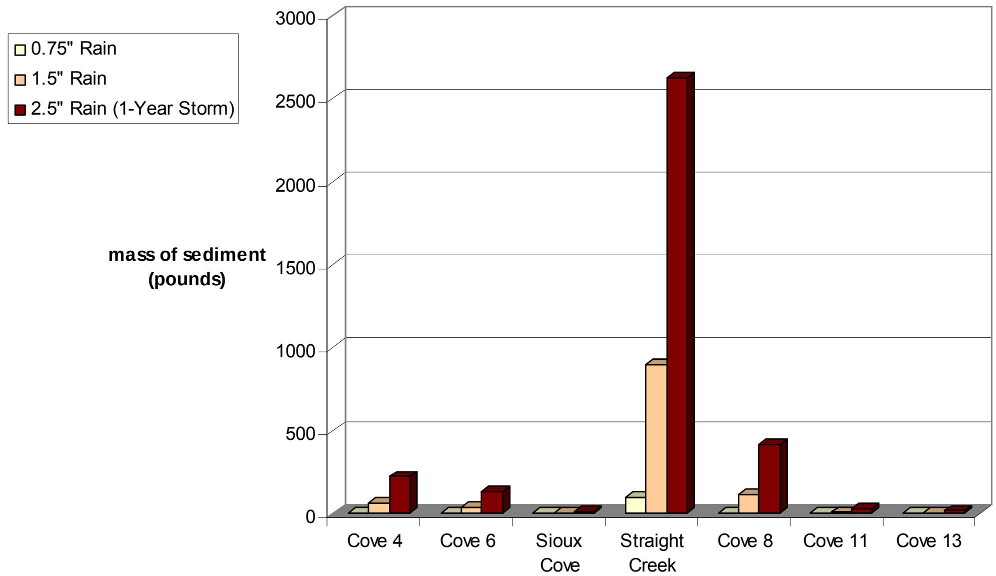

Figure 7. **The mass of sediment that enters Lake Waynoka tributaries during 0.75-inch, 1.5-inch and 2.5-inch storm events**

5 STUDY CONCLUSIONS

Based on LAC accounts, direct observations of the lake during sampling activities, and the study results described in this report, the MAD team has found Lake Waynoka to be relatively stable and in good health. However, certain site enhancements and fine-tuning of WPOA lake management strategies could benefit the lake and its fishery. In addition, a few isolated problem areas requiring attention were identified in the upper coves, particularly at Straight Creek cove.

Straight Creek, which delivers the highest volumes of water and sediment to the lake, presents a specific set of problems that will require engineering solutions: 1) washout behind a wingwall of the Waynoka Drive box culvert, 2) high transport of sediment bed load associated with the proportionally massive volumes of water that flow through this creek, and 3) severe erosion, particularly on the steep south bank of the creek.

In general, problem levels of sediment accumulation have been found to be associated with inorganic material (gravel, sand, silt and clay). The amount of organic material present in Lake Waynoka does not exceed a normal range and is not considered a cause for concern. Regular lake draw downs facilitate aerobic decomposition of organic material that enters the lake, preventing excessive accumulation of detritus. The results of the sampling confirm the presumption that a majority of sediment within Lake Waynoka originates from Straight Creek; however Cove 8 has also been identified as a major contributor of sediment to the lake.

The opportunities for improvement identified through this study fall into three main categories: 1) priority projects/tasks requiring immediate attention; 2) projects/tasks that will control sedimentation issues and make lake management efforts more sustainable; and 3) projects/tasks that will improve and sustain the fishery at Lake Waynoka. The latter two categories contain recommendations that may be phased in gradually, over a period of years. Specific recommendations regarding these opportunities are discussed in the next section.

6 RECOMMENDATIONS

6.1 Highest Priority Projects and Tasks

Through the course of this study and site investigation, several high-priority projects and tasks have been identified. These are considered to require the most urgent attention to address property owner concerns and curtail further degradation of Lake Waynoka. It is recommended that action be taken on these recommendations within the next three months, to take advantage of the winter drawdown on Lake Waynoka.

