Scope of Work

An Assessment of Forest Protection Opportunities and Potential Reductions in Sediments, Nutrients, and Total Organic Carbon in the Freshwater Potomac River

While source water protection is seen as an important component of a multi-barrier approach to providing high quality water, it can be difficult to assess the financial benefits of source water protection programs. This project provides an initial step for evaluating the costs and benefits of protecting forested land within the Potomac River basin. Regardless of who pays for forest protection, the first step in such an evaluation is to conduct a rigorous and scientifically defensible study to answer the question: Do existing forests or forested buffers play a role in water quality, and how significant is it with respect to drinking water treatment costs? This project will apply sophisticated watershed modeling tools to answer the research question.

Forested lands comprise about 58 percent of the land cover within the 11,560 square mile area of the non-tidal Potomac basin – the source water area for the participating utilities. A portion of this is protected through federal, state, and local management programs or through private conservation easements. Federal land holdings, including the George Washington National Forest in the basin's headwaters, comprise about ten percent of the freshwater Potomac watershed.

This study will evaluate the potential economic benefits of forest protection to water utilities. It is recognized that this is only part of the equation for conducting a cost-benefit analysis. Future research will be needed to provide a detailed cost-benefit analysis of operational and capital cost savings as compared to the costs of forest or buffer protection.

The objectives of this research are to:

1) determine water quality changes near Fairfax Water, Washington Aqueduct, and WSSC's Potomac intakes by preserving varying degrees of existing forested lands (DC Water is a wholesale customer of Washington Aqueduct and does not have its own intake.);
2) conduct an initial assessment of the impact of water quality changes on treatment costs; and
3) use the results to develop recommendations for source water protection activities.

The following eight tasks are designed to meet the above objectives. Each task's purpose, methodology, and anticipated results are described in detail in subsequent sections:

Objective 1

1) Identify current land cover conditions

2) Identify opportunities for forest protection
3) Develop future land cover scenarios
4) Model sediments and nutrients using the Chesapeake Bay Program (CBP) Watershed Model (Watershed Model)
5) Model total organic carbon (TOC) by adapting the Watershed Model

Objective 2

6) Develop water quality and treatment cost relationships

Objective 3

7) Review forest protection considerations
8) Produce final report and outreach materials

The project will be executed in two phases. Phase I will cover parts of Tasks 5 and 6. Phase II will cover Tasks 1 through 4, the remaining parts of Tasks 5 and 6, and Task 8.

Phase I

Tasks 5.a-f: Calibrate the Chesapeake Bay Watershed Model for TOC

Purpose: The existing version of the Watershed Model can simulate TOC concentrations but the model has not yet been calibrated. Early in the Watershed Model development process, it was intended that TOC should be fully simulated and calibrated. The TOC simulation is fully functional in the Watershed Model. Observed in-stream TOC concentration data was collected for the calibration of the river simulation. Somewhere in the development process, however, the calibration of TOC in the Watershed Model was dropped, so TOC is not a calibrated parameter (though the statistics comparing observed and simulated TOC are calculated and reported). In the river simulation, TOC is calculated as the sum of refractory organic carbon (ROC) and the carbon component of biochemical oxygen demand (BOD). Land-based ROC loads are based on the load of refractory nitrogen (RON).

Methodology: This task will update the current implementation of TOC simulation in the Watershed Model so that the TOC simulation is on par with the simulation of sediment and nutrients in the model. Taking the following steps will provide a model suitable for simulating planning scenarios in Phase II:

Task 5.a – Literature survey of estimates of land use export coefficients
The most frequently used method of simulating land use loads is to start by calibrating the land simulation to target export coefficients for each land use. Export coefficients are simply the average annual load lost per acre from a land use. The literature will be reviewed to determine any estimates of TOC (or BOD and ROC) target export coefficients to be used in the calibration.

Task 5.b – Solicit and analyze any TOC monitoring data from point sources and MS4s
CBP keeps a point source database, and although TOC is listed as a variable, data does not appear to be in the database for Potomac River sources. The absence of TOC data will be confirmed. If data are available, it will be analyzed for use in estimating point source ROC loads.

Any observations of TOC or ROC in regulated stormwater within the basin will be obtained to better determine TOC loading rates from developed land.

