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Charles County Water Source Feasibility Study – Phase A-2

Technical Memorandum
October 31, 2018

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List of Acronyms

Abbreviation	Definition
AOP	Advanced Oxidation Processes
BAC	Biologically active carbon
CAT	Corrective action thresholds
CBP	Chesapeake Bay Program
CCG	Charles County Government
CCL	Contaminant Candidate List
CFR	Code of Federal Regulations
Cl_2	Chlorine
CPV	Competitive Power Ventures
CT	Contact time
DBP	Disinfection byproduct
DOC	Dissolved organic carbon
DPR	Direct potable reuse
GAC	Granular activated carbon
GIS	Geographical information system
g/mol	Grams per mole
gpm	Gallons per minute
GWUDI	Groundwater under the direct influence of surface water
H_2O_2	Hydrogen peroxide
HAA5	The sum of 5 haloacetic acid concentrations (monochloroacetic acid, monobromoacetic acid, dichloroacetic acid, trichloroacetic acid, and dibromoacetic acid)
HGL	Hydraulic grade line
IPR	Indirect potable reuse
LRAA	Locational running annual average
LT2ESWTR	Long-term 2 Enhanced Surface Water Treatment Rule
MCL	Maximum contaminant level
MDE	Maryland Department of Environment
MF	Microfiltration
mg/L	Milligrams per liter
mgd	Million gallons per day
MGS	Maryland Geological Survey
mL	Milliliter
MPN	Most probable number
NA	Not applicable
NOM	Natural organic matter

NSWC	Naval Surface Warfare Center
NTU	Nephelometric Turbidity Units
O&M	Operation and maintenance
O_3	Ozone
PAC	Powdered activated carbon
pCi/L	Picocuries per liter
RBF	Riverbank filtration
RO	Reverse osmosis
SWTR	Surface Water Treatment Rule
TAZ	Traffic Analysis Zones
TDS	Total dissolved solids
TOC	Total organic carbon
TRC	Total residual chlorine
TTHM	Total trihalomethanes (the sum of bromoform, chloroform, bromodichloromethane, and chlorodibromomethane concentrations)
UCMR	Unregulated Contaminant Monitoring Rule
UF	Ultrafiltration
USEPA	United States Environmental Protection Agency
UV	Ultraviolet irradiation
WMA	Washington DC metropolitan area
WSSC	Washington Suburban Sanitary Commission
WTP	Water treatment plant
WWTP	Wastewater treatment plant
µg/L	Micrograms per liter

Executive Summary

The Charles County Government (CCG) has commissioned a Water Source Feasibility Study in response to projected population growth, declining water levels in regional aquifers, potential changes in groundwater quality and associated treatment requirements, and conditions laid out by the Maryland Department of the Environment. The main objective of this study is to evaluate potential options for meeting the Waldorf and Bryans Road water systems' future demand. However, due to the fact that nearly all water for domestic, industrial, and agricultural use in the County is withdrawn from the same confined aquifers, the findings of this study are meaningful to other nearby systems and may serve as a foundation for potential regional water supply solutions in the future.

The evaluation included two phases, Phase A-1 and Phase A-2. In Phase A-1 (refer to Appendix B), a comprehensive review of all potential water sources in the County was conducted, such as increased allocations from the Washington Suburban Sanitary Commission (WSSC), development of a surface water supply, new wells in confined and unconfined aquifers, water reuse, and a combination thereof. Water source alternatives were evaluated based on preliminary screen criteria: capital cost, operation and maintenance cost, water quality, supply reliability, ease of operation, constructability, ease of permitting, environmental stewardship, public acceptance, and regional benefits. Ultimately, these criteria and their associated pass/fail assessments for each water supply alternative enabled removal of options from further consideration that had notable conceptual weaknesses. Eleven water supply alternatives passed the preliminary screening process and were further evaluated in Phase A-2. The results of Phase A-2 of the evaluation are presented here, including the development and triple bottom line (TBL) assessment of the final water supply scenarios.

Following the completion of the Phase A-1 report, additional information became available for some of the alternatives. Supplemental analyses were conducted to further determine the feasibility of the eleven remaining alternatives from Phase A-1. The findings from the updated analyses and, where applicable, the basis for why some of the eleven alternatives were eliminated from further consideration, are summarized below.

- Alternatives B-2 and S-1: Riverbank Filtration and Surface Water Treatment Plant – Alternatives combined into a single Upper Reaches Potomac River Supply alternative with conventional surface water intake or riverbank filtration options within the alternative.
- Alternative S-5: Morgantown Generating Station – This alternative was removed from consideration due to potential issues with long-term reliability and lack of response from the facility owner.
- Alternative R-1: Non-Potable Reuse – This alternative was removed from consideration due to limited ability to offset potable water supply needs given future demands.
- Alternative P-1: Increased WSSC Allocations – Costs for CCG to purchase water from WSSC at current rates and water quality at current and proposed connection locations were added to the evaluation of this alternative.

- Alternative W-1: Countywide Agreement – This alternative was removed as a stand-alone option because it would not provide additional water supplies to meet CCG demands. However, it remains a viable option to share costs and better manage water resources across Charles County.
- Alternative C-1: Aquifer Storage and Recovery – This alternative was removed as a stand-alone option because it would not provide additional water supplies to meet CCG demands. However, it was included in scenarios to extend reliability of seasonally variable water supplies.
- Alternative C-2: Conjunctive Use – This alternative was removed as a stand-alone option because it would not provide additional water supplies to meet CCG demands. However, it is included in scenarios that include both groundwater and surface water resources.

Using one or more feasible water supply alternatives from Phase A-1, comprehensive water supply scenarios were developed for evaluation in Phase A-2. The scenarios include the range of alternative water sources available to the County and were developed to maximize supply reliability and cost-effectiveness. Scenarios were sized to augment CCG's existing water supplies (groundwater wells and WSSC connection) to meet projected demands for 2045 (baseline average day demands of 11.2 mgd and max day demands of up to 20 mgd). In order to confidently assume future use of existing groundwater supplies, the addition of greensand filtration to existing groundwater wells was assumed to address concerns related to dissolved iron and manganese contamination (i.e., brown water). Greensand filtration for existing groundwater supplies was assumed in every water supply scenario.

