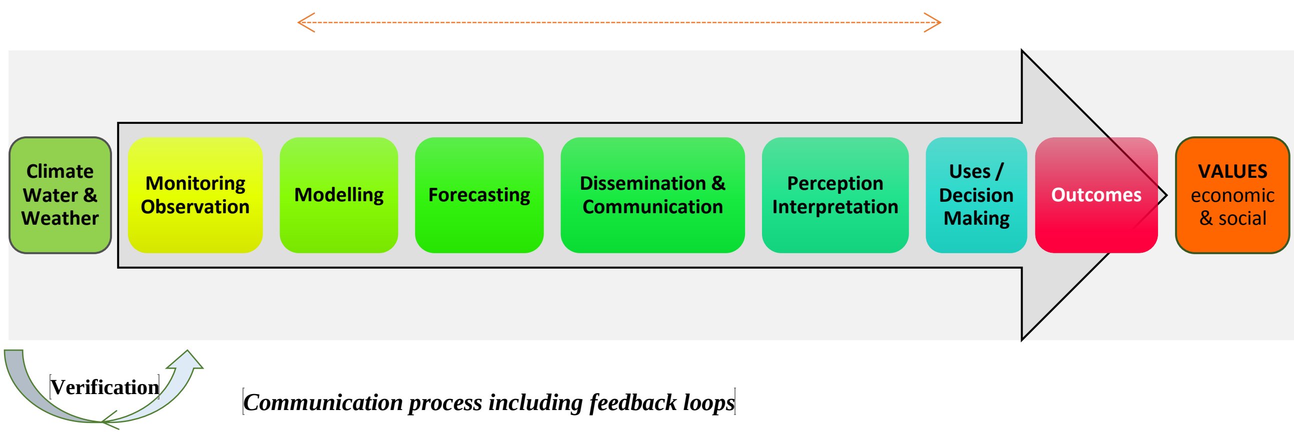
Estimating Costs and Benefits for Provision of Hydromet Services in Bangladesh

1. **Background.** Not including earthquakes and epidemics, the EM—DAT database (http://www.emdat.be/database) records 251 major hydro-meteorological disasters in Bangladesh in the 35 year period 1980–2015. These include cold waves, heat waves, severe winter conditions, riverine floods, flash floods, coastal floods, landslides, tropical cyclones, and convective storms. These average 7.2 events a year with roughly 5,500 deaths, almost 10,000,000 people affected, and nearly US$500 million in damages each year. In terms of societal impacts these are in large part related to tropical cyclones averaging 1.4 events per year with nearly 5,000 deaths, 1,500,000 affected, and US$130 million in damages. These tropical cyclone impacts are likely related to a few specific events such as the April 1991 tropical cyclone that struck in the Chittagong region with 130 knot winds and 20 foot storm surge, killing over 138,000, leaving 10 million homeless, and causing over US$1.5 billion (1991 US$) in damages. This also understates the socio-economic impacts of hydro-meteorological events in Bangladesh as the EM-DAT only records major disasters and the vast majority of events are likely smaller lower impact events that could still cumulatively represent similar or even greater magnitudes of impacts.

Figure 6.1. Hydro-meteorological Information Value Chain



2. **Economic Value of Improvements in Hydro-Meteorological Services.** A hydro-meteorological value chain shows that value, in economic and social terms, is ultimately at the end of the process that starts with observation of weather, water, and climate through to decision-making and outcomes. As such, the value of an accurate, timely and relevant forecast can only be realized if a beneficial value is achieved at the end of the process. Often, it is assumed that by merely improving observations - through improved technologies for example - an end economic value will be secured.

3. For the purposes of this analysis in assessing economic benefits of improved hydro-met information, products, and services we assume that these flow through as needed from product creation and dissemination to end-users decision making. As such, the economic and social values that can derive from this project will require not only investing in hard infrastructure but in the entire processes that ensures that outcomes are properly realized and measured.

4. **Economic Analysis**. To estimate the value of strengthening Bangladesh's hydro-meteorological services, a Cost-Benefit Analysis (CBA) was undertaken. The objective of the analysis was to verify the economic justification for the project, guide the project's priorities and investments during implementation, position the value of Bangladesh's hydro-met services in a wider sociopolitical context, and create a baseline against which progress can be compared.

