Volumetric Water Benefit Accounting 2.0– Interim Installment 4
Guidance on Updated VWB Calculation Methods

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1. Introduction

Volumetric Water Benefit Accounting (VWBA) meets a critical need in corporate water stewardship by providing a common framework for quantifying and communicating the volumetric water benefits resulting from water stewardship activities.

Building on corporate water stewardship practitioner experience over the past years, this installment introduces

- foundational principles and processes for how to quantify VWBs using the methods described, and to allow practitioners, when required, to go beyond the methods listed herein and identify and apply existing or new methods that may be suitable to estimate VWBs;
- guidance to assist with identifying appropriate VWB indicators and methods based on the objective of the activities; and
- new and revised VWB indicators and methods to estimate the volumetric water benefits of a wider range of activities than what was previously provided.

The new and revised indicators and methods are consistent with the VWBA principles described below and updated from the current VWBA guidance (VWBA 1.0), where applicable. This installment includes eight appendices, which encompass the addition of new methods and indicators, modification to existing methods, additional guidance related to method applications where warranted, and a table linking activities and objectives to indicators and methods. Five of these appendices were included in the original VWBA but were updated to incorporate changes. Three new appendices were developed to include new methods and indicators.

This installment document includes the following sections:

- Principles for calculating VWBs;
- Guidance for indicator and method selection;
- Summary of revisions to the quantification methods; and
- Updated and new appendices with methods for VWB quantification.

2. Principles for Calculating VWBs

Seven principles have been developed to assist practitioners when calculating VWBs using the methods and indicators described herein or evaluating the suitability of other appropriate methods and approaches to estimate VWBs. These principles were developed by building on the existing guidelines in VWBA 1.0 and incorporating corporate water stewardship practitioner experience in estimating and tracking VWBs.

Principle 1: Calculate the volumetric output from project activities.

VWB is a quantitative estimate of the volume of water resulting from water stewardship activities, relative to a unit of time, that modify the hydrology in a beneficial way and/or help reduce shared water challenges. Therefore, VWB is a quantitative measure of **volumetric output**. The term *output* refers to the change in a water-related indicator that results from a particular activity and that helps achieve one or more project objectives. What qualifies as being beneficial depends on the context and relates to the shared water challenges that are being addressed. For example, if a constructed wetland (i.e., project activity) is designed to capture storm water and reduce flooding (i.e., objective) the relevant VWB indicator is *volume captured* (i.e., volumetric output), which can lead to desired outcomes (e.g., reduced flooding and erosion and improved water quality) and impacts (e.g., improved aquatic habitat).

Principle 2: Align indicators and methods with the activity objectives.

Understanding the primary objective of a water stewardship activity is necessary to define the indicator, which, in turn, is required to define the appropriate method for calculating VWBs. For this reason, it is important to understand the objective of each activity to inform the selection of the appropriate VWB indicator and method for VWB quantification. An activity may have multi-benefit objectives or may not have been implemented with volumetric output as the main objective. In these situations, the activity should be aligned with one primary objective for the purpose of VWB quantification (see Section 3, "Guidance for Indicator and Method Selection") by assessing the shared water challenges addressed by the activity.

Principle 3: Apply practical and scientifically defensible methods.

VWBA provides recommended methods that are informed by scientific principles and are pragmatic and relatively simple to apply. The list of methods included in VWBA is not exhaustive, and the VWB may be quantified with other approaches that are practical and scientifically defensible (i.e., using existing models, activity-specific research, empirical measurements, or observations).

Principle 4: Use conservative inputs and assumptions.

When calculating VWBs, conservative estimates of the inputs and assumptions should be used, based on available data or through discussions with technical staff familiar with the project. Any assumptions should be clearly documented. Taking a conservative approach in the calculation avoids potential overestimation of the VWBs. Assumptions, data sources, and/or calculations used to estimate VWBs should be updated with direct measurements whenever possible and practical.

Principle 5: Use appropriate temporal scale.

The VWB resulting from an activity is typically reported as a long-term annual average value in units of volume per year (e.g., liters per year or similar units). When relevant, the annual average VWB should be estimated based on multi-year data to account for variations in precipitation and other factors. If VWBs are measured directly, the annual volumes can be based on direct measurements or averaged based on multi-year measurements. For some activities, the VWB reflects only the portion of the year when benefits are generated (e.g., seasonally). Example activities include habitat restoration for fish spawning, seasonal crop fallowing, or restoring flow to a dewatered reach during the dry season. In these cases, the annual average VWB should be based on the seasonal VWB that matches the temporal scale of the challenge being addressed by the activity (i.e., time of year when the benefit is relevant).

Principle 6: Compare with- and without-project conditions.

VWBs reflect a measure of change or improvement from the without-project condition that results due to the activity. Therefore, the VWB calculations should compare the two conditions: the without-project condition and the with-project condition. The VWB is quantified based on the difference in volume between the two conditions. The VWB calculations should be accompanied by a clear description and evidence (e.g., photographs, field measurements) of the with- and without-project conditions.

Principle 7: Avoid double counting of volumes.

A unit of volume resulting from a VWB can only be counted once within the reporting period. The same volume of water may provide multiple benefits, but the VWB should not be counted more than once to avoid double counting. For example, if the VWB for a specific activity is quantified based on reduced runoff, the same volume cannot be quantified again for increased recharge. However, if a project consists of multiple activities that generate distinct VWB outputs, then each activity should be evaluated separately with appropriate indicator and method; and the volumes can be added to report total VWBs for the project. For example, a project may implement land conservation and reforestation activities in distinct land segments within the same site. In this example, the resulting VWBs from each activity can be added together to report the total VWB for the project.

3. Guidance for Indicator and Method Selection

The following three steps provide an updated approach to help practitioners better understand and identify an appropriate indicator and method to estimate VWBs. These steps have been developed recognizing that there is a wide range of potential activities that companies may be interested in supporting and many ways that each of the methods can be applied. These range from simple estimates (typically used during early-stage project evaluation and cost-benefit analysis) to more detailed, robust, and complex estimates or measurements (typically used to report progress, communicate publicly, and make claims associated with an organization's water stewardship activities associated with investing in water replenishment, regeneration, or restoration and watershed health more broadly).

Recommended steps for identifying VWB indicators and methods

The following steps aim to assist practitioners in the selection of VWB indicators and methods to address activity-specific objectives. Review the table provided below to support the selection of indicators and methods. If needed, engage a subject-matter expert to support the selection of an appropriate VWB indicator and method.

- **Step 1: Identify primary volumetric objective.** Following identification of a proposed water stewardship activity, confirm how the activity contributes to addressing a shared water challenge. In other words, understand the objective of the activity. Despite many watershed activities not having a volumetric output as the primary objective, and in some cases having more than one objective, it is necessary to select a single volumetric objective to identify an appropriate VWB indicator. The following list includes some common volumetric objectives of water stewardship activities:
    - Reduced water demand
    - Increased water availability
    - Maintained water balance
    - Improved or maintained water-related habitat
    - Improved resilience through flood or drought mitigation
    - Improved resilience through increased supply
    - Improved access to water, sanitation, and hygiene (WASH)
    - Improved water quality through nonpoint-source pollution reduction
    - Protected water quality through nonpoint-source pollution prevention
    - Improved water quality through point-source pollution reduction

  Note that while the objective informs the selection of the indicator, and the indicator measures the outputs of the activity, the scale of the activity may not be sufficient to result in a measurable change in the ultimate goal of addressing a shared water challenge. For example, a single activity can result in reduced water withdrawals at a given location (i.e., the output) but not at a scale that would lead to measurable changes in regional water stress.

- **Step 2: Select VWB indicator.** Based on the volumetric objective and how the activity helps reduce shared water challenges through modifying the hydrology in a beneficial way (e.g., by increasing groundwater recharge, reducing water demand, or improving water supplies) or through other means (e.g., through the provision of safe drinking water or improving water quality), select an appropriate VWB indicator.

- **Step 3: Select VWB method.** Based on the objective and VWB indicator, select an appropriate VWB method. Use the table provided below to support the selection of an appropriate method.

***** BEGIN BOX*****

Volumetric water benefit accounting vs. water quality benefit accounting

Similar to VWBA, a Water Quality Benefit Accounting (WQBA) framework is being developed to support calculation and reporting of water quality benefits of water stewardship activities. The indicators for water stewardship activities differ depending on whether a VWB (a volume of water per time) or Water Quality Benefit (a pollutant mass per time) is of interest. To date, most companies investing in water stewardship are doing so to meet volumetric water goals and targets. For this reason, there is strong interest and demand from corporations to support activities that improve water quality, when relevant in the local catchment context, and report the outcomes as VWBs. VWBA addresses the need to calculate the VWB from water quality improvement projects and keep those types of projects relevant and available for companies with volumetric water targets and goals. As a result, the methods to calculate VWBs from projects that aim to improve water quality will not be phased out. Both VWBA and WQBA can complement each other and be applied to evaluate the water quantity and water quality benefits, respectively.

*****END BOX*****

Volumetric objectives and the recommended VWB indicator and calculation methods for the most commonly implemented water stewardship activities

What direct benefit activity are you interested in pursuing?		Volumetric objective (i.e., how is the activity addressing a local shared water challenge by modifying the hydrology in a beneficial way or through other means?)	VWB indicator (i.e., what will you measure/estimate to determine the volumetric outputs?)	VWB method (i.e., how will you determine the volumetric outputs?)	Appendix: calculation methodology
Agricultural practices	Agricultural best management practices (BMPs) including cover crops, mulching, reduced or no-till, laser leveling, terraced/contour planting, agroforestry, regenerative agriculture, grazing management, and others	Improved water quality through nonpoint-source pollution reduction	Reduced runoff	Curve number method	A-1
			Volume improved	Nonpoint-source pollutant-reduction method	A-13
	Agricultural nutrient management, pesticide management, herbicide management, and others	Improved water quality through nonpoint-source pollution reduction	Volume improved	Nonpoint-source pollutant-reduction method	A-13
Demand management	Legal water transactions involving surface and groundwater, operational efficiency measures, water reuse and recycling, changes in agricultural practices that reduce demand, changes in water sources, low flow fixtures, or other activities that reduce demand	Reduced water demand	Reduced withdrawal	Withdrawal and consumption methods	A-2
		Reduced water demand	Reduced consumption	Withdrawal and consumption methods	A-2
	Leak detection and repair	Reduced water demand	Reduced withdrawal	Withdrawal and consumption methods	A-2
	Removal of invasive species, forest thinning, crop conversion, fallowing, and others	Reduced water demand	Reduced consumption	Withdrawal and consumption methods	A-2
Green or gray infrastructure	Rain gardens, bioswales, storm water detention or retention ponds, pond dredging/desilting, drainage water management, blind inlets, and other interventions designed to capture runoff	Improved water quality through nonpoint-source pollution reduction	Volume captured	Volume captured method	A-5
		Improved resilience through flood/drought mitigation	Volume captured	Volume captured method	A-5
	Green infrastructure activities including constructed wetland treatment systems, bioretention basins, and others	Improved water quality through nonpoint-source pollution reduction	Volume treated	Volume treated method	A-6
	Gray infrastructure including wastewater treatment plants, and others	Improved water quality through point- source pollution reduction	Volume treated	Volume treated method	A-6

