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CCRD WHITE PAPER

EVALUATING ADAPTION OPTIONS: ASSESSING COST, EFFECTIVENESS, CO-BENEFITS, AND OTHER RELEVANT CONSIDERATIONS

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EVALUATING ADAPTION OPTIONS: ASSESSING COST, EFFECTIVENESS, CO-BENEFITS, AND OTHER RELEVANT CONSIDERATIONS

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CONTENTS

1. INTRODUCTION: CONTEXT AND OBJECTIVES

Defining an economic development path that is resilient to climate-associated risks requires that the array of applicable adaptation options be identified and then evaluated in terms of their respective pros and cons. The options need to be properly analyzed so that the most prudent and necessary suite of adaptations can be discerned and selected for implementation (and, conversely, so that less effective, more costly, or maladaptive options are avoided). The objective of this White Paper is to describe a process that enables users to evaluate adaptation options so that stakeholders in developing nations can more readily recognize the relative pros and cons of the alternatives and, thereby, better determine which option(s) are most suitable for implementation.

In the United States Agency for International Development (USAID) climate resilient development framework (Figure 1), the evaluation and selection of adaptation options occurs in the "design" stage. It is a critical step that follows the process of identifying possible adaptation options, and it comes before the "implement/manage" stage for the adaptations selected.

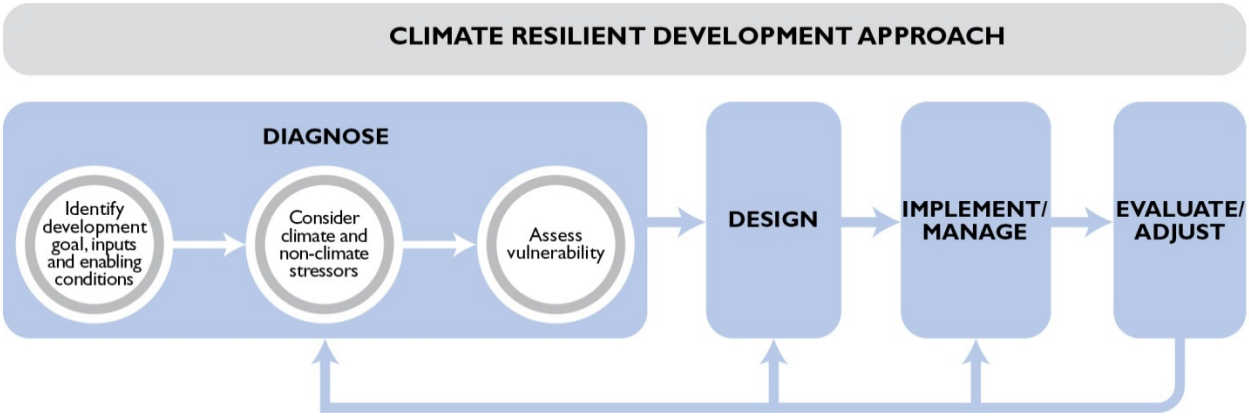

Figure 1. Climate Resilient Development Framework.

USAID has already developed valuable guidance and training materials that address the critical steps in the framework that precede the evaluation and selection of options. For example, USAID's guidance document, *Climate Resilient Development: A Guide to Understanding and Addressing Climate Change,* and the associated water annex, coastal annex, and vulnerability assessment annex facilitate the "diagnosis" phase. The water and coastal annexes also contain guides to potential "adaptation actions" so that stakeholders can readily identify some potentially applicable adaption options. These and other materials help users identify and assess climate-related vulnerabilities, and support their identification of potentially valuable options for adapting to and managing climate-related risks.

This White Paper lays out the path for developing the next step in the climate resilient development framework. It describes an approach for evaluating adaptation alternatives in order to ascertain which adaptation actions (if any) make the most sense for sustaining and supporting climate resilient development. In essence, the approach described in this White Paper is intended to guide practitioners working in developing nations by laying out a simple and logical process that encourages stakeholders to recognize and consider the key factors that typically define whether an adaption option (or suite of options) is likely be a

sound choice for their circumstances. It is intended to help users sort through and rank their options or, more generally, help them distinguish the better options from the lesser ones.

The balance of this White Paper is organized with the following sections:

2. Overview of the Proposed Evaluation Framework: Two Paths
3. Guiding Principles for the Evaluation Framework
4. Defining Criteria to Support the Evaluation
5. Practical Issues and Options for Applying the Evaluation Criteria
6. Sectorial Trial Applications of the Framework
7. Review of Existing Guidance and Associated Tools
8. Observations, Conclusions, and Suggested Next Steps

In addition, there are two appendices related to Section 6 that portray trial applications of the tiered screening approach to climate adaptation options in two different sectors.

2. OVERVIEW OF THE PROPOSED EVALUATION FRAMEWORK: TWO PATHS

The objective of this White Paper is to develop a practical framework to help development practitioners efficiently assess the general advantages and disadvantages (e.g., costs, benefits, and effectiveness) of potential adaptation options. The ultimate goal is to contribute to the user's ability to distinguish and select the adaptation options most suitable for their circumstances.

The evaluation approach developed here provides two different evaluation pathways, to accommodate realities that often arise in the development context. One pathway facilitates an expedited review, so that adaptation options can be quickly screened and ranked via a simple process that recognizes data and time limitations, and other constraints that often apply. However, in instances where the simple screening process may not provide an adequate assessment of adaptation options (e.g., where costs are high, uncertainties large, important co-benefits or external costs exist, and/or significant irreversibilities might arise), then a second evaluation pathway is described to facilitate a more suitable and in-depth assessment.

To illustrate how the process is designed to function from the outset, the logic-driven flow diagram depicted in Figure 2 reveals that users start with a quick and simple initial screening exercise to determine if some adaptation options can be quickly discarded from consideration (e.g., because they are identified as irrelevant, impractical, or undesirable). This is referred to as the "Tier 1" screening. As described in greater detail in Section 4 below, Tier 1 focusses on a quick assessment of the cost, feasibility, and effectiveness of the relevant adaptation options being considered. Discarded options get set aside in the rose-colored box (but can and should be reconsidered if time horizons, circumstances, or other relevant factors change).

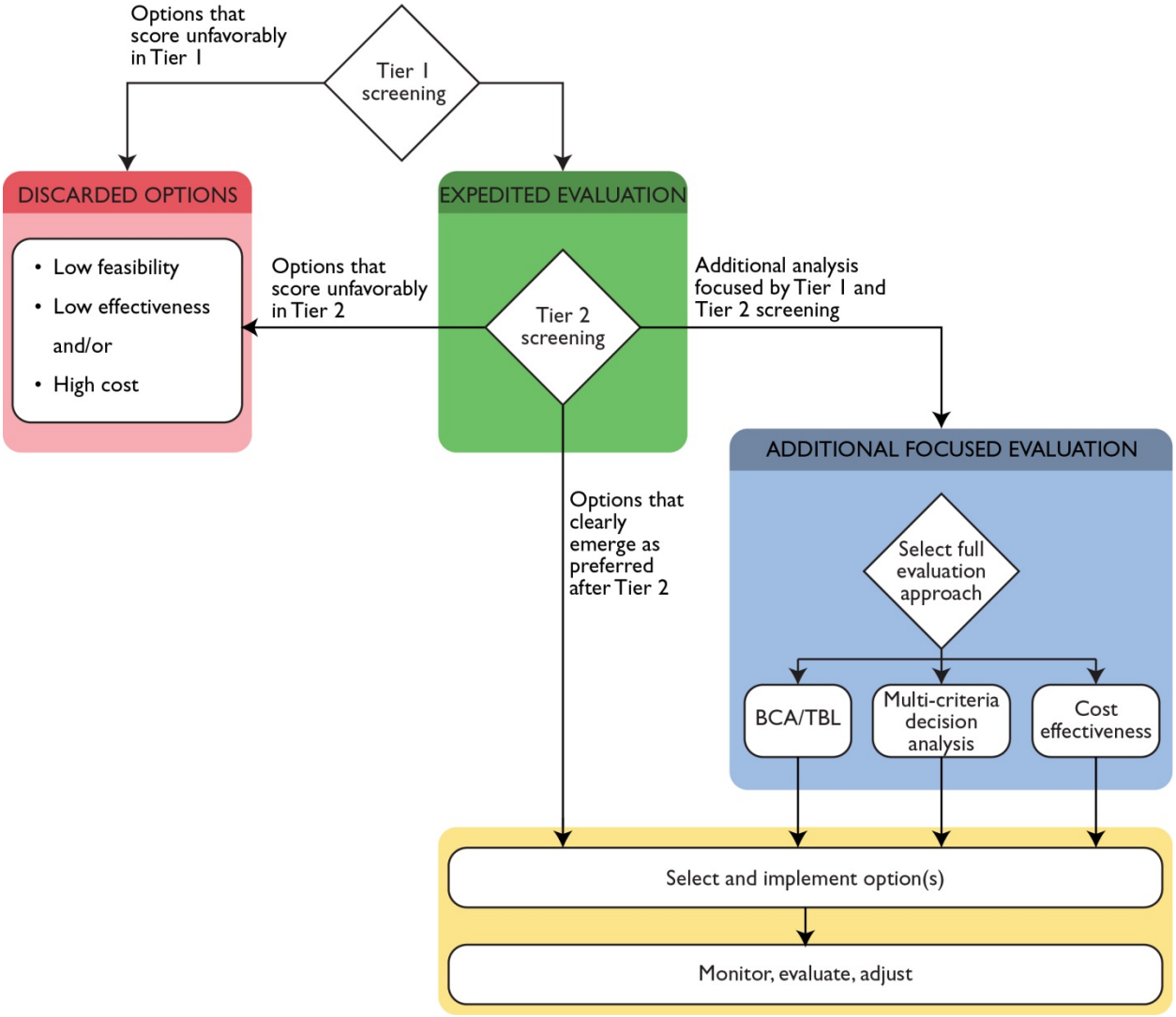

Figure 2. Overview of the Evaluation Process: Accommodating an Expedited Pathway as Well as Indicating Where an Additional, Focused, and More In-depth Assessment Is Necessary.

The remaining suite of viable adaptation options are then directed through the "expedited evaluation" pathway (the green shaded area in the figure), in which the "Tier 2" screening evaluation is undertaken. The Tier 2 evaluation consists of additional factors that are important to consider when comparing and ranking a range of alternative adaptations (e.g., unintended costs such as major externalities, or potentially valuable additional co-benefits, as described in Section 4).

At this stage, the process splits into two pathways that are intended to facilitate application in two complementary types of situations:

1. Proceeding to option selection and implementation, in those instances where sufficient insight is gained at the conclusion of the Expedited Evaluation (i.e., when the two-tiered screening levels can adequately inform a choice or ranking of options). Where this applies, the user can then proceed directly to selecting the best option (or suite of options). This is shown in Figure 2 as the arrow

exiting the bottom of the green shaded box and progressing directly to the gold shaded "select and implement" stage.

2. Proceeding to additional focused, in-depth evaluation in those instances where the expedited screening has not yielded sufficient clarity about which option(s) are most suitable. In these instances, users are encouraged to conduct additional, more detailed assessments (e.g., benefit-cost analysis, BCA), where the additional analysis is guided and focused by the outcomes of the simple screening tiers. This is depicted in Figure 2 by the pathway that moves from the green shaded Tier 2 screening process and extends rightward into the blue shaded area.

