Eagle Mountain Lake

Watershed Protection Plan

2016

Watershed Protection Plan

for

Eagle Mountain Lake

Prepared for the

Stakeholders of the Eagle Mountain Lake Watershed

by

Tarrant Regional Water District and Texas A&M AgriLife Research

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SECTION II. EAGLE MOUNTAIN LAKE WPP MODELING REPORT

1. INTRODUCTION

A Watershed Protection Plan (WPP) is a watershed-based plan developed by local stakeholders to restore and/or protect water quality and designated uses of a waterbody through a combination of voluntary, non-regulatory water resource management measures. Public participation is critical throughout plan development and implementation, as ultimate success of any WPP depends on stewardship of the land and water resources by local landowners, business and residents of the watershed. This plan was developed by stakeholders to address growing water quality issues in Eagle Mountain Lake and to protect this major drinking water supply from further degradation. The plan provides a comprehensive analysis and planning vehicle for restoring and protecting water quality in Eagle Mountain Lake.

This WPP defines a strategy and identifies opportunities for widespread participation of stakeholders to work together, and as individuals, to implement practices and programs that restore and protect water quality. As these measures are put into place and water quality changes over time, adaptive management will be implemented to continue progress toward water quality goals.

WPPs are an important part of the State's approach to managing nonpoint source (NPS) pollution. As described in the 2012 *Texas Nonpoint Source Mangement Program*, WPPs are reviewed by the State (Texas Commission on Environmental Quality and Texas State Soil and Water Conservation Board) and then the Environmental Protection Agency (EPA) to assess a plan's consistency with the nine elements contained in the EPA's *Nonpoint Source Program and Grants Guidelines for States and Territories*. Acceptance of the WPP by EPA is necessary for implementation and future updates to be considered eligible for Clean Water Act (CWA) §319(h) funding.

2. EAGLE MOUNTAIN LAKE AND ITS WATERSHED

Permitted in 1928 for municipal, industrial, and irrigation use, Eagle Mountain Lake is one of four reservoirs owned by the Tarrant Regional Water District and operated for water supply, irrigation, flood control, and recreational purposes. The Tarrant Regional Water District (TRWD) system supplies raw drinking water for approximately 1.8 million people in the north Texas region. Construction on the Eagle Mountain Lake dam was completed in 1932, impounding flows from a 1,970 square mile watershed that extends across portions of Tarrant, Parker, Wise, Montague, Jack, Clay, Young, and Archer Counties. Approximately 1,110 square miles of this watershed is impounded by the Lake Bridgeport dam in western Wise County, which controls inflows to Eagle Mountain Lake from the western 56% of the watershed. Although flows and water quality passing through Lake Bridgeport are considered in modeling efforts, the planning and implementation described in this WPP apply only to the 860 square mile (550,000 acre) portion of the watershed not controlled by the Lake Bridgeport reservoir (Figure 2.1).

Figure 2.1. Eagle Mountain Lake watershed.

Land Use

The Eagle Mountain Lake watershed is located in the Cross Timbers ecoregion and is characterized with nearly level to rolling, moderately dissected uplands. Stream valleys are narrow and have steep gradients. The vast majority of soils in the watershed are characterized as sandy and sandy loams over substrates of sand, clay mud and sandstone, and with low slope stability. The area has maintained a mostly agricultural economy characterized in early years by sheep and cattle production, later by wheat, corn, cotton, and more recently by livestock, hay, grain, peanut, and pecan production. As illustrated in Table 2.1 and Figure 2.2, the Eagle Mountain Lake watershed remains predominantly rural, with agricultural land uses of rangeland, pasture, and cropland comprising over 70% of the watershed.

Division of large landoldings into small farms began in the 1880's. By the early 20th century, heavy cropping had depleted soil productivity and contributed to serious erosion problems. By the 1960's local, state, and national resources were being applied through programs such as the Flood Control Act of 1944 (PL-534), Watershed Protection and Flood Prevention Act of 1954 (PL-566), and the Texas State Soil Conservation Law (1939) to address the effects of flooding and erosion. The number of cropping operations declined significantly during the depression in the 1930's, and by 1983 only 11 percent of the land was devoted to crops.

Table 2.1. Land Use by Category.

Land Use	Percent	Acres
Rangeland	59.72%	329,084
Forest	17.78%	97,976
Urban/Residential	9.77%	53,837
Pasture	9.30%	51,247
Cropland	3.39%	18,680
Wetland/Water	0.04%	220
Total	**100%**	**551,045**

Although development is occurring in areas near the lake and around cities, urban land use covers less than 10% of the watershed and occurs primarily in small communities scattered throughout the watershed. Urbanization is occurring in localized areas near existing towns, but still does not represent a significant part of the overall watershed. Comparison of the most recent national land cover database (Homer et al 2011) to data used in the original study (Vogelmann et al 2001) indicates that approximately 9,600 acres (1.7% of the watershed) changed classifications between 2001 and 2011. Overall, only 2,100 acres (0.39% of watershed) was converted from agricultural to more intensive land uses, and approximately 1,900 acres (0.34% of watershed) were converted from cropland, rangeland, or pasture to urban/residential.

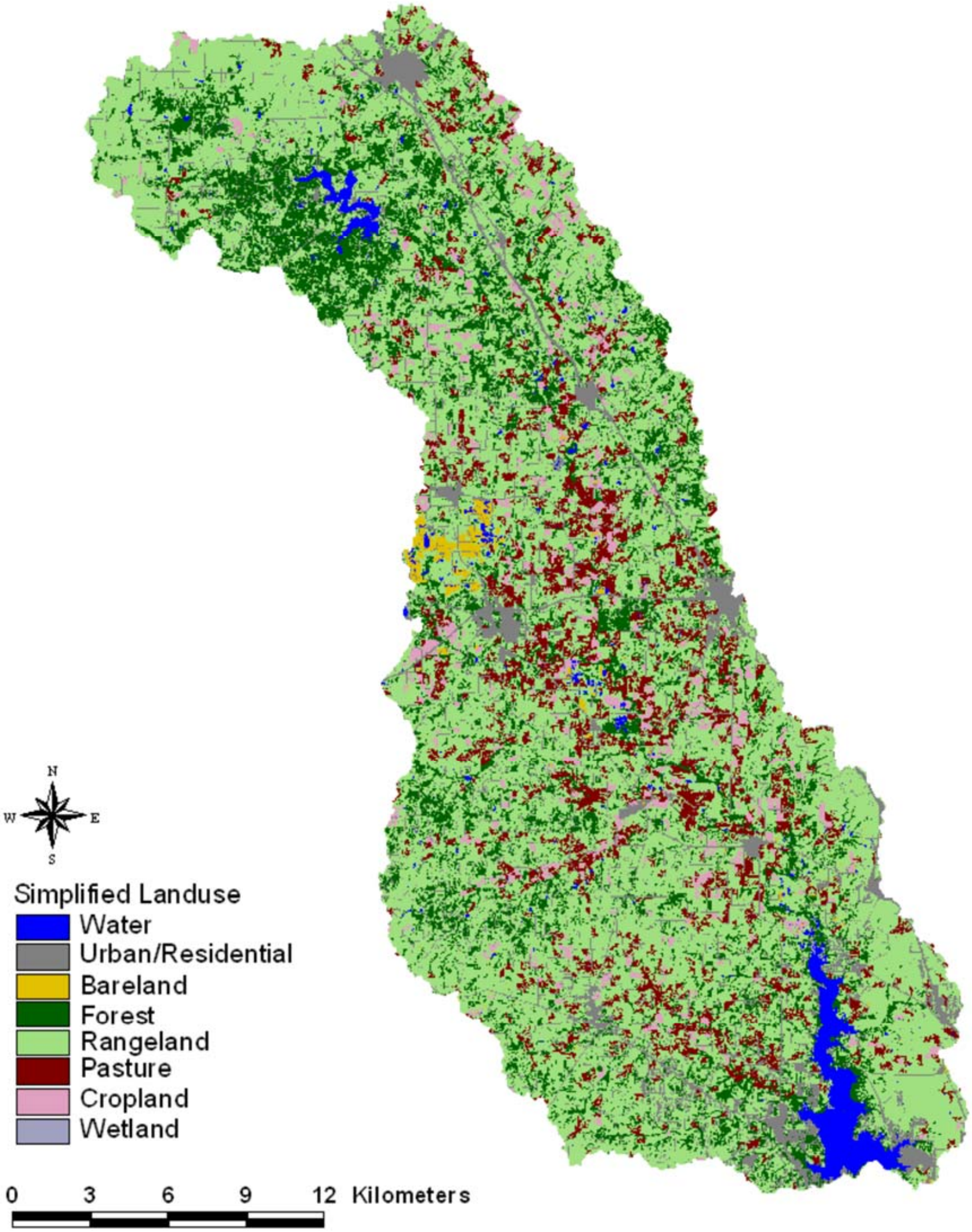

Figure 2.2. Land use distribution, Homer et al 2001.

Water Quality

The TCEQ determines the appropriate uses and minimum standards for water bodies throughout the state. Every two years, the agency assesses which water bodies are meeting these standards, not meeting the standards, or are in danger of not meeting the standards. The state has determined that, while Eagle Mountain Lake is meeting standards, data show clear signs of increasing eutrophication, or algae growth due to high nutrient inputs to the lake. Studies by TRWD and others have also documented increasing trends in nutrients such as nitrogen and phosphorus, suggesting that unless reversed, water quality may fall to levels below what is required for meeting the state's standards.

Long-term analyses also indicate statistically significant relationships between nutrient and chlorophyll-a, or algae, concentrations in Eagle Mountain Lake and other lakes in the region. This relationship between "causal" and "response" pollutants allows for the use of both chemical and biological data to establish comprehensive water quality goals for the lake, as well as implementation milestones for the watershed.

Water quality reports described in the following paragraphs clearly indicate that, without measures to reverse the trend of increasing eutrophication, Eagle Mountain Lake will likely exceed current nutrient and chlorophyll-a screening levels, and possibly future criteria. Water quality is of utmost priority to those who live in, manage, and benefit from the lake and its watershed. Therefore, it is the goal of this WPP that measures be taken to reverse eutrophication so that Eagle Mountain Lake continues to meet its designated uses.

Uses, Criteria and Screening Levels

Eagle Mountain Lake has historically met the designated water quality standards, however, concerns for screening level indicators of eutrophication have been documented in the state's 305(b) Integrated Report, beginning in 2002.

In 2010, the state of Texas adopted numeric chlorophyll-a criterion of 25.37 ug/L for Eagle Mountain Lake. In 2013, EPA disapproved the criterion as not protective of the reservoir's designated uses, under 50 CFR §131.11(a)(1). Therefore, TCEQ's existing screening criteria of 26.7 μg/L remains in effect for future determination of water quality concerns.

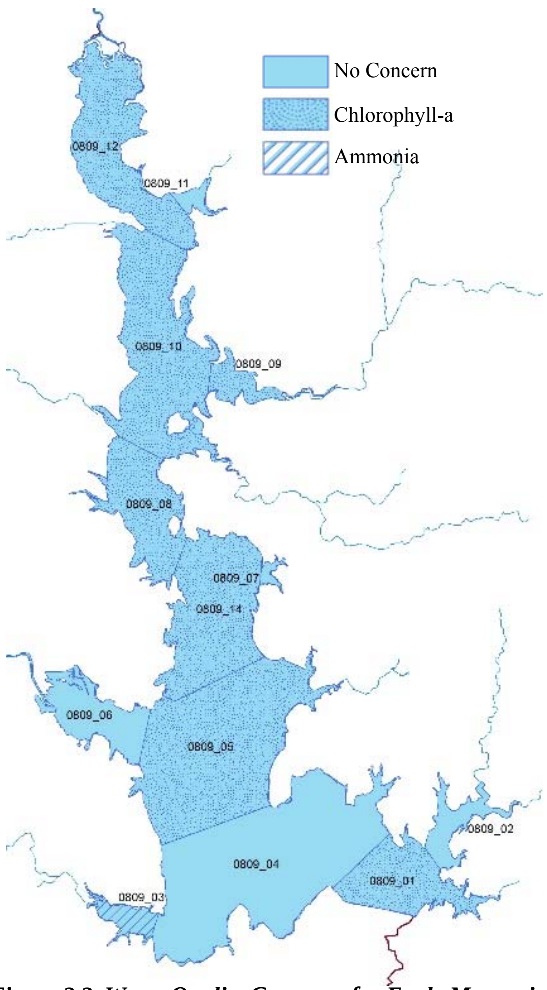

Figure 2.3. Water Quality Concerns for Eagle Mountain Lake, TCEQ 2014.

2014 TCEQ Integrated Report

As shown in Figure 2.3, the 2014 Integrated Report identifies concerns (CS) in Eagle Mountain Lake for ammonia and chlorophyll-a. Screening level concentrations for these parameters are 0.11 mg/L and 26.7 ug/L, respectively. While chlorophyll-a concerns are relatively widespread across the lake, ammonia concerns are limited to one assessment units on the west side of the lake.

Trophic State Classification

Included in the 2010 Integrated Report is a report on the trophic classification, or the degree of nutrient enrichment, of Texas reservoirs. Based on this analysis, which uses a trophic state index based on chlorophyll-a concentrations, Eagle Mountain Lake is classified by TCEQ as "hypereutrophic," or characterized as highly productive with excessive nutrient loading.

Long-Term Trend Analyses

In a study conducted by researchers at the University of Texas at Arlington (TRWD 2011), 20 years of water quality data from the period 1989 – 2009 were analyzed for seven area reservoirs. The results demonstrated indications of ongoing eutrophication, with statistically significant increases in chlorophyll-*a*, total nitrogen, and total phosphorus. Analyses of Eagle Mountain Lake data indicate a potential doubling of chlorophyll-a median concentrations in the next 25 years (Figure 2.4).

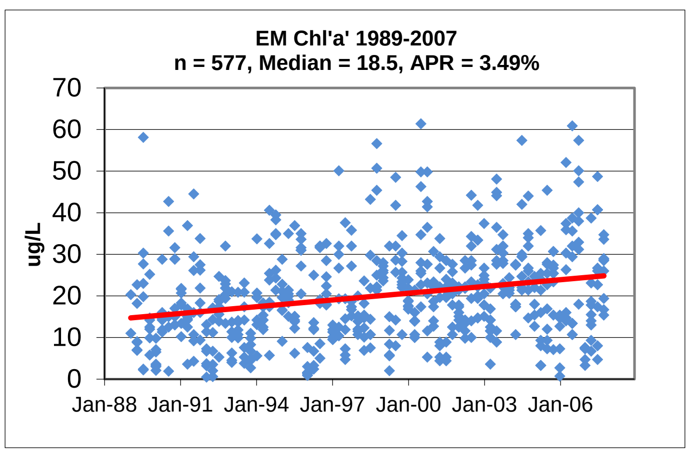

Figure 2.4. Chlorophyll-a concentrations (TRWD 2011)

3. SOURCES AND LOADS

Potential sources of nutrient and sediment loadings to the lake were identified using NLCD land use and TCEQ wastewater treatment plant daily discharge permit data. Figure 3.1 illustrates the categories of sources identified and the modeling approach used to evaluate them. Loadings from watershed sources to the lake were estimated using the Soil and Water Assessment Tool (SWAT). The model was run for a 35 year period to estimate annual loadings of total phosphorus (TP), total nitrogen (TN), and sediment from point and nonpoint sources in the watershed.

