Identification and Evaluation of Viable Remediation Alternatives to address Injuries related to Land Disposal of Poultry Waste within the Illinois River Watershed

Prepared by: 5/15/2008

Todd W. King, P.E.[1], BCEE[2] Date
CDM

My fee for this work is $175 per hour in accordance with the contract terms and conditions between Motley-Rice and CDM.

I have not provided depositions or expert testimony in the previous four years.

[1] Professional Engineer No. 35557 Michigan
[2] Board Certified Environmental Engineer, American Academy of Environmental Engineers

Section 1 Introduction

1.1 Purpose and Objectives

This report identifies and evaluates viable remediation alternatives that can be employed to mitigate or correct the injuries resulting from the Defendants' land disposal of poultry waste within the Illinois River Watershed (IRW) in northwestern Arkansas and northeastern Oklahoma. This report was prepared on behalf of the State of Oklahoma (State) to address injuries to the portion of the IRW within the State of Oklahoma.

The objective of this report is to identify cost-effective and environmentally prudent means of remediation that can be employed to reduce the State's injuries. The selection of remediation technologies considers: (1) the effectiveness of the proposed method to protect human health and the environment; (2) implementability of the proposed method; and (3) cost.

1.2 Consulted Experts and Investigation Findings

The development of this report was guided by discussions with content experts working for the State. These experts include: Dr. Roger Olsen, CDM; Dr. Bert Fisher, Lithochemia, LLC; Dr. Dennis Cooke, Kent State University; Dr. Gene Welch, University of Washington; Dr. Scott Wells, Portland State University; Dr. Bernard Engel, Purdue University; Dr. Jan Stevenson, Michigan State University; and Dr. Gordon Johnson, Oklahoma State University. In addition, discussions with Mr. Dan Butler and Ms. Shannon Phillips, of the Oklahoma Conservation Commission, were held to understand current best management practices (BMPs) implemented in the region and their potential effectiveness at meeting remedial goals. Geographic information system (GIS) data and analyses were provided by Mr. Robert van Waasbergen, Applied Environmental Data Services.

The basis for existing conditions within the IRW cited in this report—including causation, injuries, and trends—are based on the above expert discussions and work products. The screening of technologies and response of the IRW system to their implementation is based on collaborative discussions with these experts, literature review of relevant data as cited within this report, and best professional judgment of the author.

1.3 Site Background and Description

The Illinois River Watershed (IRW) flows from the northwestern part of Arkansas, into northeastern Oklahoma and ultimately to the Arkansas River. The IRW runs through Delaware, Adair, Cherokee and Sequoyah counties in Oklahoma and Benton, Washington and Crawford counties in Arkansas. Major tributaries include the Baron Fork, Caney Creek and Flint Creek.

The Illinois River is 98.8 miles long (OWRB, 2002), with 56.3 miles flowing from the Oklahoma border to Lake Tenkiller. Lake Tenkiller is a man-made reservoir which starts near Tahlequah in the Horseshoe Bend area. Another former reservoir, Lake Francis, starts approximately one mile over the Oklahoma border, east of Watts. The entire watershed is approximately 1.06 million acres, with 54% in Oklahoma.

Portions of the Flint and Baron Fork (sometimes called Barren Fork Creek) as well as the mainstem of the Illinois River are designated as Scenic Rivers by the Oklahoma Scenic Rivers Act in 1977 (OWRB, 2002). These include 70 miles of the Illinois River from the Lake Francis dam down to its confluence with the Baron Fork. The Baron Fork is a scenic river from the confluence to the Illinois River upstream for 35 miles. Flint Creek is a scenic river 12 miles from its confluence upstream.

In Lake Tenkiller, the Illinois River is the principal flow (63%), while Caney Creek (8%) and Baron Fork (29 %) make up the remaining major surface inflows (2006 data). The watershed-to-reservoir area ratio is 80 (Cooke and Welch, 2008). The ratio for lakes is often 10 or less.

Phosphorus, usually in lowest supply, limits algal growth. When the amounts of P are increased, more algae are able to bloom. Blooms consume oxygen, die, and then consume oxygen decomposing. This affects fish as well as other life in Lake Tenkiller (Cooke and Welch, 2008).

Several studies have confirmed that reducing P inputs is the most effective way to control eutrophication and improve water quality (Cooke and Welch, 2008). When P sources were reduced, water bodies recovered quickly.

1.4 Report Organization

This report is organized into the following sections:

- Section 2 summarizes human health and environmental injuries and addresses the development of remedial response objectives and general response actions
- Section 3 lists remedial technologies and develops potential remedial alternatives.
- Section 4 gives a detailed evaluation of alternative remedial options
- Section 5 identifies actions that require additional investigation and assessment
- Section 6 compares the remedial alternatives

Section 2
Development of Remedial Response Objectives and General Response Actions

2.1 Summary of Human Health and Environmental Injuries

This study addresses two key aspects of the remedial relief the State seeks in its litigation against the Poultry Defendants. The first key aspect is the need, based on the investigations made to date, for a cessation of land application of poultry waste within the IRW. The second key aspect is to identify remediation alternatives that will reduce existing injuries and mitigate the risk of future injuries to human health and the environment as identified by the injury analysis prepared by the State's experts.

The State's experts have identified several injuries that are related to land disposal of poultry waste. These injuries are categorized as (1) Human Health impacts; (2) Tenkiller Ferry Lake (Lake Tenkiller) impacts; and (3) Rivers and Streams impacts. The preliminary injuries to be addressed by remediation are:

<u>Human Concerns and Health Issues</u>

- Bacterial pathogens and indicator bacteria in the IRW rivers and steams
- Bacterial pathogens and indicator bacteria in the IRW groundwater
- Cyanobacteria (blue-green algae) in IRW surface waters
- Disinfection byproducts (DBPs) including trihalomethanes (THMs) and haloacetic acids (HAA5s) in drinking water
- Taste and odor of drinking water

<u>Lake Tenkiller</u>

- Chlorophyll *a* and blue-green algae dominance
- Transparency/water clarity
- Taste and odor (public water supplies)
- Blue-green algae
- Disinfection byproducts including THMs and HAA5s (public water supplies)
- Habitat loss

- Water quality standards exceedances

<u>Rivers and Streams</u>

- Biodiversity
- Blue-green algae
- Disinfection byproducts including THMs and HAA5s
- Benthic and suspended algae
- Water quality standards exceedances

2.2 Restoration and Remediation Regions

In order to focus the selection and evaluation of applicable remedial technologies, CDM defined three response regions in the IRW, namely: (1) the watershed, (2) rivers and streams, and (3) Lake Tenkiller. Each of these regions is discussed below.

2.2.1 Watershed

The IRW includes approximately 1.06 million acres through northwestern Arkansas and northeastern Oklahoma. The IRW lies within the Ozark Highlands and Arkansas Valley Ecoregions. Watershed areas for response regions include land where poultry waste has been applied and impacted groundwater.

2.2.2 Riverine

The rivers and streams of the Illinois River watershed include all lotic waters, including tributaries and the mainstem. There are over 3,800 miles of streams that run through the IRW (van Waasbergen, 2008). For the purposes of this report, the rivers are considered separately from Lake Tenkiller, which begins at the Horseshoe Bend area.

2.2.3 Lake Tenkiller

Lake Tenkiller is a reservoir approximately 40 kilometers (km) long with a surface area of 51.6 km^2. Created in 1954, Lake Tenkiller receives the majority of its inflow from the Illinois River, Baron Fork, and Caney Creek. According to U.S. Geological Survey gauge records of average daily flows between 1997 and 2006, the Illinois River, Baron Fork and Caney Creek contributed approximately 69.4%, 24.0% and 6.6% of the inflow to Lake Tenkiller, respectively. References to Lake Tenkiller in this report refer only to the impounded area of the reservoir which begins in the Horseshoe Bend area.

2.3 Remedial Action Objectives

The remedial action objectives for the site have been developed to protect human health and the environment for the areas of the IRW that fall within the borders of the State of Oklahoma. The IRW, its rivers and streams, and Lake Tenkiller have been impacted by the over application of poultry waste to land within the states of Arkansas and Oklahoma. The primary injuries, summarized in Section 2.1, have been simplified to three main contaminants of concern (phosphorus, bacteria, and total nitrogen) for the purposes of describing sources, pathways, transport and impact to human and environmental receptors.

All of the remedial action objectives are predicated on the cessation of land application of poultry waste within the IRW (cessation). Without cessation, the effectiveness of any reasonable remediation action will be compromised and the primary injuries will continue. Further, cessation and implementation of remedial actions will constitute steps towards the recovery of the rivers, streams and Lake Tenkiller to the "… unique natural scenic beauty, water conservation, fish, wildlife and outdoor recreational values of present and future benefit to the people of the state…" (Oklahoma Scenic Rivers Act).

2.3.1 Phosphorus

The relevant pathway for phosphorus is the precipitation based transport of P from lands where poultry waste has been applied to groundwater and surface water. Rivers, streams and groundwater within the IRW transport P in water and sediment to Lake Tenkiller. The P causes undesirable impacts to rivers and streams and results in eutrophication of Lake Tenkiller. The complete list of injuries was presented in Section 2.1.

The remedial action objective for phosphorus is to remove, immobilize or otherwise prevent the transport of P from land where poultry waste has been applied to waters of the State. Limiting P transport will advance the efforts to achieve goals that are consistent with the water quality criteria and to restore the physical, chemical and biological integrity of the water.

2.3.2 Bacteria

The relevant pathway for bacteria is the precipitation based transport of bacteria from lands where poultry waste has been applied to groundwater. This bacteria transport results in human health risks from drinking contaminated groundwater. In addition, the impact of bacteria runoff to surface water negatively impacts human health due to risks associated with ingestion and recreation that is common on the rivers and streams of IRW.

The remedial action objective for bacteria is the cessation of land application of poultry waste within the IRW. Research indicates that bacteria survive months within soil and groundwater (Gerba et al., 1975) and cessation of land application of poultry waste alone will effectively address this contaminant of concern in approximately one year. Without cessation, the remedial action objective for bacteria is to treat or replace all impacted private drinking wells, within the State of Oklahoma, that pose a risk to human health. CDM estimated that 878 drinking water wells are potentially impacted within the Oklahoma portion of IRW for bacteria. This is based on an estimated 1463 groundwater wells within the IRW for Oklahoma and the finding that 36 of 60 private wells sampled by CDM in 2006 and 2007 were reported with detections of bacteria.

2.3.3 Total Nitrogen

The relevant pathway for total nitrogen (N) is the precipitation based transport of N from poultry waste applied land to groundwater resulting in human health risks from drinking contaminated groundwater.

The remedial action objective for N is to treat or replace all impacted private drinking wells within the State of Oklahoma that pose a risk to human health. CDM estimated that 190 drinking water wells are potentially impacted within the Oklahoma portion of IRW for N. This is based on an estimated 1463 groundwater wells within the IRW for Oklahoma and the finding that 8 of 60 private wells sampled by CDM in 2006 and 2007 were reported with total nitrogen results greater than 10 mg N per liter. The oxidation of N to nitrate at concentrations greater than 10 mg N per liter exceeds the maximum contaminant level for nitrate under the National Primary Drinking Water Regulations promulgated by the U.S. Environmental Protection Agency.

2.4 Development of remediation goals (RGs)

As part of the consultation with the State's injury experts, CDM defined specific metrics that provided measurable indices of the degree of injury for each media and receptor of concern in the IRW. These endpoints or remedial goals (RGs) are developed to address the identified human health and environmental concerns. The following RGs have been identified for each of the response regions.

