WILLAMETTE PARTNERSHIP

Lower Boise Framework Update: Findings & Recommendations

The findings and recommendations in this report are solely those of Willamette Partnership's and do not represent the position of IDEQ or any member of the expert group that provided feedback during Willamette Partnership's evaluation.

Summary

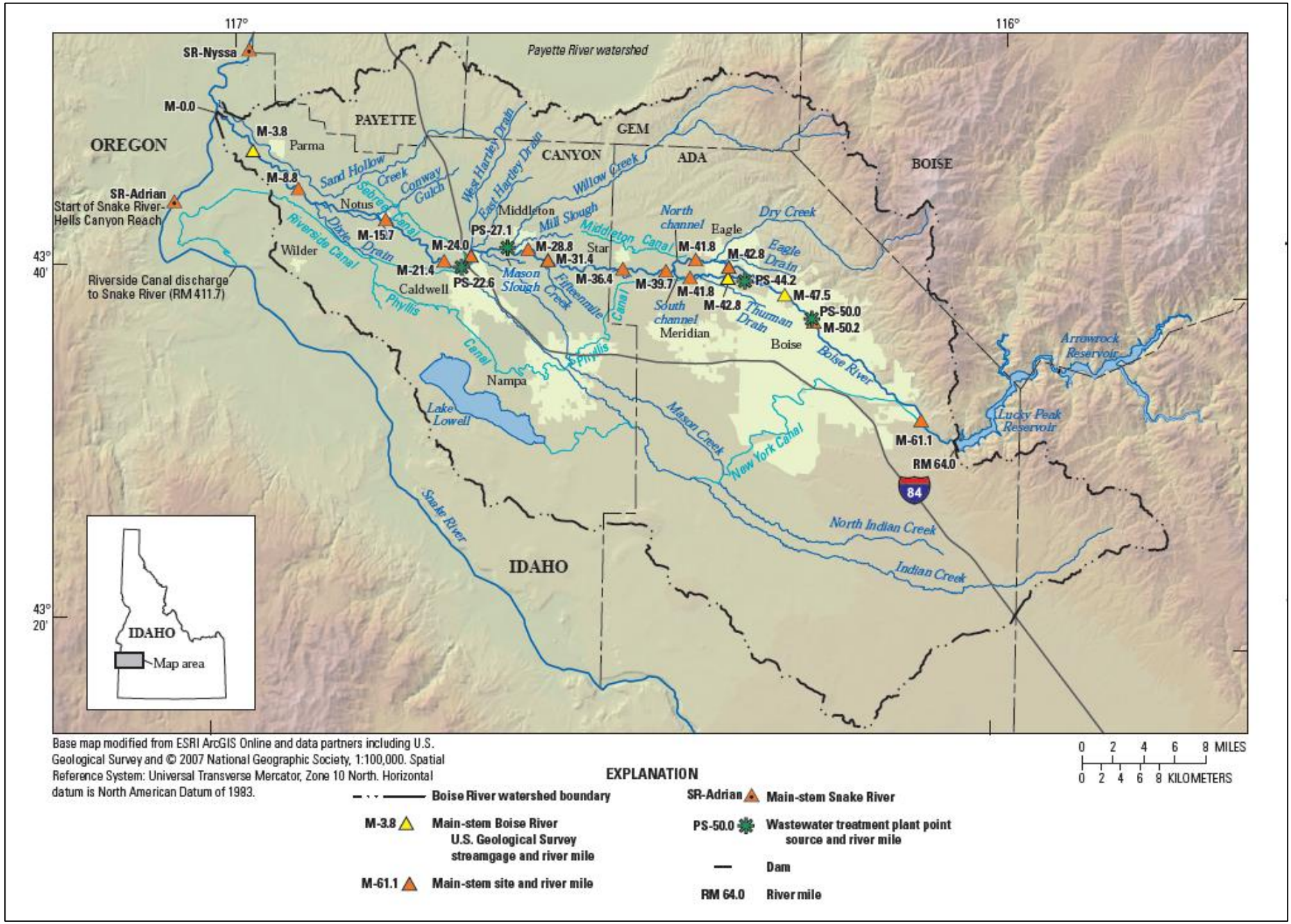
The Idaho Department of Environmental Quality (IDEQ) is in the process of establishing a Total Maximum Daily Load (TMDL) for total phosphorus (TP) in the Lower Boise River watershed (Figure 1). The draft TMDL sets targets for TP concentration in the Boise River, major tributaries, and point source effluent discharge (IDEQ, 2015). It is designed to limit algal blooms as one of the primary impairments. Idaho DEQ has established guidance for water quality trading as one means to achieve TMDL targets (IDEQ, 2010), and TP was used as an example pollutant in developing a watershed-specific Lower Boise River pollutant Lower Boise Framework (hereafter referred to as the "Lower Boise Framework") (IDEQ, 2010 at Appendix A) in the Lower Boise River watershed.

