Appendix N

Tiered Risk Assessment Management (TRAM): water quality end use standards for harvested stormwater for non-potable uses

N.1 Tiered Risk Assessment Management (TRAM): water quality end use standards for harvested stormwater for non-potable uses

This work was commissioned by the District of Columbia Department of the Environment (DDOE) to provide a frame work for applicants to follow when proposing a non-potable use of harvested stormwater runoff to comply with site stormwater retention regulations. Suggested water quality standards are drawn from a literature review of the field and rely largely on international guidance developed in Australia and the United Kingdom, guidance has also been drawn from the State of Texas and from the California County of Los Angeles. The proposed application process presented here requires the assessment of contaminates of concerns based on the collection surface(s), along with an assessment of the public health threat for categories of microbial and chemical contaminants. Under this scheme, an applicant is required to consider the potential risk of exposure and related magnitude of human health impacts with exposure. A tiered risk assessment-management (TRAM) approach is provided to evaluate site conditions and determine treatment level if needed. If treatment is required this guidance provides a procedure for evaluating any remaining public health risk (residual risk) at the time of the commissioning of treatment practices, as well an on going procedure to ensure those practices meet public health standards throughout their maintenance and operation.

N.2. Health Risks

Rainwater collection systems have a long history going back as far as 3000 BC in India. It was used widely for agriculture throughout South East Asia over 2,000 years ago and in early Rome rainwater harvesting systems provided central air conditioning. Although rainwater harvesting has a significant and successful history, its popularity has declined as the large urban central water distribution system has grown. The return to rainwater harvesting in current times is driven largely by two factors, water scarcity and pollution of receiving waters. However, as we reconsider the collection of stormwater for non-potable uses, we must also recognize thiscan pose health risks. Health risks are due to two principal categories of contaminants—pathogenic microorganisms and toxic chemicals. Although both categories of contaminants need to be evaluated to ensure public health will be protected, microorganisms will typically pose the greatest health risk at most sites where stormwater is harvested for non-potable uses. Microbial hazards include bacteria, viruses, protozoa, and—to a lesser extent—helminthes. Chemical hazards can include inorganic and organic chemicals, pesticides, potential endocrine disruptors, pharmaceuticals, and disinfection byproducts. Proposals for stormwater harvested for non-potable uses submitted to DDOE will require an assessment of the public health threat for both categories of contaminants. This assessment starts with an analysis of the likelihood of exposure and can proceed through risk-based screening to determine if stormwater harvested for non-potable uses will pose a threat to public health.

DDOE cannot anticipate all site conditions within the wide spectrum of projects that may be proposed to harvest stormwater for non-potable uses to comply with District of Columbia stormwater regulations. For this reason, DDOE has developed a tiered risk assessment-management (TRAM) approach that applicants shall follow. Formal risk assessments can be costly, time consuming, and—for many stormwater projects—unnecessary. DDOE developed the TRAM approach to reduce the cost and level of effort associated with preparing the submission of a Stormwater Management Plan (SWMP) that incorporates stormwater harvesting for non-potable uses. The TRAM approach is based on the concept that increasing levels of sophistication, level of effort, and cost of a risk assessment only need to be considered as site conditions warrant. From a risk management perspective, the overarching goal in any project proposing to harvest stormwater for non-potable uses is to demonstrate that public health will be protected when the stormwater project is fully operational.

In addition to providing a cost-effective approach for making risk management decisions, the TRAM approach can be used to identify the most cost-effective risk mitigation strategy (should it be necessary). The two types of health risks planners must consider are maximum risk (posed by untreated stormwater) and residual risk (posed by treated stormwater).

Maximum risk is defined as the risk associated with maximum exposure to untreated stormwater. It is the risk posed by stormwater under the intended non-potable use prior to any preventive measure to disinfect or otherwise decontaminate stormwater. Estimating the maximum risk is necessary for DDOE to issue a permit, and it must be based on the specific exposures that are reasonably anticipated for the untreated stormwater. High-priority contaminants significantly contributing to the maximum risk should be the primary focus if a treatment plan is required. If the maximum risk is acceptable, no treatment of collected stormwater is necessary. However, if the maximum risk exceeds acceptable levels, stormwater must be treated to reduce health risks to acceptable levels.

DDOE will not be prescriptive with regard to the technology selected to protect public health. However, the threshold criterion for approving a SWMP with harvest for non-potable uses system is ensuring public health will be protected.

DDOE will make a determination on the effectiveness of the risk reduction strategy based on the magnitude of the second type of risk—namely, residual risk. Residual risk is defined as the risk remaining after stormwater has been treated based on the specific types of human exposure associated with the intended stormwater reuse.

For permitting purposes, DDOE will require proof that the residual risk from both microbial and chemical contaminants will be reduced to acceptable levels. The magnitude of residual risk is dependent on the magnitude of the maximum risk (the pretreatment risk) and the efficiency of the risk mitigation technology selected for the project.

N.3 Evaluating the Threat to Public Health

The threat to public health is a function of two site-specific criteria—namely, the likelihood of exposure and the magnitude of health risks associated with site-specific exposure conditions. Tables 1 through 3 present a useful matrix that planners can use to evaluate these two primary criteria during project planning. Proposed plans submitted to DDOE should be based on the classification scheme presented in these tables because it will streamline both the process of planning a stormwater project and DDOE's review of the submitted plans.

Table 1 presents three categories for determining the likelihood of exposure. For some stormwater programs, human exposures will only occur under unusual site conditions. For example, in closed systems where contact with collected stormwater is not anticipated (unless there is a breach in the system), the likelihood of exposure would be classified as unlikely. Under these conditions, stormwater use would not pose a health threat and a treatment system would be unnecessary.

Where exposures are classified as possible or likely, a more detailed analysis of potential maximum health risks for the untreated stormwater will be required. An applicant will identify all proposed collection surfaces to determine potential contaminates of concern (COC). If collection surfaces include any existing surfaces, i.e. contributing drainage areas that exist pre-project will remain as part of the final development and will contribute to the proposed rainwater harvest system, sampling of those site conditions maybe required to identify COC.