6.1.1 Repair Straight Creek Culvert at Waynoka Drive

Initial observations of erosion surrounding the existing eight foot by eight foot (8’ x 8’) box culvert that Straight Creek flows through, under Waynoka Drive, seemed to indicate the culvert might be undersized for the volume of water that flows through it. It was noted that the road bed of Waynoka Drive at the Straight Creek culvert is currently deteriorating, perhaps due to undermining by high flows through the culvert, and may need repairs in the near future. An engineering analysis was conducted to determine the appropriate size for the culvert, which found that the existing culvert is likely to be more than adequate to handle all storm runoff including the 100-year storm; however, its capacity depends on the slope of the culvert, which has yet to be determined. The engineers at Stone, recommend placing large (Type B) rip-rap at the culvert outlet, flush with the culvert's invert, to reduce the flow velocity as it enters the lake. Stone also suggests placing 18-inch rip-rap in a zone 16' wide, 3' deep, 30' long at the culvert outlet to reduce erosion of the substrate and shoreline as stormwater exits the culvert.

The wingwall on the upstream side of the Waynoka Drive culvert is eroding and may be contributing to destabilization of the road. Options to protect further erosion of the box culvert wingwall include construction of the sediment forebay discussed below, which would interrupt and slow the stream velocity, thereby reducing its impact on the wingwall. Other possibilities include increasing the span of the wingwall, or adding grouted rip-rap or gabions behind the wall. Further information is needed to develop a cost estimate for this location. However, the same linear foot estimates presented in section 6.1.3 can be used as a guide.

6.1.2 Excavate Existing Accumulated Sediment in Straight Creek Cove

The existing accumulated sediment within Straight Creek cove will have to be removed to restore the channel for recreational boat use. The most efficient method for removing this sediment, in terms of economics and time, is through excavation during the scheduled winter drawdown. According to the LAC, a 2010 quote they received for excavating a 3 foot depth (1 yard) of material over a 900-foot-long (300-yard), 120-foot-wide (40-yard) area in Straight Creek cove was for approximately $72,000 (12,000 cubic yards of removal). Installing a sediment forebay or Sediment Collector prior to raising the water level in the spring would help to prevent the newly-excavated cove from refilling with sediment, reducing the need for excavation in the future. These options would serve to keep sediment from reaching the cove by capturing it and depositing it in areas where cleanout would be easier and less expensive. These options are discussed in Section 6.2.

6.1.3 Stabilize South Bank of Straight Creek

The severely-eroded south bank of Straight Creek may be protected from further damage through: placement of very large rock at the washout base, construction of a pre-cast retaining wall, or construction of a gabion wall. Engineered concrete retaining walls or segmented, modular retaining walls are a very expensive solution to the erosion problem; using a pre-cast retaining wall may run $1,950 per linear foot (lf) compared to $325/lf for a rip-rap wall and $500/lf for a gabion wall. Because this area is not in a navigable area of the lake, and is hidden from view most of the year, a gabion retaining wall is appropriate for the area. The gabions are installed in an interlinked fashion, and should be staked into the sediment to prevent relocation in strong currents. The gabions can be tied back into the bank and will prevent slope erosion and stabilize the bank. If any of these methods are selected, they should be installed while the lake level is drawn down.

6.2 Projects and Tasks for Improved Sustainability

Sediment in Lake Waynoka primarily originates from non-point sources (*e.g.*, those that don't have a pipe connecting the source to the lake), such as construction sites and agriculture. Although it is harder to control runoff from non-point sources, the WPOA is fortunate in that the majority of Lake Waynoka's watershed lies within WPOA's boundaries, and can therefore be regulated by the WPOA. Currently, WPOA sediment and erosion control regulations are poorly developed and enforcement is lacking, as was evident during the watershed investigation.

Unprotected bare ground is highly prone to rain and wind erosion. Runoff from rain events will carry soil from bare ground downhill. Since the lake is the lowest spot within the WPOA watershed, runoff eventually reaches the lake and sediment is deposited, which can lead to a rapid accumulation and shallower conditions, particularly in the already shallow coves. Opportunities exist to control sediment sources, and where these efforts are insufficient, sediment loads may be captured and controlled in a more effective and sustainable manner than routine excavation or dredging of the lake.

Once the recommendations described in Section 6.1 have been implemented (or at least initiated), the WPOA is encouraged to consider the following recommendations to improve the sustainability of lake management efforts and better manage available resources for lake improvement. These recommendations may be phased in gradually, as resources permit, noting that efforts that will control sediment release to the lake are of great importance to prevent a recurrence of the sediment accumulation that prompted this study. In general, that the WPOA is encouraged to implement these recommendations within a two- to three-year time frame.

