

Buckeye Lake Nutrient Assessment and Management Recommendations

FINAL

December 2014

Prepared for
U.S. Environmental Protection Agency, Region 5
and
Ohio Environmental Protection Agency

Prepared by
Tetra Tech, Inc.

1. Introduction

Excess nutrients have been identified as the source of nuisance algal blooms in Buckeye Lake, in central Ohio (Figure 1). These nutrients may come from a wide range of sources, including runoff from cropland, animal feeding operations (AFO), urban stormwater, failing septic systems, and wildlife. Internal loading of phosphorus is also believed to be a significant source of nutrients in Buckeye Lake. USEPA Region 5 is using Buckeye Lake as a pilot project to evaluate and demonstrate the most effective ways to reduce nutrient loads in largely agricultural watersheds. The goal of this project was to provide technical support for Ohio EPA’s comprehensive nutrient management efforts in Buckeye Lake and its watershed.

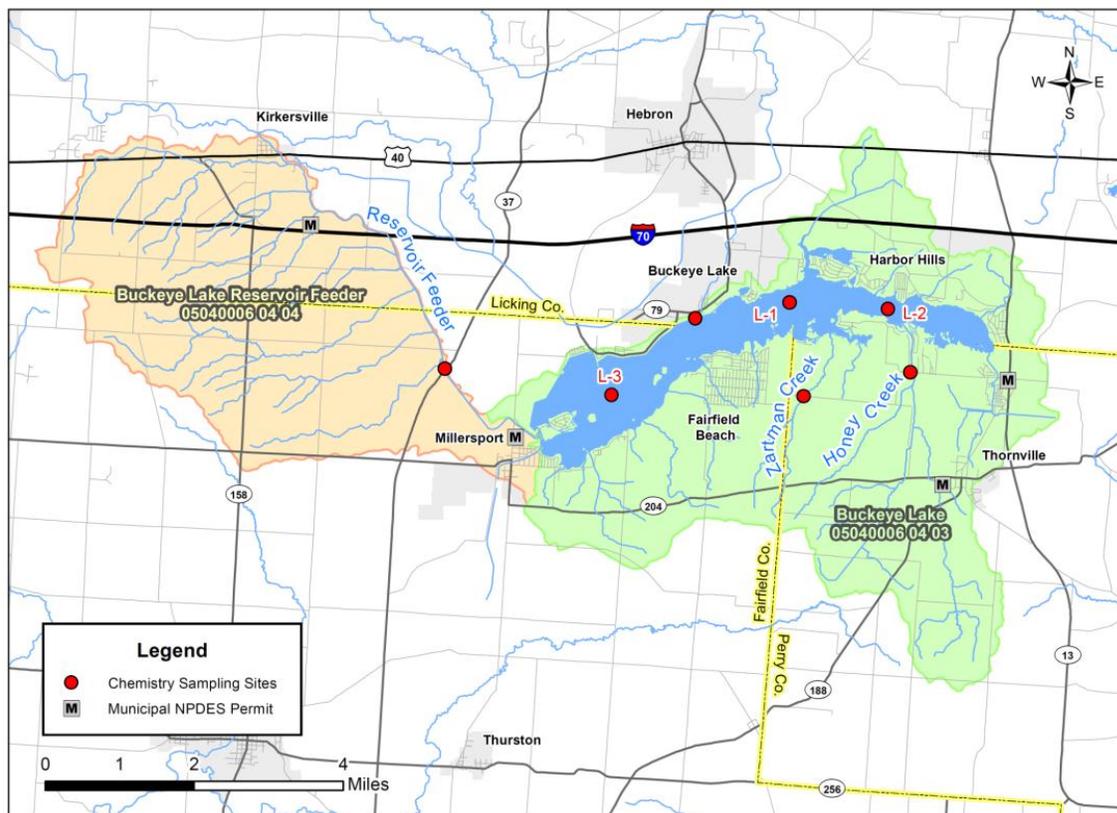


Figure 1. Buckeye Lake watershed showing existing water quality monitoring stations.

2. Background

Buckeye Lake is located approximately 30 miles east of Columbus, Ohio. The lake has a surface area of 3,200 acres and a mean depth of approximately five feet. Buckeye Lake drains two 12-digit hydrologic unit codes (HUCs) – 05040006 04 03 and 05040006 04 04 – shown in Figure 1. The lake outlet flows into the South Fork Licking River to the north. The Buckeye Lake watershed primarily consists of row crop agriculture (53.5%), with remaining land use of grass/pasture (12.8%), forest (15.9%) and developed land (16.6%). There are two significant point sources in the watershed: Millersport Sewage Treatment Plant (STP) and Thornville Wastewater Treatment Plant (WWTP), which discharges to Honey Creek. Both point sources have NPDES permits and total phosphorus (TP) limits of 1.0 mg/L. The Buckeye Lake watershed includes several population centers including Buckeye Lake, Harbor Hills, Thornville, Fairfield

Beach, and Millersport. Figure 1 also shows two other municipal NPDES permit holders. The facility near the east edge of Buckeye Lake serves Crown Wehrle Estates and discharges outside of the watershed to Jonathan Creek. The facility along the Reservoir Feeder Creek near I-70 serves Regal Inn Motel and is largely diverted into the South Fork Licking River due to a diversion structure located near Kirkersville Cemetery.