When sampling existing surfaces that are proposed to contribute to the rainwater harvesting system in the proposed development contaminant levels in these samples will be compared with risk-based levels that DDOE has derived for a select group of chemicals. Samples will also be screened for microbial threats. Table 2 presents three categories of risks that roughly characterize maximum risk. Whether stormwater treatment is necessary will depend on the magnitude of maximum risk, which will be quantified with a risk-based screening approach. When contaminant levels are equal to or less than the risk-based levels, the maximum risk is classified as low or acceptable, and stormwater can be used without any treatment. When contaminant concentrations in stormwater are less than ten-times the risk-based concentration, the maximum risk is characterized as minor and DDOE will use its discretion to decide whether treatment is necessary.

Table 3 shows the matrix of all possible outcomes for the combined evaluation of the likelihood of exposure and magnitude of health risks. These represent the classification of the health threat. Treatment technologies will not be required for stormwater harvesting projects posing a low threat. DDOE will use professional judgment to determine if moderate threats require a treatment system. Treatment systems will be required for high threats to public health.

Finally, all proposals shall present an analysis of both intended and unintended uses and exposures. While these situations may be rare and unique, they could pose a high risk to a small number of individuals. This could include inadvertent cross connections with drinking water systems and maintenance personnel or children being unintentionally exposed to untreated stormwater. Rainwater harvest proposals should identify how those unintended uses and exposures will be avoided. Some examples of protective measures include backflow protectors, use of purple pipes and identification stamps, water coloring and signage.

Table 1. Likelihood Exposure Will Occur

DESCRIPTOR	DESCRIPTION OF LIKELIHOOD
Unlikely	Exposure could occur only in unusual circumstances
Possible	Exposure might occur
Likely	Exposure will probably occur

Table 2.Magnitude of Health Risk

DESCRIPTOR	RISK
Insignificant	Low or Acceptable Levels
Minor	Minor
Severe	Major

Table 3.Characterizing Threat to Public Health

LIKELIHOOD OF EXPOSURE	MAGNITUDE OF PUBLIC HEALTH THREAT		
	Insignificant	Minor	Severe
Unlikely	Low	Low	Low
Possible	Low	Moderate	High
Likely	Low	Moderate	High

N.4 Applying the Tiered Risk Assessment-Management Approach

DDOE's intent in developing the TRAM approach is to expedite the permitting process and keep investigative costs to a minimum. It is based on the concept that the complexity of investigations should match the complexity of the site and conditions of exposure. DDOE will only require that sufficient information be presented to satisfy the requirement that public health is protected. The level of effort necessary to verify this threshold will depend on site-specific characteristics, which will vary from site to site.

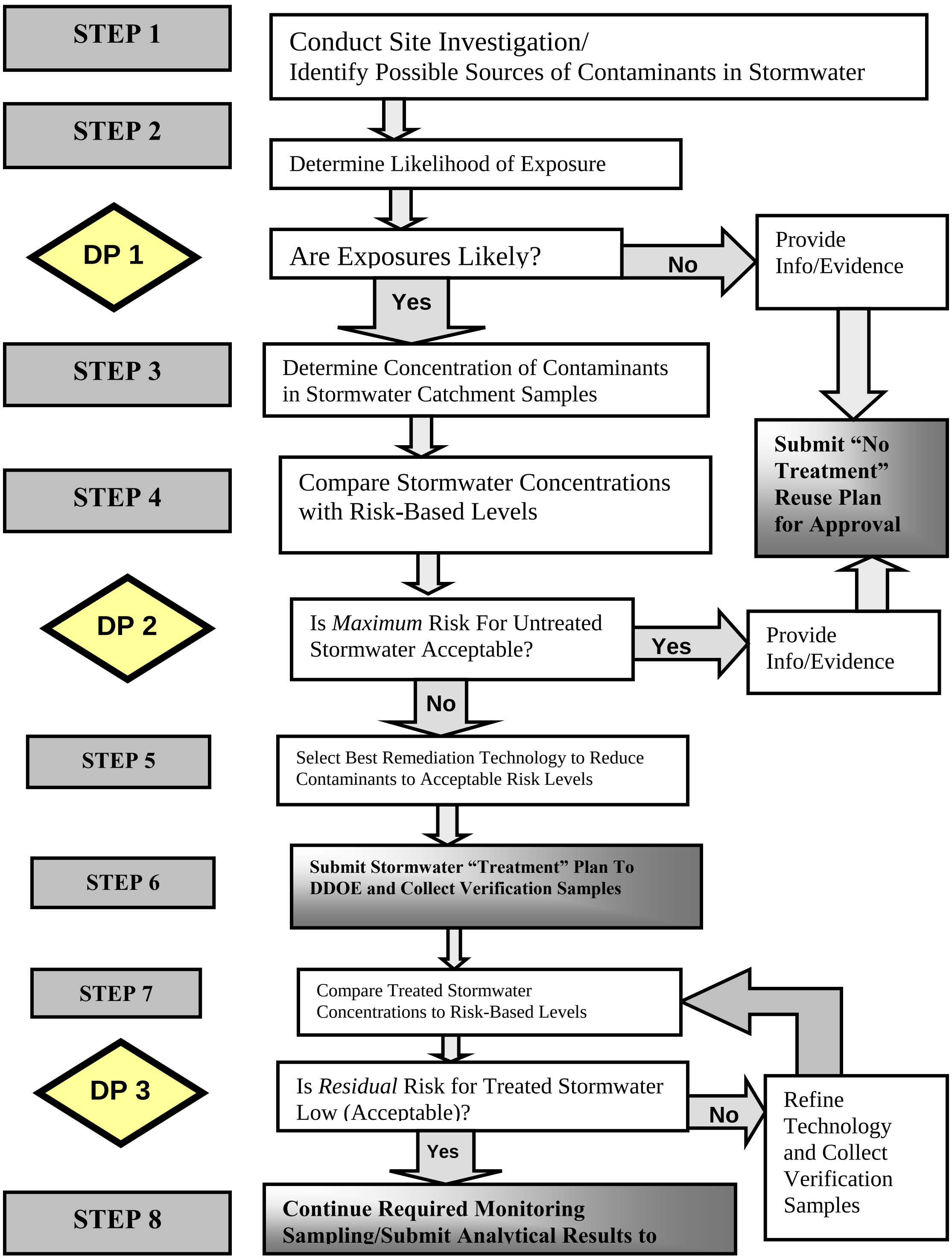
The TRAM approach is presented in a risk assessment-management decision-making framework. Although there are a total of nine steps in this process, proposed plans need only present sufficient analyses to demonstrate public health will be protected. For many sites, the entire nine-step process will not be needed to demonstrate exposure to treated or untreated stormwater will pose low risks. A determination regarding the appropriate course of action can often be made in the first four steps. DDOE believes that the most cost-effective approach for project teams is to follow the TRAM, so the complexity, level of effort, and costs of investigation will be a direct function of the site-specific conditions instead of a one-size-fits-all prescribed approach.