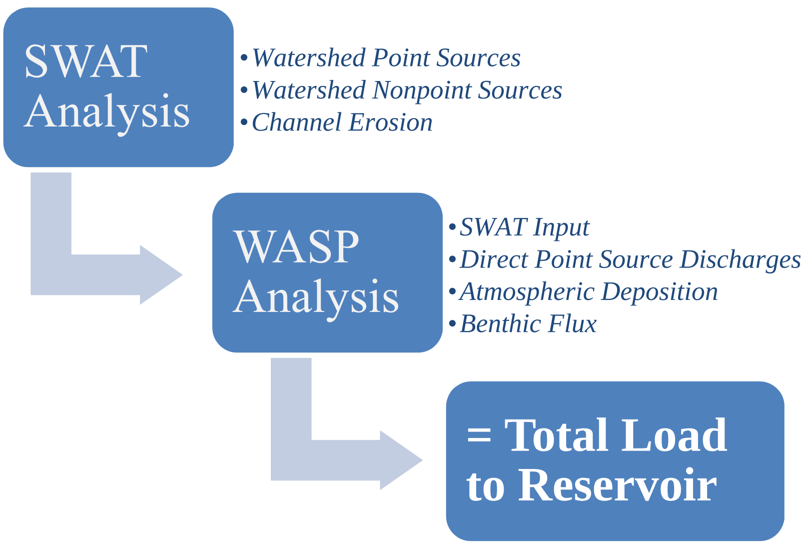

Figure 3.1. Pollutant Load Modeling Approach

Integration of SWAT with the Water Analysis Simulation Program (WASP) model was then used to estimate the impact of watershed, direct discharges and internal loadings on sediment and nutrient concentrations. An eleven year WASP model was used to integrate pollutant loads from the watershed (SWAT input), direct loads to the lake from point source discharges, atmospheric deposition, and internal loading or “benthic flux.”

Sediment yields from rill, gully, and channel erosion were also estimated and stream reaches were prioritized depending on the amount of sediment delivered to the lake.

No gaps or deficiencies were identified in the land use or discharge data used to estimate sources or loads. This analysis estimated that less than 5% of the total loading to the lake comes from direct point source discharges and internal benthic loading. Technical notes regarding SWAT and WASP efforts are contained in Appendices A and B, respectively.

Table 3.1 contains the estimated loading from nonpoint and point sources. Nonpoint sources were identified using available land use information and categorized as rangeland, pasture, cropland, forest, wetland, stream channels, and urban. The highest contributions of sediment and total phosphorus are from cropland and stream erosion. The highest contributions of total nitrogen are from Rangeland, Urban, Channels, and Cropland. Technical notes regarding SWAT modeling of land uses and determination of sediment and nutrient exports are located in Appendix A and the Eagle Mountain Lake WPP Modeling Report in Section II.

Table 3.1. Estimated annual sediment and nutrient loading to Eagle Mountain Lake

Category	Acres	TP			TN			Sediment		
		(kg/yr)	(kg/yr/ac^{-1})	(%)	(kg/yr)	(kg/yr/ac^{-1})	(%)	(met-t/yr)	(met t/yr/ac^{-1})	(%)
Nonpoint Sources										
Cropland	18,680	55,643	3.0	32.16	157,227	8.4	14.90	92,358	4.9	31.16
Channels	n/a	43,341	--	25.05	163,031	--	15.45	138,122	--	46.60
Urban	53,837	27,960	0.5	16.16	167,041	3.1	15.83	26,379	0.5	8.90
Rangeland	329,084	25,018	0.1	14.46	465,352	1.4	44.10	32,189	0.1	10.86
Pasture	51,247	12,111	0.2	7.00	30,073	0.6	2.85	4,653	0.1	1.57
Forest	97,976	519	0.0	0.30	26,697	0.3	2.53	2,667	0.0	0.90
Wetland	220	0	--	0.00	738	--	0.07	29	--	0.01
Point Sources	n/a	8,443	--	4.88	45,057	--	4.27	0	--	0.00
TOTAL LOAD	551,044	173,035	0.3	100%	1,055,220	1.9	100%	296,397	0.5	100%

As discussed previously, agricultural production is the dominant land use in the Eagle Mountain Lake watershed, and is a leading driver of water quality in the Eagle Mountain Lake watershed. Early agricultural systems were primarily row crops, such as cotton. By 1920, serious erosion was occurring, much of the topsoil was gone, and gullying was rampant. It is assumed that this trend continued until the 50's and 60's at which time the NRCS began structural erosion control practices as well as non-structural land management practices in the basin. At the same time, the number of cropping operations declined owing to the depression in the 1930's and then poor yields and market value for crops following this period. In Wise County as of 1983, only 11 percent of the land was devoted to crops, with the majority in range and pasture. Land use analyzed for the current study indicates that cropland has dropped to less than 4% of the watershed and is generally located in lower-lying areas across the central and southern portions of the watershed.

Estimates provided here of loading from stream channel erosion are based on analysis of stream conditions, historic aerial photographs, and measures of the sediment pool in the lake. See the Eagle Mountain Lake Erosion Study in the WPP Modeling Report section of this WPP. The average annual rates determined by the study indicate a ratio of 44 % from gully erosion, 34% from channel, and 22% from sheet and rill erosion. These analyses also indicate that the highest rates of erosion occurred from the 1930’s to 1960’s and that rates have diminished since this time due to changes in land use and conservation practices.

Figure 3.2 illustrates the relative timeline of agricultural practices and erosion rates determined for the watershed. In general, the trends across the watershed appear to confirm that from the time the reservoir was built and began filling, the watershed was probably near peak erosion rates with the majority of sediment coming from gullied terrain. Changes in reservoir sediment deposits seems to reflect the positive impact of historical state, federal, and local soil erosion management within the watershed.

1880	*Intensive Farming Begins*
1920	*Depression, farming declines*
1930	*Eagle Mountain lake built*
1940	***Erosion rates >800 ac-ft/yr***
1950	
1960	*Widespread adoption of USDA programs*
Currently	***Erosion rates >200 ac-ft/yr***

Figure 3.2 ***Timeline of Agricultural Practices and Erosion Rates in the Eagle Mountain Lake Watershed.***

Urban: While just under 10% of the overall watershed, urban areas are the third highest source of total phosphorus and a significant source of total nitrogen. This can be attributed to the over application of fertilizers on urban lawns and landscapes. Lawns only utilize the nutrients they need at a given point in time. Excess nutrients are then leached from the soil due to over irrigation or during rainfall.

The watershed contains 14 wastewater treatment plants (WWTP), two of which discharge directly into the lake. WWTPs voluntarily collected weekly nutrient and flow data for one year, which were combined into monthly loading estimates for modeling purposes. Combined, these 14 WWTPs contribute less than 5% of the total phosphorus and total nitrogen loading to the lake. The technical report on evaluation of point source loading is located in Appendix C.

As noted in previous sections, this WPP focuses on concerns for Eagle Mountain Lake water quality, specifically from impacts due to nutrient and sediment inputs. While other sources of pollutants do occur in the watershed (e.g. OSSFs, pets, wildlife, and feral hogs), stakeholders feel they are not a significant contributor to overall lake water quality. Successful calibration and validation of the models also indicate that the sources identified in Table 3.1 account for the major sources of nutrients and sediment with a measurable impact on water quality.

Identification of loads by sub-basin is key to targeted management and improved water quality. Figure 3.3 illustrates estimated total sediment and nutrient loads from each sub-basin and provides a mechanism to identify those that deliver relatively higher loads of sediment and nutrients to the lake. Sub-basins in the eastern and southern areas generate relatively more sediment and nutrients than other parts of the watershed, although some streams in the northern portion are considered sources of high sediment loads. This corresponds somewhat with the location of croplands and range, which occurs throughout the watershed. Areas identified as forested are generally located in areas where lower nutrient and sediment loads are predicted.

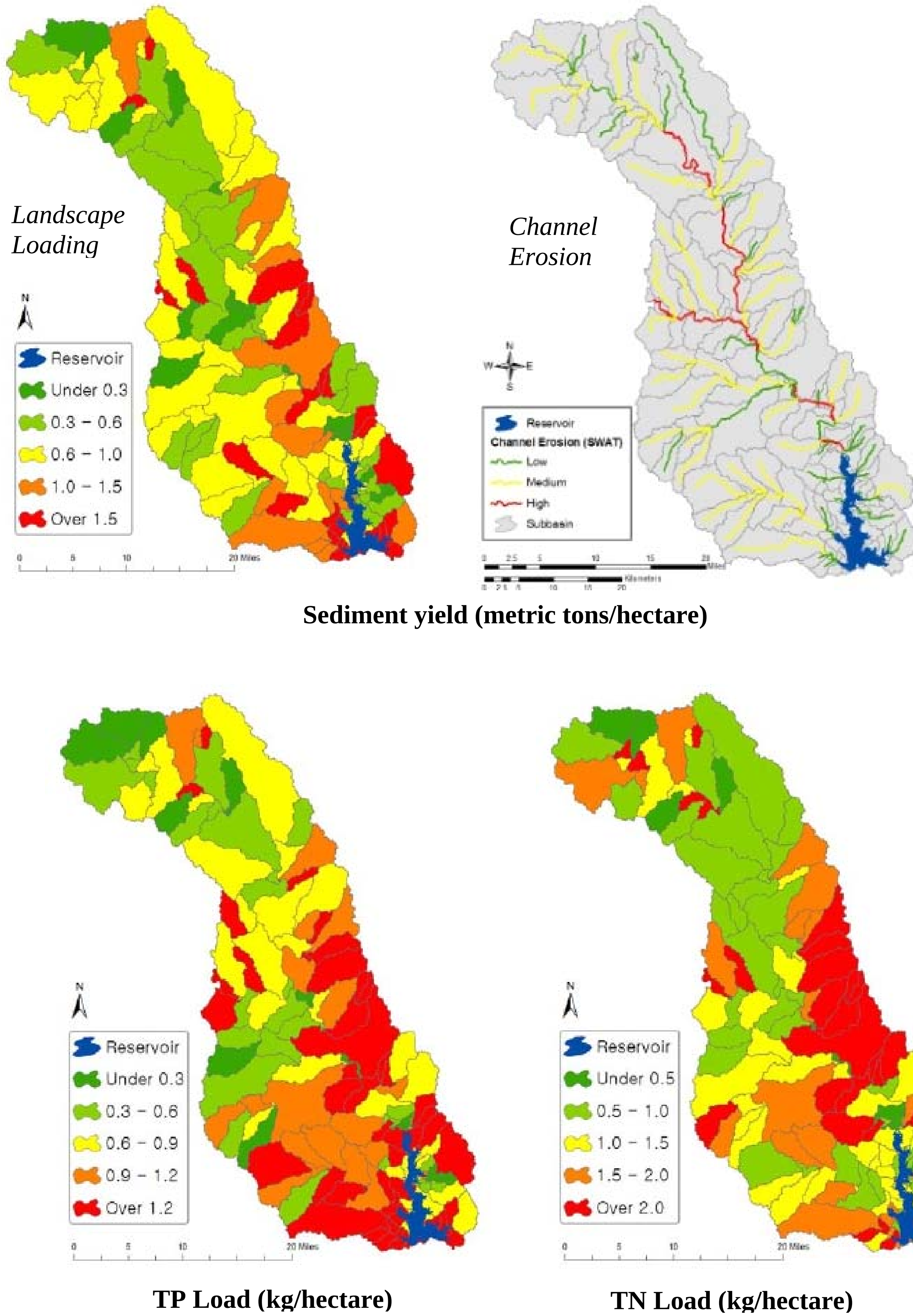

Figure 3.3. Estimated Loads to Eagle Mountain Lake by Sub-Basin

4. LOAD REDUCTIONS NEEDED TO MEET WQ GOALS

The primary water quality parameters of concern identified in the TCEQ Integrated Report, and of the watershed stakeholders, are associated with eutrophication, caused by excessive loadings of nutrients, primarily phosphorus. The modeling efforts described in previous sections were used to estimate the nutrient reductions required for a meaningful reduction in algae concentrations, measured as chlorophyll-a, in the main body of the lake.

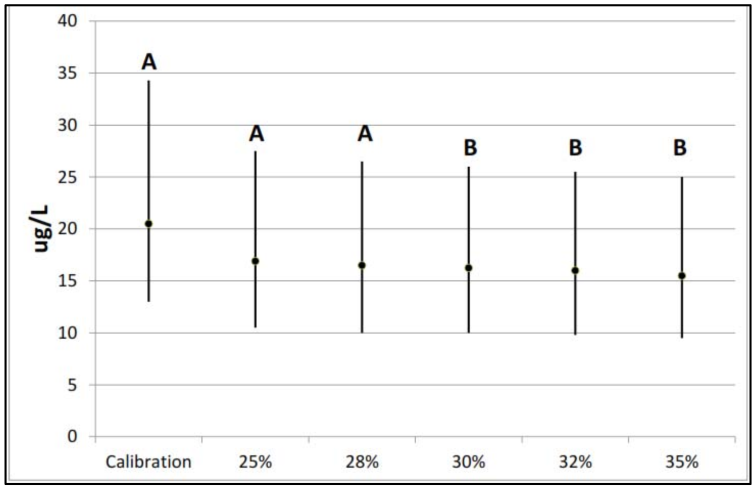

Figure 4.1. Statistical Analysis of the Effects of TP Reduction on Chlorophyll-a Concentrations.

WASP was used to estimate the threshold at which total phosphorus reductions to the lake would result in a measurable change in chlorophyll-a concentrations. As illustrated in Figure 4.1, a statistically significant reduction in chlorophyll-a was observed from the calibrated model concentration when TP was reduced by 28-30%. This exercise was used to establish a water quality goal of 30% reduction in total phosphorus in order to achieve a statistically significant reduction in chlorophyll-a. Technical notes on the statistical and modeling analysis are presented in Appendix B and the Modeling Report in Section II.