- Scenario 1: Increased Allocations from WSSC – This scenario includes 10 mgd of additional capacity from WSSC to meet projected average and max day demands.
- Scenario 2: Upper Reaches Potomac River Supply – This scenario includes 10 mgd of new capacity supplied from a surface water treatment plant in the upper reaches of the Potomac River in Charles County to meet projected average and max day demands. This scenario does not require additional WSSC allocation beyond current levels.
- Scenario 3: Surface Water Treatment Plant plus Increased Allocations from WSSC – This scenario includes 5 mgd of new capacity supplied from a surface water treatment plant in the upper reaches of the Potomac River in Charles County to meet average day demands. Max day demands would be met with 5 mgd of additional capacity from WSSC.
- Scenario 4: Managed Aquifer Recharge and Increased Allocations from WSSC – This scenario includes 5 mgd of new confined aquifer groundwater allocations to meet average day demands. Groundwater allocations would be increased based on aquifer recharge with highly treated wastewater from the Mattawoman Wastewater Treatment Plant. Max day demands would be met with 5 mgd of additional capacity from WSSC.
- Scenario 5: Increased Groundwater Appropriations, Surficial Aquifer, and Increased Allocations from WSSC – This scenario includes an additional allocation of 2.5 mgd of confined aquifer groundwater and a new allocation of 2.5 mgd of surficial groundwater to

meet average day demands. Max day demands would be met with 5 mgd of additional capacity from WSSC.

A triple bottom line assessment of the five Water Supply Scenarios was conducted in order to evaluate each scenario across a broad range of decision-making criteria spanning economic, environmental, and social factors. The five Water Supply Scenarios were assigned scores for each criterion. These scores were then coupled with criteria weightings, which represent the relative importance of each criterion in the decision-making process (Figure ES-1). Criteria weightings were assigned based on discussions with CCG staff.

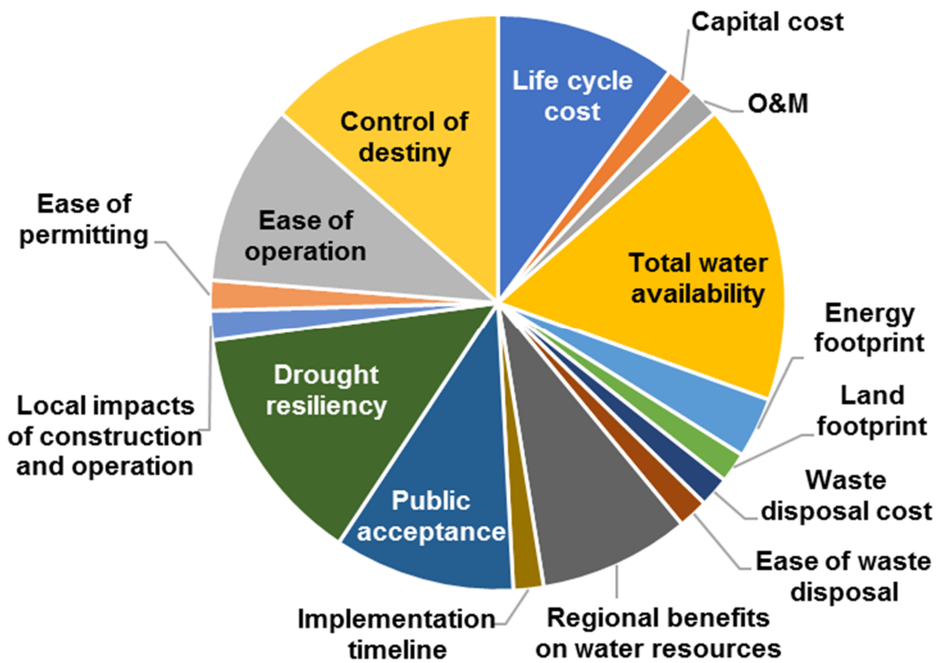


Figure ES-1: Relative Criteria Weightings in the TBL Assessment

The TBL results for each scenario are presented in Figure ES-2. Water Supply Scenario 2, an upper reaches Potomac River supply, is the highest ranked option, followed by Water Supply Scenario 3, an upper reaches Potomac River supply with increased allocations from WSSC. The lowest ranked option is Water Supply Scenario 5, increased groundwater appropriations.

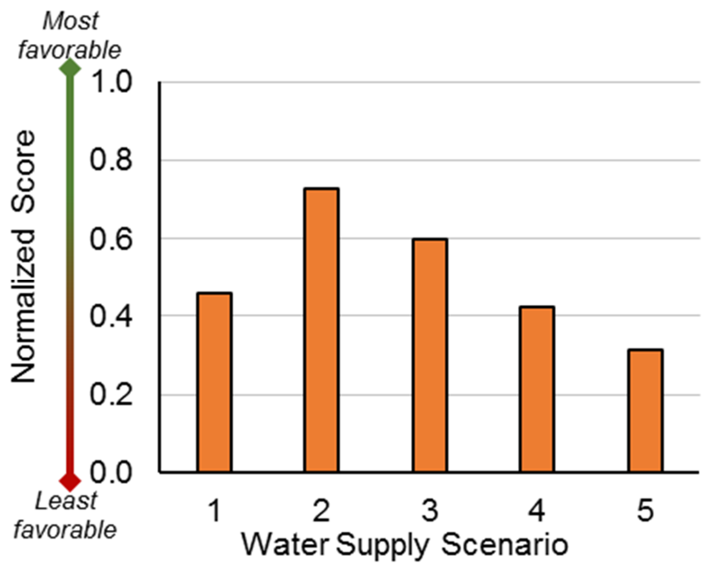


Figure ES-2: Overall Weighted TBL Score for Each Water Supply Scenario

Therefore, Water Supply Scenario 2 is the primary recommendation for CCG's long-term expansion of the water supply system to meet future demands. Scenario 2 includes the continued use of existing groundwater allocations and a new upper reaches Potomac River supply (i.e., riverbank filtration or a surface water intake with a new treatment facility) to meet projected average day demands. Maximum day demands would be met with additional dependence on the upper reaches Potomac River supply and existing WSSC allocations as necessary (Table ES-1). An important benefit from this option is that the Potomac River has the potential to supply significantly more water than CCG's planned needs. This provides additional options to CCG for an expanded intake and treatment plant, such as supplying water to neighboring communities, reducing WSSC purchases completely, or discontinuing withdrawals from poor quality wells.

