# BMW ADAPTIVE IMPLEMENTATION PLAN FOR pH TMDL

May, 2013

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Barr Lake & Milton Reservoir Watershed Association

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# LIST OF ACRONYMS

| | |
|---|---|
| Association | BMW Association |
| Barr | Barr Lake |
| BMP | Best Management Practice |
| BMW | Barr Lake and Milton Reservoir Watershed |
| CDPHE | Colorado Department of Public Health and Environment |
| CDPS | Colorado Discharge Permit System |
| Chl | chlorophyll a |
| Commission | Water Quality Control Commission |
| DO | dissolved oxygen |
| DSN | Colorado Data Sharing Network |
| FRICO | Farmers Reservoir and Irrigation Company |
| Guidance | August 2006 U.S. EPA Guidance Memorandum |
| L/E | Littleton and Englewood WWTP |
| LID | low impact development |
| RWHTF | Robert W. Hite Treatment Facility |
| µg/L | micrograms per liter |
| mg/L | milligrams per liter |
| Milton | Milton Reservoir |
| MOS | margin of safety |
| MS4 | municipal separate storm sewer system |
| NPS | non-point source |
| NRC | National Research Council |
| pH TMDL | Total Maximum Daily Load to Achieve pH Compliance in Barr Lake and Milton Reservoir, Colorado |
| Plan | Adaptive Implementation Plan |
| POTW | Publicly Owned Treatment Works |
| Pumps | Burlington Pump Works |
| SP CURE | South Platte Coalition for Urban River Evaluation |
| SPR | South Platte River |
| S.U. | standard units |
| TMDL | Total Maximum Daily Load |
| TN | total nitrogen |
| TP | total phosphorus |
| TSS | total suspended solids |
| UAA | Use Attainability Analysis |
| WWTPs | wastewater treatment plants |

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# 1. BACKGROUND

This Adaptive Implementation Plan (Plan) is intended as a companion document to the *Phased Total Maximum Daily Load to Achieve pH Compliance in Barr Lake and Milton Reservoir, Colorado* (pH TMDL) prepared by the Barr Lake and Milton Reservoir Watershed (BMW) Association (originally dated December 31, 2010). The pH TMDL was developed by the BMW Association (Association) to address impairment in both water bodies due to elevated pH. The Phased TMDL and Implementation Plan are consistent with EPA's Watershed Planning Guidelines (U.S. EPA 2005), which are designed to achieve water quality improvement. This Plan summarizes activities associated with Phase I of the pH TMDL.

## 1.1 Watershed Description

Barr Lake and Milton Reservoir are two off-channel water bodies in the South Platte River system, northeast of Denver, Colorado. These reservoirs are used mainly as irrigation supplies, but also serve other uses, including wildlife habitat, recreation, and drinking water supply. The BMW is very large, approximately 833 square miles (533,000 acres). With over 500 miles of streams and rivers draining this area, it encompasses portions of six counties: Adams, Weld, Arapahoe, Denver, Jefferson, and Douglas. Adding to the hydrologic complexity of the watershed, these natural waterways are supplemented by over 550 miles of man-made canals, ditches, and pipelines (BMW 2008). The watershed extends south of Denver along the path of the South Platte River, and north from Denver onto the plains, with Barr Lake and Milton Reservoir as the defined terminal points. Not all water from the watershed passes through these reservoirs, as neither is directly on the South Platte River; diversions from the river represent the primary source of water for the two reservoirs.

Approximately 89% of the Barr-Milton watershed is privately owned. Nearly 55% of the watershed supports agriculture, including grasslands, pasture, small grains, and row crops. Cattle and calves are the primary livestock. Residential and commercial/industrial areas, including most of the Denver metropolitan area, cover 38% of the watershed and are located primarily in the southwestern extent of the watershed and along the South Platte River. Less than 2% of the watershed is covered by open lands (BMW 2008). This Barr-Milton watershed area includes over 75% of the Denver metropolitan area. Additionally, urban growth is occurring near the reservoirs, especially near Barr Lake where dry-land acreage is transitioning to residential development.

The complexities associated with the point sources, controlled water transfers, the influence of urbanization in the southern half of the watershed, elusive non-point source (NPS) contributions from agricultural areas in the northern half, and over all variability associated with chemical reactions in the reservoirs have cumulative impacts, creating a high level of uncertainty with respect to how to solve the pH problem in these water bodies.

## 1.2 Water Quality Status

Barr Lake (Barr) and Milton Reservoir (Milton) have been included on the 303(d) list since 2002 as impaired due to exceedances at the upper pH standard of 9.0 standard units (S.U.), resulting in nonattainment of the Class 2 Aquatic Life Warm Water, Recreation, and Water Supply use classifications. The Colorado

Department of Public Health and Environment (CDPHE) rates the pH TMDL priority as "medium."

Although pH is the parameter cited on the 303(d) list, the water quality issues are broader. Both reservoirs are "hyper-eutrophic" (AMEC 2008a, 2008b) due to excessive nutrient loading. This is evidenced by the typical summertime water clarity of two feet, chlorophyll *a* levels of 20–150 micrograms per liter (µg/L), and total phosphorus concentrations of 500–1,500 µg/L. Both reservoirs exhibit severe algae blooms from July to October. Photosynthetically elevated pH, low clarity, low species diversity, and dissolved oxygen sags are all symptoms of a persistent water quality problem in the reservoirs.

These symptoms impact other designated uses of the reservoirs. For example, the reservoirs are used for agricultural irrigation by approximately 400 farmers. Additionally, the lakes are used for recreation, where approximately 80,000 visitors/year visit the State Park at Barr Lake and 68 households have recreational access to Milton.

# 2. RESTORATION STRATEGY

## 2.1 Background

Appreciable reductions in total phosphorus (TP) concentrations and commensurate chlorophyll *a* (Chl) and pH reductions in Barr and Milton require a multi-pronged approach. Options evaluated in the water quality model include: 1) reductions in phosphorus loads from wastewater treatment plants (WWTPs), with the Metro Wastewater Reclamation District's Robert W. Hite Treatment Facility (RWHTF), Littleton and Englewood WWTP (L/E), and Centennial facilities as the top priorities, but extending to other WWTPs in the watershed, 2) a reduction in the internal load of TP in Barr and Milton, 3) reductions from other watershed sources, and 4) an optimization of the water quality through selective water transfers to the reservoirs. Water quality modeling simulations suggest that TP load reductions in excess of 90% are necessary to achieve the desired response in pH (AECOM 2009). The flexibility of the watershed and lake models makes it possible to simulate additional combinations of management alternatives and the model calibration will be revisited as new data are collected. Simulations of management scenarios were run using the combined SWAT-WASP model to guide planning (AECOM 2009), which indicates that no single action will achieve the desired results, i.e., attainment of the pH standard.

Conclusions drawn from the AECOM (2009) scenario modeling include:

- Compliance through TP input reduction will likely require total phosphorus discharge permit limits for wastewater treatment facilities, best management practices for regulated stormwater, and strong control of internal loading.
- For TP load control to work as a pH management strategy, many smaller inputs will have to be addressed as well as the few identified large ones. This will include many non-point sources.
- Management of water transfers in the watershed offers potential to improve water quality in Barr, but potentially at the expense of the water quality in Milton. Water transfer management that will benefit both reservoirs may be possible, but would involve water rights issues and would likely reduce certainty of summer water supply from the reservoirs.
- In-reservoir approaches for minimizing algal production are available that, when combined with a watershed-based effort, will help achieve water quality goals.

The Plan elements that follow are offered as options to achieve the pH standard in both reservoirs. The plan for phasing and adaptive implementation is further refined in Sections 3 and 4. Recommendations in this Section are intended to provide options for point source and watershed load reduction strategies. An attempt has been made to narrow the range of management options in accordance with known loading issues and desired loading reductions. Management options within the reservoirs also are included, as these can provide potential acceleration of recovery of the reservoirs and protection for the investment represented by watershed controls.

The successful implementation of this TMDL will be based on compliance with water quality standard for pH. It is anticipated that TP reductions and commensurate Chl and pH reductions associated with this TMDL will be conducted adaptively over time. A phased approach offers an opportunity to reassess the loading targets, compare water quality to the pH standards, and revise the Plan, if necessary.

## 2.2 Point Sources

Point source management includes any modification to a permitted discharge of nutrients directly into the South Platte River (SPR), tributaries to the SPR, or canals within the watershed that result in reductions of TP concentrations. In general, such modifications are applicable to those facilities identified as subject to wasteload allocations in the TMDL. It is expected that for POTW permitting, future effluent TP restrictions will involve concentration limitations that include annual and 30-day averaging periods.

Municipal Separate Storm Sewer Systems (MS4s) are also point sources under the Clean Water Act. Management techniques to be applied are the same as those applied to non-regulated stormwater systems, such as removing illicit connections, source controls, and pollutant trapping. Future evaluations will identify if further reductions can be made from these facilities located within the BMW.

Reduction of the TP load originating from largest WWTPs (the RWHTF, L/E, and Centennial) is the centerpiece of watershed activity for successful restoration of Barr and Milton. Achieving a desirable TP concentration in WWTP discharges will require changes in treatment technology. For example, there are multiple options for removing TP from wastewater (Metcalf and Eddy 2002). The most common physical/chemical approaches include flocculation using alum, with or without filtration, and dissolved air flotation. Each of these options carries substantial capital and operational cost and each affected facility, e.g., those with wasteload allocations, will need to determine an appropriate approach based upon its current treatment configuration and future effluent limitation requirements as determined in permit renewals.

