Bear River Trading Calculator
Technical Documentation

Contents

1.0 Introduction .......................................................................................................................... 1
2.0 Trading Calculator Description ............................................................................................ 2
  2.1 Non-point Sources and Point Sources Screens ................................................................. 3
  2.2 Sellers/Buyers Screen ......................................................................................................... 6
3.0 Example: Non-point source to point source trade .............................................................. 7
  3.1 Seller setup .......................................................................................................................... 7
  3.2 Buyer setup ....................................................................................................................... 10
  3.3 Review Scenario ............................................................................................................... 11
  3.4 Revise Scenario ................................................................................................................. 13
4.0 Example: Point source to multiple non-point source trade .................................................. 15
  4.1 Buyer Setup ....................................................................................................................... 16
  4.2 Seller Setup ....................................................................................................................... 17
5.0 Example Point source to point source trade ...................................................................... 20
  5.1 Seller Setup ....................................................................................................................... 20
  5.2 Buyer Setup ....................................................................................................................... 22
  5.3 Review Scenario ............................................................................................................... 24
6.0 Example: Seasonal trade ..................................................................................................... 27
  6.1 Buyer Setup ....................................................................................................................... 27
  6.2 Seller Setup ....................................................................................................................... 28
  6.3 Review Scenario ............................................................................................................... 30
Appendix A: Bear River Model Flow Diagram ........................................................................... 31
Appendix B: Bear River Subbasin Map ....................................................................................... 33
Appendix C: Supporting Equations ............................................................................................. 34
  1.0 Sources .............................................................................................................................. 34
  2.0 Sellers/Buyers ................................................................................................................... 39
1.0 Introduction

As part of the USEPA Targeted Watersheds Program, water quality pollutant trading has been explored as an option for reducing point and non-point source total phosphorus (TP) into the Bear River from Oneida Narrows Reservoir to Cutler Reservoir, including the Cub River. The Trading Calculator was developed as a tool for watershed managers to examine different trading scenarios including many buyers and sellers, potential pollutant reduction, and likely reduction cost\(^1\). This document is intended to help watershed managers understand how the Trading Calculator works and its use in implementation of management actions.

The premise of water quality trading is that one pollutant source can reduce its load and then sell the reduction to a pollutant source required to reduce its load below its capabilities. Water quality trades can occur with either non-point or point sources as sellers of tradeable credits. The buyer is usually a point source that is required to reduce pollutant loads due to a more stringent discharge permit. Other sources within the watershed, however, may be able to reduce their pollutant loading at a lower cost. These sources then have tradeable credits that can be sold to the regulated point source. Although non-point sources usually are not regulated, a trading program can provide economic incentives for non-point sources to establish practices to reduce loads.

Pollutant trading is complicated within watersheds because of the nature of pollutant transport. With the case of TP, it may be taken up by plants, adsorbed to soil, settled into sediments, or diverted so that TP loads to a stream in the upper part of the watershed will have a disparate impact compared to the same amount of TP released near the river’s terminus. The instream portion of the water quality modeling framework implemented for the Bear River was used to determine delivery ratios that account for phosphorus settling and uptake between sources and a receptor point. Delivery ratios relate the amount of TP at a source to the amount of TP at a receptor point. The Trading Calculator uses the point source and farm field TP load estimates from the water quality modeling framework to determine how much TP load reduction is available for trading between different sources. The user is required to provide information about total maximum daily load (TMDL) reduction requirements and best management practices (BMPs) effectiveness and cost.

\(^1\) In addition to facilitating water quality trades between stakeholders, the Trading Calculator is useful as an interface to the model results. Additional uses for the Trading Calculator may include identifying areas of concern in the watershed, ranking BMP projects that will receive funding, and estimating phosphorus reductions for grant reporting. These applications are not specifically addressed in this document.
This document outlines the Trading Calculator’s functions, capabilities, and limitations. It also provides examples of trading scenarios as listed below. Note that more comprehensive sources should be consulted to provide guidance on establishing formal trade agreements. The EPA has prepared a number of documents as a reference for managers of watersheds considering water quality trading (http://www.epa.gov/owow/watershed/trading/WQTToolkit.html).

2.0 Trading Calculator Description

To begin use of the Trading Calculator, create a folder on your C drive: C:\Bear. Copy the files Trading.exe (the executable version of the Trading Calculator) and BRResults.mdb (the database of model results) into this folder. Scenarios saved as files by the trading calculator will be located in the C:\Bear folder.

Double click Trading.exe to open the Trading Calculator. The opening screen is shown in Figure 1. The Trading Calculator consists of four screens, Non-point sources, Point sources, Delivery ratio viewer, and Sellers/Buyers. The user will typically work through these sequentially.

![Figure 1: Opening screen of the Trading Calculator.](image)

The current version of the Trading Calculator is limited by uncertainty in the identification of the non-point source farms and fields. An updated spatial dataset needs to be incorporated before the non-point source numbers are used.
**Non-point sources**: This tab is used to select a specific farm field and calculate the tradeable load of TP and the cost per TP credit from the field. The landowner is saved as a buyer or seller.

**Point sources**: This tab is used to determine the tradeable credits coming from point sources and their associated costs. The pointsource is saved as a buyer or seller.

**Delivery ratio viewer**: This tab shows the delivery ratios between the sources and the selected receptor point. Though interesting, it does not require user input and will not be covered in this document.

**Sellers/Buyers**: This tab incorporates information saved from the *Non-point sources* and *Point sources* screens to compare trading scenarios.

### 2.1 Non-point Sources and Point Sources Screens

The *Non-point sources* and *Point sources* tabs have similar formats. Each has a *Select Subbasin* frame in the upper left part of the screen which is used to select the location of the farm field or point source. The right section (*Select farm/field* frame for non-point sources and *Select point load/headwater* frame for point sources) identifies farms and fields or point sources located within the selected subbasin. The lower part of both tabs is the *Tradeable credits* frame and the *Cost information* frame. All of these sections are subsequently described in detail.