Table ES-1: Scenario 2 Upper Reaches Potomac River Supply

Source of Supply	Average Day Supply Mix (mgd)	Design Capacity (mgd)
Existing groundwater	6.2	9.33
Existing WSSC	0	1.42
Upper reaches Potomac River supply	5.0	10.0
Total	**11.2**	**20.75**

Demand analyses indicated there could potentially be a near-term supply deficit as a new surface water intake and treatment plant are brought on-line.[1] Additional water from WSSC via the existing connection and new confined aquifer wells were determined to be the best options to bridge the supply deficit. Further, if there were a major unforeseen obstacle that prevented the construction of a

[1] It is unclear how the on-going implementation of the Watershed Conservation District will affect growth and demand projections. Once fully implemented, demand projections should be re-evaluated to confirm timelines for needed additional supply capacity.

new Potomac River intake, a new connection to WSSC would be the next best option for CCG. As such, it is recommended that CCG continue negotiations with WSSC to confirm costs of additional supply and service reliability, as well as pursue the confined aquifer element of Scenario 5 to expand the use of groundwater over the near-term to ensure adequate supplies prior to implementation of new long-term supplies.

The following graphics provide detailed next steps for CCG to move these recommendations forward and address important design questions in the process. The Water Supply Roadmap (Figure ES-3) shows the various steps and potential outcomes prior to initiating design of the new Potomac River supply and associated surface water treatment plant, as well as that required for the exploration of additional supplies from WSSC and/or groundwater. At the end of the Water Supply Roadmap, CCG will have determined the necessary implementation timeline and capacity of the new Potomac River water treatment plant. Subsequent tasks for the implementation of the new water treatment facility and associated finished water transmission to the existing CCG system are outlined in Figure ES-4 and Figure ES-5.

A preliminary CIP schedule and implementation timeline were created to support CCG planning and budgeting for the recommended Scenario 2, development of a new Potomac River supply and water treatment facility (Figure ES-6). The timeline shows that the overall program is estimated to span approximately eight years, resulting in Potomac River supply being brought on-line in 2027, assuming a start date in early 2019. The overall estimated cost of the CCG Potomac River water supply program is estimated at $162 million.

The Water Supply Roadmap, task outlines, and CIP schedule provide CCG with a detailed, flexible pathway for increasing available water supply and meeting projected demands over the planning horizon of this project.