In June, 2012, the Water Quality Control Commission (Commission) adopted Regulation No. 85, the Nutrient Management Control Regulation (5 CCR 1002-85). For this TMDL, the Division has proposed an adaptive discharge permit implementation approach for the RWHTF, L/E, and Centennial that is consistent with Regulation No. 85 requirements. Such adaptive implementation is compatible with the phased implementation approach of this TMDL and also is consistent with TMDLs approved by EPA in other parts of the country. According to EPA,

> *Adaptive implementation is an iterative implementation process that makes progress toward achieving water quality goals while using any new data and information to reduce uncertainty and adjust implementation activities. The National Research Council report suggests that adaptive implementation include "immediate actions, an array of possible long-term actions, success monitoring, and experimentation for model refinement." By using the adaptive implementation approach, one can utilize the new information available from monitoring following initial TMDL implementation efforts to appropriately target the next suite of implementation activities.*

And, as EPA has noted with respect to the Great Lakes:

> *Some TMDLs may be based on attaining water quality standards over a period of time, with specific controls on individual sources being implemented in stages. Determining this reasonable period of time in which water quality standards will be met is a case-specific determination...*
>
> *As with all TMDLs, these TMDLs must be established at a level necessary to meet water quality standards. However, in this situation, the time frame in which water quality standards will be achieved is based on a planned staged implementation of controls and a determination of the appropriateness of this timeframe is made on a case specific basis. Additionally, the types of additional measures that are recommended for inclusion in phased TMDLs as envisioned in the 1991 Guidance, such as monitoring to verify load reductions, evaluation of effectiveness of controls, and revision of load and wasteload allocations as necessary are required…*

The initial effluent limitations for total phosphorus at the RWHTF, L/E, and Centennial will be set at 1.0 mg/L phosphorus as a running annual median (most recent 12 calendar months) and 2.5 mg/L phosphorus as the 95$^{th}$ percentile of all samples taken in the most recent 12 calendar months. The Division will incorporate this initial effluent limit into permits upon the first permit renewal after approval of this TMDL, with compliance schedules if appropriate. The limits are the same as required for "existing" facilities in Regulation No. 85 that are not subject to exclusions or delayed implementation. These controls will be considered interim effluent limitations.

As indicated in the TMDL allocation tables, in subsequent permit renewals, the most restrictive final permit effluent limitations at the largest facilities for total phosphorus would be 100 µg/L implemented as an annual average plus a 30-day average not to exceed 3 times the annual average at any hydraulic capacity (rated or existing) for the identified wastewater treatment facilities with wasteload allocations. When combined with other management strategies identified in this Plan this effluent concentration level will allow Barr and Milton to meet the pH standard.

In addition to the three largest POTWs identified in the TMDL as having wasteload allocations, other facilities located within the Barr-Milton datashed will be subject to the Regulation No. 85 effluent limitations.

## 2.3 Non-Point Sources

Non-point sources contribute to the total nutrient load to Barr and Milton, but even if these sources were completely removed from the watershed the external TP load to Barr would be reduced by only <5% and Milton would be reduced by only <11%. Non-point sources of nutrients will need to be addressed for implementation of the TMDL to be successful. As point sources are reduced, non-point sources will become a larger percentage of the remaining load. Implementing Best Management Practices (BMPs) to reduce non-point source inputs should be an element of the improvement of Barr and Milton.

Because "background" sources of TP from upstream sources are included in the TMDL allocation tables as loads, it may be possible to obtain significant TP reductions through in-canal treatments, e.g., dosing of aluminum or other P inactivators.

Non-point source management alternatives include any modifications to a land use type within the watershed to alter runoff quality and/or quantity. Different land uses clearly discharge different levels of nutrients based on the practices occurring on that land use type. For example, more TP is exported from agricultural cropland than from natural grasslands or urban landscape. Similarly, more TP is exported from highly developed areas than from natural forest areas. The types of watershed modifications to control non-point sources of nutrients might include changing a land use from a high nutrient export type to a low export type or applying one or more BMPs to reduce the export from the land. In the case of the BMW, this would generally be the conversion of agricultural land to developed land or a fractional reduction in nutrient loads from agricultural land or developed land resulting from the effects of one or more BMPs.

Experience suggests that aggressive implementation of watershed BMPs may result in a maximum practical TP loading reduction of 60-70% for the watershed area treated (Center for Watershed Protection 2000). Greater reductions are possible, but costs, space requirements, and legal ramifications (e.g., land acquisitions, jurisdictional issues) limit attainment of such reductions. Most techniques applied in a practical manner do not yield >60% reductions in TP loads (Center for Watershed Protection 2000, Simpson and Weammert 2009). Better results may be possible with widespread application of low impact development (LID) techniques, as these reduce post-development volume of runoff as well as improve its quality, but there is not enough of a track record yet to generalize attainable results for LID on a watershed basis.

There are a number of BMPs that could be applicable to the Barr and Milton watersheds, depending on site-specific conditions (Table 2-1). BMPs fall into three main functional groups: 1) Recharge/Infiltration practices, 2) LID practices, and 3) Extended Detention practices. The table lists the practices, pollutants typically removed, and degree of effectiveness for each type of BMP. Specific information on the BMP performance is well summarized by the Center for Watershed Protection (2000).

Residential areas are close to the tributaries of Barr and Milton. Some communities with MS4s have been installing BMPs that encourage infiltration or stormwater detention to reduce channel erosion and reduce TP concentrations by settling and contact with the soil prior to entry to the reservoirs. Such practices may have been operating for Phase I and Phase II municipalities for years. Other local control options, such as ordinances to restrict application of phosphorus-containing fertilizers to turf, may be considered for evaluation.

Several large interstate highways and numerous smaller state, city, and residential roads are located throughout the BMW. Detention practices can improve the quality of stormwater originating from the highways and developments in the BMW.

Application of BMPs to non-regulated sources of phosphorus is an option that could provide reductions in overall stormwater and runoff loads.

Agriculture constitutes a large portion of the lower watershed; therefore, agricultural BMPs should be evaluated during implementation of the TMDL. BMPs might include buffer strips to prevent nutrient export from fields, conservation tillage, use of cover crops, proper animal waste management, and minimized use of fertilizers.

Section 319 of the Clean Water Act was established to assist states in non-point source control efforts. Under Section 319, grant money can be used for technical assistance, financial assistance, education training, technology transfer, demonstration projects and monitoring to assess the success of specific non-point source implementation projects. Applicability of 319 assistance programs will be evaluated as the TMDL is implemented.

***Table 2-1. Best Management Practices Selection Matrix***

**Key**
- Adverse Impact
- Moderate Mitigation
- Good Mitigation
- Minimal Mitigation
- Moderately Suited
- Well Suited
- Not Applicable

| Management Practice | Ability to Mitigate | | | | | | | | | | | | | | | | Applicability | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Runoff Volume (↑) | Peak Flow Rates (↑) | Bankfull Flow (↑) | Baseflow (↓) | Mod. Sed. Transport | Channel Morph. Changes[1] | In-Stream Temp. (↑) | Sediment conc. (↑) | Nutrient conc. (↑) | Metal Conc. (↑) | Hydrocarbon Conc. (↑) | Bacteria/Pathogens (↑) | Organic carbon Conc. (↑) | MTBE Conc. (↑) | Pesticide conc. (↑) | Deicer conc. (↑) | New Development | Retrofit | Urban | Sub-Urban | Residential Sub-Division | Commercial | Industrial | |
| **Recharge / Infiltration Practices[2]** | | | | | | | | | | | | | | | | | | | | | | | | |
| Infiltration Swale | | | | | | | | | | | | | | | | | | | | | | | | Permeable site soils required. Pre-treatment recommended. |
| Infiltration Trench/Galley | | | | | | | | | | | | | | | | | | | | | | | | Permeable site soils required. Pre-treatment recommended. |
| Retention/Infiltration Basin | | | | | | | | | | | | | | | | | | | | | | | | Permeable site soils required. Pre-treatment recommended. |
| **Low Impact Development Practices** | | | | | | | | | | | | | | | | | | | | | | | | |
| Bioretention | | | | | | | | | | | | | | | | | | | | | | | | |
| Disconnecting Impervious Area | | | | | | | | | | | | | | | | | | | | | | | | |
| Flow Path Practices | | | | | | | | | | | | | | | | | | | | | | | | Includes increasing roughness, sheet flow, flow path length, and flattening slopes. |
| Green Roof | | | | | | | | | | | | | | | | | | | | | | | | |
| Minimize Disturbance Area | | | | | | | | | | | | | | | | | | | | | | | | Used as a component of LID site design. |
| Minimize Site Imperviousness | | | | | | | | | | | | | | | | | | | | | | | | Includes imiting use of sidewalks, and reducing road/driveway length/width. |
| Porous Pavement | | | | | | | | | | | | | | | | | | | | | | | | |
| Preserve Infiltratable Soils | | | | | | | | | | | | | | | | | | | | | | | | Used as a component of LID site design. |
| Preserve Natural Depression Areas | | | | | | | | | | | | | | | | | | | | | | | | Used as a component of LID site design. |
| Rain Barrels/Cisterns | | | | | | | | | | | | | | | | | | | | | | | | |
| Rain Garden | | | | | | | | | | | | | | | | | | | | | | | | |
| Soil Amendment | | | | | | | | | | | | | | | | | | | | | | | | Used as a component of LID site design. |
| Vegetated Filter Strip | | | | | | | | | | | | | | | | | | | | | | | | |
| Vegetation Preservation | | | | | | | | | | | | | | | | | | | | | | | | Used as a component of LID site design. |
| **Extended Detention Practices** | | | | | | | | | | | | | | | | | | | | | | | | |
| Created Wetland/Biofilter Detention | | | | | | | | | | | | | | | | | | | | | | | | |
| Extended Detention Pond | | | | | | | | | | | | | | | | | | | | | | | | |
| Wet Detention | | | | | | | | | | | | | | | | | | | | | | | | |
| **Other Best Management Practices** | | | | | | | | | | | | | | | | | | | | | | | | |
| Deep Sump Catch Basins | | | | | | | | | | | | | | | | | | | | | | | | Pre-treatment prior to infiltration BMPs |
| Sand/Organic Filter | | | | | | | | | | | | | | | | | | | | | | | | |
| Swale | | | | | | | | | | | | | | | | | | | | | | | | Dry swale with some infiltration. |
| Water Quality Inlet | | | | | | | | | | | | | | | | | | | | | | | | Includes proprietary hydrodynamic devices. Pre-treatment prior to exfiltration BMPs. |