3. Evaluation of Existing Efforts

Tetra Tech reviewed and evaluated existing efforts by Ohio EPA and Buckeye Lake for Tomorrow, Inc. (BLT) including all water and sediment quality monitoring efforts and data, nutrient modeling efforts, and existing nutrient reduction plans. Tetra Tech provided technical support to Ohio EPA modeling staff and provided suggestions for modeling nutrients (phosphorus) in Buckeye Lake. Ohio EPA completed a phosphorus mass balance model for Buckeye Lake which was used to assess nutrient loading dynamics to Buckeye Lake as well as to identify where more information needs to be collected.

Tetra Tech staff also attended a two day stakeholder meeting at Buckeye Lake and met with Ohio EPA staff, BLT members, Ohio DNR representatives, Fairfield County Soil and Water Conservation District, and concerned lake residents. During their visit to Buckeye Lake Tetra Tech toured the lake and shoreline as well as the watershed. Tetra Tech also presented their initial assessments of Buckeye Lake water quality and nutrient loading, nutrient modeling efforts, and outlined possible nutrient reduction strategies.

3.1. Assessment of Existing Water Quality and Nutrient Dynamics

Water quality monitoring efforts at Buckeye Lake by Ohio EPA were conducted in 2011 and 2012. During this effort three tributary sites were monitored (Reservoir Feeder Creek, Zartman Creek and Honey Creek) in addition to three in-lake locations (L-1, L-2, and L-3) and the lake outlet (Wasteweer Run on the lake's north side). These monitoring locations are shown in Figure 1 and indicated by red dots. Ohio EPA also collected sediment cores at the three in-lake monitoring locations.

3.1.1. BUCKEYE LAKE WATER AND SEDIMENT QUALITY

Buckeye Lake is a shallow, hyper-eutrophic lake as indicated by high concentrations of TP and chlorophyll (chl). Nuisance algal blooms caused by excessive nutrient concentrations (phosphorus) have become common at Buckeye Lake and in some cases produce toxins (i.e., microcystin). Weekly monitoring for algal toxins is conducted at Brooks, Crystal, and Fairfield beaches at Buckeye Lake to notify those using the beaches when water conditions are unfavorable for swimming and other recreational activities. Average microcystin concentrations at the three beaches in 2011, 2012, and 2013 were 2.6, 4.0, and 26 µg/L, respectively, with maximum concentrations occurring at Fairfield beach in 2013. The Ohio Department of Public Health recommends posting a public health advisory when microcystin concentrations are above 6 µg/L and a no contact advisory when microcystin concentrations are at or exceed 20 µg/L.

TP concentrations measured at the three in-lake monitoring locations in 2011 and 2012 are shown in Figures 2 and 3. In both 2011 and 2012 TP concentrations in the lake follow a similar pattern with peak concentration occurring in the late summer. This is a typical pattern for lakes that experience internal loading of phosphorus as demonstrated by the increase in water column phosphorus concentrations during late summer period when external loading is at a minimum. Hydrologic conditions in 2012 were much drier during the summer than in 2011 which most likely led to higher internal loading of phosphorus and subsequent higher TP concentrations at L-1.

Annual mean TP concentrations, using data from all three in-lake locations, was 109 µg/L in 2011 and 121 µg/L in 2012. These concentrations are much higher than the in-lake TP concentration goal of 50 µg/L (BLT 2013). The data collection time periods were slightly different in 2011 than in 2012, with collection efforts in 2011 starting in May and extending through December and efforts in 2012 starting in March and extending through October. To compare nutrient concentrations during similar time periods for 2011 and 2012, summer (June through September) means were calculated using data from all three in-lake locations. Annual and summer mean TP, chl and Secchi disk depth (measure of water column transparency) for 2011 and 2012 are summarized in Table 1. Summer means and annual maximum and minimum whole lake means for 2011 and 2012 are also compared to historical data collected in 1973 in Table 1. Samples were collected on three dates in 1973 during the open-water season at three stations and results reported as ranges, means, and medians in a 1975 report by USEPA (USEPA 1975).

Summer mean TP concentrations in Buckeye Lake in 2011 and 2012 are slightly less or similar to the mean TP concentration in July 1973; however, summer mean chl concentrations in 2011 and 2012 are slightly higher than in July 1973. Mean summer Secchi disk depth in 2011 and 2012 is the same as measured in July 1973.