As shown in Figure 2, options that pass through the expedited evaluation can be ranked or compiled into a suitable mix of adaptation actions, and then considered for selection and implementation (the gold portion of the diagram). In other words, the expedited evaluation provides a relatively simple and fast "exit ramp" and enables the adaptation selection and implementation process to move ahead quickly. This approach accommodates the fact that many users in the developing nation context are resource and data limited, and need tools that can help them move ahead and narrow their range of options without requiring large amounts of information, time, or specialized technical or adaptation expertise.

There will also be cases where the results of the first two tiers of screening reveal that a more in-depth assessment of the suite of adaptation options is indicated. These are instances in which the expedited evaluation process indicates a need for (or value of) switching over to a more in-depth assessment of the suite of applicable options (suggesting that the user move laterally from the green box to the blue-shaded area of Figure 2).

Options and circumstances that indicate the value or need for a more in-depth evaluation can then be assessed by a variety of possible decision support techniques (e.g., BCA), with the type of analysis selected in accordance with the users' circumstances and preferences. In these instances, the screening tiers will help indicate what key questions and issues may require further analysis (e.g., an analysis to help determine whether external costs or co-benefits may be sufficiently large to warrant how one compares or ranks options). This will enable users to focus any subsequent in-depth analyses on the issues and questions most pertinent to understanding the relative merits and limitations of their options. At this stage, users would be directed to suitable guidance and a range of tools to help them select and implement the preferred type of focused, in-depth evaluation of adaptation alternatives. Guidance that should accompany this Evaluation Framework will also help indicate what factors and impacts might be most important to consider within the in-depth assessments.

In the more in-depth assessments, the evaluation approaches to be applied would typically include some form of "business case evaluation" in which the pros and cons are systematically evaluated and compared to see which adaptation options appear to be the wisest investments. The type of evaluation approach could be either BCA (with a recommended use of a Triple Bottom Line framework: BCA/TBL), multi-criteria decision analysis (MCDA, or some variation) or, where applicable, cost-effectiveness analysis (C-E). Other approaches may also be considered. It is envisioned that guidance and associated tools will be made available to assist users with selecting and conducting their more in-depth evaluation (as detailed later in this White Paper).

In the instances where additional focused (and typically more in-depth) evaluation is considered, the selection of which type of evaluation approach to apply can be based on several factors, and may often be situation- and site-specific. The key factors to take into consideration include:

1. The level of complexity that is suitable and feasible to apply (given data and other potential limitations)
2. The scale of the decision being made (e.g., more rigorous evaluation is justified for an expensive, irreversible project than a relatively low budget, low impact situation)
3. The preferences and cultural context and capabilities of the in-country users and stakeholders (to facilitate their meaningful participation in the process)
4. The requirements of potential funding partners (e.g., a multilateral development bank may expect an analysis including rate of return estimates)
5. The specific criteria and issues that prompted the assessors to steer the evaluation process into the blue box for additional, but focused in-depth evaluation (e.g., to examine the extent of potential externalities, or the value of co-benefits, that might alter the ranking of options)

In most instances, MCDA is the simplest method to apply because it typically is based on subjective inputs from the stakeholders engaged in the deliberations. Thus, there is not necessarily a need for any objective quantitative assessment (although having objectively quantified results for some outcomes can be very useful for anchoring and guiding the scoring). Instead, what is required is that those invited to participate in the deliberations provide a score (e.g., on a scale from 1 to 10) for how well each option addresses each of the criteria the group has decided to take into consideration. The participants then also need to assign weights to those criteria (these weights might also be on a 1 to 10 scale). An overall score is thus developed for each option, by summing the weighted scores across the criteria. In a simple application, the users may rely on the Tier 1 and Tier 2 criteria from the Expedited Evaluation, and convert that exercise into a MCDA by assigning scores and weights to sort out which criteria are most important for evaluating their adaptation choices within the context of their local situation.

MCDA is a fairly straight-forward technique to apply, and can also work well in situations in which a range of stakeholders may be engaged in the process and may hold divergent views on key issues. For example, the facilitator of the process can demonstrate if or how the options' overall scores and rankings shift when the weights are modified to reflect different perspectives and opinions about what criteria are most important.

An important limitation of MCDA is that it ultimately entails subjective judgments, and is not based on objective metrics. In addition, the cultural context may impact the viability of a MCDA approach. For example, in one developing nation effort to apply MCDA, the local stakeholders reportedly were unwilling (or felt unable) to assign weights to the different criteria that they were scoring as part of a collaborative effort. This may have reflected a cultural aversion to making some factors "more important" than others, or it may have reflected a general lack of familiarity with analytic frameworks that involved subjective scoring by the participants. In such instances, practitioners can decide to proceed with equal weights as a base case, and then determine how much weights might have to change in order to alter the ranking of options.

C-E can be a relatively straight-forward and objective approach to apply, insofar as there is (1) suitable agreement on what costs are included (e.g., lifecycle), (2) reasonably reliable estimates of those costs, and (3) each option under consideration yields the same outcomes. In such instances, the users can identify which option provides the targeted outcome at least cost. A critical limitation of C-E is that it is not a suitable

approach when the options produce different levels and/or types of outcomes. For example, if there are different co-benefits or different external costs associated with the different options, then a C-E analysis would not reflect these important considerations. The Tier 2 screening will help identify when such differences across options renders C-E unsuitable as an evaluation approach.

BCA is a widely valuable and well recognized approach to options evaluation. As a practical matter, an objective, highly quantitative BCA may not be feasible in some situations, especially in a developing nation context. Nonetheless, a simpler and partially qualitative style BCA has been demonstrated to be very feasible and highly effective in many such development settings, even for impacts that relate to nonmarket values that are generally considered hard-to-quantify. Guidance materials and template-based tool-kits have been successfully developed and implemented in these areas, as described in Section 7. Therefore, we believe it is feasible to provide sound guidance and training for more in-depth evaluation using BCA and the other potential evaluation techniques, for practical applications to adaptation option evaluation in developing nation settings (additional discussion is provided in Section 7).

3. GUIDING PRINCIPLES FOR THE EVALUATION FRAMEWORK

The evaluation process proposed here is intended to adhere to and reflect several important principles (highlighted in the text below). These guiding principles include ensuring the approach (and associated guidance, tools, and training) is practical, realistic, useful, and informative in the context of promoting climate resilient development. These guiding principles thus include providing an approach that can be quick and simple to implement, where suitable. It is also intended to be reasonably robust when circumstances warrant a more careful and focused assessment. And, the approach is designed to be fully integrated and dovetailed to USAID's climate resilient development framework. It also is intended to complement the Fast Track Implementation (FTI) program (see the text box on the next page).

The approach is also intended to be highly ***flexible*** in several regards. First, it is not overly prescriptive about which criteria, methodologies, or scoring approaches should be applied by the user (these should be selected by the in-country stakeholders). Second, it is intended to ***accommodate various "on ramps"*** for users who may be in different stages of the adaptation planning process. It also provides different suitable "off ramps" where users can exit the process at the stage where they have the results they need to make an educated recommendation or decision.

Other desirable features that the approach aims to accommodate include (1) applying a ***comparative*** perspective (as users will always compare options, even if there is only one adaptation option to compare to the status quo "do nothing" baseline); (2) recognizing ***complementarities*** wherein a blended suite of multiple adaption options may be most suitable to deploy (rather than a single option); (3) indicating where and how site- and circumstance-specific factors can make adaptation ***not a "one size fits all" proposition*** all in terms of finding the best or most relevant remedies; and (4) aiming to help identify and ***promote proven, sound adaptation strategies*** (e.g., no-/low-regret options, adaptive management strategies), as suitable.

HOW THE EVALUATION FRAMEWORK PROCESS DOVETAILS WITH FAST TRACK IMPLEMENTATION

FTI is one of the activities being developed under USAID's Climate Change Resilient Development (CCRD) program. The intent of FTI is to facilitate an accelerated implementation of pre-evaluated adaptation actions. The actions to be "fast tracked" are those that are generally believed to be wise investments under many circumstances, but especially in locations with immediate adaptation needs due to high risk under current climate or high vulnerability under projected future climate. This text box describes the valuable commonalities and complementarities between FTI and the Evaluation Framework developed in this White Paper.

A key component of FTI is a list of technologically simple, low-cost adaptation options that – in many circumstances – would likely be sound investments supporting climate resilient development. Many types of actions could fall into this category, including simple building or equipment changes, planting vegetation, changing processes or inputs, institutional change or changes in behavior, or changing the schedule or intensity of maintenance. Many of these options will make sense irrespective of climate change, or provide co-benefits outside of the climate arena, by addressing non-climate stressors and development needs. By pre-evaluating adaptation options that typically can be implemented quickly and in a relatively straight-forward manner, FTI is aimed at expediting the implementation of adaptation actions for particularly high risk locations. In compiling a list of adaptation options, the FTI initiative has developed and is applying a set of criteria that is virtually identical to the Tier 1 and Tier 2 screening criteria described in this White Paper. In essence, FTI is identifying options that rank favorably along many of the criteria, as these options will very often be sound investments or actions under many circumstances. The FTI tool describes the characteristics of each option according to each criterion. The descriptions of these characteristics are drawn from the empirical literature, which is included as supporting information in the tool. This succinct suite of information is intended to help a decision maker discriminate among potential fast-track options to help them get to implementation quickly, if possible.

This paper develops an Evaluation Framework process that is intended to be applied more broadly to the selection of adaptation options. The process presented herein focuses on identifying the relative pros and cons of more complex or costly projects that may provide important climate resilient development benefits, while not necessarily meeting the criteria for FTI. For example, any high cost initiative or one that requires many years to implement is likely to be excluded from the FTI list, but may be critical to meeting development goals in a climate resilient manner. Another important value of this broader framework is that if a climate-related risk can be addressed by an FTI option, but also can be addressed by a non-FTI alternative, then the Evaluation Framework provides a simple process by which the alternatives can be compared.

While the above referenced guiding principles are generally viewed as desirable, it is not easy to accommodate all of them simultaneously. There are challenges associated with the need to consider potential tradeoffs between some of these worthy objectives. For example, the desire to make the approach relatively simple and easy to navigate (so that the approach can be implemented quickly and with readily available data and skills) needs to be balanced against the desire to ensure the analysis is appropriately robust (so that stakeholders can make reasonably well-informed decisions about which adaption options to select for implementation). This challenge is addressed by providing a two-path approach as described previously, with expedited evaluation available where suitable, and any in-depth analyses being applied only when needed. In addition, the screening tiers will help guide and focus any additional, more detailed evaluation upon the criteria that the 2-tiered screening indicate to be most relevant to the option evaluation (i.e., focusing on the factors that are key to differentiating the better options from the lesser adaptation approaches).

Likewise, there is a desire to make the evaluation process and selection of criteria stakeholder-driven, which needs to be balanced against the desire to steer users to seriously consider all those criteria that external adaptation practitioners and "experts" consider to be highly relevant to informed decision-making for climate resilient adaptations. Toward this end, the approach suggests a range of criteria (see the following section) that raise important issues that many believe should be part of a sound evaluation. By suggesting and describing these criteria, the hope is that they will be taken into consideration in some manner by the user.