**Select subbasin frame**

The *Select subbasin* frame initializes the selection of sources. It allows the user to select a receptor point, the watershed and subbasin of interest, and an option to switch between U.S. and metric units.

- The *Receptor point* drop down box is used to select the location at which delivered and tradeable load is determined (e.g., a point of compliance).

**NOTE**: The user can choose any point in the model flow diagram (found in Appendix A) as a receptor point. SBR6, Bear River above Cutler, is the point used for regulation compliance for this stretch of the Bear River, so it will be used as the receptor point throughout this document.

- The *Watershed* drop down box allows for selection of the area in which the source is located. The user can select Bear River above Cub, Cub River, or Bear River to Cutler. Selecting a watershed narrows the possible subbasins for selection.
- The *Subbasin* drop down box is used to further refine selection of a non-point source. Within the basin, there are 50 subbasins that have been delineated by the modeling effort. Subbasins are identified by numbers, and some have an associated drainage description. Appendix B provides a map of all of the subbasins, and the flow diagram in Appendix A can also be referenced.
• The *Point load* drop down box is used to select a point source. When a point source is selected from the *Point load* drop down box, the watershed, subbasin, and farms are automatically populated.

**NOTE:** A point source can be selected using either the *Subbasin* drop down box or the *Point load* drop down box. Selecting a subbasin will populate the point load drop down box, and selecting a point load will populate the subbasin box accordingly. Because there are few point sources incorporated into the modeling framework, if a point source is being selected, it is more straightforward to select the point source first.

• The *Units* drop down box is used to switch between metric (kilograms) and U.S. (pounds) units. The *Load Units* box displays which units are being used.

**NOTE:** Non-point source loads are displayed in thousandths of pounds or grams, and point source loads are displayed in pounds or kilograms. On the Sellers/Buyers tab, the loads are all displayed in pounds or kilograms.

**Select farm/field frame**

On the *Non-point sources* tab, selecting a subbasin allows for the selection of a specific field in the *Select farm/field* frame on the upper right portion of the screen.

• The *Farm ID* box is populated with numbers corresponding to a particular landowners within a selected subbasin. Selecting a farm then allows for the selection of fields within that farm.

• The *Field ID* box is populated when a farm is selected. Multiple fields can be selected using the control or shift keys.

**NOTE:** The current farms and fields in the database accessed by the Trading Calculator are not an accurate representation of the frames or fields within the basin. Publically available spatial data were used to identify farms and fields, however many common boundaries did not match well between coverages. As a result, there is uncertainty in the farm and field results in the current version of the Trading Calculator. It is recommended that a more accurate and updated spatial dataset of land ownership and land management be used before the numbers of the Trading Calculator are used.

**Select point load/headwater frame**

On the *Point sources* tab, when a subbasin or a point load is selected, the *Select point load/headwater* frame will be populated with point sources in that subbasin. With the present subbasin delineation, there are no subbasins containing more than one point load.
Tradeable credits frame
When a field or a point source is selected, the tables in the Tradeable credits frame in the lower part of the Non-point sources or Point sources tabs are automatically populated. The values in the tables on the right (Delivered load, Target delivered load, Delivered load net of BMP reduction for non-point sources, Delivered load net of removal for point sources and Tradeable load) are automatically calculated using the information in the tables on the left as input. The calculations are detailed in Appendix C.

- The Load by season table consists of loads from the selected source as determined by the water quality modeling framework.
- The Delivery ratio to receptor point table contains values specific to each subbasin and are extracted from the database of model results.
- The Required TMDL reduction table is input by the user. The default is 0.
- The BMP’s effectiveness by season table (on the Non-point sources tab) is input by the user. The default is 50. On the Point sources tab, the parallel table is the Removal efficiency by season. It also has a default value of 50 and employs user-entered values.
- The Current BMP Update (on the Non-point sources tab only) button and box are used to apply a percent reduction to the Load by season values for non-point sources.

NOTE: Using the Current BMP Update may be necessary because Load by season is determined by the water quality modeling framework based on the land use coverage specified for the selected farm and field without accounting for any conservation practices or BMPs. If there is a BMP already implemented for this land parcel, the Current BMP Update can apply a percentage reduction to the Load by season values. Alternately, the Load by season values are editable, so if a BMP is currently implemented seasonally, the loads can be adjusted manually.

- The Delivered load table shows the load from this source that arrives at the receptor point.
- The Target delivered load table are values of the load that should reach the receptor point after TMDL requirements are met.
- The Delivered load net of BMP reduction (on the Non-point sources tab) table is the load that arrives at the receptor point after a BMP is implemented. The parallel table on the Point sources tab is Delivered load net of removal and represents the load that arrives at the receptor point after a treatment technology has been installed.
- The Tradeable load table consists of values of the load that the source has available to buy or sell after TMDL requirements are met and BMPs are implemented.

Cost information frame
The bottom frame, Cost information, permits the user to provide information with respect to the cost of BMP or treatment implementation and load reduction. Parameters are different between the Non-point sources and Point sources tabs.
For non-point sources:
- The **BMP cost** is input by the user and is a per acre cost. The default is $20/acre.
- The **Acres to which BMP is applied** is automatically extracted from the database, but can be modified by the user.

**NOTE:** The user must have local knowledge of the farm, the field, and the potential area to which the BMP will be applied. Costs of BMPs may be known on a per acre basis, or the BMP cost may be a lump sum. In this case, the cost per acre can be determined and entered, or a total value can be entered. For example, if a riparian buffer is to be installed that will cost $5000 regardless of the acreage, $5000 could be entered as the **BMP cost** and 1 could be entered as the **Acres to which BMP is applied** to result in a total cost of $5000.

For point sources:
- The **Mitigation cost** is the cost to implement a water treatment technology and is entered by the user. The default is 0. It may be a one-time cost or it may be an annual cost of a plant upgrade as the Trading Calculator uses loads and trades on an annual basis.
- The **Total mitigated load** is the amount of annual TP load that the specified technology removes and is calculated by the Trading Calculator.

For both non-point and point sources:
- The **Average cost per credit** is calculated by the Trading Calculator. See Appendix C for calculations.