Ohio EPA collected sediment cores at the three in-lake water quality monitoring locations. These sediment cores were sectioned and analyzed for TP, organic phosphorus, biogenic phosphorus, iron bound phosphorus and aluminum bound phosphorus. Sediment cores at L-1, the deepest location, had the highest TP concentration (~1600 mg/kg) of the three locations. The high TP concentrations in the sediment at L-1 were mostly due to high concentrations of organic phosphorus and biogenic phosphorus. Under the right conditions, organic and biogenic phosphorus can mobilize out of the lake sediments into the overlying water column where it can become available for algal and plant uptake. TP concentrations in the sediment cores at L-1 in Buckeye Lake were very similar to TP concentrations in Lake Ketchum, WA which is the most hypereutrophic lake in Washington State. Legacy sediment phosphorus from historic agricultural impacts in Lake Ketchum continue to fuel internal phosphorus loading leading to excessive algal blooms.

Table 1. Annual and summer whole lake mean TP, chl, and Secchi disk depths calculated for Buckeye Lake in 2011 and 2012 compared to historical data collected in 1973. Annual whole lake maximum and minimums as well as number of observations for 2011 and 2012 are in parentheses following the annual mean value.

Recent Data: Annual Mean			
Year	Mean TP (µg/L)	Mean Chl (µg/L)	Mean Secchi Disk (m)
2011	109 (46 to 223, n = 14)	170 (57 to 266, n = 14)	0.3 (0.2 to 0.5, n = 14)
2012	121 (49 to 214, n = 13)	143 (55.5 to 252, n = 13)	0.3 (0.2 to 0.5, n = 13)
Recent Data: Summer Mean			
2011	121	197	0.3
2012	160	196	0.3
Historical Data			
Date	TP (µg/L)	Chl (µg/L)	Secchi Disk (m)
4/26/1973	173	247	0.2
7/30/1973	165	141	0.3
10/8/1973	273	172	0.3

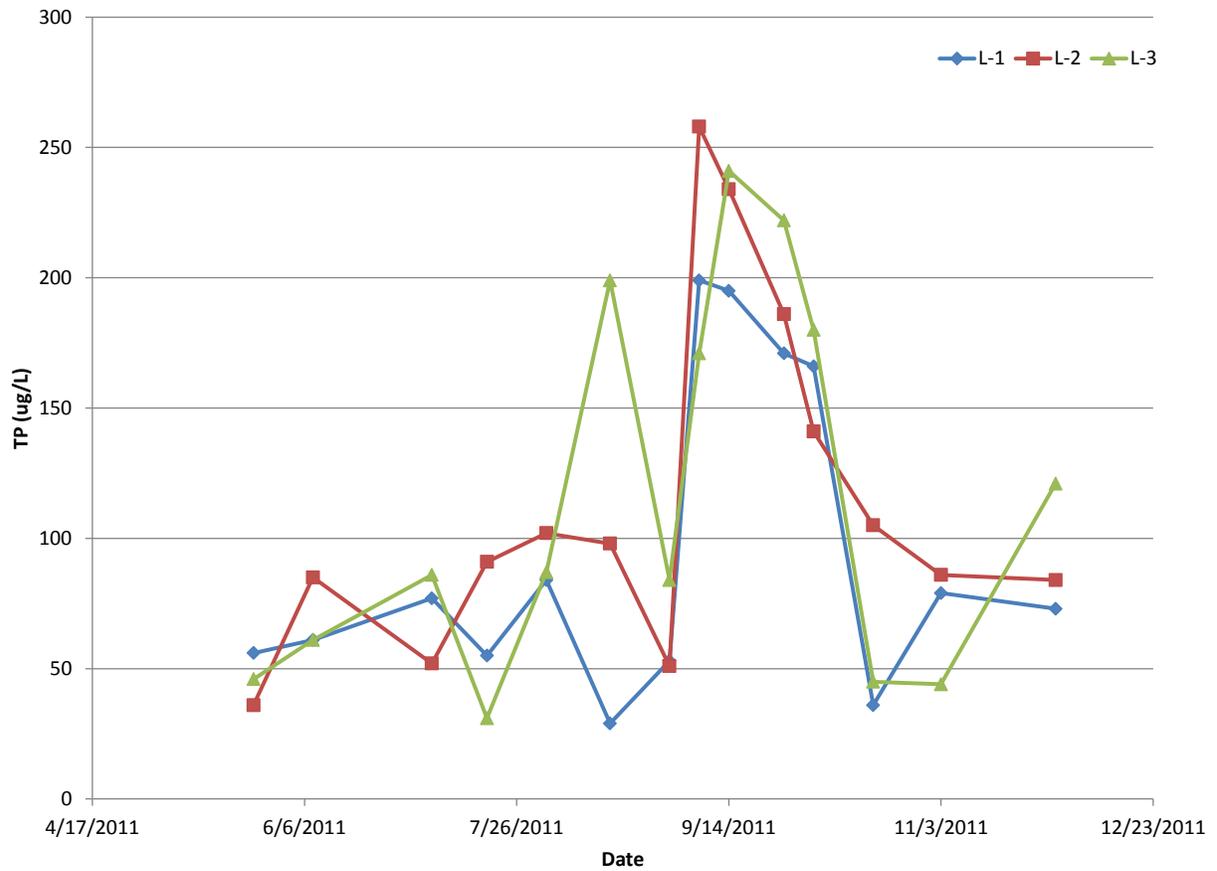


Figure 2. TP Concentrations at Stations L-1, L-2, and L-3 in Buckeye Lake, 2011.