4. DEFINING CRITERIA TO SUPPORT THE EVALUATION

As in any evaluation process, a key aspect is describing potential criteria upon which to base an evaluation of adaptation options. Ultimately, the in-country stakeholders will need to identify and weigh the criteria that they consider to be of greatest importance. To facilitate and help guide and inform this process, we propose suggesting key criteria that are in harmony with USAID's guidance on climate resilient development.

The criteria are split below into the first list of criteria that are more or less universally useful to consider, and may be applied in the initial "Tier 1" screening (i.e., the diamond at the top of Figure 2). The second list includes criteria that may be considered in the second tier of the expedited evaluation process (the "Tier 2" diamond within the green shaded area of Figure 2), and may presuppose strategic goals or other key aspects of a specific decision-making context.

The proposed Tier 1 evaluation criteria are as follows:

- ***Effectiveness:*** How well does the adaptation option reduce the specific climate risks of concern and generate the primary benefit sought (e.g., damages reduced, costs avoided, lives saved), over an appropriate time horizon? How well does it address the applicable climate-related vulnerabilities (e.g., reduce exposure and/or sensitivity, and/or increase adaptive capacity)? Does the option align with and promote overall development goals (e.g., promote food security, improve public health and safety)? Note that "effectiveness" typically needs to be assessed relative to the specific context of the climate risks posed, and the development objectives being sought (e.g., how well does the option protect exposed communities and critical infrastructure from anticipated increases in the frequency and severity of coastal storm surge inundation?).

- ***Feasibility:*** Is there sufficient technical and financial capacity, political support, and cultural alignment to implement the adaptation option? Is the adaptation option relatively straightforward to implement and maintain from a technical perspective (e.g., is the infrastructure relatively easy to build and operate)? Will key institutional actors and stakeholders support the action (e.g., can the associated changes in governance, such as zoning requirements, be passed and enforced effectively; and are the adaption-related changes aligned with local cultural norms)? Is this an activity that can be funded with resources available for development aid (e.g., does funding eligibility make this option financially viable)?
- ***Cost:*** Is one option less expensive than another, when considering both the near-term (e.g., initial) costs, as well as the costs required over the longer-term (e.g., to maintain and operate the adaption option over time)? Is there sufficient funding to set up and implement the option (e.g., how expensive are the initial costs to build or otherwise put the adaptation option into effect)? How much will it cost to operate and maintain the option over its lifetime (e.g., how much will it cost to effectively enforce a change in governance, or to ensure a flood protection structure is routinely inspected and repaired)? Who will bear the costs?

The additional criteria below – or a selected subset (such as unintended costs, and additional benefits) – may constitute the Tier 2 screening that constitutes the suggested expedited evaluation pathway. These considerations may also be relevant for analyzing adaptation options along the more in-depth evaluation path.

- ***Unintended costs:*** To what extent are there costs and other unintended negative consequences (e.g., externalities) associated with the adaption option, beyond the direct expense of its implementation? For example, construction of a seawall to protect communities against sea level rise may adversely impact the near-shore coastal ecosystem. It may thus impose costs by harming local fisheries, reducing community access to important shoreline and marine resources, and diminishing the prospects of developing a robust sea-side tourism sector. While such costs are not part of the direct expense of implementing an adaptation option (e.g., they are not the direct cost of actually designing and constructing the seawall), such "external" or unintended costs can be very high, and should be taken into full consideration when comparing adaptation options.
- ***Additional benefits:*** To what extent might an adaptation option provide valuable co-benefits, in addition to the primary benefit of reducing the specific climate-related risk of concern? For example, building a dam and associated reservoir may be considered as one option to enhance water supply reliability for a key urban or agricultural region, given the anticipated increased variability of rainfall and increased risk of prolonged drought. However, the dam may also provide other important benefits (sometimes referred to as "co-benefits"), such as the potential to generate hydropower, improve downstream flood protection, expand a fishery, or develop lake-based tourism and recreational sectors. These additional benefits – beyond the primary benefit associated with increasing water storage to address the specific climate-related risk imposed by drought – should be taken into full consideration when comparing one option to the other available adaptations. Any external costs also should be considered as well.[1]
- ***Implementation timing:*** How long will it take to develop and implement the option? Can the option be implemented within relevant planning/funding/political timelines? Timing may be especially relevant for some climate-related risks, but less critical in other circumstances. For example, the ability to quickly implement flood protection measures will be very important in areas that are already facing high inundation risks due to existing topography and climate conditions. In contrast, some coastal areas vulnerable to long-term sea level rise may have a decade or longer before

1. In this example, the dam might also generate unintended costs, such as submerging important lands and disrupting riparian and aquatic ecosystems. Any such untended costs should be considered, along with the additional benefits the dam might provide.

facing significantly higher risks of inundation. Thus, the criterion of whether some adaptation options may take longer than others to finance and implement will be important in some contexts, but less critical in other applications.

- ***Flexibility:*** How easily can adjustments be made in response to evolving conditions and/or information? Are there incremental steps that can be taken (e.g., might a proposed dam be designed and constructed in such a manner that its height can be cost-effectively increased in the future, if and when changing climate conditions indicate more water storage or flood protection is needed)? Note that a flexible option may sacrifice optimality to some degree. Flexibility may be an especially important consideration for adaptation options that are intended to be long-lived, are relatively costly, and/or impose irreversible consequences.
- ***Robustness:*** Does the option perform well under a wide range of possible climate futures? It is sometimes, but not always, the case that planning for a broad array of future climate conditions (a robust approach) may not address outlier scenarios of low-probability, high-consequence outcomes. It also may be relatively costly to select an adaption option that is more robust than an alternative option, such that the incremental cost of additional robustness may need to be taken into consideration and weighed against the addition risk protection the more robust option offers. (This latter context would be an example of where more in-depth analysis may be suitable, with the focus being on comparing the difference in benefits and costs from deploying an option that may not cover as many climate scenarios compared to a more "robust" alternative).

Note that these criteria are commonly used in analyzing options. However, climate change may add new dimensions to many of them. For example, "effectiveness" is no longer related only to the development goal (e.g., how many homes are built for the poor?) but also to climate vulnerability (e.g., are the houses built resilient to potential climate impacts?). Also, implementation timing may take on new importance in addressing near-term versus long-term climate vulnerabilities (as demonstrated in the trial application provided in Appendix B). These and other criteria need to be reassessed from a conventional development perspective to ensure that climate variability and change are adequately incorporated.

5. PRACTICAL ISSUES AND OPTIONS FOR APPLYING THE EVALUATION CRITERIA

After the suitable criteria are selected, a key challenge is determining how they can and should be used to evaluate adaptation options. Based on the two-pathway approach, application of criteria can be carried out either as a quick analysis, or as a more detailed evaluation using an approach such as BCA. The level of effort should be consistent with the scale of the decision, the size of the investment, and time and resource constraints, among other factors. Furthermore, such scoring can be conducted as part of a participatory exercise with stakeholders or as an expert-driven evaluation.

For the expedited assessment path, the evaluation can be qualitative or semi-quantitative. For example, each criterion can be evaluated in a descriptive textual format or scored based on a systematic or quantitative method such as green, yellow, or red; high, medium, or low; or ranked with scores from 1 through 5). These types of relatively simple qualitative scores and rankings are depicted in the illustrations developed in

Appendices A and B. Another example is the interactive matrix approach, as developed in the context of the Iloilo case study (Vogel et al., 2013).

Another option is to apply a "Consumer Reports" style format, such as depicted in Figure 3. Figure 3 depicts the suggested Tier 1 screening criteria, and compares – qualitatively – two general adaptation approaches for addressing urban flooding from precipitation-driven stormwater events. In this depiction, the more innovative and soft path "Green Infrastructure" option is less expensive and considered more feasible than the alternative of a more traditional, constructed "gray infrastructure" approach; however it has less proven effectiveness than the gray approach. After Tier 1, both options are considered viable for further evaluation (i.e., neither should be discarded), and it is not evident that one approach is clearly superior to the other.[2] (Interested readers should refer to Appendix A for a more detailed discussion of how these two adaptation alternatives compare to one another).

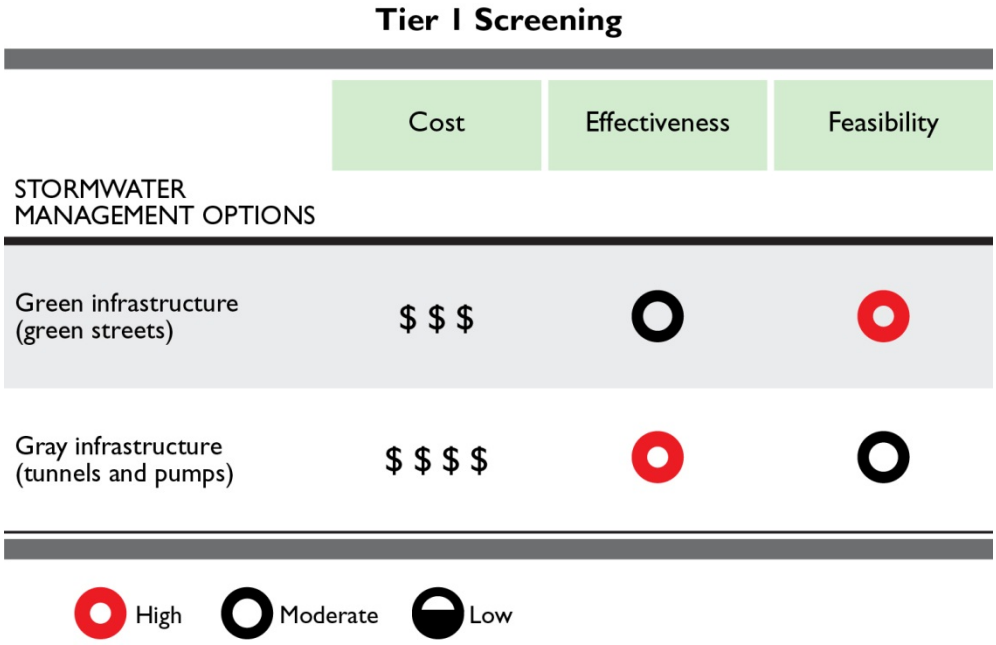

Figure 3. A "Consumer Reports"-style Evaluation Summary for Tier 1.

Figure 4 provides a similar graphic summary for the Tier 2 evaluation criteria. This reveals that the green infrastructure approach may have several key advantages to the gray approach in terms of lower unintended costs, higher co-benefits, and greater flexibility. Thus, when completing the Tier 2 screening, the users may feel informed enough to suggest the green infrastructure approach as preferred to the alternative. In this case, they proceed to selection and implementation of the preferred option. Alternatively, they may consider whether further analysis may be warranted to better understand the relative effectiveness of the alternatives, and whether the co-benefits of the green approach may be sufficiently high to warrant the potential loss of effectiveness (in which case they move forward with focused additional analyses).

2. However, if the "effectiveness" criterion is deemed to be the most critical factor in this setting, then one might be more inclined to use the more proven, tried and true gray infrastructure approach. Alternatively, if cost savings and/or feasibility are considered of paramount importance, one might lean toward the green infrastructure approach.