Task 5.c – Collect additional existing in-stream data for calibration
The Watershed Model already has a fairly extensive dataset of observed concentrations. To the extent possible, gaps in the calibration dataset will be filled. This will include an evaluation of TOC concentrations in the Potomac River, using observed TOC concentrations from participating utilities.

Task 5.d – Use ESTIMATOR to calculate empirical load estimates
During the Watershed Model river calibration, edge-of-stream nutrient loads are adjusted to achieve better agreement with empirical estimates of average annual river loading rates at the fall line and at other key calibration points through the use of regional factors. Regional factors are generally set by comparing simulated loads to empirical load estimates calculated with ESTIMATOR. Currently there are no regional factors for TOC. In this project, regional factors will be calculated for TOC using ESTIMATOR and incorporated into the TOC river calibration.

Task 5.e – Revise Watershed Model code
The river simulation in the Watershed Model is calibrated using an automated calibration routine, which examines the differences between observed and simulated concentrations and adjusts parameters. This code will be updated to include the calibration of TOC.

Task 5.f – Recalibrate the TOC simulation in the Watershed Model
Calibration runs will be conducted. It may take a few calibration runs to adjust the sensitivity of parameter changes to differences between observed and simulated concentrations.

Anticipated Results: A version of the Watershed Model that can estimate TOC loads for the non-tidal Potomac basin. A documented literature survey of estimates of land use TOC export coefficients.

Task 6.a: Develop water quality and treatment cost relationships

Purpose: Using past water quality and treatment cost information, relationships will be developed for Fairfax Water, Washington Aqueduct, and WSSC.

Methodology:
Task 6.a – As a first step, existing studies linking water quality conditions and utility treatment costs will be reviewed for their applicability to the Potomac basin. At a minimum these will include Pyke et al. 2003; Freeman et al. 2008; Forster et al. 1987; Holmes 1988; Dearmont et al. 1998; Forster and Murray 2001. Following the review of the methods others have used and the data available from the utilities, a method for developing these relationships will be proposed. At this point, project advisor Chi Ho Sham will be asked to review the proposed methodology and provide input. Input from the Project Advisory Committee will also be incorporated. Once the

method is agreed upon, relationships between the water quality parameters and water treatment costs will be developed.

Phase II

Task 1: Identify current land cover conditions

Purpose: This task will use existing land cover and land use datasets to quantify, map, and assess current cover in the non-tidal Potomac basin.

Methodology: These steps will be followed to complete Task 1:

- Collect latest land use/cover and ownership data for the basin.
- Using a geographic information system (GIS):
  - Characterize land use in the basin as agriculture, forest, or urban.
  - Assess the identified forest lands:
    - Determine which areas are riparian buffers, based on distance from streams and rivers, and which are upland areas.
    - Evaluate the extent of stream and riparian water quality buffers that are protected through local or state entities through resource protection ordinances. These areas will include both forested and non-forested areas.
    - Characterize the extent of protected forest land by local, state, and federal ownership, as well as private lands under stewardship plans, conservation easements, or other development restricted areas.
    - Identify the portion of the protected forest lands that are actively managed, if these data are available.
    - Summarize spatial extent of forest cover and riparian buffers by owner and management type.
- Describe current forest protection activities of the Chesapeake Bay Program, each basin state, and counties which border the freshwater mainstem Potomac River and major tributaries (South Branch, Antietam, Conococheague, Shenandoah, Monocacy).
- Summarize findings in tables, maps, and a written report.

Anticipated Results: This task will provide a detailed understanding of forested land in the non-tidal Potomac basin. Specifically, the existing forest will be characterized by ownership, level of protection, and management type. Summary tables and maps produced will be used in later tasks, including in the development of communication materials.

Task 2: Identify opportunities for forest protection

Purpose: The majority of the Potomac watershed is forested and a portion of these lands are already protected. This task will characterize the remaining unprotected forested lands as opportunities for forest protection within the watershed. Specific costs to actually protect these lands will not be assessed as part of this study; however, general cost estimates will be developed. By providing a more detailed look at the results of Task 1, a spatially explicit estimate of forest protection opportunities will be developed.