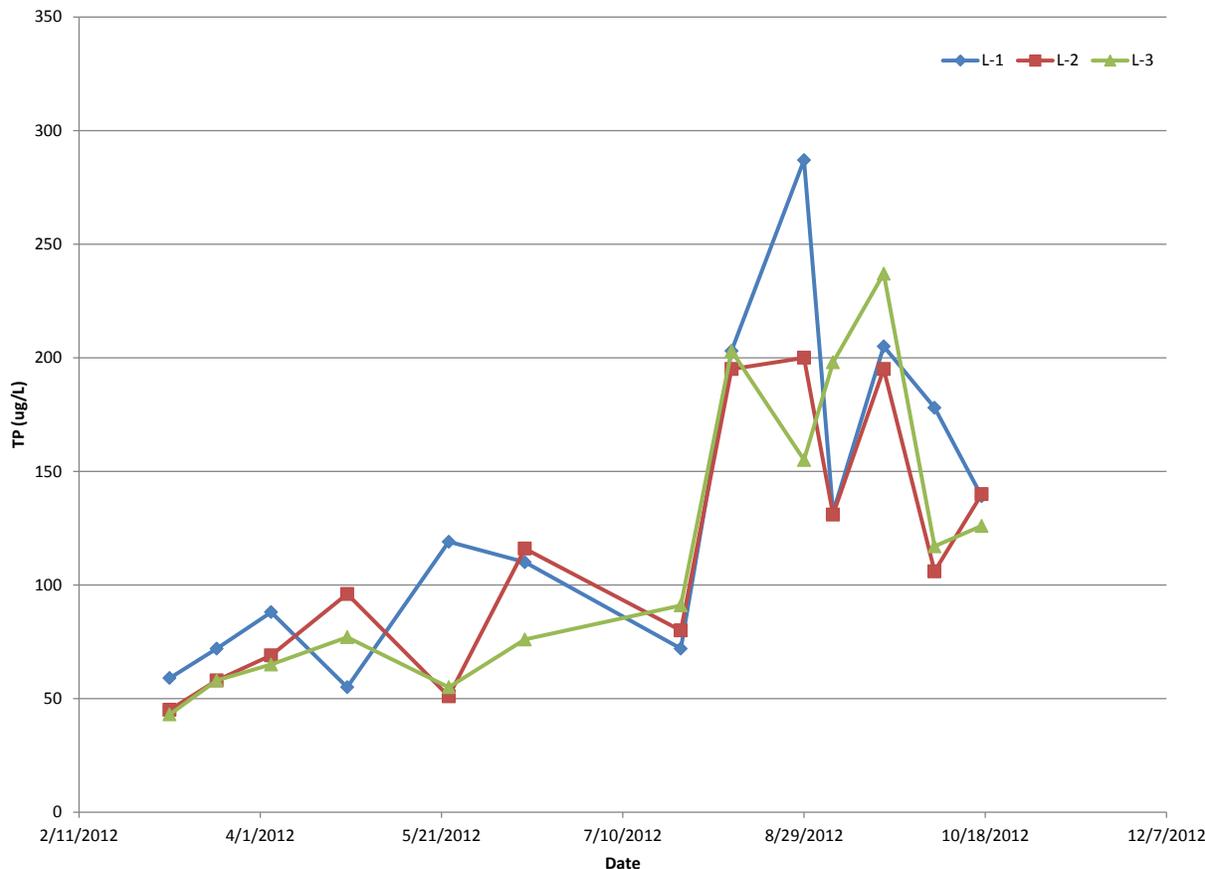


Figure 3. TP Concentrations at Stations L-1, L-2, and L-3 in Buckeye Lake, 2012.

3.1.2. BUCKEYE LAKE TRIBUTARY WATER QUALITY

Buckeye Lake has three main tributaries that were sampled by Ohio EPA in 2011 and 2012. Reservoir Feeder Creek has a drainage area of 16.9 square miles, although only 11.9 square miles actually drains into the lake according to Ohio EPA. This is due to a diversion structure located near Kirkersville Cemetery which diverts flow into an eastwards-flowing ditch called Pigeon Swamp ditch. It is thought that except for very high flows, none of the flow above this diversion structure drains into Buckeye Lake. Zartman Creek has a drainage area of 1.74 square miles and Honey Creek has a drainage area of 6.9 square miles. The rest of the watershed consists of minor tributaries and nearshore drainage and is 14.3 square miles in size.

Annual and summer mean TP concentrations for the three tributaries sampled by Ohio EPA are summarized in Table 2. Mean TP concentrations in 2011 and 2012 are also compared to historical mean TP concentrations from samples collected during May 1973 through April 1974 in Table 2. There was no historical TP data collected for Zartman Creek in 1973 or 1974.