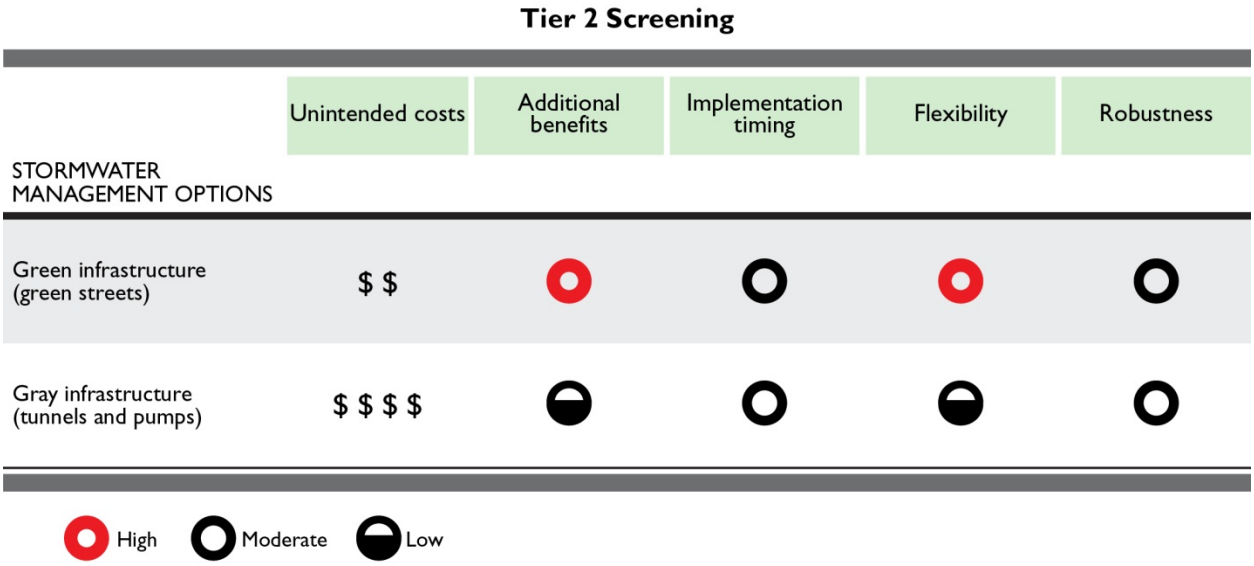

Figure 4. A "Consumer Reports"-style Evaluation Summary for Tier 2.

While the above illustration using the simple graphic summaries provides an example of how simply the issues and evaluation can be depicted, there remain several practical challenges that need to be acknowledged. A key challenge in this approach is that each of the above "key criteria" can be hard to define and measure – in either in-depth assessments, or in quick screening approaches. For example, consider the "costs" metric(s). How should cost be characterized? Estimating total lifecycle costs can be very complicated and may require a high amount of project-specific knowledge and site-specific considerations. Also, what metric of cost is to be used (e.g., per household, per unit of output, initial outlay, lifecycle), and at what scale (e.g., some options may be very costly at a small scale, but relatively inexpensive per unit of output if implemented at a larger scale, and vice versa)? And, what data exist to inform users of the potential costs for various options?

Likewise, questions arise related to how to define and characterize "effectiveness." How do we account for site-specific considerations? Also, in the context of the "screening," we may not necessarily need to assess every option according to all the criteria. For some options in some settings, it may quickly become evident that some options are not good candidates (e.g., some options may not be feasible for the applicable physical or socio-cultural setting, such that they can go to the "discard" bin in Figure 2). Or, it may be that users only need to assess options on some (but not all) criteria (e.g., costs may be a less relevant issue if a donor agency will be covering the expense).

6. SECTORIAL TRIAL APPLICATIONS OF THE FRAMEWORK

To better demonstrate and "test drive" the proposed Evaluation Framework, two "trial" applications of the approach have been developed. The two trial illustrations for the screening and expedited evaluation of adaptation actions are:

1. Urban stormwater/flood control, comparing green infrastructure to more traditional gray infrastructure options, which is provided in Appendix A. Green infrastructure refers to stormwater capture and improved infiltration of stormwater in high precipitation events through the use of permeable payment, vegetative swales, and other techniques relying often on vegetation and related natural systems. Gray infrastructure options are more traditional engineered solutions, typically entailing the construction of storm drains connected to large underground tunnels in which water is stored until it can be treated and released more gradually. Additional detail is offered in Appendix A.
2. Coastal flooding of hard infrastructure (e.g., roads, buildings) due to periodic and increasingly severe storm surge, and sea level rise, which is provided in Appendix B. In this illustration, the adaptation options range from elevating and strengthening an existing sea wall (a "protect and harden" adaptation strategy), relocating a major coastal roadway to a more inland location (a "retreat" adaptive strategy), and developing pump stations to remove waters in times of heavy rain or surge events (an "accommodate and manage" strategy). Additional detail is provided in Appendix B.

In each sector-oriented trial, a small suite of adaptation options (e.g., 2 to 5 options) were identified, and the streamlined characterization of these options was attempted according to the Tier 1 and Tier 2 criteria developed in Section 4 above. The intent of this exercise was to help evaluate the ease of use, and effectiveness of the simple framework for screening and evaluating adaptation options. The trial application process helped identify where aspects of the proposed approach were unclear or difficult to interpret, which led to some revisions and improvements reflected in version presented in this White Paper.

In each exercise, the revised Evaluation Framework was shown to be relatively user friendly and effective at helping to sort through the adaptation options. In the urban stormwater illustration, the author developed simple rankings (low, medium, and high) to score each criterion, and applied simple color-coded tables (green, yellow, red) to present the findings in a manner that is very easy for reviewers to interpret (see Appendix A). This is a similar concept, but applies a different visual presentation approach to the "Consumer Reports" style summary figures provided in Figures 3 and 4.

In the coastal roadway flooding illustration, the trial application revealed how the Tier 1 screening can be an effective approach for easily determining that one of the options was not viable or worthy of additional consideration, and could be discarded from additional evaluation. This streamlined the Tier 2 screening, but also raised an important issue regarding how the time horizon for the adaptation planning exercise might inadvertently lead to discarding an option that was worthy of continued consideration when a longer timeframe was considered. This is an issue that needs to be addressed in the guidance we suggest be developed to support the Evaluation Framework.

In addition, the Tier 2 evaluation of the coastal flooding example indicated that there were some complex tradeoffs to consider when comparing the remaining options, and that some additional, more in-depth analysis was probably warranted. This trial application thus also revealed the manner in which a more detailed assessment could be focused on a manageable set of key issues (see Appendix B).

7. REVIEW OF EXISTING GUIDANCE AND ASSOCIATED TOOLS

This section includes a *brief* description of what already exists in the literature or in guidance documents or tools. We conducted a search of the peer-reviewed literature and of materials developed by other development-oriented agencies (e.g., World Bank, Global Environment Facility, entities from the European Union) to identify materials potentially relevant to how to identify and evaluate/select adaptation options (especially where the tool or guidance is applicable in a development context). The objective of this search was to ensure that we could draw on existing resources to avoid any reinventing the wheel. We also sought to identify where there might be key gaps and limits of traditional, more in-depth evaluation approaches (e.g., BCA), including the key issues of how to best address uncertainties which can be extensive in the case of longer-term climate change, and how to apply the techniques in a developing nation context.

The search and associated review of the literature indicated that there are no materials that we identified that systematically describe an Evaluation Framework for analyzing adaptation options within a developing nation context (or within a developed economy, for that matter), in a reasonably streamlined manner. Therefore, it appears that the Evaluation Framework that we propose in this White Paper (especially the tiered screening aspect) reflects a novel approach and that there are no similar or alternative approaches available. As such, this approach may fill a need that has not previously been addressed. The FTI is also developing a tool that will complement the Evaluation Framework by helping users see how various FTI adaptation options align with the criteria. The two efforts can be coordinated to ensure efficiency and consistency.

While there is no apparent expedited evaluation approach already available, in contrast, we did locate a small number of published articles and guidance-type materials directed at applying the more in-depth evaluation methods that constitute the "additional focused evaluation" pathway in our Evaluation Framework. The most directly applicable document was issued by the United Nations Framework Convention on Climate Change, *Assessing the Costs and Benefits of Adaptation Options: An Overview of Approaches* (UNFCC, 2011), which offers a brief description of BCA, MCDA, and C-E approaches and offers a few abbreviated case study examples. This was the only document that touched directly on the process of evaluating adaptation options using suitable techniques.

There also were a small number of papers that provide case-specific applications of BCA-type approaches to evaluating adaptation to individual climate-related challenges in specific locations. These include Wintle et al. (2011), Yohe et al. (2011), Mathew et al. (2012), Cartwright et al. (2013), and International Institute for Environment and Development (IIED, 2013). These are highly case-specific and some are sophisticated academic exercises not generally applicable to practical implementation in the development context. Nonetheless, these can offer useful insights to include in future guidance development.

In addition, beyond the climate change sphere, there are some practical guidance-oriented documents already available that offer pragmatic approaches, templates, and procedures for BCA and related evaluation techniques for resource and environmental management applications. These include field-tested materials developed by Stratus Consulting's Dr. Raucher and associates, for the developing nation context, for applications to a wide range of environmental impacts associated with critical economic sectors, for the Asian

Development Bank (ADB).[3] These materials are found in *Economic Evaluation of Environmental Impacts: A Workbook* (ADB, 1996). This "workbook" includes templates to guide users through each step of the evaluation process, and includes several case study illustrations to clearly demonstrate the approach and indicate what completed templates should contain. Training session materials were also developed and multiple successful training sessions were provided for ADB professionals and planners in developing nations served by the Bank. These materials can be readily updated and re-targeted to adaptation option evaluation, and can serve as a solid foundation for suggested future guidance and training related to the evaluation of adaptation options for climate resilient development.

Another pair of similar guidance documents and associated toolkits have been developed for the WateReuse Foundation (Raucher et al., 2006) and the Water Environment Research Foundation in collaboration with the International Water Association (Raucher et al., 2007). These guidance documents and associated tool-kit templates and case study illustrations address water supply, wastewater, and biosolids management issues, and they can be readily updated and expanded to serve as a practical and conceptually sound basis for valuable guidance and training on BCA and related in-depth evaluation methods for adaptation options.

An example of materials available for developing the types of guidance and training described above is depicted in Figure 5. This diagram indicates the 12-step process outlined in ADB (1996), and Raucher et al., (2006, 2007), for structuring a BCA-type TBL analysis.