This report is an evaluation of potential updates to the Lower Boise Framework based on information from the TMDL (IDEQ, 2015), recent USGS data (Etheridge, 2013; Etheridge, MacCoy & Weakland, 2014), and relevant scientific literature reflecting a better understanding of phosphorus dynamics in the Lower Boise (MacCoy, 2004; Donato & MacCoy, 2005). A group of expert reviewers provided feedback throughout the process. The table below lists the topics of the Lower Boise Framework that were investigated, and a recommended approach to updating each area.

Table 1. Recommendation from the investigation for the Lower Boise framework

Area of Investigation	Recommended Approach	Summary Justification
Credit life (duration)	Annual credit life, monthly permit limits	Due to groundwater interactions, point source phosphorus loading and NPS phosphorus reductions are released relatively evenly throughout the year via baseflow. Annual credits can be applied toward monthly permit limits.
Credit unit	Total phosphorus	The TMDL is written for TP. There is not sufficient understanding or data to account for dissolved and particulate phosphorus differently. Permits are typically written for TP.
Location/Attenuation ratios	Do not use a location/attenuation ratio	TP mass is conserved in the watershed (i.e., there is no evidence of significant attenuation from one point of discharge to another location). Other ratios may be considered to account for uncertainty and/or achieve net environmental benefit.
Nonpoint source (NPS) Baselines	Use of a phased-in baseline can encourage early action and help meet TMDL objectives	There is good reason to incentivize early installation of BMPs, and there are some simple BMPs that effectively reduce sediment and particulate phosphorus runoff. The BMPs that address dissolved phosphorus and loading to groundwater are also important, but less understood and can be addressed in sequence.

Figure 1: Map of the Lower Boise River watershed below Lucky Peak reservoir to the confluence with the Snake River.



Background

The Lower Boise River watershed is identified in the Idaho water quality standards as water body ID17050114, with 36 Assessment Units (AUs) and several site-specific standards described under Section 140.12 (IDAPA 58.01.02). As described in the Lower Boise River TMDL (IDEQ, 1999), the watershed drains approximately 1,290 square miles of rangeland, forests, agricultural lands and urban areas into the Snake River at the confluence between the cities of Adrian and Nyssa, Oregon. The Lower Boise River is a 64-mile long 7th-order stream, which flows northwest from the Lucky Peak Dam outfall east of Boise, through Ada and Canyon counties, to its mouth on the Snake River near Parma, Idaho. The watershed also drains portions of Elmore, Gem, Payette, and Boise counties. There are at least seven 3rd order, one 4th order, and one 6th order tributaries to the Lower Boise River.

The U.S. Geological Survey has completed various studies and conducted ongoing water-quality, hydrologic, and biological monitoring in the Lower Boise River watershed since 1994. In 2013, in cooperation with IDEQ, USGS developed a TP mass balance model for the Lower Boise River between Veteran's Parkway—upstream of any point-source discharges—and Parma, Idaho, near the confluence with the Snake River (Etheridge, 2013). The model was generated using the results of three synoptic sampling periods, wherein water quality samples were collected from numerous places throughout the watershed during a single day. The first synoptic event was during irrigation season in August 2012. The second synoptic event was in late October 2012 after irrigation season ended, and the third was in March of 2013 (Etheridge, 2013). USGS has also developed regression models that estimate TP concentrations and loads in the Boise River near Parma (Parma) and at the mouth of a major tributary to the Boise River called Mason Creek (Wood and Etheridge, 2011; Etheridge et al., 2014). Both regression models utilize continuously monitored water-quality parameters as explanatory variables (surrogates) to estimate TP concentrations and loads every 15 minutes. The TP mass balance model and both surrogate regression models were used in this report to inform updates to the Lower Boise Framework in regards to seasonality, trading ratios, and TMDL load allocations (LAs).

Connections to water quality trading in the Lower Boise River

In order for water quality trading to successfully contribute to water quality targets, the water quality benefit associated with credits generated by nonpoint sources needs to line up in space and time with the point source discharges they are used to offset. In the decade since the original version of the Lower Boise Framework, new research on phosphorus dynamics (both in surface and in ground waters) has emerged to further inform the underlying science that supports trades.

