respondents, behind future generations and cultural traditions. This is complementary to the low reported tribal use of streams for watering livestock (15%) and irrigation (10%), and correlates with observations from Chapter Two showing very little agricultural use on tribally-owned lands. This research indicates that cultural resiliency, environmental health, and activities like hand fishing are valued more highly than growing cash crops by the PBPN.

9.2.4 Riparian Knowledge

All questionnaire respondents except for one responded that they prefer to keep trees along streambanks. Major reasons cited were wildlife habitat, erosion prevention, and bank stabilization. This correlates with observations from Chapter Two, finding that nearly all stream miles on tribally-owned land have some lateral width of riparian timber or other native vegetation. The newsletters also included an education article on the importance of "timber," or riparian forests. However, it was a bit surprising that there was only one newsletter in the analysis period that mentioned riparian "timber."

> "There are numerous BMP strategies that can be used in any combination, depending on the size, slope, and soil composition of the field. These include…..wetland creation, and riparian buffers….The benefits of a healthy riparian buffer are many." (Summer 2013).

This may be explained by the observations from Chapter Two and the strong preference for trees in questionnaire responses. Perhaps the value of these areas is understood well by the community, and the educational newsletters focus on more pertinent issues.

Disadvantages of trees noted by some (even those who prefer to keep trees along streambanks) were erosion and fallen trees. Fallen trees are typically perceived as an issue by landowners when they are deposited in fields following overbank floods (personal observation by co-PI Mehl); however, intact riparian forests can strain tree trunks and branches from floodwaters before they are deposited in fields. The fact that a few survey respondents associate trees with erosion indicates an opportunity for education or outreach.

9.2.5 Restoration and Education

The PBPN Department of Planning and Environmental Protection, or "tribal EPA," is very active and visible in the community with regular education and outreach events. Education and intergenerational knowledge transfer are highly valued by the community. The tribal EPA works on many environmental restoration projects and environmental analyses to ensure the health of the community, which they explicitly define as including both human and non-human entities:

> "Everyone lives in a watershed. You and everyone in your watershed are part of the watershed community. The animals, birds, and fish are, too. You influence what happens in your watershed, good or bad, by how you treat the natural resources—the soil, water, air, plants, and animals. What happens in your small watershed also affects the larger watershed downstream. There are many things you and your watershed community can do to keep your watershed healthy and productive." (Fall 2013)

This is an egalitarian viewpoint that expands the consideration of who you are helping by doing the right thing. This quote also emphasizes the expanded definition of a "community" common in Traditional Ecological Knowledge (Pierotti and Wildcat, 2000; Pierotti, 2010). There is a responsibility to keep the whole "watershed community" healthy and productive, and to be cognizant of how your actions affect others downstream.

Nonpoint source pollution is the greatest challenge to water quality on the reservation (Schmidt and Mehl et al., 2007). The newsletters emphasize education on nonpoint source pollution, especially fertilizers, erosion and sedimentation, and the importance of planting cover crops (Fall 2013, Fall 2014). They also include articles on algae and harmful algal blooms (HABs), the benefits of best management practices (BMPs), and proper septic maintenance (Summer 2014). It seems that these educational articles are effective, as questionnaire respondents identified nonpoint source pollution as the biggest threat to reservation streams other than improper waste disposal.

> "Water will travel over the land base, picking up and transferring pollutants and sediment. Eventually, the water will find its way to the streams, creeks, ponds, reservoirs, rivers, wells, and lakes. The majority of local water quality issues arise from herbicides, pesticides, fertilizers, and sediment. Cultivation of cropland, construction activity, poor grazing practices, and removal of trees and vegetation along stream banks will increase the amount of sediment that is sent downstream into ponds, lakes, and rivers. This sediment will have, in most cases, pesticides, and phosphorus attachments and this adds to increased pollutants in our water supply." (Winter 2012)

Not only does the tribal EPA provide education, they serve as an accessible resource to community members:

> "To learn what you can do to take care of your watershed, call 1-800-THE-SOIL or your local Natural Resources Conservation Service office." (Fall 2013)

The tribal EPA has been successful in securing grants for restoration projects. For example, they were awarded a NFWF 5-Star grant, which they used to restore a wetland area using native grasses, shrubs, and trees. They note that the area is open to the public and is used as an environmental education area (March 2013).