What direct benefit activity are you interested in pursuing?		Volumetric objective (i.e., how is the activity addressing a local shared water challenge by modifying the hydrology in a beneficial way or through other means?)	VWB indicator (i.e., what will you measure/estimate to determine the volumetric outputs?)	VWB method (i.e., how will you determine the volumetric outputs?)	Appendix: calculation methodology
	Well construction and rehabilitation, household water connections, piped water systems, rainwater harvesting, water reuse, point of use treatment, drinking water treatment facilities, and other activities that develop new or alternative sources of water supply for irrigation or domestic use (including hand washing, bathing, and cleaning).	Improved resilience through increased supply	Volume provided	Volume provided method	A-3
	In-stream barrier removal, dam reoperation, floodplain reconnection, levee or berm removal, side channel reconnection, riparian habitat improvements, process-based restoration, wet meadow restoration, beaver dam analogs, water level management for habitat, wetland or peat bog protection or restoration, wetland creation, and others	Improved/maintained water-related habitat	Increased inundation	Inundation method	A-11
		Improved water-related habitat	Maintained inundation	Inundation method	A-11
		Improved water-related habitat	Volume provided	In-stream habitat volume method	A-12
		Improved water-related habitat	Increased recharge	Recharge method	A-4
		Improved water-related habitat	Maintained recharge	Recharge method	A-4
	Sustainable drainage systems, check dams, infiltration basins, infiltration wells, infiltration trenches, infiltration shafts, and other activities that facilitate increased recharge	Increased water availability	Increased recharge	Recharge method	A-4
	Restoration and creation activities for wetlands or other aquatic habitats that store water, inclusive of invasive species removal, dredging, etc.	Improved/maintained water-related habitat	Volume captured	Volume captured method	A-5
	Conservation easements or other activities that protect wetlands or other aquatic habitats that store water	Improved/maintained water-related habitat	Volume maintained	Volume captured method	A-5
	Washing stations, pollutant storage equipment, street sweeping, impervious area disconnection, and urban soil amendments, among others	Improved water quality through nonpoint-source pollution reduction	Volume improved	Nonpoint-source pollutant-reduction method	A-13
Land conservation and restoration	Forest conservation, meadow conservation, grassland conservation, and other activities that preserve land vegetation cover	Protected water quality through nonpoint source pollution prevention	Avoided runoff	Curve number method	A-1
		Maintained water balance	Maintained recharge	Recharge method	A-4

What direct benefit activity are you interested in pursuing?		Volumetric objective (i.e., how is the activity addressing a local shared water challenge by modifying the hydrology in a beneficial way or through other means?)	VWB indicator (i.e., what will you measure/estimate to determine the volumetric outputs?)	VWB method (i.e., how will you determine the volumetric outputs?)	Appendix: calculation methodology
		Maintained water balance	Maintained seasonal water storage	Recharge method	A-4
	Reforestation, grassland restoration, and other activities that restore vegetation cover	Improved water quality through nonpoint-source pollution reduction	Reduced runoff	Curve number method	A-1
		Increased water availability	Increased recharge	Recharge method	A-4
		Increased water availability	Increased seasonal water storage	Recharge method	A-4
WASH	Activities that increase access to potable household and community water supply New water supply for domestic use	Improved WASH	Volume provided	Volume provided method	A-3
	Activities that increase access to sanitation facilities where excreta are safely disposed of in situ or removed and treated offsite	Improved WASH	Volume treated	Volume treated method	A-6

4. Summary of Revisions to the Calculation Methods

The table below summarizes the revised and new appendices covered in this installment. Revised appendices refer to the appendices that are currently in VWBA but modified herein to reflect changes. Two of the existing appendices, Appendix A-7 and A-8 are now replaced by Appendices A-4 and A-12, respectively. Any remaining existing appendices for which no changes are required are not included in this installment. New appendices refer to the appendices that are not in the current VWBA that were developed as part of Installment 4 and intended to be incorporated into VWBA 2.0. The indicators addressed in each appendix are shown in the table below. The new indicators are denoted with underlined, italicized text. The "Summary of changes" column provides a brief description of the changes implemented in each appendix. For the purpose of this installment, the numbering of the appendices follows the existing order of the current VWBA (i.e., no changes to the numbering of the existing appendices and the numbering of the new appendices are continued from the existing order).

Appendix title	**Existing or new VWBA appendix?**	**Indicators covered–existing and *<u>new</u>***	**Summary of changes**	**Installment 4 Page number**
Appendix A-2. Withdrawal and Consumption Methods	Existing Appendix	Reduced withdrawal Reduced consumption	• Added application of the method for activities that reduce evaporative demand. • Added application of the method for activities that reduce non-revenue water (NRW).	11
Appendix A-3. Volume Provided Method	Existing appendix	Volume provided	• Expanded method to include additional activities.	16
Appendix A-4. Recharge Method	Existing appendix	Increased recharge Maintained recharge *<u>Increased seasonal water storage</u>* *<u>Maintained seasonal water storage</u>*	• Renamed method (formerly capture and infiltration method). Incorporated recharge method (formerly A-7), added application using the storage method for groundwater, and added application to estimate the change in groundwater recharge and seasonal soil water availability from land cover restoration activities. • Former Appendix A-7 is removed.	20
Appendix A-5. Volume Captured Method	Existing appendix	Volume captured *<u>Volume Maintained</u>*	• Expanded method to include additional activities and added application for storage volume method for surface water	27

Appendix title	Existing or new VWBA appendix?	Indicators covered–existing and ***new***	Summary of changes	Installment 4 Page number
Appendix A-6. Volume Treated Method	Existing appendix	Volume treated	• Existing method modified to incorporate fraction improved. • Added application for sanitation facilities	30
Appendix A-11. Inundation Method	New Appendix	Increased inundation Maintained inundation	• New appendix for activities where inundation is the primary hydrologic function provided or protected. The inundation method was previously covered in A-7. Former Appendix A-7 is removed.	37
Appendix A-12. In-stream Habitat Volume Method	New Appendix	Volume provided	• New method for activities with the primary objective of creating, restoring, or protecting water for aquatic habitat. • This appendix now replaces the former Appendix A-8, which has been removed. • The hydrograph method previously described in Appendix A-8 is excluded from VWBA.	39
Appendix A-13. NPS Volume Treated Method	New Appendix	Volume improved	• New method for activities that reduce nonpoint-source pollutant loading to groundwater or surface water	41

5. Updated and New Appendices

Appendix A-2. Withdrawal and consumption methods

Objectives and indicators

The withdrawal and consumption methods enable the estimation of VWBs of activities that reduce water withdrawal, non-revenue water (NRW), or water consumption.

Objectives	Output Indicator
Reduced water demand	Reduced withdrawal Reduced consumption

Example activities include legal water transactions involving surface and groundwater, operational efficiency measures, leak detection and repair, consumer use efficiency measures, such as low-flow fixtures, agricultural water demand reduction measures involving surface and groundwater resources, fallowing, forest thinning, and removal of "thirsty" invasive species.

Methodology description

The primary considerations in the selection of the appropriate indicator (reduced withdrawal or reduced consumption) and the associated method are the volumetric objectives and activity type as discussed below.

<u>Withdrawal method</u>

Several types of activities can reduce the volume of water withdrawn from a source (i.e., surface water or groundwater), including legal transactions (e.g., water rights leases or purchases), operational efficiency measures, leak repair, irrigation canal piping, efficiency measures, and water reuse. The reduced withdrawal volume is calculated as the difference in withdrawal volume for the with-project condition compared to the without-project condition. The without-project" condition describes the current withdrawal. The with-project condition represents withdrawal after the implementation of efficiency measures, demand reduction, leak repair, or legal transactions. If metered or monitored data are not available, the withdrawal volume can be estimated.

$$\mathbf{VWB = Withdrawal_{\text{without-project}} - Withdrawal_{\text{with-project}}}$$

<u>Consumption method</u>

For activities that reduce consumptive demand, including agricultural activities such as crop conversion to low water use crops, irrigation efficiency improvement measures that convert from less efficient irrigation methods (such as flood irrigation) to more efficient irrigation methods (such as drip irrigation), or land cover restoration (such as the removal of invasive species), the reduced consumption is calculated as the difference in consumption for the with-project condition compared to the without-project condition.

$$\mathbf{VWB = Consumption_{\text{without-project}} - Consumption_{\text{with-project}}}$$

Land cover restoration and the associated vegetation changes can affect water consumption by altering evapotranspiration (ET). Vegetation density, type, and climate govern the magnitude and timing of ET. Certain land-cover restoration activities, such as the removal of thirsty nonnative or invasive vegetation species and forest fire management through thinning treatment (i.e., reducing canopy density or selective removal of trees), can reduce consumptive use (by reducing evaporation, transpiration, or both), thereby increasing local water availability. Crop conversion can also reduce consumption when crops with a higher ET rate are replaced with crops having a lower ET rate. For land- cover restoration activities that reduce ET demand, the VWB can be estimated as the reduction in consumption based on the difference in ET between the without-project and with-project conditions.

Example applications

- **Legal transactions to keep water in-stream**

For activities that involve legal transactions, the VWB can be determined based on the water rights leased or purchased and the duration (e.g., 10 cfs of water rights are leased for in-stream flow between December and February). The VWB is based on the volume of water served by the water right and available in-stream. The diversion flow rate can vary over time. To account for this variability, a conservative estimate of diversion flows (i.e., diversion flows representative of a dry period) should be used. For example, when the objective is to reduce withdrawal to restore streamflow in a dewatered reach or enhance streamflow for a targeted fish population, the period of diversion or flow rate may be narrowed to focus only on the period of ecological significance, such as the spawning period and/or the flow rate providing that benefit. Application of this approach provides a more conservative VWB estimate.

$$\text{VWB} = (\text{Diversion flow rate reallocated for in-stream flow}) \times (\text{Duration of diversion})$$

Required inputs

Variable	Input
Diversion flow rate	Average monthly diversion flow rate (or other time scales may be used, if available)
Duration of diversion	Number of days during which diversion occurs

- **Agricultural irrigation efficiency measures**

Activities that involve agricultural irrigation efficiency measures are less straightforward and may encompass a wide range of projects with varying levels of complexity. Either the reduced consumption or reduced withdrawal method is applicable based on the local context. The following simple cases offer examples:

> Case 1: Irrigated cropland is in an area with competing demands for existing water resources where the water is tightly allocated. Improved irrigation efficiency measures are implemented with the objective of reducing irrigation water applied. In this context, the reduced withdrawal approach is applicable.