Methods and Findings

As part of evaluating potential updates to the Lower Boise framework, Willamette Partnership:

- Reviewed current data and literature incorporated into the TMDL;
- Reviewed recent USGS data and publications; and
- Convened an expert group that included Marti Bridges, Idaho DEQ; Ben Cope, US EPA Region 10; Alex Etheridge, USGS; Julia Bond, The Freshwater Trust; and Scott Job, Tetra Tech. Each expert had extensive knowledge of the Lower Boise system, existing phosphorus data, and how modeling results translate into decisions for a trading program. The expert group provided feedback for A) the evaluation methodology, B) draft findings, and C) final findings; and
- Developed an updated conceptual model for phosphorus dynamics in the Lower Boise (see Figure 2)

Four questions were investigated:

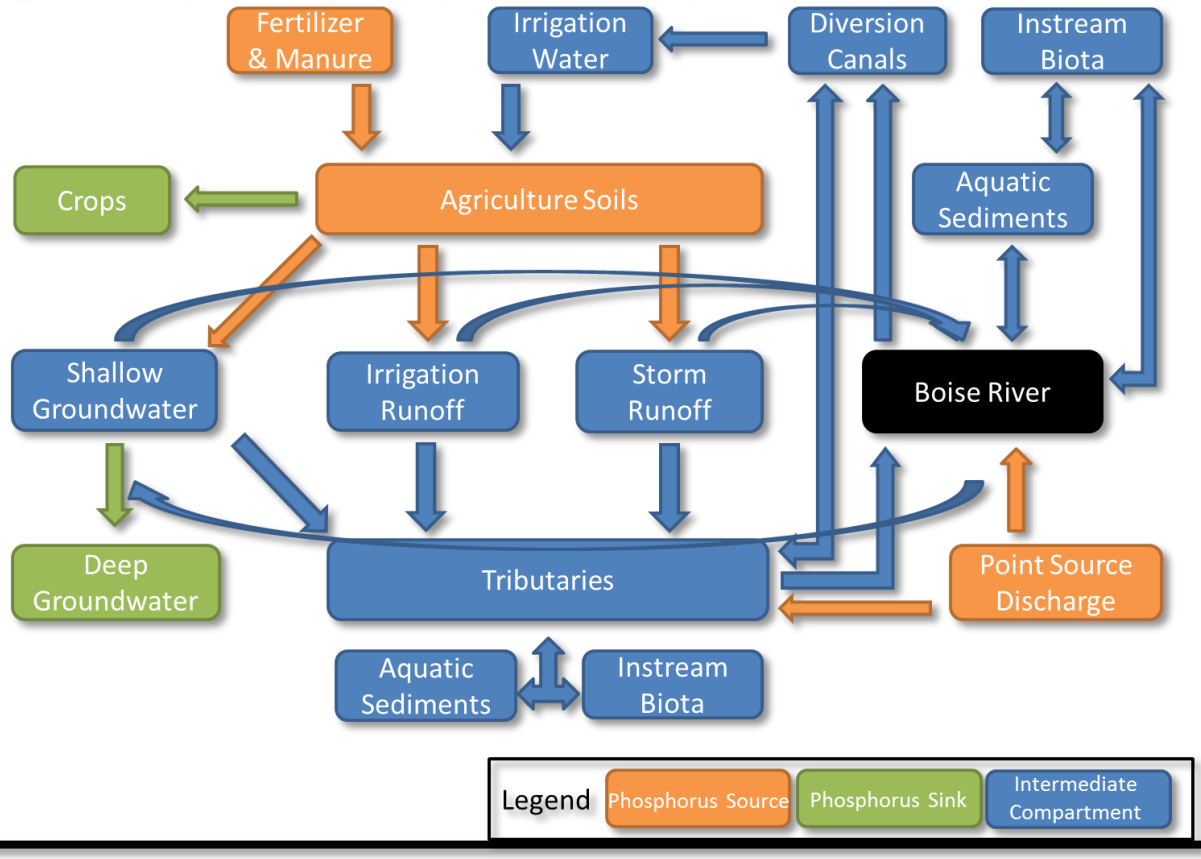
- How does phosphorus move through the system and what, if any, location ratios should be used to account for attenuation between tributaries and the mainstem?
- Should dissolved and particulate phosphorus be accounted for differently?

- What is an appropriate credit life for water quality benefits from agricultural BMPs?
- If different baseline BMP scenarios are implemented, how are those connected to meeting the nonpoint source load allocations articulated in the draft Lower Boise phosphorus TMDL?