Figure 1 presents the TRAM decision-making framework. There are two important features of this framework that make it cost effective. First, investigative costs (including sampling and analysis) can be minimal for sites where there will be no human exposures to stormwater. Second, there are several exit points in the nine-step process at which investigations can be terminated and the proposed plan submitted to DDOE. The overall goal of the TRAM approach is to identify priorities as early as possible in the process to ensure public health will be protected. This requires the following:

- Identifying and documenting contaminant hazards and hazardous events;
- Estimating the likelihood that a hazardous event will occur;
- Estimating the consequences of the hazardous event occurring;
- Characterizing the overall risk by combining the hazards and hazardous events with their likelihood and consequence.

Depending on the complexity of the site, these requirements may necessitate the following assessments:

- Initial screening-level risk assessment;
- An assessment of the maximum risk (in the absence of preventive measures);
- An assessment of the residual risk (in the presence of preventive measures).


STEP 1
Conduct Site Investigation/
Identify Possible Sources of Contaminants in Stormwater
STEP 2
Determine Likelihood of Exposure
DP 1
Are Exposures Likely?
No
Provide
Info/Evidence
Yes
STEP 3
Determine Concentration of Contaminants
in Stormwater Catchment Samples
Submit "No
Treatment"
Reuse Plan
for Approval
STEP 4
Compare Stormwater Concentrations
with Risk-Based Levels
DP 2
Is Maximum Risk For Untreated
Stormwater Acceptable?
Yes
Provide
Info/Evidence
No
STEP 5
Select Best Remediation Technology to Reduce
Contaminants to Acceptable Risk Levels
STEP 6
Submit Stormwater "Treatment" Plan To
DDOE and Collect Verification Samples
STEP 7
Compare Treated Stormwater
Concentrations to Risk-Based Levels
DP 3
Is Residual Risk for Treated Stormwater
Low (Acceptable)?
No
Refine
Technology
and Collect
Verification
Samples
Yes
STEP 8
Continue Required Monitoring
Sampling/Submit Analytical Results to

STEP 1: Conduct Site Investigation

The goal of the initial site investigation is to identify potential contaminants that could enter the stormwater catchment and to characterize potential human exposures. This information will be used as the baseline investigation for subsequent steps in the TRAM approach. At minimum, the proposed plan should provide a general description of the site and any potential chemical or microbial contamination that may be present. Information should include:

- Site location and map showing all the properties within the proposed stormwater catchment system, in the simplest scenario this identification is the proposed roof area
- Zoning classification of all properties contributing to the stormwater catchment
- Total acreage of the stormwater catchment for the stormwater project
- Description of site property and surrounding areas based on available data and information. In the simplest scenario this is limited to an identification of the proposed roof materials and roof characteristics
- Description of any portion of the site regulated under the Resource Conservation and Recovery Act (RCRA), Superfund Program, or any other environmental investigation by the District of Columbia or the Environmental Protection Agency
- The current status of any ongoing or unresolved Consent Orders, Compliance Agreements, Notices of Violation (NOV), or other activities
- Schematic showing the location of sewer manholes
- Location of any obvious chemical spill residue (e.g., discolored soil, die-back of vegetation, etc.)
- Location of all aboveground or underground storage tanks
- Planned future uses of the site

If the site is zoned industrial, and the proposed catchment area contains surfaces other than the a proposed roof area, it will be necessary to conduct a more robust baseline investigation than for other types of properties to determine if chemical or microbial contamination is present. For sites zoned industrial, all potential chemical contaminants that were used, stored, or released on the property should be identified.

On sites where the catchment area includes surfaces beyond a proposed roof the receiving environment for all stormwater in the catchment must be characterized. All sources of variation due to seasonal and diurnal effects, as well as major rain events, must be characterized. This baseline information is very important because it provides a point of reference for evaluating untreated stormwater. It will also be important to determine whether validation and/or verification sampling or monitoring is warranted.

Stormwater contaminants detected in catchment can be due to both roof water runoff and contamination of soil within the area stormwater will be collected. Therefore, when existing roof areas and other existing surfaces will contribute to the proposed rainwater harvest system the existing roof systems must be inspected, and land use must be characterized as part of the proposal process.

Some of the important roof characteristics include the following:

- Whether vehicular traffic is allowed (i.e., parking structures)
- Whether there are overflow or bleed-off pipes from roof-mounted appliances, such as air conditioning units, hot water services, and solar heaters that will contribute to the collection area
- Whether any flues or smoke stacks from heaters, boilers, or furnaces could have contaminated roof surfaces
- Whether the roof is covered with lead flashing or exposed areas painted with lead-based paints
- Whether the roof is covered with a vegetated roof system

A short narrative of how the property has historically been used should also be provided if the proposed collection areas include existing land surfaces and information is available. This land use description is very important because some land uses have been shown to be associated with high contaminant levels. Land uses of particular interest include the following:

- Industrial land uses can result in either widespread or point sources of contamination due to organic compounds and/or inorganic metals
- Runoff from major roads and freeways with high traffic volumes can contain relatively high levels of hydrocarbons and metals (particularly, lead)

- Residential areas that experience frequent sewer overflows

Plans should describe how the stormwater will be collected, stored, and used. This will provide important exposure information necessary to estimate potential threats to public health. At minimum, the plan should provide:

- How stormwater will be collected
- The total amount of stormwater that will be collected from each source (roof water, parking lots, etc.)
- How stormwater will be stored (aboveground cistern, belowground storage tank, etc.)
- Description of the end use(s) of stormwater (municipal irrigation, spray fountain, pool, etc.)
- List of all types of individuals who could potentially be exposed to stormwater under the intended use(s) (e.g., landscapers, maintenance workers, children, joggers, etc.)
- Age groups for all types of exposed individuals (e.g., children, adults, elderly)
- Estimated time (e.g., hours, days, years) each type of individual could be exposed to stormwater under its intended use
- List of activities the exposed individuals will be engage in onsite (recreational, sports, gardening, etc.)
- Type and routes of exposures for all exposed individuals (ingestion of sprays during irrigation, ingestion during car wash, ingestion of fruit and vegetables irrigated with stormwater, etc.)
- List of potential exposures associated with unintended stormwater uses (system malfunction, cross plumbing, etc.)
- List of sensitive populations that may be exposed (children, infirm, invalid, etc.)