### 2.2 Sellers/Buyers Screen

When seller and buyer information are recorded, they are saved as records in the database and displayed on the **Sellers/Buyers** tab. The upper portion of the screen retains the information of the last source selected. The lower portion of the screen compares the buyer’s and seller’s tradeable loads and the costs of trades.

**Seller’s tradeable credits frame**

When a non-point or point source is saved as a seller, this frame is populated with information from the source’s screen. Corresponding calculations are found in Appendix C.
- The **Receptor ID** is the receptor point.
- The **Source ID** is the Field ID for non-point sources or the name of the point source.
- The **Delivery ratio** is the average annual delivery ratio from the non-point or point source tab.
- The **Tradeable credits** is the amount of load that the seller can trade accounting for the delivery ratio between the source and the receptor point.
- The **Break even price** is the unit cost of the seller’s reduction as measured at the receptor point.
The Buyer's allowable load is calculated when a buyer is selected. This value is the amount of physical loading that the buyer could purchase from the seller and represents how much (in TP loading) the seller’s credits would be worth at the buyer’s location and is determined using the buyer’s delivery ratio (see Appendix C for details).

The Effective credit price is the minimum price per credit for this trade. It represents the unit cost of the load reduction based on the Buyer’s allowable load.

**Buyer’s effective credits frame**

When a non-point or point source is saved as a buyer, this frame is populated with information from the source’s screen.

- The Receptor ID is the receptor point.
- The Source ID is the Field ID for non-point sources or the name of the point source.
- The Delivery ratio is the average annual delivery ratio from the source tab.
- The Req’d load reduction is the annual load of TP that the buyer still needs to eliminate in order to meet their TMDL requirements.
- The Break even price is the unit cost of the technology already specified on the corresponding sources screen.

### 3.0 Example: Non-point source to point source trade

This is a simple water quality trading scenario involving a point source that is required to reduce its discharging TP load. The point source will pay a non-point source to implement a BMP that will reduce the non-point TP load so that the point source does not have to spend as much money on its treatment. The non-point source will be a seller and the point source will be a buyer. The Trading Calculator will be used to determine if a reduction in load from the non-point source will be able to offset the load from the point source and if a trade will be economical.

### 3.1 Seller setup

The Non-point sources tab will be used to initialize this scenario setup. First, select a specific field from the top part of the screen. For this example, the non-point source of interest is located in the watershed Bear River to Cutler, subbasin SB49, farm ID 32984, and field ID 13685.

1. Verify that SBR6, Bear River above Cutler is selected as the Receptor point.
2. Select Bear River to Cutler as the Watershed.
3. Select Subbasin SB49, Summit Creek from USFS boundary.
4. Select Farm ID 32984.
5. Select Field ID 13685. The lower part of the screen is automatically populated as shown in Figure 2.
For this example, the landowner already has a nutrient management program that provides approximately 25% reduction in TP unaccounted for in the modeling framework. There is no required TMDL reduction. The BMP under consideration is a sediment basin, which is projected to provide a TP reduction of 80%. The 80% reduction is above and beyond the 25% reduction that is already achieved.

6. Change the value in the Current BMP Update box from 0 to 25.
7. Click the Current BMP Update button. The loads should appear as shown in Figure 3.
8. Leave the values in the *Required TMDL reduction* table as 0.

9. In the *BMP’s effectiveness by season* table, click in the *Winter* cell and type in 80.

10. Click the *Repeat* button above the *BMP’s effectiveness by season* table to populate all of the seasonal cells.

The total cost of the sediment basin is approximately $8000. The area of the field extracted from the database is 7.34 acres. Applied to the entire field, the BMP cost per acre is $1090.

11. Enter 1090 in the *BMP cost* box.

12. Leave 7.34 as the *Acres to which BMP is applied*.

13. Click on the *Recalculate Loads* button to update all of the calculated values. The screen should look like Figure 4.

14. Click the *Record seller info* button to save this farm field as a seller.

Figure 4: Non-point source tab with all information entered for the Section 3 example.
3.2 Buyer setup

A point source will now be specified as a buyer. For this example, a new TMDL requires a 50% reduction from Caspers Ice Cream. Caspers currently has no treatment at all, but they hypothesize that by installing a new processing instrument within their facility, they can reduce their load by 30%. They want to investigate whether they can offset the other 20% of their required reduction by trading with this nonpoint source. The price of the new instrument is $30,000.

1. Click on the Point sources tab to access the Point sources screen.
2. In the Point load drop down box, select Caspers Ice Cream.
3. Enter 50 in the Winter cell of the Required TMDL reduction table.
4. Click the Repeat button above the Required TMDL reduction table to populate all of the seasonal cells.
5. In the Winter cell of the Removal efficiency by season table, enter 30.
6. Click the Repeat button above the Removal efficiency by season table to populate all of the seasonal cells.
7. In the Cost information frame, enter 30,000 as the Mitigation cost.
8. Click on the Recalculate loads button to update all of the calculated values, and the screen should look like Figure 5.
9. Click the Record buyer info button to save Caspers as a buyer.
3.3 Review Scenario

After saving sources as buyers and sellers, the information for the trade is accessed on the Sellers/Buyers screen. Click on the Sellers/Buyers tab to view the results of this trade (see Figure 6). This field can trade up to 11.3 lb/year of TP at the receptor point (Seller’s tradeable credits), which is equivalent to 12.9 lb (Buyer’s allowable load) at the buyer’s location. The buyer needs to eliminate 17.0 lb/year TP (Req’d load reduction) to meet their TMDL requirements.

In order to be competitive, the buyer’s offer would need to exceed $616/lb TP (Effective credit price). For this scenario, the cost to trade with this non-point source is quite a bit less than the cost incurred to purchase new equipment ($1166/lb TP Buyer’s Break even), so it may appear attractive to the buyer. The buyer may also want to compare the price of trading with the price of additional treatment options, which may make trading more or less attractive.

It is important to note that the buyer needs to purchase 17 lb/year while the seller can only offer 12.9 lb/year. The buyer needs to reduce loading by about another 4 lb/year. This reduction could likely be achieved through additional trading, perhaps with the same farmer from another...
of his fields as he will already be making a significant investment in constructing sediment basins on his land. This will be explored in section 3.4.