5. MANAGEMENT MEASURES AND ACTIVITIES

Best Management Practices

BMP Selection

Stakeholders utilized local experience and previous studies to develop a list of 24 potential BMPs or management measures that would address the identified sources and meet the load reduction goal. SWAT was used to identify appropriate land use categories for each measure, and eligible areas within each sub-watershed. Some measures require implementation on a "project basis," rather than disperse acreages, and were considered in relation to the magnitude/scale of the project necessary to produce the intended environmental results. Appendix D contains a full description of each measure. Table 5.1 contains the list of measures selected by stakeholders, as well as the total eligible acres of associated land use for implementation.

Table 5.1. Best Management Practices Evaluated for the Eagle Mountain Reservoir Watershed.

BMP	Description	Category	Eligible Area	
			Total	Unit
1	Conversion of Cropland to Grass/Hay	Cropland	17,509.0	acres
2	Fert. Mgt. - 25% reduced P application	Cropland	17,509.0	acres
3	Establish Filter Strips	Cropland	17,509.0	acres
4	Establish Grassed Waterways	Cropland	3,503.0	acres
5	Terracing	Cropland	8,646.0	acres
6	Prescribed Grazing	Pasture & Range	50,162.0	acres
7	Pasture Planting - reseeding	Pasture & Range	50,162.0	acres
8	Critical Pasture Planting - shaping	Pasture & Range	190,580.0	acres
9	Grade Stabilization - gully plugs	Pasture & Range	203,703.0	acres
10	Prescribed Burning	Pasture & Range	64,247.0	acres
11	Brush Management	Pasture & Range	32,123.5	acres
12	Phase II Urban Storm water BMPs	Urban	1.0	project
13	Voluntary Urban Nutrient Mgt.	Urban	1.0	project
14	Required Urban Nutrient Mgt.	Urban	1.0	project
15	Herbicide Application - Riparian corridor	Channel	49.5	miles
16	Riparian Buffer Strips - Med Erosion Areas	Channel	288.3	miles
17	Riparian Buffer Strips - Critical Areas	Channel	52.2	miles
18	Wetland Development - West Fork Trinity	Channel	1.0	project
19	Wetland Development - Walnut Creek	Channel	1.0	project
20	Hypolimnetic Aeration	Reservoir-in-Lake	1.0	project
21	P Inactivation with Alum	Reservoir-in-Lake	1.0	project
22	WWTP - Level I to Level II	Point Source	ALL	projects
23	WWTP - Level I to Level III	Point Source	ALL	projects
24	Flood Protection Sites - Big Sandy/Salt Creek	Flood Protection	17	sites

Adoption Rates

The potential reduction in P inflow levels for each BMP is greatly influenced by the current level of implementation attached to each BMP along with the additional area that could be expected to adopt each practice. If a BMP was identified to be highly implemented already, the prospects for additional implementation (and further TP reduction) are greatly limited. However, if a BMP is currently implemented at a low adoption rate, but has the potential to be adopted on a wider scale, then it provides greater TP reduction possibilities.

In April 2011, a meeting was held with Eagle Mountain watershed landowners, stakeholders and local/regional NRCS personnel to discuss the alternative BMPs and identify the current and most likely adoption rates that could be expected should sufficient cost-share programs and/or incentives be provided. The most likely adoption rate represents a rate that participants identified as realistic with a combined effort of promotion, education and assuming adequate funding is available to construct and maintain the respective BMPs.

Cost Benefit Analysis

While implementation of any of these, and other, management measures will facilitate reduction of nutrients and sediment to the lake, a thorough economic analysis was conducted to determine the most cost efficient suite, or subset, for targeted implementation. Appendix E contains technical notes on the economic analysis.

For each BMP, an array of economic and financial information was compiled and integrated in order to assess the relative environmental and economic merits of the practice over the term of the project period. The information related to each BMP specifically included:

- level of current implementation and magnitude of additional adoption possible;
- the reduction impacts on TP, TN, and sediment inflow;
- expected life (i.e., years of productive reduction in TP, TN, and sediment) for the BMP;
- construction period, i.e., length of time required to construct and implement the BMP;
- initial investment and practice establishment costs (including incentives) required;
- recurring annual costs required, i.e., operating and maintenance costs;
- intermediate capital replacement costs to insure each BMP reaches its expected useful life;
- appropriate inflation rate by which to increase future costs.

The cost information for each BMP was assessed through consultations with agency professionals and was thoroughly discussed and reviewed among project team members and stakeholders. The sequence and timing of establishment, operation and maintenance costs, and the expected duration for each BMP was constructed to reflect the project period.

The cost and nutrient/sediment reductions were transformed to relate the annual cost per unit of TP, TN, and sediment reduction and then ranked according to respective efficiency in addressing TP reduction in the watershed. Table 5.2 presents the best estimates of the current and most likely adoption rates, the extent of implementation, annual cost, and the estimated reductions at full implementation.

Table 5.2. Estimated Adoption Rates, Cost, and Load Reductions.

Category	Description	Adoption Rate		Implementation Area		Annual Cost	TP Load Reduction		TN Load Reduction		Sediment Load Reduction	
		Current	Most Likely	Total	Unit	$/kg TP	Percent	kg/yr	Percent	kg/yr	Percent	m-tn/yr
Cropland	Establish Filter Strips	0.0%	25%	4,377	ac	$6.39	3.9%	6,748	2.3%	24,270	5.7%	16,895
Cropland	Establish Grassed Waterways	20%	30%	1,050	ac	$9.65	1.8%	3,114	0.0%	0	0.0%	0
Past.-Rng	Grade Stabilization - gully plugs	25%	50%	25,081	ac	$14.92	2.1%	3,633	1.2%	12,663	1.3%	3,853
Channel	Herbicide Application - Riparian	0%	5%	2.5	mi	$15.37	0.7%	1,211	2.1%	22,160	2.6%	7,706
Urban	Required Urban Nutrient Mgt.	10%	70%	1	proj	$27.06	3.8%	6,575	0.5%	5,276	-1.5%	-4,446
Cropland	Terracing	20%	30%	2,593	ac	$53.39	1.7%	2,941	0.2%	2,110	0.4%	1,186
Cropland	Cropland Conversion	0%	25%	4,377	ac	$55.31	6.5%	11,246	0.9%	9,497	2.1%	6,224
Past.-Rng	Prescribed Burning	1%	5%	2,508	ac	$72.62	0.8%	1,384	0.1%	1,055	0.2%	593
Reservoir	P Inactivation with Alum	0%	100%	1	proj	$110.92	3.3%	5,710	0.0%	0	0.0%	0
Flood Prot	Flood Prot - Big Sandy/Salt Crk	0%	100%	17	sites	$204.82	4.2%	7,267	5.0%	52,761	4.1%	1,2152
Past.-Rng	Pasture Planting - reseeding	5%	10%	5,016	ac	$209.35	0.3%	519	0.1%	1,055	0.1%	296
Past.-Rng	Prescribed Grazing	10%	30%	15,048	ac	$215.65	0.0%	0	0.0%	0	0.0%	0
Past.-Rng	Brush Management	10%	30%	9,637	ac	$285.78	0.3%	519	-1.3%	-13,718	0.3%	889
Urban	Voluntary Urban Nutrient Mgmt.	10%	15%	1	proj	$389.18	0.5%	865	0.4%	4,221	0.0%	0
							29.9%	**51,732**	**11.5%**	**121,350**	**15.3%**	**45,349**

Based on this information, the net present value (NPV) and annuity equivalent value (AEV) were calculated for all costs over the expected useful life of each BMP for the project period. The NPV calculation represents the value of the investment, while the AEV represents the annual payment necessary to finance the implementation of the BMP. Transforming NPV into an AEV facilitates accurate relative comparisons of costs across BMPs over time.

In order to determine how many BMPs are needed to achieve water quality goals, SWAT modeling incorporated sequential adoption of BMPs beginning with full adoption of the most cost-efficient BMP at its marginal adoption rate and then advancing to the next most cost-efficient BMP. The process was repeated until the watershed management goal of 30 % TP reduction was achieved (Table 5.3). Subsequent WASP analysis confirmed that implementation of the selected suite of BMPs resulted in a statistically significant reduction in lake chlorophyll-a concentrations.

Table 5.3. The Suite of Cost-Effective Best Management Practices that Approach the 30 Percent Target Reduction of Total Phosphorous (P) Inflow into the Eagle Mountain Reservoir.

BMP	Description	Percent Reduction			Net Present Value ($)	Annuity Equivalent Value ($)
		TP	*TN*	*Sediment*		
Cropland	Conversion of Cropland to Grass/Hay	6.50%	0.90%	2.10%	7,551,931	363,667
Cropland	Establish Filter Strips	3.90%	2.30%	5.70%	728,542	35,083
Cropland	Establish Grassed Waterways	1.80%	0.00%	0.00%	107,529	5,178
Cropland	Terracing	1.70%	0.20%	0.40%	1,304,367	62,812
Pasture & Range	Grade Stabilization - gully plugs	2.10%	1.20%	1.30%	536,213	25,822
Pasture & Range	Prescribed Burning	0.80%	0.10%	0.20%	187,874	9,047
Pasture & Range	Pasture Planting - reseeding	0.30%	0.10%	0.10%	639,342	30,788
Pasture & Range	Prescribed Grazing	0.00%	0.00%	0.00%	2,634,405	126,861
Pasture & Range	Brush Management	0.30%	-1.30%	0.30%	3,491,074	168,114
Channel	Herbicide Application - Riparian	0.70%	2.10%	2.60%	46,945	2,261
Urban	Required Urban Nutrient Mgt.	3.80%	0.50%	-1.50%	2,975,270	143,275
Urban	Voluntary Urban Nutrient Mgt.	0.50%	0.40%	0.00%	6,075,608	292,574
Reservoir	P Inactivation with Alum	3.30%	0.00%	0.00%	12,952,601	623,738
Flood Protection	Flood Protection - Big Sandy/Salt Crk	4.20%	5.00%	4.10%	32,380,041	1,559,275
TOTAL		29.9%	11.5%	15.3%	71,611,742	3,448,495

The optimal suite of BMPs identified in this analysis is greatly influenced by stakeholder identification of current and most likely adoption rates for each BMP, and includes cost-benefit considerations. For example, stakeholders did not select WWTP upgrades due to the extremely high cost of upgrades for the amount of nutrient reduction attained. If a higher adoption rate for the most cost-efficient BMPs can be achieved, the potential exists for the costs of the watershed protection plan to be greatly reduced. While several BMPs included an estimate of an incentive payment to secure participation, consideration should be given to the additional participation that could be secured if incentive payments were higher than those assumed in this analysis. There are limits to the amount of financial incentive that can be provided to secure additional adoption of specific BMPs while maintaining cost-efficiency relative to other alternatives. However, those limits should be identified and the differential value built into a plan that would encourage maximum participation for the most cost-efficient BMPs.

Education and Outreach Strategy

The Eagle Mountain Lake and Watershed Education and Outreach Plan is a multi-faceted approach that accounts for branding, message identification, targeting audiences, message delivery, evaluation, and seeking partnerships with appropriate agencies to maximize resources and avoid duplication of efforts. Between August 2008 and November 2011, eight stakeholder meetings were held to develop the WPP. Representatives who provided input include agricultural producers and landowners, local agricultural agencies, concerned citizens, water supply entities, municipal and county governments, as well as state and federal agencies. A strong partnership resulted from this planning process, with efforts emphasizing water quality benefits through watershed-based planning and implementation. The education and outreach plan builds on these relationships to further these efforts.

The driving force for the development of the watershed education and outreach campaign is to provide information to targeted audiences that will assist in reversing the trend of nutrient and sediment loadings that have contributed to the impairment of Eagle Mountain Lake. The objectives for the educational and outreach plan are ambitious and targeted toward long-term public awareness regarding water quality in Eagle Mountain Lake. Various communication strategies will be used to identify and link with groups and develop educational programs that will increase awareness of water quality, pollutant sources, and conservation practices.

A variety of audiences will be targeted during the educational program to publish and share information with the public. Among these are those who work, live, play, or conduct business within the boundaries of the watershed, including agricultural producers (farmers, ranchers and wildlife managers), small acreage landowners, sportsmen, homeowners, and youth. Because the population of the watershed is quickly expanding, those involved in development and management of public and private lands will also be targeted audiences for watershed awareness. Among these are developers, elected officials, chambers of commerce, civic organizations, media, and realtors.

Water quality-based messages and solutions that will be presented to the public will emphasize the importance of implementation and long-term maintenance of agricultural best management practices. In anticipation of population growth, the management of urban storm water and wastewater treatment facilities will be a priority. Education of stakeholders regarding landscaping, city ordinances, storm drain labeling, pet waste cleanup and water quality monitoring activities will prepare the populace for long-term watershed protection and improvement. Additional details of the education and outreach strategy are located in Chapter 7.

6. TECHNICAL AND FINANCIAL ASSISTANCE

Successful implementation of the Eagle Mountain Lake WPP will require support and assistance from a variety of sources. A detailed estimate of the cost of implementation activities is provided in Chapter 7. While some management measures require only minor adjustments to current activities, some of the most important measures require significant funding for both initial and sustained implementation. All of the BMPs require a long-term commitment; both in terms of financial investment as well as resolute determination from resource owners and managers to assure the BMPs perform to their potential. Successful implementation of the plan will involve multiple approaches to funding; strong partnership alliances to leverage technical, financial, and personnel resources; coordination of those resources, and a plan for the systematic implementation of practices that can be implemented as funding becomes available. The funding sources available will need to be fully exploited in order to secure the financial commitments necessary for this watershed protection plan to achieve the intended objectives.

Existing Watershed Programs

This section summarizes key management efforts that have been implemented in the watershed for the protection of water quality in Eagle Mountain Lake and its watershed. These activities demonstrate the level of support and commitment by entities in the watershed to the protection of water quality.

Tarrant Regional Water District

TRWD owns Eagle Mountain Lake and manages it for water supply, irrigation, flood control, and recreational purposes. Since the late 1980's, TRWD has been an active partner with federal, state, and local entities in watershed planning in the upper Trinity River watershed. To this end, the District utilizes both regulatory and voluntary tools to protect water quantity and quality. These tools are described below.

- On March 27, 2012 the TRWD Board of Directors passed a resolution to take the leadership role in the coordination and management of watershed protection efforts in those watersheds upstream of its reservoirs and the Trinity River within the bounds of the Fort Worth Federal Floodway System. The Watershed Program focuses on developing strong working relationships and coordinating activities among steering committee members, stakeholders, and other federal, state, and local governments, as well as developing technical information for watershed characterization, load reduction estimates, and Best Management Practice (BMP) selection and implementation.
- The "Watershed Rule" (30TAC ss311.61 – 311.66 Subchapter G) was enacted to regulate and control wastewater discharges to the District's reservoirs. Under this rule, permitted discharges (except oxidation ponds) within 5 stream miles of Lakes Worth, Eagle Mountain, Bridgeport, Cedar Creek, Arlington, and Richland-Chambers must meet limits of 10 BOD and 15 TSS and employ tertiary filtration. As of late 2014, even stricter requirements are in effect for the Benbrook Lake watershed.
- The "General Ordinance" was adopted by TRWD in 2002 and regulates various activities related to the lands, physical properties, and improvements owned by the District. Key activities related to water quality protection include construction, commercial activities, waste disposal, and sanitation.
- The On-Site Sewage Facilities (OSSF) Rule authorizes the District to permit, inspect and license systems within its jurisdictional area - within 2,000 feet of the conservation pool

elevation (649 foot msl). Authorized under Chapter 5, 7, and 26 of the Texas Water Code and Chapters 341 and 366 of the Texas Health & Safety Code, the rule allows the District to implement more stringent requirements in these areas closest to the lake.