2.4.1 Watershed

- Eliminate poultry waste land application within the IRW
- Prevent transport of phosphorus from poultry waste via runoff and leaching to rivers, streams and Lake Tenkiller
- Eliminate bacterial contribution of poultry waste to groundwater and surface water
- Replace groundwater wells used for drinking water that have been impacted by nitrogen or bacteria above safe thresholds for human health

2.4.2 Riverine

- Reduce phosphorus concentrations in rivers and streams to achieve compliance with water quality standards and improve habitat, biodiversity and aesthetics

- Protect the public water users supplied by surface water from unacceptable levels of disinfection byproducts (DBPs) such as trihalomethanes (THMs) and halo-acetic acids (HAA5s) forming materials in the raw water taken from IRW rivers and streams

- Reduce bacteria in surface waters to concentrations that are acceptable for swimming, fishing and recreation

2.4.3 Lake Tenkiller

- Reduce phosphorus concentrations in Lake Tenkiller to levels that reverse eutrophication and meet water quality standards

- Protect the public water users supplied by surface water from unacceptable levels of DBPs such as THM and HAA5 forming materials in the raw water taken from the lake

- Reduce cyanobacteria in surface waters

- To restore fish habitat while remedial measures are implemented, maintain a minimum dissolved oxygen content of 5 milligrams per liter (mg/l) at all times.

2.5 General Response Actions

General response actions are used to identify generic technologies that are usually medium-specific. These technologies are used to remedy one or more injuries from one or more pollutants. General response actions attempt to achieve remedial action objectives and can be used in combination with other general response actions.

Three types of general response actions were defined for this study: removal, treatment and containment.

2.5.2 Removal

Removal is the physical relocation of contaminants of concern to an acceptable disposal facility. For the purposes of this study, the cessation of poultry waste application to lands within the IRW has been categorized as a removal general response action.

2.5.1 Treatment

Treatment involves the use of physical, chemical or biological means to immobilize, destroy or transform contaminants of concern.

2.5.3 Containment

Containment isolates the contaminant of concern from the environment and reduces or eliminates the transport of the contaminant to levels that reduce or prevent injuries.

With in-situ containment, additional monitoring of the technology is required to ensure that design and performance goals are being met.

Section 3 Evaluation of Remedial Technologies and Development of Potential Remedial Alternatives

3.1 Overview

This section considers and evaluates remedial technologies and their potential to address remedial action objectives. For the purposes of this evaluation, remediation is defined as those technologies that have been demonstrated to reduce the subject injuries of the IRW.

A list of remedial action technologies were developed for each response region that had a potential to aid in achieving one or more of the RGs. These technologies were then screened to eliminate options that were not expected to be effective or implementable for this site. Technologies that achieved similar goals but were clearly excessive in cost than retained technologies were also eliminated. Technologies that were considered potentially effective and implementable, but where additional investigations or assessments are required to adequately evaluate these actions, are so designated within this section and listed in Section 5. Retained technologies were evaluated against effectiveness, implementability and cost metrics and final technologies were selected for more detailed evaluation as presented in Section 4.

It is important to note that the technologies have been evaluated based on a cessation of poultry waste application to land within the IRW. Continued land application of poultry waste would significantly increase costs associated with implementation of evaluated technologies and would overwhelm any benefits in reducing the injuries that the technologies would address. Based on modeled watershed response (B. Engel, 2008), the failure to cease the application of poultry waste to land within the IRW will result in increasing injuries to the IRW and prevent attainment of the RGs presented herein.

3.2 Screening criteria for remediation technologies

After consultation with the State experts, CDM reviewed the gathered information to ensure that a complete set of screening criteria was identified to reliably narrow the technologies to the most appropriate candidates for inclusion as part of the detailed alternatives developed to address the injuries. The technology primary screening criteria were: (1) effectiveness; (2) implementability; and (3) cost. The screening criteria were defined and used as follows:

- *Effectiveness* – With respect to the primary screening, effectiveness is defined as the ability of a technology to remove or otherwise address the target contaminant of concern and reduce the associated injuries. The effectiveness of the technology across the entire IRW is not addressed during the primary screening.

- *Implementability* – With respect to the primary screening, implementability is defined as the applicability of a technology to be installed or executed across the entire IRW. This criterion is used to screen out those technologies that are not practically achievable.

- *Cost* – With respect to the primary screening, cost is used only to eliminate those technologies deemed to be extraordinarily expensive or technologies that are similar in effectiveness and implementability, but substantially more costly than another technology that addresses the same contaminant of concern.

The technologies are organized and presented based on response region and general response action.

3.2.1 Response Region: Watershed

The watershed area of the IRW includes both land and groundwater areas. Contaminants of concern, soils, surface water runoff and groundwater that flow into the rivers and streams of the IRW are considered as part of the watershed response region. The watershed response region includes lands where poultry waste has been applied.

3.2.1.1 Removal

Cessation of land application within the IRW and proper poultry waste management (Cessation) —Land application of poultry waste within the IRW has resulted in the injuries listed in Section 2.1. Ongoing application of poultry wastes within the IRW would further harm human health and the environment and eliminate most if not all of the benefits of any remedial action. Cessation of poultry waste land application must be implemented to begin addressing the injuries identified for the rivers and streams of IRW and Lake Tenkiller. Poultry waste should be managed in accordance with applicable laws and regulations and not allowed to negatively impact human health or the environment within or outside the IRW.
RETAINED FOR REMEDIAL EVALUATION.

Excavation – Removing soils with excessive P is commercially available and would be effective. However, the logistics and costs of excavating P rich soil and replacing them with non-P rich soils would make this technology infeasible and not implementable on an IRW-wide scale. However limited excavation focused on specific criteria may be warranted to reduce source areas of highly P enriched soils. This action is retained for further consideration with the provision that additional investigations and assessments would be required to: (1) identify lands with high P concentrations that are susceptible to runoff and/or leaching; (2) identify P loadings to groundwater and surface water associated with identified areas; (3) estimate P reductions and costs; and

(4) compare to other technologies identified to determine relative benefits.
REQUIRES ADDITIONAL INVESTIGATION AND ASSESSMENT.

3.2.1.2 Treatment

Buffer strips adjacent to streams and rivers – Also known as vegetative filter strips (VFS), grass or other plants are strategically placed in areas to catch nutrient runoff or capture nutrients through infiltration. Placing buffer strips along the fields is an option that is commercially available, implementable and potentially effective (Edwards et al., 1994).
RETAINED FOR REMEDIAL EVALUATION.

Chemical treatment of fields and pastures with alum (alum field application) – Aluminum sulfate (alum) has been reported to reduce the amount of soluble P when used as a chemical treatment to poultry waste prior to spreading on fields (Moore et al., 2007). Alum is commercially available and the technology is implementable. However, the effectiveness of alum in immobilizing P in-situ to fields and pastures as found within the IRW has not been demonstrated on a large-scale basis. For this reason, this technology requires additional investigation and assessment.

Potentially, alum would be applied to land where poultry waste has been applied, and excess P persists. The long-term effectiveness of alum amended poultry waste was tracked as it was applied to several fields over seven years (Moore and Edwards, 2007) where reductions of soluble P were up to 87%. However, aluminum can potentially damage aquatic ecosystems and is potentially phytotoxic to plants at low pH. Moore and Edwards (2005) found the amounts of aluminum in runoff were similar from fields with plots applied with treated and untreated poultry waste. Additional studies would focus on quantifying the reduction in P runoff and leaching from fields and potential impacts to pH to determine if aluminum toxicity is of concern. CDM identified no long-term studies of alum applied directly to poultry waste impacted land to reduce P runoff and leaching.

Additional studies would address the effectiveness of alum application as it relates to the reduction in P loading to the watershed based on the following factors: application method, location, environmental impact, reduction in runoff P, reduction in leaching P, pH changes and potential toxicity of aluminum.
REQUIRES ADDITIONAL INVESTIGATION AND ASSESSMENT.

Chemical treatment of fields and pastures with lime – Treating fields with lime is commercially available and implementable. With respect to the treatment of poultry waste prior to field application, Moore and Miller (1994) tested four forms of lime and alum and found treatment of poultry waste with alum, calcium oxide (CaO) and calcium hydroxide ($Ca(OH)_2$) effective at reducing P in runoff from fields fertilized with poultry waste. However, calcitic and dolomitic limestone was ineffective in reducing P in runoff. Alum has been found to be more effective than lime in reducing P runoff in poultry waste studies. Further, CDM identified no long-term

studies that demonstrate the effectiveness of P reduction from runoff from poultry waste applied land; therefore this technology was not retained.
NOT RETAINED.

Crop and nutrient management with nitrogen supplementation – Crop management involves P removal with the harvest of crops. Nutrient management is the need-based determination of how nutrients are applied to farmland for optimal crop (including pasture grass and hay) growth. Nutrient management plans generally involve inventorying farmland, nutrient needs for crops and soil nutrient content. The balance of nutrients necessary to meet crop production objectives is determined. Pastures, grasslands and fields that have been used extensively for poultry waste land application have P in soil at levels well above the agronomic need.

Crop production and removal on poultry waste applied lands is a technology that may potentially be used to reduce the amount of P in the soil. Crops are fertilized with nitrogen from a source with little or no P content. Harvested crops would then be shipped out of the IRW reducing the P mass within the IRW. Where the crop is consumed within the IRW, (e.g. as cattle feed), and the livestock is transported outside the IRW, there is also a net reduction in P.

Coblentz et al., (2004) discussed removal of excess P by using ryegrass and bermudagrass. With added nitrogen, approximately 38.0 lbs per acre P were removed, but the rate of removal of P did not increase with increased N. K was removed at a faster rate, causing concern that soils would eventually be depleted of K.

While this action is viable, the potential quantities of P removed from the IRW and resultant reduction in P loading to the IRW has not been quantified. Further, the rate of loading reductions via crop uptake of P is estimated to take a substantial period (decades) of P-free fertilization practices before soil test phosphorus (STP) would be reduced to levels that are below the agronomic maximum of 65 mg/kg. Due to: (1) the time frame for implementation; (2) unknown effectiveness of this technology in the short term for removing P from soil; and (3) the uncertainties associated with reductions in P loading to groundwater, streams, rivers and Lake Tenkiller, this technology requires additional investigation and assessment.
REQUIRES ADDITIONAL INVESTIGATION AND ASSESSMENT.

Residential treatment system for drinking water – Private groundwater wells within the IRW have been impacted by N and bacteria. Residential treatment systems for drinking water are commercially available to reduce N and bacteria to acceptable levels for human consumption. This technology is effective and implementable for residential drinking water.
RETAINED FOR REMEDIAL EVALUATION.

Residential supplied drinking water – In lieu of treating groundwater from private wells, drinking water can be supplied as bottled water. This technology is commercially

available, effective and implementable.
RETAINED FOR REMEDIAL EVALUATION.

Residential replacement of groundwater wells – As an alternate to treating or supplying drinking water, contaminated residential groundwater wells can be replaced with deeper wells that draw water from deeper in the aquifer that has not been impacted by N or bacteria. This technology is commercially available, effective and implementable.
RETAINED FOR REMEDIAL EVALUATION.

Pump and treat groundwater – Pumping and treating ground water would involve removing groundwater impacted by the poultry waste application. The water would be chemically treated and recharged to the aquifer or discharged to a surface water body. Although this technology is commercially available it could not be reasonably employed on the scale of an IRW-wide remediation. Additional uncertainty exists as to the effectiveness of this technology in meeting RGs. Therefore this technology was eliminated from further consideration.
NOT RETAINED.

Retention/detention basins—Retention or detention basins involve the capture or detention of surface water runoff within constructed ponds or basins. The capture of surface water flows from fields with newly applied poultry waste would reduce the immediate loading of P to rivers and streams. However, the load of soluble P to groundwater would likely increase. This technology may further serve to reduce P by providing an alternate water source for livestock, reducing traffic through streams and rivers of the IRW.