5. **At the time the economic analysis was undertaken, project costs were estimated at US$127.5 million.** Following an initial year investment of US$10.0 million, the balance of the total investment is allocated across a project implementation period of the remaining five years as shown in Table 6.1. In addition to the initial investment, factors for capital maintenance (for example,, to account for depreciation) and for operation and maintenance (O&M) are estimated to be 10 percent of total costs. This rate may overstate actual costs if not all investment is in depreciable capital (for example,, buildings, equipment) and there is a risk of double counting by including depreciation and O&M as separate items. Hence, this assumption is conservative and may be overestimating the costs. During and beyond implementation, costs will be incurred for capital maintenance (for example,, depreciation of capital) at an assumed 10 percent of total project investment to date (that is,, maximum of US$12.75 million/year) for the time period of the analysis. Costs will also be incurred for operation and maintenance (for example,, operational costs – ongoing labor, energy, maintenance, training, and so on) at an assumed rate of 10 percent of total project investment to date (that is,, maximum of US$12.75 million/year) for the time period of the analysis. As the GOB contribution during project implementation will cover O&M, we calculate additional ongoing O&M starting in 2023.

6. Table 6.1 shows estimated annual costs, cumulative costs, depreciation, assumed operation and maintenance flows over the first six years of the project in current values (that is,, not discounted to present values) as well as all future years (2023+ costs remain the same for all years of analysis).

Table 6.1.Baseline Cost, Depreciation. O&M Assumptions

Fiscal Year	Annual	Cumulative Cost	Depreciation 10%	O&M 10%	Total Invest, Depr, O&M
2017	10,000,000	10,000,000	1,000,000	0	11,000,000
2018	21,900,000	31,900,000	3,190,000	0	25,090,000
2019	26,900,000	58,800,000	5,880,000	0	32,780,000
2020	36,900,000	95,700,000	9,570,000	0	46,470,000
2021	21,900,000	117,600,000	11,760,000	0	33,660,000
2022	9,900,000	127,500,000	12,750,000	0	22,650,000
2023	0	127,500,000	12,750,000	12,750,000	25,500,000

7. **Benefits:** For the benefit estimates in this phase of the analysis, two estimation approaches were utilized: (a) benchmarking approach, and (b) benefit transfer (BT) and value of statistical life (VSL).

8. In prior assessments of the value of hydro-met services the World Bank has used a benchmarking approach developed to estimate an order-of-magnitude benefits of reducing damages from weather-related events resulting from hydro-met services. Benchmarking is carried out by first using data and estimates from other countries and expert judgment to define and adjust two benchmarks for each country: a) the average annual direct economic losses

caused by hydro-met hazards as a share of GDP; and b) the potential changes in annual losses with modernization of hydro-met services as a percentage of the total level of losses. In a second step, these factors may be adjusted to account for country-specific estimates of weather and climate conditions, structure of the economy and other factors. These factors will be a function of the weather dependency of the economy (that is,, national economic structure and hydro-meteorological vulnerability) and the current and potentially improved quality of hydro-met products and services (that is,, the efficiency of hydro-met services with and without modernization). The benchmarking analysis is based on a series of exercises conducted in Eastern Europe and Central Asia Region which concluded that the mean annual losses from hydro-met hazards and events varies between 0.1 percent to 1.1 percent of GDP and that that the share of preventable or prevented losses with modernization ranges from 20 percent to 60 percent of total weather and climate-related losses.

9. Using the simplest top down benchmarking approach two different factors are estimated:

(a) *Vulnerability Factor*: Average annual direct economic losses caused by hydro-met hazards as a share of GDP. Bangladesh is one of the world's most hydro-met vulnerable countries and has experienced large scale natural disasters that have had significant impacts on gross domestic product. Based on the existing estimates for ECA countries, experts recommend that a 1 percent annual loss factor is used for Bangladesh.

(b) *Loss Reduction Factor*: Potential changes in annual losses with modernization as a percentage of the total level of losses. While the national hydro-meteorological services in Bangladesh are in need of improvement there has been considerable advancement in reducing the impacts of hydro-met events in the last 30 years in Bangladesh. For the purposes of this analysis, a conservative estimate of 20 percent is used as potential further loss reductions with modernization.

(c) Gross Domestic Product (GDB) of Bangladesh in 2014 was US$173.8 billion (http://www.worldbank.org/en/country/bangladesh)

10. A benchmark estimate of benefits is calculated as the product of these factors: GDP x Vulnerability Factor x Loss Reduction Factor = Benchmarking Benefit Estimate

11. As shown in Table 6.2, a top down benchmarking estimate indicates a potential annual value of improved hydro-met services of US$347.6 million/year in Bangladesh. Based on the chosen factors this represents 2/10ths of 1 percent of Bangladesh's GDP.