> Case 2: Irrigated cropland relies on a water source that is already scarce (e.g., depleted groundwater), and the existing irrigation method results in excessive non-beneficial consumption (i.e., water evaporated and not used by the crop). Improved irrigation efficiency measures are implemented to promote sustainable use of the scarce water resource through reduction in nonbeneficial consumptive use. In this context, the reduced consumption approach is applicable.

The above examples illustrate that improved irrigation efficiency measures are adopted in both cases, but either the reduced consumption or reduced withdrawal method is applicable, depending on the project objective and local context. If the context is less clear, the reduced consumption method will provide a conservative estimate of the VWB.

For activities that involve improving irrigation efficiency at a farm, the withdrawal is based on the volume of irrigation water applied. The source of irrigation water can be either surface or groundwater.

$$\textbf{Withdrawal volume} = \textbf{Irrigation water applied}$$

Some irrigation efficiency improvements (e.g., lining of distribution canal) may reduce withdrawals at the point of irrigation diversion. For these types of activities, the VWB can be based on the withdrawal volumes at the point of diversion.

The withdrawal volume can be based on metered or monitored data, or estimated if direct monitoring is not available. For surface water withdrawals, the water applied can be estimated based on the diversion flow rate and the duration of diversions. For groundwater withdrawals, the water applied can be estimated based on the pumping rate and the duration of pumping.

The reduced withdrawal is calculated as the difference in irrigation water applied between the without-project and with-project conditions. The VWB is calculated as the decrease in withdrawal volume.

The consumption method adjusts the withdrawal volume to subtract return flows. Consumption is estimated based on withdrawal volume and adjusted to account for return flow fraction. Return flow fraction, expressed as a percentage, is the fraction of the withdrawal volume that is not consumed and is returned to the source. The reduced consumption volume is calculated as the difference in consumption volume between the with-project and without-project conditions. The VWB is calculated as the decrease in consumption volume.

$$\textbf{Consumed volume} = \textbf{(Withdrawal volume)} \times \textbf{(1 – Return flow fraction)}$$

As noted earlier, return flows are the portion of water withdrawn that is returned to the source through percolation or surface runoff. The return flows may enter the same water body either at the location where the water is withdrawn or at another location downstream (or upstream); in this latter case (another location), the return flow fraction must be supported with available information. Return flows vary with crop and irrigation type and can be measured or estimated using other appropriate resources (i.e., literature, local studies, consultation with subject matter experts).

Required inputs

Equation	Variable	Input
Withdrawal volume	Diversion flow rate or pumping rate	Average monthly diversion flow rate or pumping rate (or other relevant time scales may be used, if available)
	Duration of diversion	Number of days during which diversion occurs
Consumed volume	Withdrawal volume	Calculated based on diversion flow rate or pumping rate and the duration of diversion volume
	Return flow fraction	Return flow fraction based on irrigation and crop type

- **Forest management**

Forest landscapes are key resource areas for water supplies. Wildfires in overgrown forests pose a substantial risk to water supplies because they can lead to increased flooding and erosion and delivery of sediment, nutrients, and metals to rivers, lakes, and reservoirs, which can negatively affect water-supply reservoirs, water quality, and drinking-water treatment processes. Forest management practices often involve mechanical thinning and/or prescribed burn to promote forest health, enhance wildlife habitat, and help reduce the risk of wildfires. The hydrologic impact of vegetation changes due to these forest management practices can decrease ET (i.e., consumptive use) and increase water availability. The VWB of forest management activities is estimated as the reduction in consumption based on the reduced ET as follows:

$$\text{VWB} = \text{Area affected} \times [\text{ET}_{\text{without-project}} - \text{ET}_{\text{with-project}}]$$

Application of the method requires specifying the area affected by the activity and the ET rates for the with-project and the without-project conditions. Direct ET measurements require advanced techniques and may not be practical. The ET rates corresponding to the "with-project and without-project conditions should be obtained from the literature, relevant local studies or modeling, or using relevant empirical equations reported in the literature. New tools that use remote sensing to measure ET (e.g., such as OpenET or other satellite tools) may provide data to support these calculations.

Required Inputs

Variable	Input
Area affected	Surface area affected by the activity
$\text{ET}_{\text{without-project}}$	Evapotranspiration rate for the without-project condition (i.e., before forest management treatment)
$\text{ET}_{\text{with-project}}$	Evapotranspiration rate for the with-project condition (i.e., after forest management treatment)

- **Invasive species removal**

Landscape restoration involving the removal of invasive and nonnative plant species is considered a potential strategy for enhancing water supplies. A common example of water-thirsty invasive species is the Arundo reed (e.g., *Arundo donax*) infestation in semi-arid climates. Arundo is a densely vegetated reed that has high water consumption and is characterized by rapid growth rate and vegetative reproduction. Arundo eradication measures can have a positive impact on the ecosystem, including reduced ET, increased water availability, and restored habitat. The VWB of invasive species removal, such as the Arundo eradication, is estimated as the reduced ET as follows:

$$VWB = \text{Area affected} \times \text{\% Cover} \times [ET_{\text{without-project}} - ET_{\text{with-project}}]$$

Required inputs

Variable	Input
Area Affected	Surface area affected by the activity
$ET_{\text{without-project}}$	Evapotranspiration rate for the without-project condition (i.e., ET rate of the invasive species)
$ET_{\text{with-project}}$	Evapotranspiration rate for the with-project condition (i.e., ET rate of land cover that replaces the invasive species)
% cover	Percentage of the area affected by the invasive species

- **Leak detection and repair projects**

For activities involving leak detection and repair, the VWB is calculated based on the volume lost from leaks before and after leak detection and repair. For building-scale projects, this volume represents reduced withdrawal from the source. For utility-scale projects, this volume represents reduced nonrevenue water (NRW). For the purpose of this method, NRW refers to physical losses due to leaks in the distribution system. The VWB is calculated by comparing leak volume for the with-project and without-project conditions. The without-project condition describes the leak volume before project implementation. The with-project condition represents leak volume after detection and repair.

$$VWB = \text{Leak volume reduction} = \text{Leak volume}_{\text{without-project}} - \text{Leak volume}_{\text{with-project}}$$

The leak volumes for the without-project and the with-project conditions should be based on metered data where possible, particularly in large-scale utility distribution systems. Where metering is not feasible, the leak volumes can be estimated based on the number of leaks and the average loss rate per leak.

Required inputs

Variable	Input
Leak volume $_{\text{without-project}}$	Metered or estimated leak volume without the project (i.e., before leak detection and repair intervention)
Leak volume $_{\text{with-project}}$	Metered or estimated leak volume with the project (i.e., after leak detection and repair intervention)

Appendix A-3. Volume provided method

Objectives and indicators

The volume provided method enables estimation of VWBs of activities that provide a volume of water that contributes to improving human health and/or livelihood, as well as social or economic security or resiliency.

Objective	Output Indicator
Improved resilience through increased supply Improved WASH	Volume provided

Example activities include well construction and rehabilitation, household water connections, piped water systems, rainwater harvesting, water reuse, point-of-use treatment, drinking water treatment facilities, and other activities that develop new or alternative sources of water supply for irrigation or domestic use (including hand washing, bathing, and cleaning).

Methodology description

The volume provided method is applied to estimate the annual volume of water provided from a new, alternative (e.g., water reuse, rainwater harvesting), restored, or improved water supply.

The VWB for activities providing a volume of water is estimated as follows:

$$\mathbf{VWB = Volume\ of\ water\ provided}_{\text{with-project}} - \mathbf{Volume\ of\ water\ provided}_{\text{without-project}}$$

The following options, in order of preference, can be used to calculate the volume provided:

- Estimate based on metered data
- Estimate based on appropriate methods, such as
  - The volume of water provided for irrigation (i.e., the withdrawal volume) can be estimated based on crop demand.
  - The volume of rainwater harvested for direct use may be estimated based on the capacity of the rainwater harvesting system and the average number of times it fills to capacity per year. Alternatively, it may be estimated based on the minimum of the available supply and storage potential.
  - For systems that rely on pipes and pumps, the volume provided may be estimated based on the pumping or delivery design capacity of the system and the operating time at this capacity. If it is known that the system will be running at less than the design capacity, the average flow rate that is anticipated can be used instead of the design capacity.
  - The volume provided can be estimated based on the number of direct beneficiaries receiving reasonable access or limited access to water, the per-capita volume and the number of days per year of access.

Example applications

- **New water supply for irrigation**

Activities that provide water for irrigation supply should meet local irrigation quality standards. The following options, in order of preference, can be used to determine the volume provided.

- Option 1: Calculate based on metered data, if available.
- Option 2: In the absence of metered flows, estimates of irrigation volumes can be based on observed surface water diversion flows and duration (e.g., for pumps submerged in rivers or dams) or groundwater pumping discharge rates and their operating hours, or estimated using other appropriate methods by considering crop type and the efficiency of the irrigation system.

The VWB is calculated as the average annual volume of irrigation water provided.

$$\text{VWB} = \text{Average annual volume of irrigation water provided}$$

Required inputs

Variable	Inputs
Measured withdrawals	Metered flows, if available, or pump discharge rates and operating times
Estimated irrigation requirements	Irrigation requirements can be obtained using computer models such as CROPWAT, or estimated based on crop water requirement, adjusted for rainfall and irrigation system efficiency by considering the following inputs: • Location • Irrigated area • Crop type • Crop evapotranspiration • Method of irrigation • Irrigation efficiency

- **Access to household or community water supply**

For activities providing water access to households or communities, the water should be free from contamination and meet relevant local quality standards for the type of use. The beneficiaries should have reasonable access either in households or outside (e.g., public areas).

The following options, in order of preference, can be used to determine the volume provided.