This technology is commercially available and potentially implementable for certain areas within IRW based on a number of factors including land use, soil type, topography and geology. It may be effective in addressing some injuries to rivers and streams, but its overall effectiveness and potential applicability to make significant improvements on an IRW-wide basis is not quantifiable based on existing information available for this report. Due to these unknowns and potential ineffectiveness of this technology in reducing soluble P loading to groundwater, streams, rivers and Lake Tenkiller, this technology is not retained.
NOT RETAINED.

3.2.2 Response Region: Riverine

The riverine area of the IRW includes the banks, surface water and sediment of rivers and streams. Contaminants of concern, bank erosion of soils, surface water and sediment transport of the rivers and streams of the IRW are considered as part of the riverine response region. The former Lake Francis area, located on the Illinois River at the border of Arkansas and Oklahoma is also included in this response region.

3.2.2.1 Removal

Sediment removal— Sediment removal by dredging or mechanical excavation is commonly used for drains and waterways for maintenance of floodways and navigation. Sediment removal is commercially available and removes P from the riverine system. However, within the IRW river system, sediment is readily transported and does not remain in as part of the streambed for extended sections of the rivers and streams. Because the contribution of P from sediment is not considered to be substantial within the riverine system of IRW, sediment removal would not be effective in meeting RGs. Therefore this technology is not retained with the exception of sediment removal actions that may be taken in conjunction with Lake Francis, as discussed below.
NOT RETAINED.

3.2.2.2 Treatment

Bank stabilization— Stream and riverbank stabilization can be used to prevent the erosion of bank soils into surface waters and improve wildlife habitat. A variety of techniques to stabilize banks range from "hard" stabilization using rock or gabions to "soft" stabilization using natural vegetation, plantings or "biologs" (natural materials such as coconut husks woven into the shape of a log). This technology is commercially available and implementable where erosion is actively occurring. However, this technology does not substantially reduce soluble P and bank erosion is not considered to be a substantial contributor to overall P loading to the rivers and streams of IRW and Lake Tenkiller.

Bank stabilization within the Illinois River system can be used to restore banks and improve wildlife habitat, however additional investigation and assessment is required to determine candidate locations for implementation, resultant P removals and cost effectiveness.
REQUIRES ADDITIONAL INVESTIGATION AND ASSESSMENT.

Constructed wetland— Wetlands can be constructed to capture sediments and nutrients from runoff or surface water. The conditions required for a constructed wetland to be effective in removing sediments and nutrients include stable hydrology, suitable substrate, maintenance and removal of accumulated sediment and suitable plantings. For effectiveness in P removal, wetland loadings should generally be less than one gram of P per square meter per year (Richardson and Qian, 1999). P loadings above this level greatly reduce the effectiveness of the wetland in removing P from water through the system. While this technology is commercially available and potentially implementable, the number of sites with suitable conditions for implementation is unknown. On a watershed-wide basis, there is insufficient area available to build wetlands in the IRW given the threshold needed for effective P removal. Therefore this action is classified as requiring additional investigation and assessment to determine if suitable sites exist for implementation. If candidate sites are identified, they may need to be evaluated to determine characteristics such as: (1) if they are

viable hydrologically; (2) likely reductions in P; and (3) cost effectiveness.
REQUIRES ADDITIONAL INVESTIGATION AND ASSESSMENT.

P inactivation with alum—Aluminum sulfate (alum) is commonly used as a treatment to reduce P from continuously cycling in a lake (Cooke at al., 2005). However, it has not been as widely used in river systems. Potential negatives associated with riverine alum application include the production of particulate floc that may cause siltation of aquatic habitats and fish gills and potential aquatic toxicity due to aluminum. Further, the P removal is short term and repeated applications would be required to provide P removal on an ongoing basis. Therefore this technology has not been retained.
NOT RETAINED.

P inactivation with ferric or lime—Ferric or lime treatment is used to remove P from wastewater and is commercially available. However, the potential negatives associated with ferric or lime application includes harm to aquatic habitats and fish gills from siltation. Further P removal is short term and repeated applications would be required to provide P removal on an ongoing basis. Therefore this technology has not been retained.
NOT RETAINED.

Drinking water surface water treatment— Surface water treatment is commercially available and implementable, but is only effective on the drinking water. It does not address other injuries. This technology consists of the removal of algae and other disinfection byproducts such as THM and HAA5 precursors that would result in unacceptable risks to human health after chlorination and disinfection of drinking water. This technology is retained for remediation to reduce risks to human health.
RETAINED FOR REMEDIAL EVALUATION.

Re-impound Lake Francis—Lake Francis is a former impoundment near Siloam Springs and the border of Arkansas and Oklahoma. The dam that formed Lake Francis was breached during a flood in 1992. Re-impounding this area could capture sediments and reduce P loading to Lake Tenkiller. An investigation by the U.S. Geological Survey (USGS) found that approximately 26 percent of the total P load into former Lake Francis was retained between 1998 and 2000. However soluble reactive P retention for the same period was negligible (Haggard, et al. unpublished). USGS postulated that sediment that total P removed was due to sediment deposition and may be resuspended during massive flooding. The re-impoundment of Lake Francis would need to evaluate the potential benefits to IRW in terms of P removal against the potential ecological impacts of re-flooding the impoundments along with the resulting loss of habitat and wetlands. If this technology was implemented, existing sediment and future sediment deposition would need to be removed to prevent the solubilization of P from sediment during anaerobic conditions (Haggard and Soerens, 2006). Based on the ineffective removal of soluble P and the negative ecological impacts of re-impounding Lake Francis, this technology has been eliminated.
NOT RETAINED.

3.2.2.3 Containment

Capping— Capping involves containing sediments with other materials, usually a sand mixture. Theoretically, capping reduces the flux of contaminants from the sediment to the water column. Due to the nature of the stream and river beds within the IRW riverine system, bedding material is already coarse and would not be effectively capped using sand or like materials. Due to the high flow events common within IRW surface waters, capping materials would be eroded and the installation of a cap is not likely to be effective or implementable for the long term. Therefore, this technology is eliminated.
NOT RETAINED.

3.2.3 Response Region: Lake Tenkiller

The Lake Tenkiller area of the IRW includes the banks, surface water and sediment of Lake Tenkiller, which begins on the Illinois River in the Horseshoe Bend area and ends at the Lake Tenkiller Dam. Contaminants of concern, surface water, sediment and lake dissolved oxygen conditions are considered as part of this response region.

Lake Tenkiller is a recreational reservoir within the IRW. Injuries from the land application of poultry waste in the IRW have included increased P and N, which have increased algal blooms and anoxic conditions in the hypolimnion. In addition, the sediments in Lake Tenkiller contain excess amounts of nutrients. The release of these nutrients, particularly P, affects the excess production of algae.

3.2.3.1 Removal

Sediment removal— Sediment removal by dredging or mechanical excavation is commonly used for waterways for maintenance of surface water flows (flood control) and navigation. Sediment removal is commercially available and is implementable and effective if (1) the dredging method effectively removes the sediment and associated contaminant of concern; and (2) new loadings to the waterway are reduced or eliminated from the tributaries to the lake or reservoir. If inflow loads are not reduced, sediment removal would need to be performed on an ongoing basis.

Problems in Lake Tenkiller sediments are excessive amounts of P (Cook and Welch, 2008). Dredging contaminated sediments in Lake Tenkiller could potentially reduce excess nutrients within the lake. This action would require transportation and disposal of dredged spoils in a facility designed to prevent reintroduction of P into surface water or groundwater. However, dredging would only remedy the nutrients that currently exist in the lake sediments. Continued inputs of P and organics from poultry waste which have eutrophied Lake Tenkiller would not be addressed through this action. In addition, due to the depth of Lake Tenkiller, dredging would be very difficult to implement successfully. Therefore the applicability of dredging cannot be adequately evaluated until the final remedial measures for the watershed and riverine response regions have been identified in sufficient detail to determine future P and

nutrient loadings to Lake Tenkiller.
REQUIRES ADDITIONAL INVESTIGATION AND ASSESSMENT.

3.2.3.2 Treatment

Complete Mix Aeration—Aeration (addition of air or oxygen) is a technology used for lake restoration to remedy anoxic (no dissolved oxygen) areas. Aeration is commercially available and potentially implementable. However, there are concerns that aeration may mix high P waters of the hypolimnion with upper layers of Lake Tenkiller exacerbating the injuries. Therefore this option is eliminated, but layered aeration, designed to avoid mixing the hypolimnion with overlying layers is discussed further, below.
NOT RETAINED.

Bank stabilization—Stabilization of the banks of Lake Tenkiller can be used to prevent the erosion of bank soils into surface waters and improve wildlife habitat. A variety of techniques to stabilize banks range from "hard" stabilization using rock or gabions to "soft" stabilization using natural vegetation, plantings or "biologs" (natural materials such as coconut husks woven into the shape of a log). This technology is commercially available and implementable where erosion is actively occurring. However, the contribution of P loading to Lake Tenkiller from bank erosion is estimated to be insignificant relative to other sources of P based on existing information. Therefore this technology is eliminated.
NOT RETAINED.

Constructed wetland— Wetland construction can be used to capture sediments and nutrients entering a system from surface waters routed through the system. This technology is commercially available and implementable within the upper reaches of Lake Tenkiller. However the current P loading to Lake Tenkiller far exceeds the available area for a constructed wetland with the potentially effective threshold loading of one gram P per square meter per year. Therefore this technology was eliminated from further consideration.
NOT RETAINED

Dilution and flushing— Dilution and flushing techniques can be used to decrease the level of lake eutrophication by adding more flow through the impoundment to reduce the overall concentration of nutrients. This technology is commercially available, but cannot be implemented for Lake Tenkiller as low-nutrient water sources are not available in sufficient quantities.
NOT RETAINED.

Drinking water surface water treatment— Surface water treatment is commercially available and implementable, but is only effective on the drinking water. It does not address other injuries. This technology consists of the removal of algae and other DBP precursors that would result in unacceptable risks to human health after chlorination and disinfection of drinking water. This technology is retained for

remediation to reduce risks to human health.
RETAINED FOR REMEDIAL EVALUATION.

Reservoir management, lake water drawdown—Drawdown is commercially available and implementable, but would not be effective. Generally, this technology is not effective for P removal from a reservoir.
NOT RETAINED.

P inactivation with alum—Aluminum sulfate (alum) is commonly used in lakes as a treatment to reduce the flux of P from sediments (Cooke et al., 2005). This treatment is commercially available, implementable, and potentially effective. However, in a reservoir, such as Lake Tenkiller, high dosages and repeated applications may be needed to be potentially effective in sequestering sediment P. With higher dosages, there is the potential for localized depression of pH with an associated potential increase in aluminum toxicity to aquatic life.

Alum treatment of Lake Tenkiller could potentially reduce the internal loading of P from lake sediments. Using alum typically increases the water clarity. Alum can be toxic to aquatic life at low pH (Cooke et al., 2005). Alum applications are generally effective in lakes from 5 to 15 years (Welch and Cooke, 1999). However, the duration of alum treatment effectiveness in a reservoir such as Lake Tenkiller will not be as long as a lake and will be further reduced proportional to the additional P inputs from the Illinois River, Caney Creek and the Baron Fork. Therefore, the applicability of P inactivation with alum cannot be adequately evaluated until the final remedial measures for the watershed and riverine response regions have been identified in sufficient detail to determine future P and nutrient loadings to Lake Tenkiller.
REQUIRES ADDITIONAL INVESTIGATION AND ASSESSMENT.