[1] *Impacts include channel enlargement/incision/embededness, changes in pool/riffle structure, and reduced channel sinousity.*

[2] *Recharge and infiltration measures require permeable soils and pre-treatment is recommended. See specific BMP descriptions for more information.*

## 2.4 Internal Sources

Management alternatives that involve mechanical, chemical, or biological modifications to either Barr or Milton directly are considered in-reservoir controls. Such controls are commonly used to improve short-term water quality conditions in waterbodies, but can be applied in an ongoing fashion to achieve longer term results. In addition, in-reservoir controls can be used to accelerate recovery of a waterbody after external sources of phosphorus have been addressed.

Reduction of external loads may ultimately lead to the reduction of the internal load, but the timing and magnitude of this reduction is unknown. Experience of the AECOM staff indicates that multiple decades are necessary for internal loads to naturally decline to the point where internal loading is not a major factor. Since the estimated internal loads represent a substantial percentage of the total load and are active during the key summer period, reduction of external TP loads without reduction in the internal load will not likely result in attainment of the pH standard in a timely manner. A 70% reduction in the internal load, in conjunction with equally large external loading reductions, will be necessary to meet the in-reservoir TP target. Depending on how the internal load is addressed, there may be some impact on recent external loading, but the longer term impacts of continued elevated loading from the watershed will not be mitigated by a single application of an in-reservoir control.

Even with uncertainty over the current internal load to Barr and Milton, some in-reservoir method likely will be needed eventually; the internal reserves are so large that even with a small percentage of phosphorus in available form, releases from the sediment are expected to offset decreases from external loading. Possible strategies include the following:

- Dredging would be the most effective strategy overall, actually removing the internal reserves.
- Inactivation with aluminum is probably more cost effective, limiting release from surficial sediments without the cost of sediment removal.
- Aeration strategies, including mixing if effective enough to prevent anoxia near the sediment-water interface, can limit phosphorus availability and disrupt algal growth, but only when continuously applied during the growing season.
- Addition of carbon dioxide or algaecides provides temporary relief and will require at least annual application.
- Biomanipulation has potential to aid pH control, either through reductions in planktivore fish that eat zooplankton that in turn eat algae, or through removal of carp and other bottom feeders that add to sediment resuspension and internal TP loading.

In-reservoir studies conducted in Phase I will help identify which of these strategies will help achieve the TMDL goal. Ongoing limnocorral studies are described in section 5.1.1.

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# 3. PHASED TMDL IMPLEMENTATION

The pH TMDL is structured as a phased TMDL per the EPA publication *Guidance for Water Quality-Based Decisions: The TMDL Process* (April 1991) and an EPA memorandum *Clarification Regarding "Phased" Total Maximum Daily Loads* (August 2, 2006). Selection of a phased TMDL necessitates use of an Adaptive Implementation Plan that allows for the development of new information used to re-evaluate the original TMDL.

Per U.S. EPA's August 2006 Guidance Memorandum (Guidance), a phased TMDL approach is "…used in situations where limited existing data are used to develop a TMDL and the State believes that the use of additional data or data based on better analytical techniques would likely increase the accuracy of the load calculation and merit development of a second phase TMDL." The pH TMDL is currently written as a phased TMDL with the possibility of multiple phases. The first phase includes load allocations, wasteload allocations, and an implicit margin of safety (MOS) that are established to attain and maintain the existing underlying pH standard, using the best available data and modeling results to date. As described in Section 5, a number of studies will be undertaken to reduce the uncertainty of the water quality goals that were used to develop the allocations. As more information becomes available through these studies, future phases of TMDL development may be necessary to revise the water quality goals, allowable load calculations, and allocations.

It is understood that the pH TMDL will require re-approval by EPA if it is necessary to embark upon a second phase of the pH TMDL that results in a revision in loading capacity, wasteload, or load allocations.

This section presents the scope of the uncertainty associated with the TMDL, which sets the stage for further studies to resolve the uncertainty, which are presented in Section 5.

## 3.1 Uncertainties Associated With the TMDL

The TMDL discusses four distinct areas of uncertainty specific to results generated through the modeling process. Each of these areas of uncertainty influence the degree of accuracy for which existing and future loads can be calculated.

1. Uncertainty associated with the relationships among pH, TP, and Chl.
2. Uncertainty with the calculated magnitude of the existing TP load.
3. Uncertainty in the derivation of internal loading of TP.
4. Uncertainty in the future effect of alkalinity on pH attainment.

Although not discussed in the TMDL, uncertainty also results from high variability induced by factors not specifically measured, including light fluctuation, possible allelopathy among organisms, grazing pressure by zooplankton as influenced by fish, erratic mixing, and periodic flushing.

Studies will be developed and implemented to address each of these areas. These are discussed in more detail in Section 5.

### 3.1.1 pH, TP, Chl Relationships

In general, relationships among TP, Chl, and pH from the BMW system are limited because the dataset is dominated by high TP values. Under existing conditions, TP concentrations are generally greater than 250 µg/L, especially in the summer. The data set is limited in that there is a lack of observed values for TP that fall at or below the TP water quality target of 100 µg/L and, therefore, there are no corresponding pH and Chl data below that target TP concentration. The lack of strong relationships for either TP or total nitrogen (TN) and response variables like Chl or pH has two component parts. First, TP and TN tend to covary positively, although more weakly in Milton than in Barr. The refill of Barr over the winter results in very high levels of both TP and TN, most of which is in available forms; consequently, there is much more TP available than algae need to bloom. Secondly, at such high TP and TN levels, other factors, such as light, temperature, mixing, or even carbon supply, can become primary determinants of algal composition and abundance.

Current model output reports a 54% explained linkage between pH, inflows, surface temperatures, and Chl in Barr and Milton. It can be seen that higher TP or TN allows for higher Chl, but the relationship is very weak; there are many cases where higher TP or TN coincides with lower Chl. Of particular concern is the potential for high pH values when chlorophyll levels are low (<10 µg/L), particularly in Milton Reservoir. Investigations conducted in preparation of the TMDL indicate that a much tighter correlation between pH and TP is expected at TP levels <100 µg/L, although this is yet to be tested based upon actual conditions. The uncertainty in these correlations affects the degree of confidence in calculated TP load reductions required to bring the reservoirs into compliance with the pH standard.

### 3.1.2 Existing TP Load

TP loads entering Barr from the Burlington-O'Brian Canal and Milton via the Platte Valley and Beebe Canals have been calculated by three separate entities: (1) by AMEC in the 2008 Reservoir Assessments using mass balance calculation methods, (2) by Lewis and McCutchan in 2009 using the mass balance approach, and (3) by AECOM in its modeling efforts of 2009. The range in outputs generated by the three entities adds further uncertainty to projecting a desirable loading level to achieve pH compliance through external TP control. In order to rectify the differences in the three results, AECOM utilized a fourth, empirical approach to perform a mass balance calculation with the data while applying best professional judgment in adjusting the critical variables. Results from the fourth approach were used as the basis for subsequent TMDL-related calculations. The high variability associated with existing load calculations makes it problematic to determine, with certainty, the necessary percent reductions in loads and wasteloads.

### 3.1.3 Internal Loading and Settling of TP

There is considerable uncertainty surrounding the internal load of phosphorus in these reservoirs. Phosphorus appears to be very dynamic in the reservoirs, with uptake by diatoms in the winter and spring resulting in high sedimentation of phosphorus and declining water column concentrations. Phosphorus values rise during the summer, while external inputs are low, suggesting substantial internal loading. There are very few submergent vascular plants in these reservoirs, so the remaining two mechanisms are chemical release of soluble P from sediments and resuspension of those sediments, potentially with dissociation of phosphorus from some particles. Both mechanisms are likely to be important in these reservoirs, given very high sediment phosphorus levels and declining water levels over the summer (AECOM 2009). Three separate estimates of internal load contributions were developed: (1) AMEC reported internal TP loads consistent with literature values for similar lake systems (2008), (2) AECOM model effort (2009) resulted in very high estimates of phosphorus sediment release that were required to offset settling observed in the spring, and (3) AECOM developed empirical estimates of phosphorus release based upon limited sediment core sampling and analysis (2009). Variability in the three sets of results is high. AECOM chose to utilize internal loading values closer to the empirical values calculated from lake data, although the sampling size was quite low. As with estimates of external TP loading, it is difficult to pinpoint the level of TP contribution from the internal load source and, therefore, difficult to ascertain the percent reduction required. This modeling has shown that control of in-lake loading will be critical in meeting the water quality goals identified in the pH TMDL.