Table 6.2. Benchmarking Calculation

GDP	US$173.8 billion
Vulnerability Factor	1%
Loss Reduction Factor	20%
Benchmarking Benefit Estimate	US$347.6 million

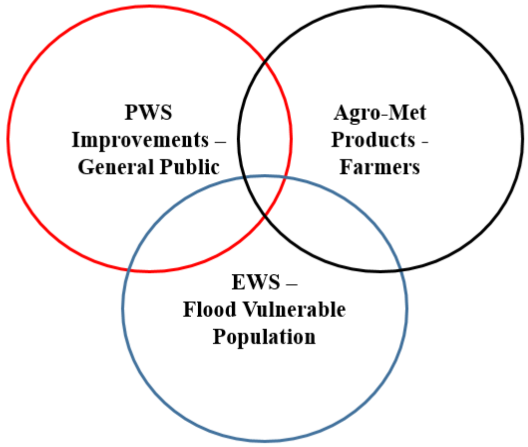
12. The second estimation approach combines benefits transfer and value of statistical life (VSL) estimates for the three components of the proposal hydro-met improvement program. In part this approach uses a common method for valuing nonmarket goods and services known as

benefits transfer (BT) where the results of existing valuation studies are transferred from the study context (that is,, Mozambique or Zimbabwe) correcting and adjusting to the current context (that is,, Bangladesh). This is the best feasible valuation approach when there is not time and resources for primary data collection and analysis. A number of cautions are relevant when using BT particularly as there is a limited literature on economic values of improved weather forecasting in developing countries. Thus the approach can generate potentially inaccurate or misleading results if not appropriately framed. Obtaining valid and reliable benefit estimates using BT methods can be challenging when differences exist among the types of conditions studied in the primary empirical research (that is,, the study context for the published monetary estimate), and the NMHS context to which we are transferring the results. The approach implemented here is largely a unit-value approach (as opposed to a transfer function) using simplified adjustments based on differences in national income (thus also assuming WTP is linear in income). The assessment is conducted to provide some reference unit values but a targeted analysis is being conducted for this project.

13. The project identifies primary project benefits accruing to (a) members of the general public from improvements in public weather systems (PWS), (b) farmers from improvements in agro-meteorological (Agro-Met) information systems, and (c) vulnerable populations from improvements in community-based flood and drought early warning systems (EWS). To derive baseline benefits estimates we used a different approach for each of these benefit areas. For Public Weather Service (PWS) benefits we undertook a benefits transfer (BT) to Bangladesh using value estimates from a study of willingness to pay (WTP) for improved weather services in Mozambique (Lazo 2015)[1]. For an agro-met decision support system (DSS) values we undertook a benefits transfer to Bangladesh using value estimates from Zimbabwe for improved seasonal forecasts (the source was a literature review of the value of climate and seasonal forecasts in Clements et al. 2013). For the value of early warning systems we undertook a benchmarking type evaluation using value of statistical lives saved (VSL) for reduction in hazardous hydro-met related fatalities. Figure 6.2 illustrates these three hydro-met information improvements and benefit areas.

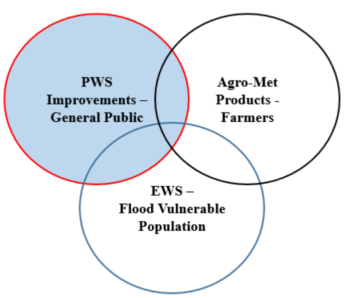
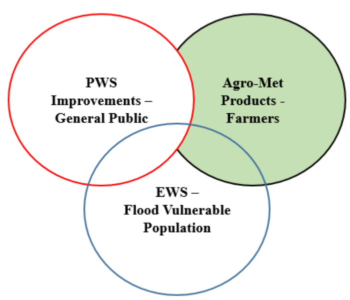
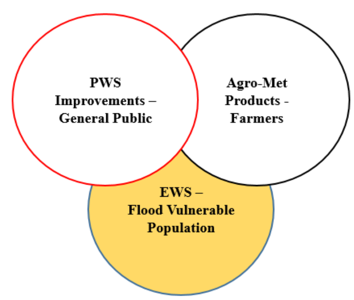
[1] Lazo, J.K., 2015: Survey of Mozambique Public on Weather, Water, and Climate Information. NCAR Technical Note NCAR/TN-521+STR, 236 pp, DOI: 10.5065/D6B56GS4.