Understanding phosphorus in the Lower Boise

In order to better understand the dynamics of phosphorus fate and transport in the Lower Boise River, a conceptual model was developed (See Figure 2) by using the Lower Boise River watershed characterization from the recent USGS publications (Etheridge, 2013; Etheridge, MacCoy & Weakland, 2014) and the draft TMDL (IDEQ, 2015). The model is a representation of phosphorus sources, sinks, reservoirs, and how they are connected within the watershed. It reflects current understanding in the scientific literature of the Lower Boise's environmental compartments, including groundwater (Domagalski & Johnson, 2011; Etheridge, 2013), instream biota (Stutter, Demars & Langan, 2010; Etheridge, 2013), aquatic sediments (Huang, Cong, & Chai, 2008; Wang, Appan, & Gulliver, 2003) and agricultural soils (Bjorneberg *et al.*, 2015).

Figure 2: Conceptual Model of Phosphorus Fate & Transport in the Lower Boise River watershed



As phosphorus travels through the watershed, it can interact with different environmental compartments that influence the residence time of phosphorus in the system. The model does not include the specific rates of transfer between system compartments because the range of delivery rates and phosphorus retention times reported in the scientific literature for each environmental compartment were highly variable. Environmental stochasticity (e.g., inclement weather, high flow events, soil chemistry, and ecosystem composition) and variability from year to year and field to field in the Lower Boise River watershed, cause too much uncertainty associated to determine the length of time that a load of phosphorus resides in any one compartment. However, hydrologic data from the USGS seasonal surveys

(Etheridge, 2013; Etheridge, MacCoy & Weakland, 2014) was used to estimate the residence time of water through the system as a whole, and inferences were made about how phosphorus loads are transported with the water.

Understanding shallow groundwater in the Lower Boise and its tributaries

All of the major tributaries to the Lower Boise River, except for Dry Creek, are perennial due to a combination of storm runoff, agricultural runoff, and baseflow. During the irrigation season, a portion of irrigation water runs off agricultural fields (carrying with it phosphorus-containing sediment loads), a portion of the water is lost via evapotranspiration, and the remainder infiltrates into the soil as shallow groundwater. The shallow groundwater forms water mounds under agricultural fields, creating a hydrologic gradient that causes the water to travel through the subsurface and, ultimately, drain into nearby canals and tributaries as baseflow (Etheridge, 2013). Thomas and Dion (1974) determined that nearly all the water in the Boise River and the water discharged to the river from many of the drains and tributaries during non-irrigation season has been characterized as groundwater (Thomas and Dion, 1974; Mullins, 1998; Fox *et. al*., 2002).

The magnitude of baseflow contribution from irrigated agricultural lands in the Boise River watershed is described in following excerpt from Etheridge, 2013:

> *If irrigation of agricultural lands in the Boise River watershed did not occur, the river probably would maintain lower flows during the winter. The Bureau of Reclamation and Idaho Department of Water Resources (2008) reported that the shallow aquifer beneath irrigated farmland in the lower Boise River watershed received an average of 1,012,000 acre-ft in annual recharge from on-farm infiltration or canal seepage in the mid-1990s. Much of this groundwater recharge from irrigation subsequently is discharged through agricultural drains and tributaries to the Boise River (618,000 acre-ft/yr) or contributed as base flow to the Boise River (233,000 acre-ft/yr).*

An analysis of shallow groundwater samples from synoptic sampling events in several subwatersheds of the Lower Boise River found phosphorus concentrations well above the proposed TMDL targets (Etheridge, MacCoy & Weakland, 2014), <u>indicating that dissolved phosphorus loads in baseflow from point and nonpoint sources permeate year round in baseflow</u>.

Recommendations

I. Location/attenuation ratios

Recommendation: Location ratios are not necessary

In some watersheds, phosphorus discharged in one part of the watershed gets taken up by crops, or is otherwise used in biological processes that permanently remove a portion of the load from the system. The Lower Boise framework assumes that phosphorus is being removed in this way and uses location/attenuation factors to account for it. The Lower Boise Framework focuses primarily on the main stem of the Boise River and treats diversions and tributaries as sinks and sources of phosphorus. It assumes that phosphorus entering the diversions from the main stem are taken up or otherwise removed from the system, and that and phosphorus entering the main stem from tributaries is derived from sources entirely within that tributary. As a result, the Lower Boise Framework contains 'location ratios' that were included to ensure that credits generated by nonpoint sources were equivalent to the point source load increase at Parma they would be traded for. In other words, location ratios were intended to account for phosphorus lost via diversions as a given load traveled downstream to Parma.

At the first meeting of the expert group, Willamette Partnership presented an approach to assessing attenuation of phosphorous using a TP mass balance model developed by USGS for the Lower Boise River (Etheridge, 2013). In the proposed approach, TP loads would be manipulated at the mouths of

major tributaries and points of discharge along the main stem of the Boise River to determine what percentage of TP loads were reaching Parma for each source. Very quickly, the expert group challenged one of the underlying assumptions made by the TP mass-balance model—that phosphorus was not conserved by treating diversions as phosphorus sinks and tributaries as entirely new sources of phosphorus in terms of original source.