P inactivation with ferric or lime—Ferric or lime treatment is commercially available and implementable, but its effectiveness on P inactivation relative to alum is lower and costs for application and raw materials are generally much greater than alum.
NOT RETAINED.

Hypolimnetic withdrawal— Hypolimnetic withdrawal is a lake restoration technique in which siphons or other structures are used to remove nutrient rich water from the bottom portion of the lake (hypolimnion). Nutrient concentrations are reduced utilizing this method when P concentrations are higher in the hypolimnion as compared to the overlying water layers. The technology is commercially available, implementable, and effective. This is currently the mode of operation for Lake Tenkiller dam. No evaluation of alternative draw offs is warranted.
NOT RETAINED, ALREADY IMPLEMENTED

Artificial circulation— Artificial circulation provides mixing to lakes utilizing mechanical mixing or aeration systems. This technology is usually used for shallow water bodies. It is commercially available, but difficult to implement on a large deep

impoundment like Lake Tenkiller. Further, circulation may stimulate algal growth by mixing high P waters from the hypolimnion and counteracting plunge and stratification that direct P to the hypolimnion.
NOT RETAINED.

Food-web manipulations— Adding piscivorous (fish eating) fish to reduce the number of zooplanktivorous (zooplankton eating) species would be a management technique to reduce planktonic (free floating) algae. Assuming the zooplankton respond, they would consume more algae and therefore increase the water clarity. This technology is commercially available and would be implementable when excess P is reduced in the system. It would also be potentially effective when P is reduced and/or oxygen added. Oxygen would need to be restored to keep the fish alive. If this technology is used, piscivorous fish would have to continually be stocked, as they do not survive beyond a year. Due to uncertainties with food-web interactions for Lake Tenkiller and the low dissolved oxygen conditions for the entire lake during portions of the year, this technology is not implementable given the current situation.
NOT RETAINED.

Algal control – copper sulfate treatment—Copper sulfate is commonly used to control algae and other nuisance plants in a water system (Cooke et al., 2005). While this is commercially available and implementable, it is effective only in the short term. In addition to concerns regarding copper toxicity, algal control does not address P which would persist in the system.
NOT RETAINED.

Layered aeration— Layered aeration is a process that adds dissolved oxygen to the water in the bottom portion of a lake (hypolimnion), to maintain a dissolved oxygen concentration that allows cold water game fish to survive during the warm periods when Lake Tenkiller becomes anoxic. Aeration of the hypolimnion also limits P release from sediments when aerobic conditions are maintained in the overlying water column (Cooke et al., 2005). The technology is commercially available, implementable and potentially effective. However, it is primarily a temporary means to restore fish habitat and requires perpetual operation during warm months until P loads to Lake Tenkiller are reduced.

Aeration could potentially reduce or eliminate anoxic conditions in Lake Tenkiller, improving conditions for fish. Blue-green algal blooms would likely decrease, eliminating taste and odor problems for people using Lake Tenkiller as a water supply. The need for aeration would be ongoing until P loadings are reduced to water quality criteria. However, lake aeration would not address continual inputs of P into the IRW and may also stimulate more algal blooms (Cooke et al., 2005). Therefore this action requires additional investigation and assessment to determine optimum location of aeration devices, mixing zones of influence, aeration zones of influence and potential stimulation of algal blooms.
REQUIRES ADDITIONAL INVESTIGATION AND ASSESSMENT.

3.2.3.3 Containment

Capping— Capping involves containing sediments with other materials, usually a sand mixture. Theoretically, capping stops contaminants from being released into the water column. While capping is commercially available and implementable, it is not likely to be effective in sequestering P and preventing the internal recycle of P from sediments to the water column. A variety of issues eliminate this technology including: (1) the limited effectiveness of a sand cap in reducing P flux from the sediment; (2) constructability issues related to loss of cap thickness and effectiveness due to mixing of cap materials and sediment; (3) costs to achieve similar degrees of P reduction relative to alum are excessive; (4) installation and maintenance of the cap will be difficult due to the morphology of Lake Tenkiller's basin; and (5) the effectiveness of the cap is defeated if nutrient sources are ongoing.
NOT RETAINED.

Section 4 Detailed Evaluation of Remedial Alternatives

4.1 Overview

This section develops and evaluates alternatives for remedial options in more detail. Each technology can then be compared to assess performance relative to the evaluation criteria. The following identified preliminary remedial technologies were evaluated based on response region and media that the technologies will be applied:

I) Watershed Response Region
   1) Removal – Cessation of land application within the IRW and proper poultry waste management
   2) Treatment – Buffer strips/vegetative filter strips
   3) Treatment – Residential treatment system for drinking water
   4) Treatment – Residential supplied drinking water
   5) Treatment – Residential replacement of groundwater wells

II) Riverine Response Region
   1) Treatment – Drinking water surface water treatment

III) Lake Tenkiller Response Region
   1) Treatment – Drinking water surface water treatment

4.2 Evaluation Criteria

Remedial technologies are discussed in detail according to the following criteria:

- *Overall protection of human health and the environment* – Benefits to human health and the environment are considered, including an alternative's protectiveness and reduction potential for exposure and risk.

- *Compliance with potentially applicable legal requirements* — Alternatives must also consider state and federal laws during the process of remediation. These laws can be chemical specific, action specific or location specific. Chemical-specific laws include federal and state regulations of specific contaminant levels (e.g. phosphorus, bacteria). Action-specific laws regulate the technologies or activities used for the remediation technology. For example, laws for dredging would include all regulatory requirements for dredging and disposal. Location specific laws are relevant regulations specific to a geographic location. For example, actions on wetlands or critical habitats would require compliance with federal and state regulations for wetlands. The list of laws considered is included as Table 4-1.

- *Long-term effectiveness and permanence* — This criterion evaluates the effectiveness of an alternative over time, after implementation.

- *Reduction of toxicity, mobility, or volume through treatment*—This criterion evaluates the ability of a technology to reduce the toxicity, mobility, or volume of the contaminant of concern through treatment.

- *Short-term effectiveness*—This criterion considers the effectiveness during construction or implementation of the alternative.

- *Implementability*—The commercial availability and the ability to execute and complete an alternative are considered in this criterion.

- *Cost*—This criterion considers the overall costs of the technology. This includes short term capital and operating costs, operation and maintenance, and other direct and indirect costs.

4.3 Watershed Response Region

Retained technologies for the watershed response region address the transport of P to rivers and streams and residential drinking water impacted by bacteria and nitrogen. Excess P exists in the soils where poultry waste has been applied. Remediation technologies attempt to address human health and the removal of excess P and other nutrients to stop their continual input into IRW rivers and streams and Lake Tenkiller.

4.3.1 Removal - Cessation of land application within the IRW and proper poultry waste management

Grasslands, pastures and fields that have been used repeatedly for the application of poultry waste for fertilization and disposal have received loadings of P that far exceed the agronomic requirements of grass, hay and other crops grown on them. These areas of land have resulted in the runoff and leaching of P which has resulted in the injuries listed in Section 2.1. The ability and effectiveness of all of the remedial options to reduce N, P and bacterial loadings will be impaired without the cessation of land application of poultry waste within the IRW. Without cessation, the loading of P to the rivers, streams and Lake Tenkiller will likely increase over the next 30 years based on the IRW watershed-wide model (B. Engel, 2008).

Overall protection of human health and the environment – The elimination of poultry waste land application within the IRW will reduce the loadings of P, N and bacteria to the river and streams of the IRW and Lake Tenkiller. Bacteria will die off over time naturally. Generally, N is not the limiting nutrient in the IRW system and therefore the reduction in N will not result in significant improvements to human health and the environment. P will gradually leach from the soil over time. Initial predictions indicate that P loadings will decline approximately 17 percent during the first decade of cessation and are expected to attain a 50 percent reduction after 50 years (B. Engel, 2008).

Compliance with potentially applicable legal requirements – This technology can be implemented in compliance with all potentially applicable legal requirements.

Long-term effectiveness and permanence – This technology would be effective in reducing N, P and bacteria. However, the existing inventory of P will likely leach at elevated levels for the next 100 years with cessation alone.

Reduction of toxicity, mobility, or volume through treatment – This technology would reduce toxicity, mobility and volume of bacteria through natural die off. N and P will continue to leach from the soil column into groundwater and surface waters.

Short-term effectiveness – Cessation and proper poultry waste management within the IRW will have no short term negative impacts on the IRW.

Implementability—This technology is implementable.

Costs—Costs of this technology are dependent on the methods chosen by the Defendants to manage poultry waste in accordance with applicable laws and regulations. As a point of reference, disposal of poultry waste within a licensed landfill was estimated by the Defendants at approximately $35 per ton. This results in the following costs: capital costs -- none; annual costs were estimated to be $16 million; and total present worth cost over 30 years was estimated at $200 million.

4.3.2 Treatment - Buffer strips/vegetative filter strips

Various terms have been used to define vegetation planted to prevent nutrient inflow, including buffers, riparian strips, and filter strips. For the purposes of this report, the term vegetative filter strips (VFS) will be used. VFS are areas of plants used to prevent the infiltration of sediments or nutrients into receiving waters (Fischer and Fischenich, 2000). Trees, herbs and grasses can be used in various densities to create a VFS.

VFS removes P by: (1) slowing overland flow and allowing P-laden sediment to settle and be retained within the VFS; and (2) growth of biomass within the VFS uptakes P from the settled sediment and soil. The major mechanism for VFS to be effective is to change flow hydraulics and slow down surface water. As surface water passes slowly and uniformly, sediment is deposited and suspended sediment is filtered by vegetation. Soluble particles are usually removed by infiltration and sorption by the soil/plant matrix.

VFS design is important in targeting the success of specific contaminant removal. Design elements include 1) width 2) slope and 3) type of plantings used.

Overall protection of human health and the environment – Removal of P through the use of VFS is partially protective of human health and the environment based on the reduction of P loading to rivers, streams and Lake Tenkiller and the associated reduction in P related injuries. Other benefits of creating VFS include stabilizing field or river bank areas and increasing accessibility for wildlife (Fischer and Fischenich, 2000).

Compliance with potentially applicable legal requirements – This technology can be implemented in compliance with all potentially applicable legal requirements. Soil erosion permits and controls would be required for disturbed areas that exceed the regulatory threshold. For those areas affecting wetlands, the following citations are relevant:

- Rivers and Harbors Act of 1899 (33 USC 403). If wetlands are to be created or the course of the river modified in any way, permits would need to be applied for through the Army Corps of Engineers.

- Executive Orders 11990-Protection of Wetlands and 11988-Floodplain management (40 CFR 6.302 40 CFR 6, Appendix A; OSWER 9280.0-03). This law is relevant if federal agencies are involved in the creation of the buffer zones which modify wetlands or floodplains.

Long-term effectiveness and permanence – Design of VFS is important in its success of preventing nutrients from entering a water body. VFS width, slope, and type of plant material all factor into its long-term effectiveness. Filters are able to reduce sediment and suspended solids from runoff as long as surface flow is shallow and uniform (Dilaha, 1989). Maintenance of VFS needs to be considered as well (Grismer et al., 2006).

Effectiveness can range from 50-98% for sediments and decreases with increased sedimentation over the years. VFS are not always effective at removing soluble P and N (Dilaha, 1989), however. Based on these considerations, cessation of poultry waste land application is required for VFS to be effective over the long term. The continued application of poultry waste would result in the build up of P within the VFS and eventually reduce the P removal efficiency such that there could potentially be no net removal of P loading from rivers and streams as compared to current conditions.