As mentioned previously, the newsletters are explicitly directed to tribal community members and there seems to be a strong sense of communal responsibility for the health of the watershed. This idea comes into conflict with the checkerboard nature of the reservation where non-tribal members with different perceptions and approaches to conservation practices reside. However, there is a recognition by PBPN Planning and Environmental Protection that everyone shares the same watershed and the same natural resources, and must work together towards improvements.

> "While the grant focuses on tribal communities, the PBPN recognizes that Indigenous people are not the only population affected by climate change. Anyone with a dependence upon, and close relationship with the environment and its resources understand the direct consequences of climate change." (Summer 2014)

In order to help both tribal and non-tribal community members improve the health of the lands and watershed, the tribe purchased a cover crop roller, an agricultural implement that crushes the stems of the cover crop and leaves a mat of protective soil mulch. The roller was purchased to be shared among the reservation community, to "reduce the amount of chemicals applied to the land and promote no-till practices." The newsletter included the following passage:

> "Remember all things are connected and water flowing over the surface can carry contaminants to our streams and lakes. Reduce no-till operations to one pass! Reduce herbicide costs ~50%, speeds residue dry down and breakdown, Creates thick, weed suppressing mat, Reduces water evaporation from the soil, Prevents soil erosion, Leaves a no-cost mulch for the following crop" (Spring/Summer 2015)

9.3 Conclusion

This study examined whether observed differences between tribal and non-tribal land management are reflective of specific cultural priorities applied to the landscape by the tribe. I hypothesized that respondents would value native land cover (forests and grasslands) and ecosystem services supported by native land cover (healthy streams, fish) over individual economic benefits. Questionnaires of tribal members, combined with analysis of tribal newsletters, provide evidence to support this hypothesis. The primary themes to emerge from this analysis (stream condition, fish and fishing, culture and community, riparian knowledge, and restoration and education) reinforced the cultural importance of healthy streams and aquatic populations, and showed that the majority of surveyed tribal members are aware of the connection between land management and stream condition. The analysis also highlights the effectiveness of the PBPN Department of Planning and Environmental Protection (the "tribal EPA") in educating the community, restoring important landscape features such as wetlands, and providing resources for community members.

This study also furthers the understanding of PBPN community concerns and desired outcomes for federal and state agencies and adjacent private landowners. Most available literature on Indigenous Land Ethics only provides an overarching worldview or examination of TEK. We have presented a more in-depth examination of community values, in a way that can help federal and state agencies and other natural resource managers close the gap between their own priorities and the priorities and values of the PBPN. This type of understanding can facilitate collaborative planning that allows the tribal community to define their own version of success and support self-determination and sovereignty.

The results of this study are also important when combined with observations from Chapter Two. This shows that where the PBPN has agency in governance, they manage their land in ways linked to tradition and cultural resilience. On a broader scale, this shows that, where a tribe has agency in governance, cultural landscape management can persist, even when a tribe has been moved from their historical homelands and into a new geography.

Future studies will include an examination of non-Native landowners and producer attitudes. A forthcoming publication by Restrepo et al. will examine non-Native landowner and producer attitudes, followed by a paper synthesizing both studies. These two studies combined can help to provide a framework for collaborative management of shared landscapes. Scientists trained in Western methods are already beginning to work with Indigenous environmental experts to create novel management practices and technologies (Striplen and DeWeerdt 2002). Ultimately, all members of the same "watershed community" must work together to support multiple cultural landscapes.

Chapter 10: Conclusions

This dissertation provides examples of an alternative lens from which to understand value and management of ecosystem services. Rather than being an "intangible" separate category, cultural ecosystem services are inextricably bundled with provisioning, regulating, and supporting services. Together these services form a functioning whole that has a greater value than the sum of its component parts. Although TEK arises from fundamentally different cultural frameworks than modern Western societies, it can offer instruction for living in and depending on an ecosystem while still maintaining and valuing that functional whole. This framework supports the findings from Chapter 7, that in many geologic settings, meaningful reduction of nonpoint source pollution will rely on whole watershed management.