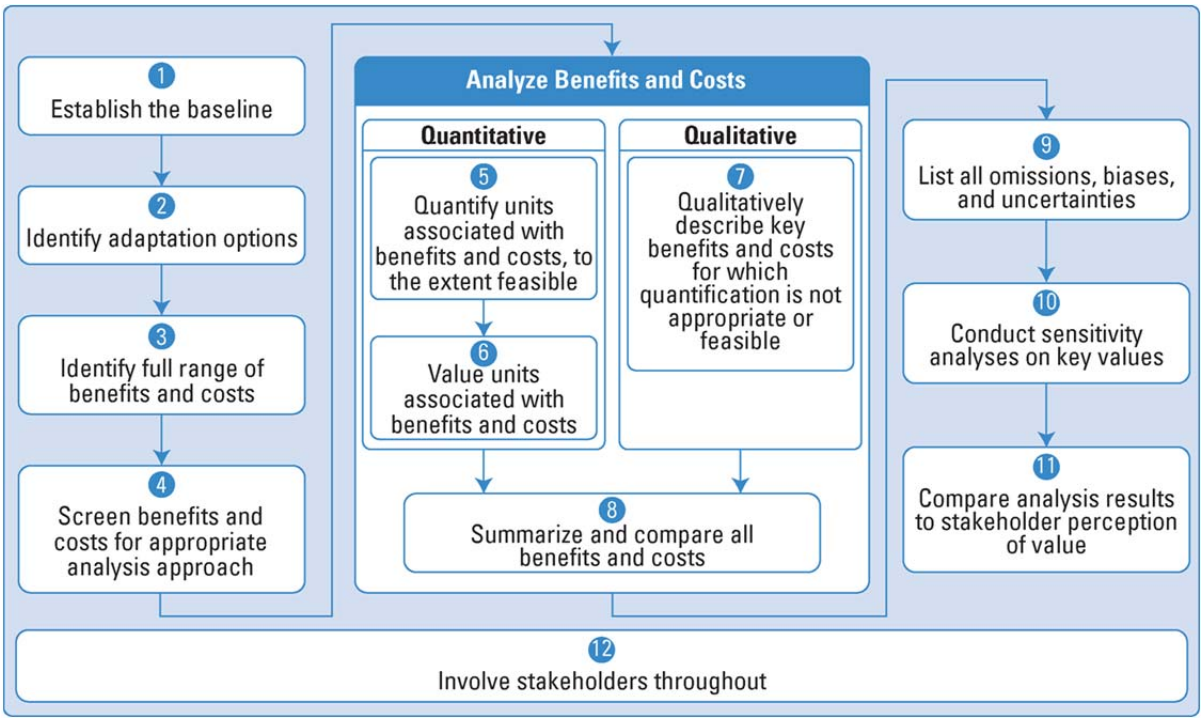

Figure 5. Guidance on the Steps for Applying BCA.

3. This material was developed by Dr. Raucher and colleagues at Hagler Bailly Inc, two years prior to Stratus Consulting's creation as a divestiture from Hagler Bailly. The sectors covered include urban water and sanitation projects, agriculture, forestry, and energy projects. These correspond well with the sectors in which adaptation options would often be applicable as part of promoting climate resilient development.

In addition, there are additional available examples and associated guidance indicating how a TBL framework can be deployed to portray the results of a suitable BCA. An example TBL outcome illustration is shown in Figure 6. This figure shows the results of a TBL-oriented BCA of the use of green infrastructure to manage urban area flooding, water quality degradation, and other related stormwater runoff issues (Raucher et al., 2009).

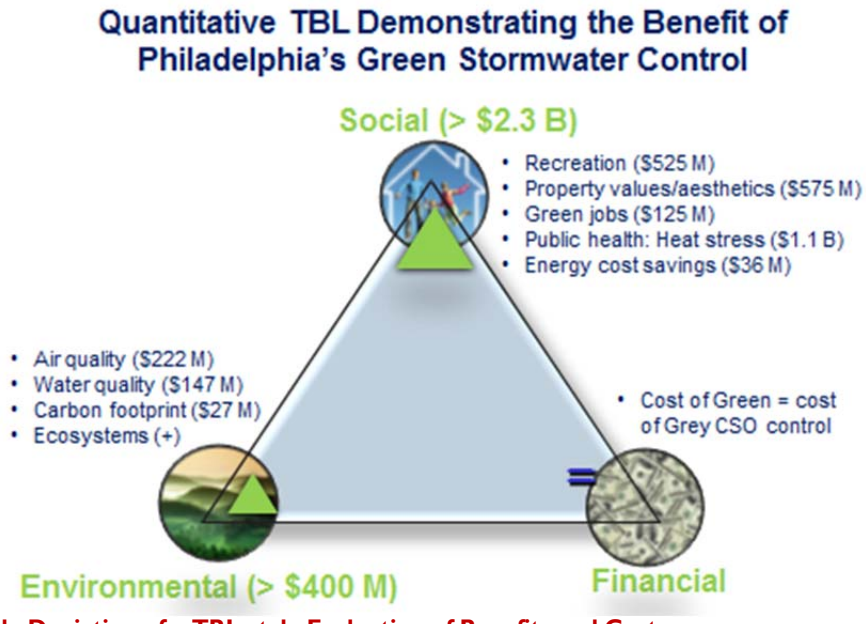

Figure 6. Example Depiction of a TBL-style Evaluation of Benefits and Costs.

8. OBSERVATIONS, CONCLUSIONS, AND SUGGESTED NEXT STEPS

This section summarizes the lessons learned and key observations about how the proposed Evaluation Framework works – for both simple screening and the more in-depth evaluation pathways. It also tees up suggested potential next steps toward actual development and implementation of the framework and supporting materials.

The key observations and lessons learned are that this relatively simple Evaluation Framework provides a fairly straight-forward and relevant way for users in developing nations to systematically conduct a streamlined screening of the options for adaptation, based on a prudent set of suggested criteria. The viability and value of this framework has been illustrated by the trial application of the tiered screening (Tiers 1 and 2) described in the appendices. However, there is room for clarifying and guiding the expedited evaluation, such that options do not become unduly set aside due to user-imposed limits on the planning and implementation timeframe. It also appears that there is no existing guidance or other materials in the literature that provides a similar framework or pathway to help guide the analysis of potential adaption options, making the proposed Evaluation Framework a novel tool for meeting an unmet need.

The work provided here also indicates that there are available materials upon which to further develop and guide (and offer training) on how users might pragmatically proceed through more in-depth evaluation, in those applications where the expedited evaluation does not provide a sufficiently clear indication of key advantages and disadvantages of options relative to each other. These existing, proven materials can be updated and suitably targeted to support the evaluation of adaptation options in the developing nation context.

Based on the above, we suggest future efforts that focus on (1) compiling the information and tools necessary for helping users apply the Evaluation Framework, and (2) test application(s) of the approach and associated supporting materials in one or more in-field case studies (e.g., in concert with a component of one or more CRIS pilot). Future potential development of the framework and supporting guidance and tools would rely on existing materials to the extent feasible, and would likely include developing additional, complementary resources (e.g., tools, guidance, data, training, illustrative examples) as needed to fill any identified key gaps. Specific ideas are developed below.

Develop Draft Guidance and Associated Tool(s) for Adaptation Options Evaluation. One logical next step to consider is to further develop the Evaluation Framework materials in a streamlined draft Guidance (and related Tool, based on step-by-step templates) so that they can be applied (and/or field tested) by practitioners.

The Guidance need not be long or complicated, and may consist of two separate parts – one describing the options and approaches for the more expedited evaluation pathway, and the second describing how to develop a more in-depth (yet still pragmatically feasible) BCA, MCDA, or other approach.

The expedited evaluation portion can be addressed in large measure based on what has been developed and test-applied in this White Paper, and improved by the experience gained and insights provided by reviewers. The portion of the Guidance pertaining to more in-depth evaluation can be derived via a relatively easy-to-develop update (and re-focus) of very similar materials Stratus Consulting team members have previously developed for various other entities where users have limited expertise or prior training (e.g., for application in the development context for ADB staffers and in-host-country personnel, and for water sector planners and other water management professionals).

For both evaluation approaches, easy-to-apply "tools" can be developed concurrently. These are envisioned as a series of simple templates – and associated illustrations and examples, and look-up tables – that users can fill in and adapt to their applications. These templates and related support materials can also be developed (to a large extent) using relatively modest updates and tailoring of existing materials developed in concert with the completed CCRD and ADB guidance documents noted above.

In any of the above activities, it will be imperative to draw on other similar guidance and tools, as may have been developed previously by USAID, the World Bank, and other parties. The key is to avoid reinventing the wheel, and compiling the most suitable suite of materials that can draw upon the existing body of knowledge to the greatest extent feasible.

Test Drive the Draft Guidance and Tools/Approach. Perhaps in concert with the above Guidance/Tool development (or, perhaps, before or after the development of draft Guidance), it would be invaluable to deploy one or more in-field trial applications of the approach in the context of on-going relevant USAID

activities (e.g., in the context of one or more of the CRIS pilots). The main objective is to see how useful and useable the approach is in a "real world" application (e.g., evaluating options for adapting to a water-oriented component in a CRIS site).

The test drive(s) would provide valuable insights into how well the approach functions in a development application context, including time and data requirements, acceptability and value for in-country stakeholders, national and local policy makers, and AID mission staff. The test drive(s) also will show whether the approach and supporting materials leads to more informed deliberations and adaptation decisions.

Following the test drive(s), the approach can be improved based on lessons learned. In addition, the trial application can be developed as a useful illustration that can be added to the Guidance, and used to help guide and train others.

Explore Potential Database Development: One potential supporting activity is the preparation of a database, or knowledge management systems, which can be used to store available information and help assess costs, effectiveness, or other information that can be used to conduct expedited or in-depth analysis of adaptation options.

As an exploratory step, it could be useful to describe the dimensions, benefits, and costs of such a tool, but not to actually build it (as it is not conceivable to create a database that provides all of the detailed information needed for all cases). An initial, limited exercise could be to determine if this is infeasible (e.g., each project may be too unique to shed useful generic information about costs for other potential applications). And, a database by itself is unlikely to be helpful unless analysts also have guidance on its use (e.g., to answer the question: "Good framework. But, how do I get the information to apply it?"). A database of resources that is tailored around the framework that we develop could be useful. It may be useful to scope it out in a separate, related white paper (perhaps as part of the follow-up to the initial white paper and framework development).

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USAID
FROM THE AMERICAN PEOPLE

A. TRIAL APPLICATION: MANAGING URBAN AREA FLOODING AND STORMWATER RUNOFF FROM PRECIPITATION EVENTS

A.1 BACKGROUND

With the rapid urbanization that is occurring in many developing countries, urban area flooding due to inadequate stormwater management has become an increasingly serious development challenge. As urban areas expand, corresponding increases in impervious area result in increased stormwater-related urban area flooding and runoff to local sewer systems and waterways. High intensity rainfall can cause flooding and/or combined sewer overflows when local sewer systems do not have the capacity to handle larger volume flows. In addition, increased stormwater runoff can result in water quality degradation as urban pollutants enter nearby streams and rivers. Climate change will exacerbate these problems in areas where rainfall, precipitation intensity, and/or the frequency of extreme events are expected to increase. Thus, adaptations to help manage urban area stormwater events are an integral part of climate resilient development.

There are numerous ways of managing stormwater flooding and runoff in urban areas. Traditional "gray infrastructure" approaches rely largely on physical infrastructure, such as large-scale concrete collection and storage systems to collect stormwater, and pumping systems (and associated energy demands) to convey the stormwater to wastewater treatment plants when they have the capacity available for treatment and discharge. Alternatively, there are "green infrastructure" approaches that rely on more natural methods to infiltrate or reuse stormwater on the site where it is generated. Specific green infrastructure practices include permeable pavement, green roofs, parks, roadside plantings, rain barrels, and other mechanisms that mimic natural hydrologic functions or otherwise capture runoff onsite for productive use.