NOTE: Sources do not have to be geographically close to make trading feasible. The sources in this example are located in different subbasins and even in different parts of the watershed (the point source discharges to the Cub and the non-point source drains to Summit Creek, a tributary of the Bear below the confluence with the Cub), but trading is still possible between them because relative location is accounted for by the delivery ratios.

The scenario can be saved by clicking the Save to database button. This creates a file, C:\Bear\trading.xml, that will load this scenario the next time the Trading Calculator is opened.

NOTE: Each time Save to database is clicked, the file will be overwritten by the new scenario, so if the user wants to save the scenarios for long term, the file names must be changed. To load a desired scenario with the Trading Calculator, the name should be changed back to Trading.xml.

Figure 6: Seller/Buyers tab used to review the Section 3 scenario.
3.4 Revise Scenario

As mentioned, the load reduction provided by the seller in this example does not satisfy the reduction required for the seller. Because this landowner is installing sediment basins on his land, the parties involved would like to explore potential load reductions resulting from incorporating the sediment basins to all of the landowner’s fields.

1. Navigate back to the Non-point sources tab.

NOTE: After clicking away from a particular subbasin (e.g., when a point load in a different subbasin is selected), the previously used source information will not be retained in the Non-point source tab.

2. Reselect this farm (watershed Bear River to Cutler, subbasin SB49, farm ID 32984).
3. Use the control or shift key to select all of the fields in the Field ID box from farm 32984.

NOTE: When multiple fields are selected, the loads extracted from the model results are totaled, the delivery ratios are averaged and the field acreages are totaled.

4. Enter 25 as the current BMP, and click the Current BMP Update button.
5. Make sure the Required TMDL reduction is 0 and change the BMP effectiveness by season to 80 for all seasons.

The total cost of the BMP expanded to the entire farm is $13,000. Divided by the 147.4 acres of the farm, the cost per acre is $88.2.

6. Enter 88.2 in the BMP cost box and click the Recalculate loads button. The screen should appear as in Figure 7.
7. Click the Record seller info button.
If the point source has been cleared or changed, it will be need to be reentered and saved as a buyer as detailed in Section 3.2. If no changes have been made, navigate to the Sellers/Buyers tab, which is shown in Figure 8. In the top frame are two sellers’ records. The first record is the single field and the second is the farm with all fields selected. Note that the Tradeable Credits and Buyer’s allowable load have increased significantly and the Break even price and the Effective Credit Price are much lower when applying the BMP to all of the fields. So, this landowner could provide more than enough of the credits to fulfill Caspers required reduction. Additionally, applying the BMP to all of the fields results in a lower cost per credit for the load reduction. The landowner could potentially sell the excess credits to another buyer or charge Caspers a higher price per credit to account for the money spent to achieve the total load reduction.
4.0 Example: Point source to multiple non-point source trade

In the previous scenario, the point source was able to obtain the reduction needed to meet its TMDL requirement from a single seller. This section will demonstrate how to use the Trading Calculator to set up a trading scenario with multiple sellers.

It is not uncommon for a third party to act as a broker for water quality trades. The third party may be a cooperative of non-point sources such as all of the landowners within a particular subbasin. The cooperative can seek out and facilitate trades for the group instead of each individual landowner acting for themselves. Collectively, the non point sources will likely have more bargaining power than they would individually. A cooperative can serve other purposes
such as providing guidance and assistance to landowners on BMP installation as well as holding landowners accountable for BMP maintenance.

### 4.1 Buyer Setup

This example will begin by setting up the information for the buyer, a point source. For this scenario, a TMDL has been implemented that requires the Richmond wastewater treatment facility to achieve a 90 percent reduction from its current TP discharge. The current system, lagoons, is to be supplemented by chemical treatment by alum coagulation. The new treatment is projected to remove about 75% of the facility’s TP. Over the next 30 years, the cost of the upgrade, chemicals, and sludge disposal will cost about $75,000 per year. Additional technology could be used to achieve the 90% required by the TMDL, but Richmond would like to investigate water quality trading as an alternative.

1. Navigate to the *Point sources* screen.
2. Select Richmond Lagoons from the *Point load* drop down box.
3. Check that SBR6, Bear River above Cutler is selected as the receptor point.
4. Enter 90 as the TMDL reduction for all seasons. Recall that the *Repeat* button can be used to populate values through all of the seasonal cells.
5. Enter 75 as the removal efficiency for all seasons.
6. In the *Mitigation cost* box, enter 75000.
7. Click the *Recalculate loads* button to ensure that all of the calculations are performed. The screen should appear as in Figure 9.
8. Click the *Record buyer info* button to save this information to the *Sellers/Buyers* tab.
4.2 Seller Setup

A group of landowners in a nearby subbasin is interested in implementing BMPs, and they want to determine whether they can make the endeavor profitable by trading credits from TP reductions. All of these landowners will commence conservation tillage on their fields bordering the creek. Conservation tillage can be effective in reducing TP discharged to the river by about 90%. The cost of conservation tillage can be difficult to estimate because reducing the amount of cultivation of the soil can actually save the landowner money. However, the landowner may lose some money because of reduced crop productivity and because herbicides will be needed for weed control. These landowners estimate a cost of $50-75/acre to switch to conservation tillage.

1. Navigate to the Non-Point Sources screen.
2. Leave the receptor point as SBR6 and the watershed as Cub River.
3. Change the subbasin to 45, Cherry Creek. This is a tributary to the Cub River that enters just above the Richmond Lagoons, and the watershed is home to a number of significant nonpoint sources of TP.
4. Select Farm ID 40366 and Field ID 7226.
5. Change the BMP effectiveness to 90 for all seasons.
6. Change the BMP cost to $50/acre.
7. Change the Acres to which BMP is applied to 150. This landowner has over 500 acres, but only 150 are near the creek.
8. Click the Recalculate Loads button. The screen should appear as Figure 10.
9. Click the Record seller info button.
10. Repeat this process for additional fields using the information for Farm ID and Field ID in Table 1. For all of the fields, the BMP effectiveness will need to be changed to 90. The BMP cost as well as the acres to which the BMP is applied vary by source, so use the cost/acre and acreage values in Table 1.
11. After saving all of the fields in Table 1 as sellers, navigate to the Sellers/Buyers screen (see Figure 11). As all of the seller’s cannot be seen on the Sellers/Buyers screen, Table 1 also includes the buyer’s allowable load and the effective credit price for each of the fields.