- TRWD is a co-permittee on the MS4 regulating storm water in the City of Fort Worth. Although TRWD's responsibilities under the permit are restricted to monitoring and collection of floatables along the West Fork Trinity floodway downstream of Eagle Mountain Lake, the City's jurisdictional area extends into the southern portion of the Eagle Mountain Lake watershed.
- Since 1989 TRWD has maintained a water quality monitoring program for its reservoirs and contributing watersheds. TRWD actively monitors the water quality of its reservoirs for the dual purposes of assessing long term reservoir health as well as providing useful data to its major water customers for treatment of their raw water supply. Understanding any trends in water quality is an important aspect of assessing reservoir health as water quality change is slow. The establishment and analysis of a historic database collected in a consistent manner continues to be a priority of TRWD in order to assess long term eutrophic (aging) trends within each reservoir over variable climatic periods. Over 25 years of monitoring has been focused on various aspects of reservoir health, including chlorophyll-a, Secchi depth, total nitrogen and sub-species, total phosphorus, and ortho-phosphorous. TRWD commissioned the first trend study on the first 10 years of monitoring data, followed by a second analysis on 20 years of data to monitor and better understand eutrophication rates.

West Fork Watershed Study Committee

In 1991, the West Fork Watershed Study Committee was formed by the Wise Soil and Water Conservation District (SWCD), Wise County Water Control and Improvement District No. 1 (WCID1), Wise County Commissioners, TRWD, and the United States Department of agriculture Natural Resources Conservation Service (NRCS) to address landowner concerns about erosion, county concerns about flooding, and regional concerns about water quality. The group conducted a study of small watershed dams and their effectiveness in reducing sediment and nutrient loads to Eagle Mountain Lake. Many of the existing dams, primarily constructed through the Watershed Protection and Flood Prevention Act of 1954 (PL 83-566), were approaching the end of their useful life. Based on results of the study, the Committee invested in the construction of eight new dams between 1994 and 2009, as well as excavation of two additional dams to recapture a portion of their original capacity. In total, an investment of just over $3,000,000 resulted in the development of almost 1,000 ac-ft of sediment capacity. This effort marks the beginning of the partnership effort leading to development of the Eagle Mountain Lake Watershed Protection Plan.

Eagle Mountain Lake Conservation Initiative

The Eagle Mountain Lake Watershed Conservation Initiative is a partnership between the NRCS, Wise SWCD, Wise County WCID1, Wise County Commissioners Court, and TRWD. The purpose of the initiative is to enhance technical assistance and conservation planning in the Eagle Mountain Lake Watershed and to encourage implementation of agricultural conservation systems to address water quality resource concerns. The partnership is committed to reducing levels of nutrient and sediment runoff throughout the watershed.

Many farmers and ranchers are interested in these systems but need technical and financial assistance to implement them. Wise SWCD has hired district technicians to focus on conservation planning and outreach within the watershed in Wise County. NRCS provides technical guidance to these technicians, as well as to landowners throughout the entire watershed. In addition to providing technical assistance throughout the watershed, NRCS also offers financial assistance to farmers and ranchers through the Environmental Quality Incentives Program (EQIP) to help with voluntary implementation of conservation systems. These systems incorporate key practices such as no-till cropping, cover crops, planting permanent grasses, and prescribed grazing management that serve to avoid erosion, reduce water runoff, and trap nutrients and sediments. Successful implementation of these systems improves water quality and makes farms and ranches more sustainable.

Implementation of conservation systems are encouraged throughout the watershed, however, the focus of this Initiative is on sub-basins identified in Chapter 3 as major sources of phosphorus loading to the Lake. Funds to carry out the Initiative come from NRCS and through an interlocal agreement between the partners. NRCS matches 50% of local monetary and in-kind expenditures. NRCS also provides administration for the Eagle Mountain Initiative contract and provides office space, on-the-job training, equipment, and vehicles for the district technicians.

North Central Texas Council of Governments Storm Water Management Program

The North Central Texas Council of Governments (NCTCOG) works with local governments and other stakeholders to implement a regional strategy to address storm water quality issues affecting North Central Texas. This regional unified approach addresses state and federal storm water quality regulations and supports regional stewardship of the urbanized surface waters of the region.

The Regional Storm Water Management Coordinating Council (RSWMCC), comprised of local government representatives, guides implementation of the regional strategy for storm water management through development of the Annual Work Program. The Work Program is funded by individual cost shares from each of the regional participants, and implemented through three programmatic Task Forces, each addressing one of the key elements of storm water regulations – public education and involvement (PETF), illicit discharge detection and elimination (IDDETF), and municipal pollution prevention (P2TF).

Cost shares for each participant are calculated according to population and to an equal share from the resource allocation assigned to the program elements under each of these three categories. NCTCOG provides administrative support and coordinates the Regional Program through the development of interlocal agreements, work programs, and cost share arrangements with member cities. The NCTCOG also seeks external funding through grant opportunities for specific projects as needed. In addition, non-traditional funding sources, e.g. partnering with non-profits on direct implementation of best management practices (BMPs), are also investigated and pursued as opportunities arise.

Additional Technical Assistance

Agricultural Management Measures

Continued technical support from TSSWCB, SWCD, and NRCS personnel is critical to targeted planning and application of appropriate management measures on individual agricultural properties. Assistance from local Extension agents, other agency representatives, and landowners already participating will be relied upon to identify and engage key potential agricultural producers. However, due to the coverage of management plans that will be needed to sustain implementation, additional resources may be necessary.

Urban Storm water and Wastewater Management Measures

Structural and programmatic urban storm water controls are the responsibility of individual cities in the watershed. However, identification and design of specific improvements to storm water conveyances and wastewater treatment facilities are beyond the scope of many smaller municipal operations. Professional engineering analysis will be essential to assess construction of new structural controls and upgrades to existing components of both storm water and wastewater facilities. Funding will be sought to support these engineering evaluations for permittees in the watershed. Continued implementation of MS4 Installation of pet waste collection stations in each of the major communities, in combination with street sweeping programs, construction of recommended structural storm water controls, and construction of wastewater facility upgrades along with enhanced monitoring and management procedures will aid in the achievement of target pollutant load reductions.

Throughout this process, the continued assistance and commitment of city officials, staff, and facility permittees and operators will be critically important to the implementation of recommended management measures.

Additional Financial Assistance

Many sources of financial assistance are available for the management measures identified in this plan. Successful acquisition of funding will be critical to full implementation of the plan and meeting water quality goals. While ongoing management measures and activities described in sections above may be funded at this time, long-term implementation of these and other measures identified in the plan will require additional funds. Traditional funding sources, such as those described below, will be utilized where available. More innovative approaches, such as support from industry and non-profit organizations will also be sought. Some of the key potential funding sources that will be explored are described below.

Environmental Quality Incentives Program (EQIP)

The Environmental Quality Incentives Program is administered by the USDA NRCS. This voluntary conservation program promotes agricultural production and environmental quality as compatible national goals. Through cost-sharing, EQIP offers financial and technical assistance to eligible participants for the installation or implementation of structural controls and management practices on eligible agricultural land. This program will continue to be engaged to assist in the implementation of agricultural management measures in the watershed.

Conservation Easement Programs (ACEP)

This program is administered by the USDA Farm Services Agency (FSA) and is a voluntary program for agricultural landowners. Under the Agricultural Land component, NRCS may contribute up to 50 percent of the fair market value of the agricultural land easement. Where NRCS determines that grasslands of special environmental significance will be protected, NRCS may contribute up to 75 percent of the fair market value of the agricultural land easement.

Clean Water Act State Revolving Fund

The State Revolving Fund (SRF) administered by the Texas Water Development Board (TWDB) provides loans at interest rates below the market to entities with the authority to own and operate wastewater treatment facilities. Funds are used in the planning, design, and construction of facilities, collection systems, storm water pollution control projects, and nonpoint source pollution control projects. Wastewater operators and permittees may pursue these funds to assist in treatment upgrades and to improve treatment efficiency in rural portions of the watershed.

Economically Distressed Area Program (EDAP)
The Economically Distressed Area Program is administered by the TWDB and provides grants, loans, or a combination of financial assistance for wastewater projects in economically distressed areas where present facilities are inadequate to meet residents' minimal needs. While the majority of the watershed does not meet these requirements, small pockets within the area may qualify based on economic requirements of the program. Groups representing these areas may pursue funds to improve wastewater infrastructure.

Regional Water Supply and Wastewater Facility Planning Program
The TWDB offers grants for assessments to determine the most feasible alternatives to meet regional water supply and wastewater facility needs, estimate costs associated with implementing feasible wastewater facility alternatives, and identify institutional arrangements to provide wastewater services for areas across the state. This source will be pursued to support wastewater elements of the WPP.

Section 106 State Water Pollution Control Grants
Through the Clean Water Act, federal funds are allocated along with matching state funds to support state water quality programs, including water quality assessment and monitoring, water quality planning and standard setting, TMDL development, point source permitting, training, and public information. The goal of these programs is the prevention, reduction, and elimination of water pollution.

Environmental Education Grants
The Environmental Education Grants program is sponsored by EPA's Environmental Education Division, Office of Children's Health Protection and Environmental Education to support environmental education projects that enhance the public's awareness, knowledge and skills to help people make informed decisions that affect environmental quality. EPA awards grants annually based upon funding appropriated by Congress. Funding from this program may be pursued to support the development of outreach and education programs.

Section 319(h) Federal Clean Water Act
The EPA provides funding to states to support projects and activities that meet federal requirements of reducing and eliminating nonpoint source pollution. In Texas, both the Texas State Soil and Water Conservation Board (TSSWCB) and the TCEQ receive 319(h) funds to support nonpoint source projects, with TSSWCB funds going to agricultural and silvicultural issues and TCEQ funds going to urban and other non-agricultural issues.

Supplemental Environmental Project Program (SEP)
The Supplemental Environmental Projects program administered by the TCEQ aims to direct fines, fees, and penalties for environmental violations toward environmentally beneficial uses. Through this program, a respondent in an enforcement matter can choose to invest penalty dollars in improving the environment, rather than paying into the Texas General Revenue Fund. Funds from this program may be used to support targeted projects such as stream or riparian restoration, technical workshops, or other activities with a direct water quality benefit.

Targeted Watersheds Grants Program

The Targeted Watersheds Grants Program is administered by the EPA as a competitive grant program designed to promote community-driven watershed projects. Federal, state, and local programs are brought together to assist in the restoration and preservation of water resources through strategic planning and coordinated project management by drawing in both public and private interests.

Texas Clean Rivers Program (CRP)

The CRP is a statewide water quality monitoring, assessment, and public outreach program funded by state fees. The TCEQ partners with 15 regional river authorities to work toward achieving the goal of improving water quality in river basins across the state. CRP funds are used to promote watershed planning and provide quality-assured water quality data.

Water Quality Management Plan Program (WQMP)

The WQMP program, administered by the TSSWCB, is a voluntary mechanism by which site-specific plans are developed and implemented on agricultural lands to prevent or reduce nonpoint source pollution from these operations. Plans include appropriate treatment practices, production practices, management measures, technologies, or combinations thereof. Plans are developed in cooperation with local SWCDs, cover an entire operating unit, and utilize financial incentives to augment participation. Funding from the WQMP program may be used to support implementation of agricultural management measures in the watershed.

National Fish and Wildlife Foundation (NFWF) Grants

The Five Star and Urban Waters Restoration Program seeks to develop nation-wide-community stewardship of local natural resources, preserving these resources for future generations and enhancing habitat for local wildlife. Projects seek to address water quality issues in priority watersheds, such as erosion due to unstable streambanks, pollution from storm water runoff, and degraded shorelines caused by development. Funding from NFWF and similar programs may be used to support targeted projects in the watershed.

7. PROJECT IMPLEMENTATION

This section presents the implementation schedule, interim milestones, and process for evaluating progress toward meeting load reduction and water quality goals. Meeting these goals revolves around a system of planning, implementation, evaluation, and adaptation to changes within the watershed. This system drives an adaptive management approach by allowing stakeholders to reevaluate implementation plans and determine whether substantial progress is being made.

Projects of the magnitude of the Eagle Mountain Lake WPP are dependent upon the consistent and continued participation of a wide array of stakeholders and affected entities. Regardless of the strategy chosen to meet the TP reduction goal, participation from many stakeholder groups is necessary. Obviously, funding availability, decision-makers' planning horizons, future land use and development intentions, the general economic environment, and municipal, county, state, and federal policy are all dynamic factors influencing which BMPs will prove to be most viable. Active involvement, educational outreach and solicitation of guidance from all stakeholders will increase the stakeholder buy-in necessary for the watershed protection plan to be successful. As education and buy-in increases, social and cultural barriers to implementation will be reduced.

Implementation of the recommended management measures will be carried out to address the sources and land uses indicated for each measure. Implementation in sub-basins with higher loading will be emphasized, although load reductions will be sought from all sources across the watershed.

Attainment of load reductions over time will be dependent upon coordinated, cumulative implementation of recommended management measures. Consistent, long-term collection of water quality data and the periodic use of modeling tools will be used to evaluate progress of pollutant load reductions. Water quality data will also be used to reevaluate trends over time and compare pre- and post-implementation conditions. Reevaluations will occur at key intervals over the implementation period, allowing stakeholders to adjust implementation strategies as needed to meet load reduction and water quality goals.

Implementation Schedule and Milestones

Implementation milestones in Table 7.1 will be used to evaluate progress in the implementation of management practices contained in the WPP. The implementation milestones, schedule, and estimated costs of implementation are the result of planning efforts by watershed stakeholders throughout the development of the WPP. Stakeholders recommend a 15 year implementation horizon, managed in three year increments. This allows key milestones to be tracked over time so that progress is more easily measurable. Multi-year increments also allow for the process of funding acquisition, hiring of staff and the implementation of new programs over time. In the event that particular milestones takes longer to achieve, efforts will be intensified or adjusted as necessary. If at some point the milestone is deemed unattainable, stakeholders will address the issue through adaptive management and implementation.