Methodology: The first step is to select criteria that can be used to identify and prioritize opportunity lands. These could include protection status, ownership, connectivity, health, and distance to stream, among others. Project advisor Chi Ho Sham will be asked to review and provide input on the selected criteria. Once selected, the criteria will be input into the GIS to identify the areas that meet the criteria. A simple cost estimation will be developed by multiplying the number of acres of opportunity lands by a state-scale cost per acre estimate as available from the available literature (e.g. Davis and Heathcote 2007 for residential, NASS 2014 for agricultural, Lynch and Palm 2007 for Maryland-specific).

Anticipated Results: Tables, maps, and a written summary of opportunity areas and the criteria used to identify them, and a rough estimate of cost.

Task 3: Develop future land cover scenarios

Purpose: Develop future land cover scenarios that can be used in Tasks 4 and 5 to model potential water quality changes. Three land cover scenarios for the year 2030 will be developed based on current and future land cover estimates and rates of forest protection in the opportunity areas identified in Task 2. Two 2030 scenarios will be developed to assess the water quality changes that could result from solely protecting forested buffers.

Methodology: This task will proceed in two phases. First, the 2030 land use projection will be developed utilizing readily available data at the Watershed Model's land-river segment scale (Task 3.a). Secondly, the land use scenarios will be developed from the baseline 2030 projection (Task 3.b).

The input data for the baseline 2030 projection will come from the Chesapeake Bay Program's projections of future land uses from the Chesapeake Bay Land Change Model (CBLCM). These projections are then used to develop inputs for the Watershed Model to estimate changes in nutrients and sediments loads.

Task 3.a – Develop 2030 land use projection at the land-river segment scale
Using the CBLCM, the Chesapeake Bay Program projects changes in pervious and impervious urban lands at the land-river segment scale for the Bay watershed. Data are available in five-year intervals from 2010 through 2030. In order to utilize the Watershed Model in Tasks 4 and 5, respectively, projections need to be available for all Watershed Model land use categories. To develop this data set from the projected urban land cover, the following steps will be conducted:

- Overlay the Watershed Model Phase 5.3.2 raster grid 2010 land use with the 2010 U.S. Census urbanized areas polygons.
- Delineate a polygon around the urban areas that is 0.5 to 1 mile wide.
- Determine the forest:agriculture ratio for the land uses in the delineated polygon.
- Multiply the impervious and pervious urban land use categories by the CBP-projected percent changes to develop acreages of those land use categories, for the future year of interest (2030).

- Adjust forest and agriculture land use categories to maintain total watershed area and calculated forest:agriculture ratio.

Task 3.b – Develop land use scenarios
Five scenarios will be developed using these methods:

Scenario 1. Protect zero percent of the protection of opportunities (baseline scenario)
The baseline scenario assumes that forest conversion will proceed as expected, with zero percent additional protection. Therefore, this scenario will use the calculated 2030 land use projection (Task 3.a) as-is.

Scenario 2. Protect 50 percent of the protection opportunities
Determine the difference in forest land use between calculated 2030 and 2010 land uses. Conserve half of the lost forests by adding them back to the 2030 projection. A methodology will be developed for assigning the remaining land area as either agriculture and urban in order to maintain the total area (e.g., will all of the conserved forests come from agricultural land, or half from agriculture and half from urban, etc.). Regional land use experts will be consulted in the methodology development.

Scenario 3. Protect 100 percent of the protection opportunities
Calculate difference in forest land use between 2030 and 2010 land uses. Conserve all of the lost forests by adding them back to the 2030 projection. Use assumptions developed in Scenario 2 to determine how to assign the other land uses to maintain the total area.

Scenario 4. Protect forest buffers at the minimum state and county requirements
Compile information on forest buffer requirements in the non-tidal Potomac basin. Use this information to calculate total area of forested buffers required for each county or Watershed Model land-river segment. Adjust CBP 2030 projected land use to meet these acreages using assumption developed in Scenario 2.

Scenario 5. Protect forest buffers out to 100 feet of the mainstem Potomac River and major tributaries
The major tributaries are defined as the South Branch, Antietam, Conococheague, Monocacy, and Shenandoah. Calculate total area of forested buffer by county or Watershed Model land-river segment. Adjust CBP 2030 projected land use to meet these acreages using assumption developed in Scenario 2.