Table 1: Inputs and outputs of a collective of non-point sources for the Section 4 example.

<table>
<thead>
<tr>
<th>Farm ID</th>
<th>Field ID</th>
<th>BMP Cost, $/acre</th>
<th>Acres to which BMP is applied</th>
<th>Buyer's Allowable Load, lb</th>
<th>Effective Credit Price, $/lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>40366</td>
<td>7226</td>
<td>50</td>
<td>150</td>
<td>72.6</td>
<td>103</td>
</tr>
<tr>
<td>35935</td>
<td>13561</td>
<td>75</td>
<td>4.67</td>
<td>27.8</td>
<td>12.6</td>
</tr>
<tr>
<td>34391</td>
<td>14766</td>
<td>75</td>
<td>3.56</td>
<td>25.5</td>
<td>10.5</td>
</tr>
<tr>
<td>34762</td>
<td>17119</td>
<td>75</td>
<td>6.23</td>
<td>22.5</td>
<td>20.8</td>
</tr>
<tr>
<td>34873</td>
<td>13589</td>
<td>75</td>
<td>5.56</td>
<td>21.5</td>
<td>19.4</td>
</tr>
<tr>
<td>34807</td>
<td>17118</td>
<td>50</td>
<td>40.48</td>
<td>17.8</td>
<td>113</td>
</tr>
<tr>
<td>35970</td>
<td>6045</td>
<td>50</td>
<td>28.91</td>
<td>14.8</td>
<td>97.8</td>
</tr>
<tr>
<td>34881</td>
<td>13572</td>
<td>50</td>
<td>20</td>
<td>14.4</td>
<td>69.5</td>
</tr>
<tr>
<td>35980</td>
<td>4706</td>
<td>75</td>
<td>11.79</td>
<td>14.1</td>
<td>62.7</td>
</tr>
</tbody>
</table>
Figure 10: Non-point sources tab for one of the sellers in the Section 4 scenario.

The total of the buyers’ allowable loads is 231 pounds, well above Richmond’s required load reduction of 169 pounds. With this excess, the cooperative could engage in trading with other point sources. Notice that the effective credit prices vary greatly from field to field. The average credit price from these non point sources is $56.6, less than the cost incurred by Richmond to treat TP with alum. In this case, it appears that trading with this cooperative of landowners will be economical for Richmond. Richmond could offer an equivalent amount ($83/credit) to the landowners to cover their costs, and the landowners would need to divide that between landowners so that each party had a similar profit margin. Alternately, the landowners might choose to bargain with Richmond on the grounds that treatment on top of the alum would be more costly than $83/credit, resulting in a higher value for trading.
5.0 Example Point source to point source trade

In the previous scenarios, the point sources were seeking water quality trades in order to meet TMDL requirements. In this scenario, a point source treats TP in excess of its TMDL requirements and can sell the credits to other point sources.

5.1 Seller Setup

For this scenario, a TMDL has been implemented that requires most of the point sources in the watershed to reduce their TP loading by 90%. Preston WWTP has determined to install an enhanced biological phosphorus removal system supplemented by alum coagulation that will result in TP removal of about 99%. Dividing the capital cost for the treatment facility into 30
years and accounting for the costs of chemicals and disposal, the yearly cost of the facility is estimated to be $100,000.

1. Navigate to the **Point sources** screen.
2. Select Preston WWTP from the **Point load** drop down box.
3. Enter 90 as the **Required TMDL reduction** for all seasons.
4. Enter 99 as the **Removal efficiency** for all seasons.
5. Enter 100000 in the **Mitigation cost** box.
6. Click the **Recalculate Loads** button. The screen should appear as in Figure 12.
7. Click the **Record seller info** button.

At the receptor point, the tradeable load from Preston WWTP is 319 lb/year. This represents the TP reduction that Preston will achieve beyond the reduction required by the TMDL, and Preston is offering these credits for sale to other treatment facilities.

![Figure 12: Point sources tab with seller information for the Section 5 scenario.](image-url)
5.2 Buyer Setup

Two point sources, Richmond and Franklin, both of which have lagoon treatment facilities, will investigate purchasing credits from Preston to achieve reductions. As in the previous scenario, Richmond is required to reduce its load by 90% and can attain a 75% reduction through chemical coagulation with alum at a cost of $75,000/year. Richmond will seek to achieve the additional required removal through trading.

1. Stay on the Point sources tab, but select Richmond Lagoons from the Point load drop down box.
2. Enter 90 as the required TMDL reduction for all seasons.
3. Enter 75 as the removal efficiency for all seasons.
4. Enter 75000 as the mitigation cost.
5. Click on Recalculate Loads. The screen should appear as Figure 13.
6. Click Record buyer info.

Franklin is also is required to reduce its TP load by 90%. As Franklin discharges very little from its lagoons, this trade will be examined with Franklin not implementing any supplemental treatment.

7. Again, on the Point sources tab, select Franklin WWTP from the Point loads drop down box.
8. Enter 90 as the TMDL requirement for all seasons.
9. Enter 0 as the removal efficiency for all seasons.
10. Enter 0 as the mitigation cost.
11. Click the Recalculate Loads button. Figure 14 shows the resulting screen
12. Click the Record buyer info button

NOTE: For Franklin, the cost per credit appears as NaN. This is not an error, but a result of there being no additional treatment and no mitigation cost.
Figure 13: Point sources tab with the first buyer’s information for the Section 4 example.
Figure 14: Point source tab for a second buyer for the Section 4 example.