6.2.1 Improve and Enforce Community Sediment and Erosion Control Rules

Writing and adopting complete and specific erosion and sediment control rules or guidelines, and enforcing them, would be a first line of defense against sedimentation in the lake. The measures, which would include silt fences, waddles, or other barriers to direct surface water runoff, should be developed by the LAC and approved by the WPOA. The rules and regulations will need to address the types of projects subject to the regulations, the specific measures that are needed, permits and fees to be assessed to enforce the regulations, and other similar factors. Input from local contractors, as well as realtors and others will be necessary.

MAD recommends that an erosion and sediment control enforcement officer be selected, and that they be trained so that they can conduct inspections of construction sites and identify deficiencies in sediment and erosion control measures and make recommendations for improvements. Development of these regulations could be controversial. The International Erosion Control Association offers some useful on-line courses, http://www.ieca.org/. If the WPOA is able to use in-house resources to develop and enforce these regulations and/or guidelines, there may be no direct costs associated with this option.

6.2.2 Install Channel Protection at Culvert Outlets

To reduce erosion that may occur as stormwater exits culverts and runs into the lake, existing culverts of all sizes that outlet to the lake should have rock channel protection installed if they are currently unprotected. The rock protection should be at least twice the width of the culvert and should extend a minimum of eight feet beyond the end of the culvert. Rock channel protection should range from $500 to $1,000 per site, depending on the size of the culvert and its accessibility.

6.2.3 Construct Stormwater Detention Feature at Community Center

Runoff from the recreation/pool areas is eroding the western slope of this lot, and has created rills several inches deep along the slope. A large amount of runoff also originates from the marina area, which flows directly into the lake. To reduce the volume of runoff from these areas, and prevent further eroded sediment from entering the lake, MAD recommends constructing stormwater detention/settling basins in each of these areas. There is sufficient room around the recreation/pool complex to construct a detention basin or several rain gardens to capture runoff from the roofs and impermeable surfaces, and such features could be integrated into the landscaping around the site. Similar basins could be easily integrated into the areas around the marina. Stormwater detention basins typically cost between $8 and $10 per cubic yard, more information is required to develop a specific cost estimate for this location.

6.2.4 Stabilize and Protect Lakeshore

Unprotected shorelines can erode, contributing sediment to the lake, but protection is generally easily achieved through natural means. A 10- to 15-foot-wide buffer of native trees, shrubs and herbaceous plants helps to hold the soil in place, reducing erosion from stormwater runoff. Actively mowing a lawn down to the edge of the lakeshore can lead to soil degradation and erosion, and provides the perfect grazing habitat for nuisance populations of Canada geese. While the preference from an erosion and sediment control perspective should be for natural buffers, this may not be possible in all locations. Where it is not possible to have natural buffers, or where homeowners desire lawns in place of natural vegetation, then the shoreline must be stabilized below the lawn with rock protection, which may run $18 to $20 per linear foot of installed rip-rap. Rock protection should consist of a 3-4 foot width of dumped rock fill and rock channel protection materials consisting of either Type B or C material defined below:

> Type B material has at least 85 percent of the total material by weight larger than a 12-inch (0.3 m) but less than a 24-inch (0.6 m) square opening and at least 50 percent of the total material by weight larger than an 18-inch (0.5 m) square opening. Furnish material smaller than a 12-inch (0.3 m) square opening that consists predominantly of rock spalls and rock fines, and that is free of soil.
>
> Type C material has at least 85 percent of the total material by weight larger than a 6-inch (150 mm) but less than an 18-inch (0.5 m) square opening and at least 50 percent of the total material by weight larger than a 12-inch (0.3 m) square opening. Furnish material smaller than a 6-inch (150 mm) square opening that consists predominantly of rock spalls and rock fines, and that is free of soil.

Sound and durable rock or stone shall be placed as a rock fill material for the protection of the slope or other surfaces. Thin slab-like pieces or any piece having a dimension larger than 36 inches should not be used. The material shall be carefully dumped in place, with the larger pieces at the outer face and the smaller pieces and spalls near the face of the slope or protected area. Care should be exercised in placing the material to insure a reasonably smooth and continuous surface, and to conform to a maximum slope of 4:1. The completed rock channel protection material shall be sufficiently uniform to avoid a concentration of fines and small pieces at any location. Some handwork may be necessary to accomplish the above requirements.