The above information will form the basis for determining the likelihood of exposure in the next step and will also be used to characterize specific exposure conditions and routes of exposure in subsequent steps.

STEP 2: Determine Likelihood of Exposure

One of the basic tenets of risk assessment states that, "Where there is no exposure, there is no risk." This truism is applicable even for sites where chemical or microbial contamination is elevated. Accordingly, the first step in the investigation for all stormwater projects is to determine the likelihood of exposure. As was indicated in Table 1, exposures can be characterized as unlikely, possible, or likely based on reasonable assumption. That is, DDOE's threshold will not be based on the *possibility* that exposures could occur, but rather on whether it is *plausible* exposures will occur. Information presented in Step 1 should form the basis for this determination. Making a determination that exposures are unlikely in this step is very important because no stormwater decontamination or disinfection will be required for those projects where exposure is unlikely. Untreated stormwater can be used as it was collected in these cases.

To make a determination that exposures are "unlikely" requires an evaluation of both intended and non-intended exposures. An example of unlikely exposure conditions would be a closed system with no intended exposures and less than ~ 50 unintended exposure events per year involving less than 1 milliliter exposure per isolated event. System malfunctions (breaches in the system, pipe bursts per year, tank leakage, cross connections, etc.) are the most likely types of unintended exposures. Likelihood of exposure should be based on the specific end use and the types of individuals who will visit the site.

DECISION POINT #1: Are Exposures Likely?

If the information submitted to DDOE is sufficient to support a determination that exposures are "unlikely," no further study or analysis is required. This is the first exit point in the TRAM process (as was indicated in Figure 1). On the other hand, if exposure is "likely" or "possible," the investigation must proceed to the next step.

STEP 3: Determine Concentration of Contaminants in Stormwater

When human exposures are likely or possible, the maximum risk must be evaluated based on the concentration of both chemicals and pathogenic organisms. The maximum risk represents the threat to public health associated with potential exposures to untreated stormwater.

All chemicals identified and qualitatively evaluated in Step 1 should be targets in the sampling plan. If the catchment area in which stormwater will be collected is zoned industrial, it is possible that those chemicals identified in the baseline investigation may have contaminated roof water, surface soil, or pavement. For areas considered open space or recreational properties, sampling for chemical contamination can be limited to pesticides.

Table 4 lists chemicals typically associated with industrial operations, as well as common pesticides. Pathogenic microbes may also be present in collected stormwater, and Table 4 lists the three primary categories of microbial threats to human health, which are bacteria, viruses, and protozoa. Stormwater samples collected in this step should represent the conditions that will occur during a major rain event. Note, however, that the concentrations of chemicals and microbes will be lower after a major rain event compared with a minor rain event due to the dilution effect. Planning for the stormwater sampling event should take into account roof, soil, and solid surface contributions to the stormwater catchment system. All samples submitted for laboratory testing should represent, as closely as possible, the conditions in which untreated stormwater will be stored and used at the site. For example, if collected stormwater will be stored in a cistern shielded from light for several days before it is used, the samples sent for laboratory analysis should be stored under the same conditions (i.e., same temperature under dark conditions to assess growth of microbial pathogens). After replicating site storage conditions, all samples should be sent to an EPA-approved laboratory for analysis of all chemicals of interest identified in the baseline investigation.

The sampling locations and number of samples collected at this stage should be based on the size of the catchment area and sources of potential contamination. For example, a non-industrial site totaling 2 to 3 acres with only one storage cistern could be adequately represented by taking a minimum of three samples at timed intervals over a holding time of 4 to 5 days. At the other end of the spectrum, a 10-acre site located in an industrial area with several storage cisterns spread out over the site may require sampling from each cistern after moderate and major storm events. Regardless of the type of site, DDOE encourages implementation of the most cost-effect approach as the goal is not to fully characterize the site for potential contamination, but rather to determine if the contaminants in collected stormwater pose a health threat.

Sampling results generated in this step should be evaluated in the risk-based screening comparison described in the next step.

Table 4. Chemicals of Interest for Baseline Investigations

Inorganic Metals		
Aluminum	Chromium	Selenium
Arsenic	Iron	Silver
Barium	Manganese	Tin
Beryllium	Mercury	Zinc
Bromate	Molybdenum	
Cadmium	Nickel	
Organic Compounds		
Acrylamide	Hexachlorobutadiene	Trichloroethylene
Benzene	Polyaromatic hydrocarbons	Trichloroethane
Carbon tetrachloride	Polybrominated biphenyls	Trichloroethene
Chlorobenzene	Polychlorinated biphenyls	Vinyl chloride monomer
Benzo[a]pyrene	Tetrachloroethene	Xylene
Epichlorohydrin	Toluene	
Ethylbenzene	Trichlorobenzenes	
Pesticides		
Aldicarb	Chlordane	
Aldrin	Diazinon	
Atrazine	Heptachlor	
Pathogenic Microbes		
Bacterium: *E. coli*		
Protozoan: *Cryptosporidium parvum*		

STEP 4: Compare Stormwater Concentrations with Risk-Based Levels

To determine whether exposure to untreated stormwater is a public health threat, maximum risk must be assessed. Determining whether stormwater exposures will pose a threat does not require that a formal risk assessment be conducted. Risk assessments can be costly and time consuming to prepare. Instead, it will only be necessary to apply risk-based screening, and DDOE has even simplified this step. Screening involves a simple comparison of the chemical and/or microbial concentrations detected in untreated stormwater (in the previous step) with acceptable risk-based screening levels. Risk-based concentrations represent safe exposure levels for chemical or microbial contaminants. They are derived based on the frequency of exposure, amount ingested, and the inherent toxicity of each contaminant.