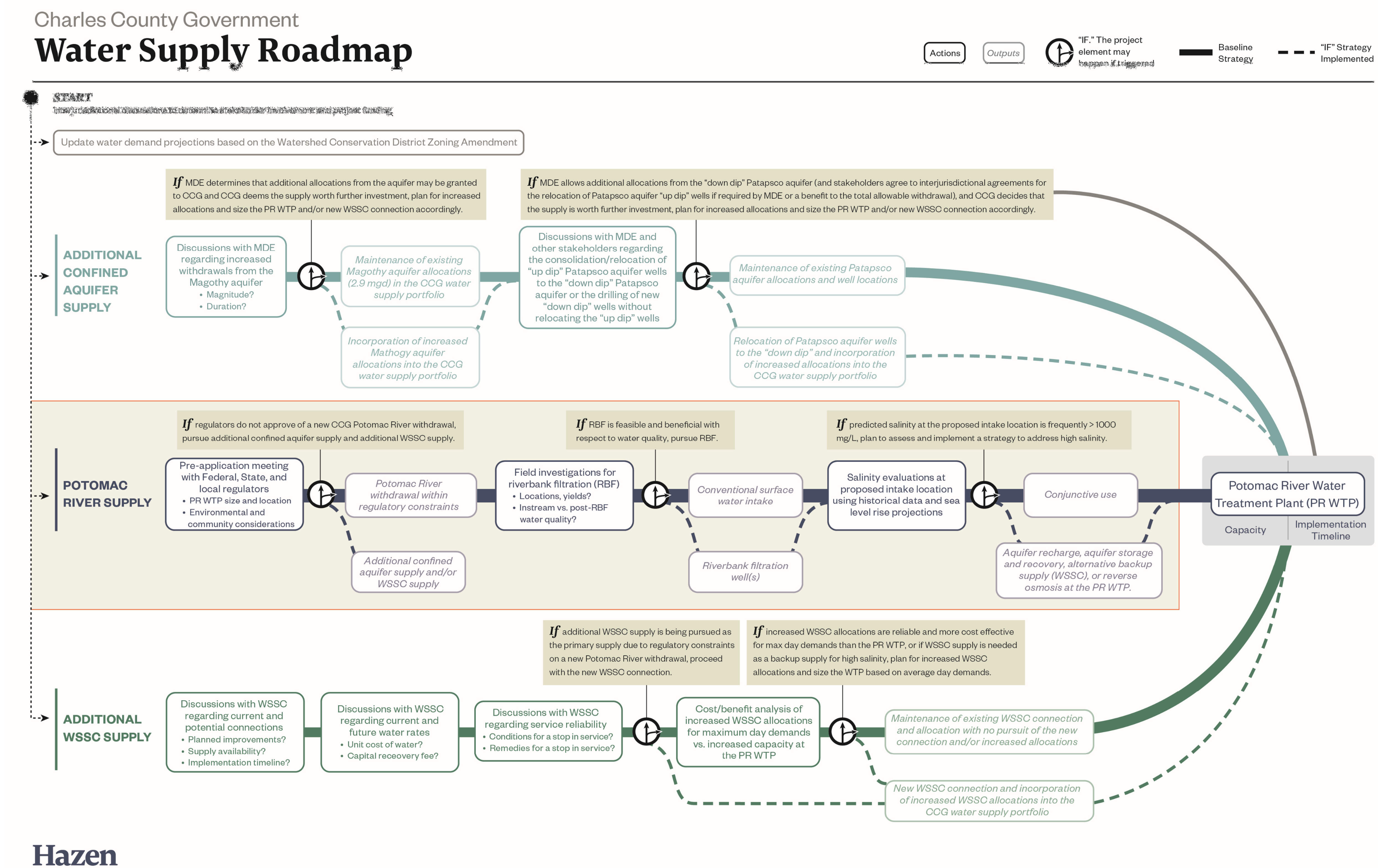


Figure ES-3: Charles County Roadmap for Increasing Water Supply Availability

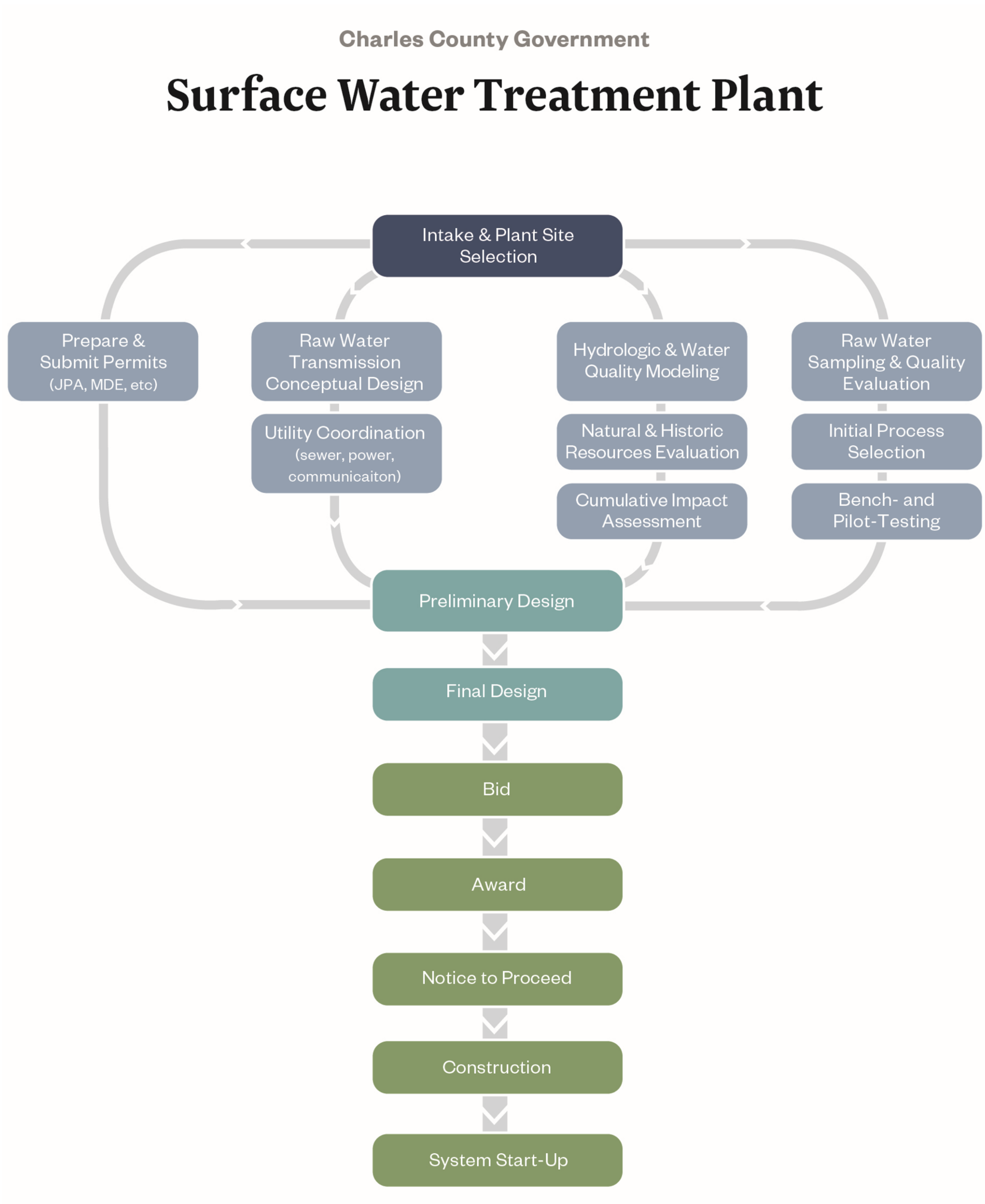


Figure ES-4: Tasks for Implementation of the Potomac River Supply and Treatment Facility (Scenario 2)