Regarding agricultural measures, both the NRCS and TSSWCB offer agricultural producers technical assistance as well as financial assistance for "on-the-ground" implementation. To receive financial assistance from TSSWCB, the landowner must develop a Water Quality Management Plan (WQMP) with the local SWCD that is customized to fit the needs of their operation. The NRCS offers options for development and implementation of both individual practices and whole farm conservation plans. Because the conditions and needs of individual farms can vary widely, WQMPs and conservation plans may contain a wide range of BMPs and practices. Table 7.1 describes implementation at the WQMP scale, rather than the BMPs scale to better facilitate tracking and reporting. Based on National Agricultural Statistics Service data for counties within the Eagle Mountain Lake watershed (USDA 2012), the weighted average farm size in the watershed is approximately 214 acres. When this statistic is applied to the implementation areas presented in Table 5.2, it's estimated that approximately 326 farm plans will be needed in subwatersheds of high phosphorus loading to achieve the reduction goal for agriculture.

Table 7.1 Schedule of Milestones, Responsible Parties, and Estimated Costs for Recommended Management Measures.

Management Measure	Responsible Party	Implementation		Unit Cost	Units Implemented					Total Cost
					Year					
		Area	Units		1-3	4-6	7-9	10-12	13-15	
Agricultural Measures										
WQMP Technicians (2)	SWCD	--	--	$110,000/yr[1]	--	--	--	--	--	$1,650,000
WQMPs - Cropland	SWCD/Producers	58	ea	$15,000	12	12	12	12	12	$869,329
WQMPs-Past & Range	SWCD/Producers	268	ea	$15,000	54	54	54	54	54	$4,017,414
Urban Measures										
Required Nutrient Mgt	TRWD	1	proj	$2,149,125	3	3	3	3	3	$ 2,149,125
Voluntary Nutrient Mgt	AgriLife (?)	1	proj	$4,388,610	3	3	3	3	3	$ 4,388,610
Reservoir Measures										
P-Inactivation	TRWD	1	proj	$ 9,356,070					1	$ 9,356,070
Flood Prot. Measures										
Big Sandy and Salt Creek watersheds	SWCD/ Landowners	17	proj	$ 1,375,831		4	4	4	5	$ 23,389,125

Table 7.2 Schedule of Education and Outreach Programs.

Management Measure	Responsible Party	Total Cost	Units Implemented in Years				
			1-3	4-6	7-9	10-12	13-15
General Watershed Awareness							
Multimedia information campaign	TRWD/Texas A&M AgriLife	$1,756,250	3	3	3	3	3
Texas Watershed Stewards Program	Texas A&M AgriLife Extension	N/A[1]	1	1		1	
Texas Riparian Workshop	Texas A&M AgriLife Extension	N/A[1]	1	1	1	1	1
Public School Education Program	Texas A&M AgriLife	$ 125,000	3	3	3	3	3
Nonpoint Source Pollution Educational Program	Texas A&M AgriLife	$150,000	3	3	3	3	3
Community Outreach Events – Display/handouts	TRWD/Texas A&M AgriLife	$ 3,000	3	3	3	3	3
Community Stream Cleanups	TRWD	$ 75,000	3	3	3	3	3
Installation of BMPs for educational purposes	TRWD/Texas A&M AgriLife	$ 25,000	1	1	1	1	1
Watershed Signage	TRWD/TXDOT	$ 15,000	3	3	3	3	3
Education Coordinator/Watershed Coordinator	TRWD/Texas A&M AgriLife	$1,425,000[2]	3	3	3	3	3
Agricultural Programs							
Producer educational workshops – Nutrient Management, Crop Management, Grazing Management, Riparian Management	Texas A&M AgriLife	$ 2,500	4	4	4	4	4
Soil Testing Campaign	Texas A&M AgriLife	$ 67,000	3	3	3	3	3
Producer Education – Ag BMPs and SWCD/NRCS Technical Assistance	Texas A&M AgriLife	$ 3,500	1	1	1	1	1
BMP demonstration sites	Texas A&M AgriLife	$ 20,000		1		1	
Urban Programs							
Workshops and information for municipalities on storm water management, urban landscape management, soil testing, low impact development	Texas A&M AgriLife	$ 90,000	4	4	4	4	4
Program to promote neighborhood association recognition for environmentally friendly landscaping	TRWD/Texas A&M AgriLife	$ 12,000	3	3	3	3	3
Small Acreage Landowner Programs							
Landowner educational programs on land management, pond management, stocking rates, nutrient management, pasture planting, septic system management	Texas A&M AgriLife	$ 7,500	3	3	3	3	3
Homeowner Programs							
Homeowner educational programs on stormwater management, rainwater harvesting, urban landscape management, soil fertility, pet waste management	Texas A&M AgriLife	$ 75,000	3	3	3	3	3

[1] *Funded through the TSSWCB through an existing CWA section 319(h) grant.*
[2] *Total includes salary and benefits (health insurance, annual/sick leave, etc.) and travel.*

As shown in Figure 7.1, it's anticipated that the cumulative reduction goal for TP could be met in approximately 15 years. This schedule is based on the TP load and annual expected reductions from implementation of the suite of management measures described in Chapter 5. Interim load reduction milestones, estimated as the sum of reductions from individual management measures implemented during each interval, will vary due to site, environmental, and other conditions observed during the implementation period. Consequently, the rate of observed load reductions may not precisely follow the projections indicated here. Rather, these load reduction milestones will be used to determine progress toward attaining load reduction and will serve as a tool to facilitate stakeholder evaluation and decision-making based on adaptive management. Meeting these milestones will require full coordination of funding, cooperation of landowners, and committed leadership.

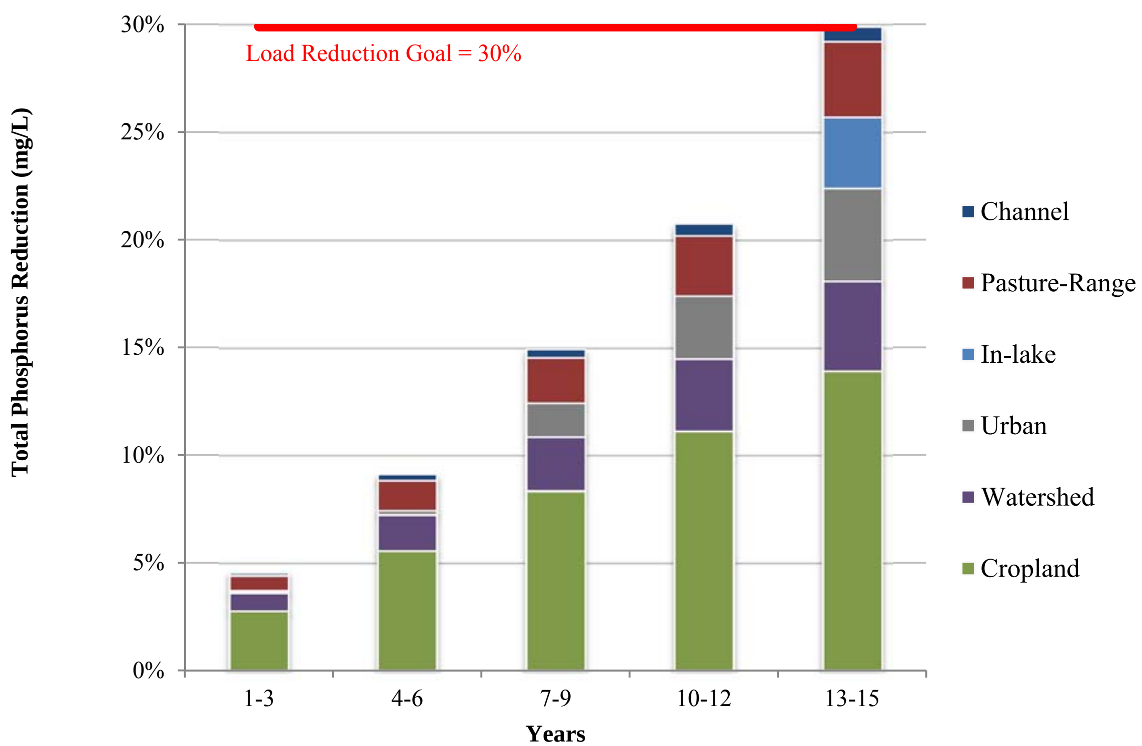

Figure 7.1. Implementation Schedule and Load Reduction Milestones.

Measuring Success

BMP effectiveness was simulated to predict effects on lake water quality, but also to determine the spatial distribution of reductions due to implementation of the plan. Figure 7.2 illustrates the estimated TP loading before and after implementation of the recommended suite of measures.

In order to accurately compare pre- and post-implementation conditions, SWAT, WASP, or other tools may be used to re-evaluate water quality conditions. Evaluations or model runs will be performed to reflect land use changes and management measures that have been implemented in the preceding intervals. These comparisons will demonstrate the predicted results of implementation and measure progress in meeting interim milestones and the cumulative 30% load reduction target.

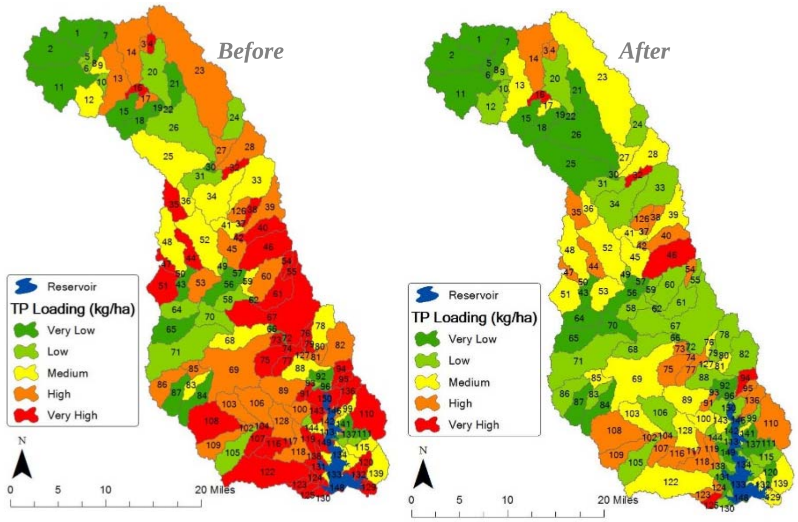

Figure 7.2. Estimated TP Loads to Eagle Mountain Lake by Sub-Basin Before and After Implementation.

As implementation progresses, new watershed and water quality data will be collected to improve the understanding of watershed conditions and drive a more efficient implementation process. Incorporation of these new data into plan updates and revisions will allow stakeholders to track implementation efforts and water quality trends, and to evaluate whether the plan is being successfully implemented. This adaptive implementation strategy will allow stakeholders to determine the need for new action or revision of existing programs.

Load reduction and water quality goals for this WPP were developed using a combination of watershed and ambient water quality data, as well as statistical and computer modeling. By maintaining the methodology used to develop the WPP for future evaluations and updates, an accurate comparison can be made of the progress in reducing phosphorus and chlorophyll-*a* as the plan is implemented.

Progress in implementing the recommended management strategies and long-term monitoring plan will be re-evaluated every five years. Based on these periodic comparisons of actual implementation to load reduction milestones, stakeholders will decide if additional modeling should be conducted and whether to make adjustment to the implementation strategy.

Monitoring Plan

Long-term water quality monitoring of Eagle Mountain Lake was begun by TRWD in 1989. These data were utilized in the analysis of long-term trends and relationship between nutrient and chlorophyll-a concentrations described in previous Chapters. Quality-assured monitoring activities consistent with these historical approaches will be continued and utilized for measuring and assessing progress in meeting load reduction and water quality goals. Data from routine monitoring of five reservoir and five tributary sites will support these analyses (Table 7.3 and Figure 7.3

Table 7.3. Monitoring Plan Parameters

Tributary Sites	Reservoir Sites	
TSS	Chl-a'	$DOPO_4$-P
VSS	TSS	TOC
NH_3-N	NH_3-N	DOC
NO_3+NO_2-N	NO_3+NO_2-N	Alkalinity
TKN	TKN	TDS
TP-P	TP-P	Chloride
DOPO4-P		
TOC		
Chloride		

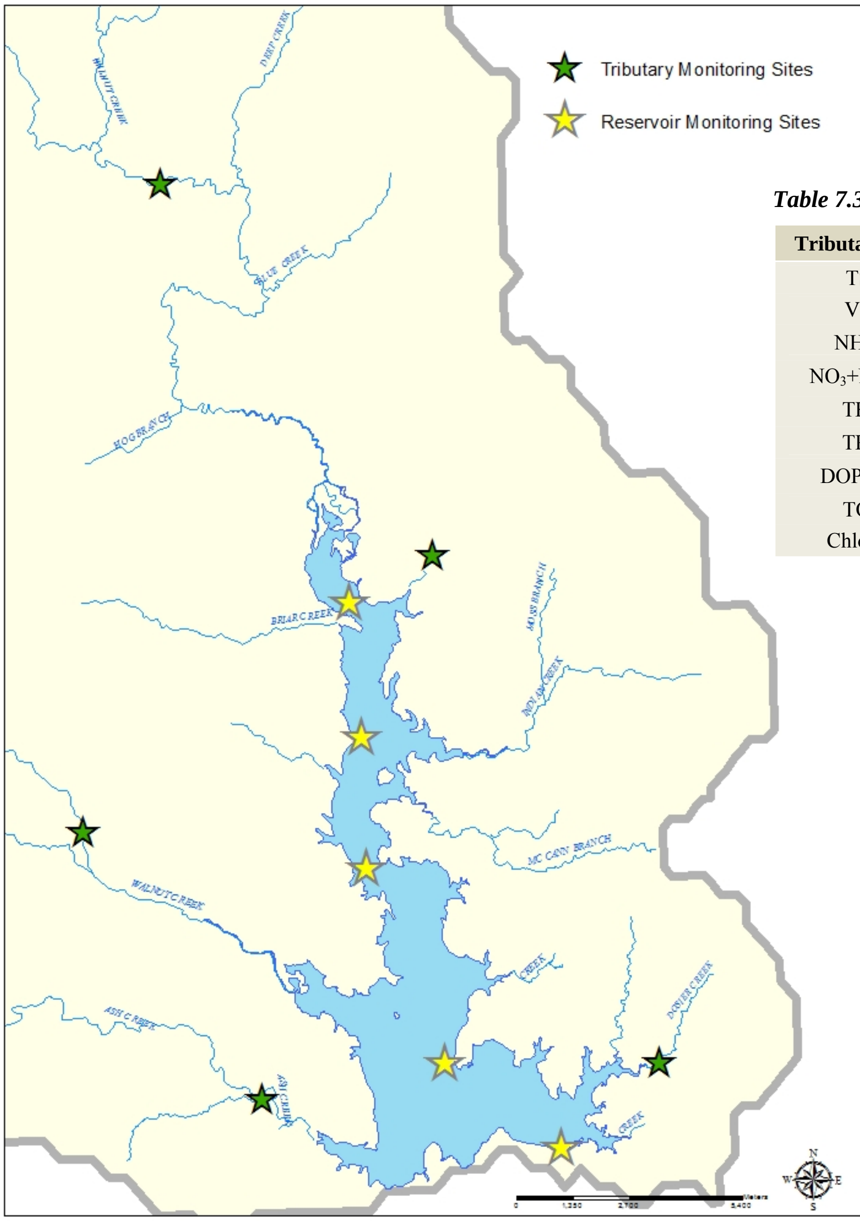

Figure 7.3. Eagle Mountain Reservoir WPP Monitoring Sites

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APPENDIX A. TECHNICAL NOTES - SWAT ANALYSIS

All model data in this report, both observed and simulated, includes inflow to Eagle Mountain watershed from Bridgeport Reservoir, also constructed in 1932. Daily inputs, such as flow, sediment, and nutrients, from Bridgeport Reservoir were represented as a point source in the Eagle Mountain watershed model.