Table 5 lists different types of stormwater use that DDOE anticipates in the District. For each stormwater use, there could be several types of exposure conditions that vary in exposure intensity and duration. For example, individuals engaged in high-intensity sports (e.g., baseball, football, soccer, etc.) would have greater exposures to contaminants in stormwater used for irrigation at a municipal park than would someone walking a pet.

Table 5. Types of Stormwater Use and Routes of Exposure

STORMWATER USE	ROUTE OF EXPOSURE ASSOCIATED WITH	GENERAL DESCRIPTION OF EXPOSURE CONDITIONS
Home lawn or garden spray irrigation	Ingestion of aerosol spray	Typical watering every other day during half year
	Ingestion after contact with plants/grass	Routine indirect ingestion via contact with plants, lawns, etc.
	Accidental ingestion of stormwater	Infrequent inadvertent ingestion.
Open space or municipal park drip or spray irrigation	Ingestion via casual contact—picnic, walking pet	Infrequent contact with wet grass, picnic tables
	Ingestion via low-intensity sports—golf, Frisbee	Typical contact with irrigated plants/grasses
	Ingestion via high-intensity sports—baseball, soccer	Frequent contact with irrigated sports field
	Ingestion by child on playground	Frequent contact with wet surfaces and frequent hand-to-mouth activity
	Public fountain with spray element	Indirect and infrequent ingestion of spray
	Public fountain with standing pool	Infrequent ingestion of pool water during hot days

Home garden drip or spray irrigation	Ingestion of irrigated vegetables and fruit	Typical ingestion of small home garden seasonal produce
Commercial farm produce drip or spray irrigation	Ingestion of irrigated vegetables and fruit	Typical ingestion of regional commercial produce
Home car wash spray application	Ingestion of water and spray	Once a week car wash for 6 months
Commercial car wash spray	Ingestion of water and spray	Car wash operator exposed 5 days per week
Toilet	Ingestion of aerosol spray	Flushing 3 times per day
Washing machine use	Ingestion of sprays	Ingestion from 1 load per day
Fire fighting	Ingestion of water and spray	Firefighter assumed exposed 50 events per year
Swimming pools	Ingestion of water	Ingestion during swimming every other day for half year

Table 6 lists the exposure assumptions that represent different types of stormwater use and the corresponding typical exposure conditions for each use. Project planners should identify the appropriate exposure conditions in this table that most closely match site-specific conditions. Stormwater use and the site-specific exposure conditions correspond to specific assumptions regarding how individuals will come in contact with untreated stormwater. The two most important criteria are the number of days contact is expected to occur and the volume of stormwater that will be ingested on each of those days.

For example, the first row indicates that an individual watering a lawn or garden is assumed to do so every other day for 6 months and will ingest 0.1 ml of stormwater each time the lawn is watered. While DDOE anticipates that these exposure assumptions will represent the majority of sites, a small number of reuse projects may be unique, and DDOE should be contacted to discuss unique sites. For these projects, planners should either contact DDOE directly to discuss alternative exposure assumptions or select an exposure scenario that is intentionally conservative. Although this may be an overly protective approach, such a comparison would be sufficient proof for DDOE that public health will be protected if the site passed the risk-based screen test.

Table 6. Exposure Assumptions Based on Stormwater Use and Exposure Conditions

STORMWATER USE	ROUTE OF EXPOSURE ASSOCIATED WITH	EXPOSURE ASSUMPTIONS	
		VOLUME INGESTED (mL)	DAYS (per year)
Home lawn or garden spray irrigation	Ingestion of aerosol spray	0.1	90
	Ingestion after contact with plants/grass	1	90
	Accidental ingestion of stormwater	100	1
Open space or municipal park drip or spray irrigation	Ingestion with casual contact-picnic, walking pet	0.1	32
	Ingestion with low intensity sports-golf, Frisbee	1	32
	Ingestion high intensity sports-baseball, soccer	2.5	16
	Ingestion child playground	4	130
	Public fountain with spray element	0.1	130
	Public fountain with standing pool	4	130
Home garden drip or spray irrigation	Ingestion of irrigated vegetables and fruit	7	50
Commercial farm produce drip or spray irrigation	Ingestion of irrigated vegetables and fruit	10	140
Home car wash spray application	Ingestion of water and spray	5	24
Commercial car wash spray	Ingestion of water and spray	3	250
Toilet	Ingestion of aerosol spray	0.01	1100
Washing machine use	Ingestion of sprays	0.01	365
Fire fighting	Ingestion of water and spray	20	50
Swimming pool	Ingestion of water	200	90

It should be stressed that although EPA and several state regulatory agencies have developed RSLs (EPA RSLs available at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/equations.htm), these should not be used for stormwater projects. These RSLs apply only to potable drinking water and, because they are overly conservative, many stormwater projects would fail the screen. Stormwater collected in the District should never intentionally or unintentionally be used as a potable drinking water source. Therefore, EPA's RSLs for drinking water, which are based on the assumption that a child and an adult will drink 1 and 2 liters of water per day, respectively, are not applicable to stormwater reuse projects. Furthermore, the drinking water RSL assumes an individual will drink the water 350 days per year for 30 years. This corresponds to 350 to 700 liters of water consumed per year, which is 500 to 1,000 times the amount of stormwater that will be ingested for most projects (as shown in Table 6). Clearly, drinking water exposure assumptions do not represent typical stormwater reuse exposures and should not be used to screen for the maximum risk.

DDOE has made the risk-based screening step easy to use by evaluating the exposure conditions presented in Table 6, ranking the intensity of each type of exposure and grouping exposures with similar intensity into one of four categories: severe, high, medium, or low. The exposure scenarios (listed in Table 6) for each of these categories are presented in Table 7.