Anticipated results: The results of Task 3.a will be tabular land use projections for 2030 for all Watershed Model land use categories. The results of Task 3.b will be tabular land use acreages by Watershed Model land use categories by county or Watershed Model land-river segment for each scenario (1-5). Maps of each scenario will be produced for Task 8.

Task 4: Model sediments and nutrients using the Chesapeake Bay Watershed Model

Purpose: Sediment will be used as an indicator of raw water quality. Nitrogen and phosphorus will also be evaluated as indicators of water quality changes. An estimate of peak sediment and nutrient concentrations will be made to provide an order of magnitude comparison between the land cover scenarios.

This task will use the CBP Watershed Model and the land cover scenarios developed in Task 3 to assess the impact on nutrient and sediment concentrations from various levels of forest protection.

Methods: Run the Watershed Model holding everything else constant while changing the land use to the scenarios created in Task 3.b. An effort will be made to separately quantify the water quality changes that can be attributed to upland forest protection versus those from forested riparian buffers.

Anticipated Results:
Tabular output of nitrogen, phosphorus, and sediment loads at the land-river segment scale for each of the land use scenarios described in Task 3. A quantitative comparison of the changes in water quality conditions between the scenarios.

Task 5 (continued from Phase I): Model TOC using adapted version of the Chesapeake Bay Watershed Model

Task 5.g – Develop input data for scenarios—run and analyze scenarios
Using the TOC-calibrated version of the Watershed Model completed in Phase I, the model will be run holding everything else constant while changing the land use to the scenarios created in Task 3.b. An effort will be made to separately quantify the water quality changes that can be attributed to upland forest protection versus those from forested riparian buffers.

Anticipated Results: An analysis of the contribution of land uses and point sources by geographic region to the TOC load delivered to the intakes of the metropolitan Washington water utilities. An assessment of TOC modeling results for each of the five scenarios developed in Task 3 for the mainstem Potomac River in 2030, including an evaluation of potential ranges for extreme events and annual average concentrations.

Task 6 (continued from Phase I): Estimate treatment cost changes due to changing forest conditions

Purpose: Using the water quality and treatment cost relationships developed in Task 6.a as part of Phase I and the results from Tasks 4 and 5, ICPRB and the utilities will estimate water treatment cost impacts from changes in sediment and TOC (Task 6.b). Task 6.c will consider additional cost considerations for Washington Aqueduct, and look into the ability to quantify the impact of increasing chloride concentrations.

Task 6.b – Results from Tasks 4, 5, and 6.a will be used to estimate treatment cost changes from changing forest conditions.

Task 6.c – Additional Considerations

One participating utility, Washington Aqueduct, will develop an estimate of operational costs and capital cost considerations. This analysis will use data gathered or developed for previous tasks. The modeling output from Task 5 will include TP and flow information. Flow information can be used to assess the "flashiness" of the river (e.g., higher magnitude, lower duration hydrograph) and the likelihood of extreme flow events can be considered. Similarly, TP concentrations and low flow predictions, that may promote algae growth, and can be considered as an indicator of bloom potential. Additionally, the urban area information from Task 3.a can be used to assess the potential for extreme pH and alkalinity events as they are more likely in urbanized watersheds with a lower proportion of baseflow.

Examples of water quality impacts and associated operational and capital cost considerations are shown in

Table 1. Operational cost projections will be based on existing unit processes. Potential capital investments and water quality impacts that drive them will be estimated quantitatively, although the probability of capital projects' necessity will only be determined qualitatively.

Table 1. Water quality impacts and associated capital cost considerations.