- Option 1. Estimate based on metered data, if available.
- Option 2. Estimate based on system capacity
    - The volume of rainwater harvested for direct use may be estimated based on the capacity of the rainwater harvesting system and the average number of times it fills to capacity per year. Alternatively, it may be estimated based on the minimum of the available supply and storage potential. See Appendix A-4 for details.
    - For systems that rely on pipes and pumps, the volume provided may be estimated based on the pumping or delivery design capacity of the system and the operating time at this capacity. If it is known that the system will be running at less than the design capacity, the average flow rate that is anticipated can be used instead of the design capacity.

- Option 3. Estimate based on the number of direct beneficiaries receiving reasonable access to water and a conservative estimate of per-capita volume provided, as described below.

When using the number of direct beneficiaries (Option 3), the VWB is calculated by multiplying the number of direct beneficiaries receiving **reasonable access** to water by a per-capita volume of water over the number of days of access (i.e., 365 days for full access projects). The World Health Organization and United Nations Children's Fund (WHO and UNICEF 2000) define reasonable access as the availability of at least 20 liters per person per day from a source within one kilometer of the user's dwelling. In the case where relevant local data are available and/or locally relevant or national guidelines define "reasonable access to water" (or a similar concept like the minimum quantity required for basic needs) as more than 20 L per person per day, the volume provided can be calculated based on the number of direct beneficiaries receiving this volume of "reasonable access to water." If the VWB is calculated using the beneficiary approach, and the supply capacity (based on delivery/pump capacity) is known, the VWB should be based on the minimum of the supply capacity or beneficiary-based volume to avoid overstating benefits.

For projects that provide **limited water access** (e.g., in schools or community centers), metering is preferred. If metering is not feasible, the volume provided can be calculated based on the number of beneficiaries, the number of days of access (typically less than 365 days per year for limited access projects), and the per-capita volume provided. For limited access projects, a per-capita volume of 20 liters per person per day is likely too high. Practitioners should work with the local implementing partner to arrive at a reasonable per-capita estimate that is reflective of actual water use during the hours of operation. Another resource is The Sphere Handbook, which provides per-capita volume ranges for a number of uses, including 2 to 6 liters per person per day for basic hygiene practices; and 3 liters per person per day for drinking and hand washing in schools. Note that these estimates are specific to humanitarian response and disaster management and may not be applicable in other contexts. In instances where project or activity-specific monitoring data show that beneficiaries are receiving more (or less) than the reasonable or basic access volume, the volume provided can be calculated based on this project-specific volume.

Because it can be difficult to determine who is using a particular water source, it is recommended that someone familiar with the project determine the number of direct beneficiaries for water supply projects.

The VWB is estimated as follows:

$$\text{VWB} = \text{Average annual volume of household or community water provided}$$

Required inputs

Variable	Inputs
Measured water volume	Metered flows, if available, or pump discharge rates and operating times
Estimated water volume (i.e., for household or community water supply)	Number of beneficiaries with improved access to water. Information regarding required per-capita availability (locally relevant water consumption rates are preferred; default is 20 L per capita per day for full access and 2 L per capita per day for limited access) If available, the maximum delivery/pumping capacity of the new supply should be compared to the beneficiary-based volume to ensure that the volume provided is not overstated.

Estimated water volume (i.e., for rainwater harvesting)	Minimum of available supply (i.e., precipitation) and storage potential (i.e., storage capacity and number of times filled to capacity)

References

Sphere Association. 2018. *The Sphere Handbook. Humanitarian Charter and Minimum Standards in Humanitarian Response. F*ourth edition. Geneva Switzerland: Sphere Association. www.spherestandards.org/handbook.

WHO (World Health Organization) and UNICEF (United Nations Children's Fund). 2000. *Global Water Supply and Sanitation Assessment 2000 Report*. Geneva and New York: WHO and UNICEF.

Appendix A-4. Recharge method

Objectives and indicators

The recharge method enables estimation of VWBs of activities that directly increase or maintain recharge or seasonal water storage or create, restore, or protect waterbodies where recharge is a hydrologic function affected by the activity. Because activities that increase or maintain recharge often also capture water, it is important to ensure that volumetric benefits are not double counted.

Objective	Output Indicators
Increased water availability Improved/maintained water-related habitat Maintained water balance	Increased recharge Maintained recharge Increased seasonal water storage Maintained seasonal water storage

Example activities include rainwater harvesting for groundwater recharge (e.g., rooftop runoff harvesting for recharge), aquifer storage and recovery, infiltration wells, infiltration basins, infiltration trenches, infiltration shafts, check dams, ponds, floodplain restoration, wetland restoration, wetland creation, floodwater supplied to an area to increase recharge, beaver dam analogs, conservation agreements to protect wetlands, land cover restoration (e.g., reforestation, grassland restoration, and other activities that restore vegetation cover), or land conservation (e.g., forest conservation, meadow conservation, and other activities that preserve vegetation cover).

Methodology description

As noted above, there are many activities that increase or maintain recharge. Increased recharge is calculated as the difference in recharge volume for the with-project condition compared to the without-project condition. The without-project condition describes the current recharge. The with-project condition represents recharge after implementation of activities that increase or maintain recharge.

$$\text{VWB} = \text{Recharge}_{\text{with-project}} - \text{Recharge}_{\text{without-project}}$$

Example applications

- **Rainwater harvesting and infiltration**

Infiltration infrastructure such as rainwater harvesting for groundwater recharge; infiltration trenches; recharge shafts, pits, wells, aquifer storage, and recovery; check dams; and ponds capture excess rainfall and runoff for groundwater recharge and community, economic, and/or ecosystem use.

The VWB can be calculated as the difference in recharge volume for the with-project condition compared to the without-project condition. The without-project condition should be evaluated to determine if recharge is occurring. Typically, the without-project condition may have no recharge function, unless the project improves the recharge capability of an existing intervention (e.g., by desilting an existing pond). The with-project condition represents the construction of rainwater or runoff capture interventions to increase recharge.

The recharge method is applied to calculate the volume recharged to groundwater, based on available supply (i.e., volume draining from catchment, which is calculated by multiplying the catchment area by the average annual precipitation (rainfall depth) and an appropriate catchment runoff coefficient), the volume captured by these interventions, and losses associated with evaporation (if any) and use (i.e., withdrawal). For projects that do not involve catchment area, the available supply calculations do not apply; and a conservative estimate of storage potential can be considered equal to the volume captured. First, the method calculates the volume captured as the minimum of available supply and storage potential.

$$\textbf{Available supply} = \textbf{Catchment area} \times \textbf{Runoff coefficient} \times \textbf{Annual rainfall}$$

$$\textbf{Volume captured} = \textbf{Minimum [Available supply, storage potential]}$$

Storage potential is based on the design storage capacity of the intervention and the number of times it fills to capacity. The number of times filled to capacity is a project-specific input that should be estimated by someone with knowledge of the system. This can be informed by the design specifications of the system, past experiences in the area/region, and average annual precipitation, among other variables. In instances where there is no way to estimate this input, and it is known that the rainwater harvesting system fills to capacity, the number of times it fills per year can be conservatively assumed to be once per year.

$$\textbf{Storage potential} = \textbf{Design storage capacity x Number of times filled to capacity}$$

Recharge volume is calculated by subtracting evaporation and usage losses (where applicable; for some features, such as infiltration pits and wells, the usage and evaporation losses may be negligible) from the volume captured as follows:

$$\textbf{Recharge volume} = \textbf{Volume captured} - \textbf{[Evaporation} + \textbf{Withdrawal]}$$

Note: For rainwater harvesting or aquifer storage and recovery projects, typically the without-project recharge volume can be assumed to be zero, and the equation simplifies to VWB = with-project recharge. The approach described above is most simply applied on an average annual basis. If data are available and more certainty is desired, sophisticated algorithms can be developed to support the application of this approach on a daily or monthly basis or to support a variation of this approach based on infiltration rates corresponding to each intervention.

Required inputs

Equation	Variable	Input
Available supply	Catchment area	Catchment area draining to the intervention
	Runoff coefficient	Catchment runoff coefficient
	Annual rainfall	Average annual precipitation from a representative weather station
Volume captured	Available supply	Catchment area draining to the intervention Catchment runoff coefficient Average annual precipitation from a representative weather station
	Storage potential	Design storage capacity Number of times filled to capacity
Storage potential	Design storage capacity	Design storage capacity of the intervention
	Number of times filled to capacity	Number of times the intervention fills to capacity
Recharge volume	Volume captured	Available supply Storage potential
	Evaporation	Evaporation from the intervention
	Withdrawal	Withdrawals from the intervention prior to recharge

- **Plugging gullies or channels or installing weirs to maintain or improve groundwater levels**

Activities such as plugging gullies or channels or installing weirs may maintain and/or improve storage volume by preventing groundwater from being drained. The increased storage volume is a simple, conservative approach for estimating increased recharge from these activities, where increased recharge is estimated based on increased groundwater storage volume.

This groundwater storage volume method is only applicable to unconfined aquifers and projects where it can be demonstrated that groundwater levels have changed over time. Users are encouraged to use other established approaches if they are available for a localized region.

The storage volume is quantified for two conditions: the without-project condition reflecting reduced storage capacity and the with-project condition reflecting increased storage capacity. The VWB for increased recharge is quantified as the difference in recharge volume between the two conditions over an annual period, with the recharge volume estimated based on groundwater storage.

$$\textbf{Groundwater storage} = \textbf{Surface area} \times \textbf{Average groundwater depth} \times \textbf{Specific yield (\%)}$$

Required inputs

Variable	Input
Surface area	The surface area beneath which groundwater storage is increased or maintained
Average groundwater depth	Average groundwater depth in the saturated zone of the unconfined aquifer affected by the project
Specific yield (%)	Ratio of the volume of water that a saturated rock or soil will yield to gravity to the total volume of rock or soil

- **Wetland restoration or creation**

Wetland restoration or creation activities, such as beaver dam analogs or floodwater diversion onto farmland or floodplains, can enhance recharge by ponding and recharging a portion of the increased volume of water stored or ponded. Where recharge occurs, the volume recharged is equal to the product of the wetland (or wetted) surface area, the infiltration rate based on soil texture, and the duration of time the wetland is inundated. If the volume supplied to the recharge area is known, and the entire volume infiltrates, this volume can be used as a surrogate for recharge volume. This method is applicable for wetland types that provide recharge function.

$$\text{Volume recharged} = \text{Wetland surface area} \times \text{Infiltration rate} \times \text{Duration of inundation}$$

The method involves a simple calculation comparing recharge volume for the with-project and without-project conditions and applies to both protected and restored wetlands.