The reduction in P loadings to the streams and rivers of the IRW and Lake Tenkiller were estimated using two scenarios, placement of VFS with a width of 100 feet on both sides of streams and rivers that intersect pastures or grassland for: (1) all streams within IRW (estimated at 84,927 acres); and (2) for streams 3rd order and above (estimated at 13,347 acres). Resultant P reductions were estimated using a model with a simulation period of 100 years. Under the all stream scenario with cessation of poultry waste land application at year 0, average P reductions ranged from a high of 13.6 percent (decade 2) to a low of 10.6 percent (decade 10). Under the 3rd order and above stream scenario with cessation of poultry waste land application at year 0, average P reductions ranged from a high of 5.4 percent (decade 1) to a low of 3.3 percent (decades 9 and 10).

Reduction of toxicity, mobility, or volume through treatment – Different types of VFS effect the reduction of P and N (Fischer and Fischenich, 2000). Chaubey et al. (1995) found a 89% reduction of soluble P, 91% reduction for total P and a reduction ranging from

19-26% total suspended solids for filter strips of fescue 21.0 m wide. Two model scenarios were developed and run to determine the overall effectiveness of VFS for 3rd order and above streams and for all streams. VFS were modeled based on land use maps and stream data in a geographical information system (GIS) framework. Where fields intersected streams or rivers, a 100 feet wide VFS was assumed. It should be noted that the "all streams" scenario does not include the large number of ditches and swales that drain fields, grasslands and pastures within the IRW and therefore total P removals estimated with respect to long-term effectiveness and permanence do not approach the literature reported removal efficiencies.

Short-term effectiveness – Constructing VFS would create the potential for increased erosion and P loading to river and streams. Work practices and soil erosion control would mitigate this potential and minimize short-term releases of P.

Implementability—Information on design standards and target nutrients is readily available (Fischer and Fischenich, 2000; Grismer et al., 2006; Mayer et al., 2005; and Parkyn, 2004). Regional studies specific to the IRW area and the poultry industry are also available. Chaubey et al., 2005 studied effectiveness of filter strips in poultry areas in Arkansas. Edwards et al. (1996) developed a readily applicable VFS design procedure using a hypothetical northwest Arkansas field.

Costs— Costs of VFS will vary with types of vegetation used, reduction of land production, and costs associated with planting, establishing and maintaining buffers (Helmers et al., 2006). Costs were developed under two scenarios, VFS placement for all streams within IRW (estimated at 84,927 acres) and for streams 3rd order and above (estimated at 13,347 acres). VFS efficiency and costs were estimated assuming 100 feet widths on both sides of streams or rivers where the land use was pasture or grasslands. The capital costs were estimated at $271 million and $43 million for all streams and 3rd order-plus streams, respectively. Annual costs were estimated at $55 million and $9 million and the total present worth cost over 30 years were estimated at $956 million and $150 million for all streams and 3rd order-plus streams, respectively.

4.3.3 Treatment – Residential drinking water

This technology addresses the human health risks present due to nitrogen and bacteria present in groundwater for the impacted drinking water wells of the Oklahoma portion of the IRW. CDM sampled 60 residential domestic drinking water wells in 2006 and 2007. Thirteen percent of the wells tested were reported with total N concentrations exceeding 10 mg/l, indicating a potential exceedance of the nitrate maximum contaminant level for drinking water. Sixty percent of the wells were reported to have a detection of bacteria and 67 percent of the wells were reported to have either N or bacteria exceedances. Extrapolating these findings to the Oklahoma portion of the IRW, an estimated 190 to 980 wells are potentially impacted due to N or bacteria. Cessation is expected to address bacteria through natural die-off (Gerba, et al. 1975). Excess P is not a human drinking water consumption risk in groundwater and is not addressed by this technology.

4.3.3.1 Residential drinking water treatment system

Technologies such as reverse osmosis, ion exchange and ultraviolet treatment can be used as groundwater point of use treatments to remediate high nitrogen and bacteria levels.

Overall protection of human health and the environment – Treating drinking water for nitrogen and bacteria on a per residence basis will reduce human health risks associated with contaminated drinking water. No reduction in risk to human health or the environment from P impacts is achieved.

Compliance with potentially applicable legal requirements – This technology can be implemented in compliance with all potentially applicable legal requirements. Additional applicable requirements may include:

- Title 785. Oklahoma Water Resources Board
  - Chapter 30. Taking and use of groundwater
  - Chapter 35. Well driller and pump installer licensing
  - Chapter 45. Oklahoma's water quality standards

Long-term effectiveness and permanence – With proper maintenance, the treatment system will be effective and permanent.

Reduction of toxicity, mobility, or volume through treatment – This technology removes N through ion exchange or reverse osmosis. Bacteria are destroyed through ultraviolet radiation.

Short-term effectiveness – This remediation would be immediately effective and initiating it would not be a detriment to human health or the environment.

Implementability – These technologies are commercially available and are implementable.

Costs — Costs of this technology will vary with the number of wells impacted and types of treatment and capacity. The capital costs were estimated at $0.43 to $4.8 million for N only and N plus bacteria impacts, respectively. Annual costs were estimated at $0.15 to $0.48 million and the total present worth cost over 30 years were estimated at $2.3 to $10.7 million for N only and N plus bacteria, respectively.

4.3.3.2 Residential drinking water supplied

As an alternative to treating groundwater, bottled water can be supplied to eliminate the risk to humans from high nitrogen and bacteria levels.

Overall protection of human health and the environment – Providing bottled drinking water for nitrogen and bacteria on a per residence basis will reduce human health risks associated with the ingestion of contaminated drinking water. No reduction in risk to human health or the environment from P impacts is achieved.

Compliance with potentially applicable legal requirements – This technology can be implemented in compliance with all potentially applicable legal requirements.

Long-term effectiveness and permanence – Because contaminated water is still available in the home, the effectiveness of the system is diminished somewhat.

Reduction of toxicity, mobility, or volume through treatment – This technology does not reduce toxicity, mobility or volume through treatment.

Short-term effectiveness – This remediation would be immediately effective and initiating it would not be a detriment to human health or the environment.

Implementability – This technology is commercially available and is implementable.

Costs — Costs of this technology are estimated as follows: capital costs – none; annual costs for N only (190 households) and N plus bacteria (980 households) at 10 gallons per day were estimated at $1.4 and $7.5 million and the total present worth cost over 30 years was estimated at $18 to 92 million, respectively.

4.3.3.3 Replacement of contaminated drinking water wells

Another alternative to address contaminated drinking water wells involves replacement of the existing wells with deeper wells.

Overall protection of human health and the environment – Replacement of drinking water wells within the IRW would improve conditions for human health for those with contaminated wells. No reduction in risk to human health or the environment from P impacts is achieved.

Compliance with potentially applicable legal requirements – This technology can be implemented in compliance with all potentially applicable legal requirements. Additional applicable requirements may include:

- Title 785. Oklahoma Water Resources Board
  - Chapter 30. Taking and use of groundwater
  - Chapter 35. Well driller and pump installer licensing
  - Chapter 45. Oklahoma's water quality standards

Long-term effectiveness and permanence – This technology would be effective provided contamination of N and bacteria have not extended to deeper extents of the aquifer. Cessation of land application of poultry waste is essential to assure that new wells do not become compromised.

Reduction of toxicity, mobility, or volume through treatment – This technology would not reduce toxicity, mobility or volume of N, P or bacteria.

Short-term effectiveness – Replacement would be effective in the short-term. No human health risks are associated with well replacement.

Implementability—The implementability of this technology is limited to those areas where a deeper, uncontaminated aquifer zone is available.

Costs—Costs of this technology are estimated as follows: capital costs for 190 new wells (N only) and 980 new wells (N plus bacteria) were estimated at $5.8 and 30 million, respectively; annual costs were estimated to be similar to existing wells and set to zero, which resulted in the total present worth cost over 30 years to be estimated at $5.8 and 30 million, respectively.

4.4 Riverine Response Region

Due to the nature of the rivers within IRW, namely coarse sediments with little fines, remedial technologies that might address P removal were screened out based on limited ability to achieve remedial goals. However, drinking water treatment of public water supplies drawing from IRW rivers was retained based on its effectiveness in addressing human health risks related to disinfection byproducts.

4.4.1 Treatment – Drinking water surface water treatment

Organic matter is correlated with precursors that form DBPs when drinking water is disinfected. The formation of disinfection byproducts such as THMs and HAA5s can be reduced by using enhanced coagulation, softening or granular activated carbon (GAC) to remove these precursors. This is usually used in systems using conventional filtration treatment (US EPA Office of Water, 2001).

Overall protection of human health and the environment – Treating water supplies contaminated with DBPs would reduce the risk of human ingestion. These disinfection by-products are considered probable human carcinogens by US EPA.

Compliance with potentially applicable legal requirements –

- Safe Drinking Water Act (40 CFR part 143). Public water systems are regulated under federal standards of SDWA. Remediation would need to be in compliance with these standards.

- The Stage 2 DBP rule (40 CFR, parts 9, 141 and 142). Remediation would put drinking water systems in compliance with this rule, which specifically addresses DBPs.

Long-term effectiveness and permanence – Treatment for DBPs with proper operation and maintenance are effective in the long term and permanent.

Reduction of toxicity, mobility, or volume through treatment – Treating drinking water supplies for DBPs would reduce the risks of these probable human carcinogens from being ingested. However it does not address the excess P in the IRW that is causing the eutrophication.

Short-term effectiveness – The initial implementation of this remediation would not have a detrimental effect on human health or the environment.

Implementability—Technologies to reduce DBPs are implementable and readily available.

Costs — Costs of this technology were estimated based on US EPA published estimates provided as part of the Federal Register when the disinfection byproduct rule was promulgated (FR Vol 71, No. 2, January 4, 2006 p. 456). Costs were escalated from 2003 dollars to 2008 dollars using the Engineering News-Record Construction Cost Index History. Four water treatment plants (WTPs) used the Illinois River for source water while one WTP used Baron Fork Creek. Capital costs for all five WTPs were estimated at a total of $220 million; annual costs were estimated to be $19 million in aggregate; and the total present worth cost over 30 years for this technology was estimated at $452 million.

4.5 Lake Tenkiller Response Region

Several remedial technologies were preliminarily retained from the screening process for the Lake Tenkiller response region. However, additional investigation and assessment will be required to determine their effectiveness and potential value in meeting remedial goals. Therefore, drinking water treatment of public water supplies drawing from Lake Tenkiller was retained based on its effectiveness in addressing human health risks related to disinfection byproducts.

4.5.1 Treatment - Drinking water surface water treatment

Organic matter is correlated with precursors that form DBPs when drinking water is disinfected. The formation of DBPs can be reduced by using enhanced coagulation, softening or granular activated carbon (GAC) to remove these precursors. This is usually used in systems using conventional filtration treatment (US EPA Office of Water, 2001).

Overall protection of human health and the environment – Treating water supplies contaminated with DBPs would reduce the risk of human ingestion. These disinfection by-products are considered probable human carcinogens by US EPA.

Compliance with potentially applicable legal requirements —

- Safe Drinking Water Act (40 CFR part 143). Public water systems are regulated under federal standards of SDWA. Remediation would need to be in compliance with these standards.

- The Stage 2 DBP rule (40 CFR, parts 9, 141 and 142). Remediation would put drinking water systems in compliance with this rule, which specifically addresses DBPs.

Long-term effectiveness and permanence – Treatment for DBPs with proper operation and maintenance are long term effective and permanent.

Reduction of toxicity, mobility, or volume through treatment – Treating drinking water supplies for DBPs would reduce the risks of these probable human carcinogens from being ingested. However it does not address the excess P in the IRW that is causing the eutrophication.

Short-term effectiveness – The initial implementation of this remediation would not have a detrimental effect on human health or the environment.