5.3 Review Scenario

Navigate to the Sellers/Buyers tab to review the potential for trades between these sources. The values in the Buyers’ allowable loads cells are specific to each buyer. Clicking on each buyer’s record will adjust the Buyer’s allowable load, lb and the Effective Credit Price, $/lb. In the Buyer’s effective credits frame, select the record for Richmond (Figure 15). Next, select the Franklin entry (Figure 16). Note that the Buyer’s allowable load, lb and the Effective Credit Price, $/lb are different for the two buyers because the buyers have different delivery ratios. Each buyer-seller relationship needs to be considered independently.
1. Richmond will be considered as the first buyer. Select the entry for Richmond in the *Buyer’s effective credits* frame.

Richmond could potentially purchase up to 367 lb/year credit from Preston (*Buyer’s allowable load*). To meet the TMDL, Richmond only needs a reduction of 170 lb/year, so only that much will be purchased from Preston. This will reduce the Buyer’s allowable load to 197 lb/year, but the delivery ratio must be used to translate this value back to Preston’s tradeable credits.
2. Multiply the allowable load after purchase by Richmond (197 lb/year) by Richmond’s delivery ratio (0.873) to get Preston’s updated tradeable credits (171 lb/year).

3. Type this value into the Tradeable Credits cell in the Seller’s tradeable credits frame.

4. Select the record for Franklin in the Buyer’s effective credits frame. The Buyer’s allowable load, lb and the Effective Credit Price, $/lb are updated as shown in Figure 17.

Franklin could purchase up to 209 lb/year from Preston, which is well above the 98.7 lb/year that Franklin needs to achieve its TMDL reduction. Where there is a surplus of seller’s credits, it does not matter which buyer is initially selected. The effective credit price will remain constant as shown in this example.

Figure 17: Sellers/Buyers information with the seller's tradeable credits updated to reflect sale to another buyer.

As with the other scenarios, price brokering could take a few different routes. Both Richmond and Franklin need to pay Preston at least $25/credit, but because Preston is installing the new treatment plant regardless of trading, the buyers may not want to pay more than that. Conversely, Preston could raise the price for Richmond given that Richmond will already be paying more ($88.9/credit) for their chemical treatment. Furthermore, the price for Richmond to install additional treatment (such as the enhanced biological facility that Preston is proposing) may be quite steep, so Preston could raise the prices even higher than the Richmond’s break even prices and remain below the cost of increased treatment. Although the Trading Calculator does not show a break even price for Franklin, there would obviously be a cost if a new treatment is implemented. The cost would likely be higher than the effective credit price of approximately $25, but Preston would not want to charge Franklin so much that new treatment is more attractive than trading.
6.0 Example: Seasonal trade

The Trading Calculator determines all trades on an annual basis; however, the user can manually enter values to pursue seasonal trades. In this scenario, regulations are established to mitigate the peak loads occurring during the spring runoff.

Loading values will be set to 0 in order to force the Trading Calculator to operate as though the loading for a single season is the total loading. This does not necessarily signify that there is no load or load reduction during those times, only that a specific time period is the focus of the scenario. Delivery ratios do not need to be modified because determination of Delivered load is based on seasonal values of load and delivery ratio. The Annual values of TMDL reduction and BMP effectiveness are averages of the seasonal values, but they do not need to be changed because the Target delivered load and Delivered load net of BMP reduction are determined by seasonal values. All of these calculations are also shown in Appendix C.

6.1 Buyer Setup

For most of the year, the Lewiston Lagoons are evaporative and do not discharge into the river. During the spring, however, rain and snowmelt cause the lagoons to exceed their capacity. Recent regulations require a 50% reduction in spring TP loads. To avoid costly new treatment, Lewiston would like to pursue trading with a non-point source.

1. Navigate to the Point sources screen.
2. Select Lewiston Lagoons from the Point load drop down box. Note that loading only occurs in the spring, the only season in which Lewiston discharges.
3. In the Spring cell of Required TMDL reduction table, enter 50.
4. As no treatment is to be implemented, enter 0 in the Winter cell of Removal efficiency by season table and click the Repeat button.
5. Enter 0 as the Mitigation cost
6. Click on the Recalculate Loads button. The screen should appear as Figure 18.
7. Click Record buyer info.
6.2 Seller Setup

The non-point source with which Lewiston will trade is a field located in a nearby subbasin. Livestock are kept in the field, and in the spring, rain and snowmelt wash a significant quantity of manure into the stream. As a result, the spring TP loading is much higher than in other seasons. The landowner is considering implementing an animal waste management system to reduce the amount of waste that goes straight into the stream if trading can make it profitable. The waste storage is estimated to be 75% effective, and the cost is estimated at $30/lb of TP removed.

1. Navigate to the Non-point sources screen.
2. Cub River should already be selected as the watershed. Select subbasin 42, farm 40298, and field 15174.
3. Because this scenario is only focused on loads during the spring, enter 0 in the Winter, Summer, and Fall cells of the Load by Season table.

NOTE: Although the Annual cell of Load by season does not update, all of the calculations are based on the seasonal values.

4. Enter 75 in the Spring cell of the BMP effectiveness by season table.
5. Enter 0 in the Winter, Summer, and Fall cells.
6. To achieve an Average cost per credit of $30/lb applied to the entire 5.34 acres of the field, the cost per acre is $25.3/acre, so enter 25.3 as the BMP cost.
7. Click the Recalculate Loads button. The screen should appear as Figure 19.
8. Click the Record seller info button.

Figure 19: Non-point sources tab for this scenario.
6.3 Review Scenario

1. Navigate to the Sellers/Buyers tab.
2. Recall that the information for the Buyer’s allowable loads is determined by the buyer’s delivery ratio. The value here is the annual average, but in this example, the seasonal delivery ratio should be used. In the Buyer’s effective credits from, change the Delivery ratio from 0.873 to 0.847, Lewiston’s spring delivery ratio.