Figure 6.2. Primary Hydro-met Information Improvements and Benefit Areas



14. As suggested by Figure 6.2, there is likely some overlap in the benefits between the different valuation approaches. For instance, many members of the general public are also farmers and will benefit from improved hydromet information regardless of new agro-met products and services. And, members of the public will also be the primary beneficiaries of improved EWS for floods and droughts. And further, farmers will benefit from early warning on floods and droughts regardless of new agro-met products and services. While we currently do not have empirical indications of these potential overlaps, we assume a 20 percent overlap between pairs of benefits estimates and in aggregating benefits estimates we adjust downward as indicated in Figure 6.3. First we take 100 percent of the WTP values, then add 80 percent of the agro-met values (adjusting for the assumed 20 percent overlap with WTP), and then add 60 percent of the EWS values (adjusting for the assumed 40 percent overlap with WTP and agro-met values – ignoring the small area where all three benefit areas may overlap). Future empirical work could evaluate the degree to which such overlap may exist and adjust accordingly.

Figure 6.3. Primary Hydro-met Information Improvements and Benefit Areas

		
100% of estimated PWS benefits from Mozambique WTP (willingness-to-pay) study (blue area)	80% of estimated agro-met benefits (green area = agro-met benefits minus overlap with PWS)	60% of hydro benefits (orange area = EWS benefits minus overlap with PWS and agro-met)

15. **Value to Households for Public Weather Services (PWS):** For an estimate of benefits from improvements in PWS products and services we identified two studies from which to

transfer values to the current project. The first set of values transferred are from a recent survey conducted in Mozambique for a World Bank project with similar objectives as this one. The values were estimated for households' willingness to pay for improvements to national hydro-meteorological services. Using a contingent valuation method (CVM) question for a single program but with two different versions representing an intermediate improvement and a maximal improvement, total WTP was estimated for the maximal improvement program (not adjusting upward for potential scenario rejection) of 40.89 MT (metical) per year per respondent. This value is equal to US$1.16 (US$0.53-US$2.62, 95 percent confidence interval (CI)). An income ratio conversion from Mozambique to Bangladesh using 2013 per capita GDP estimates from the World Bank website was used to make the adjustment (Table 6.3). This yields a Bangladeshi WTP estimate for hydro-met forecast improvement equal to US$1.84 (US$0.84–US$4.15, 95 percent confidence interval). This is taken as a per-household estimate aggregated across all households in Bangladesh (32,288,660) to get a national benefit estimate of US$59,296,282.

		Central Estimate	Lower CI	Upper CI
	WTP	1.16	0.53	2.62
GDP per capita (current US$)	Mozambique (2013)	605.00	605.00	605.00
	Bangladesh (2013)	957.80	957.80	957.80
Income Ratio: Bangladesh/Mozambique		1.58	1.58	1.58
	Adjusted Bangladesh WTP	1.84	0.84	4.15
Households		32,288,660	32,288,660	32,288,660
Bangladesh Aggregate National WTP (US$)		59,296,282	27,092,267	133,927,810

Table 6.3. Conversion of Mozambique CVM Household WTP Based on Income Ratios

16. **Benefits of Agro-Met Decision Support System:** The project proposes to support the development of a decision support system (DSS) for agro-meteorological services at the Department of Agricultural Extension (DAE). A DSS would provide information for agricultural decision making at all time scales (for example,, days to annual) and thus generate benefits in a range of decision situations. For an estimate of benefits of an Agro-Met DSS we add a value estimate for seasonal forecasts (from Clements et al 2015) and scale that up based on literature suggesting that value of forecasts in agriculture are greater for short-term decision making than for seasonal forecasts. As indicated in Clements et al.[2] (2013 – Exhibit 5) Makaudze (2005)[3] derives a per household WTP of "[US$]$0.44–0.85 in willingness-to-pay by households in Zimbabwe for improved seasonal forecasts." Using a midpoint of US$0.645 and converting to Bangladesh based on a Bangladesh/Zimbabwe income ratio of 1.058[4] yields a per household WTP of US$0.6823/year. In their review of literature of the benefits of climate services, Clements et al. find similar values for seasonal forecasts in other countries and contexts.