The assessment of the group, as illustrated by the conceptual model, is that phosphorus diverted from the Boise River can only leave the system in crops or deep groundwater percolation, while the rest of the remaining phosphorus load is temporarily retained in environmental compartments offstream (where it is comingled with phosphorus from other sources that originate offstream) eventually returning to the Boise River.

The Partnership did not conduct deep analysis on this question because there is not enough evidence to suggest significant attenuation occurs, let alone a means of quantifying a rate with current data. Therefore, we recommend that updates to the Lower Boise Framework remove attenuation ratios.

II. To lump or split phosphorus

Recommendation: Use TP as an accounting unit for trading

The upcoming TP addendum to the Lower Boise River TMDL (IDEQ, 2015) specifies Total Phosphorus (TP) concentration targets for the Boise River, its major tributaries and point source dischargers that are primarily intended to control nuisance algal blooms.

'Total phosphorus' includes all chemical forms of phosphorus. The chemical form of phosphorus, along with its reactivity and water residence time, determines how it will cycle through riverine ecosystems and different forms contribute to nuisance algal blooms to varying degrees (Withers & Jarvie, 2008). In the Lower Boise River, both particulate and dissolved phosphorus are considered bioavailable, but dissolved phosphorus is a strong driver of elevated levels algae growth because it is highly bioavailable (IDEQ, 2015). Nonpoint source phosphorus loads enter the waterbody either as particulate phosphorus associated with irrigation-induced soil loss, dissolved phosphorus from manure or agricultural fertilizers dissolved in irrigation runoff, or as dissolved phosphorus leached from the soil profile into shallow groundwater that returns to canals or tributaries as baseflow (Bjorneberg *et. al*., 2015). Point sources discharge almost entirely dissolved phosphorus either directly into the Boise River or one of its tributaries.

For the purposes of water quality trading, Willamette Partnership and the expert group decided that the necessary tools to differentiate between projects aimed at reducing dissolved and particulate phosphorus did not exist. Using TP as an accounting unit for trading will treat the dissolved phosphorus from point sources similarly to the combined particulate and dissolved phosphorus reduced by nonpoint source BMPs. The TMDL also designates TP as the metric for water quality goals. Therefore, the Partnership is recommending using TP as the unit of accounting for the Lower Boise Framework at this time, and future efforts may include the development of tools that can estimate phosphorus load reductions from BMPs that can distinguish between different chemical forms of phosphorus.

III. Credit life

Recommendation: Use an annual credit life.

Trading programs use the concept of "credit life" to match up the time when a BMP is improving water quality with when a wastewater discharger needs to offset its pollution load. The credit life can be monthly, seasonal, or annual. The original Lower Boise Framework used a monthly credit life. It is our assessment that an annual credit life is supported.

An annual credit life is supported by the current understanding of the pathway taken by diverted flows and their interaction with groundwater in the tributaries. As depicted in the conceptual model in Figure 2, nonpoint source loads follow the offstream pathway. The diverted portion of point source loads follow this same pathway, which means that their residence time is similar prior to returning to the Lower Boise River. Every point source in the Boise River is located upstream of at least one diversion which means that at least a portion of every point source discharge will be diverted at some point before Parma. It follows that significant portion of phosphorus loads discharged directly into the Boise River will enter the offstream pathway.

In the offstream pathway, phosphorus loads accumulate in environmental compartments, particularly shallow groundwater, during the irrigation season and permeate to the Boise River year round in baseflow (Etheridge, 2013; Etheridge, MacCoy & Weakland, 2014). The associated phosphorus (or phosphorus reductions) are then be delivered back to the tributaries and Lower Boise main stem relatively evenly throughout the year. This annual dynamic applies to both diverted point source loads and load reductions from agricultural BMPs, supporting and annual credit life for TP.

Monthly NPDES permit requirements are anticipated to result from the draft TMDL, which proposes to set monthly targets for TP concentration in the Lower Boise River, a few major tributaries, and all point source dischargers (IDEQ, 2015). An annual credit can be used toward a monthly permit requirement at any point in the year after the project is implemented.

There may be a lag time between the generation of water quality benefits in the tributaries and their realization in the Boise River, and since not all of the point source load is diverted, this represents a potential mismatch in the timing of credits with the effect of discharges. The expert panel noted this, but largely agreed that water quality trading represents an important tool to help reduce phosphorus loading from nonpoint sources, and this lag time may constitute an acceptable risk that can be accounted for with uncertainty ratios or other program elements.