Tributary mean TP concentrations in 2011 and 2012 were significantly lower than mean TP concentrations observed in 1973/1974 both on an annual basis and on a summer (June-September) basis. Mean TP concentrations in Honey Creek were an order of magnitude smaller in 2011 and 2012 than mean observed in 1973/1974. This dramatic reduction in TP is most likely due to improvements made to the Thornville WWTP which reduced TP concentrations in their effluent. Reductions in TP in Reservoir Feeder Creek are most likely due to watershed improvements, best management practices (BMPs) and

land use changes. The Reservoir Feeder Creek sampling location in 1973/1974 was upstream of Millersport STP and would not have captured any additional phosphorus loading as a result of discharge from the STP. This also indicates that the reduction in TP in Reservoir Feeder Creek is mostly likely due to watershed improvements and BMPs is not attributed to improvements at Millersport STP. According to the BLT Buckeye Lake Nutrient Reduction Plan (2013) the TP concentration target goal for tributaries to Buckeye Lake is 50 µg/L on an annual basis. Based on the 2011 and 2012 data collected by Ohio EPA, Honey Creek and Zartman Creek are currently meeting that goal.

Table 2. Annual and summer mean TP calculated for major Buckeye Lake Tributaries in 2011 and 2012 compared to historical data collected in 1973. Annual maximum and minimums as well as number of observations are in parentheses following the annual mean value.

Year	Feeder Creek	Honey Creek	Zartman Creek
Annual Mean TP (µg/L)			
1973-1974	239 (35 to 1,150, n = 14)	214 (108 to 460, n = 14)	no data
2011	115 (14 to 571, n = 13)	66 (22 to 112, n = 13)	31 (5 to 103, n = 13)
2012	77 (21 to 204, n = 9)	47 (14 to 73, n = 15)	33 (5 to 71, n = 15)
Summer Mean TP (µg/L)			
1973-1974	415	279	no data
2011	90	66	26
2012	113	55	41

Current TP concentrations in the major tributaries to Buckeye Lake are lower than current TP concentrations within the lake, both in terms of annual means and summer means. This indicates that there is an internal source of phosphorus contributing to the TP concentration within the lake, which is most likely a driving factor of the nuisance algal blooms. In addition, the relatively high numbers of waterfowl (Canadian geese) are important contributors to the phosphorus loading in the lake. However, loading from waterfowl is limited to only certain portions of the year (i.e., ice free periods) and therefore is unlikely to be the single most significant source of phosphorus in the late summer.

3.1.3. BUCKEYE LAKE NUTRIENT MODELING AND DYNAMICS

Ohio EPA staff created a phosphorus mass balance model for Buckeye Lake, with technical assistance from Tetra Tech, to better understand the magnitude and timing of external and internal phosphorus loading into Buckeye Lake. The phosphorus mass balance model was determined for the time period from May 2011 to October 2012 and utilized all available tributary and lake data collected during that time period. Ohio EPA staff used a Hydrological Simulation Program FORTRAN (HSPF) to estimate daily flows from the tributaries into Buckeye Lake. The flow records were separated into Reservoir Feeder Creek, Zartman Creek, Honey Creek, and the remaining basin drainage. A CE-QUAL-W2 model was used to model the lake outputs, including outflow and surface evaporation. Once calibrated the phosphorus mass balance model was used to run restoration scenarios.

Results from the Ohio EPA mass balance modeling of Buckeye Lake showed that internal loading is the dominant phosphorus loading mechanism during the summer months (June-September). In 2011, internal loading accounted for 90 percent of the total summer TP load and in 2012 internal loading accounted for 78 percent of the total summer TP load. The 2011 and 2012 summers were different in terms of weather. While the middle of the summer in 2011 was considerably wetter than that of 2012, large precipitation

events in early and late summer 2012 caused the total amount of external loading to be more than double the previous year. There were similar levels of internal loading during both summers but varying levels of external loading.

Annually (considering loading from October 23rd, 2011 to October 20th, 2012), internal and external loading of phosphorus to Buckeye Lake was very similar, contributing 49 percent and 51 percent, respectively, of the total load. Of the total annual phosphorus load to Buckeye Lake, Reservoir Feeder Creek contributed 23 percent while minor tributaries and the nearshore drainage contributed 20 percent, according to the mass balance. Honey Creek contributed 4.5 percent of the annual TP load and Zartman Creek only 1.1 percent. The load from Thornville WWTP is accounted for in the Honey Creek loading while Millersport STP loading was similar to that of Zartman Creek at only 1.3 percent.

While evaluating the phosphorus mass balance it became evident that there were some data gaps associated with the model. The largest data gap is the lack of flow data and general understanding of the hydrology/hydraulics of the lake and its watershed. There is no continuous flow data and only a few instantaneous flow measurements for the major tributaries into Buckeye Lake; hence the need for using HSPF to determine flows into the lake. It appears that the HSPF model was able to provide a good estimate of flow for Honey and Zartman Creeks (r^2 values of 0.79 and 0.76 respectively; Ohio EPA 2014) however for Reservoir Feeder Creek the HSPF model was not particularly accurate at estimating flows (r^2 value of 0.46), especially during times of high flow (Ohio EPA 2014). A model (CE-QUAL-W2) was also used to determine lake outflow and lake level which is very important to a mass balance and dictates the mass of phosphorus in the lake at a given time.