The model initially over-predicted in-lake phosphorus during the late winter and springtime infill period. To counteract this, a process of associating phosphorus with predicted total suspended solids (TSS) and then settling the TSS was applied. An acceptable calibration was achieved in both reservoirs during the later winter and springtime infill period by adjusting the phosphorus to TSS partitioning coefficient and the settling rate of TSS.

The diffusion of dissolved phosphorus from the lake sediments to the water column, which occurs under low dissolved oxygen (DO) conditions at the sediment-water interface, is not uncommon in eutrophic systems. Resuspension of particulates, with some dissolution of attached phosphorus, is also expected in these shallow systems through the influence of wind and bottom feeding fish. Without incorporating internal loading processes into the lake models, the predicted phosphorus concentrations during the summer months were consistently lower than actual data indicated. With continued settling of particulates, the net internal load is much lower, as reflected in other mass balance estimation efforts. The seasonal nature of phosphorus settling and resuspension appears very important in the BMW system and was adequately simulated by this process, although the exact mechanisms may deviate from the way the model portrays them.

Internal loading of phosphorus may be an important input source in at least Barr. Internal loading in both reservoirs is sufficient to support algal blooms and contravene the pH standard, and is expected to increase substantially if external loading is decreased.

### 3.1.4 Effect of Alkalinity

Under the current alkalinity concentrations in the reservoirs, the equilibrium pH would be close to 8.5 S.U., leaving very little room for photosynthetic activity to outstrip respiration without exceeding a pH of 9.0 S.U. more than 15% of the time. The presence of any phosphorus would raise the average pH and risk exceeding the standard under the expected variability in pH levels. If the baseline alkalinity is not altered, there is little chance of reduced phosphorus loading being sufficient to limit algal productivity to meet the pH standard. There is reason to believe, however, that watershed actions related to TP control will also result in reduced in-lake alkalinity. The TMDL analysis assumes that alkalinity will be reduced from its current average concentrations above 150 mg/L to a value closer to 95 mg/L, consistent with background conditions in surrounding lakes and streams. Further studies on the site-specific effect of alkalinity in the reservoirs, as well as the feasibility of reducing alkalinity loading from the watershed, need to be conducted to verify the validity of the TMDL assumptions for this parameter. As alkalinity has a bearing on the capacity for changes in pH, changes in alkalinity assumptions will affect required load reductions.

## 3.2 Other Uncertainties That Could Affect Implementation Activities

At the present time there is a temporary modification of the pH standard for both Barr and Milton that will expire on 12/31/2015. The basis of the temporary modification is the attainability of the underlying pH standard and the ability of permitted point source dischargers to comply with requirements of the TMDL, e.g., through permit requirements to implement wasteload allocations. During Phase I, feasibility and other related studies will be undertaken to better understand the impacts of phosphorus reductions from point sources on pH levels in the reservoirs.

As discussed previously, the Water Quality Control Commission adopted a statewide approach to regulate nutrients (both phosphorus and total inorganic nitrogen) in June 2012. This coordinated nutrient reduction strategy will initially implement Regulation No. 85-based effluent limitations statewide for the forty-four largest facilities first. Then, once statewide total phosphorus and total nitrogen criteria become effective, enforceable phosphorus and nitrogen water quality standards will be adopted in subsequent basin hearings, generally after 2022. This will include standards for warm water lakes and reservoirs. Site-specific standards may be developed during this timeframe.

Identification of appropriate and cost-effective phosphorus reduction strategies will be an important aspect of the implementation strategy for permitted point sources, including POTWs and MS4s. Phase I studies are expected to include collection and evaluation of information that can assist individual entities to assess capital improvement options. As the U.S. Environmental Protection Agency (EPA) stated recently regarding secondary treatment nutrient removal capability at domestic wastewater treatment facilities (letter to Natural Resources Defense Council dated December 14, 2012):

> *We also note that the feasibility of replacing current secondary treatment systems to add nutrient removal is highly site-specific, depending on numerous factors unique to each site. These include the current system's size, design, and retention time, the system's age and remaining useful life, whether combined sewer systems are present (which create significantly higher influent flows during periods of high rainfall), the availability and cost of land for any necessary expansion, zoning codes and local land use concerns, and differences in sludge generation and associated dewatering and disposal costs.*

Such considerations will need to be carefully evaluated for each affected regulated point source subject to a wasteload allocation under the TMDL.

# 4. ADAPTIVE IMPLEMENTATION

The National Research Council (NRC) in *Assessing the TMDL Approach to Water Quality Management* (2001) found that uncertainties associated with estimates of the TMDL and forecasted improvements based on controls were such that implementation of the TMDL could result in ineffective and wasteful use of limited resources. The NRC concluded that a "learning while doing" approach would be more effective in addressing predictive uncertainties.

This Adaptive Implementation approach calls for ongoing assessment of improvements and costs from implementation of controls, and use of this information to improve the predictive models and adjust Plan elements. For example, data collected at each stage of the studies will be used to make "mid-course" adjustments to improve or enhance ongoing management and control activities. Adaptive Implementation, focused on monitoring and evaluation, will be used to reduce the uncertainties associated with implementation.

## 4.1 Rationale For Adaptive Implementation

Regarding the use of TMDLs with Adaptive Implementation, the Guidance (U.S. EPA 2006) offers the following:

> *"Implementation of TMDLs can take many years and when uncertainty about the effectiveness of implementation exists, TMDLs would benefit from containing elements that would facilitate adaptive implementation such as, for example, provisions for a flexible load allocation/waste load allocation scheme."*

And:

> *"...EPA believes that in appropriate cases it should be feasible for States to develop TMDLs that facilitate implementation of practicable controls while additional data collection and analysis are conducted to guide implementation actions."*

Phase I activities will seek to resolve uncertainty about the effectiveness of certain implementation activities to achieve the pH standard. This process is summarized in Figure 4-1 (based on Shabman et al. 2007).

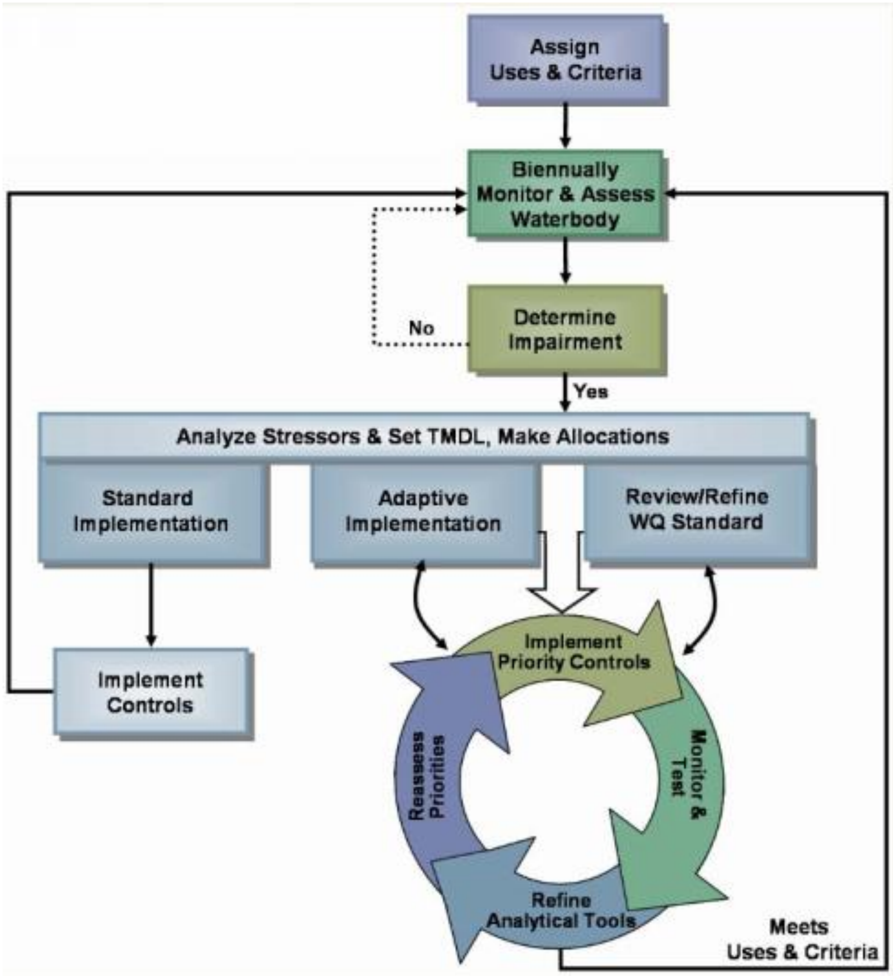


Figure 4-1. The Adaptive Implementation Process.