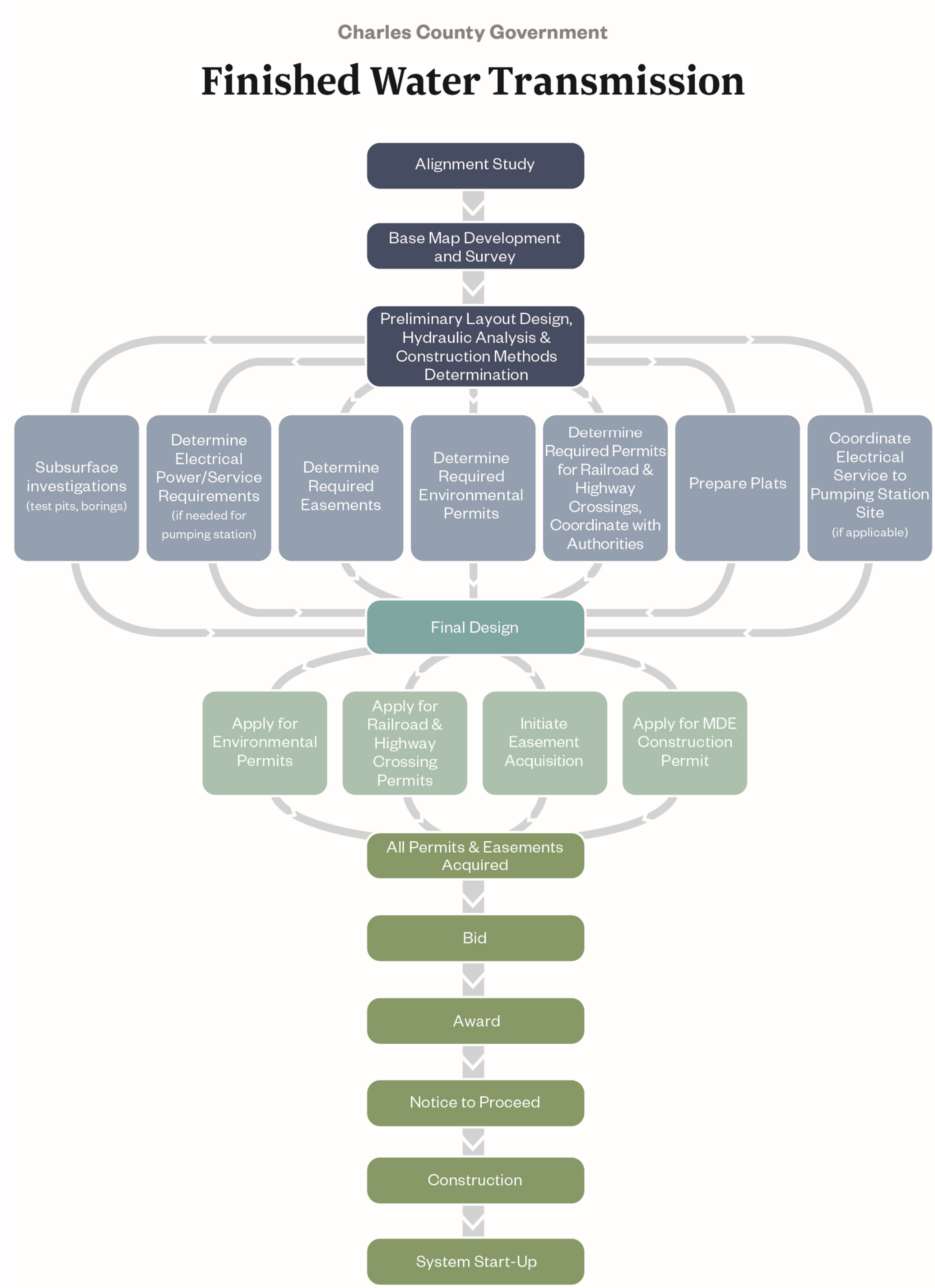
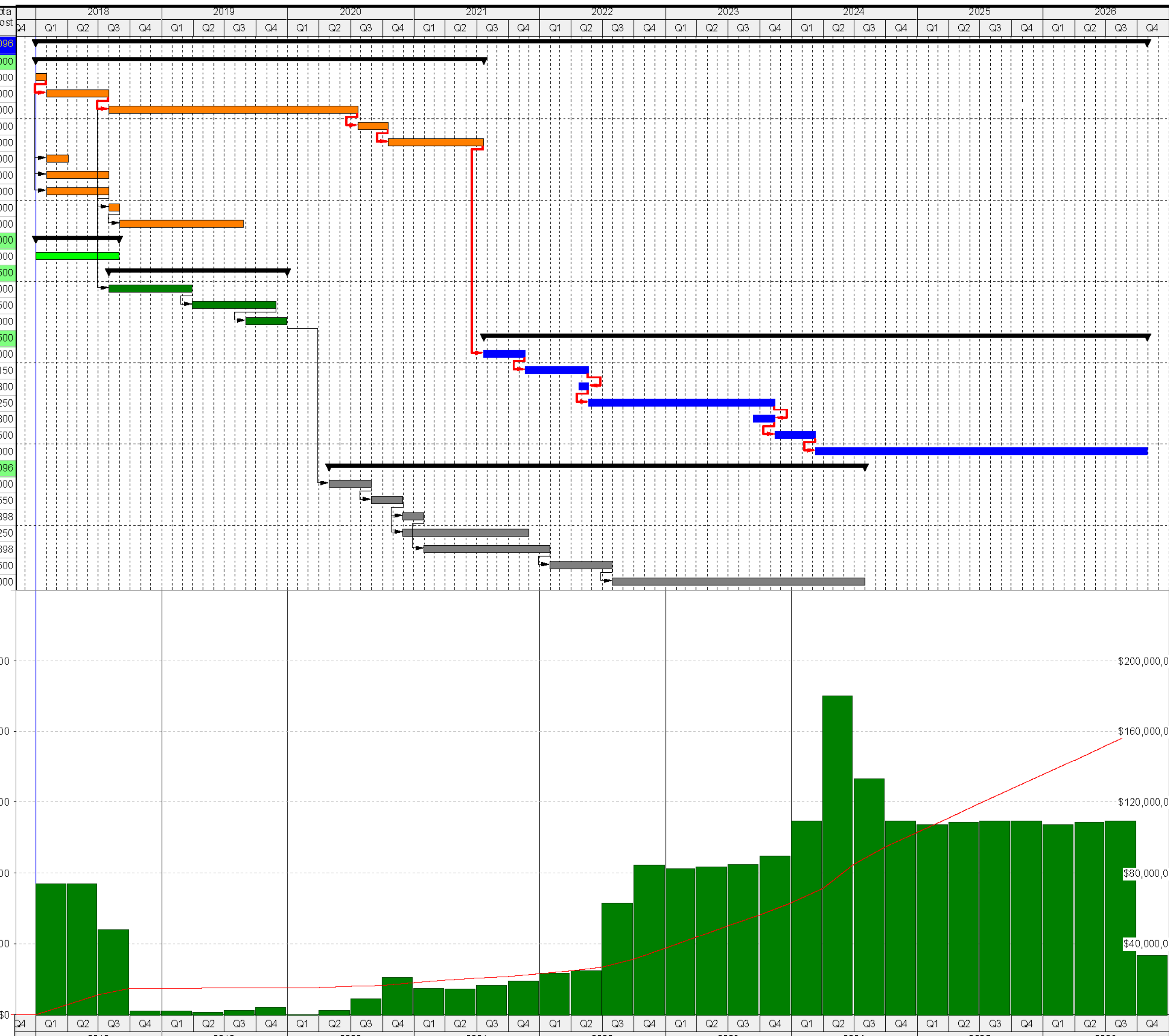


Figure ES-5: Tasks for Implementation of Finished Water Transmission from the Potomac River Supply and Treatment Facility (Scenario 2)