Required inputs

Variable	Input
Surface area	Ponded surface area, reflecting average conditions
Duration	Average number of days each year that ponding occurs
Infiltration rate	Infiltration rate specific to the soil texture underlying the ponded area

- **Wetland protection**

When wetlands are drained and the land is converted to other uses such as cropland or residential development, this may lead to a reduction or loss of recharge function. Wetland protection, accomplished through conservation easements or acquisition, protects the groundwater recharge capacity of the wetlands. The need for protection and the likely future use of the land if not protected should be established. This can be accomplished through communication with local experts, evaluation of maps or reports describing trends in wetland losses, or evaluation of aerial or satellite imagery over time.

The recharge volume is quantified for two conditions: the without-project condition (drained or degraded wetland) and the with-project condition (current condition with intact healthy wetland). First, the annual recharge volume is calculated for each condition based on the average ponded surface area, number of days of ponding, and infiltration rate. The VWB for maintained recharge is then quantified as the difference in annual recharge volume between the two conditions.

$$\text{VWB} = \text{Recharge}_{\text{with-project}} - \text{Recharge}_{\text{without-project}}$$

- **Land cover restoration or land conservation**

Activities that involve restoration or conservation of land cover may improve groundwater recharge and seasonal soil water availability. Two indicators (i.e., increased recharge and increased seasonal water availability) are presented here since they are calculated using the same method and input variables. However, users should only select the indicator that is most relevant to the local shared water challenge being addressed by the activity. While land cover restoration is not always associated with an increase in groundwater recharge or seasonal soil water availability, this method is intended to estimate the change in groundwater recharge and seasonal soil water availability where relevant. Note that when land cover restoration activity is implemented to reduce runoff, then the curve number method (described in Appendix A-1) is recommended.

This method estimates the water balance at the activity level, considering precipitation, evapotranspiration, runoff, infiltration, and groundwater recharge based on soil water content. Users are encouraged to engage a subject-matter expert to run more advanced calculations on a daily time step, such as those described in the Soil and Water Assessment Tool (SWAT) methodology (Neitsch et al. 2011), or another model selected by a subject-matter expert or credible institution.

The method presented here summarizes the key equations for a simplified water balance approach to estimating groundwater recharge and seasonal soil water availability for the purpose of VWB calculations. The equations below do not necessarily account for the complexity of hydrologic processes of forested and other vegetated landscapes but rather are intended to demonstrate the key components of calculating recharge and seasonal water availability per this VWB method. Users are encouraged to use more advanced methods and models to estimate these variables on a daily basis using local land cover, soil, geology, and climate characteristics.

The VWB calculation is summarized as follows on a daily basis, after which it can be aggregated to an annual or seasonal scale. For seasonal water availability, the annual estimate is based on the water made available during a season of interest. The season of interest is determined by the user as the period of time (e.g., months before the beginning of the dry season) when it is critical for seasonal water availability to increase to address the shared water challenge.

$$SWA = SW \cdot \%\, Available + R$$

Where:

SWA = Seasonal water availability (mm) estimated for the season of interest

SW = Soil water content (mm) aggregated over the season of interest

% Available = Factor (%) to account for the fact that not all soil water content is available for use due to soil characteristics

R = Recharge (mm) aggregated over the season of interest

$$R = I \text{ } if \text{ } SW \geq SW_{SAT};$$
$$R = Rr * I \text{ } if \text{ } SW < SW_{SAT} \,\&\, SW > SW_{FC};$$
$$R = 0, \text{ } otherwise$$

Where:

R = recharge (mm)

I = infiltration (mm)

SW = soil water content (mm)

SW_{SAT} = soil water content at saturation (mm)

SW_{FC} = soil water content at field capacity (mm)

Rr = recharge rate (%)

The equation considers that if the soil water content is above the soil saturation, 100 percent of the water infiltrated is considered as water recharged. If the soil water content is between the soil saturation and field capacity, the recharge rate parameter is used to determine the percentage of water that is recharged.

$$I = P_{net} - ET - Q$$

Where

I = infiltration (mm)

P_{net} = Net precipitation (mm)

ET = Evapotranspiration (mm)
Q = Runoff (mm)

$$P_{net} = P_{gross} - CS$$

Where

P_{net} = Net precipitation (mm)
P_{gross} = Gross precipitation (mm)
CS = Canopy storage (mm)

For this method, users are required to calculate variables on a daily basis to capture daily changes in the soil water content before aggregating to a seasonal or annual scale.

Increased recharge

The VWB is equivalent to the volume of water recharged by the activity in comparison to the without-project condition.

$$\mathbf{VWB = R_{\text{with-project}} - R_{\text{without-project}}}$$

Increased seasonal water storage

The VWB is equivalent to the volume of water recharged by the activity in comparison to the without-project condition. The VWB should be based on the specific weeks and/or months of the season of interest. The estimated VWB for the season represents the annual VWB from the activity.

$$\mathbf{VWB = SWA_{\text{with-project}} - SWA_{\text{without-project}}}$$

Required inputs

Equation	Variable	Input
Seasonal water availability (SWA)	*SW* = Soil water content	Daily soil water content as calculated by the chosen method, such as SWAT (Neitsch et al. 2011)
	% Available	Factor (%) based on soil characteristics to conservatively account for the fact that not all soil water content is available for use
	R = Recharge	Daily recharge as calculated by the chosen method, such as SWAT (Neitsch et al. 2011)
Recharge (*R*)	*I* = Infiltration	Daily precipitation, evapotranspiration, and runoff as calculated by the chosen method, such as SWAT (Neitsch et al. 2011)
	SW = Soil water content	Daily soil water content as calculated by the chosen method, such as SWAT (Neitsch et al. 2011)
	SW_{SAT} = Soil water content at saturation	Water content fraction of total soil volume at saturation based on soil texture
	SW_{FC} = Soil water content at field capacity	Water content fraction of total soil volume at field capacity based on soil texture
Infiltration (*I*)	P_{net} = Net precipitation	Daily gross precipitation and canopy storage
	ET	Daily evapotranspiration calculated by the chosen method, such as SWAT (Neitsch et al. 2011), using climate inputs of at least three years of daily data from a nearby representative station.
	Q	Daily runoff as calculated by the chosen method, such as SWAT (Neitsch et al. 2011)
Net precipitation (P_{net})	P_{gross} = Gross precipitation	At least three years of daily data from a nearby representative station.
	CS = Canopy storage	Daily water intercepted by vegetative surfaces as calculated by the chosen method, such as SWAT (Neitsch et al. 2011)

References

Neitsch, S.L., J.G. Arnold, J.R. Kiniry, and J.R. Williams. 2011. “Soil and Water Assessment Tool Theoretical Documentation Version 2009.” College Station: Texas Water Resources Institute.

Appendix A-5. Volume captured method

Objectives and indicators

The volume captured method enables estimation of VWBs of activities that capture and/or store or protect a volume of water for flood/drought mitigation, water quality, and/or habitat benefits.

Objective	Output Indicator
Improved water quality through nonpoint-source pollution reduction Improved resilience through flood/drought mitigation Improved/maintained water-related habitat	Volume captured Volume maintained

Example activities include storm water detention or retention ponds, rain gardens, pond dredging or desilting, where the objective is to improve water quality or resilience through flood/drought mitigation. Other relevant activities include invasive species removal to create open water and conservation easements to protect wetlands from being drained, where the objective is to improve or maintain water-related habitat due to the volume captured or volume maintained.

Methodology description

The volume captured method can be applied to calculate the volume captured or volume maintained due to storm water management, aquatic habitat restoration or protection, or other relevant activities listed earlier.

The VWB for activities that capture and or store a volume of water is calculated as

$$\textbf{VWB} = \textbf{Volume captured}_{\text{with-project}} - \textbf{Volume captured}_{\text{without-project}}$$

The VWB for activities that protect or maintain a volume of water is calculated as

$$\textbf{VWB} = \textbf{Volume maintained}_{\text{with-project}} - \textbf{Volume maintained}_{\text{without-project}}$$

Example applications

- **Storm water management**

Storm water BMPs are commonly used to intercept and slow runoff, helping to reduce flooding risk and improve water quality. BMPs that are typically implemented for storm water management include green roofs, permeable pavement, grass channels, bioretention, dry and wet swales, soil amendments, rain tanks, cisterns, ponds, and constructed wetlands.

The volume captured through storm water management can be calculated using the runoff reduction method (Hirschman et al. 2008). This method involves two steps.

1. First, the volume of storm water directed to a BMP is calculated. This supply volume is calculated by multiplying annual average rainfall by the runoff coefficients that correspond to the catchment land cover conditions.

$$\text{Supply volume} = \text{Annual average rainfall x Surface area x Runoff coefficient}$$

The proportional area of pervious (forest, turf, etc.) and impervious (concrete, metal, etc.) surfaces and their corresponding runoff coefficients should be considered in the supply volume calculations. This is done by calculating the supply volume associated with each surface's characteristics in the runoff contributing area and then adding to calculate the total supply volume.

2. The volume captured is then calculated by multiplying the supply volume estimated in Step 1 by a runoff reduction factor corresponding to the BMP. The BMP-specific runoff reduction factor can be obtained from relevant literature (e.g., Hirschman et al. 2018).

The VWB is calculated as the volume captured:

$$\text{Volume captured} = \text{Supply volume} \times \text{Runoff reduction factor (\%)}$$

Required inputs

Equation	Variable	Input
Supply volume	Annual average rainfall	Annual average rainfall depth for a representative weather station
	Surface area	Total catchment area draining to the BMP
	Runoff coefficient	Land cover characteristics Runoff coefficients corresponding to each land cover in the catchment draining to the BMP
Volume captured	Supply volume	Annual average rainfall Total surface area draining to the BMP
	Runoff reduction factor	BMP-specific runoff reduction factor (%)

Note: Small-scale BMPs, such as rainwater tanks and cisterns for capturing rainwater from residential rooftops, may be installed at multiple locations within the same project area. Because the individual rooftop areas may be small, the volume captured by each BMP may not be significant. In these cases, the rooftop areas can be aggregated, and multiple BMP installations can be represented as a single activity to calculate the total VWB.

For storm water BMPs, typically the without-project volume captured can be assumed to be 0, and the equation simplifies to VWB = with-project volume captured.

- **Water body restoration**

When water bodies, such as lakes, reservoirs, ponds, or wetlands, have lost the capacity to hold water, they are unable to provide aquatic habitat, water quality, or recreational benefits. Capacity loss may be due to sedimentation, drainage, or invasive species.

The storage volume is quantified for two conditions: the without-project condition (reduced volume captured) and the with-project condition (increased volume captured). The annual average volume captured is calculated for each condition. The volume captured can be calculated as follows:

$$\text{Volume captured} = \text{Surface area} \times \text{Average water depth}$$

The VWB is then quantified as the difference in volume captured between the two conditions over an annual period.