## 4.2 Adaptive Management Approach

The Association and its members perform regular water quality monitoring throughout the basin and will continue to do so as the TMDL is implemented. These data will be used to measure changes in water quality in the reservoirs over time. TMDL implementation also will include permit compliance schedules for upgrades at permitted wastewater and stormwater discharges that have wasteload allocations as discharge permits are renewed. Analysis of reservoir management and in-lake and canal treatment options also will begin once the TMDL is approved. Data collection and analysis will provide feedback on the water quality changes in the watershed and the reservoirs over time. The response measured in the reservoirs will be used to refine the assumptions made in development of the allocations, which will allow for adaptive changes to this TMDL Implementation Plan. Additional modeling runs based on refined data will provide information to reduce identified uncertainties. Another step in TMDL implementation is the identification and implementation of BMPs to control appropriate non-point sources of phosphorus in the watershed. Changes resulting from new regulatory initiatives and/or any court decisions will be incorporated into this Plan and the TMDL, if required.

Any subsequent TMDL phases (beyond Phase I) will necessarily incorporate information and results from the previous Phase. Identified Phase I studies are outlined in Section 5.

# 5. DESCRIPTION OF PROPOSED PHASE I STUDIES

This section describes the studies that will be conducted in Phase I to reduce uncertainty as well as assess the feasibility of various phosphorus reduction strategies. Each study will have a plan to describe the objective of the study and will contain details for implementing the study. Each study plan and results will be incorporated into this Implementation Plan. As such, the Implementation Plan is a "living" document that will be updated periodically.

As outlined in Appendix A, there are two categories of proposed studies: (1) studies to address technical uncertainty issues, and (2) studies to assess feasibility of phosphorus reduction strategies. The results from the identified studies will be used to evaluate the overall effectiveness of TMDL implementation and may be utilized in the future to develop appropriate site-specific water quality standards for the reservoirs.

## 5.1 Studies to Reduce TMDL Uncertainties

This section outlines studies currently identified to resolve uncertainties associated with the TMDL. Table A-1 in Appendix A summarizes the Phase I studies.

### 5.1.1 pH, TP, Chl Relationships

One key study to reduce the underlying uncertainty around the TMDL will utilize limnocorrals to establish the relationships between TP, Chl, and pH. The limnocorral study will use four impervious curtains to isolate a column of reservoir water in the deepest area of Barr. The study will include a control corral and three test corrals. Within the limnocorral, aeration and alum techniques will be used to reduce TP to concentrations well below the current concentrations. Then intense monitoring and observations will take place to document how Chl and pH respond to the decrease in TP.

In 2011, corrals were tested with aeration. The purpose of the aeration was to see if algae, Chl, TP, and pH would decrease with destratifcation. Preliminary results showed that the mixing of the entire water column did not reduce the TP, but it did delay the blue-green algae blooms by about a month. Blue-green algae prefer calm water and do not do as well when force to the bottom of the water column. Eventually, the algae were able to bloom and cause high Chl. The end result was the pH standard would most likely not be met with just aeration even though it helped deter algal blooms. Alkalinity did not change with aeration which needs to be reduced to 95 mg/L.

In 2012, alum was used to chemically strip the TP out of the water column in three of the corrals. The dosage of alum was about 12 mg of Al/L. Initial results show that that pH drops below 9.0 as TP drops from about 400 ug/L to less than 100 ug/L. Alkalinity is also reduced with alum. Results also indicate that the Chl and pH can be met when TP is less than about 200 ug/L as long as the alkalinity is also below 100 mg/L.

In one of the test corrals, the average TP for the study was 137 ug/L which resulted in an average Chl of 2.8 ug/L, an average pH of 7.42, an average alkalinity of 95 mg/L, and an average Secchi depth of 3.8 meters. All standards were met.

For 2013, more limnocorral studies using alum will be conducted. This will help with reducing the uncertainty with the relationships by duplicating the study. Also, a drought occurred in 2012 causing the reservoir elevation to drop significantly.

Information gathered from the limnocorral studies will be used to update the models and correlation equations in 2013 and 2014. The data will be used to improve the mass balance calculations for the current target loading estimates.

### 5.1.2 Existing TP Load

Lake inflows and outflows are an important component of the equation used to derive existing and future allowable load calculations. New flow monitoring and recording devices have been installed at various locations along the Burlington-O'Brian Canal (inflow to Barr) and Beebe and Platte Valley Canals (inflow to Milton), as well as at the outlet structures. This new flow information is being recorded and compiled to create a more reliable database than that used in the current model for the period through 2005.

Water quality sampling has been refined over time to fill in data gaps identified by the technical studies and to reduce redundancy. An explanation of the sampling plan modifications that will take place as part of this phased TMDL is provided in Section 7.1. The results of data analysis will be used to determine if adjustments are needed to ongoing or planned restoration and management measures, if additional actions are needed, or if certain actions are no longer required.

More accurate flow information combined with targeted water quality data will be used in subsequent model runs.

### 5.1.3 Internal Loading and Settling of TP

With the small scale mesocosms in Barr (e.g., limnocorral studies), many other unknowns will be addressed. Internal loading has never been measured. By removing TP from the water column through the limnocorral studies described in Section 5.1.1 above, the rate and magnitude of internal loading can be measured as TP levels build back up in the limnocorral without further influx of TP from the water column.

As external loads are reduced, internal loading will play a bigger role in the overall annual loading. Internal loading will be studied and estimated during the limnocorral studies. In addition, internal loading will be calculated each time the water quality models are updated.

### 5.1.4 Effect of Alkalinity

"Background" pH and alkalinity levels are unknown. Eliminating the hypereutrophic conditions within the limnocorrals by using alum addition, for example, should allow estimation of background pH and alkalinity levels specific to Barr. This condition will also provide an indication of the probable alkalinity chemistry once phosphorus removal activities have been implemented.

## 5.2 Studies to Assess Feasibility of Phosphorus Reduction Strategies

Because external TP loads must be reduced significantly, evaluation of appropriate nutrient reduction technologies will be important for permitted dischargers. Information from such studies can help POTWs and MS4 communities plan and budget for needed capital improvements. This information can also provide information that may be applicable to controlling non-point sources of phosphorus, including internal loads. These studies also will help the Association plan for future regulatory challenges such as enforceable nutrient standards and other water quality requirements.

### 5.2.1 Use Attainability Analysis to Resolve Uncertainty Associated With the pH Standard

The federal Clean Water Act (CWA) §101(a)(2) allows states to change designated uses by completing a Use Attainability Analysis (UAA) for the affected water bodies. A UAA is a regulatory tool available to states, tribes, and public and private proponents that can be used to modify the designated uses and applicable water quality criteria for a particular water body.

In order for a designated use to be modified, the UAA must demonstrate that the water body meets at least one of the six candidate conditions listed in Table 5-1 below.

| Table 5-1. Applicable Conditions for Completing a UAA[a] | |
|---|---|
| **Condition** | **Description** |
| 1 | Naturally occurring pollution concentrations prevent the attainment of the use. |
| 2 | Natural, ephemeral, intermittent, or low-flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met. |
| 3 | Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place. |
| 4 | Dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use. |
| 5 | Physical conditions related to the natural features of the water body, such as lack of proper substrate, cover, or flow; or depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses. |
| 6 | Stringent controls would result in substantial and widespread economic and social hardship. |

Studies and research will be needed to see if a UAA is appropriate to set a site-specific pH standard for the reservoirs. Because of the uniqueness of the watershed and the anthropogenic forces acting on the reservoirs, a site-specific water quality standard may be appropriate for both reservoirs. As such, the Association will investigate the option of identifying refined uses for Barr and Milton. This could include determining the effort required to refine the uses and, using data collected to determine pH, TP, Chl, and alkalinity linkages, evaluate whether a site-specific pH standard should be investigated based on UAA guidelines.

### 5.2.2 Cost-Benefit Analyses for Controls at POTWs

The purpose of a TMDL and its implementation is to improve water quality on a watershed basis, rather than on an individual basis, as overall water quality is influenced by both point and non-point sources. Focusing on an individual constituent or issue in a watershed can lead to unintended consequences from resulting increased use of chemicals, energy, and other resources. Individual POTWs will need to investigate the feasibility and cost to rate payers and the environment for treating wastewater to specific levels for TP. For example, at certain levels of treatment, energy and chemical intensive treatment practices may cause significant environmental harm, e.g., increased greenhouse gas emissions associated with energy consumption.

The City of Westminster finished a major facility upgrade of its Big Dry Creek Wastewater Treatment Facility in the fall of 2008. The upgrade included a capacity expansion and the addition of biological nitrogen and phosphorus removal. The design flow went from 9.2 to 11.9 MGD. The average influent flow 2012 YTD was 7.2 MGD. The average effluent flow was 4.9 MGD. Prior to the upgrade effluent phosphorus averaged approximately 3.3 mg/L. After the upgrade annual averages have ranged from 0.6 to 1.6 mg/L and annual medians have been from 0.3 to 1.2 mg/L. Phosphorus removal is not currently required and has not been completely optimized during this period.