Table 7. Categorizing exposures based on stormwater use: Severe, High, Medium, and Low

EXPOSURE CLASSIFICATION	STORMWATER USE	ROUTE OF EXPOSURE
SEVERE	Swimming pools	Ingestion of water
HIGH	Commercial farm produce drip or spray irrigation	Ingestion of irrigated vegetables and fruit
	Fire fighting	Ingestion of water and spray
	Commercial car wash	Ingestion of water and spray
MEDIUM	Open space or municipal park drip or spray irrigation	Ingestion by child on playground
	Open space or municipal park drip or spray irrigation	Public fountain with standing pool
	Home garden drip or spray irrigation	Ingestion of irrigated vegetables and fruit
	Home car wash spray application	Ingestion of water and spray
	Home lawn or garden spray irrigation	Accidental ingestion of stormwater
	Home lawn or garden spray irrigation	Ingestion after contact with plants/grass
LOW	Open space or municipal park drip or spray irrigation	Ingestion via high-intensity sports—baseball, soccer
	Open space or municipal park drip or spray irrigation	Ingestion via low-intensity sports—golf, Frisbee
	Open space or municipal park drip or spray irrigation	Public fountain with spray element
	Toilet	Ingestion of aerosol spray
	Home lawn or garden spray irrigation	Ingestion of aerosol spray
	Washing machine use	Ingestion of sprays
	Open space or municipal park drip or spray irrigation	Ingestion with casual contact—picnic, walking pet

Project planners should select one of these four categories that best represent site-specific conditions. The selection should be based on how stormwater will be used, who will contact the storm water, and by what route of exposure. For example, stormwater used to fill a swimming pool is ranked “severe” because the frequency of exposure combined with the high rate of ingestion of pool water while swimming is considerably greater than all other exposures. It should be noted that exposure assumptions for formal risk assessments are typically established with worst possible exposure assumptions. While the worst exposure may be hypothetically possible, DDOE expects projects to rely on realistic and common sense expectations. For this reason, detailed and complex “future exposure analyses” are unnecessary. Proposals need only submit sufficient information to allow DDOE to convey to the public that a thorough analysis has been performed and that public health is being protected.

Although exposure assumptions are typically based on broad “what if” hypothetical scenarios in formal risk assessments, DDOE encourages proposals that are based on realistic expectations to determine the most likely threats to public health. DDOE recognizes that, in many cases, the anticipated exposure conditions will be based on subjective judgment rather than on a detailed complex “future hypothetical exposure” analysis. Accordingly, proposals need only submit sufficient information to show that all potential exposures have at least been considered. This will allow DDOE to convey to the public that a thorough analysis has been performed and that public health is being protected.

In addition to the obvious and planned stormwater use, proposals must also consider inadvertent or unauthorized use of stormwater. That is, while the major focus should be on the intended uses, it is important to consider exposures that could result from inadvertent use of untreated stormwater as it may result in higher-than-intended exposure to humans and the receiving environment. For example, even though the intended use of strormwater may be for non-drinking purposes, such as irrigation of parks and gardens, people may occasionally drink from a recycled water tap by accident. Obviously, a failsafe system should be put in place to prevent this from occurring. However, preventive measures can sometimes be circumvented, and the plan should evaluate the exposure as a low-probability event to determine the magnitude of the potential threat to public health in the event of occurrence.

DDOE has derived RSLs for all the chemicals that are routinely detected in environmental media, particularly at industrial sites, which were presented in Table 4. It is impractical to derive RSLs for all possible combinations of chemicals and for all stormwater uses and exposure conditions, but this list should be the starting point for sampling efforts. However, if the baseline investigation provides sufficient evidence that chemical contamination at the site is unlikely, sampling may be unnecessary. DDOE recognizes that sampling and laboratory analyses can be expensive and time consuming and may not be warranted. For example, if the property is currently and has always been zoned for residential use, there may be no reason to suspect a chemical release has occurred. In this situation, the planner could submit the baseline investigation and justification for a waiver to sample, which DDOE would review and consider.

The RSLs that should be used for risk-based screening are presented in Table 8. These levels represent the acceptable concentrations corresponding to either a cancer risk of 1E-6 or noncancer hazard index of 1.0. They correspond to the site-specific end use of the stormwater and exposure conditions as discussed previously. EPA's risk management framework states that a risk level between 1E-6 and 1E-4 is a discretionary range. The reason DDOE selected a risk-based screening level for cancer risk of 1E-6 is that it is likely that multiple chemicals will be detected for some projects. DDOE will use discretion in setting the acceptable "cumulative" risk level for projects where the individual contaminant levels slightly exceed the concentrations presented in Table 8.

To use the table, planners only need to identify the column that matches the site-specific exposure category and identify the row corresponding to the chemical of interest. That sample concentration is then compared with the RSL. If the sample concentration is below the RSL, it can be concluded stormwater does not pose a threat to human health, and no further action is necessary. If the sample concentration exceeds the RSL, the analysis must continue on to the next step in the TRAM process as described in the next section.

Table 8. Risk-Based Chemical Concentrations for Sites Categorized As Severe, High, Medium, and Low Exposures