Another approach for estimating the volume captured for activities that involve desilting waterbodies to restore storage capacity is shown below.

Volume Captured = Increased storage capacity based on the volume of sediment removed

These approaches provide a conservative estimate of the volume captured. However, if information is available to calculate the volume of the water body and the number of times it refills, then the benefit can be calculated based on the number of times the water body refills completely.

Required inputs

Variable	Input
Surface area	Surface area of the water body reflecting average conditions
Average water depth	Average depth of the affected water body
Increased storage capacity	Volume of sediment removed by desilting or other means to increase storage capacity

The basis for determining the surface area, the average water depth and any other inputs should be documented.

- **Water body protection**

Water body protection, for example through conservation easements, maintains the surface volume and associated benefits in water bodies, such as lakes, wetlands and ponds. The volume maintained (i.e., stored) is quantified for two conditions: the without-project condition (reduced volume) and the with-project condition (volume maintained). The volume may be calculated based on surface area and average water depth or site-specific studies.

The need for protection and the likely future use of the water body if not protected should be established. This can be accomplished through communication with local experts, evaluation of maps or reports describing trends in wetland losses, or evaluation of aerial or satellite imagery over time.

References

Hirschman, D., M. Aguilar, J. Hathaway, K. Lindow, and T. Schueler. 2018. *Updating the Runoff Reduction Method*. Technical Report. Nashville TN: Metro Government of Nashville and Davidson County, Tennessee Metro Water Services, Storm Water Division.

Appendix A-6. Volume treated method

Objectives and indicators

The volume treated method enables estimation of the VWB of activities that have the primary objective of improving water quality (WQ).

Objectives	Output Indicator
Improved WQ through point-source pollution reduction Improve WQ through nonpoint-source pollution reduction Improved WASH	Volume treated

Example activities include a variety of natural and nature-based solutions that are designed to capture and treat nonpoint-source runoff, such as constructed treatment wetlands and bioretention basins. This method applies to constructed treatment systems and other gray or nature-based infrastructure designed to intercept polluted water streams to improve WQ. It can also be applied to gray infrastructure, such as wastewater treatment plants (WWTPs) and improved sanitation facilities.

Methodology description

The VWB for activities treating a volume of water is estimated as:

$$\mathbf{VWB = Annual\ volume\ of\ water\ treated \times (1/N_{challenges}) \times \Sigma\ (Fraction\ improved_i),}$$

where

Challenges refer to water quality challenges, and i refers to pollutants

The ***fraction improved*** is specific to the relevant pollutant(s) of concern for the receiving water and is computed using the following equation:

$$\mathbf{Fraction\ improved = Incremental\ improvement\ by\ activity / Total\ improvement\ needed}$$

If more than one WQ challenge is identified, then a fraction improved should be computed for each individual pollutant (i) and an appropriate number of challenges ($N_{challenges}$) should be assigned. If the treatment system does not affect one of the pollutants identified as a WQ challenge, then a ***fraction improved*** value of 0% must be assigned for that pollutant (i). The ***fraction improved*** is calculated by comparing the with-project WQ conditions relative to the without-project conditions and evaluating that change relative to the total improvement needed, for example a reduction in annual pollutant loading or average water-body pollutant concentration. Both the incremental improvement and the total improvement needed must be expressed in the same units so that the resulting ***fraction improved*** is a unitless number. If the incremental improvement achieved by the activity is greater than the total improvement needed, a maximum value of one (1.0) should be used for the fraction improved.

<u>Example</u>: an annual treatment volume of 1,000 m^3 is determined for a constructed wetland, and two pollutants of concern are identified as TSS and TP, with influent concentrations of 200 mg-TSS/L and 0.5 mg-P/L, effluent concentrations of 100 mg-TSS/L and 0.2 mg-P/L and WQ targets of 50 mg-TSS/L and 0.1

mg-P/L, respectively. The fraction improved for TSS is (200-100)/(200-50) = 100/150 = 0.67 and for TP is (0.5-0.2)/(0.5-0.1) = 0.3/0.4 = 0.75 and $N_{challenges}$ is 2. The final VWB is calculated as 1000 m^3/year × (1/2) x (0.67 + 0.75) = 708 m^3/year.

Example applications

- **Constructed natural or nature-based treatment systems**

This application is relevant to natural or nature-based structures that are designed to intercept polluted water volumes and discharge cleaner water. Example activities include those used in both agricultural and urban landscapes to intercept surface runoff such as constructed treatment wetlands, bioretention basins, rain gardens, retention and detention basins, buffers, filters, bioreactors, and grassed waterways. The method is applied in a stepwise fashion to calculate the volume of water treated and the fraction to which it is improved toward a defined target.

- **Step 1**: The appropriate standard(s) or target(s) should address the project objectives and established impairments and be based on locally relevant, established threshold(s) tied to the recognized uses of the receiving water (e.g., designated or actual uses). For example, an appropriate target for a constructed wetland designed to treat agricultural runoff contributing to high levels of nitrate in drinking water should bring the discharge WQ to an appropriate nitrate concentration standard, such as the U.S. Environmental Protection Agency's (USEPAs) maximum contaminant level (MCL) of 10 mg/L for drinking water. If locally relevant numeric WQ criteria or quantitative guidelines do not exist, relevant guidelines or standards published by the World Health Organization (WHO), USEPA, the European Union, or another reputable organization may be applied. If the project objective is to provide clean water needed for irrigation, the treatment system should bring discharge water to an appropriate irrigation WQ target.
- **Step 2:** WQ data collected at the inlet(s) are evaluated to confirm that the incoming water is not meeting the target. If there is not a clearly defined inlet or if it is not practical to collect new measurements, but published studies or other reliable documents are available confirming local water impairments, then estimates of incoming WQ from such studies may be used in place of site-specific measurements.
- **Step 3**: WQ data collected at the outlet(s) are evaluated to determine if the system is improving WQ from a condition of not meeting the target(s) to a condition of fully or partially meeting the target(s) for each challenge identified. This determination may not be needed if the system is designed according to a recognized standard based on demonstrated technologies that have been tested and proven to achieve the desired WQ.
- **Step 4**: The capacity of the natural or nature-based treatment system to fully or partially treat the volume intercepted to the appropriate WQ standard(s) or targets(s) should be evaluated to confirm that the system is properly sized. The annual flow through the treatment system should be based on metering where feasible. In the absence of metered flow data, the flow through the treatment system can be computed based on site characteristics, including drainage basin area, precipitation, and a runoff model (see **Appendix A-1**), recognizing that a different approach may be required for treatment systems intercepting flow volumes from artificial subsurface (tile) drainage or systems receiving other forms of non-runoff inflow volumes.

$$\text{VWB} = \text{Annual volume of water treated} \times (1/N_{\text{challenges}}) \times \Sigma\,(\text{Fraction improved}_i)$$

$$\text{Fraction improved} = \text{Incremental improvement by activity}/\text{Total improvement needed}$$

Required inputs

Variable	Input
Metered volume treated	Measurements of annual flow through the treatment system
Estimated volume treated (surface runoff approach where relevant)	Surface runoff calculations or other relevant method to estimate annual volume treated by natural or nature-based systems
Number of challenges	Number of WQ challenges identified or the number of pollutants of concern for the receiving water. Legacy pollutants can be included in this total if they are a primary pollutant of concern.
Incremental improvement by activity	Incremental improvement by activity (calculated from the influent and effluent WQ)
Total improvement needed	Total improvement needed (calculated from the influent WQ and the WQ target(s))
WQ standard or target	Locally relevant, numeric WQ criteria or guidelines, or in the absence of such criteria, relevant guidelines or standards published by reputable national or global organizations.
Influent WQ	Monitoring data to demonstrate that the WQ of the influent water does not meet the WQ target(s) (before treatment). Samples should be collected at a defined system inlet. Published studies or other reliable documents may be used in place of site-specific measurements.
Effluent WQ	Effluent WQ measurements, collected at a defined system outlet, to demonstrate that the WQ target(s) are fully or partially met as a result of treatment

- **Wastewater treatment plants**

This application is relevant to the creation of new WWTPs or enhancements to existing WWTPs that remove pollutants from one or more effluent streams, resulting in cleaner water discharged to receiving water bodies. The method is applied in a stepwise fashion to calculate the volume of water treated and the fraction to which it is improved toward a defined target.

- **Step 1**: The appropriate target(s) should address the project objectives and established impairments and be based on a locally relevant, established WQ target(s) tied to the recognized uses of the receiving water (e.g., designated or actual uses). For example, if the treatment plant is being constructed to address fecal coliform bacteria, then the target should be based on effluent standards that are appropriate for the use of the receiving water (e.g., drinking, irrigation, swimming). If locally relevant numeric water quality criteria or quantitative guidelines do not exist, relevant guidelines or standards published by WHO, USEPA, the European Union, or another reputable organization may be applied.
- **Step 2:** WQ data collected at the inlet are evaluated to confirm that the incoming water is not meeting the target. WQ data collected at the inlet may not be needed if it is known that the treatment plant is receiving raw sewage and accepted standards, or design values can be used to define influent pollutant concentrations.
- **Step 3**: WQ data collected at the outlet are evaluated to determine if the system is improving water quality from a condition of not meeting the target to a condition of fully or partially meeting the target(s) for each challenge identified. Unlike the potential use of standard values

for raw sewage to define influent concentrations, effluent concentration data should be measured to demonstrate attainment of the target and evidence that the WWTP is functioning as intended.