DATA SOURCES

D E M (Digital Elevation Model) is elevation information created in a digital format. The data was obtained from N R C S (Natural Resources Conservation Service) Data Gateway at 30 meter resolution.

The National Land Cover Dataset (NLCD) created in 1992 (Vogelmann et al 2001) was used as SWAT land use data input. Due to rapid urban development in the watershed, the Texas A&M Spatial Sciences Lab (SSL) enhanced this data for urban expansion using an aerial photograph from 2003.

The soils dataset SSURGO (Soil Survey Geographic), which is the most detailed soils dataset available, was obtained from the NRCS Data Gateway and used as input for the SWAT model.

When National Weather Service stations lacked precipitation data during the period of record (1950-2004), nearby stations provided substitute data, and SWAT generated missing temperature data. For rainfall data from 1999-2004, NEXRAD data was used to enhance missing rainfall or to create spatially distributed rainfall with finer resolution. It was done by averaging NEXRAD grid data for all sub-basins near an individual climate station.

WWTPs voluntarily collected weekly nutrient and flow data for one year, which provided point-source loading inputs. Weekly data have been combined into monthly loadings for each WWTP and then routed through the creeks.

Data from two types of water quality monitoring studies were used in this analysis. One was an intensive, short-term, low flow study and the other a continuous, long-term water quality analysis of samples taken from various monitoring sites. For the low flow study, Tarrant Regional Water District (TRWD) collected a total of 14 samples at different locations along the stream network on August 18, 2004. The samples were analyzed for dissolved oxygen, biological oxygen demand, ammonia, phosphorus, Chlorophyll-a, organic nitrogen and nitrate-nitrite concentrations. Observed data from 10 of the 14 locations were used to calibrate nutrients under low flow conditions. The TRWD also set up an independent QUAL-2E model based on the measured channel geometry and hydraulics developed during a dye study. The calibrated QUAL-2E kinetic terms and coefficients were then used as initial estimates of instream water quality parameters in SWAT.

The TRWD used data from six monitoring sites on main tributaries of Eagle Mountain Lake where grab samples were collected from 1991 to 2004 to test for water quality. For SWAT calibration, data from five monitoring sites were used to modify SWAT's instream model parameters.

MODEL SET-UP

The Eagle Mountain Lake watershed contains a total of 56 inventory-sized dams, including both NRCS flood prevention dams, farm ponds, and other privately owned dams. Physical data such as surface area, storage, drainage area, and discharge rates for these dams where input into SWAT to allow routing of runoff through the impoundments. Four structures were large enough to be simulated as reservoirs while the rest were simulated as small ponds

APPENDIX A. TECHNICAL NOTES - SWAT ANALYSIS

SWAT's input interface divided each sub-basin into HRUs with unique soil and land use combinations. The number of HRU's within each sub-basin was determined by: 1) creating an H R U for each land use that equaled or exceeded 2% of each sub-basin's area, and 2) creating an H R U for each soil type that equaled or exceeded 10% of any of the land uses selected in 1).

CALIBRATION AND VALIDATION

The calibration period was based on the available period of record for stream gauge flow. Measured stream flow was obtained from two USGS stream gages (08043950 and 08044500)/

Appropriate plant growth parameters for brush, native grasses, and other land covers were input for each model simulation. Initial inputs were based on known or estimated watershed characteristics.

SWAT was calibrated for flow by adjusting appropriate inputs that affect surface runoff and base flow. Adjustments were made to runoff curve number, soil evaporation compensation factor, shallow aquifer storage, shallow aquifer re-evaporation, and channel transmission loss until the simulated total flow and fraction of base flow were approximately equal to the measured total flow and base flow, respectively.

Validation was performed by applying the same model parameters to a different period (1971-1990). Validation was done in an earlier period than calibration because the land use dataset used in this model represented land cover in 2001. Therefore, it would be more appropriate to calibrate the model for the period that includes the year of the land cover dataset. For calibration period, r2 , N S E (Nash-Sutcliffe Model Efficiency) (Nash and Sutcliffe, 1970), observed mean, and modeled mean were 0.947, 0.913, 7.15 m3/s, and 7.04 m3/s respectively. For validation period, they were 0.964, 0.921, 8.59 mVs, and 8.50 m3/s respectively.

Sediment calibration was done based on a sedimentation study conducted by Texas Water Development Board (TWDB) conducted during the modeling study. Simulated sediment from SWAT for the 1971 to 2004 period (34 years) was compared to the measured sediment, and appropriate input parameters were adjusted until the predicted annual sediment load from overland and channel erosion was approximately equal to the measured.

Nutrient calibration consisted of two parts: first, the model was calibrated based on a low flow study conducted August 18, 2004, and second, using long term tributary monitoring data.

BMP SIMULATION

Eighteen BMPs were simulated at the rate, and on land uses, indicated in the BMP evaluation and economic analysis. The adoption rate was also used for sensitivity analyses of each BMP and it provided useful information on the effectiveness of each BMP. To assess the 30% TP reduction goal, each B M P was implemented in the model one at a time until the total TP reduction at the lake reached 30%.

APPENDIX B. TECHNICAL NOTES - WASP ANALYSIS

DATA SOURCES

The Eagle Mountain Lake segmentation consists of 17 segments (Figure B-1). The surface segments are defined as the 6 main thalweg segments 1-6, which includes the West Fork cove segment, and 4 additional cove interface segments 14-17. Subsurface segments 7-11 characterize the Eagle Mountain Lake WASP model to the depth of the typical thermocline of approximately 7 meters. Subsurface segments 12 and 13 define the two hypolimnetic segments in the Eagle Mountain Lake WASP model. Each surface and subsurface segment is physically and hydraulically connected to adjacent and adjoining segments where appropriate, by vertical and/or horizontal interfaces.

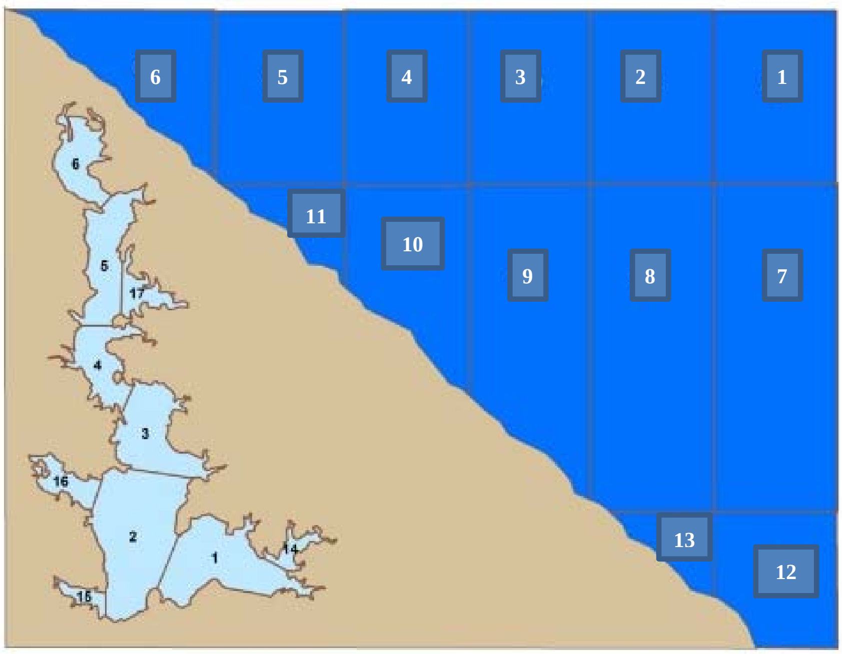

Figure B-1. WASP Segmentation profile.

Horizontal dispersion was estimated from the 4/3 Power Law used routinely in historic TRWD water quality models. Horizontal dispersion ranged from 0.6935 m^2/sec to 7.235 m^2/sec throughout horizontal segment interfaces in the model. Vertical dispersion between the surface segments and underlying subsurface segments (2 - 7,3 - 8,4 - 9, 5 - 10, and 6 - 11) were arbitrarily set at a high rate (0.001 m^2/sec) to ensure uninhibited mixing vertically between segments.

Hypolimnetic dispersion coefficients for subsurface segments 7-12 and 8 -13 were initially estimated using Thomann and Mueller's (1987) temperature differential technique. However, due to the paucity of data for several locations, a consistent time function for each subsurface and hypolimnetic subsurface segment (7-12 and 8 -13) proved difficult. Observation of temperature plots from field data comparing one meter below the surface to one meter above the reservoir floor illustrated that there are distinct temperature differentials each summer and minimal mixing between these subsurface segments (7-12 and 8-13). Based on these temperature plots, TRWD determined the time frame of the temperature differentials for each year at Sampling Station 7 and applied typical lake vertical dispersion rates listed by Chapra (1997) for each time frame of each respective year. These rates varied from 0.0005 m^2/sec for well-mixed time periods to 0.00001 m^2/sec for summer stratification time periods.

An external hydrodynamic flow model utilized the external flows to the system (precipitation, evaporation, pumpage, discharge, and tributary inflows) as recorded by TRWD and the corresponding geometry of each segment to solve for the advective flows between adjacent segments. The program specifies a matrix solution employing the criteria of minimum kinetic energy and the solution is input into the appropriate flow field for each segment in WASP.

APPENDIX B. TECHNICAL NOTES - WASP ANALYSIS

The physical settling of particulate matter in any reservoir is an important transport phenomenon of non-dissolved nutrients and often leads to a distinct longitudinal gradient or slope in concentration.

Only three of the eight state variables were assigned settling velocities. Organic nitrogen and organic phosphorus in each segment were estimated from limited laboratory measurements of total and filtered samples. The fraction of organic nitrogen that was determined to be in the undissolved phase (varied from segment to segment based on field data) was given a settling velocity of 2.3x 10.6 m/sec (0.20 m/day). Algae were given a rate of 5.0 x 10.7 (0.04 m/day) and the fraction of organic phosphorus that was in the undissolved phase were given a settling velocity of 2.8x 10.6 m/sec (0.24 m/day). Organic phosphorus was given a higher settling velocity because it binds with inorganic clay readily, while organic nitrogen is more often associated with organic matter. The longitudinal profiles of observed data support this position.

Five light curves were used to represent the longitudinal gradient from the turbid north end of Eagle Mountain to the relatively clearer waters in the southern end near the dam. The "inlet segment" curve represents the north end area of Eagle Mountain, while "intake segment" curve represents the southern end of the lake near the dam.

This nutrient loading system includes two WWTPs that discharge treated effluent directly to Eagle Mountain: Fort Worth Boat Club (FWBC)) and Larry Buck RV Park. FWBC collected weekly nutrient discharge data from October 2001 through January 2002. This data was used to calculate the annual load of nutrients in kilograms/day (kg/d). Since nutrient discharge data was only available for one time period in the simulation period, this data was summarized and repeated for the 10-year simulation for the calibration model.

Nutrient loading from the atmosphere was calculated using precipitation and nutrient data (NH3, NOx, ON, and OP) provided by TRWD from rainwater analysis. This data was compared to literature estimates and found to be very similar. The loads where then converted to a constant daily rate and applied to the model (all surface segments).

Benthic flux in the form of ammonia (NH4) and orthophosphate (OP) was added to the two hypolimnetic segments (12, 13). Analysis of intensive survey data from two summers allowed estimation of release rates from hypolimnetic increases in concentration. Flux was applied from April through September when observed data showed increases in both ammonia and dissolved phosphorus in the hypolimnion.

Nutrient loading from the watershed includes both PS discharges from WWTPs located in the Eagle Mountain watershed, and overland flow from approximately 800 square miles. These combined nutrient loads from the watershed were estimated using the SWAT model and supplied to WASP via an external NPS file. The nutrient loads for all eight state variables were entered as kg/d.

CALIBRATION

The model was calibrated for a 10-year period (1994-2003) for Eagle Mountain Lake. Calibration concentrated on achieving overlapping observed and predicted data percentiles for each segment and mimicking the longitudinal trends (gradients) of each parameter. R-square results were significant for TN and TP, both annually and seasonally, demonstrating a good basis for the model. R-square values were not significant for Chl-a but the Relative Percent Difference calculation suggest that the error in observed and predicted data was similar to the difference we have seen in duplicates sent in for laboratory analysis. We feel this is as good as we can expect with a single algae group model. The excellent fit for P implies that this may be a good parameter for BMP evaluation.

Annual and 10-year mass balance of the nutrients coming into Eagle Mountain, leaving Eagle Mountain and the percent retained by the lake were calculated using all sources of incoming nutrients for the calibration period (1994-2003). Using the incoming nutrient data along with the inflows and outflows from the reservoir, the percent of nutrients retained by Eagle Mountain was calculated

The response of the calibrated WASP model to five nutrient loading scenarios was evaluated independently by systematically shutting each off. Statistical testing with a Kruskal-Wallis Multiple Comparison test (alpha = 0.05) shows all simulations that are not significantly different from the calibration.

WATERSHED REDUCTIONS

Five load reductions were simulated during the calibration years by scaling the NPS file to create reductions ranging from 15% to 65%. A significant reduction in Chl-a and TP concentration is not realized until about a 25% to 35% reduction in watershed loading is achieved. In order to narrow down the target load reduction, a fine resolution analysis was done for load reductions between 25% and 35%. Five scalars were applied within this range and compared to the calibration model for a statistically significant reduction in Chl-a and TP concentrations. The concentrations for both parameters were not significantly reduced until somewhere between 28% and 30%. Therefore, a 30% reduction in P loading to the reservoir was recommended based on model results in order to have a significant impact on reservoir water quality.