Water Quality Impact	Operational Expense	Long-Term Challenge	Capital Cost Considerations
Solids loading	- Coagulant dose - Solids handling	- Storms overwhelm existing solids handling facilities	- Upgrade solids handling infrastructure
Algal blooms: toxins and taste and odor compounds	- Treatment chemicals (permanganate, carbon, ozone, copper) - Filter performance (backwash, filter aid)	- Existing treatment inadequate to remove toxins, taste and odor - Filter performance unacceptable during algal blooms	- Install treatment for toxins, taste and odor compounds - Install algal removal process (e.g., dissolved air flotation)
Extreme flow events	- Switch production to more costly sources	- High flows damage intake structures - Inadequate flow during drought	- Rehab intake structures - Build more storage, develop additional sources
Increased road salt use	- Not applicable	- Greater corrosion in distribution system	- More frequent replacement of distribution system components

- Extreme pH and alkalinity events - High pH events (low flow, algal blooms) - Low alkalinity events (high flow)	- Acid addition (if available) - Switch coagulants (if available)	- Effectiveness of coagulant addition - Lead and Copper Rule compliance	- Build acid addition facilities - Add pre alkalinity adjustment

Project advisor Thomas Grizzard will be consulted throughout this task.

Cost-benefit analyses for relating avoidance of operational or capital expenses to the protection of forestry resources will not be performed. A rudimentary estimate of land protection costs will be completed to provide a general sense of potential costs.

Additionally, the ability to estimate treatment costs due to increasing chloride levels will be explored and executed, if possible and if time and funds allow. This work would use estimates of future urban areas generated in Task 3.a and most likely the relationships developed in Corsi et al. (2015) between annual chloride concentrations and the percent of urban land cover in a watershed. Corsi's work included a site near the intakes considered in this proposal. The author is currently being consulted to determine if and how we can use his work for this project. Estimates of future chloride levels can potentially be linked to utility treatment costs based on pH adjustments required to address increased chloride levels.

<u>Anticipated results:</u> The results of this task include summary tables of operational costs associated with water quality changes for each scenario, a summary of capital cost considerations for Washington Aqueduct, and an estimate of potential land protection costs.

Task 7: Review forest protection considerations

<u>Purpose:</u> Assuming the results from Tasks 4, 5, and 6 indicate an inverse relationship between forest cover and treatment costs, this task will identify criteria for evaluating and prioritizing protection opportunities in the Potomac watershed. It will also provide considerations for additional research, information, and partners involved with forest protection.

<u>Methodology:</u> The task will be completed using the following steps:

- Determine ways of prioritizing opportunity areas
    - Identify existing forest protection/prioritization tools used in the region. These could include:
        - U.S. Forest Service Forests to Faucets;
        - CBP, state, and county protection strategies;
        - tools used by non-profit organizations, such as The Nature Conservancy and the Potomac Conservancy; and/or

    - tools used by other utilities and source water planners.
  - Review the purpose, methods, and criteria for each tool and determine if they can be used by water utilities to make prioritization decisions.
  - If no existing tool meets the specifications desired by the utilities, identify which criteria are not addressed.
  - Determine if the existing models can be adapted to meet utility needs. Or, alternatively, if results from these tools can be further screened with utility-identified criteria.
- Summarize risk mitigation benefits of forest protection. Climate change, wildfire, pests, rapid population growth, changes to land use regulations, and the potential for new drinking water regulations, among others, will be considered. A key resource will be Gartner et al. 2013.
- Given all the information generated in the previous tasks, ICPRB will work with each utility to decide if additional information or research is needed as part of a future effort. This could include an assessment of the costs of different protection scenarios.
- Review findings of above sub-tasks with Chi Ho Sham to ensure a tool or key factor has not been neglected.

Anticipated Results: An assessment of existing forest prioritization tools will be completed and utility-specific criteria will be identified. Risk mitigation factors will be explored and key ones for further research will be identified.

Task 8: Produce final report and outreach materials

Purpose: Summarize the project's methods and results, draw conclusions, and, with input from the participating utilities, make recommendations for next steps.

Methodology: A report will be prepared, consisting of graphics and maps that can be used for conveying and disseminating information to multiple entities. The report will include an executive summary to provide a high-level overview of the key modeling results and study conclusions. The results of this study will also be summarized in a prepared presentation that will be made available for use in briefing executive staff of state and local agencies, water utilities, and Boards of Directors, as well as for elected officials. One or two PIs will present the project at a professional conference. If appropriate, web content will be generated for the Partnership's website and those of members. Work identified in the Communications Plan will be carried out as part of this task.

Anticipated Results: A written report, presentation, and web content.