6.2.5 Reduce Sediment Loading from Priority Streams

It is likely that little can be done to control erosion and sediment runoff from the areas of Straight Creek and Cove 8's tributary located outside the WPOA boundary. Measures that would help to control runoff from agricultural areas include no-till farming, growing a cover crop outside of the growing season and maintaining a wider buffer between the farm field and riparian area. Discussions with the various landowners may be fruitful, especially if the landowner is also a lake user. Trading an annual lake use membership, in exchange for maintaining a wider buffer, may pay dividends.

Although it may not be possible to prevent erosion and sediment runoff from the agricultural areas, it is possible to reduce the amount of sediment that flows into the lake from these areas. As the majority of sediment entering Lake Waynoka flows through Straight Creek, MAD recommends installing sediment removal measures along Straight Creek, with an in-stream solution, an "off line" sediment capture feature (as could be constructed on the recently-purchased WPOA properties adjacent to Straight Creek), or a combination of elements. A few appropriate engineered sediment removal options for this location are discussed below. It is important to note that these options may require the obtainment of permits from the Ohio EPA and the U.S. Army Corps of Engineers (USACE), and that the construction and maintenance of these facilities will necessitate the removal, transport, and disposal of soil and dredge material.

6.2.5.1 Option: Porous Rock Dam

After determining the property boundaries upstream of Waynoka Drive, a porous dam constructed of large rip rap and extending across the creek and into the WPOA property could function as a sediment trap. Water would build up behind the dam and slowly filter through it, while much of the sediment would be trapped behind it and settle out. This unit would act similar to the sediment forebay discussed below, but might have slightly lower construction costs.

6.2.5.2 Option: Sediment Forebay

A sediment forebay, or a wetland with a sediment forebay, could be constructed on WPOA-owned property immediately upstream of the Straight Creek box culvert to trap sediment before it enters the lake. The forebay could consist of a concrete structure through which Straight Creek would be diverted. The velocity of the stream would be reduced as it passed through the forebay allowing sediment to fallout of suspension and accumulate in the forebay. In essence, the forebay would replace the current cove area for sediment deposition. It would be necessary to periodically remove the sediment from the forebay, but it could be designed so that sediment could be removed during dry periods of the year using conventional earth moving equipment. Further analysis is required to determine the particulars of either a forebay or wetland (*i.e.* size, configuration, access, depth, etc). Construction of a forebay at this location could be expensive due to the amount of excavation that would be required to create a flat area near the creek bed. Observations appear to indicate that the area is four to eight feet higher than the base of Straight Creek at the culvert.

A very rudimentary cost estimate for forebay construction and maintenance was developed to provide an indication of the costs. Assuming that a rubble-type diversion structure is constructed at the upstream end of the forebay, and the creek is engineered to flood over approximately 1.5 acres, the estimated costs range from $120,000 to $150,000, depending on the depth of excavation required. If an upstream concrete structure is constructed, this will likely add $30,000 to $40,000 to the cost. Permits will likely be required to divert the stream and excavate within the stream channel; costs for permitting costs will range from $5,000 to $10,000. Forebay maintenance will include some reseeding every year and mowing, with a major silt cleanout no more frequent than every 5 years. With a properly designed forebay, cleanout would be in the $35,000 to $40,000 range once every 5 to 10 years, with annual maintenance costs in the $1,000 to $2,000 range.

6.2.5.3 Option: Wetland Complex

The forebay could also be constructed as the first part of a wetland complex. Wetlands remove nitrogen and phosphorous from stormwater runoff, which are generally present in runoff from agricultural areas and at high levels can lead to algal blooms. Combining a forebay with a wetland would facilitate removal of both sediments and nutrients. In this scenario, the sediment forebay would likely have a smaller footprint with the wetland covering most of the area. Both the sediment forebay and wetland complex options would require re-routing Straight Creek, so that a majority of its flow passed through the created features. Assuming that the wetland complex would be located in the same place as the sediment forebay, and would cover the same area, the cost for the wetland complex would also be $120,000 to $150,000. Seeding the area and installing wetland vegetation would add about $10,000 to $15,000.

6.2.5.4 Option: Sediment Collector by Streamside Systems ®

Another option for reducing sediment input to the lake would be to install one, or a series, of sediment collectors in Straight Creek to capture and remove sediment before it enters the lake. Sediment Collectors are constructed of stainless steel and are held in place with stainless steel rods. Collectors are installed so that they sit on the surface of the stream bed and do not impede stream flow, navigation, or recreation.