The City and County of Broomfield has completed two of the three-phase expansion of the Broomfield Wastewater Reclamation Facility to include biological nutrient removal, solids handling, and wastewater reuse. The first phase expansion and upgrade was completed in January 2005. This phase expanded the wastewater treatment capacity to 8.0 mgd and added nitrification, de-nitrification, phosphorus treatment, solids dewatering processes and 6 mgd wastewater reuse treatment and pumping processes. The second phase was completed in November 2010. This expanded the treatment capacity to 12.0 mgd and added a new screening building, new grit removal, additional nitrification, de-nitrification, phosphorus treatment, secondary clarification, and UV disinfection capacity. The expansion costs for nutrients were $14.7 million. In 2011, the average effluent total phosphorus was 0.11 mg/L. Phosphorus removal is not currently a permit requirement so optimization of the system has not been a priority to date.

### 5.2.3 Cost-Benefit Analysis for MS4s and NPS Controls

The long-term effectiveness of best management practices to reduce TP loadings from non-point sources and permitted MS4s within the BMW is not well understood More information will need to be collected specific to BMW.. The Association will conduct literature studies and evaluate the efficacy of pilot studies to determine costs and benefits associated with various BMPs to reduce MS4 and NPS TP loads. In addition, the association will work with MS4s in the BMW to examine existing stormwater data and BMPs in the BMW to determine the relative contributions of various permitted stormwater dischargers within the watershed as well as the effectiveness of current BMPs.

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### 5.2.4 Source Controls

Source controls could reduce the TP load to Barr and Milton. The Association will do a literature survey to identify potentially appropriate source controls for phosphorus. Source controls could include bans on lawn fertilizers as well as dish and laundry detergents. The costs of product bans will be compared to the cost of treatment at the POTW and cost/effectiveness of removal with BMPs, depending on the source.

A good example of phosphorus source control is a recent phosphorus ban in lawn fertilizers in Ann Arbor, Michigan. The City of Ann Arbor is under a regulatory mandate to reduce phosphorus loading to the Huron River in order to meet water quality standards. Studies show that about 24% of the phosphorus comes from nonpoint sources and about 43% comes from point sources. In 2006, an ordinance was approved to ban phosphorus in manufactured lawn fertilizers to help reduce the nonpoint sources. Initial study results show about a 30% reduction in phosphorus concentration downstream of the affected area.

It is possible that the Barr-Milton watershed could see reductions in phosphorus if fertilizer ordinances were enacted. With over 2.5 million people living within the watershed, changing how lawns are maintained could have a major impact. Any such initiatives likely would have to be developed at the local level.

### 5.2.5 In-Reservoir Treatment Options

In-reservoir restoration is likely to be needed in addition to external loading controls to meet the pH standards in Barr and Milton. More information is needed in order to select the appropriate actions for the treatment of the internal loading. A feasibility analysis will determine the best plan of action to reduce and/or manage the second largest source of phosphorus over the long term, including chemical treatment options. The Association will also evaluate potential mechanisms to ensure that in-lake treatments can be performed to satisfy the Division's requirements and concerns.

### 5.2.6 In-Canal Treatment Options

The Association will perform a literature review to identify possible methods for removing TP from the canals and ditches that feed Barr and Milton. An Engineering Feasibility Study will be conducted to evaluate various levels and types of treatment. The feasibility study will include jar testing of chemical treatment options, determining sedimentation rates in the canals, and estimating wetland retention times needed to reduce TP.

In-canal treatment can provide quicker and more cost effective water quality improvements than in-reservoir treatment. In-canal treatment takes place when upstream phosphorus is intercepted in the ditch before the water reaches the reservoir and is removed. For both reservoirs, the canals and ditches are heavily managed and controlled, which can allow for consistency and predictability regarding any in-canal phosphorus treatment. One possible example could be phosphorus interception along the Burlington Ditch, Beebe Canal, and/or the Platte Valley Canal. In addition, the water quality for each growing season is heavily influenced by the nutrient loads entering the reservoirs during the previous winter refill period. An in-canal treatment system could help provide nutrient reductions from nonpoint sources and from sources upstream of the Barr/Milton watershed.

In Florida, there are several examples of the use of alum to chemically remove phosphorus from canals. The basic design is that the water is diverted into a side channel where alum is added. Flocculation occurs, binding up phosphorus and settling out the aluminum hydroxide particulate. Once the floc, suspended solids, and phosphorus have settled out, the treated water is subsequently diverted back to the ditch and sent downstream to the reservoir. There are even mobile alum units that are used when the canal flows are intermittent and change among ditches. Constructed wetlands can also be used in-canal to remove phosphorus. This would require more land but is just as effective as long as the constructed wetlands are maintained in order to act as a sink for phosphorus.

### 5.2.7 Trading Opportunities and Offsets

Phosphorus credit trading and offsets could facilitate achieving the required load reductions within the BMW. Because the loading comes from a variety of sources, both point and non-point, and given the necessity of addressing all sources, the opportunity exists for exploring what might be the most cost-effective and environmentally beneficial solutions for achieving those reductions. The full range of opportunities will be assessed as part of the adaptive implementation process. Trades may involve point sources alone, e.g., between wastewater treatment facilities, since there is currently not enough data or information to develop a robust non-point to point source trading program. Offsets could occur where control of point or non-point nutrient sources reduces levels of nutrients for the purpose of creating assimilative capacity to allow new or expanded discharges.

BMW ADAPTIVE IMPLEMENTATION PLAN FOR pH TMDL

# 6. SCHEDULE

## 6.1 The implementation schedule and description are detailed for Phase I only. Since this is an adaptive process, new information acquired will dictate what additional information will be needed and whether any revisions are needed to the TMDL. Description/Schedule Phase I

The Association has identified projects and an associated schedule to help resolve uncertainties associated with the TMDL. A table of projects and action items (Table A-1) and a schedule (Table A-2) are included in Appendix A.

Each study completed in Phase I will be documented, including the results and conclusions of the study as well as next steps and/or additional studies identified. The conclusions, next steps, and identified additional studies will be used to update the studies table (Table A-1). Results from the studies also will be used to refine the model and assumptions to possibly revise the TMDL and associated allocations.

Regarding controls at wastewater treatment facilities, permit renewals are expected to follow completion of the South Platte Basin rulemaking hearing in 2015. This watershed-based permitting approach will likely not occur until 2016. The initial phosphorus effluent limitation requirements included in the RWHTF, L/E, and Centennial facilities' permits will be considered interim and will be based on the requirements of Regulation No. 85.Timing of the implementation of phosphorus controls at each facility having a wasteload allocation (or that is otherwise subject to Regulation No. 85 requirements) will be unique to each facility, with specific deadlines set forth in individual compliance schedules.

## 6.2 Description/Schedule Phase II

If the Phase I studies and information or wasteload and load reductions indicate that additional phases are needed, this Implementation Plan will be updated accordingly.

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# 7. MONITORING

As described in the *Barr Lake and Milton Reservoir Watershed Management Plan* (BMW 2008), significant monitoring of the BMW system has been undertaken and is ongoing. Historical monitoring efforts have including monitoring at 360 water quality sampling stations and 40 waterbodies within the BMW. A majority of the sampling on streams has been located around and through of Denver. However, extensive data exist for both Barr and Milton.

Monitoring programs have been undertaken by a number of different stakeholders within the watershed. The most detailed description of past monitoring activities is provided by Hydrosphere (2005). Flow and water quality monitoring stations are shown, descriptions of flow and water quality monitoring locations are provided, and the typical sampling frequency is summarized by organization conducting the monitoring. That report also summarizes the eutrophication-related monitoring undertaken by the various watershed stakeholder groups. Many of these efforts are ongoing, along with the ongoing monitoring of the Association.

The existing monitoring programs (including sampling of approximately 93 active water quality monitoring locations) will be continued with some changes. Changes from the existing monitoring programs that have been recommended or adopted to date include:

- Installation of automated flow gages at three locations (the Platte Valley Canal and the Beebe Canal immediately upstream of Milton, and the Burlington-O'Brian Canal headgate), to generate accurate flow data.
- Installation and operation of automated *in situ* continuous pH monitoring systems in Barr and Milton to characterize spatial and temporal variation in pH.
- Collection of meteorological data at Milton to support flow and pollutant transport assessments.
- Consistent analysis for key parameters at all watershed monitoring locations to minimize data gaps and dependence on estimation procedures.
- Increased monitoring frequency where time gaps hinder loading assessment
  - <u>Samples from reservoirs</u>. It is desirable to collect samples weekly for March through October and monthly for November through February for the first 3 years after initiation of TMDL implementation or until measurable load reductions begin. Frequency during March through October may be scaled back thereafter based on review of data collected.
  - <u>Samples from streams and canals</u>. It is desirable to collect samples on at least on a monthly basis at all locations. Collection twice per month is preferred for the direct inflows into the reservoirs throughout the year.
  - <u>Samples from POTWs/MS4s</u>. Collection of samples twice per month is desired from flowing discharges. More data are needed from WWTP discharges to validate estimated loading. Regular sampling may be difficult for MS4s, which should only flow in response to precipitation events, and flexibility can be maintained as appropriate. The intent is to adequately characterize inputs and minimize estimation error.

- Reduction in the number of sampling locations in Barr and Milton to one primary location in each, near the outlet or at a central location of each water body, eliminating other reservoir locations.
- Single stations were found to adequately represent reservoir conditions from monitoring conducted so far. Multiple automated sampling or *in situ* analysis instruments may be deployed (e.g., pH) and periodic surveys to characterize spatial variability (e.g., Chl) are warranted, but routine sampling of most chemical features of the reservoir can be conducted at a single location with limited loss of information but substantial cost savings. Surface, mid-depth and near bottom measures are needed from the chosen location, which would be near the deepest point of each reservoir.