- **Step 4**: The annual flow through the WWTP should be based on metering. In the absence of sufficient metered flow data, the annual flow through a WWTP may be estimated based on the average annual percentage of the total design capacity of the plant that is realized, up to a maximum VWB of the design capacity or the number of beneficiaries. Where both the design capacity and number of beneficiaries approach apply, it is recommended that both be calculated and the more conservative or lower volume between the two be counted as the VWB to prevent overclaiming.

$$\textbf{VWB} = \textbf{Annual volume of water treated} \times (1/N_{\text{challenges}})\ \Sigma\ (\textbf{Fraction improved}_i)$$

Required inputs

Variable	Input
Metered volume treated	Measurements of annual flow through the treatment system
Estimated volume treated (design capacity approach where relevant)	Pumping or treatment capacity of system Average annual percentage of the design capacity that is realized
Number of challenges	Number of water quality challenges identified, or the number of pollutants of concern for the receiving water. Legacy pollutants can be included in this total if they are a primary pollutant of concern.
Incremental improvement by activity	Incremental improvement by activity (calculated from the influent and effluent WQ)
Total improvement needed	Total improvement needed (calculated from the influent WQ and the WQ target(s))
WQ standard or target	Locally relevant, numeric WQ criteria or guidelines, or in absence of such criteria, relevant guidelines or standards published by reputable national or global organizations.
Influent WQ	Monitoring data to demonstrate that the WQ of the influent water does not meet the WQ target(s) (before treatment). Samples should be collected at a defined system inlet.
Effluent WQ	Effluent water quality measurements, collected at a defined system outlet, to demonstrate that the WQ target(s) are fully or partially met as a result of treatment

- **Improved sanitation facilities**

This application is relevant to improved sanitation facilities that are not shared with other households and where excreta are safely disposed of in situ or removed and treated offsite (WHO and UNICEF 2023). This includes sanitation access activities that improve water quality of wastewater (including sewage and fecal sludge), either on-site or off-site from where it was produced, to the point where it can be safely discharged or reused (i.e., connection to septic, sewage treatment, or fecal sludge treatment systems). While wastewater collection and conveyance systems do not directly treat wastewater, they provide a volume treated benefit in instances where it can be shown that the wastewater is delivered to a functioning treatment system that treats the water to relevant water quality targets.

The primary requirement for a volume of water to be considered treated relates to the quality of the effluent. The project activities should improve the quality of the wastewater so that it meets relevant discharge or reuse water quality targets. Because of this need to treat sanitary sewage or fecal sludge to acceptable levels, unlike the constructed natural or nature-based treatment system and wastewater treatment plant example applications, a ***fraction improved*** is not computed for improved sanitation facilities.

The method involves a four-step process for estimating the annual volume of water delivered to the treatment system using metered data, the design capacity of the system, or the number of direct beneficiaries.

- **Step 1**: It is not expected that data on specific pollutants will be available; instead, it should be demonstrated that the discharge is sent to a functioning treatment system that meets relevant requirements.
- **Step 2**: Water quality data for the without-project discharge from sanitation facilities is not needed if it is known that the sanitation system is producing raw sewage.
- **Step 3**: As described under the two applications noted earlier, confirm that the discharge from the treatment facility meets locally relevant water quality target(s) (i.e., for the with-project condition). Attainment of locally relevant water quality target(s) should be demonstrated with monitoring data, where possible, or by following design specifications based on similar, well-proven demonstration systems.
- **Step 4**: Estimate the volume of water treated annually. The annual flow through the sanitation system should be based on metering. In the absence of sufficient metered flow data, the annual flow may be estimated based on the average annual percentage of the total design capacity of the plant that is realized, up to a maximum VWB of the design capacity or the number of beneficiaries. Where either the capacity or beneficiaries approach applies, it is recommended that both are calculated and the more conservative or lower volume between the two is counted as the VWB to prevent overclaiming.

  Estimation of volume treated based on design capacity:

  $$\textbf{Volume treated} = \textbf{Design capacity of system} \times \textbf{Time operating at capacity}$$

  Estimation of volume treated based on number of beneficiaries:

  $$\textbf{Volume treated} = \textbf{Number of direct beneficiaries} \times \textbf{Per-capita volume (water treated per beneficiary per day)} * \textbf{Number of days of access per year}$$

Direct beneficiaries are defined as those people who are discharging wastewater to the system to be treated (not downstream beneficiaries). It is expected that these beneficiaries either were not connected to treatment before the project (and thus discharging wastewater directly to the environment), or their wastewater was inadequately treated.

The number of beneficiaries, which can be disaggregated in many ways (e.g., gender, age), should be conservatively determined to prevent overcounting individuals that benefit from the activities. There are multiple ways to determine the number of beneficiaries, including but not limited to surveying the number of people receiving services from project activities, using reported data, or estimating the number of people benefitting based on the number of households with new sanitation services (e.g., based on household loans) and the average household size from census data [e.g., UN Database on Household Size and Composition (UN 2022)]. In accordance with the WHO/UNICEF JMP definition of basic service, sanitation should be on-premises and not shared with other households, and hygiene should be located on premises (WHO and UNICEF 2023).

The table below provides guidance on the minimum per-capita water volumes required for a variety of hygiene and sanitation-related uses that would produce wastewater. These volumes can be conservatively used to define the per-capita volume of water discharged for treatment based on the type of treatment provided. For example, the volume of 22 liters per person per day (minimum hygiene + conventional flushing toilet) can be used for an activity where a household with a conventional flushing toilet is connected to a septic system.

Use	Type	Minimum Volume for Survival [liters per person per day (Sphere Association 2018)]
Basic hygiene practices	Hygiene	2–6
Hand washing (public)	Hygiene	1–2
Conventional flushing toilets	Sanitation	20–40
Pour-flush toilets	Sanitation	3–5
Toilet cleaning	Sanitation	2–8 (per toilet)

In instances where relevant local data are available and/or locally relevant or national guidelines define reasonable or basic access to wastewater treatment (or a similar concept), the volume treated can be calculated based on that volume. Additionally, in instances where project-specific monitoring data show that beneficiaries are receiving treatment of more (or less) water, the volume treated can be calculated based on this project-specific volume.

Required inputs

Variable	Input
Estimated volume treated (design capacity approach where relevant)	Pumping or treatment capacity of the system Average operating time per day Number of days active per year
Estimated volume treated (beneficiaries approach where relevant)	Number of direct beneficiaries Per-capita volume of water (average volume treated per beneficiary per day) Number of days of access per year

References

Sphere Association. 2018. *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response.* Fourth edition. Geneva, Switzerland: Sphere Association. www.spherestandards.org/handbook.

(UN) United Nations, Department of Economic and Social Affairs, Population Division. 2022. Database. *Database on Household Size and Composition 2022*. UN DESA/POP/2022/DC/NO. 8. Copyright © 2022 by United Nations, made available under a Creative Commons license (CC BY 3.0 IGO). https://population.un.org/household/#/countries/840.

WHO (World Health Organization) and UNICEF (United Nations Children's Fund). 2023. *Progress on Household Drinking Water, Sanitation and Hygiene 2000–2022: Special Focus on Gender*. https://www.unwater.org/publications/who/unicef-joint-monitoring-program-update-report-2023.

Appendix A-11. Inundation method

Objective and indicators

The inundation method enables estimation of VWBs for activities that create, restore, or protect areas where inundation is the primary hydrologic function provided or protected. These activities can provide flood attenuation, aquatic habitat, water quality, or recreational benefits.

Objective	Output Indicator
Improved/maintained water-related habitat	Increased inundation Maintained inundation

Example activities include, but are not limited to, removal of levees, berms or other obstructions to restore periodic inundation to floodplains, oxbow lakes, or wetlands, as well as floodwater applications to create wetland habitat (e.g. for migrating birds). This method also applies to activities that protect floodplain inundation, such as incentives supporting floodplain livelihoods or agreements that protect floodplains from being disconnected.

Methodology description

The VWB for projects that increase or maintain inundation volume is calculated as

$$\textbf{VWB} = \textbf{Inundation volume}_{\text{without-project}} - \textbf{Inundation volume}_{\text{with-project}}$$

Example applications

- **Floodplain reconnection**

The VWB of activities that restore inundation volume is quantified for two conditions: the without-project condition (disconnected floodplain) and the with-project condition (improved, reconnected condition of the floodplain). First, the annual inundation volume is calculated for each condition based on the average surface area inundated, average water depth, and average number of inundations. The VWB is then quantified as the difference in inundation volume between the two conditions over an annual period. The inundation volume can be calculated as follows:

$$\textbf{Inundation volume} = \textbf{Surface area inundated} \times \textbf{average water depth} * \textbf{Average number of inundations}$$

Required inputs

Variable	Input
Surface area inundated	Surface area inundated, reflecting average conditions
Average water depth	Average depth of water within the area inundated, based on measurements, project design, or a hydraulic model in the absence of measurements
Average number of inundations	Average number of inundations each year based on project design, local hydrology, or a hydraulic model.

The basis for determining the surface area inundated, the average depth of inundation, and the average number of inundations should be documented. In cases where floodwater is applied to an area to provide habitat, the inundation volume can be simply calculated based on the volume applied.

- **Floodplain protection**

The VWB of activities that maintain inundation volume is quantified for two conditions: the without-project condition (disconnected floodplain) and the with-project condition (maintained, connected floodplain).

The need for floodplain protection and the likely future use of the land if not protected should be established. This can be accomplished through communication with local experts, evaluation of maps or reports describing trends in floodplain losses, or evaluation of aerial or satellite imagery over time.

First, the annual inundation volume is calculated for each condition based on the average surface area inundated, average water depth, and average number of inundations. The VWB is then quantified as the difference in inundation volume between the two conditions over an annual period.

Appendix A-12. In-stream habitat volume method

Objectives and indicators

The in-stream habitat volume method enables the estimation of VWBs for activities with the primary objective of creating, restoring, or protecting a volume of water for water-related habitat. These activities can also provide water quality and fire-resilience benefits, among others.

Objectives	Output Indicator
Improved/maintained water-related habitat	Volume provided

Example activities include side channel reconnection, instream barrier removal, dam reoperation, process-based restoration, and water level management for habitat.

Methodology description

The habitat volume method is applied to calculate the volumetric water benefit from activities that protect or restore flows to aquatic habitats containing species that are considered as threatened and/or endemic to the area. The benefit is calculated based on the long-term average annual (or seasonal, when relevant) increased volume providing critical aquatic habitat benefits.

The volume provided is calculated as a function of the ecology of the target species:

$$\mathbf{VWB = Volume\ provided_{\,with\text{-}project} - Volume\ provided_{\,without\text{-}project}}$$

Where

$$\mathbf{Volume\ provided = Minimum\ flow\ during\ period\ of\ ecological\ significance\ for\ target\ species \times Flow\ duration}$$

This method requires that the user determine the relevant period of ecological significance based on the local context. For example, the period may be based on the provision of critical low flows during the dry season to maintain enough water in the habitat to sustain local biodiversity or provide minimum flows needed for spawning, rearing or overwintering. Documentation should be provided from a credible source to justify the selected period of ecological significance and the volume of water required to sustain the habitat. To minimize subjectivity when identifying the period of ecological significance, the user should focus on the most critical threshold for the species and/or habitat being restored.
This method applies when the status of the habitat under the without-project conditions is insufficient to sustain the identified species of concern (e.g., identified threatened, endemic, or sensitive species in the watershed) and/or habitat for the relevant time period, according to the local context and guidelines, and when the activity under the with-project conditions demonstrates a positive change to the status of the habitat that provides sufficient water volume to sustain the identified species and/or habitat, according to the local context and guidelines.