[2] Clements, J., A. Ray, and G. Anderson. 2013. The Value of Climate Services Across Economic and Public Sectors: A Review of Relevant Literature. Prepared for: United States Agency for International Development.
[3] Makaudze, E.M. 2005. Do Seasonal Climate Forecasts and Crop Insurance Matter for Smallholder Farmers in Zimbabwe? Using Contingent Valuation Method and Remote Sensing Applications. PhD Dissertation. Ohio State University.
[4] Based on the ratio of Bangladesh to Zimbabwe per capita income in 2013 from http://data.worldbank.org/indicator/NY.GDP.PCAP.CD

17. In a summary of the extant literature on the value of weather forecasts in agriculture, Katz[5] provides per hectare benefit estimates for a range of crops, forecasts, and decision contexts. A qualitative assessment of this literature indicates benefits from short-term forecasts (days to weeks) in general at twice or more the value of seasonal forecasts (in large part forecasts of El Nino). Based on this assessment and a conservative approach we triple the per household WTP estimate from Makaudze to capture some of the short-term benefits of an Agro-Met DSS as well (that is,, value of seasonal forecasts plus twice that as value of shorter-term forecasts). We thus use a per household WTP for the Agro-Met DSS of US$2.0468. With 32,288,660 households in Bangladesh, 60 percent of these in agriculture, and assuming that one-third (33.3 percent) of those households use the Agro-Met DSS yields annual benefits of US$13,204,223.

18. Agriculture and Forestry represented about 15.3 percent of Bangladesh's GDP between 2008 and 2013 or 569 billion taka. Based on current exchange rates this is over US$7 billion. The benefits from the Agro-Met DSS are thus about 0.180percent (that is,, less than 1 percent) of agricultural output. Given the vulnerability to weather variability of agriculture in Bangladesh and the potential for improved decision making, this represents a lower bound estimate.

19. **Benefits of EWS in Reducing Loss of Life:** A primary benefit of enhanced early warning systems (EWS) is for the protection of life in impending hazardous conditions such as typhoons, floods, tornadoes, and landslides. The EM-DAT database (http://www.emdat.be/) "contains essential core data on the occurrence and effects of over 18,000 mass disasters" by type, year, and country (including Bangladesh). EM-DAT only records major disasters (for example,, at least 10 fatalities or 100 or more people affected/injured/homeless) and so will not capture smaller events. Counting only meteorological, hydrological, and climatological events and not counting two years of exceptional natural disasters in Bangladesh (1970 and 1991), in the four decades from 1965 to 2014, an average of 2,618 individuals died in natural disasters in Bangladesh. Visual examination of the data indicates that the number of fatalities has been falling over time. This has occurred even with increased population and is likely due in part to prior advances in early warning systems, hazard mitigation, and response. In addition, regression analysis indicates that fatalities have been falling over time falling but at a decreasing rate (that is,, fatalities have fallen but will not fall to zero).[6] In the decade 2005–2014 an average of 722 individuals died each year in major disasters (driven largely by Cyclone Sidr in 2007 for which EM-DAT indicates 4,275 fatalities). Not counting Cyclone Sidr, in the decade 2005–2014 an average of 295 individuals died each year in major disasters. (As smaller events that are not recorded in EM-DAT are likely more impactful in aggregate than major disasters this analysis is likely an underestimate of impacts and thus of benefits from impact reductions.) Assuming that 10 percent of these fatalities could be avoided with the improvements in project related EWS, this represents 29.5 fewer fatalities each year on average. Note that having excluded the major disasters (for example,, disasters in 1970, 1991, and Cyclone Sidr in 2007) from the fatality measures we are likely understating the potential value of improved EWS.

20. To adjust VSL estimates from the US to Bangladesh we use Eq. 1 from Hammitt and

[5] Katz, R. Economic Value of Weather and Climate Forecasts: Case Studies: Agriculture. http://www.isse.ucar.edu/staff/katz/agriculture.html (accessed March 23, 2016)

[6] In "Reduced death rates from cyclones in Bangladesh: what more needs to be done?" Ubydul Haque et al. analyze reductions in typhoon-related fatalities in Bangladesh (http://www.who.int/bulletin/volumes/90/2/11-088302/en/) noting the possibility of further reductions.

Robinson (2011)[7], where "elasticity" is the income elasticity of VSL meaning the per cent change in VSL estimates as income changes by one percent. In this case Bangladesh is indexed as Country B and the US is indexed as Country A. Eq. 1: $VSL_B = VSL_A * (Income_B / Income_A)^{elasticity}$

21. For VLS_A, we use a policy-based recommended median point estimate of VSL of US$9.1 million[8]. We use a midpoint estimate of the income elasticity of VSL of 0.40 from Doucouliagos et al. 2014[9]. And we use median GDP per capita from the World Bank[10] for US and Bangladeshi income. This yields a Bangladeshi VSL of US$1,899,024. Applying this to the average fatality reduction of 29.5/years yields an annual expected benefit of US$56,021,195.