Both the traditional and green infrastructure approaches to stormwater management can be very expensive to retrofit within dense urban areas. Both approaches can also generate important benefits for local watersheds and urban-area communities. While engineered gray solutions are known to be highly effective in helping to manage storm flows, green infrastructure approaches may generate a broader and more valuable array of environmental, public health, and social benefits than do traditional strategies. In order to gain a clearer appreciation of which option (or mix of approaches) may be most valuable to a community, it is important to assess the types and levels of costs and benefits associated with the alternative approaches.

The evaluation criteria described in this White Paper provide a framework for weighing the advantages and disadvantages of alternative green and gray infrastructure approaches (or combinations thereof). The following sections demonstrate one way that relevant criteria can be applied and evaluated to help decision makers assess various options.

A.2 EVALUATION CRITERIA: GREEN VS. GRAY

This section applies the evaluation criterion to hypothetical green and gray infrastructure alternatives in a hypothetical city. For each criteria, specific objectives are identified and rated on a four-point scale (high, medium, low, none). Based on these ratings, we compare the two alternatives in a summary table. Throughout this process, we note areas that may require more in-depth analysis.

For this analysis, it is assumed that the current gray infrastructure system is in need of complete replacement (either outdated with inadequate capacity to handle existing or projected stormwater events, or non-existent in an area undergoing rapid and perhaps unplanned habitation). The options for developing or replacing the stormwater management system include an additional/new gray infrastructure system, or implementing green infrastructure throughout the relevant city area (or, conceivably, some targeted combination of the two).

A.2.1 FIRST-TIER CRITERIA

Effectiveness. Gray infrastructure is an effective, time-tested, and well known solution for reducing urban flooding, combined sewer overflows, and stormwater runoff. Gray infrastructure solutions are typically designed to handle flows for a specific event (e.g., 100-year storm). Events that exceed the design capacity can cause flooding, combined sewer overflows, and water quality issues.

There is less certainty regarding the effectiveness of green infrastructure for managing stormwater in dense urban areas, partly due to the fact that it has not been implemented at scales comparable to gray infrastructure in many areas.

For these reasons, we rated the effectiveness criterion (reduce flooding and improve water quality) as "high" for gray infrastructure (assuming storms do not exceed design capacity – this issue is further discussed under the flexibility criterion) and "medium" for green infrastructure. If special circumstances in this hypothetical city required additional detail on the effectiveness of green infrastructure, or specific types of green infrastructure, a more in-depth study may be required.

In terms of climate-related vulnerabilities, both alternatives aim to reduce exposure to urban stormwater issues (with perhaps different levels of effectiveness). However, the green infrastructure alternative provides additional adaptive capacity by offering a more flexible, "no regrets" strategy. Green infrastructure also aligns better with overall development goals because in addition to stormwater management and water quality benefits, it can reduce greenhouse gas emissions (by serving as a carbon sink) and improve public health and safety (green infrastructure practices can improve air quality, reducing the effects and frequency of asthma and other respiratory diseases, and can help to reduce the urban heat island effect, resulting in fewer heat-related illnesses and deaths). Green infrastructure can also create more local jobs compared to gray infrastructure. These additional benefits are not rated as part of the effectiveness criteria but are included in the discussion below under "additional benefits" criteria.

Table A.1 shows the effectiveness criteria rankings for the green and gray infrastructure alternatives.

Table A.1. Illustrative Rankings for "Effectiveness"

Specific objective	Green approach	Gray approach
Reduce damages from flooding	Medium	High
Improve water quality (i.e., reduce combined sewer overflows and stormwater runoff)	Medium	High
Overall effectiveness rating	Medium	High

Feasibility. As noted in Section 4 of the White Paper, "feasibility" includes multiple considerations, including technical, financial, cultural/social, and political. From a technical perspective, both the green and gray infrastructure alternatives can be relatively straightforward to implement and maintain. Both alternatives will require expertise for project design and management. However, many aspects of implementation, operations, and maintenance for the green infrastructure alternative are suitable for unskilled laborers (often requiring no experience) and provides those opportunities over a long time horizon (continuous low-level maintenance of green assets). By contrast, traditional gray infrastructure requires large construction contractors (who may not be available within the local labor force) and skilled laborers (e.g., with experience in tunneling/working with large machinery), who typically are employed for a relatively short duration (during the initial construction phase). For this hypothetical example, green infrastructure approaches therefore seem to be a better match for local technical resources.

In terms of ***financial*** capacity, on one hand it may be more difficult to obtain funding or development aid for the green alternative due to some of the uncertainty surrounding its effectiveness and the relative "newness" of this approach for stormwater management. There may also be external development agencies more willing to fund a large capital intensive project (such as gray infrastructure) than a project entailing less technology and engineering support.

On the other hand, the green infrastructure alternative may be a better match for specific sources of funding due to its many co-benefits. For example, many development agencies are looking to fund projects that provide adaptive capacity, align better with overall development goals, and/or offer climate change mitigation benefits (e.g., climate resilient low emissions development, CRLED). The green alternative may also be more likely to obtain funding from transportation agencies/donors for green street projects. Given the limited availability for funding traditional projects, the green alternative may have a better chance of being funded with additional development aid. In this case, a more in-depth analysis is needed in order to assess available funding options.

Similarly, there may be some initial reluctance to implement green infrastructure from regulatory agencies and political leaders, because it is a relatively new approach. In the United States, this initial reluctance has largely been overcome largely due to pilot studies and further analysis of effectiveness. This is not expected to have a significant impact on overall feasibility in a development context. Also, local political leaders may see advantages in backing projects that enhance the aesthetics of local neighborhoods and provide more local job opportunities to their constituents.

Based on these assumptions, Table A.2 shows the feasibility ratings for both the green and gray infrastructure alternatives for technical and financial capacity, and political support. Given the importance of technical capacity/feasibility in the initial evaluation of alternatives, and the uncertainty associated with political support, we rated overall feasibility as high for the green approach, and medium for the gray approach.

Table A.2. Illustrative Rankings for "Feasibility"

Specific feasibility objective	Green approach	Gray approach
Technical capacity	High	High
Financial capacity	Undetermined (subject to further analysis)	Undetermined (subject to further analysis)
Political support	Medium to high	High
Overall feasibility rating	High	Medium

It is important to note that when balancing multiple objectives for a given criterion (e.g., technical, financial, and political feasibility), it can be difficult to determine what the overall rating for the criterion should be. In this case, after weighing the different factors, we determined that technical feasibility is one of the most important objectives, at least in the initial screening phases. We therefore provided a little more weight to technical feasibility and have ranked the overall feasibility criterion accordingly. However, in subsequent stages of analysis, we will have a chance to more closely examine each objective, and in some cases (such as in MCDA), apply a quantitative ranking to weight how the objectives are factored into the analysis.

Cost. Compared to gray infrastructure, the green infrastructure alternative has much lower capital costs. However, depending on the mix of practices used, the maintenance costs of green infrastructure may be greater than those associated with traditional infrastructure. A more in-depth analysis of costs may be necessary to find the optimal mix of green infrastructure practices.

Based on existing information, Table A.3 applies cost criteria ratings based on experience in other cities. It is important to note that although total life cycle costs take into account both initial capital and long-term operations and maintenance (O&M) costs, we analyze them separately here because different parties could likely be funding these portions of the project.

For this analysis, total life cycle costs are the most important part of the cost criteria. We therefore apply an overall cost rating of medium for green infrastructure and high for gray infrastructure.

Overall Evaluation in First Tier. Overall, neither option would be eliminated in the first tier evaluation. Also, neither option appears to be unambiguously superior to the other at this stage. For example, gray infrastructure may be rated with a higher effectiveness, but it is considered to be more expensive and perhaps less feasible than the green infrastructure alternative. Thus, proceeding to the second tier is important.

Table A.3. Illustrative Rankings for "Cost"

Specific cost objective	Green approach	Gray approach
Capital and other initial costs	Low	High
Annual O&M costs	Medium/low	Low
Total life cycle costs	Medium	High
Overall cost rating	Medium	High

Alternatively, if one option clearly outperformed the other on all aspects of the first-tier evaluation, or if one option were not considered feasible or effective, then one might consider proceeding along a fast track toward implementation (perhaps bypassing the second tier evaluation).

A.2.2 SECOND-TIER CRITERIA

Unintended (external) Costs. In addition to the financial costs associated with the alternatives, there are also social and environmental costs that must be taken into account. First, both alternatives will result in some level of disruption (e.g., noise, traffic) during implementation. Due to its smaller installation sites, many of which will require manual labor as opposed to large construction machinery, the green infrastructure may result in fewer impacts. However, these impacts are not expected to be significant under either alternative.

In addition, both alternatives will use energy for implementation and maintenance. However, the gray infrastructure will require substantially more energy compared to the green infrastructure alternative, due to the extensive pumping requirements associated with conveying water to the wastewater treatment plant and treating it. This increased energy use will result in increased emissions of CO_2e and other air pollutants, and a larger carbon footprint under the gray alternative.

Further, under the gray alternative, stormwater will continue to be collected, pumped to wastewater treatment plants, treated, and discharged into the nearby river. This will result in continued degradation of the stream channel and decreased habitat, compared to restoration of hydrological processes and improved groundwater recharge under the green infrastructure alternative. These additional costs of the gray alternative are reflected in the next section (as benefits for the green alternative).

Additional Benefits. In addition to the primary benefit of reducing urban flooding, combined sewer overflows, and urban runoff, the green infrastructure alternative also will result in a number of valuable co-benefits. These benefits include increased recreational areas (e.g., due to increased green space and parks, and improved water quality), increased local employment opportunities, increased urban aesthetics, reduced urban heat island effect (which will reduce heat-related illnesses), improved habitat, energy savings within the stormwater system and for buildings (due to reduced heating and cooling needs), improved air quality due to reduced energy use (which will result in reduced respiratory illnesses), and reduced carbon footprint (due to reduced energy-related emissions and green practices that serve as carbon sinks).

Most of these co-benefits do not apply to the gray infrastructure alternative. However, by improving water quality, the gray infrastructure will increase water-based recreational opportunities to some extent. The gray alternative will also provide some local employment, and will increase community aesthetics due to reduced flooding and combined sewer overflows.

Table A.4 provides a summary of the ratings for the additional benefits associated with the green and gray alternatives. Given that only a few additional benefits are realized under the gray approach, we apply an overall rating of "low" to the gray infrastructure alternative, and an overall rating of "high" to the green infrastructure alternative.

Table A.4. Illustrative Rankings for Additional Benefits

Additional benefits (compared to baseline of current gray infrastructure system that is in disrepair)	Green approach	Gray approach
Increased recreational opportunities	High	Medium
Increased local employment	High	Medium
Community aesthetics/livability	High	Low
Reduced urban heat island affect	High	None
Improved habitat[a]	Medium	None
Energy savings	High	None
Reduced carbon footprint	High	None
Improved air quality	High	None
Overall additional benefits rating	High	Low

a. This does not include habitat improvements due to improved water quality. Improved water quality is included separately in the effectiveness criteria.