Where a traditional society has agency, it often translates into land management based on TEK, as illustrated in Chapter 8. However, due to the history of displacement and marginalization experienced by the vast majority of Indigenous people around the world, agency is often lacking. Like most Indigenous tribes in the United States, the Prairie Band Potawatomi have a greatly diminished and fractionalized land base due to government policies during the 1800s and early 1900s. This limits the amount of land they are able to manage from their preferred framework, as described in Chapter 9. In the 1980s, the United States began incorporating methods for tribes to gain agency in managing natural resources through the Clean Air Act and Clean Water Act (USEPA 2015), providing a channel for tribes to set standards for air and water quality on their reservation lands. However, it is still extremely difficult for tribes to regulate activities on adjacent private lands (Milford 2004; Sly 1990). There is also little recourse for landless tribes, such as the PBPN's sister tribe, the Citizen Band Potawatomi.

The lack of specific cultural understandings of values and priorities of many tribes by government agencies is illustrative of a common problem in natural resource management: when Indigenous people are invited to the table for discussions, they are often expected to speak with one "pan-Indigenous" voice (Pierotti 2011, pg. 161; Ranco 2007). This is why I am careful here to speak of TEK frameworks in the plural sense.

TEK frameworks may shift as a result of displacement, incorporation of local knowledge and technologies and the subsequent development of LEK. The frameworks will certainly vary between cultures and experiences. Displaced populations may retain values shaped by their TEK of their original homelands, and may value and manage for similar features after displacement (for example, the emphasis on forests and streams by the PBPN after displacement to the Great Plains). The variable nature of these frameworks highlights the importance of inviting multiple Indigenous voices and stakeholders to the resource management table.

Although the frameworks and cultural practices may vary, TEK systems are united by their inextricable links to resource use, ecosystem management, and cultural integrity. Loss of land tenure and the associated loss of agency represents a significant erosion of sovereignty and cultural resilience. When given greater agency to apply frameworks based on TEK, there are benefits conferred not only to environmental management, but also to cultural resilience (Gregory and Trousdale 2009). Social structures based on TEK frameworks allow Indigenous communities to persist in the face of displacement from their traditional environments, and this model of resilience has proved invaluable in the face of challenges such as sustainable environmental management and climate change (Maldonado 2014). This begs the question, what would happen if Indigenous people were given greater voices and agency in ecosystem management around the world? Because TEK frameworks can help communicate integral connections between nature and human well-being, the result may very well be the increased awareness of the importance of intact ecosystems, human-nature connections and responsible long-term management that some seek to communicate through contemporary ecosystem services valuation frameworks.

Affective ecologies describe the emotional relationships between humans and the natural world, which may be translated as affinity or care for a place (Barbiero 2011). However, “care” for a place may look very different from various cultures and associated management strategies. One of the largest fundamental divides between Western strategies and traditional strategies is whether a “cared-for” place can be or should be used and lived in by humans (Pierotti 2011, pg. 29). Western strategies tend to set aside these cared-for places and disallow any significant human activity on them, as seen in programs such as CRP or U.S. National Parks. This inevitably leads to the mindset that humans are not capable of using a place with care, and that these set-aside "pristine" areas will counteract the overexploitation and sacrifice of most other areas. There is no commonly accepted framework for using and living in a place with care. This is where TEK frameworks could provide a great benefit, as TEK includes knowledge for use with care. Other authors have long asserted that care for a place can engage people in planetary stewardship (e.g. Nassauer, 2011; Leopold, 1949). The integration of TEK could expand this idea by communicating the link between ecosystems and human well-being, and providing strategies for sustainably using and living in a cared-for place.

Some investigators (e.g. Lele et al., 2015) have argued that the cultural ecosystem service lens is not always appropriate for understanding common pool resource systems. To this end, there are negative feedbacks encoded within TEK that guard against over-exploitation of resources and tragedy-of-the-commons scenarios. As illustrated in Chapter 9, TEK values are based on strategies that allow long-term survival in a certain environment. Long-term survival does not allow for overexploitation of resources that would ultimately lead to the failure of future generations. This is reflected by the TEK of the PBPN in their concern for extending riparian buffers, which confers a long-term advantage to stream health and biodiversity and habitat of game animals. Driven by these concerns, PBPN land practices run in opposition to the management strategies of some adjacent private landowners, who often make land management decisions based on short-term benefit. They may, for example, cut down buffers or remove CRP to extend crop land when prices are high (Hellerstein and Malcolm 2011).