Regardless of the limitations associated with the inflow, outflow, and lake level data, it is evident that internal loading in the summer is occurring and driving the productivity of the lake.

3.2. Review of Existing Nutrient Management Plan

BLT along with the Fairfield Soil and Water Conservation District and Ohio DNR are aggressively working in the watershed to reduce nutrients flowing into Buckeye Lake. Some of the activities these groups have completed include: an extensive tributary assessment and study, community outreach/education and awareness, and the development of a Buckeye Lake Nutrient Reduction Plan. Ohio EPA is responsible for monitoring water quality parameters in the lake via an YSI water quality sonde.

The extensive tributary assessment and study included walking over 90 miles of tributaries feeding into Buckeye Lake and documenting the overall condition of each stream, inventorying drain tiles, and collecting some water quality samples. Fairfield Soil and Water Conservation District personnel led a watershed tour and shared their knowledge of conditions throughout the watershed with Tetra Tech. The information and data collected during the tributary assessment will be extremely valuable when considering and designing projects within the watershed to remove excess nutrients.

The current draft of the Buckeye Lake Nutrient Reduction Plan (BLT 2013) outlines several nonpoint source and in-lake nutrient control strategies that could be implemented at Buckeye Lake. Tetra Tech reviewed the assessment of these strategies in the plan and is in agreement with the conclusions and applicability of each strategy. However, in-lake plant harvesting would most likely have a very small to negligible impact on the internal cycling of phosphorus and overall TP concentration in Buckeye Lake. In-lake plant harvesting would be beneficial for opening boating lanes and providing access to shoreline property but most studies have shown phosphorus concentrations following in-lake plant harvesting were either unchanged or increased (Cooke et al. 2005).

The plan also includes an implementation strategy and schedule and recognizes that improving water quality in Buckeye Lake will need to be a multi-year effort and will require a long term commitment from stakeholders. Both the external load reduction and internal load reduction strategies in the BLT plan include actions that Tetra Tech would recommend to reduce loading of excess nutrients to Buckeye Lake. The BLT Buckeye Lake Nutrient Reduction Plan suggests the following actions for reducing nutrients in Buckeye Lake:

- External Load Reduction
 - Reduce nutrients entering the lake from stream and tributaries that flow into Feeder Creek,
 - Expand the use of cover crops to improve nutrient retention in the soil and reduce erosion especially during early spring runoff,
 - Further implement the 4R concept: Right fertilizer source, at the Right rate, at the Right time, and in the Right place,
 - Introduce the use of bank stabilization techniques along the steep embankments of Feeder Creek to reduce amount of sediment entering the lake,
 - Install a newly constructed wetland at Brooks Park to control unexplained excess nutrients entering the lake from this tributary,
 - Install a newly constructed wetland to control nutrient loading coming into the lake and to adjust water temperatures in run-off from the near Interstate 70 rest area.
- Internal Load Reduction
 - Canada Geese population management and removal,
 - Lake dredging at the east end of the lake to remove nutrient rich sediment,
 - Alum application to the deepest section of the lake near the center No-Wake area where the lake sediment contains the highest concentrations of phosphorus.
- Education and Communication
 - Pick-up after your Pet campaign,
 - Encourage the use of No-Phosphorus fertilizer on lawns and landscaping,
 - Insist that residents and visitors do not feed the geese,
 - Encourage the use of compost for yard waste instead of dumping leaves and grass clippings into the lake,
 - Encourage fishermen to catch and keep carp from the lake.

3.3. Modeled Nutrient Reduction Scenarios

Ohio EPA staff, with guidance from Tetra Tech, ran the calibrated phosphorus mass balance model for Buckeye Lake for several nutrient reduction scenarios. These nutrient reduction scenarios were run over a time period of several years and included setting the TP concentrations for Feeder, Honey, Zartman Creeks, and the nearshore drainage to 50 µg/L (the tributary TP goal, BLT 2013). With external loading set at 50 µg/L the model was then run with internal loading reductions of 20 percent, 50 percent, and 80 percent. Running various nutrient reduction scenarios in the mass balance model helps to predict and understand the lake's response to reductions in both external and internal loading.

Figure 4 shows the model results for the various nutrient reduction scenarios. Although the scenarios were run for several years only one year is shown in Figure 4 for comparison. Reducing external loading down to the target tributary TP goal results in only a slight decrease in lake TP during late summer and fall. When reductions in external loading are combined with a reduction in internal phosphorus loading the lake TP concentrations are further reduced; however only when external loading has been reduced and internal loading is reduced by 80 percent does the lake TP concentration fall below the target goal of 50 µg/L (Figure 4). This indicates that **both** external and internal loading in Buckeye Lake need to be aggressively reduced to achieve the target goal of 50 µg/L in the lake. Even with a lake concentration of 50 µg/L, Buckeye Lake would still see episodic nuisance blooms of algae but it would be a significant improvement over existing conditions.