Implementation Timing. The gray infrastructure alternative can be implemented, and reach full effectiveness, over a shorter time period than the green infrastructure alternative. For example, it may take 5 to 10 years to completely construct/replace the existing system. However, upon construction, full effectiveness is achieved. The green infrastructure alternative will take longer to implement and mature to full effectiveness, but will start showing some results as soon as the first significant installation is made. Given these tradeoffs, we rated the gray infrastructure alternative as slightly higher in terms of implementation timing.

Flexibility. Due to its decentralized nature, the green infrastructure alternative offers much more flexibility in responding to evolving conditions and/or information. For example, if changing climate conditions indicate additional stormwater management controls are necessary, green infrastructure practices can be installed, on

an incremental basis, in targeted areas of the city. Further, existing green infrastructure installations can be modified to increase effectiveness if conditions on the ground indicate the need for an alternative approach.

By contrast, once gray infrastructure has been integrated into the city's stormwater management system, it is much more difficult (and costly) to adapt to changing conditions. For example, if a 25 foot diameter tunnel has been built to handle storm flows, it is a very difficult (and costly) task to expand the tunnel to 30 feet in light of changing conditions. The tunnel would need to be excavated and reinstalled. "Overbuilding" the infrastructure system upfront to accommodate the potential additional flows can be very costly. For this reason, we rated the flexibility criteria as "high" for the green infrastructure alternative, and "low" for the gray infrastructure alternative.

A.3 SUMMARY AND OVERALL RANKINGS

Table A.5 provides a summary of the ratings and importance rankings for each objective described above. Ratings are color-coded to provide a more visual picture of how the alternatives compare, with green implying a "good" or preferable ranking, yellow implying a ranking that should be considered with caution, and red implying a less preferable ranking. This is because a "high" rating does not always mean good (e.g., high costs are less preferable).

Table A.5. Illustrative Overall Ranking Depiction

	Green approach	Gray approach
First-tier criteria		
Effectiveness criteria	Medium	High
Feasibility	High	Medium
Costs	Medium	High
Second-tier criteria		
Unintended (external) costs[a]	Low	High
Additional benefits	High	Low
Implementation timing	Medium	High
Flexibility	High	Low

a. There is a potential to double-count unintended (external) costs with additional benefits (co-benefits), depending on the impact and how the baseline is defined.

As shown in the table, with the top tier criteria, which includes effectiveness, feasibility, and cost, the green infrastructure alternative starts to look like a better approach given its lower costs and high feasibility. However, given the importance of effectiveness, both alternatives appear to be viable alternatives.

Moving on to the secondary criteria, it becomes more evident that the green infrastructure alternative is the best option. Further analysis may be necessary (e.g., TBL/BCA, MCDA) to determine the optimal mix of green infrastructure practices that should be applied.

B. TRANSPORTATION SECTOR ILLUSTRATION

B.1 INTRODUCTION

Transportation planning and investment decisions balance multiple priorities, such as economic development, affordable housing, and tourism. Not only do communities value these priorities differently, but the process that communities use to make transportation decisions will reflect local cultural expectations, the regulatory environment, and available resources. For example, transportation planners and investors may rely to a greater or lesser extent on tools such as land use planning, economic modeling, development regulation, and stakeholder engagement.

In communities where development is occurring rapidly, transportation projects may occur piecemeal, in response to short-term economic needs, rather than long-term goals. An ongoing challenge for many rapidly developing communities is to ensure that infrastructure keeps pace and/or anticipates future growth in a way that is sustainable in the long-term. Climate-related events such as heavy rainfall, storm surge, and heat waves disrupt and damage transportation systems. In many communities, these events place additional strain on infrastructure, necessitating adaptation. Existing climate hazards, combined with projected changes in climate, heighten a growing need for communities to build and maintain more resilient transportation systems.

The purpose of this appendix is to test the Evaluation Framework outlined in the main body of this White Paper. The case study developed in this appendix uses, as a basis for the illustration, one of the development challenges currently facing Metro Manila. Some of the adaptation options that are currently being considered to reduce flood hazard at Roxas Boulevard are evaluated using the Tier 1 and Tier 2 criteria presented in the body of the paper. The purpose of the test application is to highlight the challenges, tradeoffs, and shortcuts that users of these criteria might experience while implementing the Evaluation Framework.

B.2 CASE STUDY CONTEXT: METRO MANILA

Metro Manila is one of several flat, low-lying provinces surrounding Manila Bay. These coastal provinces are gently sloping, with elevations that do not exceed 5 m above mean sea level. The bay supports diverse needs of the national economy, including domestic and international shipping, agriculture, aquaculture, and tourism (Perez et al., 1996). However, it has suffered severe ecological degradation over the past several decades due to reclamation, pollution, deforestation, overfishing, and other factors. Additional economic development perspective is gained by noting that approximately 43% of Metro Manila's inhabitants live in informal settlements, such as slums and squatter areas. Poverty reduction, especially for the urban poor, is a critical objective of the Filipino government and multiple donor agencies have funded infrastructure projects aimed at urban poverty reduction (ADB, 2011).

Even under current climate conditions, the coastal communities surrounding the Bay face substantial ecological challenges and natural hazards. Reclamation projects and high rates of groundwater extraction have accompanied rapid coastal development, resulting in chronic inland flooding, drainage problems, erosion, and subsidence (Perez et al., 1996). The city's geographic location makes it vulnerable to tropical cyclones,

monsoons, and local thunderstorms. Over the past decades, Manila has suffered both droughts and extreme floods. A recent study found that the cost of flooding in Metro Manila for a 1-in-30-year storm is nearly $1 billion. Under a high emissions scenario, this estimate is projected to increase to $1.5 billion (World Bank, 2010).

Since 1965, sea level has been rising more rapidly than the global average, due to extreme rates of subsidence. Evidence suggests that communities have repeatedly elevated and rebuilt fishpond dikes in response to subsidence and rising sea level. Residents of Manila report that spring-tide heights have increased and that flooding due to typhoons and southwest monsoons takes longer to subside (Rodolfo and Siringan, 2006).

Roxas Boulevard is an 8-lane highway that runs along the coast of Manila Bay, connecting the center of Manila with Pasay City and Paranaque City. This scenic stretch of road is bordered by the Baywalk (a major tourist attraction) on one side. The road provides access to the U.S. Embassy and many high-end resorts and restaurants. Roxas Boulevard and the Baywalk are currently protected by a sea wall. However, sections of that sea wall have been repeatedly damaged during past storm events. In 2012, a new sea wall was built to protect the Baywalk and Roxas Boulevard.

B.3 ADAPTATION STRATEGIES UNDER CONSIDERATION

Infrastructure adaptation options can be characterized as falling under three main strategies: accommodate and manage, protect and harden, and retreat. As climate change worsens, communities around the world will likely rely on combinations of all three strategies. For example, relocation is an expensive option that most communities will not pursue in the short-term, but may consider in the long-term. For the purposes of this exercise, we considered the following four adaptation options:

- Relocate the road away from the coast
- Protect the road with a taller and/or broader sea wall
- Build new pumping stations to reduce road flooding during storms and heavy rain
- Develop and enforce regulations requiring developers to include mitigation measures to ensure that site runoff does not increase following development

Each of these four adaptation options (with the exception of relocation) is something that the community has considered or implemented at the site.

B.4 EVALUATING ADAPTATION OPTIONS

The paper describes a two-tiered initial evaluation process. In the first tier, options are evaluated with regard to effectiveness, feasibility, and cost, under the assumption that any option that is insufficient on these three criteria does not warrant additional analysis. Based on a review of these three criteria, options are relegated to one of three paths. Those that do meet minimum standards for these criteria are "discarded" and not evaluated further is the first path. Those that pass this first screening are additionally evaluated using a fuller set of criteria ("Tier 2"). As a result of this Tier 2 screening, options that are clear winners and are high priorities for implementation can be moved forward to the implementation stage. However, if the 2-tiered screening does not indicate a clearly preferred option (or suite of options), then the third path is taken in which an additional, focused and more in-depth evaluation (such as using BCA) is recommended.

B.5 TIER 1 EVALUATION CRITERIA: EFFECTIVENESS, FEASIBILITY, AND COST

Table B.1 details the Tier 1 evaluation of each adaptation option's effectiveness, feasibility, and cost for the Roxas Boulevard case study. Based on these criteria, the only option that might be discarded (at least in the near to mid-term) is relocating the road away from the coast. The high cost and low feasibility of this option make it less attractive compared to the other adaptation options considered for this site. However, eventually, it might become the only feasible long term response to climate change.

This illustration raises an important point – adaptation options need to be evaluated in the context of the timing in which the planning is being considered. In this instance, the relocation option is not considered viable in the near to middle term, because it is unlikely to be politically, economically, or socially viable to relocate a lot of people and associated infrastructure. Hence, this option is set aside from the next level of evaluation in this illustration. But, this option should be retained for consideration if a longer-range timeframe is part of the planning horizon.

In the longer-term, relocation may become a more viable (and perhaps even a necessary) adaptation alternative. And, in a long-term perspective, planners and policy-makers may be able to devise an economically practical pathway to relocation that is gradual and phased in as existing bits of infrastructure reach the end of their service lives (thereby minimizing social and economic disruption). Thus, the option to relocate should not be completed discarded.

This example indicates a need to provide guidance to users of the Evaluation Framework to carefully consider their adaptation planning timeline when screening options. Importantly, an option that is "discarded" because of timeline considerations should be re-considered for timelines for which it is more applicable.

B.6 TIER 2 EVALUATION CRITERIA: EXTERNAL COSTS, CO-BENEFITS, IMPLEMENTATION TIMING, AND FLEXIBILITY

The second tier of criteria is designed to help decision makers further distinguish between the costs and benefits of adaptation options. These criteria are unintended (e.g., external) costs, additional benefits (co-benefits), implementation timing, and flexibility. As a result of the Tier 2 evaluation, as depicted in Table B.2, two of the remaining options begin to emerge as good candidates for implementation: protection and development planning/regulation. The expensive option of building new pumping stations, or similar options to reduce flooding, are indicated as requiring more detailed evaluation before being selected.

B.7 INSIGHTS GLEANED BY APPLYING THE EVALUATION FRAMEWORK CRITERIA

Since not all adaptation options need to be evaluated in equal depth, screening is a helpful way to facilitate a more efficient and streamlined adaptation planning and implementation process. While each community is likely to use its own process to evaluate adaptation options, it is useful to begin with a standard set of suggested criteria. We found during this pilot test that the Tier 1 and Tier 2 screenings, taken together, provide a robust and comprehensive set of criteria for evaluating adaptation options.

Table B.1. Tier 1 Evaluation of Adaptation Options for Roxas Boulevard, Manila. The green, red, and yellow "traffic light" colors indicate whether the evaluation of each criterion resulted in "go ahead" (green), "stop and consider" (yellow), or "stop" (red) decision. Gray indicates that no final evaluation was possible.