APPENDIX C. TECHNICAL NOTES - EVALUATION OF PERMITTED DISCHARGES

This report addresses the point sources, specifically wastewater treatment facilities discharging directly into the Eagle Mountain Reservoir or through watershed streams that eventually enter the reservoir. The objectives of this evaluation are to identify significant sources of pollutant sources, to quantify both current and long-term impacts, to evaluate options available for maintaining and improving water quality, and finally to address the costs of implementing those practices. Facilities evaluated in this report include:

City of Alvord Wastewater Treatment Plant	City of Azle Ash Creek Wastewater Treatment Plant
City of Bowie North Wastewater Treatment Plant	City of Boyd Wastewater Treatment Plant
City of Bridgeport Wastewater Treatment Plant	City of Chico Wastewater Treatment Plant
City of Decatur Wastewater Treatment Plant	Fort Worth Boat Club Wastewater Treatment Plant
Garrett Creek Ranch Wastewater Treatment Plant	Larry Buck RV Park Waste Water Treatment Plant
City of Newark Wastewater Treatment Plant	Paradise ISD Wastewater Treatment Plant
City of Rhome Wastewater Treatment Plant	City of Springtown Wastewater Treatment Plant

Sources of information for the evaluations include: site visits, interviews with the plant personnel, reviews of the existing plans and historical reports, data collected by plant personnel for the District, data acquired through TCEQ, and responses to a questionnaire developed specifically for this project to aid in acquiring data and information on each plant. Data were organized as follows:

- Description of the existing TPDES permit conditions and projected future limits
- Historical effluent data
- Brief description of the treatment process
- Population growth and flow projections
- Facility needs and costs to meet Level I effluent limits through 2050
- Facility needs and costs to meet Level II effluent limits through 2050
- Facility needs and costs to meet Level Ill effluent limits through 2050

The evaluation of each facility included assessing the ability of each plant to properly treat projected 2050 flows under three varying discharge limit criteria. The existing permit conditions are referred to as Level I. The next level of treatment, referred to as Level II, includes reduction of phosphorus to 1.0 mg/L and total nitrogen to 10 mg/L. The most stringent level of treatment considered, referred to as Level III, includes reducing the phosphorus limit to 0.5 mg/L and total nitrogen to 5 mg/L.

The average total nitrogen and total phosphorous concentrations that were determined as part of special nutrient testing were used to calculate the Level I loads at 2050 flows: this will best compare the impact of each permit level across time. If no other data were available, TN was approximated at 16 mg/L and TP at 6 mg/L.

Many of the plants examined for this study were performing at Level II requirements or better, so the impact of implementing Level Ill parameters was evaluated relative to the current treatment level.

APPENDIX D. BEST MANAGEMENT PRACTICES

A short description of the 24 BMPs identified by stakeholders as potentially suitable for the Eagle Mountain Lake watershed is presented below.

Cropland

BMP 1 Conversion of Cropland to Grass. Conversion of cropland to grass acreage falls under the USDA NRCS Conservation Reserve Program in which producers receive financial assistance to retire lands from growing annual crops and establish perennial pastures (grass or hay). This practice works to establish a permanent vegetative cover to allow for the utilization of nutrients and minimizes soil disturbance and erosion (USDA National Resources Conservation Service 2010). It is assumed that converted cropland will be used for haying rather than livestock, eliminating the need for fences and water ponds as part of the transition process. For the purposes of this economic analysis, it is assumed the conversion is permanent, extending throughout the 50-year project planning horizon. Overall, one acre of all cropland acres deemed eligible for the practice is considered as the management unit of analysis for this BMP.

BMP 2 Fertilizer/Nutrient Management - 25 percent reduction in P with split applications. This BMP involves a 25 percent reduction in phosphorous application on cropland, with two split applications, one preplant and the other after the crop has emerged. The intent is to manage the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments to minimize agricultural nonpoint source pollution of surface soil and groundwater resources. Soil fertility testing is an important element of nutrient management and this BMP. Soil testing encourages the budget and supply of nutrients for plant production, and proper utilization of manure and organic materials (USDA Natural Resources Conservation Service 2010). For the purposes of this economic analysis, it is assumed this BMP has an expected life of one year. The management unit of analysis is one acre on all cropland acres deemed eligible for the practice.

BMP 3 Establishment of Filter Strips. Filter strips are vegetated areas that are situated between surface water bodies (i.e. streams and lakes) and cropland, grazing land, forest land, or disturbed land. They are generally located where runoff water leaves a field for the purpose of trapping or filtering sediment, organic material, nutrients, and chemicals from the runoff water. Filter strips are also known as vegetative, filter or buffer strips and are commonly about 15 meters in width. Specifically designed vegetative strips slow runoff water leaving a field so that larger particles, including soil and organic material, can settle out. Due to the entrapment of sediment and establishment of vegetation, nutrients can be absorbed into the sediment that is deposited and can remain on the field landscape, enabling plant uptake of the nutrients (USDA National Resources Conservation Service 2010). For the purposes of this economic analysis, this BMP has an expected life of five years. The management unit of analysis is 21 acres, with one acre of filter strip per 20 acres of cropland, on all cropland acres deemed eligible for the practice.

BMP 4 Establishment of Grassed Waterways. Grassed waterways are natural or constructed channels established for the transport of concentrated flow at safe velocities using adequate vegetation. The vegetative cover slows the water flow, minimizing channel surface erosion. When properly constructed, grassed waterways can safely transport large flows of runoff down slopes. This conservation practice improves the soil aeration and water quality due to its nutrient removal through plant uptake and sorption by the soil. Entrapment of sediment and the establishment of vegetation allow nutrients to be absorbed into the trapped sediments and to remain in the agricultural field rather than being deposited into the different waterways. A grassed waterway is often used to safely discharge the overland runoff to the main channel, thus preventing the formation of gullies. Grassed waterways are graded to required dimensions based on the field conditions, while permanent vegetation is established to maintain the grade. Grassed waterways can also be used in conjunction with other conservation measures, such as terraces, to safely convey the excess runoff (USDA National Resources Conservation Service 2010). For the purposes of this economic analysis, this BMP has an expected life of 10 years. The management unit of analysis is 41 acres, with one acre of filter strip per 40 acres of cropland, on all cropland acres deemed eligible for the practice.

BMP 5 Terracing. Terraces consist of a series of earthen embankments constructed across fields at designed vertical and horizontal intervals based on land slope, crop rotation, and soil conditions. Construction of terraces involves a heavy capital investment to move large quantities of earth for forming earthen embankments. Terracing is recommended for land with a grade of two percent or higher (USDA National Resources Conservation Service 2010). For the purposes of this economic analysis, this BMP has an expected life of 10 years. The management unit of analysis is 21 acres, with one acre of terraces per 20 acres of cropland, on all cropland acres deemed eligible for the practice.

Pasture and Rangeland BMPs

BMP 6 Prescribed Grazing. Prescribed grazing is the controlled harvest of vegetation with grazing animals, managed with the intent to improve or maintain desired species competition and vigor of plant communities. This BMP prevents soil erosion by maintaining a permanent vegetative cover on grazed fields and pastures and increases harvest efficiency by ensuring adequate forage throughout the grazing season. Prescribed grazing involves rotating livestock to enable vegetative re-growth and includes the combined use of fencing and stock watering facilities (USDA National Resources Conservation Service 2010). This practice can be used to improve or maintain surface and/or subsurface water quality and quantity. It reduces accelerated soil erosion, maintains or improves soil condition, and can improve or maintain riparian and watershed function. This practice applies to all lands where grazing and/or browsing animals are managed. For the purposes of this economic analysis, it is considered that the adoption of this BMP is permanent. The management unit of analysis is 500 acres on all pasture and rangeland acres deemed eligible for the practice.

BMP 7 Pasture Planting. Pasture planting involves planting (reseeding) of pastures with native or introduced vegetation and allows for the reduction and absorption of nutrients. Grass, forbs, legumes, shrubs, and trees work to restore a plant community similar to historically natural conditions. Further, native or introduced forage species that are well adapted to North Central Texas could be planted periodically to maintain a dense vegetative cover and improve the hydrologic condition of the rangeland. Similarly, well adapted perennial vegetation such as grasses, legumes, shrubs and trees could be planted in rangeland with medium to low vegetative cover (USDA National Resources Conservation Service 2010). For the purposes of this economic analysis, it is assumed that the expected life of this practice is 10 years. The management unit of analysis is 10 acres, with one acre reseeded and the remaining nine acres assumed to have adequate grass cover, on all pasture and rangeland acres deemed eligible for the practice.

BMP 8 Critical Pasture Area Planting. This BMP is similar to BMP7 (Pasture Planting), with two major variations. First, the "critical pastureland area" refers to gullied areas which require mechanical "shaping" prior to the reseeding operation which is not necessary with BMP 7. Second, the density of such critical areas and the associated requisite reseeding is less than that for BMP 7, with only one acre reseeded per 40 acres assumed to have adequate grass cover. For the purposes of this economic analysis, it is assumed that the expected life of this practice is 10 years. The management unit of analysis is 41 acres, with one acre reseeded and the remaining 40 acres assumed to have adequate grass cover, on all pasture and rangeland acres deemed eligible for the practice.

BMP 9 Grade Stabilization - Gully Plugs. Grade stabilization structures are constructed lakeside, along the stream bank, or across a gully or grass waterway with reinforcements placed to reduce erosion and sedimentation from steep embankments that are prone to soil loss during storm events. A dam or embankment drops water to a lower elevation while protecting the soil from gully erosion or scouring. Structures are typically a small dam and basin with a pipe outlet. Structures must be logistically situated for maximum effectiveness. Structures for this BMP are designed as "gully plugs," requiring approximately 4,500 cubic yards of dirt work per structure. For the purposes of this economic analysis, it is assumed that the expected life of this practice is 25 years. The management unit of analysis is one structure with one structure being appropriate for every 1,000 hectares (2,471 acres) of pasture and rangeland acres deemed eligible for the practice.

BMP 10 Prescribed Burning. Prescribed burning is the practice of applying controlled fire to a predetermined area to control undesirable vegetation and improve plant production quantity and/or quality. This practice has been shown to enhance seed and seedling production, facilitate distribution of grazing and browsing animals, and restore and maintain ecological sites. This BMP requires a period of pre-burn restricted grazing to allow for sufficient fuel load and post-burn restricted grazing enabling forage re-growth as well as a formal burn plan that complies with all applicable federal, state and local laws and regulations. For the purposes of this economic analysis, it is assumed that the expected life of this practice is 10 years. The management unit of analysis is 200 acres on all pasture and rangeland acres deemed eligible for the practice.

BMP 11 Brush Management. Brush management is the removal, reduction, or manipulation of woody trees and shrubs to restore desired vegetative cover to protect soil from erosion, reduce sediment, improve water quality, and enhance species diversity. Brush management practices can be accomplished using one or a combination of the following alternatives: mechanical, prescribed burning, chemical/herbicide applications, or biological (i.e. intensive grazing with goats). For the Eagle Mountain Lake watershed, it was determined that a combination of mechanical and chemical applications would be the most likely methods employed. For the purposes of this economic analysis, it is assumed that the expected life of this practice is 10 years. The management unit of analysis is 20 acres on all pasture and rangeland acres deemed eligible for the practice.

Urban BMPs

BMP 12 Phase II Urban Storm water BMP's. Phase II urban storm water practices represent a combination of educational programming for residents and the creation and enforcement of ordinances for new development and construction projects. These ordinances typically involve common practices such as utilization of sediment fences, porous pavement, storm water inlet protection, seeding and mulching, and the installation of wet ponds or sediment basins to accommodate storm water events (Andrews 2011; Ernst 2011). This annual program is assumed to realize an effectiveness of 50 percent. For the purposes of this economic analysis, it is assumed that the expected life of this practice is one year. The management unit of analysis is all urban areas in the Eagle Mountain Lake watershed.

BMP 13 Voluntary Urban Nutrient Management. This BMP uses education and outreach to control the effects of landscaping and lawn care practices on storm water. Lawns produce significant amounts of nutrient-rich storm water runoff, and research shows that such runoff can potentially cause eutrophication in streams, lakes, and estuaries. Research also suggests that suburban lawns and municipal properties produce more surface runoff than previously believed. Pesticide runoff can contaminate drinking water supplies with chemicals toxic to both humans and aquatic organisms. This BMP involves a continuing education program combined with annual soil testing by property owners to identify existing soil nutrient needs and discourage over-application of commercial fertilizer. For the purposes of this economic analysis, it is assumed that the expected life of this practice is one year. The management unit of analysis is all urban areas in the Eagle Mountain Lake watershed, except for those within the 2,000 foot boundary surrounding the lake which is the dominion of BMP 14 (Required Urban Nutrient Management).

BMP 14 Required Urban Nutrient Management in 2000 ft. buffer strips around Lake. This BMP focuses on the urban areas of the watershed inside the 2,000 foot boundary area immediately surrounding the Eagle Mountain Lake. Whereas BMP 13 is considered a "voluntary" program for property owners, BMP 14 is required of all property owners within the designated boundary area surrounding the lake. The '"required" nature of BMP 14 involves the formal (legal) development of required nutrient management protocols as well as the presence of an inspector whose job it would be to monitor compliance. Similarly to BMP 13, annual soil testing and an educational outreach program would be necessary. For the purposes of this economic analysis, it is assumed that the expected life of this practice is one year. The management unit of analysis is those urban areas within the 2,000 foot boundary surrounding Eagle Mountain Lake.

Channel BMPs

BMP 15. Herbicide Application to Riparian Corridor. This BMP involves the targeted application of herbicide within a 150 foot buffer width along the riparian corridor. Similar to BMP 11 (Brush Management) the purpose of this practice is to reduce, remove or manipulate the density of woody trees and shrubs and restore desired vegetative cover. This BMP is designed to protect soil from erosion, reduce sediment, improve water quality, and enhance species diversity. The herbicide can be applied using an aerial spraying strategy or individual plant treatment. For the purposes of this economic analysis, it is assumed that the expected life of this practice is five years. The management unit of analysis is one mile of riparian corridor (both sides) for all channel areas deemed appropriate for this practice within the Eagle Mountain Lake watershed.

BMP 16 Riparian Buffer Strips - Medium Erosion Areas. The purpose of establishing riparian buffer strips is to establish or maintain a good vegetative buffer and cover in and around the watershed channels. A riparian area is a fringe of land that occurs along the stream or water typically characterized by a dense complex of grass and herbaceous cover. If the riparian buffer is not adequately established and farming activities occur near the edge of the stream, the banks may become unstable, resulting in significant sloughing and channel scour. Establishing and maintaining a good riparian buffer may require fencing (i.e. livestock grazing exclusion) as a complimentary management practice to ensure the establishment of the buffer (USDA Natural Resources Conservation Service 2010). Management practices may also include waterway plantings to stimulate vegetative growth within the riparian corridor. For the purposes of this economic analysis, it is assumed that the expected life of this practice is 20 years. The management unit of analysis is one mile of riparian corridor (both sides) for all channel areas deemed appropriate for this practice within the Eagle Mountain Lake watershed, with the exception of 52.2 miles identified as critical erosion areas.