Note the values for Buyer’s allowable load and Effective Credit Price are modified, as shown in Figure 20. Lewiston must reduce its TP load by 21 lb/year and could purchase 21.3 lb/year from this landowner. The price per credit must exceed $25.4, but this landowner could bargain for a higher price because it would likely cost Lewiston more than $25.4/credit to install additional treatment. Another consideration with this scenario is margin of error. Because the Buyer’s allowable load (21.3 lb) is very close to the Req’d load reduction (21 lb), regulators may require Lewiston to purchase additional credits to insure that the required reduction is unequivocally met.

Figure 20: Sellers/Buyers tab for this example.
Appendix A: Bear River Model Flow Diagram

Figure A-1 is a diagram of the Bear River modeling schema. For the water quality modeling framework, subbasins were delineated and numbered as shown in the map in Appendix B. These correspond to subbasins in Figure A-1 (e.g., SB1, SB26, etc). The water quality modeling framework routes flow and TP loading from the landscape to the stream and then downriver. At each model node, flow and TP are collected from the contributing stream reaches and subbasins, and model output is calculated. The nodes are represented in Figure A-1 by ovals and labels (e.g., NBR1, LCR7, SBR2, etc). In the Trading Calculator, any one of these nodes can be selected as a receptor point. There are two types of arrows in Figure A-1 to represent model linkages. The solid arrows correspond to instream flow and pollutant routing, while the dotted arrows show flow and pollutant routing from subbasins to nodes.

The subbasins, stream reaches, and nodes in the modeling framework have been grouped into five model segments: North Bear River, Middle Bear River, Upper Cub River, Lower Cub River, and South Bear River. The segments are represented by various colors in Figure A-1. The model segments are also included as part of the node identifiers.
Figure A-1: Bear River model flow diagram
Appendix B: Bear River Subbasin Map
Appendix C: Supporting Equations

A few simple equations are used to derive the values in the Trading Calculator and populate the fields that are not input by the user. This appendix will document the calculations that are performed internally on the Non-point sources, Point sources, and Sellers/Buyers tabs. It should be noted that seasonal values are imported from the database and used in many of the calculations for non-point and point sources, but all of the cost information is determined on an annual basis using a sum (for loads) or an average (for delivery ratios, TMDLs, and BMPs) of the seasonal values. Section 6 of this document shows an example of isolating a particular season in order to determine trade potential.

1.0 Sources

When a specific farm and field are selected on the Non-point sources tab (Figure C-1) or a point load selected on the Point sources tab (Figure C-2), the values in the Load by season and Delivery ratio to receptor point tables are automatically loaded from the database of model results. The Required TMDL reduction, BMP effectiveness by season (for non-point sources), and Removal efficiency by season (for point sources) tables require user input values. The tables on the right are then calculated based on the values in the tables on the left.

Note that the units are different between the Non-point sources and the Point sources tabs. The values in the tables for non-point sources are given either in grams or in thousandths of pounds (displayed as lb x 1000) while the values for point sources are reported as kilograms or pounds.
Figure C-1: Non-point sources tab.
1.1 Delivered Load

The *Delivered load* represents the load from the source at the receptor point and accounts for the delivery ratio. It is determined identically for non-point and point sources. The delivered load of each season is the product of the load for that season and the delivery ratio for that season. The annual delivered load is the sum of all of the seasonal delivered loads. This is shown in Equations 1 and 2.

\[
DL_{season} = \text{Load}_{season} \times DR_{season}
\]  
(1)

\[
DL_{annual} = \sum DL_{season}
\]  
(2)
where $DL_{season}$ and $DL_{annual}$ represent the Delivered load, $Load_{season}$ is the Load by season, and $DR_{season}$ is the Delivery ratio to receptor point. For the example shown in Figure C-1:

$$DL_{winter} = Load_{winter} \times DR_{winter} = 2341 \times 0.997 = 2334$$

$$DL_{annual} = \sum DL_{season} = 2334 + 1150.2 + 413.3 + 2467.6 = 6365.1$$

### 1.2 Target Delivered Load

The Target delivered load represents the load from the source at the receptor point as required by the TMDL and is calculated in the same way for non-point and point sources. The values for delivered load are multiplied using the TMDL reduction percentage as shown in Equation 3. Equation 4 shows that the annual target delivered load is the sum of the seasonal target delivered load.

$$TDL_{season} = DL_{season} \times (1 - TMDL_{season}) \quad (3)$$

$$TDL_{annual} = \sum TDL_{season} \quad (4)$$

where $TDL_{season}$ and $TDL_{annual}$ represent the Target delivered load and $TMDL_{season}$ represents the seasonal Required TMDL reduction as a decimal. Using the values in Figure C-1:

$$TDL_{winter} = DL_{winter} \times (1 - TMDL_{winter}) = 2334 \times (1 - 0.40) = 1400.4$$

$$TDL_{annual} = \sum TDL_{season} = 1400.4 + 690.1 + 248 + 1480.6 = 3819.1$$

### 1.3 Net Delivered Load

The Delivered load net of BMP reduction (for non-point sources) and Delivered load net of removal (for point sources) represent the load from the source at the receptor point after load reduction resulting from implementation of a BMP, a treatment technology, or another practice. The net delivered load is calculated using delivered load with the removal provided by the BMP or treatment as shown in Equation 5. The annual net delivered load is the sum of the seasonal net delivered loads, as in Equation 6.

$$NDL_{season} = DL_{season} \times (1 - Re_{mseason}) \quad (5)$$

$$NDL_{annual} = \sum NDL_{season} \quad (6)$$

where $NDL_{season}$ and $NDL_{annual}$ represent the Delivered load net of BMP reduction or Delivered load net of removal and $Re_{mseason}$ is the BMP’s effectiveness by season (for non-point sources) or
the Removal efficiency by season (for point sources) as a decimal. Again, using the values from Figure C-1:

\[
NDL_{winter} = DL_{winter} \times (1 - Re m_{winter}) = 2334 \times (1-0.75) = 583.5 \\
NDL_{annual} = \sum NDL_{season} = 583.5 + 287.6 + 103.3 + 616.9 = 1591.3
\]

1.4 Tradeable Load

The Tradeable load is the amount of reduction in load, beyond the requirement of the TMDL, which can then be traded with other sources. It is the difference between the target delivered load and the net delivered load, as shown in Equation 7 for both non-point and point sources. The annual tradeable load is the sum of the seasonal tradeable loads, as in Equation 8.