In sum, an annual credit life is the most appropriate option for credits generated by nonpoint source load reductions in the Lower Boise River watershed because of the residence time associated with phosphorus loads in the offstream pathway. This is consistent with the delivery of point source discharge loads, which also primarily follows the offstream pathway, and is compatible with anticipated monthly NPDES permit limits.

IV. Baseline Best Management Practices and Phased-in baseline

Recommendation: Use three phases of baseline BMP expectations. Phase 1: Nutrient management plan is required. Any BMP installed above current requirements and condition is creditable; Phase 2: Minimum BMPs to address surface runoff; Phase 3: Baseline BMPs are expected to address surface runoff, but BMPs that reduce groundwater loading of dissolved phosphorus are creditable.

Idaho DEQ expressed interest in evaluating how certain BMPs might contribute toward meeting load allocation goals in the draft TMDL as a means of informing a set of baseline BMPs. In water quality trading, baseline requirements need to be met before credits can be generated. Baseline requirements apply to only those participating in the trading program.

Willamette Partnership evaluated four BMPs for their effectiveness at reducing irrigation-induced phosphorus loading across the Mason Creek watershed and estimating their potential to achieve TMDL targets for tributaries dominated by agriculture. Mason Creek was chosen for this analysis because it is representative of nonpoint source conditions without other influences (there are no significant point sources of phosphorus in the tributary) and sufficient data existed to conduct the analysis. Willamette Partnership evaluated the BMPs listed in Table 2, each of which have practice standards defined by the Natural Resource Conservation Service (NRCS).

Table 2: Description of the BMPs evaluate here.

Practice Standard	Description
Conservation crop rotation (NRCS std. #328)	As it relates to TP load reduction, this practice consists of growing crops in a planned sequence on the same field to manage the balance of plant nutrients in the soil and to conserve soil. This practice applies to cropland where annually planted crops make up at least one-third of the crop sequence (time basis). For the purposes of this practice, a cover crop is a crop in the rotation.
Residue and tillage management (NRCS std. #329)	As it relates to TP load reduction, this practice consists of managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year round while limiting soil-disturbing activities to only those necessary to place nutrients, condition residue, and plant crops.
Irrigation water management (NRCS std. #449)	Irrigation water management actively reduces the amount of irrigation-induced soil erosion from agricultural fields by reducing surface irrigation rates to minimize transport of sediment, nutrients and chemicals to surface waters and that minimize transport of nutrients and chemicals to groundwater.
Nutrient management (NRCS std. #590)	Nutrient management refers to optimizing the amount, source, placement, form and timing of the application of nutrients and soil amendments to produce the maximum crop yield with the least amount of waste.

Estimating TP load from Mason Creek

The Surface Irrigation Soil Loss (SISL) equation (Bjorneberg, Prestwich, and Evans, 2007) was used to calculate the mean annual irrigation-induced sediment loss for current conditions in Mason Creek. Of the approximately 16,500 acres of agricultural fields in Mason Creek, around 15,200 were determined to be surface-irrigated using ortho-imagery. The mean annual SISL load was estimated to be at 21,600 tons of sediment, based on 8 years of crop data from USDA. It was then converted to a mean annual irrigation-induced TP load of 43,000 lbs using an average phosphorus concentration of 2lbs TP/ton sediment common in southern Idaho (Ross & Associates, 2000). The result equates to an average of 2.8lbs TP per surface-irrigated acre in Mason Creek over the course of the irrigation season (see Table 2).

Annual TP load reductions for each BMP were estimated by multiplying the mean annual SISL load by an efficiency rating subtracting a level of uncertainty from the load. Values for efficiency ratings and uncertainty were obtained from Idaho Soil Conservation Commission (ISSC, 2013), largely based on the work of David L. Carter. These BMP ratings were empirically derived for each BMP and fit to conditions common in southern Idaho. They are intended to represent the percentage of the current irrigation-induced phosphorus load that is prevented from leaving a field after BMP implementation.

Two of the chosen BMPs were considered to actively reduce irrigation-induced phosphorus loading (NRCS #329 & #449), while the other two (NRCS #328 & #590) were considered to be 'enhancement BMPs'—serving to reduce uncertainty associated with load reduction estimates. Scenarios were created that combined different BMPs together to see how they performed, and the results were a range between 50% and 95% TP load reduction from the mean annual SISL TP load estimate, with uncertainty in each scenario ranging from 5% to 15% depending on which enhancement BMPs are implemented (see Table 3).