22. Table 6.4 shows the summation of the three benefits estimates qualitatively adjusted for potential double counting. An annual benefit upon full program implementation of US$103,472,378 is used in the subsequent benefit-cost analysis.

Table 6.4. Summary of Baseline Benefit Estimates

	Aggregate Annual Benefits	**Adjustment for Double Counting**	**Adjusted Benefits for Aggregation**
National WTP for PWS	59,296,282	100%	59,296,282
Annual WTP for Agro-Met DSS	13,204,223	80%	10,563,378
VSL from EWS	56,021,195	60%	33,612,717
Baseline Aggregate Benefits (PWS+DSS+EWS)			103,472,378

23. Another recent study, this in Vietnam, estimates the benefits to households of an improved cyclone warning service through the use of a discrete choice experiment survey with over 1,000 respondents. The analysis examines issues with respect to preference heterogeneity, variation in benefit estimates based on analysis approaches, potential bequest and altruistic values, and impacts of value elicitation on benefit estimates. The valuation focuses only on improvements in tropical cyclone information which is only a subset of likely improvement in Bangladesh and would only apply directly to cyclone prone areas in Bangladesh (approximately 40 percent of Bangladesh population). As such, and for the purpose of this preliminary analysis, it is assumed that non-cyclone vulnerable populations in Bangladesh have comparable values for the range of other hazards subject to improved forecasts (that is,, riverine, urban, and flash floods, landslides, drought, extreme winds, and so on). This may represent a lower bound estimate though as the Bangladesh program proposes a much wider range of information improvements including hydrological and climatological that are not considered in the analysis for Vietnam. The results for Vietnam for annual WTP are US$0.61 for a medium improvement and US$0.90 for maximal improvement. Values are expressed as thousands of Vietnamese Dong

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[7] Hammitt, J.K. and L.A. Robinson, 2011. "The Income Elasticity of the Value per Statistical Life: Transferring Estimates between High and Low Income Populations". *Journal of Benefit-Cost Analysis*. Vol. 2(1) Art 1.
[8] Rogoff, P. and K. Thomson.2014. Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analyses – 2014 Adjustment. US DOT. https://www.transportation.gov/sites/dot.gov/files/docs/VSL_Guidance_2014.pdf.
[9] Doucouliagos, H. T.D. Stanley, and W.K. Viscusi. 2014. "Publication selection and the income elasticity of the value of a statistical life." Journal of Health Economics. 33:67–75.
[10] Source: http://data.worldbank.org/indicator/NY.GDP.PCAP.CD 2011-2015 average).

(VND) (as of July 17, 2015 1,000 VND = US$0.0459672). The value elicitation was for a one-time payment so the WTP estimates are converted to an annualized value using a 12 percent rate of discount (r) and dividing the one-time payment by 1/r.

24. Table 6.5 illustrates the conversion of per household WTP in Vietnam to Bangladesh using simple income ratios and then the aggregation to a national benefit estimate for the medium and maximal improvement programs. The results of this exercise indicate a range of point estimates of WTP for the medium and maximal improvement programs that when transferred to Bangladesh and aggregated indicate potential national WTP of US$9.9 million to US$14.6 million depending on program attributes.

Table 6.5. Conversion of Vietnam CVM Household WTP Based on Income Ratios

	Program	**Medium Improvement**	**Maximal Improvement**
	WTP	0.61 US$	0.90 US$
GDP per capita (current US$)[11]	Vietnam (2013)	1,908.6	1,908.6
	Bangladesh (2013)	957.80	957.80
Income Ratio: Bangladesh/Vietnam		0.50	0.50
Adjusted Bangladesh WTP		0.31	0.45
Households		32,288,660	32,288,660
Bangladesh Aggregate National WTP		9,884,160	14,583,187

25. **CBA Results.** Table 6.6 below summarizes the key variables for the benefit-cost analysis including timing of benefits and costs and the discount rate. For all calculations, real values were applied that do not factor in inflation or potential changes in exchange rates. A discount rate of 12 percent was applied as a baseline discount rate as is required by the Bank's guidelines on economic analysis. However, the Team also looked at the discount rates that could be applicable for Bangladesh. Information on the website Trading Economics suggest private sector Bangladeshi interest rates range from a low of 4.50 to a high of 8.75 with an average of 7.25 percent during the period 2008–2015. Applying baseline rates of 10–12 percent is therefore a conservative estimate for comparing an Internal Rate of Return (IRR) to an Economic Rate of Return (ERR).