Implementability—Technologies to reduce DBPs are implementable and readily available.

Costs —Costs of this technology were estimated based on US EPA published estimates provided as part of the Federal Register when the disinfection byproduct rule was promulgated (FR Vol 71, No. 2, January 4, 2006 p. 456). Costs were escalated from 2003 dollars to 2008 dollars using the Engineering News-Record Construction Cost Index History. Fourteen water treatment plants (WTPs) use Lake Tenkiller for source water. Capital costs for all fourteen WTPs were estimated at a total of $233 million; annual costs were estimated to be $28 million in aggregate; and the total present worth cost over 30 years for this technology was estimated at $583 million.

Section 5
Actions requiring additional investigations and assessments

Additional actions that may address P, N and bacteria within the IRW were identified in Section 3. For these actions, there is currently insufficient data available to further evaluate or recommend the applicability of these actions to assist in achieving the remedial goals. The following actions are retained for additional investigation and assessment as recommended in Section 3.

I) Watershed Response Region
  1) Removal – Excavation
  2) Treatment – Alum field application
  3) Treatment – Crop and nutrient management with nitrogen supplementation

II) Riverine Response Region
  1) Treatment - Bank stabilization
  2) Treatment – Constructed wetland

III) Lake Tenkiller Response Region
  1) Removal – Sediment removal
  2) Treatment - P inactivation with alum
  3) Treatment - Layered aeration

Section 6
Summary of Remedial Alternatives

The remedial alternatives evaluated in Section 4 are summarized as follows:

Summary of Costs for Remedial Alternatives
Illinois River Watershed

PRELIMINARY COST ESTIMATE FOR ALL REMEDIAL ALTERNATIVES

Tab Number	Description	Target Contaminant of Concern	Overall Protectiveness of Human Health and the Environment	Compliance with potentially applicable legal requirements	Long-term effectiveness and permanence	Reduction of toxicity, mobility, or volume through treatment	Short-term effectiveness	Implementability	Capital Cost	Annual Costs	Total Project Present Worth Cost
1	4.3.1 Removal - Cessation with proper poultry waste management	P, N, Bacteria	High	High	High	High	High	Yes	$0	$16,107,000	$199,872,000
2	4.3.2 Treatment - Buffer strips along fields (all streams)	P, N, Bacteria	Medium	High	Medium	Low	Low	Yes	$271,183,000	$55,202,550	$956,194,000
3	4.3.2 Treatment - Buffer strips along fields (>3rd order streams)	P, N, Bacteria	Low	High	Medium	Low	Low	Yes	$42,619,000	$8,675,550	$150,274,000
4	4.3.3.1 Treatment - Residential drinking water systems (with cessation 190 wells & without cessation 980 wells)	N, Bacteria	Medium	High	Medium	High	High	Yes	$432,000 to $4,713,000	$148,200 to $479,891	$2,271,000 to $10,668,000
5	4.3.3.2 Treatment - Residential drinking water supplied (with cessation 190 wells & without cessation 980 wells)	N, Bacteria	Medium	High	Medium	None	High	Yes	$0	$1,444,456 to $7,450,352	$17,924,000 to $92,452,000
6	4.3.3.4 Treatment - Residential drinking water replace wells (with cessation 190 wells & without cessation 980 wells)	N, Bacteria	Medium	High	High	None	High	Yes	$5,805,000 to $29,939,000	$0	$5,805,000 to $29,939,000
7	4.4.1 Treatment – Drinking water surface water treatment (IRW rivers and stream WTPs)	DBPs	High	High	High	High	High	Yes	$220,342,000	$18,635,763	$451,594,000
8	4.5.1 Treatment - Drinking water surface water treatment (Lake Tenkiller WTPs)	DBPs	High	High	High	High	High	Yes	$232,705,000	$28,219,525	$582,882,000

Section 7
References

Chaubey, I., D.R. Edwards, T.C. Daniel, P.A. Moore, Jr. and D.J. Nichols, 1995. Effectiveness of vegetative filter strips in controlling losses of surface-applied poultry waste constituents. Transactions of the ASAE 38: 1687-1692.

Coblentz, W.K., M.B. Daniels, J.L. Gunsaulis, K.A. Teague and J.D. Speight, 2004. Using bermudagrass forage systems to mine phosphorus from high soil-test phosphorus soils. University of Arkansas Cooperative Extension Service, publication no. FSA9514.

Cooke, G.D. and Welch, E.B., 2008. Personal communication.

Cooke, G.D., E.B. Welch, S.A. Peterson, and S.A. Nichols. 2005. Restoration and management of lakes and reservoirs, 3rd Edition. CRC Press, Taylor & Francis Group. Boca Raton 591 p.

Daniels, M.B., K. VanDevender and T. Riley, 2004 Nutrient management planning for livestock operations: an overview. Publication no. FSA9515, University of Arkansas, Cooperative Extension Service.

Dillaha, T.A., R.B. Reneau, S. Mostaghimi and D. Lee, 1989. Vegetative filter strips for nonpoint source pollution control. Transactions of the ASAE 32: 513-519.

Edwards, D.R., T.C. Daniel, P.A. Moore, Jr. and A.N. Sharpley, 1994. Solids transport and erodibility of poultry waste surface-applied to fescue. Am. Soc. Agricult. Engineers 37: 771-776.

Edwards, D.R., T.C. Daniel and P.A. Moore, Jr., 1996. Vegetative filter strip design for grassed areas treated with animal manures. Applied Engineering in Agriculture 12: 31-38.

Engel, B. 2008 – Personal communication.

Fischer, R.A. and J.C. Fischenich, 2000. Design recommendations for riparian corridors and vegetated buffer strips. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-24), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Gerba, C.P., C. Wallis and J.L. Melnick. 1975. Fate of wastewater bacteria and viruses in soil. Journal of Irrigation and Drainage Engineering 101:157-174.

Gilliam, J.W. 1994. Riparian wetlands and water quality. J. Environ. Qual. 23: 896-900.

Goodwin, H.L., F.T. Jones, S.E. Watkins and J.S. Hipp, 2003. New Arkansas laws regulate use and management of poultry waste and other nutrients. University of Arkansas Cooperative Extension Service, publication no. FSA29.

Goodwin, H.L., R.I. Carreira, K.B. Young, S. J. Hamm and A. C. Armstrong, 2007. Assessment of multimodal transport of baled poultry waste and dewatered biosolids from northwest Arkansas. Final report for project 7015, Dept. of Agricultural Economics and Agribusiness, University of Arkansas. 49 pp.

Grismer, M.E., A.T. O'Geen and D. Lewis, 2006. Vegetative filter strips for nonpoint source pollution control in agriculture. University of California Div. of Ag and Nat. Resources Publication no. 8195.

Haggard, B.E., W. R. Green, and R. L. Blazs. Phosphorus concentrations and loads in the State of Oklahoma’s Scenic Rivers: the Baron Fork, Flint Creek, and the Illinois River, 1998-2000. unpublished.

Haggard, B.E. and T.S. Soerens, 2006. Sediment phosphorus release at a small impoundment on the Illinois River, Arkansas and Oklahoma, USA. Ecological Engineering 28: 280-287.

Haraughty, S. 1999. Comprehensive basin management plan for the Illinois River basin in Oklahoma. Oklahoma Conservation Commission Water Quality Division. 126 pp.

Helmers, M.J., T. Isenhart, M.Dosskey, S. Dabney and J. Strock, 2006. Buffers and vegetative filter strips. EPA symposium, U.S. Environmental Protection Agency, 17 pp.

Line, J.E. 2002. Campylobacter and Salmonella populations associated with chickens raised on acidified litter. Poultry Science 81: 1473-1477.

Maguire, R.O. , D.Hesterberg, A. Gernat, K. Anderson, M. Wineland and J. Grimes, 2006. Liming poultry manures to decrease soluble phosphorus and supress the bacteria population. J. Environ. Qual. 35: 849-857.

Moore, P. 2005. Treating Poultry waste with Aluminum Sulfate (Alum). University of Arkansas Cooperative Extension Fact Sheet.

Moore, P.A., Jr. and D.R. Edwards, 2005. Long-term effects of poultry waste, alum-treated litter,and ammonium nitrate on aluminum availability in soils. J. Environ. Qual. 34: 2104-2111.

Moore, P.A., Jr. and D.R. Edwards, 2007. Long-term effects of poultry waste, alum-treated litter and ammonium nitrate on phosphorus availability in soils. J. Environ. Qual. 36:163-174

Moore, P.A., Jr. and D.M. Miller, 1994. Decreasing phosphorus solubility in poultry waste with aluminum, calcium, and iron amendments. J. Environ. Qual. 23: 325-330.

North American Lake Management Society, 2004. The use of alum for lake management. Position statement 2, adopted by NALMS Board of Directors, February 26.

Oklahoma Conservation Commission, 2007. Poultry waste transport from the Illinois River Watershed (Oklahoma) to non-nutrient limited watersheds. Draft report for FY 2002 319 (h) EPA Grant C9-996100-10, Project 6.

Oklahoma Water Resources Board, 2002. Illinois River Basin Tour. 21 pp.

Richardson, R.J. and S.S. Qian, 1999. Long-term phosphorus assimilative capacity in freshwater wetlands: a new paradigm for sustaining ecosystem structure and function, Env. Sci. Tech. 33: 1545-1551.

Sims, J.T. and N.J. Luka-McCafferty, 2002. On-farm evaluation of aluminum sulfate (alum) as a poultry waste amendment: effects on litter properties. J. Environ. Qual. 31: 2066-2073.

Slaton, N.A., K.R. Brye, M.B. Daniels, T.C. Daniel, R.J. Norman and D.M. Miller, 2004. Nutrient input and removal trends for agricultural soils in nine geographic regions in Arkansas. J. Environ. Qual. 33: 1606-1615.

Stevenson, R.J. 2008—Personal communication.

U.S.E.P.A. Office of water (4606), 2001. Stage 1 Disinfectants and Disinfection byproducts rule: a quick reference guide. Publication EPA 816-F-010.

van Waasbergen, R. 2008 – Personal communication.

Welch, E.B. and G.D. Cooke, 1999. Effectiveness and longevity of phosphorus inactivation with alum. J. Lakes Reservoir Management 15: 5-27.