Table 3: List of BMPs, efficiency ratings, and uncertainty for each scenario

BMP (NRCS Code)	Efficiency Rating	Uncertainty
Scenario #1: Residue Management, Strip-Till or No-Till (329-A) ONLY	90%	10%
Scenario #2: Residue Management, Mulch Till (329-B) ONLY	85%	10%
Scenario #3: Residue Management, Ridge Till (329-C) ONLY	80%	10%
Scenario #4: Surge Irrigation (449) ONLY	50%	5%
Scenario #5: Surge Irrigation (449) & Residue Management, Strip-till or No-till (329-A)	95%	15%
Scenario #6: Surge Irrigation (449) & Residue Management, Mulch Till (329-B)	92.5%	15%
Scenario #7: Surge Irrigation (449) & Residue Management, , Ridge Till (329-C)	90%	15%

Confirming estimates with measure data

Time series data for discharge (USGS gage #13210983) and TP concentration[1] at the mouth of Mason Creek were used to confirm that the scale of the mean annual SISL load estimate was credible, and to speculate about the fraction of irrigation-induced TP loads that reach the sampling site over a given irrigation season. It is important to note that the two models are investigating two different points within the watershed- the SISL equation predicts what leaves the edge of a given field, while the regression model predicts TP concentrations at the mouth of Mason Creek. We would not expect to detect all of the estimated SISL load at the mouth of Mason Creek for a given time period due to the delay in sediment transport to the mouth of Mason Creek as well as combined predictive error from regression model and SISL load calculation.

The results indicate that around 60% of the estimated 2011 SISL TP load passed through the sampling site during the 2011 irrigation season, and that the total 2011 SISL TP load was within the 90% prediction interval for the sampling site TP regression model. Taking into account uncertainty in the TP concentration values from the regression equation and attenuation of sediment loads from edge of field to the sampling site, these results support the credibility of the sediment load estimate derived using the SISL equation.

Connecting TP loads to instream concentration targets

Lastly, annual TP load estimates for each scenario were distributed across the irrigation season in 15-minute intervals, combined with baseflow TP loads, and converted to concentrations. Figure 3 below displays the potential progress of each scenario toward achieving the 0.07mg/L TP target. Results of the model indicate that implementing all 4 BMPs on all 15,200 irrigated acres in Mason Creek would help achieve compliance with the TMDL concentration target for 30% of the days during irrigation season, with a minimal 3.75% uncertainty factor. This is a significant advance compared to current conditions, in which the tributary never achieves compliance with the TMDL during irrigation season with 10% uncertainty.

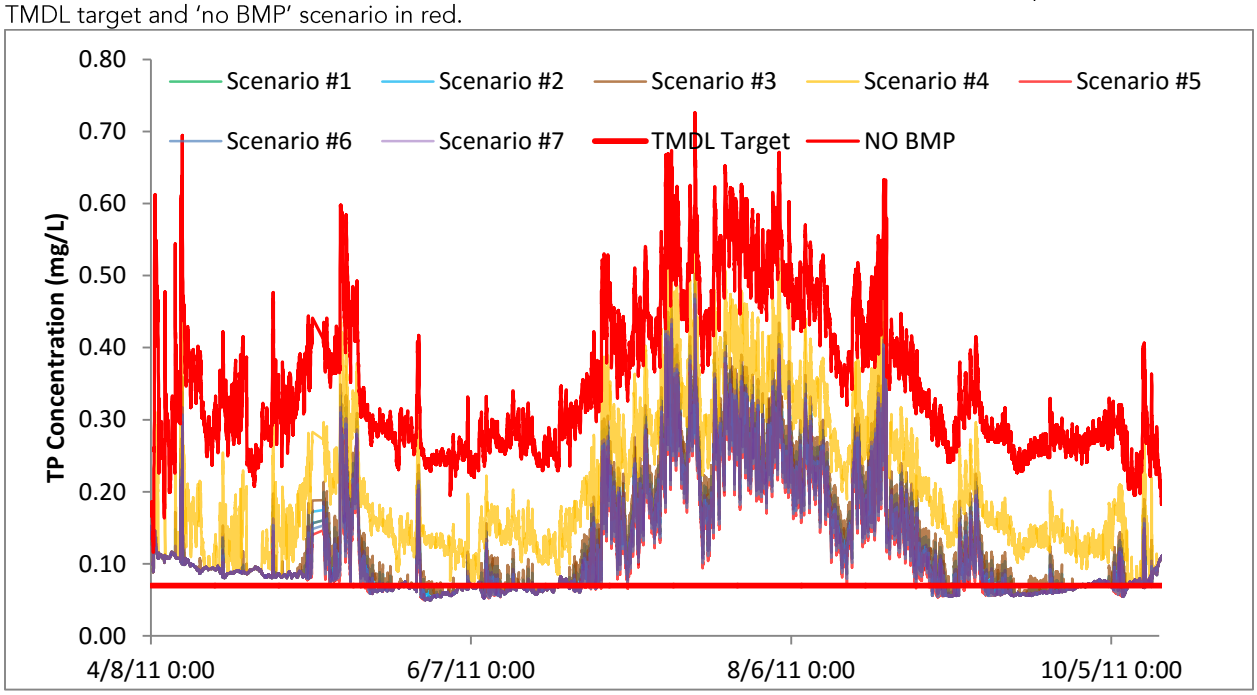
It is important to note that the estimated reductions come from only the particulate P in surface runoff. The effect of BMPs on the shallow groundwater/baseflow is not well understood and we were not able to include it in this analysis. These results, wherein highly efficient BMPs achieve TMDL targets only 30% of the time, further indicate that dissolved P in the shallow groundwater/baseflow is important to address in meeting load allocations.