Streamside Systems constructs and installs Sediment Collectors for stream restoration projects around the country, primarily to improve fish habitat for species that spawn in gravel and cobble substrates. The collectors can be designed to target a specific size of sediment for removal with the smallest size being 0.06mm, which is the size of a very fine sand grain. Once sediment is collected it can be dewatered and then used as fill, or if it has a higher nutrient content, as fertilizer. Straight Creek, which delivers the majority of sediment that enters Lake Waynoka, transports primarily fine gravels and sands (4.76mm to 0.149mm). For this location, three to four Sediment Collectors could be connected together and placed near the mouth of Straight Creek. These would be designed to remove sediments in the size range of fine gravels to fine sands, which would result in a significant reduction in the amount of sediment that accumulates within the Straight Creek cove.

The costs for purchase and installation of the system are estimated at $64,000. Either electricity or solar panels are required to run the system and would be additional costs. Anticipated maintenance costs would include disposing of the accumulated sediment (which can be collected in a drop-box and used as road base or for other WPOA needs), lubrication of the pump and motor, and periodic removal of any accumulated material from the grates. A complete description of the Sediment Collector's performance and an estimate of the proposed costs are included in Appendix G.

6.3 Lake Habitat & Fishery Recommendations

6.3.1 Establish and Enhance Shoreline and Aquatic Vegetation

As a general recommendation to improve water quality, lake ecology, and the productivity of the fishery, Lake Waynoka could benefit from the establishment or enhancement of shoreline vegetation. As a man-made reservoir, the original plant communities existing at the impounded water level formed by the dam (*i.e.*, the Lake Waynoka shoreline) were, in most areas, probably upland (non-wetland) fields and forests. This initial condition failed to provide a good "starter" community for appropriate and desirable shoreline vegetation. Over time, narrow fringes of submerged (underwater) and emergent (growing in water but extending above the water surface) aquatic vegetation have developed, but these communities have likely been compromised by wave action, steep topography, the introduction of grass carp (or amurs, used to control "weeds"), and the annual drawdown cycle at Lake Waynoka.

Aquatic plants are a natural part of a healthy water body, providing habitat for fish and wildlife, shoreline protection, improved aesthetics, and improved water quality and clarity. The Ohio State University Extension office (Lynch, 2006) describes submerged plants as "critical to a well-structured fish assemblage." For these reasons, establishing and enhancing vegetation is highly recommended. However, consideration must be given as to what areas of the lake are best suited to these restoration efforts. In general, suitable areas will be: 1) protected from high waves and wakes, 2) in areas with more gentle slopes, resulting in shallower water depths (less than 3'), and 3) in areas with suitable substrates (soft sediment or soil, rather than hardpan clay or rock). These parameters are most likely to be satisfied in the coves, as opposed to the central reservoir, which is more prone to turbulence from boats and wind action. A customized plan will need to be developed, and some adjustments to the recommended species list may result from additional investigation of existing plant communities in the lake.

Any specific locations selected for a vegetation establishment effort may require some adaptive measures to improve the odds of success, particularly during the initial plant establishment period. In particular, even in relatively sheltered coves, some form of wave protection (*e.g.*, plastic fence, coir fiber rolls, or more substantial permanent breakwalls) may be necessary. An ideal assortment of plant species will include a combination of emergent plant species, floating leaved species, and submerged aquatics. Table 3 presents a recommended list of species by type. It is important to note that, although native to Ohio, some of these species have a reputation to proliferate rapidly, so some caution is necessary in considering their introduction into Lake Waynoka.

Plants may be established by seeding (*e.g.*, creating "seed bombs" of clay and seed mix that can be dropped in shallow water), installation of stakes (*e.g.*, willow cuttings for shoreline stabilization), or planting of rooted material (often referred to as "plugs"). It is strongly recommended that plantings be phased in gradually and monitored to determine which species are most successful, given the potential adverse effects of winter drawdown on aquatic plant species. Those that fare best under the standard Lake Waynoka management strategy should be used more heavily in future plantings.