Chemical (µg/L)	Drinking Water	Exposure Category			
		Severe	High	Medium	Low
Acrylamide	4.3E-02	1.6E+00	2.2E+01	5.8E+01	6.3E+02
Aldicarb	3.7E+01	1.3E+03	1.8E+04	4.9E+04	5.3E+05
Aldrin	4.0E-03	1.5E-01	2.0E+00	5.4E+00	5.8E+01
Aluminum	3.7E+04	1.3E+06	1.8E+07	4.9E+07	5.3E+08
Arsenic, Inorganic	4.5E-02	1.6E+00	2.3E+01	6.1E+01	6.6E+02
Atrazine	2.9E-01	1.1E+01	1.5E+02	3.9E+02	4.2E+03
Barium	7.3E+03	2.7E+05	3.7E+06	9.8E+06	1.1E+08
Benzene	4.1E-01	1.5E+01	2.1E+02	5.5E+02	6.0E+03
Benzo[a]pyrene	2.0E-01	7.3E+00	1.0E+02	2.7E+02	2.9E+03
Beryllium	7.3E+01	2.7E+03	3.7E+04	9.8E+04	1.1E+06
Bromate	9.6E-02	3.5E+00	4.8E+01	1.3E+02	1.4E+03
Cadmium	1.8E+01	6.7E+02	9.1E+03	2.5E+04	2.7E+05
Carbon Tetrachloride	4.4E-01	1.6E+01	2.2E+02	5.9E+02	6.4E+03
Chlordane	1.9E-01	6.9E+00	9.5E+01	2.6E+02	2.8E+03
Chlorobenzene	9.1E+01	2.7E+04	3.7E+05	9.8E+05	1.1E+07
Chromium	4.3E-02	4.0E+03	5.5E+04	1.5E+05	1.6E+06
Diazinon	2.6E+01	9.3E+02	1.3E+04	3.4E+04	3.7E+05
Epichlorohydrin	2.1E+00	8.0E+03	1.1E+05	2.9E+05	3.2E+06
Ethylbenzene	1.5E+00	5.5E+01	7.5E+02	2.0E+03	2.2E+04
Heptachlor	1.5E-02	5.5E-01	7.5E+00	2.0E+01	2.2E+02
Hexachlorobutadiene	8.6E-01	3.1E+01	4.3E+02	1.2E+03	1.3E+04
Iron	2.6E+04	9.3E+05	1.3E+07	3.4E+07	3.7E+08
Manganese	8.8E+02	3.2E+04	4.4E+05	1.2E+06	1.3E+07
Mercury	1.1E+01	4.0E+02	5.5E+03	1.5E+04	1.6E+05
Molybdenum	1.8E+02	6.7E+03	9.1E+04	2.5E+05	2.7E+06
Nickel	1.8E+03	6.7E+04	9.1E+05	2.5E+06	2.7E+07
Polybrominated Biphenyls	2.2E-03	8.0E-02	1.1E+00	3.0E+00	3.2E+01
Polychlorinated Biphenyls	5.0E-01	1.8E+01	2.5E+02	6.7E+02	7.3E+03
Selenium	1.8E+02	6.7E+03	9.1E+04	2.5E+05	2.7E+06
Silver	1.8E+02	6.7E+03	9.1E+04	2.5E+05	2.7E+06
Tetrachloroethylene	1.1E-01	4.0E+00	5.5E+01	1.5E+02	1.6E+03

Chemical (µg/L)	Drinking Water	Exposure Category			
		Severe	High	Medium	Low
Tin	2.2E+04	8.0E+05	1.1E+07	2.9E+07	3.2E+08
Toluene	2.3E+03	1.1E+05	1.5E+06	3.9E+06	4.3E+07
Trichlorobenzene	2.3	8.4E+01	1.2E+03	3.1E+03	3.4E+04
Trichloroethane	2.4E-01	8.8E+00	1.2E+02	3.2E+02	3.5E+03
Trichloroethane	9.1E+03	2.7E+06	3.7E+07	9.8E+07	1.1E+09
Trichloroethylene	2.0	7.3E+01	1.0E+03	2.7E+03	2.9E+04
Vinyl Chloride	1.6E-02	5.8E-01	8.0E+00	2.2E+01	2.3E+02
Xylene	2.0E+02	2.7E+05	3.7E+06	9.8E+06	1.1E+08
Zinc	1.1E+01	4.0E+02	5.5E+03	1.5E+04	1.6E+05

Stormwater projects must also include an evaluation of threats from microbial pathogens. Although this can be a complex investigation (there are many hundreds of different microbial pathogens), DDOE has developed a tiered approach to reduce time and costs based on the indicator pathogens *Escherichia coli* (*E. coli*) and *Cryptosporidium parvum* (*C. parvum*). With this approach, planners should first monitor for *E. coli* because it is less expensive to analyze than Cryptosporidium. *E. coli* is a termed a reference or indicator microbe because it is associated with human and wildlife fecal waste (it should be noted, however, that no simple statistical correlation exists between *E. coli* and human pathogen concentrations in stormwater*).* *C. parvum*, however, causes gastrointestinal illness that may be severe and sometimes fatal for people with weakened immune systems (which may include infants, the elderly, and individuals who have AIDs). It will only be necessary to monitor for *C. parvum* if the *E. coli* results exceed the RSLs presented in Table 9, if the stormwater storage system is large and at ground level, or stormwater is stored in a reservoir.

Table 9 presents RSLs for *E. coli* that are based on EPA guidance for swimming and wading (*Ambient Water Quality Criteria for Bacteria* (EPA440/5-84-002 January 1986). The current level that is acceptable for swimming and wading is 160 CFU/100mL, which corresponds to a risk of developing gastroenteritis of 8 in 1000 and is generally accepted as a safe level by local and state regulatory agencies. This formed the basis for the “severe” category and was also used to derive the RSL for the three other categories using the attenuated exposure assumptions presented in Table 6. For sites classified as severe exposures, the RSL should be interpreted to mean that when the site sample concentration for *E. coli* $\leq$ 160 CFU/100mL, the stormwater is safe for swimming or wading, and no further action is necessary for microbial contaminants. If this RSL is exceeded, however, samples must be collected for the next tier, which involves analyzing for *C. parvum*.

Unlike *E. coli,* no regulatory agency has yet to develop a safe level for *C. parvum* exposure. Although the EPA's recently revised new *Long Term 2 Enhanced Surface Water Treatment Rule* (LT2 rule; EPA 815-R06-006 February 2006) stresses the importance of monitoring for *C. parvum* to protect drinking water sources, no exposure-specific RSL is available. It should be noted, however, that DDOE's approach for monitoring microbial contaminants is similar to the strategy in the LT2 rule, because DDOE concurs with EPA that a tiered monitoring approach based on *E. coli* and *C. parvum* is the most cost-effective strategy for protecting the public from gastrointestinal illness.

Table 9 presents RSLs for each exposure category for *C. parvum.* These levels were developed based on the WHO approach using Disability Adjusted Life Years (DALYs); they are also consistent with the tolerable levels developed in *Australian Guidelines For Water Recycling: Managing Health And Environmental Risks (Phase 2) Stormwater Harvesting And Reuse* (July 2009) and are set at 1E-6 risk level.