Summary of Costs for Remedial Alternatives
Illinois River Watershed

PRELIMINARY COST ESTIMATE FOR ALL REMEDIAL ALTERNATIVES

Tab Number	Description	Capital Cost	Annual Costs	Total Project Present Worth Cost
1	4.3.1 Removal - Cessation with proper poultry waste management	$0	$16,107,000	$199,872,000
2	4.3.2 Treatment - Buffer strips along fields (all streams)	$271,183,000	$55,202,550	$956,194,000
3	4.3.2 Treatment - Buffer strips along fields (>3rd order streams)	$42,619,000	$8,675,550	$150,274,000
4	4.3.3.1 Treatment - Residential drinking water systems (with cessation 190 wells & without cessation 980 wells)	$432,000 to $4,713,000	$148,200 to $479,891	$2,271,000 to $10,668,000
5	4.3.3.2 Treatment - Residential drinking water supplied (with cessation 190 wells & without cessation 980 wells)	$0	$1,444,456 to $7,450,352	$17,924,000 to $92,452,000
6	4.3.3.4 Treatment - Residential drinking water replace wells (with cessation 190 wells & without cessation 980 wells)	$5,805,000 to $29,939,000	$0	$5,805,000 to $29,939,000
7	4.4.1 Treatment – Drinking water surface water treatment (IRW rivers and stream WTPs)	$220,342,000	$18,635,763	$451,594,000
8	4.5.1 Treatment - Drinking water surface water treatment (Lake Tenkiller WTPs)	$232,705,000	$28,219,525	$582,882,000

TABLE 1

Summary of Costs for Remedial Alternatives
Illinois River Watershed

PRELIMINARY COST ESTIMATE
Tab 1-4.3.1 Removal - Cessation with proper poultry waste management

	CAPITAL (DIRECT & INDIRECT)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
	Direct Costs:					
1	None	0	Each	$0	$0	
				Subtotal:	$0	
				30% Contingency(2):	$0	
				Total Contractor Costs:	$0	
				Engineering, Legal, Permits, Contractor OH&P(25%):	$0	
				Total Capital Costs:	$0	
				Rounded Total:	$0	

	ANNUAL (POST-REMEDIAL SITE CONTROL)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
1	Disposal outside IRW	354,000	Ton	$35	$12,390,000	Unit cost from Exhibit J:Rausser and Dicks
				Subtotal:	$12,390,000	
				30% Contingency(2):	$3,717,000	
				Total:	$16,107,000	
				30-Year Present Worth Cost (3):	$199,872,426	
				Rounded Total:	$199,872,000	
				Total Project Present Worth Cost:	$199,872,000	

Notes:

1. Unit cost shown includes material and labor costs unless otherwise noted.
2 A 30% contingency is included provide for unexpected circumstances or variability in estimate areas, volumes, labor and material costs. Contingency allowance developed basec
3 30-year present worth based on a 7.0 percent discount rate as published in USEPA, 1993c, and has been applied to Annual/O&M Costs

TABLE 2

Summary of Costs for Remedial Alternatives
Illinois River Watershed

PRELIMINARY COST ESTIMATE
Tab 2-4.3.2 Treatment - Buffer strips along fields (all streams)

	CAPITAL (DIRECT & INDIRECT)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
	Direct Costs:					
1	Land acquisition	84,927	Acre	$1,465	$124,418,055	http://www.ers.usda.gov/publications/arei/ah722/arei1_1/arei1_1landuse.pdf (avg of 19 states)
2	Initial prep and planting	84,927	Acre	$500	$42,463,500	Acreage est. by Robert van Waasbergen, intersection of pastures and grassland with 100' buffer each side
				Subtotal:	$166,881,555	
				30% Contingency(2):	$50,064,467	
				Total Contractor Costs:	$216,946,022	
				Engineering, Legal, Permits, Contractor OH&P(25%):	$54,236,505	
				Total Capital Costs:	$271,182,527	
				Rounded Total:	$271,183,000	

	ANNUAL (POST-REMEDIAL SITE CONTROL)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
1	Maintenance	84,927	Acre	$500	$42,463,500	Repare of channelized flow, re-planting
				Subtotal:	$42,463,500	
				30% Contingency(2):	$12,739,050	
				Total:	$55,202,550	
				30-Year Present Worth Cost (3):	$685,010,716	
				Rounded Total:	$685,011,000	
				Total Project Present Worth Cost:	$956,194,000	

Notes:

1. Unit cost shown includes material and labor costs unless otherwise noted.
2 A 30% contingency is included provide for unexpected circumstances or variability in estimate areas, volumes, labor and material costs. Contingency allowance developed
3 30-year present worth based on a 7.0 percent discount rate as published in USEPA, 1993c, and has been applied to Annual/O&M Costs

TABLE 3

Summary of Costs for Remedial Alternatives
Illinois River Watershed

PRELIMINARY COST ESTIMATE
Tab 3-4.3.2 Treatment - Buffer strips along fields (>3rd order streams)

	Item	Quantity	Units	Unit Cost ($)	Item Cost ($)	Comments
	CAPITAL (DIRECT & INDIRECT)					
	Direct Costs:					
1	Land acquisition	13,347	Acre	$1,465	$19,553,355	http://www.ers.usda.gov/publications/arei/ah722/arei1_1/arei1_1landuse.pdf (avg of 19 states)
2	Initial prep and planting	13,347	Acre	$500	$6,673,500	Acreage est. by Robert van Waasbergen, intersection of pastures and grassland with 100' buffer each side
				Subtotal:	$26,226,855	
				30% Contingency(2):	$7,868,057	
				Total Contractor Costs:	$34,094,912	
				Engineering, Legal, Permits, Contractor OH&P(25%):	$8,523,728	
				Total Capital Costs:	$42,618,639	
				Rounded Total:	$42,619,000	

	Item	Quantity	Units	Unit Cost ($)	Item Cost ($)	Comments
	ANNUAL (POST-REMEDIAL SITE CONTROL)					
1	Maintenance	13,347	Acre	$500	$6,673,500	Repare of channelized flow, re-planting
				Subtotal:	$6,673,500	
				30% Contingency(2):	$2,002,050	
				Total:	$8,675,550	
				30-Year Present Worth Cost (3):	$107,655,257	
				Rounded Total:	$107,655,000	
				Total Project Present Worth Cost:	$150,274,000	

Notes:

1. Unit cost shown includes material and labor costs unless otherwise noted.
2 A 30% contingency is included provide for unexpected circumstances or variability in estimate areas, volumes, labor and material costs. Contingency allowance developed
3 30-year present worth based on a 7.0 percent discount rate as published in USEPA, 1993c, and has been applied to Annual/O&M Costs

TABLE 4

Summary of Costs for Remedial Alternatives
Illinois River Watershed

PRELIMINARY COST ESTIMATE

Tab 4-4.3.3.1 Treatment - Residential drinking water systems (with cessation 190 wells & without cessation 980 wells)

	CAPITAL (DIRECT & INDIRECT)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
	Direct Costs:					
1	Nitrogen only system (RO or Ion Exchange)	190	Each	$400	$76,000	76 gpd RO system http://www.bigbrandwater.com/reverseosmosis2.html
2	Bacteria system (UV)	878	Each	$2,000	$1,756,000	http://www.bigbrandwater.com/trojanp20.html
3	Installation	1,068	Each	$1,000	$1,068,000	
				Subtotal:	$2,900,000	
				30% Contingency(2):	$870,000	
				Total Contractor Costs:	$3,770,000	
				Engineering, Legal, Permits, Contractor OH&P(25%):	$942,500	
				Total Capital Costs:	$4,712,500	
				Rounded Total:	$4,713,000	

	ANNUAL (POST-REMEDIAL SITE CONTROL)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
1	Filters	2,280	Each	$50	$114,000	one filter per month per system
2	UV Bulbs	878	Each	$150	$131,700	1 bulb every other year
3	Power	1,234,468	kWhr	$0.10	$123,447	160 Watt power consumption
				Subtotal:	$369,147	
				30% Contingency(2):	$110,744	
				Total:	$479,891	
				30-Year Present Worth Cost (3):	$5,954,985	
				Rounded Total:	$5,955,000	
				Total Project Present Worth Cost:	$10,668,000	

Notes:

1. Unit cost shown includes material and labor costs unless otherwise noted.
2 A 30% contingency is included provide for unexpected circumstances or variability in estimate areas, volumes, labor and material costs. Contingency allowance developed ba
3 30-year present worth based on a 7.0 percent discount rate as published in USEPA, 1993c, and has been applied to Annual/O&M Costs

TABLE 4

Summary of Costs for Remedial Alternatives
Illinois River Watershed

PRELIMINARY COST ESTIMATE

Tab 4-4.3.3.1 Treatment - Residential drinking water systems (with cessation 190 wells)

	CAPITAL (DIRECT & INDIRECT)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
	Direct Costs:					
1	Nitrogen only system (RO or Ion Exchange)	190	Each	$400	$76,000	76 gpd RO system http://www.bigbrandwater.com/reverseosmosis2.html
2	Bacteria system (UV)	0	Each	$2,000	$0	http://www.bigbrandwater.com/trojanp20.html
3	Installation	190	Each	$1,000	$190,000	
				Subtotal:	$266,000	
				30% Contingency(2):	$79,800	
				Total Contractor Costs:	$345,800	
				Engineering, Legal, Permits, Contractor OH&P(25%):	$86,450	
				Total Capital Costs:	$432,250	
				Rounded Total:	$432,000	

	ANNUAL (POST-REMEDIAL SITE CONTROL)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
1	Filters	2,280	Each	$50	$114,000	one filter per month per system
2	UV Bulbs	0	Each	$150	$0	1 bulb every other year
3	Power	0	kWhr	$0.10	$0	160 Watt power consumption
				Subtotal:	$114,000	
				30% Contingency(2):	$34,200	
				Total:	$148,200	
				30-Year Present Worth Cost (3):	$1,839,020	
				Rounded Total:	$1,839,000	
				Total Project Present Worth Cost:	$2,271,000	

Notes:

1. Unit cost shown includes material and labor costs unless otherwise noted.
2 A 30% contingency is included provide for unexpected circumstances or variability in estimate areas, volumes, labor and material costs. Contingency allowance developed ba:
3 30-year present worth based on a 7.0 percent discount rate as published in USEPA, 1993c, and has been applied to Annual/O&M Costs

TABLE 5

Summary of Costs for Remedial Alternatives
Illinois River Watershed

PRELIMINARY COST ESTIMATE

Tab 5-4.3.3.2 Treatment - Residential drinking water supplied (with cessation 190 wells & without cessation 980 wells)

	CAPITAL (DIRECT & INDIRECT)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
	Direct Costs:					
1	None	980	Each	$0	$0	Wells with N and or Bacteria issues
				Subtotal:	$0	
				30% Contingency(2):	$0	
				Total Contractor Costs:	$0	
				Engineering, Legal, Permits, Contractor OH&P(25%):	$0	
				Total Capital Costs:	$0	
				Rounded Total:	$0	

	ANNUAL (POST-REMEDIAL SITE CONTROL)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
1	Water	3,577,000	Gal	$1.52	$5,437,040	10 gpd per household
2	Cooler rental	11,760	Month	$25	$294,000	Per month
				Subtotal:	$5,731,040	
				30% Contingency(2):	$1,719,312	
				Total:	$7,450,352	
				30-Year Present Worth Cost (3):	$92,451,725	
				Rounded Total:	$92,452,000	
				Total Project Present Worth Cost:	$92,452,000	

Notes:

1. Unit cost shown includes material and labor costs unless otherwise noted.
2 A 30% contingency is included provide for unexpected circumstances or variability in estimate areas, volumes, labor and material costs. Contingency allowance developed ba:
3 30-year present worth based on a 7.0 percent discount rate as published in USEPA, 1993c, and has been applied to Annual/O&M Costs

TABLE 5

Summary of Costs for Remedial Alternatives
Illinois River Watershed

PRELIMINARY COST ESTIMATE
Tab 5-4.3.3.2 Treatment - Residential drinking water supplied (with cessation 190 wells)

	CAPITAL (DIRECT & INDIRECT)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
	Direct Costs:					
1	None	190	Each	$0	$0	Wells with N and or Bacteria issues
				Subtotal:	$0	
				30% Contingency(2):	$0	
				Total Contractor Costs:	$0	
				Engineering, Legal, Permits, Contractor OH&P(25%):	$0	
				Total Capital Costs:	$0	
				Rounded Total:	$0	

	ANNUAL (POST-REMEDIAL SITE CONTROL)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
1	Water	693,500	Gal	$1.52	$1,054,120	10 gpd per household
2	Cooler rental	2,280	Month	$25	$57,000	Per month
				Subtotal:	$1,111,120	
				30% Contingency(2):	$333,336	
				Total:	$1,444,456	
				30-Year Present Worth Cost (3):	$17,924,314	
				Rounded Total:	$17,924,000	
				Total Project Present Worth Cost:	$17,924,000	