ESTIMATED CIP SCHEDULE FOR IMPLEMENTATION OF A NEW POTOMAC RIVER WATER SUPPLY AND ASSOCIATED TRANSMISSION INFRASTRUCTURE

Hazen

Activity Name	Original Duration (Months)	Budgeted Total Cost
Est. CIP Schedule for Impl. of a New Potomac River Water Sup. and Assoc. Conv.	107	$162,495,096
Surface Water Treatment Plant Feasibility/Planning	43	$2,095,000
Pre-Application Meeting	1	$50,000
Intake and Plant Site Selection	6	$200,000
Raw Water Sampling and Quality Evaluation	24	$35,000
Initial Process Selection	3	$30,000
Bench- / Pilot-Testing	9	$1,250,000
Natural and Historic Resources Evaluation	2	$100,000
Hydrologic and water quality modeling	6	$200,000
Other supporting evaluations	6	$80,000
Cumulative Impact Assessment	1	$30,000
Prepare and Submit permits (JPA, MDE, etc.)	12	$120,000
Maintenance of Existing Water Supplies	8	$13,915,000
Greensand Filtration for Existing Groundwater Wells (9.3 mgd)	8	$13,915,000
Finished Water Distribution Feasibility/Planning	17	$875,500
Alignment Study	8	$309,000
Base Map Development and Survey	8	$257,500
Subsurface Investigations	4	$309,000
Surface Water Treatment Plant Implementation (10 mgd)	64	$96,772,500
RFP/Award Engineering	4	$759,000
Preliminary Design	6	$2,922,150
Determination of Required Easements and Permits	1	$151,800
Final Design	18	$5,123,250
Acquisition of Required Easements and Permits	2	$151,800
Bidding	4	$1,897,500
Construction	32	$85,767,000
Finished Water Distribution Implementation	52	$48,837,096
RFP/Award Engineering	4	$383,000
Preliminary Design	3	$1,474,550
Determination of Required Easements and Permits	2	$78,898
Final Design of Improvements	12	$2,585,250
Acquisition of Required Easements and Permits	12	$78,898
Bidding	6	$957,500
Construction	24	$43,279,000



FW IMP | FW PLAN | SW PLAN | MW PLAN | SW IMP | summary

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Figure ES-6: Estimated CIP Schedule and Implementation Timeline for a New Potomac River Water Supply and Transmission Infrastructure

Introduction

The Charles County Government Department of Public Works - Utilities Division (CCG) is the primary water utility for the County, operating 31 of the approximately 52 water systems serving Charles County residents in addition to approximately 6,000 customers in Prince George's County. The County's water supply system consists of multiple individual systems, some of which are connected and others that are standalone. The largest system is the Waldorf system, which comprises nearly 90% of the demands for the overall CCG system. The County has historically relied on groundwater as the primary source of supply, supplemented with purchased finished water from the Washington Suburban Sanitary Commission (WSSC). As the County's population has increased, groundwater resources have become stressed, requiring the County to shift to deeper aquifers. While current average day demands of approximately 5.3 mgd for the Waldorf system are within the permitted allocation of approximately 7.07 mgd (5.67 mgd from groundwater sources and a maximum of 1.4 mgd from WSSC), the system may reach capacity by 2020 to 2030. In light of projected growth and in response to continued water level decline (i.e. drawdown) of the regional aquifers, the Maryland Department of the Environment (MDE) is requiring the County to perform this Water Alternatives Analysis Study[2] to evaluate options for supplying future demand.

The purpose of the study is therefore to evaluate the feasibility of developing, treating, and distributing alternative water sources for the CCG Public Water System. While options under consideration in this report are not strictly limited to the Waldorf and Bryans Road systems, successful water supply options must be able to supply or offset a significant demand in those two systems given expected development patterns. The evaluation is a comprehensive review of potential water sources in the County, including increasing the quantity of water purchased from WSSC; developing a surface water supply; developing new wells in the confined aquifers; developing new withdrawals from the unconfined aquifer; water reuse; and combined alternatives. Several of these options could involve collaboration and future interjurisdictional agreements/partnerships; however, the focus of this effort is evaluating water supply options to address projected deficits, most of which are attributed to the Waldorf and Bryans Road systems.

The primary result of this study is the development of a recommended plan for developing future water resources in the County that will help to shape the future of drinking water supply in the region. Phase A-1 of this study involved an initial screening of a broad range of potential options in order to eliminate those with fatal flaws. The surviving options were further analyzed, as described herein. This Phase A-2 report presents the final subset of options as five potential Water Supply Scenarios involving combinations of the surviving long-term water supply options. Because no single alternative from Phase A-1 was optimal in terms of both cost and reliability, Water Supply Scenarios were developed to conduct a detailed comparison of cost and non-cost factors that would affect the ultimate success of new water supplies for the County. The five Water Supply Scenarios presented herein are described in terms of a triple bottom line analysis to compare the economic, environmental, and social implications of each.

[2] Condition No. 20 in permit CHI970G009(14)

Summary of Phase A-1 Report

The Phase A-1 report (refer to Appendix B) included water demand projections for CCG over a 30-year planning horizon, a comprehensive review of potential water sources in Charles County, and the results of the initial water supply alternative fatal flaw analysis. The results from the Phase A-1 report are summarized below.

Demand Analyses

CCG water demands were projected over a 30-year planning horizon in order to compare existing water allocations with what is anticipated to be needed in the future under both average day and maximum day demands. Average day demands are important for calculating annual operations and maintenance (O&M) costs over the life of the system, while maximum day demands are necessary for sizing water source and treatment facilities per the Maryland Design Guidelines for Drinking Water Facilities. Multiple demand forecast scenarios were developed to account for future uncertainties in growth and usage trends. Scenarios included baseline forecasts with and without additional projected fixture efficiency and with and without application of estimated standard error.

Projections were developed using a rate of use model, in which water use is assumed to vary over the projection period as a function of housing units and employment. Several scenarios were evaluated to test the sensitivity of projections to potential changes in assumed conditions, such as the rate of water use, fixture efficiency (i.e., the replacement of inefficient plumbing fixtures with more efficient fixtures over time), and growth. For the baseline scenario, water use per housing unit and employee was determined using historical data (e.g., daily billed water use, average number of housing units, employment) across six fiscal years, ultimately arriving at a water use rate of 158.5 gallons per day per housing unit and 32.1 gallons per day per employee. Average use was then projected through 2045 based on residential and employment population growth from the County's Traffic Analysis Zone (TAZ) estimates and assessment of service area employment by the County's Planning and Growth Management Department.