\[
TL_{season} = TDL_{season} - NDL_{season} \quad \text{(7)} \\
TL_{annual} = \sum TL_{season} \quad \text{(8)}
\]

where \( TL_{season} \) and \( TL_{annual} \) represent the Tradeable load (i.e. credits). If the BMP or treatment reduction is greater than the TMDL reduction, than the tradeable load will be positive and the credits can be sold. Conversely, if the BMP or treatment reduction is less than the TMDL requirement, than the tradeable load will be negative and credits must be purchased to make up this deficit. Again, for the example in Figure C-1:

\[
TL_{winter} = TDL_{winter} - NDL_{winter} = 1400.4 - 583.5 = 816.9 \\
TL_{annual} = \sum TL_{season} = 816.9 + 402.5 + 144.7 + 863.7 = 2227.8
\]

1.5 Cost Information

Both the Non-point sources and the Point sources tabs have Cost information, but the calculations vary between the two. On the Non-point sources tab, the BMP cost is supplied by the user. The Acres to which BMP is applied is automatically populated by the area of the field stored in the database. The user may need to modify this value to arrive at the appropriate total cost of the BMP. The Average cost per credit ($/unit P) is calculated based on the annual reduction provided by BMP implementation, regardless of TMDL regulation. It may seem that the annual tradeable load (the difference between net delivered load and target delivered load) should be used to determine cost, but the premise is that the landowner will use trading to offset all costs incurred by BMP implementation, even if BMPs are implemented to achieve a TMDL requirement. This is shown in Equation 9. Also, at this point, units are converted from grams
and thousandths of pounds to kilograms and pounds so that the units on cost per credit are $/kg or $/lb.

\[
\frac{\text{Cost}}{\text{Credit}} = \frac{\text{cost/acre} \times \text{acreage}}{D\ell_{\text{annual}} \times \text{Rem}_{\text{annual}}} \times 1000
\]  

(9)

where \(\frac{\text{Cost}}{\text{Credit}}\) is the Average cost per credit, \(\text{cost/acre}\) is the BMP cost, and \(\text{acreage}\) is the Acres to which BMP is applied. Using the Figure C-1 example:

\[
\frac{\text{Cost}}{\text{Credit}} = \frac{\text{cost/acre} \times \text{acreage}}{D\ell_{\text{annual}} \times \text{Rem}_{\text{annual}}} \times 1000 = \frac{100 \times 5.12}{6365.09 \times 0.75} \times 1000 = 107
\]

On the Point sources tab, the Mitigation cost is the cost to upgrade the water treatment to provide the removal efficiency already specified as the Removal efficiency by season in the table above and is supplied by the user. The Total mitigated load is the amount of TP removed by the technology and is determined by Equation 10. These values are used to calculate the Average cost per credit as shown in Equation 11. There is no need for unit conversion on this tab, so the cost/credit units are $/kg or $/lb.

\[
TML = D\ell_{\text{annual}} - NDL_{\text{annual}}
\]  

(10)

\[
\frac{\text{Cost}}{\text{Credit}} = \frac{\text{cost}}{TML}
\]  

(11)

where \(TML\) represents the total mitigated load, \(\frac{\text{Cost}}{\text{Credit}}\) is the Average cost per credit, and \(\text{cost}\) is the Mitigation cost. Using the values in Figure C-2:

\[
TML = D\ell_{\text{annual}} - NDL_{\text{annual}} = 3538.8 - 884.5 = 2654.1
\]

\[
\frac{\text{Cost}}{\text{Credit}} = \frac{\text{cost}}{TML} = \frac{1000000}{2654.1} = 376.8
\]

2.0 Sellers/Buyers

When sources are saved as sellers or buyers, information is transferred to the Sellers/Buyers tab where calculations are performed to determine the how many credits a buyer could purchase from a seller and the minimum credit price. The sources in Figures C-1 and C-2 are used as a seller and a buyer, respectively, in Figure C-3. The top frame contains information on the seller. The Delivery ratio, Tradeable Credits, and Break even price are directly transferred from the appropriate source tab and refer to the load and price at the receptor point. Similarly, the buyer’s Delivery ratio, Req’d load reduction, and Break even price in the bottom frame are transferred
from the appropriate source tab and represent a reduction as measured at the receptor point. Note that for non-point sources, the units of Tradeable Credits have been converted from thousandths of pounds or grams on the Non-point sources tab to pounds or kilograms on the Sellers/Buyers tab.

Figure C-3: Sellers/buyers tab using the sources in Tables C-1 and C-2.

When the record for a buyer is selected, the Buyers’ allowable loads are populated. The Buyer’s allowable load and Effective Credit Price take into account the different locations of the buyer and the seller. The Buyer’s allowable load is the equivalent of the seller’s credits at the buyer’s location. The amount of credits changes between the receptor point and the buyer’s location based on the buyer’s delivery ratio, as in Equation 12. The Effective Credit Price is the unit price of the credits based on the Buyer’s allowable load as shown in Equation 13. The total cost
remains constant, but the price per credit varies from the Break even price because the Buyer’s allowable load varies from the seller’s Tradeable Credits.

\[ AL_{buyer} = \frac{TL_{seller}}{DR_{buyer}} \]  
\[ CP = \frac{BP_{seller} \times TL_{seller}}{AL_{buyer}} \]

where \( AL_{buyer} \) is the Buyer’s allowable load, \( TL_{seller} \) is the seller’s tradeable load or Tradeable credits, \( DR_{buyer} \) is the Delivery ratio of the buyer, \( CP \) is the Effective Credit Price, and \( BP_{seller} \) is the seller’s Break even price. For the example in Figure C-3:

\[ AL_{buyer} = \frac{TL_{seller}}{DR_{buyer}} = \frac{2.23}{0.818} = 2.73 \]
\[ CP = \frac{BP_{seller} \times TL_{seller}}{AL_{buyer}} = \frac{107 \times 2.23}{2.73} = 87.4 \]