The recommended monitoring program is intended to build on existing data and allow for detection of water quality changes associated with wasteload and load reductions and in-lake management activities.

## 7.1 Ongoing Monitoring and Sampling Program Modifications

Base monitoring will continue during TMDL implementation. RWHTF will continue to conduct all in-reservoir monitoring on a monthly schedule while FRICO will continue to monitor the canals, inlets, and outlets. The South Platte Coalition for Urban River Evaluation (SP CURE) organization will continue to coordinate the monthly monitoring of the SPR. Additionally, other state, federal, and upstream watershed organizations will continue to monitor for flow and water quality. Between RWHTF, FRICO, and SP CURE, the ongoing monitoring will continue to provide valuable information to update the water quality models and the phased pH TMDL. Ongoing monitoring is summarized in more detail in the BMW Plan (2008). Also, each stakeholder responsible for monitoring within the BMW has a detailed written monitoring plan.

With the adoption in 2012 of Regulation No. 85, additional monitoring data may be collected pursuant to those specific regulatory requirements.

Modifications to the monitoring program will be made as new information and questions arise from implementing the TMDL. As a result of uncertainties identified in the modeling and development of the TMDL, more information will be collected longitudinally on the Burlington-O'Brian Canal, Plate Valley Canal, and Beebe Draw. Alkalinity has been identified as an important factor affecting the background pH levels in the reservoirs and more emphasis will be directed to understanding the sources and behaviors of alkalinity.

In developing the reservoir assessments and the watershed model, it was noted that there was a lack of flow data at critical locations upstream and downstream of the reservoirs. FRICO has already modified its flow monitoring program to include three stations on the inflows to Milton and one outlet station for Barr.

An adaptive implementation approach requires a monitoring program with distinct review points and strategy adjustment based on results. During the initial period of TMDL and restoration measure implementation, monitoring data acquired will be analyzed on an annual basis, and summarized in annual reports. Additional information needs or modifications to the existing monitoring programs will be identified as part of the annual monitoring program data analysis.

Key aspects of the monitoring program that will be reviewed and modified as needed as part of the annual reporting process include:

- Sampling locations
  - Additional locations to address data needs (e.g., for new sources) as awareness of needs increases.
  - Elimination of certain locations that provide less useful data.
- Sampling frequency

  - Increase in sampling frequency for specific parameters or sampling locations as needed to properly evaluate changes.
  - Decrease in sampling frequency for specific parameters and/or sampling locations where results are stable or less useful.
- Parameters for analysis
  - Addition of new parameters at one or more sampling locations, as warranted.
  - Elimination of parameters at one or more sampling locations where there is minimal relevance to management actions.
- Special studies and investigations
  - Additional studies or investigations needed to respond to newly identified or ongoing issues not addressed by routine monitoring as planned.
- Revision of measurement goals

## 7.2 Adaptive TMDL Implementation/Adaptive Management Monitoring

The adaptive TMDL implementation approach means that some activities will commence before others, based on expected magnitude of results and feasibility, progress will be tracked, and the Plan will be adjusted in accordance with that progress and its implications for successful compliance with the pH standard. Monitoring data will be used to support adaptive implementation of the TMDL, as well as adaptive management of certain restoration activities.

It is uncertain whether pH improvements will be gradual or exhibit a threshold effect as TP and Chl are reduced (i.e., no significant change in pH until TP falls below a threshold of 200 µg/L followed by gradual or rapid declines). The ambient and source monitoring programs discussed in Section 6.1 will be used to document water quality changes and progress toward the TMDL goal. As new data become available, it may be appropriate to re-evaluate whether planned (but not yet implemented) load reductions and/or additional restoration measures are needed to achieve the TMDL goal, or if other adjustments to the TMDL are appropriate.

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# 8. MODEL AND TMDL UPDATES

## 8.1 Database Updates

The Association is in the process of having its members upload their historic and current water quality data to the Colorado Data Sharing Network (DSN). Efforts will be made to determine if any critical sources of data are lacking and, if so, assist with the upload of that specific information.

Water flow information is also in the process of being automated. The critical inflow and outflow information for the reservoirs is largely collected by FRICO. Most of FRICO's systems have been updated over the past few years with new flow monitoring gages and recording systems. Most of the flow data is now recorded continuously with the ability for direct and field-assisted downloads. This information is being compiled into a separate database available for future model updates.

## 8.2 Model Updates and Refinement of Water Quality Targets

It is anticipated that the water quality models will be updated in 2013 - 2014 based on more recent quality and flow data (post-2005), as well as results from the limnocorral studies described in Section 5. The limnocorral results will provide updated information on *in situ* internal phosphorus loading and rates of primary productivity. This information will allow for related model assumptions to be revised, as appropriate. Another model update may occur subsequently to reflect data collected after some nitrogen reduction improvements are complete to determine if in-lake N to P ratios have been altered and, if so, if they have any influence on productivity and pH.

Calculations of existing TP loads will be re-evaluated concurrent with future model updates. Revisions to the mass balance calculations will utilize updated TP concentrations as well as updated and more accurate flow data. Output from the limnocorral studies and updated model runs may affect the underlying assumptions related to pH, chlorophyll and TP relationships, necessitating a re-examination of the water quality targets for chlorophyll and pH. Any changes in assumptions and output may also suggest a re-evaluation of the allowable TP loads.

## 8.3 TMDL and Implementation Plan Updates

It is currently anticipated that the TMDL and Plan will be periodically re-evaluated by the Association. At the onset, it is clear that TMDL and Plan updates will be desirable after completion and analysis of model updates. As the model updates occur, TMDL and Plan updates may be developed. Those portions of the TMDL subject to modification include a discussion of model uncertainty reduction, revised water quality targets, and a revised allocation scheme, as appropriate.

The TMDL and Plan will continue to be re-evaluated periodically, with revisions incorporated as necessary. Those portions of the TMDL and Plan that are likely to change include information specific to implementation. As future studies examine the issues of source reduction feasibility, attainability, cost/benefit tradeoffs, and trading opportunities, the results will shape plans for the scheduling and phasing of implementation activities.

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# 9. FUNDING PLAN

Since the inception of the Association the organization has worked towards long term financial sustainability. In 2005 the dues structure for the organization was set to provide the necessary level of matching funding required by the pH TMDL grant. Since 2007, the organizational membership fees have increased on an annual basis in preparation for the completion of the 319 grant.

The dues structure has been set to generate approximately $125,000 to $140,000 annually in dues.

The funding levels have been set based on sustaining the organization and providing the ability for the Association to actively promote and pursue projects that have been identified as necessary for addressing technical questions concerning the pH TMDL.

From time to time the funding provided by dues may be supplemented by special assessments for projects that are necessary to answer specific questions or resolve issues concerning the TMDL. These projects may only benefit one set of stakeholders in the watershed and therefore may be more appropriately funded by special assessments from those entities most likely to benefit from the results of this work.

The dues structure is not meant to provide necessary remedial actions or facility upgrades such as nutrient removal facilities at a POTW or removal/inactivation of the internal loads. The dues are intended to maintain the sustainability of the organization and secondarily to promote studies such as sediment sampling and limnocorrals that further help answer key questions about the two water bodies.

In addition to the base level of funding from dues and/or special assessments, the organization will continue to pursue other sources of funding that may be appropriate including grants, fees, and increased membership.

# 10. WORKS CITED


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Barr Lake & Milton Reservoir Watershed Association