A maximum day peak factor was estimated using daily water system production from January 2013 through October 2015 in the County. The peak day factor was derived by dividing the maximum day demand by the annual average day demand in the fiscal year that the maximum day demand occurred. Using the resulting peak day factor of 1.65, forecast scenarios were developed for the maximum day demand from the average demands.

Deficits were calculated for the Waldorf and Bryans Road systems based on a combined available supply of 7.64 mgd and 10.73 mgd for average day and max day demands across the forecasted demand scenarios (Table 1 and Table 2).[3] Available supplies consist of permitted allocations for Waldorf and Bryans Road wells for average annual and month of maximum use in addition to a

[3] Demand projections were developed prior to the passage of the Watershed Conservation District. It is unclear how this policy will affect growth and demand projections. Once fully implemented, demand projections should be re-evaluated to confirm timelines for needed additional supply capacity.

maximum of 1.4 mgd of purchased water from WSSC.[4] Based on the existing water supplies and demand projections for the two systems, a supply deficit based on maximum day demands is expected to occur by 2020 for nearly all demand scenarios (Figure 2). Further, CCG will become increasingly reliant on purchased water from WSSC to meet average demands by 2020, and it is unlikely CCG will be able to meet average demands by 2030 with current supplies (including WSSC allocations) (Figure 1).

An additional 10 mgd of new supply to meet expected future demands is estimated for the purposes of this planning analysis. This estimate accounts for potentially large demand increases from growth and development, and also provides a suitable buffer for other potential future conditions, such as reductions in permitted groundwater allocations, loss of wells from unacceptable water quality, or sale of finished water to La Plata. For estimating the lifecycle costs for each Water Supply Scenario, capital costs were based on 10 mgd of additional supply capacity, and annual O&M costs were based on the 2045 baseline average day water demand of 11.2 mgd.

Table 1: CCG Waldorf & Bryans Road Systems Average Day Water Demand Projections*

Forecast Scenario	Average Demand Surplus/Deficit (mgd)						
	2015	2020	2025	2030	2035	2040	2045
Baseline w/Std. Error (+)	1.31	0.44	(0.31)	(1.35)	(2.22)	(3.01)	(4.05)
Baseline Estimate	1.58	0.73	0.02	(0.98)	(1.81)	(2.58)	(3.57)
Baseline w/Std. Error (-)	1.84	1.02	0.34	(0.62)	(1.42)	(2.14)	(3.10)
Baseline w/Efficiency/Std. Error (+)	1.31	0.89	0.46	(0.19)	(0.76)	(1.29)	(2.00)
Baseline w/Efficiency	1.58	1.16	0.76	0.13	(0.40)	(0.92)	(1.60)
Baseline w/Efficiency/Std. Error (-)	1.84	1.44	1.05	0.46	(0.06)	(0.55)	(1.20)

* Black values indicate supply surplus and red values in parentheses indicate supply deficit.

[4] Waldorf system is currently permitted for 5.67 mgd for average annual withdrawals and 8.55 mgd for the month of maximum use. Bryans Road system is currently permitted for 0.57 mgd for average annual withdrawals and 0.781 mgd for the month of maximum use.

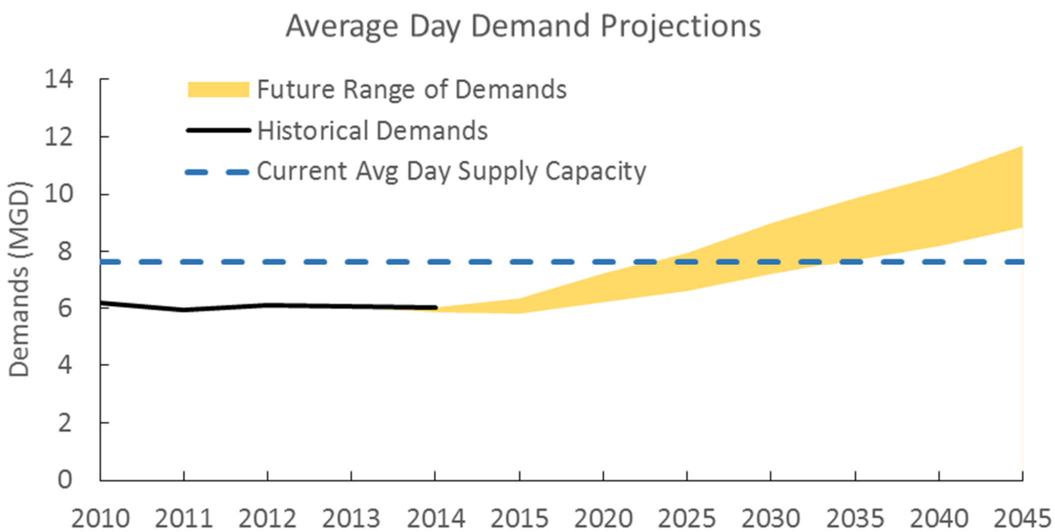


Figure 1: CCG Waldorf & Bryans Road Systems Average Day Water Demand Projections

Table 2: CCG Waldorf & Bryans Road Systems Maximum Day Water Demand Projections*

Forecast Scenario	Max Day Demand Surplus/Deficit (mgd)						
	2015	2020	2025	2030	2035	2040	2045
Max Day w/Std. Error (+)	0.30	(1.15)	(2.38)	(4.11)	(5.53)	(6.85)	(8.56)
Max Day (baseline estimate)	0.72	(0.67)	(1.85)	(3.50)	(4.87)	(6.12)	(7.77)
Max Day w/Std. Error (-)	1.16	(0.18)	(1.31)	(2.89)	(4.21)	(5.41)	(6.99)
Max Day w/Efficiency/Std. Error (+)	0.30	(0.42)	(1.12)	(2.19)	(3.11)	(3.99)	(5.17)
Max Day w/Efficiency	0.72	0.04	(0.63)	(1.66)	(2.55)	(3.39)	(4.52)
Max Day w/Efficiency/Std. Error (-)	1.16	0.50	(0.14)	(1.14)	(1.97)	(2.78)	(3.86)

* Black values indicate supply surplus and red values in parentheses indicate supply deficit.