Notes:
1. Unit cost shown includes material and labor costs unless otherwise noted.
2 A 30% contingency is included provide for unexpected circumstances or variability in estimate areas, volumes, labor and material costs. Contingency allowance developed ba:
3 30-year present worth based on a 7.0 percent discount rate as published in USEPA, 1993c, and has been applied to Annual/O&M Costs

TABLE 6

Summary of Costs for Remedial Alternatives
Illinois River Watershed

PRELIMINARY COST ESTIMATE
Tab 6-4.3.3.4 Treatment - Residential drinking water replace wells (with cessation 190 wells & without cessation 980 wells)

	CAPITAL (DIRECT & INDIRECT)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
	Direct Costs:					
1	Abandon well	980	Each	$400	$392,000	
2	Install new well	568,400	LF	$20	$11,368,000	depth 580' based on 95pctile Delaware Cty
3	New piping	568,400	Each	$10	$5,684,000	
4	New pump	980	Each	$1,000	$980,000	
				Subtotal:	$18,424,000	
				30% Contingency(2):	$5,527,200	
				Total Contractor Costs:	$23,951,200	
				Engineering, Legal, Permits, Contractor OH&P(25%):	$5,987,800	
				Total Capital Costs:	$29,939,000	
				Rounded Total:	$29,939,000	

	ANNUAL (POST-REMEDIAL SITE CONTROL)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
1	Assume similar to existing	1	Lump Sum	$0	$0	
				Subtotal:	$0	
				30% Contingency(2):	$0	
				Total:	$0	
				30-Year Present Worth Cost (3):	$0	
				Rounded Total:	$0	
				Total Project Present Worth Cost:	$29,939,000	

Notes:

1. Unit cost shown includes material and labor costs unless otherwise noted.
2 A 30% contingency is included provide for unexpected circumstances or variability in estimate areas, volumes, labor and material costs. Contingency allowance developed basec
3 30-year present worth based on a 7.0 percent discount rate as published in USEPA, 1993c, and has been applied to Annual/O&M Costs

TABLE 6

Summary of Costs for Remedial Alternatives
Illinois River Watershed

PRELIMINARY COST ESTIMATE
Tab 6-4.3.3.4 Treatment - Residential drinking water replace wells (with cessation 190 wells)

	CAPITAL (DIRECT & INDIRECT)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
	Direct Costs:					
1	Abandon well	190	Each	$400	$76,000	
2	Install new well	110,200	LF	$20	$2,204,000	depth 580' based on 95pctile Delaware Cty
3	New piping	110,200	Each	$10	$1,102,000	
4	New pump	190	Each	$1,000	$190,000	
				Subtotal:	$3,572,000	
				30% Contingency(2):	$1,071,600	
				Total Contractor Costs:	$4,643,600	
				Engineering, Legal, Permits, Contractor OH&P(25%):	$1,160,900	
				Total Capital Costs:	$5,804,500	
				Rounded Total:	$5,805,000	

	ANNUAL (POST-REMEDIAL SITE CONTROL)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
1	Assume similar to existing	1	Lump Sum	$0	$0	
				Subtotal:	$0	
				30% Contingency(2):	$0	
				Total:	$0	
				30-Year Present Worth Cost (3):	$0	
				Rounded Total:	$0	
				Total Project Present Worth Cost:	$5,805,000	

Notes:
1. Unit cost shown includes material and labor costs unless otherwise noted.
2 A 30% contingency is included provide for unexpected circumstances or variability in estimate areas, volumes, labor and material costs. Contingency allowance developed basec
3 30-year present worth based on a 7.0 percent discount rate as published in USEPA, 1993c, and has been applied to Annual/O&M Costs

TABLE 7

Summary of Costs for Remedial Alternatives
Illinois River Watershed

PRELIMINARY COST ESTIMATE
Tab 7-4.4.1 Treatment – Drinking water surface water treatment (IRW rivers and stream WTPs)

	CAPITAL (DIRECT & INDIRECT)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
	Direct Costs:			Millions		
1	OK1021701 TAHLEQUAH PWA - Illinois River	1	Lump Sum	$ 82.28	$82,277,741	WTP data from http://sdwis.deq.state.ok.us/
2	OK1221637 CHEROKEE CO RWD #11 - Illinois River	1	Lump Sum	$ 74.83	$74,833,104	EPA cost data from Fed Reg Vol 71, No. 2 Jan 4, 2006 p.456
3	OK1021694 FLINT RIDGE RURAL WATER DISTRICT - Illinois River	1	Lump Sum	$ 29.33	$29,331,386	ENR escalation from 2003 to 2008 = 1.2085
4	OK1021775 SEQUOYAH CO RWD # 5 - Illinois River	1	Lump Sum	$ 29.33	$29,331,386	
5	OK1021770 ADAIR CO RWD #5 - Baron Fork	1	Lump Sum	$ 4.57	$4,568,300	
				Subtotal:	$220,341,918	
				30% Contingency(2):	$0	EPA estimate assumed to include contingencies
				Total Contractor Costs:	$220,341,918	
				Engineering, Legal, Permits, Contractor OH&P(25%):	$0	EPA estimate assumed to include these costs
				Total Capital Costs:	$220,341,918	
				Rounded Total:	$220,342,000	

	ANNUAL (POST-REMEDIAL SITE CONTROL)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
				Millions		
1	OK1021701 TAHLEQUAH PWA - Illinois River	1	Year	$ 4.06	$4,060,711	WTP data from http://sdwis.deq.state.ok.us/
2	OK1221637 CHEROKEE CO RWD #11 - Illinois River	1	Year	$ 6.45	$6,453,630	EPA cost data from Fed Reg Vol 71, No. 2 Jan 4, 2006 p.456
3	OK1021694 FLINT RIDGE RURAL WATER DISTRICT - Illinois River	1	Year	$ 4.06	$4,060,711	ENR escalation from 2003 to 2008 = 1.2085
4	OK1021775 SEQUOYAH CO RWD # 5 - Illinois River	1	Year	$ 4.06	$4,060,711	
5	OK1021770 ADAIR CO RWD #5 - Baron Fork	1	Year	$ 0.74	$737,212	
				Subtotal:	$18,635,763	
				30% Contingency(2):	$0	EPA estimate assumed to include contingencies
				Total:	$18,635,763	
				30-Year Present Worth Cost (3):	$231,251,955	
				Rounded Total:	$231,252,000	
				Total Project Present Worth Cost:	$451,594,000	

Notes:

1. Unit cost shown includes material and labor costs unless otherwise noted.
2 A 30% contingency is included provide for unexpected circumstances or variability in estimate areas, volumes, labor and material costs. Contingency allowance developed based upon USEPA, 19
3 30-year present worth based on a 7.0 percent discount rate as published in USEPA, 1993c, and has been applied to Annual/O&M Costs

TABLE 8

Summary of Costs for Remedial Alternatives
Illinois River Watershed

PRELIMINARY COST ESTIMATE
Tab 8-4.5.1 Treatment - Drinking water surface water treatment (Lake Tenkiller WTPs)

	CAPITAL (DIRECT & INDIRECT)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
	Direct Costs:			Millions		
1	OK1020210 SEQUOYAH COUNTY WATER ASSOC	1	Lump Sum	$ 82.28	$82,277,741	WTP data from http://sdwis.deq.state.ok.us/
2	OK1021721 CHEROKEE CO RWD #13	1	Lump Sum	$ 29.33	$29,331,386	EPA cost data from Fed Reg Vol 71, No. 2 Jan 4, 2006 p.456
3	OK1021773 GORE PWA	1	Lump Sum	$ 29.33	$29,331,386	ENR escalation from 2003 to 2008 = 1.2085
4	OK1021711 CHEROKEE CO RWD # 2 (KEYS)	1	Lump Sum	$ 29.33	$29,331,386	
5	OK1021713 EAST CENTRAL OKLA WATER AUTH	1	Lump Sum	$ 29.33	$29,331,386	
6	OK1021756 TENKILLER UTILITY CO	1	Lump Sum	$ 4.57	$4,568,300	
7	OK1021707 LRED (CHICKEN CREEK)	1	Lump Sum	$ 3.89	$3,891,515	
8	OK1021731 LRED (LAKEWOOD)	1	Lump Sum	$ 3.89	$3,891,515	
9	OK1021703 LRED (WILDCAT)	1	Lump Sum	$ 3.89	$3,891,515	
10	OK1021727 LRED (WOODHAVEN)	1	Lump Sum	$ 3.89	$3,891,515	
11	OK1021730 FIN & FEATHER RESORT	1	Lump Sum	$ 3.89	$3,891,515	
12	OK1021745 TENKILLER AQUA PARK	1	Lump Sum	$ 3.89	$3,891,515	
13	OK1021763 BURNT CABIN RWD	1	Lump Sum	$ 3.89	$3,891,515	
14	OK1021702 PETTIT MT WATER	1	Lump Sum	$ 1.29	$1,293,143	
				Subtotal:	$232,705,333	
				30% Contingency(2):	$0	EPA estimate assumed to include contingencies
				Total Contractor Costs:	$232,705,333	
				Engineering, Legal, Permits, Contractor OH&P(25%):	$0	EPA estimate assumed to include these costs
				Total Capital Costs:	$232,705,333	
				Rounded Total:	$232,705,000	

	ANNUAL (POST-REMEDIAL SITE CONTROL)					
	Item	**Quantity**	**Units**	**Unit Cost ($)**	**Item Cost ($)**	**Comments**
				Millions		
1	OK1020210 SEQUOYAH COUNTY WATER ASSOC	1	Year	$ 4.06	$4,060,711	WTP data from http://sdwis.deq.state.ok.us/
2	OK1021721 CHEROKEE CO RWD #13	1	Year	$ 4.06	$4,060,711	EPA cost data from Fed Reg Vol 71, No. 2 Jan 4, 2006 p.456
3	OK1021773 GORE PWA	1	Year	$ 4.06	$4,060,711	ENR escalation from 2003 to 2008 = 1.2085
4	OK1021711 CHEROKEE CO RWD # 2 (KEYS)	1	Year	$ 4.06	$4,060,711	
5	OK1021713 EAST CENTRAL OKLA WATER AUTH	1	Year	$ 4.06	$4,060,711	
6	OK1021756 TENKILLER UTILITY CO	1	Year	$ 0.74	$737,212	
7	OK1021707 LRED (CHICKEN CREEK)	1	Year	$ 0.99	$991,007	
8	OK1021731 LRED (LAKEWOOD)	1	Year	$ 0.99	$991,007	`
9	OK1021703 LRED (WILDCAT)	1	Year	$ 0.99	$991,007	
10	OK1021727 LRED (WOODHAVEN)	1	Year	$ 0.99	$991,007	
11	OK1021730 FIN & FEATHER RESORT	1	Year	$ 0.99	$991,007	
12	OK1021745 TENKILLER AQUA PARK	1	Year	$ 0.99	$991,007	
13	OK1021763 BURNT CABIN RWD	1	Year	$ 0.99	$991,007	
14	OK1021702 PETTIT MT WATER	1	Year	$ 0.24	$241,709	
				Subtotal:	$28,219,525	
				30% Contingency(2):	$0	EPA estimate assumed to include contingencies
				Total:	$28,219,525	
				30-Year Present Worth Cost (3):	$350,177,247	
				Rounded Total:	$350,177,000	
				Total Project Present Worth Cost:	$582,882,000	

Notes:

1. Unit cost shown includes material and labor costs unless otherwise noted.
2 A 30% contingency is included provide for unexpected circumstances or variability in estimate areas, volumes, labor and material costs. Contingency allowance developed based upon USEF
3 30-year present worth based on a 7.0 percent discount rate as published in USEPA, 1993c, and has been applied to Annual/O&M Costs