Table 6.6. Key Variables for Benefit Cost Calculations

Key Variables	**Value**
First year of costs	2017
First year cost of investment (millions US$)	10.0
Subsequent cost of investment (next five years) (millions US$)	See Table 6.1
Timeline of initial investment (Years)	6
Annual depreciation (% of initial investment)	10%
Annual maintenance and repair (% of initial investment)	10%
Project analysis period	100 years
Timeline of increasing O&M costs (starts with investment) (Years)	6
Households in Bangladesh [a]	32,288,660
Benefit Estimates (Annual US$)	

[11] http://data.worldbank.org/indicator/NY.GDP.PCAP.CD accessed July 17, 2015.

Top-Down Benchmarking	347,600,000
Sector Specific Benchmarking Calculation	347,252,400
Working Group Benchmarking Calculation – Step 1	750,168,418
Working Group Benchmarking Calculation – Step 2	724,924,912
Baseline Benefits	
Mozambique CVM Household WTP - Central Estimate (WTP for PWS)	59,296,282
WTP for Agro-Met DSS	10,563,378
VSL from EWS	33,612,717
Baseline Aggregate Benefits (PWS+DSS+EWS)	103,472,378
Mozambique CVM Household WTP - Lower CI	27,092,267
Mozambique CVM Household WTP – Upper CI	133,927,810
Vietnam CVM Household WTP – Medium Program	9,884,160
Vietnam CVM Household WTP – Maximal Program	14,583,187
Discount rate	
Discount rate – Base Case	12%
Discount rate – Lower value for sensitivity analysis	3%
[a] The World Bank (http://data.worldbank.org/country/bangladesh) indicates a population of 156,600,000 in Bangladesh and the Bangladesh Bureau of Statistics http://www.bbs.gov.bd/RptHIES_2_1.aspx?page=/PageReportLists.aspx?PARENTKEY=73 indicates an average 2005 household size of 4.85 thus we use 32,288,660 as the number of households.	

26. Using the baseline analysis variables indicated previously and the Baseline Aggregate Benefits (PWS+DSS+EWS) a baseline was established (see Table 6.7).

Table 6.7. Baseline Variables for Baseline Benefit-Cost Calculations

Key Variables	Value
First year of costs	0
First year cost of investment (millions US$)	10.0
Subsequent cost of investment (next four years) (millions US$)	See Table 6.1
Timeline of initial investment (Years)	6
Annual depreciation (% of initial investment)	10%
Annual maintenance and repair (% of initial investment)	10%
Project analysis period	100 years
Timeline of increasing O&M costs (starts with investment) (Years)	6
Baseline Aggregate Benefits (PWS+DSS+EWS)	103,472,378
Discount rate	12%

27. Table 6.8 shows the results from the baseline benefit-cost calculations. A net present value of US$414.3 million and a benefit-cost ration (BCR) of 2.67 indicate that the project is economically viable. The present value to households is US$661.7 million using a time horizon of 100 years for the project with basic assumptions and a 12 percent discount rate. A present value of total costs of US$247.4 million was estimated using the same assumptions and discount rate as for the benefits. The net present value (NPV) of the project is US$414.3 million. The Internal Rate of Return (IRR) is 75.07 percent. This IRR represents a significantly better return than a relevant comparison Economic Rate of Return (ERR) of private sector Bangladeshi interest rates averaging 7.25 percent.

Table 6.8. Results of Baseline Benefit Cost Calculations

Total Present Value (PV) Benefits	661,748,359
Total PV Costs	247,429,343
Net Present Value (NPV)	414,319,016
Benefit-Cost Ratio (BCR)	2.67
Internal Rate of Return[12]	75.07

28. A sensitivity analysis was conducted using (a) different benefits estimates; (b) a lower discount rate; (c) an analysis of no ongoing investment in program upkeep and operations and maintenance; and (d) a shortened analysis timeline. Using a lower bound benefit estimate from Vietnam and all other baseline CBA parameters generates a NPV of (US$184.2 million) and a BCR of 0.26 (Table 6.9). If it could be ascertained that this was a best estimate of benefits to be realized in Bangladesh this would bring the program into question with respect to standard CBA policy criteria.[13] On the other hand, using the largest benefit estimate from a benchmarking approach, a significant NPV of US$4.6 billion and BCR 19.4:1 are derived.