Table 9. Risk-Based Microbial Levels for Sites Categorized As Severe, High, Medium, and Low Exposures

Chemical	**Swimming**	**Exposure Category**			
		Severe	**High**	**Medium**	**Low**
Microbial Pathogens (infectious units per L)					
Escherichia coli CFU/100 mL	126 [1]	126	1714	4615	50000
Cryptosporidium [2] (oocysts/L)	NA	0.001	0.016	0.033	0.320

[1] Ambient Water Quality Criteria for Bacteria (EPA440/5-84-002 January 1986). RSLs correspond to a risk level of 8 in 1000 of developing a gastrointestinal disease.

[2] Australian Guidelines for Water Recycling: Managing Health And Environmental Risks (Phase 2) Stormwater Harvesting And Reuse. July 2009. RSLs correspond to a 1E-6 risk level of developing a gastrointestinal disease.

The risk-based screening results for both chemicals and microbes are considered in the next step.

DECISION POINT #2: Is Maximum Risk for Untreated Stormwater Acceptable?

This step represents the important risk management decision point in the TRAM approach and it is dependent on the previous risk-screening comparison. The comparison of chemical and microbiological contaminant levels with RSLs is the only criteria needed to make this determination. This is a pivotal decision, since if the maximum risk is acceptable, no further investigation is necessary, stormwater treatment will not be required, and the proposed plan for no treatment can be submitted to DDOE for review. This represents the second exit point from the TRAM process.

On the other hand, if one or more contaminants fail the risk-based screen, action will generally be necessary to lower risks to an acceptable level. The magnitude of the exceedance will be the primary determinant for making risk management decisions. If the exceedance is less than one or two orders of magnitude, DDOE can exercise its discretion about the best path forward and whether a treatment system is necessary. DDOE will rely on factors such as availability of treatment systems, severity of the toxic effect, probability of exposures, and whether measures can be implemented to prevent exposures. DDOE's determination will ultimately be based on a cost-benefit evaluation, and the most effective remedy with the lowest cost will be selected.

If the appropriate remedy is treatment, planning should proceed to the next step.

STEP #5: Select Appropriate Treatment Technology to Reduce Contaminants to Acceptable Risk Levels

Selecting the appropriate remedy will depend on the type(s) of contaminant(s) posing the health threat. For microbial pathogens in small-to-medium sized stormwater projects, ultraviolet (UV) disinfection is the most practical and cost effect approach. Although chlorination may also be suitable, protozoa such as *C. parvum* will require a higher Ct value (disinfectant concentration × contact time) because inactivation is more difficult to achieve compared with that for bacteria and viruses.

If chemical contaminants pose an unacceptable risk, it must be determined whether they are soluble or are bound to particles. If they are particulate-bound, it may be necessary to reduce their concentration with filtration, flocculation, or other treatments that reduce suspended solids.

Proposed plans should present the type of treatment selected that will target specific chemical and/or microbial risks. Planning should proceed to the next step.

STEP 6: Submit Stormwater "Treatment" Plan to DDOE and Collect Verification Samples
Proposed plans should provide a full description of the treatment system that is selected to reduce contaminant levels. The operating efficiency and specifications are necessary because verification samples will be used to validate the system is operating as designed.

The design of a monitoring program will be specific to each project, but it should take into account both peak and average rainfall. The point of compliance will be the stormwater in the catchment rather than separate points across the property because the catchment water represents the average of all contributions because it is likely that one or more individual samples will fail risk-based screening. The extent of sampling required to verify the system is functioning properly will be project-specific with more extensive sampling required for projects where a greater number of individuals are exposed to chemicals that are considered more toxic. As a rule of thumb, projects classified as "severe" and "high" will require a slightly more complex sampling design. Also, projects that require a higher log reduction of contaminant levels will receive a greater degree of scrutiny.

STEP 7: Compare Treated Stormwater Concentrations with Risk-Based Levels
The log reduction necessary to achieve acceptable risk levels represents the difference between the maximum (untreated stormwater) and residual (treated stormwater) risk. Sample concentrations should be $\leq$ the target concentrations corresponding to the intended use and exposures, and those target goals are the same RSLs that were presented in Tables 8 and 9.

DECISION POINT #3: Is Residual Risk for Treated Stormwater Acceptable?

This step requires that a decision be made as to whether the treatment system efficiently reduced contaminant levels to acceptable concentrations. If the verification samples indicate the treatment system is performing as designed, the proposal should include the results and conclusions and proceed to the next step. As noted previously, DDOE will use discretion in determining whether the project meets the acceptable "cumulative" risk level for projects where the individual contaminant levels slightly exceed the concentrations presented in Table 8. For example, DDOE may determine that exceedances do not rise to a level requiring action if the number of potentially exposed individuals is very small. Additionally, DDOE may use its discretion to waive action when exceedance are less than an order of magnitude above risk-based screening levels.

If the treatment system fails to meet the design specifications and cannot achieve the required risk-based acceptable concentrations, the investigation must go back to Step 7 and repeat the subsequent steps of the TRAM process. This requires that either the selected treatment system be modified or an alternate technology selected.

Step 8: Continue Required Monitoring Sampling/Submit Analytical Results to DDOE

The purpose of a monitoring program is to confirm continued compliance with the required end use water standards. The applicant will submit a post construction monitoring program that will access the ongoing lifecycle compliance including annual verification of performance as well as performance verification after significant maintenance or modifications to the treatment system. Monitoring assesses:

- Overall performance of the systems harvesting stormwater for non-potable uses;
- Quality of the harvested stormwater being supplied or discharged;
- Changes in the receiving environment or exposed populations.

Ultimately, the goal of monitoring is to provide continued assurance that the treatment system is operating at levels specified in the permit and public health is being protected. For example, systems relying on UV radiation for disinfection would need to replace the UV source at pre-specified intervals, and monitoring should be conducted soon after the unit is replaced. The original proposal should present a detailed monitoring plan that anticipates routine maintenance or major modification to treatment systems. As a rule of thumb, greater emphasis on monitoring will be necessary for those projects where the exposed population is significant and/or the maximum risks associated with untreated stormwater are significantly above risk-based levels. This monitoring program will be part of the approved SWMP and detailed in the deed of covenants as part of the BMP's long term maintenance obligations.