	Effectiveness	Feasibility	Cost	Tier 1 evaluation
Relocate road away from coast	*Highly effective* - Reduces climate risk by lessening exposure - Likely to require a long "lead time" to implement	*Low feasibility* - Public opposition likely - Significant impacts on tourism and economic development - May require multiple, fairly complex engineering projects	*Very high cost* - Very expensive capital investment - May require purchasing additional land for relocation - Would likely negatively impact local businesses, may reduce real estate value - Loss of access to important sites, such as the U.S. embassy, hotels, and restaurants	Discard option in short-term
Protect road	*Moderately effective up to a certain threshold* - Efforts to protect the road will be successful up to a certain threshold point (for example, the height of the sea wall) - Protection options will require continuous upkeep	*Highly feasible* - Local support for engineered solutions is strong, although there is some opposition from environmental groups - Strong political support	*Moderate cost* - Capital costs and maintenance costs are moderate and highly certain - May result in environmental costs to the bay, which are harder to quantify	Additional evaluation in Tier 2
Build new pumping stations	*Partially effective, particularly for rainfall or mild storms in the short-term* - Will not mitigate storm damage due to waves - Road closures still likely during extreme events, but duration of flooding likely to be shorter - Future development pressures are likely to exacerbate drainage in the absence of policy changes, pumping stations won't be sufficient to keep pace with development - Would be most effective if used in combination with broad-scale improvements to drainage	*Feasible* - Building new pumping stations to better drain the site is feasible - Availability of land is one possible constraint - Larger scale improvements to drainage will require significant political will	*Low to moderate cost* - Capital costs and maintenance costs are moderate and highly certain	Additional evaluation in Tier 2

	Effectiveness	Feasibility	Cost	Tier 1 evaluation
Institute and enforce stronger development regulations	*Effectiveness depends on execution, but likely low in the short-term and high in the long-term*	*Feasibility depends on execution* - Past efforts to improve drainage and regulate development in metro Manila have encountered significant setbacks - Lack of coordination between local governments and the national government impedes effective development policy - Regulations exist, but are often not enforced - There are ongoing efforts to improve coastal planning and coordination between local and national governments	*Very difficult to evaluate* - There may be short-term costs to economic development, but long-term benefits - Many of the costs and benefits are highly uncertain and will be realized over a long time horizon	Additional evaluation in Tier 2

Table B.2. Tier 2 Evaluation of Adaptation Options for Roxas Boulevard, Manila. The green, red, and yellow "traffic light" colors indicate whether the evaluation of each criterion resulted in "go ahead" (green), "stop and consider" (yellow), or "stop" (red) decision. Gray indicates that no final evaluation was possible.

	External Costs	Co-benefits	Implementation timing	Flexibility	Tier 2 evaluation outcome
Relocate road away from coast	*High costs following implementation, long-term potential for avoided costs* - Impacts to local businesses and the national economy - Environmental impacts of construction and new road	*Long-term benefits likely to emerge over time, some short-term benefits* - May encourage development away from the coast, resulting in long-term cost savings - Road construction will provide a short-term source of employment and investment in the region	*Long-term solution with a high degree of planning required* - Option likely only makes sense as a long-term solution, but beginning to plan for eventual relocation early would be helpful - Requires a long "lead time"	*Very low flexibility* - Site selection for new road is likely to be extremely limited - Once construction has started, flexibility is minimal	*Costs and benefits of this option are highly uncertain. Continued monitoring and planning will be necessary to determine whether this option will become necessary in the long-term.*
Protect road	*Moderate* - Environmental impacts to bay - Increased shore erosion possible	*Low to moderate* - Some sea wall designs incorporate a walkway, which could increase tourism and local enjoyment of bay	*Short-term option with immediate effectiveness, but high likelihood of decreased effectiveness over time* - A seawall currently exists, but maintenance and expansion of shoreline protection could be undertaken at any time with immediate effectiveness - Requires a short "lead time	*Highly flexible* - Iterative improvements to the sea wall are possible	*Implement, but with recognition that accompanying, longer-term solutions will be necessary*

	External Costs	Co-benefits	Implementation timing	Flexibility	Tier 2 evaluation outcome
Build new pumping stations	*Low* - Some environmental impacts of site possible, including increased emissions	*Low*	*Short-term option with immediate effectiveness, but high likelihood of decreased effectiveness over time*	*Low flexibility*	*Conduct a full evaluation, to determine whether this option (other drainage options) – or a combination of drainage options – might present a better solution*
Institute and enforce stronger development regulations	*High short-term costs following implementation, long-term potential for avoided costs*	*Low in the short-term, high in the long term*	*Low effectiveness in the short-term, but potential for high effectiveness in the long-term*	*High flexibility*	*Pursue in collaboration with stakeholders*

One barrier that a user may run into is that the Tier 1 criteria separate cost and effectiveness, but in reality, users are likely to make tradeoffs between these two concepts. Thus, the Tier 1 process screened out the road relocation option, partially due to its enormous cost and low feasibility in the short term. However, this might emerge as the only cost effective option in the long-term. Thus (as noted above), this option should remain under consideration as part of a longer-term planning horizon.

In addition, because cost is a critical factor not only in "discarding" an option but evaluating it relative to other options, applying the Tier 2 criteria in the absence of the Tier 1 criteria can be difficult. Thus, stakeholders might consider evaluating options based on the full set of criteria, once the Tier 1 hurdle has been met. Indeed, the Evaluation Framework is not intended to have users discard criteria once a screening has been completed. Rather, the central idea is to use all the criteria in combination, and not overlook any of the findings in the final evaluation of options. The Tier 1 and Tier 2 screenings are a mechanism for introducing key factors and considerations into the mindset of stakeholders, so that important considerations (such as costs, effectiveness, and co-benefits) become a core part of the overall dialogue throughout the adaptation planning process.

B.8 THE DEVELOPMENT OF AN ADAPTATION PLAN AND STRATEGY

In a real-world context, users are likely to consider bundles of adaptation options, rather than individual actions. For example, building pumping stations to lessen road flooding is effective in the short-term, but will rapidly become ineffective in the absence of broader drainage updates and development regulations to keep more people and infrastructure out of flood prone areas. This situation could pose several challenges for users of the Evaluation Framework, if they focus on trying to define only a single option as superior to all others. Instead users should view the Evaluation Framework process as a way to structure their thinking about the suite of options available to them, and understand their respective strengths and limitations. Using that mindset, users can begin to consider what mix of options may work best for them in combination and/or as sequenced over time (rather than approaching the problem as if only a single option should be selected and implemented).

The Potential Misperception of Eliminating Options. The ultimate goal of the process is to develop the information set needed to develop an adaptation plan or strategy that relies on the mix of the best options available. From this perspective, it is important that users do not consider the Evaluation Framework as resulting in a sequential elimination of options. The Tier 1 and Tier 2 screening steps are only intended to discard options that clearly are unsuitable (e.g., infeasible) or are clearly far less desirable than the other available alternatives. For example, in the current case study, the goal is to preserve the services on the road and the value of the surrounding area to commerce and tourism. Thus, there may be some clear losers among the options, and equally may be some clear winners (in the sense of "no regrets" options). Beyond these, however, the development of an adaptation plan or strategy should be taken as a whole, so that the goals are set and met cost-effectively, using available resources and considering the range of options. The objective of the Evaluation Framework is to help stakeholders understand the comparative advantages and disadvantages of their options; it is not intended to imply that options should be forever eliminated from consideration or, conversely, that only a single option should be considered for implementation.

Evaluate the Options in a Comparative Context, as a Group. As noted above, developing an overall adaptation plan may typically require that options are compared and contrasted, rather than evaluated individually. Further, it may be that the entire group of viable options is evaluated in whatever level of detail is needed to provide adequate information for decision making. From the perspective of developing a plan, then, the question is what level of detail and type of analysis is needed to address the impacts of concern – a question that cannot be answered on an option by option basis by evaluating the options individually. Thus, it is important to reiterate (and make evident in supported documentation and training) that the evaluation process is intended to examine options in a *comparative* context, where the *relative* advantages and disadvantages of the various options can be articulated and taken into consideration. The objective is to help stakeholders identify where there may be tradeoffs and complementarities between options.

Consequently, the Tier 1 and Tier 2 approach may still leave the larger question unanswered: how to develop a broader adaptation plan that meets multiple climate and development goals, and operates in the context of other decisions being made. In this context, one challenge facing decision makers will be how to aggregate information across criteria and build consensus around suites of adaptation strategies. In addition, it is important to recognize that, at the completion of the Tier 2 screening, more detailed additional analysis will often be necessary and valuable – hence the path to additional focused evaluation. In these cases, the tiered screenings should help clearly define what issues and concerns need to be the focal point of any additional analysis – thus making the additional analysis more efficient and streamlined.

Timing of Adaptation. Timing of adaptation relative to expected impacts is of critical importance. Users of this framework will need to balance near-term adaptation options that address existing vulnerabilities to extreme weather (with a high degree of certainty) against long-term adaptation options that address future vulnerabilities to climate change (with a low degree of certainty). This framework's Tier 1 and Tier 2 criteria do not currently specify how the user should balance current efficacy, feasibility, and cost against future efficacy, cost, and feasibility. As noted above, for example, even though relocating the road is currently not politically or economically feasible for Metro Manila, policymakers may want to begin laying the groundwork now for the future necessity of relocation. It might be useful for future work to identify strategies for understanding when to implement adaptation. For example, some agencies in the U.S. have selected "trigger" points for making relocation decisions.

Timing is currently addressed in the "implementation timing" Tier 2 criterion. However, it is hard to rate implementation timing as a "high," "medium," or "low" since adaptation options addressing existing vulnerabilities are not necessarily better or worse than adaptation options address future vulnerabilities. In particular, users will likely want to consider one suite of adaptation options in the short-term, while beginning to plan for longer term solutions. These are the types of issues and associated analyses that could be explored though the use of the in-depth assessment pathway described in the framework. And, as noted above, adaptation planners should be encouraged to consider how different suites of options may be suitable, with sequencing across timespans from one set of actions to address near-term vulnerabilities while also planning a pathway for options that will be more viable and/or effective for addressing the climate risks anticipated in the longer run.

B.9 CONCLUSION AND RECOMMENDATIONS FOR NEXT STEPS

The idea of screening is a good one – and can be used to identify options that are clear winners and losers. Further, the Tier 1 and Tier 2 screening also has benefits when applied to the analysis of options that can be largely analyzed discretely. However, many decisions do not involve the adoption (or not) of individual options, but rather the development of a set of options to address an economic impacts. When options are part of the broader adaptation plan, the screening is only the first step in the development of such a plan. In such instances, additional (and more in-depth) evaluation is likely to be beneficial, and the Tier 1 and Tier 2 screening can help articulate the specific issues and questions upon which the additional evaluation should focus.

In many situations, stakeholders will consider options as a group rather than individually or sequentially. To address these cases, the screening process represents only the initial steps toward development of a comprehensive, long-term adaptation plan. Such a plan needs to recognize the context of decision making (including available resources and institutional constraints, the timing and magnitude of economic impact and adaptation options, and the involvement of stakeholder groups). A framework to support such a comprehensive adaptation planning process – initiated by the screening steps and the path to additional focused analysis – can help to determine the level – and type – of analysis needed to support the development of such a plan, including the data needs and depth of analysis (e.g., how quantitative the analysis should be), and the type of analysis to be done (BCA, etc.).