The question of use with care highlights another important fundamental difference between monetary value strategies and traditional strategies. Monetary valuation strategies tend to be risk-prone in most situations, with the ever-present danger that short-term profit will take precedence over long-term conservation (e.g. Hellerstein and Malcolm 2011; Pannell et al. 2006). The short-term benefit framework is now showing us the limitations of the earth. TEK can provide alternative frameworks that operate in a more risk-averse manner, arising from long-term survival in a landscape and a desire to keep it healthy for future generations (Brownrigg 1981). Incorporating components of TEK frameworks, with their deep knowledge of functioning ecosystems, may provide an alternative incentive for restraint from overexploitation that may be overlooked by monetary valuation frameworks.

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Appendix

This Appendix includes the full text of the original questionnaire that was distributed to PBPN community members, and is the basis for data analysis in chapter 9.

Agreement for Participation in Research

Thank you for agreeing to participate in this survey. The purpose of this research is to determine management issues and priorities important to local communities. This research is part of a dissertation project for Heidi Mehl, a student in the Department of Geography at Kansas State University.

There is no right or wrong answer to any question, and you are not required to respond to any question you do not wish to answer. There is **no** risk to you of legal or regulatory action based on your participation in this survey. **Your personal information will never be shared.**

Participation in this research is voluntary, and refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may discontinue participation at any time without penalty or loss of benefits, to which you are otherwise entitled.

Because this research may deal with certain cultural and intellectual property, I would like to assure you that the utmost caution will be taken to respect that property.

By signing this document, you indicate that you have been made aware of the goals and purposes of this research and are participating voluntarily, without compensation.

This information is for demographic purposes only and will never be shared.

Name								
Address								
Phone								
Email								
Age	18-25	26-35	36-45	46-55	56-65	66-75	76-85	86+
Are you affiliated with a Native American tribe?	Yes	No	If yes, which one?					

Signature of participant **Date**

For questions/comments about this research, please do not hesitate to contact: Heidi Mehl, 126 Seaton Hall, Department of Geography, Kansas State University, Manhattan, KS 66506
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Thank you for participating! There are no right or wrong answers. Please feel free to write additional details on any question, or to skip any question you do not wish to answer.

You may choose more than one answer for all multiple-choice questions.

1. What is most important to you?

Stopping erosion	Stabilizing stream banks
Improving water quality	Stopping fertilizer from washing away
Providing habitat for wildlife	Provide habitat for culturally-important plants and animals
Improving the way my land looks	Other:

2. Do you prefer to keep trees/timber near streambanks, or to remove trees/timber from near streambanks?

Keep	Remove
What are the benefits of trees/timber near streambanks?	What are the disadvantages of trees/timber near streambanks?

3. How do you typically use streams/rivers in your area?

Irrigation	Watering livestock
Drinking water	Fishing
Swimming	Cultural uses/ceremonies
Recreation	Other:

4. How accessible are streams/rivers for the purpose(s) selected in the previous question?

Easy to access	Difficult to access	Easy for some purposes, difficult for others
Additional comments:		

5. Do you think the quality of streams in your area is:

Good	Fair	Poor
Please explain your answer:		

6. Which water issues are concerns in your area?

Contamination from fertilizers	Contamination from pesticides
Contamination from livestock waste	Contamination from industrial waste
Contamination from lawn care products	Chemicals in drinking water
Contaminated well water	Declining populations of important aquatic species
None	I don't know
Other:	

7. How did you become aware of the issues in the previous question?

Personal observation	Community knowledge
Local/tribal environmental office newsletters	K-State extension agents/workshops
USGS publication	USDA/NRCS publication
TV or newspapers	Other:

8. Have you observed any changes or declines in the populations of fish, frogs, crawfish, mussels, etc?

Yes	No	I don't know
If yes, what have you observed?		

9. Have you ever noticed anything unusual in fish caught from local streams (lesions, brown or bright orange gills, etc)?

Yes	No	I don't fish in local streams
Additional comments:		

10. Has anybody in your community become sick from swimming or wading in local streams or ponds, especially children?

Yes	No
Not sure	Nobody I know swims in local streams or ponds
Additional comments:	

11. What is the most important reason to you for maintaining healthy streams?

To support economic opportunities for my family and my community	To support cultural traditions and practices
To make sure future generations have the same resources we have	It's not that important with today's technological advances
Other:	

12. What goals for streams and ponds in your area would you like to see met?

13. What barriers have you encountered to meeting the goals described above?

Too expensive	Local/state regulations
I can't get the help I need	I don't control all of the areas that need to be included
Haven't had time to address	I have not encountered any barriers
Other:	

14. Do you have any other issues or concerns regarding streams and land management that you would like to share?