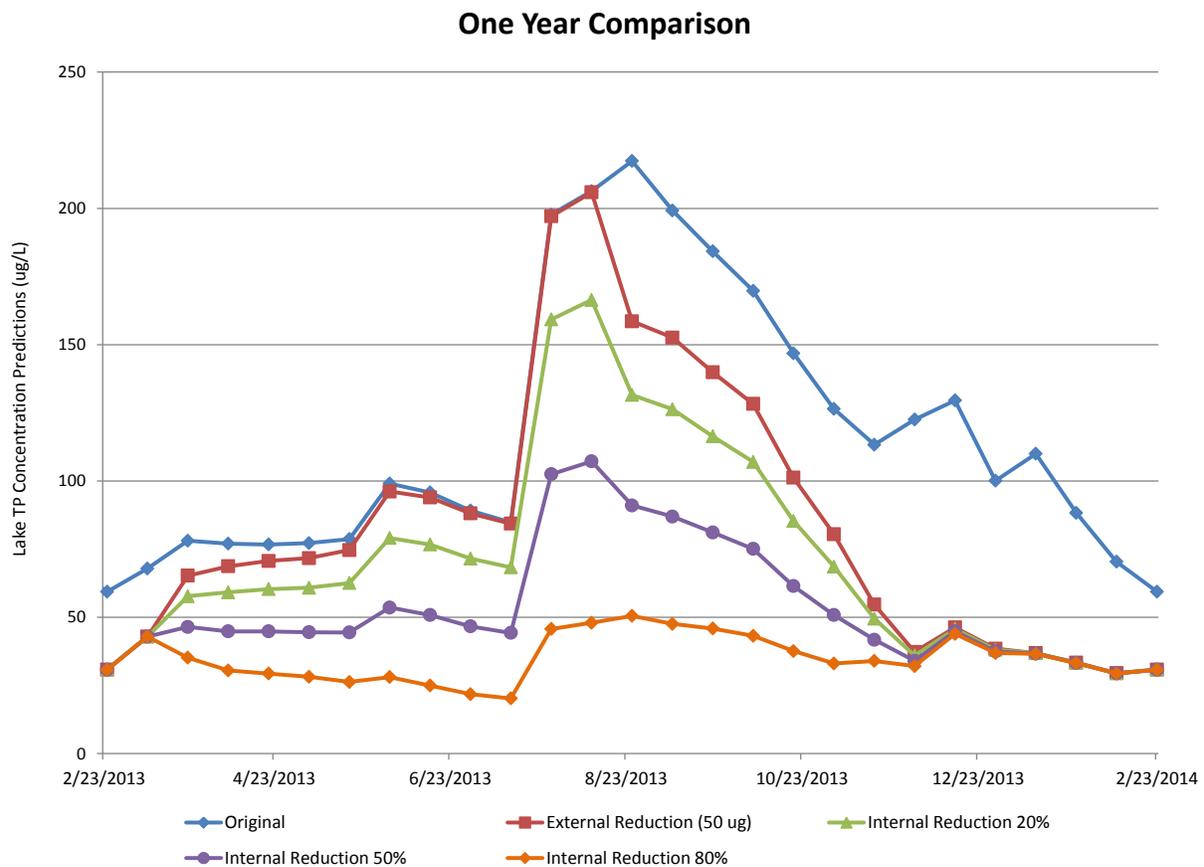


Figure 4. Predicted Buckeye Lake TP concentrations for various nutrient reduction strategies.

4. Evaluation of Potential Management Actions

4.1. Recommended Future Monitoring Activities

After extensive review of existing water quality available for Buckeye Lake and its tributaries, Tetra Tech recommends that the current monitoring program continue with the following additions to help further the understanding of Buckeye Lake water quality and nutrient dynamics.

1. Tetra Tech strongly encourages Ohio EPA to install the necessary equipment to obtain continuous flow data for Reservoir Feeder Creek. There is a significant lack of information concerning the hydrology of the watershed and water budget of Buckeye Lake. Specifically for Feeder Creek it was assumed that this was the largest external loading source based on prior knowledge; however, the mass balance model showed that the nearshore and minor tributary drainage contributed almost as much phosphorus to the lake. This could be the result of an incomplete understanding of Feeder Creek flows and the weak relation between observed and modeled flows. Truly understanding how much water enters Buckeye Lake via Reservoir Feeder Creek will help refine the external load from that part of the watershed which will allow a more targeted approach for reducing external loading.
2. Tetra Tech recommends that Ohio DNR/Ohio EPA install or continue to operate level loggers on the dam of Buckeye Lake as well as in the outlet structure to obtain accurate records of both lake level and outflow. Until late 2014 there was a significant lack of information concerning how much water is in the lake and how much water leaves the lake. Understanding the water budget of the lake and hydraulic flushing rate are very important to determining the most effective ways to manage excess nutrients and improve water quality. USGS has installed a gage on the lake near Millersport that records water temperature, precipitation, and lake elevation. The first available data from this gage is from August 2014.
3. Tetra Tech recommends that Ohio EPA focus its water quality monitoring efforts on capturing high flow events throughout the watershed to better understand stormwater runoff impacts and pollutant sources to the lake. This is true especially for Feeder Creek where a diversion in the upper watershed is thought to divert most of the flow away from Buckeye Lake. However, there is not a clear understanding of when or how much water bypasses the diversion and makes its way downstream. Given the nature of the watershed, high runoff events have the potential to carry high amounts of sediment and nutrients to the lake.
4. Tetra Tech also recommends that sampling of the drain tiles within the Feeder Creek basin be conducted during storm events. This monitoring effort would help local stakeholders understand the magnitude of nutrient runoff via drain tiles and would allow a more targeted effort in nutrient control.