# APPENDIX A:  PHASE I STUDIES AND SCHEDULE

## Table A–1.  Phase I Studies.

| | Question | Project | Scope | Tasks | Resources | Other Studies/Info Needed | What To Do With Answer | Start Date | End Date | Estimated Cost ($) | In Kind Cost (%) | BMW Cost (%) | Responsible Party | Importance (1 very to 5 not) | Estimated Time (years) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phased TMDL - Addresses Uncertainty | How does Chl a change as TP decreases? | Establish TP and Chl a Linkage | Collect TN, TP, and Chl a samples pre-alum | Sample top, mid, bottom of 3 limnocorrals, pre-alum treatment | 2 people, boat, van dorn sampler, sample bottles, lab | Replicate using aeration/mixing alternative. Use data to determine internal load rate. | Update water quality models and TMDL* | June 2011 | 2012 | $25,000 - $100,000 | 75% | 25% | Metro, BMW, State Parks, FRICO | 1 | 2 |
| | | | Jar test various alum dosages | Jar test for each of 3 alum concentrations, mid-level sample, 3 limnocorrals | jar tester, lab supplies | | | | | | | | | | |
| | | | Collect TN, TP, and Chl a samples post-alum | Sample top, mid, bottom of 3 limnocorrals, post-alum, weekly for 1 month | 2 people, boat, van dorn sampler, sample bottles, lab | | | | | | | | | | |
| | | | Determine TP and Chl a relationship | Evaluate test data to determine how lowering TP impacts Chl a. | BMW Technical Committee | | | | | | | | | | |
| | How does Chl a change as pH decreases | Chl a and pH Linkage | Measure pH profile pre-alum | pH profile of 3 limnocorrals, pre-alum | 2 people, boat, pH meter | Replicate using aeration/mixing alternative. Can also determine primary productivity rate and pH linkage. | Update water quality models and TMDL* | July 2011 | 2012 | | | | | | |
| | | | Measure pH profile post-alum | pH profile of 3 limnocorrals, post-alum, weekly for 1 month | 2 people, boat, pH meter | | | | | | | | | | |
| | | | Determine Chl a and pH relationship | Evaluate test data to determine how lowering pH impacts Chl a | BMW Technical Committee | | | | | | | | | | |
| | How does alkalinity/buffering change as pH decreases? | pH and Alkalinity Linkage | Collect alkalinity samples pre-alum | Sample top, mid, bottom of 3 limnocorrals, pre-alum treatment | 2 people, boat, van dorn sampler, sample bottles, lab | Replicate using aeration/mixing alternative | Update water quality models and TMDL* | August 2011 | 2012 | | | | | | |
| | | | Collect alkalinity samples post-alum | Sample top, mid, bottom of 3 limnocorrals, post-alum treatment | 2 people, boat, van dorn sampler, sample bottles, lab | | | | | | | | | | |
| | | | Determine pH and alkalinity relationship | Evaluate test data to determine how lowering pH impacts alkalinity | BMW Technical Committee | | | | | | | | | | |
| | What pH is needed to support existing uses? | UAA Studies/UAA Development | Gather pertinent data for study | Obtain existing use data, where available. | BMW Technical Committee | Fisheries, recreation, drinking water treatment, and ag use data | If outside of current standard - develop site-specific standard for pH | 2014 | 2016 | <$25,000 | 100% | 0% | BMW | 1 | 0.5 |
| | | | Develop UAA study plan | Identify data needs, develop work plan and RFP, hire consultant | BMW Technical Committee | | | | | $25,000 to $100,000 | 50% | 50% | BMW | | |
| | | | Conduct UAA Study | Implement work plan and define the use based on the study. | Consulting Firm | | | | | | | | | | |
| Adaptive Implementation of TMDL | What P treatment options are available and at what cost? | Effectiveness and Cost for POTWs | Develop summary of treatment options, including expected P removal and cost | What has been achieved at other POTWs (CO and national), survey of rates (literature review) | BMW Technical Committee, POTW consultants | TP effluent limit, Best Available Technology for TP treatment | Informs boards/councils for planning/budgeting | 2011 | 2012 | ? | 100% | 0% | POTWs with allocations | 3 | 2 |
| | How does implementation of different levels of treatment at POTWs impact pH in Barr and Milton? | System response to treatment at POTWs. | Determine facility specific effluent concentrations for POTWs with allocations | Complete engineering/water quality analysis to determine end of pipe concentrations to meet TMDL | BMW Technical Committee, POTW consultants | Refined flow information for modeling | Update water quality models and TMDL* | 2011 | ? | ? | 100% | 0% | | | |
| | What are options for treatment of stormwater? | Feasibility/Cost for MS4s | Establish BMP Efficiency/Options | Determine what BMPs are currently used, identify other available techniques and their efficiencies and installation/maintenance costs | BMW Technical Committee, Consultant | Information from MS4 entities (with allocations) on current BMP practices | Informs boards/councils for planning/budgeting | 2011 | 2011 | <$25,000 | 0% | 100% | MS4 entities with allocations | 3 | 1 |
| | | | Stormwater BMP Report | Summarize findings | | | | | | | | | | | |
| | How does implementation of different types of stormwater treatment impact pH at Barr and Milton? | System response to stormwater treatment | Refine analysis of stormwater contributions and delineate by permitted area | Determine P loads from each MS4 area using information provided by permit holders and/or new model techniques | BMW Technical Committee, MS4 permit holders and/or their consultants | Discharge quantity/quality data, land use information from MS4s | Update water quality models and TMDL* | 2012 | 2013 | <$25,000 | 100% | 0% | | 3 | 2 |
| | What are options for treatment of NPS? | Feasibility/Cost for NPS | Establish BMP Efficiency/Options | Determine what BMPs are currently used, identify other available techniques and their efficiencies and installation/maintenance costs | BMW Technical Committee, NRCS, Colorado State Coop Extension Service | CAFO Nutrient Management Plans, information on other current BMP practices | Assist with education and Ag BMPs | 2012 | 2014 | $25,000 - $100,000 | 50% | 50% | BMW | 4 | 2 |
| | | | NPS BMP Report | Summarize findings | | | | | | | | | | | |
| | How does implementation of NPS controls impact the natural system? | System response to control of NPSs | Refine analysis of nonpoint contributions and delineate by type (ag, residential, ISDS, etc.) | Determine P loads from each land use type | | Return flow data, crop type and other ag land use data | Update water quality models and TMDL* | | | | | | | | |
| | What are options and effectiveness of source control? | Preventative Source Control | Identify phosphorus product sources. | Literature search to identify types of products that contain phosphorus. | BMW Technical Committee, other states with P product bans | Estimates on quantity of P applied to lawns in datashed and quantity of P going to POTWs from detergents | Compare costs of P Ban to cost to treat at POTW or through MS4 programs | 2012 | 2012 | <$25,000 | 100% | 0% | BMW | 3 | 1 |
| | | | Research option of a product ban. | Literature search and contact with other entities to determine plausibility of product ban. | | | | | | | | | | | |
| | | | Preventative Source Control Report. | Summarize findings. | | | | | | | | | | | |
| | How does implementation of source controls impact the pH at Barr and Milton? | System response to source control | - | - | - | - | Assume trade offs occur at POTW and/or MS4 level, pursue legislation if appropriate | - | - | - | - | - | - | - | - |
| | What are options for treatment of internal load? | In-Reservoir Treatment Options | Explore in-lake treatment options | Literature search regarding types of in-lake treatment, effectivenss, and cost | BMW Technical Committee | Data from limnocorral studies to determine in-situ P loading, and to evaluate effectiveness of alum versus aeration | Determine how treatment is accomplished and how its funded | 2012 | 2013 | $25,000 - $100,000 | 25% | 75% | BMW | 1 | 2 |
| | | | Hold treatment workshop | Evaluation and rank treatment options. | | | | | | | | | | | |
| | | | In-Reservoir Treatment Report | Summarize findings | | | | | | | | | | | |
| | How does implementation of in-reservoir treatment impact pH at Barr and Milton? | System response to in-reservoir treatment | - | Combine findings with limnocorral studies to refine water quality models | - | - | Update water quality models and TMDL* | - | - | - | - | - | - | - | - |
| | What are options for treatment in canals? | Polishing/Treatment in Canals | Identify treatment options, effectiveness, cost | Engineering evaluation of mechanical versus passive treatment options | BMW Technical Committee, Consultant | Refined flow information for loading calculations, land availability | Determine how treatment is accomplished and how its funded | 2013 | 2013 | $25,000 - $100,000 | 25% | 75% | BMW | 2 | 1 |
| | How does treatment/polishing in calansl impact the pH at Barr and Milton? | System response to canal treatment/polishing | - | - | - | - | Update water quality models and TMDL* | - | - | - | - | - | - | - | - |
| | What are options for pollutant trading? | Trading Opportunities | Identify and analyze options | Compare opportunities and their costs, benefits, risks | BMW Technical Committee, Consultant | Pulls information from the Feasibility/Cost for NPS, Feasibility/Cost for MS4s, and Further Refinement of Stormwater Contributions | Make information available to potential trade partners | 2014 | 2015 | <$25,000 | 0% | 100% | BMW | 4 | 2 |

*  *Model updates will occur in 2012 and again in 2014-2016.*

Table A-2. Implementation Schedule.

| Date | Action |
|---|---|
| | |
| March 2012 | Statewide nutrient reduction strategy adopted by Water Quality Control Commission. |
| 2013 | Update water quality models with new data and study results. |
| 2014 | Determine if TMDL or Implementation Plan should be revised based on 2013 model updates. |
| 6/2015 | Regulation 38 SPR Basin Triennial Hearing. |
| 12/31/2015 | pH Temporary Modification expires. |
| 2016 | Determine if TMDL or Implementation Plan should be revised, as needed. |
| 2016 | Update water quality models with new data and study results, as needed. |
| 2016 | Discharge permit renewals scheduled for wastewater treatment facilities located in the South Platte Basin; implementation of Regulation No. 85-based interim effluent limitations for the largest facilities |
| 2018 | Determine if TMDL or Implementation Plan should be revised, as needed. |
| | Update water quality models with new data and study results, as needed. |
| 6/2020 | Regulation 38 SPR Basin Triennial Hearing. |
| 2020 | Update water quality models with new data and study results, as needed. |
| 2021 | Determine if TMDL or Implementation Plan should be revised, as needed. |
| 2022 | Update water quality models with new data and study results, as needed. |
| 2023 | Determine if TMDL or Implementation Plan should be revised, as needed. |
| 2024 | Update water quality models with new data and study results, as needed. |
| 6/2025 | Regulation 38 SPR Basin Triennial Hearing |
| 2025 | Determine if TMDL or Implementation Plan should be revised, as needed. |
| 6/2030 | Regulation 38 SPR Basin Triennial Hearing |
| 6/2035 | Regulation 38 SPR Basin Triennial Hearing |
| 6/2040 | Regulation 38 SPR Basin Triennial Hearing |