Target species can be identified by local or regional experts (e.g., fisheries scientists and researchers) or published studies or literature. Similarly, appropriate resources may be consulted to determine the minimum flows. For example, if the project improves habitat for migratory fish, the local context and guidelines could be determined by subject-matter experts or other credible local institutions to help inform the minimum flow requirements for the fish species to travel upstream. In some cases, the restoration project may benefit more than one species. The VWB calculation can consider a longer period of ecological significance to encompass multiple species.

Example applications

- **Aquatic habitat restoration**

For activities that restore aquatic habitat (e.g., barrier removal, reconnection of side channels, dam reoperation, or process-based restoration), the VWB can be determined based on the volume provided for aquatic habitat.

First, the annual average volume provided is calculated for the without-project and with-project conditions. If the period of ecological significance is for a subset of the year (e.g., a season, particular month, or number of days), the volumetric benefit should be based only on the volume during this period with that volume considered the annual volume. The VWB is then quantified as the difference in volume provided between the two conditions over an annual period.

Required inputs

Variable	Input
Critical habitat	The aquatic habitat protected or restored, which supports species that are considered as threatened and/or endemic to the area.
Minimum flow	Minimum flow associated with optimal depth or velocity for critical habitat
Period of ecological significance	Identify the period during which the minimum flows provide critical habitat for target species benefiting from the project
Flow duration	Duration of period of ecological significance

- **Barrier removal**

For activities that involve barrier removal that frees up an impounded volume and contributes to the natural flow and habitat function, a simple pathway to assess the VWB is to calculate the volume of water no longer impounded. This conservative approach may be used when data are not readily available to support a more detailed quantification.

$$\textbf{VWB} = \textbf{Volume provided} = \textbf{impounded volume}_{\text{without-project}} - \textbf{channel volume}_{\text{with-project}}$$

Required inputs

Variable	Input
Impounded volume	The volume of water impounded behind the barrier
Channel volume	The volume in the portion of the channel in the same footprint of the impounded volume, following barrier removal

Appendix A-13. Nonpoint-source pollutant-reduction method

Objectives and indicators

The nonpoint- source pollutant reduction method enables the estimation of the VWB of activities that improve water quality (WQ) by avoiding or controlling nonpoint-source pollutant loading.

Objectives	Output Indicator
Improved WQ through nonpoint-source pollution reduction	Volume Improved

The volume treated method described in Appendix A-6 may be adapted to estimate the VWB from additional activities with an objective of reducing nonpoint-source pollutant loading to groundwater or surface water where one or more WQ impairments are a shared water challenge. While the volume treated method emphasizes projects such as wastewater treatment plants and constructed treatment wetlands that are designed to **intercept** polluted water volumes and clean it to a relevant standard, this method expands on the volume treated method to include landscape activities that seek to **avoid** elevated pollutant levels in non-point source runoff or **control** non-point source pollutant levels at the source prior to entering a water body. This differs from the volume treated method, which is focused on point-source treatment or other solutions that intercept and treat polluted water volumes. Example activities that avoid nonpoint-source pollution may include improved fertilizer and manure management, precision agriculture, reduced pesticide application, land retirement, conservation crop rotation or use of alternative crops, habitat restoration or preservation, and pet waste control programs, among others. Example activities that control nonpoint-source pollution may include the use of blind inlets, washing stations, pollutant storage equipment, pasture and grazing management, street sweeping, impervious area disconnect, and urban soil amendments, among others. Although the method applies to project-scale quantifications, its intended use is for land uses clearly linked to known impairments in receiving waterbodies and for activities known to help mitigate those receiving water body impairments. The method can be applied to any location with a known hydrologic linkage to the impaired water body.

Methodology description

This method applies to nonpoint source pollution and is used to estimate the VWBs associated with reduction of pollutants entering water bodies (such as rivers, lakes, ponds, and groundwater) for activities being funded with the primary purpose of improving WQ when impairment(s) are known. Volumes of water resulting from water stewardship activities that help address shared water challenges related to WQ (SDG Target 6.3) are considered a VWB. The method involves a five-step process:

Step 1: Identify known WQ concerns in the receiving water body, including those that are not addressed by the activity, and the relevant WQ pollutants (if available).
Step 2: Identify locally relevant WQ threshold(s) for each pollutant identified. If locally relevant numeric WQ criteria do not exist, relevant guidelines or standards published by the WHO, USEPA, the European Union, or another reputable organization may be applied.

Step 3: Confirm that the without-project conditions of the water body do not meet the local WQ threshold for the pollutant(s) of concern that are addressed by the activity, either annually or seasonally, depending on the local context and guidelines. Ideally, this step should be done using available WQ data or documents synthesizing real-world WQ measurements that confirm the water-body impairment.

Step 4: Confirm that the proposed activity will improve the WQ of the water body by targeting a known source of the pollutant(s) of concern. Improvement should be demonstrated with monitoring data, information from local and relevant studies, use of a WQBA method (WRI et al. forthcoming), or by following design specifications based on similar, well-proven practices.

Step 5: Estimate the volume of water improved annually or seasonally, depending on the local context and guidelines, based on the change in the pollutant(s) of concern. This step involves accounting for any relevant pollutants with a known impairment linked to the source where the activity occurs, where changes to the without-project condition are affected (improved) after implementation of the activity.

Example application

- **Nonpoint-source pollution reduction**

For activities that reduce nonpoint-source pollution the VWB can be determined based on the volume improved, as described below.

Equation 1. VWB

For situations where water quality impairments to surface water bodies (streams, rivers, lakes) are the primary shared water challenge of concern and nonpoint sources contribute to impairment, the VWB is computed as

$$\textbf{Volume improved} = \textbf{With-project runoff x Average fraction improved x Fraction challenges addressed}$$

The ***fraction improved*** and ***fraction challenges addressed*** are described in the next sections. The with-project runoff should be computed using the curve number method, the runoff coefficient method, or a similar approach for the activity's landscape. Although this is typically applied annually, for situations where the primary WQ impairment of concern is a seasonal occurrence, then the with-project runoff should be calculated using an appropriate method and only applied to those seasonal conditions and time frame to avoid overclaiming the VWB.

For situations where impairments to groundwater are the primary WQ concern, the VWB is computed as

$$\textbf{Volume improved} = \textbf{With-project recharge} \times \textbf{Average fraction improved} \times \textbf{Fraction challenges addressed}$$

The "with-project" recharge should be computed using the recharge method, water balance modeling, or a similar approach to estimating the amount of annual precipitation that eventually infiltrates from the activity's landscape into the groundwater aquifer that is impaired. Groundwater WQ impairments typically do not vary by season, so only annual recharge volumes should apply.

Equation 2. Fraction improved

The second variable in the ***volume improved*** equation is computed as

> **Average fraction improved = Average (incremental improvement by activity/total improvement needed)**

The ***fraction improved*** is specific to the relevant pollutant(s) of concern for the activity. If more than one pollutant is targeted by the activity, then a fraction improved should be computed for each pollutant affected by the activity, and an appropriate ***fraction challenges addressed*** should be computed. The ***fraction improved*** is calculated by comparing the with-project WQ conditions relative to the without-project conditions and evaluating that change relative to the total improvement needed, for example a reduction in annual pollutant loading or average water-body pollutant concentration.

The incremental improvement by the activity (i.e., the with-project condition relative to the without-project condition) can be measured or estimated in many ways, but it is recommended that a WQBA method be used (WRI et al. 2023). For WQBA methods that also can be used to estimate runoff, the with-project runoff and incremental WQ improvement should both be computed using a WQBA method for consistency. Examples of WQBA methods include pollution-reduction efficiency, modified simple method, simple or mechanistic modeling, the treatment system method, or using a region-specific method. The total improvement needed, based on the locally relevant water quality threshold identified in Step 2, may be expressed as an absolute pollutant load-reduction target attributable to the source, a percent pollutant load-reduction target for the source, or an absolute pollutant concentration target for the water body and relevant time period (i.e., average annual, seasonal, flow-based, etc.). Both the incremental improvement and the total improvement needed must be expressed in the same units so that the resulting ***fraction improved*** is a unitless number. If the incremental improvement achieved by the activity is greater than the total improvement needed, a maximum value of one (1.0) should be used for the fraction improved.

Equation 3. Fraction challenges addressed

The third variable in the ***volume improved*** equation is computed as

> **Fraction challenges addressed = Number of WQ challenges affected by activity/Number of WQ challenges caused by land use**

The share of WQ challenges addressed is used to partition the total ***volume improved*** available for improvement based on the number of distinct and reasonably identifiable WQ challenges caused by the land-use practice. This factor should include only the WQ challenges that are linked to the source and exclude WQ challenges where the landscape being improved by the activity is known not to be a pollutant source or linked to the impaired condition. The factor is estimated to conservatively allocate a portion of the full water volume that can be claimed by addressing a specific WQ challenge with an activity. To quantify this factor, the user should identify the main WQ challenges (e.g., sedimentation, eutrophication, ecotoxicity from chemicals), as defined by the local guidelines and the known causes of those WQ challenges or the extent to which the landscape being improved by the activity is linked to the WQ impairments. If multiple pollutants are linked to a single WQ challenge—for example, nitrogen and phosphorus both linked to eutrophication—it may be necessary to explicitly account for these as two separate challenges, especially when separate WQ standards, targets, or goals have been established for the separate pollutants.

Required inputs

Equation	Variable	Input
Volume improved	With-project runoff	Runoff computed using curve number method, runoff coefficient method, a WQBA method, or other relevant surface runoff method that adequately models the runoff for the period of interest.
	With-project recharge	Recharge computed using recharge method, water balance modeling, a WQBA method, or other relevant recharge method.
Average fraction improved	Incremental improvement by activity	Incremental reduction (improvement) in pollutant loads or concentrations, computed using a WQBA method.
	Total improvement needed	The difference between the without-project WQ load or concentration condition and the pollutant threshold or WQ standard that must be met to achieve the desired outcome.
Fraction of challenges addressed	Number of WQ challenges affected by activity	Number of WQ challenges meaningfully affected by the activity via full or partial attainment of the desired WQ outcome.
	Number of WQ challenges caused by land use	The total number of WQ challenges linked to the landscape or land use. Legacy pollutants can be included in this total if they are a primary pollutant of concern.

References

WRI (World Resources Institute), LimnoTech, and TNC (The Nature Conservancy). Forthcoming. *Water Quality Benefit Accounting (WQBA): Standardized Methods for Quantifying Water Quality Benefits of Water Stewardship Activities*.