The potential TP load reductions from these BMPs may be underestimated as a result of assumptions made about the relative TP contributions from irrigation runoff and groundwater, the even distribution of

[1] Time series concentration values were obtained using the TP regression equation (R^2 = 0.75) developed by Etheridge, MacCoy and Weakland (2014) using turbidity and season as surrogates to estimate TP concentration.

TP load reductions across the irrigation season,[2] and assumptions made by the regression model and SISL load estimates. Further refinement of the model can be bolstered by additional data regarding the contribution of agricultural operations to dissolved phosphorus loads in water, a time- or flow-weighted distribution of TP load reductions over the course of the irrigation season and an expansion of the sampling dataset that would allow for more accurate predictions using the regression model.

Figure 3: Estimated TP concentrations for each BMP scenario during irrigation season, 2011 graphed against the TMDL target and 'no BMP' scenario in red.



Connection to trading baseline

The expert panel agreed that a set of baseline BMPs should be consistent with what it would take to achieve the nonpoint source load allocation. Willamette Partnership recommends that baseline BMPs be introduced in phases in order to reduce the initial overhead cost and encourage landowner participation. Of the four BMPs evaluated, Willamette Partnership is recommending that the first phase of baseline BMPs require landowners to sit down with an agency representative or other water quality specialist to create a nutrient management plan as a minimum requirement. There are a several reasons for this: (1) it can generate data on current land use practices in the watershed for land managers, (2) it provides landowners with valuable information to improve agricultural operations, (3) it is low cost, (4) it establishes a relationship between agency and landowners, and (4) it is a good way to educate landowners about a new revenue stream through water quality trading in the Lower Boise.

During the first phase, any combination or all of the remaining BMPs would be eligible to generate credits. In the second phase, one or two of the additional BMPs would be added to the baseline. The third and final phase of baseline BMPs would require all four of the evaluated BMPs to be implemented and only projects that remove dissolved phosphorus from irrigation water will be allowed to generate credits. The results of this study indicate that reductions in the irrigation-induced runoff TP load (or SISL TP load) can only make so much progress in achieving the TMDL load allocation, and, in addition, nonpoint sources need to reduce TP loads that leach into the groundwater to achieve the TMDL targets.

[2] Using an even distribution of TP load reductions across all 15-minute interval TP loads underestimates the reduction in TP concentration. In cases where the average BMP TP load reduction is greater than the predicted 15-minute interval load, the excess load reduction does not carry over to the next time-step.

For the future

The conceptual model illustrates the complexity of phosphorus cycling in the Lower Boise River watershed. Future research can help to better quantify the effectiveness of BMPs, identify how portions of phosphorus loads from different sources cycle through the watershed, and better estimate the time between credit generation and the water quality benefit to the Boise River.

Tracer studies can be used to track both point and nonpoint source TP loads in the Boise River and through the environmental compartments noted in the conceptual model. Studies of this sort would give us more information on how different sources of phosphorus line up in space and time as well.

The relationship between discharge and TP concentration is documented by Wood and Etheridge (2011). The relationship between discharge and TP tends to remain fairly constant at Parma with higher concentrations at low flows and low concentrations at high flows; however, immediately following high flow events, the equilibrium concentration to flow relationship appears to be lower relative to before the event, suggesting that phosphorus loads are being flushed through the system during high flow. This may be evidence of environmental compartments like aquatic sediments and instream biota being flushed through the system that would otherwise act as stable phosphorus inputs to the water. Since aquatic sediments likely contribute TP loads to the water column at a rate relative to the amount of phosphorus stored in that compartment, flushing events may have implications for water quality goals and trading credits generated from particulate phosphorus reductions for dissolved phosphorus effluent.

Lastly, to more accurately quantify the TP load reductions from projects on agricultural lands throughout the base, the accepted 2lbs TP/1 ton sediment ratio should be tested in different regions of the basin. Sampling studies may find that some soils are richer than others in the basin, and, thus, would be a better target for nonpoint source reducing targets.

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