4.2. Recommended Nutrient Management Strategies

Tetra Tech recommends the following nutrient management strategy actions to help reduce excess nutrients in Buckeye Lake and to improve water quality; these actions are listed in descending order of importance. It was apparent during stakeholder meetings in May that BLT, Ohio EPA, Ohio DNR and Fairfield/Licking/Perry Counties are committed to restoring Buckeye Lake and Tetra Tech endorses their efforts.

1. Tetra Tech applauds the efforts and work already being done by local stakeholders in the watershed and the lake. Tetra Tech recommends that all stakeholders continue their well-conceived watershed efforts and community education and outreach including implementing aggressive agriculture BMPs and education. The work done in the watershed by Fairfield Soil and Water Conservation District should continue to be built upon and supported.
2. Tetra Tech recommends the implementation of various watershed BMPs while waiting for the data from the monitoring activities outlined above. This would include constructed wetlands areas in the state park where land is already owned by an active stakeholder. A constructed wetland would remove sediment and nutrients as well as slow down high flows into the lake. Other possible watershed BMPs include streambank rehabilitation and erosion reduction strategies as

well as flow/runoff reduction strategies that would reduce the amount of sediment and nutrients entering the creeks and eventually Buckeye Lake.

3. Tetra Tech recommends the control and treatment of the “legacy” phosphorus in the lake sediments to control internal loading of phosphorus. It is evident that most of the summer load is from internal loading sources which would be a combination of sediment phosphorus and waterfowl. There is a high concentration of phosphorus in the sediment and that phosphorus has to be inactivated for the lake to recover further and in any reasonable length of time.
4. Tetra Tech recommends aggressive management and control of the resident geese population as well as other non-migratory waterfowl. Waterfowl population management was very successful in reducing nutrients in several lakes in Washington State including Green Lake, Lake Stevens, and Lake Ballinger. These programs included education, feeding restrictions, direct harassment of the geese via trained dogs, radio controlled model boats and airplanes, and adding of eggs.
5. Tetra Tech acknowledges that partial lake sediment dredging may occur for navigation purposes. This removal of sediment will have a nutrient removal benefit if conducted under phosphorus control protocols; however, the limited area proposed for dredging decreases the overall effectiveness as a lake management tool. It is recommended that any dredge spoil resulting from dredging be removed from the lake and the watershed. If the dredge spoils cannot be relocated then they need to be treated (i.e., with alum or another inactivation agent) to prevent any leaching of phosphorus back into the lake. In addition, prior to dredging, the sediment profile should be sampled to understand potential phosphorus release from the newly exposed sediments. If it is determined there is a high potential of phosphorus release after dredging then that phosphorus will need to be inactivated immediately after dredging.

5. Conclusion

Although steps have been taken to reduce external sources of nutrients, significant efforts need to be continued to reduce external and internal nutrient loading to the lake. To aid in this process it is encouraged that all aspects of the monitoring, education and watershed management activities be continued and enhanced. It should also be recognized that in-lake actions are needed to allow the lake to continue to improve within a reasonable time frame. These activities include monitoring; modeling; waterfowl control; site specific dredging for both navigation and phosphorus control; and phosphorus inactivation of specific sediment areas that are adding to the internal phosphorus loading driving the algal production should be explored.

6. References

- Buckeye Lake for Tomorrow, Inc. 2013. Buckeye Lake Nutrient Reduction Plan. Prepared for the Ohio Environmental Protection Agency. December 31, 2013.
- Cooke, G.D., E.B. Welch, S.A Peterson, and S.A. Nichols. 2005. Restoration and Management of Lakes and Reservoirs. 3rd Edition. Taylor and Francis Group, Boca Raton, FL. 591 pp.
- Ohio EPA. 2014. Buckeye Lake Modeling Summary. Ohio Environmental Protection Agency, Division of Surface Water Modeling & Assessment Section. February 24, 2014.
- USEPA. 1975. Report on Buckeye Lake Fairfield, Licking, and Perry Counties, Ohio. EPA Region V. Working Paper No. 396.