BMP 17 Riparian Buffer Strips - Only in Critical Areas. Similar to BMP 16, this BMP is focused on the critical areas of the watershed channels requiring substantial rehabilitative structures and associated infrastructure. The remediation practices involved with this BMP include structure development, fencing, and waterway plantings. For the purposes of this economic analysis, it is assumed that the expected life of this practice is 50 years. The management unit of analysis is one mile of riparian corridor (both sides) for the 52.2 miles of channel identified as a "critical area" and deemed appropriate for this practice.

BMP 18 Wetland Development - West Fork Trinity (302.1 acres). Constructed Wetlands provide a sediment retention and nutrient removal system utilizing the natural, chemical, physical, and biological processes involving wetland vegetation, soils, and their associated microbial populations to improve water quality. Constructed wetlands are designed to use water quality improvement processes occurring in natural wetlands, including high primary productivity, low flow conditions, and oxygen treatment to anaerobic sediments. Nutrient retention in wetland systems occurs via sorption, precipitation, and incorporation (USDA Natural Resources Conservation Service 2010). This BMP is designated to be implemented on 302.1 acres of the West Fork of the Trinity River. Among the many cost categories associated with a constructed wetland are: land acquisition costs, legal costs, mechanical land work, diversion and reentry structures, annual maintenance, and periodic dredging. For the purposes of this economic analysis, it is assumed that the expected life of this practice is 50 years. The management unit of analysis is one designated wetland project encompassing 302.1 acres.

BMP 19 Wetland Development - Walnut Creek (20.6 acres). This BMP is similar to BMP 18, but this wetland is designated to be implemented on 20.6 acres along Walnut Creek. The purpose for this BMP and general cost categories to obtain the land, establish the wetland, and maintain its functionality are identical to BMP 18. For the purposes of this economic analysis, it is assumed that the expected life of this practice is 50 years. The management unit of analysis is one designated wetland project encompassing 20.6 acres.

In-Lake BMPs

Based on feedback from TRWD personnel, it was noted that BMP 20 (Hypolimnetic Aeration) and BMP 21 (P Inactivation with Alum) are mutually exclusive. In other words, the final management plan could incorporate one of the practices, but not both.

BMP 20 Hypolimnetic Aeration. Hypolimnetic aeration is intended to provide oxygen to the bottom of the reservoir to prevent anaerobic conditions from occurring. Anaerobic conditions allow for the chemical bonds between iron or calcium with phosphorous to break, liberating the phosphorous for algae consumption. A flux of sediment phosphorous has been estimated for

Eagle Mountain Lake and aeration could reduce this flux to a certain extent. For the purposes of this economic analysis, it is assumed that the expected life of this practice is 20 years. The management unit of analysis is one designated hypolimnetic aeration project within the Eagle Mountain Lake watershed.

BMP 21 P Inactivation with Alum. The addition of powdered alum at various lake depths is designed to suppress the mixing and transport of P. Alum settles P to the bottom of the reservoir and prevents the utilization of the nutrient by aquatic plant life, thereby preventing the development of eutrophic conditions. For the purposes of this economic analysis, it is assumed that the expected life of this practice is 20 years. The management unit of analysis is one designated P Inactivation with Alum project within the Eagle Mountain Lake watershed.

WWTP and Watershed BMPs

Waste Water Treatment Plant (WWTP) data were obtained from an October 2008 Alan Plummer Associates Inc. report titled, "Eagle Mountain Wastewater Treatment Facilities Report." This report addressed wastewater treatment facilities discharging directly into the Eagle Mountain Lake or through watershed streams that eventually enter the lake. No Level II or Level III permits were anticipated for three of the WWTPs to ensure operating parameters because these facilities were below the minimum size threshold flow of 0.02 millions of gallons per day (Fort Worth Boat Club, Garrett Creek Ranch, and Larry Buck RV Park). The remaining 11 WWTPs are the focus of BMPs 22 and 23.

BMP 22 Wastewater Treatment Plant (WWTP) from Level I to Level II quality status. BMP 22 is an investigation of the effects of permitting the wastewater treatment plants in the Eagle Mountain Lake watershed to a 1 mg/L level of P and 10 mg/L level of N. In the evaluation of the Eagle Mountain Lake watershed WWTPs, the Alan Plummer Associates study team considered three levels of treatment. Level I is the current level of treatment, as dictated by the existing discharge permit limits, with the capacity of the plants assumed to be expanded to satisfy 2050 projected flows. It is assumed that all plants would be upgraded at Level I to satisfy future demand. Achieving Level II quality status includes the costs associated with upgrades necessary to reduce P to 1.0 mg/L and N to 10 mg/L. For each of the WWTPs, the additional costs associated with the necessary upgrades as well as additional operating and maintenance costs are provided in the Alan Plummer Associates report (Alan Plummer Associates, Inc. 2008). For the purposes of this economic analysis, it is assumed that the expected life of this practice is 50 years. The management unit of analysis is one designated project, encompassing the transition from Level I to Level II quality status by all WWTPs subject to the permitting regulations.

BMP 23 Wastewater Treatment Plant (WWTP) from Level I to Level HI quality status. BMP 23 is similar to BMP 22, but involves additional upgrades to the WWTPs to attain Level III quality status through 2050. Achieving Level III quality status includes the costs associated with upgrades necessary to reduce P to 0.5 mg/L and N to 5 mg/L. For each of the WWTPs, the additional costs associated with the necessary upgrades as well as additional operating and maintenance costs are provided in the Alan Plummer Associates report. These costs are inclusive of the estimates for each WWTP to transition from Level I to Level II and then contain additional expenses (upgrade and operating and maintenance) to transition to the Level III quality standards. For the purposes of this economic analysis, it is assumed that the expected life of this practice is 50 years. The management unit of analysis is one designated project, encompassing the transition from Level I to Level III quality status by all Eagle Mountain Lake watershed WWTPs subject to the stricter permitting regulations.

BMP 24 Flood Protection Sites (Big Sandy and Sandy Creek). BMP 24 addresses the possibility of constructing new ponds to serve as flood protection sites. This BMP involves construction and maintenance of 17 designated new pond sites; 13 located in the Big Sandy area of the watershed and 4 located in the Salt Creek area. In total, the 17 proposed ponds would contain 386 surface area acres, ranging in size from 9 to 43 surface area acres. The purpose of this BMP is to use strategically located ponds as a water retention tool that will reduce erosion and reduce nutrient and sediment runoff into the reservoir. For the purposes of this economic analysis, it is assumed that the expected life of this practice is 50 years. The management unit of analysis is one designated project, encompassing all 17 designated flood protection sites in the Big Sandy and Salt Creek areas of the Eagle Mountain Lake watershed.

APPENDIX E. TECHNICAL NOTES – ECONOMIC ANALYSIS

During 2009-2011, Texas A&M AgriLife Extension Service and Texas A&M AgriLife Research scientists, in conjunction with Tarrant Regional Water District (TRWD) managers, NRCS professionals, and others worked to identify a portfolio of BMPs capable of contributing to such reductions. The economics component of this project consisted of integrating water quality modeling results with the associated costs of BMP implementation.

Based on the marginal adoption rate, described below, and the potential spatial areas affected, the original SWAT and WASP estimates of the effectiveness levels for the BMPs in terms of their impacts in reducing TP, TN, and sediment inflows into the Eagle Mountain Reservoir were adjusted.

The final task was to identify the optimal suite, or cost-effective combination, of BMPs that could be expected to achieve the management target of a 30 percent reduction in TP inflow into the Eagle Mountain Reservoir.

ADOPTION RATES

Discussions with project collaborators, stakeholders, and decision-makers responsible for adopting and implementing the BMPs were asked to identify various adoption rates with and without assistance through cost-share programs or other incentives. Also identified during these discussions were levels of incentives that would be required to induce landowners to participate in implementing the various agricultural BMPs. The adoption rate used in the WPP represents that portion of the total area in which a BMP is likely to be implemented, considering property owners' goals and objectives, economic incentives, and other relevant conditions. The following levels of adoption were discussed.

The *current adoption rate* indicates the expert panel's assessment of existing adoption for the BMP practice within the Eagle Mountain Reservoir Watershed.

The *most likely adoption rate* represents an adoption rate that participants identified as a realistic rate that could be expected with a combined effort of promotion, education and assuming adequate funding is available to construct and maintain the respective BMPs through a long-term planning horizon.

The *feasible adoption rate* represents the maximum expected rate for each BMP that could be expected. This scenario recognizes that convincing all stakeholders would never be possible for many of the land management practices even if incentives were provided.

The *marginal adoption rate* was used and considers the additional implementation of each BMP between the current and most likely rates. The marginal adoption rate reflects the additional implementation (to the current level) for each BMP in the watershed that could be expected if an adequate level of incentives were provided as part of a watershed protection program.

COSTS FOR IMPLEMENTATION

The cost information for each BMP was assessed through consultations with agency professionals and was thoroughly discussed and reviewed among expert panel members and stakeholders. The sequence and timing of establishment, operation and maintenance costs as well as the expected duration for each BMP was constructed to reflect a 50-year planning period. For each BMP considered, additional specifications were declared, allowing the calculation of units (e.g., acres, structures, etc.) that could be imposed on the potentially eligible spatial areas. This was necessary to aggregate the cost of implementing each BMP across the area represented by the marginal adoption rate.

The net present value (NPV) of all costs over the expected useful life of each BMP were calculated. In addition, an annuity equivalent value (AEV) was calculated for each of the BMPs, assuming implementation of the marginal adoption rates within the SWAT- (and WASP-) designated sub-watershed areas of the Eagle Mountain Reservoir Watershed. A social discount rate of 4.20 percent was assumed to facilitate calculations of net present values and annuity equivalent values. These two cost calculations are analogous to the concepts of an investment in a residential mortgage. The NPV calculation represents the value of the mortgage (i.e. a $200,000 home), while the AEV calculation would be synonymous with an annual payment with a loan rate of 4.20 percent. Table E-1 shows the estimated annual cost of BMPs with respect to reductions in TP, TN, and sediment loads.

Table E-1. Cost of BMPs Evaluated for Eagle Mountain Reservoir Watershed

		Annual Cost for Reduction in:		
		Total P	Total N	Sediment
BMP	Description	$/kg	$/kg	$/ton
1	Conversion of Cropland to Grass/Hay	$ 55.31	$ 18.88	$ 34.56
2	Fertilizer Management - 25% reduced P	$ 441.45	$ NA	$ NA
3	Establish Filter Strips	$ 6.39	$ 2.66	$ 3.64
4	Establish Grassed Waterways	$ 9.65	$ 24.54	$ 4.60
5	Terracing	$ 53.39	$ 23.81	$ 29.85
6	Prescribed Grazing	$ 215.65	$ 200.37	$ 428.01
7	Pasture Planting - reseeding	$ 209.35	$ 194.51	$ 415.49
8	Critical Pasture Planting - shaping	$ 1,005.37	$ 53.75	$ 489.06
9	Grade Stabilization - gully plugs	$ 14.92	$ 3.50	$ 8.10
10	Prescribed Burning	$ 72.62	$ 42.87	$ 69.37
11	Brush Management	$ 285.78	$ 265.53	$ 257.81
12	Phase II Urban Storm water BMPs	$ 421.33	$ NA	$ 491.90
13	Voluntary Urban Nutrient Mgt.	$ 389.18	$ 83.89	$ NA
14	Required Urban Nutrient Mgt.	$ 27.06	$ 32.33	$ NA
15	Herbicide Application - Riparian corridor	$ 15.37	$ 14.28	$ 13.87
16	Riparian Buffer Strips - Med Erosion Areas	$ 1,431.70	$ 313.00	$ 81.54
17	Riparian Buffer Strips - Critical Areas	$ 998.83	$ 201.57	$ 65.24
18	Wetland Development - West Fork Trinity	$ 298.97	$ 32.45	$ 87.58
19	Wetland Development - Walnut Creek	$ 538.23	$ 94.71	$ 197.49
20	Hypolimnetic Aeration	$ 62.43	$ NA	$ NA
21	P Inactivation with Alum	$ 110.92	$ NA	$ NA
22	WWTP - Level I to Level II	$ 416.69	$ NA	$ NA
23	WWTP - Level I to Level III	$ 1,153.13	$ 2,306.26	$ NA
24	Flood Protection Sites - Big Sandy/Salt Creek	$ 204.82	$ 173.31	$ $180.24

EFFICIENCY RANKINGS

Explicit recognition of the initial SWAT effectiveness levels for TP, TN, and sediment for each BMP were incorporated into the analysis, along with the details of the eligible spatial area of the watershed and the selected adoption rate of each BMP. The cost and nutrient and sediment reduction information presented is also transformed to relate the annual cost per unit of TP, TN, and sediment reduction. In calculating these costs per unit of reduction, each item is evaluated independently, assuming all costs are associated with reducing that item (TP, TN, or sediment) and ignoring any allocation of costs toward reducing the others.

Each BMP was assessed by its cost per kilogram of TP reduction, and the BMPs were ranked by their costs to identify their relative cost-efficiency. This ranking integrates the annual cost of BMP implementation with the respective efficiency in addressing TP reduction in the watershed.

OPTIMAL SUITE OF BMPs

In order to determine how many BMPs are needed to achieve the 30 percent TP reduction goal, SWAT modeling incorporated sequential adoption of BMPs beginning full adoption of the most cost-efficient BMP at is marginal adoption rate and then advancing to the next most cost-efficient BMP. The environmental implications of this implementation were successively tabulated to determine if additional BMPs were necessary. BMP implementation was targeted at the sub-basin level which indicated the greatest potential for total P reduction. The process was repeated until the watershed management goal of 30 percent total P reduction was achieved. This list of BMPs is identified as the cost-efficient BMP suite since the selection was based solely on the BMPs which were found to be the most efficient in terms of lowest cost per unit of TP reduction.

Cropland BMPs are the greatest contributors, providing 44.4 percent of the expected reduction. Flood protection sites BMPs are second in importance contributing 13.4 percent of the total reduction, followed by urban BMPs at 12.1 percent, pasture and range BMPs at 11.2 percent, reservoir-in-lake BMPs at 10.5 percent, and channel BMPs at 8.3 percent. The takeaway from this illustration is that a comprehensive suite encompassing participation by six distinctly different categories of cooperators is needed to achieve the watershed management plan objectives. Additionally, the combined contributions by agricultural cropland and agricultural pasture and range BMPs (55.6 percent) underscore the importance of programs that secure agriculture's participation in the Eagle Mountain Lake WPP.