Table 6.9. Sensitivity Analysis with Alternate Benefit Estimates

	Baseline	Lower Bound	Upper Bound
Annual Benefits	103,472,378 (PWS+DSS+EWS)	9,884,160 (Vietnam Medium Program)	750,168,418 (Benchmarking)
Total Present Value (PV) Benefits	661,748,359	63,213,263	4,797,635,170
Total PV Costs	247,429,343	247,429,343	247,429,343
Net Present Value (NPV)	414,319,016	-184,216,080	4,550,205,827
Benefit-Cost Ratio (BCR)	2.67	0.26	19.39

29. The choice of a 12 percent discount rate is based on a review of other BCAs in developing countries. The 12 percent rate is likely set higher than that used in developed in countries to attempt to control for project risk (for example,, possible failure of project to achieve projected benefits) and to avoid “crowding” out private sector capital which likely incurs a similarly high rate of interest. This rate (12 percent) may thus not reflect broader social rates of time preference. Table 6.10 illustrates the same baseline BCA but using a lower discount rate (3 percent) that may more closely reflect discount rates in developed countries. Using a 3 percent discount rate rather than 12 percent indicates a NPV of US$3,022.6 million and BCR of 3.57, as may be expected (given that benefits generally incur in future years compared to upfront investment costs) there is a higher NPV and BCR using a lower discount rate.

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[12] The IRR was generated using an Excel spreadsheet data function that choose the variable value in one cell (parameter cell) to set a specific other cell (target cell) to a predetermined value. In this case, using the spreadsheet that calculates project benefit and cost flows and discounts these, the value of the Discount Rate (parameter cell) is found that equalizes the present value of costs and the present value of benefits (that is, sets the NPV cell (that is, the target cell) equal to zero).

[13] The Vietnam estimates are only for values of meteorological forecasts and warnings for tropical cyclones and this would not represent potential total benefits of the program in Bangladesh to improve hydrological, meteorological, and climate information across all phenomenon and areas. In other words the Vietnam estimates are likely a significant understatement of potential benefits to Bangladesh.

Table 6.10. Sensitivity Analysis with Alternate Discount Rate

	Baseline	Alternate
Annual Benefits	12%	3%
Total Present Value (PV) Benefits	661,748,359	3,022,626,044
Total PV Costs	247,429,343	845,891,429
Net Present Value (NPV)	414,319,016	2,176,734,615
Benefit-Cost Ratio (BCR)	2.67	3.57

30. Operation and Maintenance is a critical issue with project implementation as it requires an internal commitment by the Government to support the ongoing, long-terms costs of the project. Given the likely increase in costs necessary to maintain capital and equipment as well as increased ongoing operations and maintenance in the baseline analysis, the assessment assumes a 10 percent costs for depreciation (for example,, to maintain initial project equipment at adequate levels) and 10 percent costs for operations and maintenance. As an alternative analysis, it is assumed that after the first five years there is no ongoing O&M or investment to counter depreciation. In Alternate 1 it assumed that benefits end immediately after the sixth year and in Alternate 2 there is an assumption that these benefits diminish to zero over five years. As shown in Table 10, the NPV and BCR is reduced considerably and the BCR less than 2.0. This indicates that if there is not a commitment to ongoing support of the initial investment the policy decision may question the initial investment.

Table 6.11. Sensitivity Analysis with No Ongoing O&M or Depreciation

	Baseline	Alternate 1 – Benefits End After Yr 6	Alternate 2 – Benefits Diminish After Yr 6
Total Present Value (PV) Benefits	661,748,359	172,484,871	250,985,029
Total PV Costs	247,429,343	126,853,986	126,853,986
Net Present Value (NPV)	414,319,016	45,630,885	124,131,043
Benefit-Cost Ratio (BCR)	2.67	1.36	1.98

31. For the baseline analysis benefits and costs are projected over 100 years as this is clearly a long lived investment. To assess the impact of the length of the analysis timeline a sensitivity test was conducting using a 15 year project analysis rather than the 100-year baseline approach. As shown in Table 6.12 the basic policy conclusion does not change although the NPV and BCR fall.

Table 6.12. Project Analysis Over 15 Years rather than 100 years)

Total Present Value (PV) Benefits	485,322,433
Total PV Costs	203,950,483
Net Present Value (NPV)	281,371,951
Benefit-Cost Ratio (BCR)	2.38

32. Due to the nature of the program (to support an ongoing modernization program), alternative designs were not evaluated. The analysis is based on the assumption that a particular investment has been identified as least cost.