It is important to note that, from a fisheries standpoint, the benefits of aquatic plants hinge on the provision of structure: hiding places for young fish, habitat for invertebrate prey, etc. The particular species of plants are not as critical. Beds of aquatic vegetation will naturally sustain and enhance the fishery at Lake Waynoka, providing necessary habitat for nesting and refugia for young fish and supplementing food resources by attracting and sustaining a larger and more diverse community of invertebrate prey items. To further boost the fish community, the WPOA should periodically re-stock the lake with appropriate species, as discussed in the next section.

Table 3. Recommended Shoreline and Aquatic Plants for Lake Waynoka

Submerged Aquatic Species	
Common Name	**Scientific Name**
Coontail	*Ceratophyllum demersum*
Common elodea	*Elodea canadensis*
Common naiad	*Najas flexilis*
Leafy pondweed	*Potamogeton foliosus*
Small pondweed	*Potamogeton pusillus*
American eelgrass	*Vallisneria americana*
Floating-leaved Aquatic Species	
Common Name	**Scientific Name**
Water-shield	*Brasenia schreberi*
American water lotus	*Nelumbo lutea*
Yellow pond lily	*Nuphar lutea*
White water lily	*Nymphaea odorata var. tuberosa*
Floating-leaf pondweed	*Potamogeton natans**
Long-leaf pondweed	*Potamogeton nodosus*
Emergent Aquatic Species	
Common Name	**Scientific Name**
Sweet flag	*Acorus calamus*
Nut-sedge	*Cyperus* spp.
Spike rushes	*Eleocharis* spp.
Blue flag	*Iris virginica*
Soft rush	*Juncus effusus*
Water willow	*Justicia americana*
Pickerelweed	*Pontederia cordata*
Broad-leaved arrowhead	*Sagittaria latifolia*
Lizard's-tail	*Saururus cernuus*
Dark-green bulrush	*Scirpus atrovirens*
River bulrush	*Schoenoplectus fluviatilis*
Soft-stem bulrush	*Schoenoplectus tabernaemontani*

*Noted as being resistant to drawdown in WDNR (1973) study

6.3.2 Supplement Fish Community through Stocking

The WPOA has set size restrictions for harvesting crappie (unspecified species, assumed *Pomoxis annularis*, the white crappie), bass (*Micropterus* spp.; largemouth [*M. salmoides*], smallmouth [*M. dolomieu*], and spotted [*M. punctulatus*]), walleye (*Sander vitreus*), channel catfish (*Ictalurus punctatus*), and bluegill sunfish (*Lepomis macrochirus*). Prior to reviewing these fishing regulations, a nearly identical list of appropriate species for re-stocking was developed: White crappie, largemouth bass, bluegill, and channel catfish are all recommended species. These represent an appropriate community of fishes for a lake with the size and habitat and water quality characteristics of Lake Waynoka, and are a typical assemblage for Ohio and Midwest sportfish lakes and reservoirs.

Walleye may also be stocked, if desired, as the lake is sufficiently large (>100 acres) and water clarity and temperatures are within the range of tolerance for this species. Although specific stocking recommendations cannot be reliably made in the absence of a formal assessment of the fishery (sampling to look at lengths, weights, population sizes, etc.), a few generalized stocking recommendations adapted from McComas (2003) are shared in Table 4.

Table 4. Recommended Fish Species for Re-stocking Lake Waynoka

Species	Stocking Rate	Notes
White crappie	50-100 per lake acre	Will tolerate higher turbidity than black crappie, species is benefited by fish shelters (underwater structure)
Largemouth bass	50-100 fingerlings per acre	McComas (2003) recommends fall stocking
Bluegill sunfish	250-500 fingerlings per acre	McComas (2003) recommends only large bluegill be stocked if bass are present
Channel catfish	100, 4-6 inch young per acre	Channel catfish typically do not successfully spawn in ponds or lakes and must be periodically re-stocked
Walleye	500 fry or 2 lbs of fingerlings per littoral acre (area <15 ft deep)	Prefer clear, cool water

7 SUMMARY

Relative to many Ohio lakes that are currently experiencing major ecological imbalances resulting in unhealthy and unpleasant conditions (*e.g.*, excessive blue-green algae growth, poor water quality), Lake Waynoka is in good condition. A few pressing issues at the upper end of the reservoir at Straight Creek require immediate action. The other recommended measures discussed in this report will benefit the lake and the WPOA community by providing a more sustainable and ecologically-sound approach to managing runoff, sedimentation, shoreline protections and fish and wildlife habitat around Lake Waynoka.

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