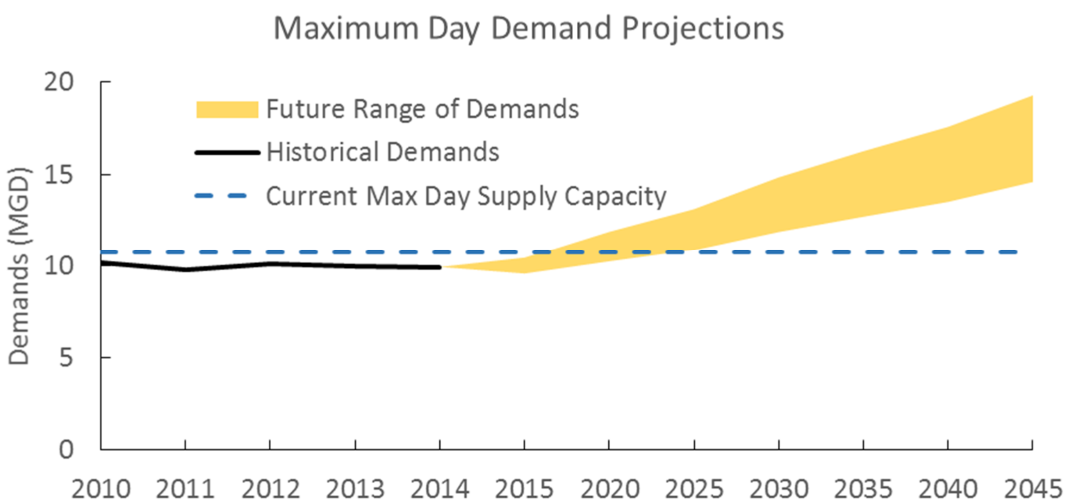


Figure 2: CCG Waldorf & Bryans Road Systems Maximum Day Water Demand Projections

Preliminary Screening Criteria

As part of the Phase A-1 report, 22 water supply alternatives were identified as the "world of options" for CCG, each belonging to one of six water supply categories: groundwater, surface water, riverbank filtration, reuse, policy, countywide, or combined alternatives. The feasibility of incorporating an alternative water supply into CCG's existing water supply portfolio depends on a range of factors, including the water source's quality, available quantity relative to demand, cost, environmental considerations, technical considerations, and customer perceptions. In order to incorporate these factors into the decision-making process, preliminary screening criteria were developed to specifically assess various aspects of each alternative water source. The overall purpose of these preliminary screening criteria was to provide a concept development roadmap for all identified water source alternatives, as well as a means by which to identify potential fatal flaws from multiple perspectives. Ultimately, these criteria and their associated pass/fail assessments enabled removal of alternatives from further consideration that have notable conceptual weaknesses, such as unproven performance or reliability, high cost, or insurmountable constructability or regulatory issues, thus limiting the "world of options" to those alternatives without fatal flaws. The preliminary screening criteria are listed below.

- Capital cost
- Operation and maintenance cost
- Water quality
- Supply reliability
- Ease of operation
- Constructability
- Ease of permitting
- Environmental stewardship
- Public acceptance
- Regional benefits

For all criteria, assessment outputs were either pass or fail, with a fail designation indicating the identification of a fatal flaw. Options were removed from further consideration if a fatal flaw was identified.

Results of Fatal Flaw Analysis

Overall, most of the water supply options available in Charles County require more treatment and monitoring than existing groundwater supplies. However, despite the intensified capital and operational aspects of the water supply alternatives relative to groundwater, 11 out of the 22 identified alternatives were determined to have low risk of fatal flaws that would prevent implementation. Fatal flaws for the water source alternatives that were eliminated during the preliminary screening ranged from lack of supply reliability to exorbitant capital cost to lack of regulatory and public acceptance. The surviving options from the Phase A-1 report included surface water and groundwater sources, riverbank filtration, reuse, and a variety of policy and management opportunities (Table 3). These surviving alternatives were further analyzed as part of the Phase A-2 effort, ultimately enabling the development and comparison of several potential Water Supply Scenarios (i.e., combinations of water supply alternatives) for the CCG Waldorf and Bryans Road systems.

Table 3: Surviving Water Source Alternatives from the Phase A-1 Report

Category	Water Supply Alternative
Groundwater	G4: New surficial aquifer wellfield
Surface Water	S-1: Surface water treatment plant – Upper reaches of the Potomac River
	S-5: Morgantown Generating Station
Riverbank Filtration	B-2: Riverbank Filtration – Upper Reaches of the Potomac River
Reuse	R-1: Non-Potable Reuse
	R-2: Managed Aquifer Recharge
Policy	P-1: Increased WSSC Allocations
	P-3: Wellfield Management Plan
Countywide	W-1: Countywide Agreement
Combined Alternatives	C-1: Aquifer Storage and Recovery
	C-2: Conjunctive Use

Updated Analyses of Surviving Phase A-1 Alternatives

Following the completion of the Phase A-1 report, additional information became available for some of the alternatives. Supplemental analyses were conducted to further determine the feasibility of the eleven surviving alternatives from Phase A-1. The findings from the updated analyses and, where applicable, the basis for why some of the eleven alternatives were eliminated from further consideration are summarized below.

Alternative P-1: Increased WSSC Allocations

The existing CCG groundwater supply is supplemented with purchased, finished potable water provided by WSSC. The existing CCG/WSSC connection site is located at 2250 Saw Mill Place, Waldorf, MD, where WSSC water is supplied to the Waldorf Water System when needed. The existing agreement between CCG and WSSC, signed in 1987, states that *"WSSC agrees to sell to the Commissioners up to 1,400,000 gallons of potable water per day."* It is also stated that the Commissioners (CCG) agree to pay WSSC monthly for the amount of water metered at a rate equal to *"70% of the prevailing rate WSSC charges a customer having an average daily consumption of 240 gallons"*, which is currently equal to 70% of $5.16 per 1,000 gallons of water. Furthermore, the agreement states that parties *"understand that the projected potable water demand for Charles County is such that in the future further extension of the WSSC water system to furnish additional potable water may be desirable."* As predicted, existing groundwater supplies and existing/projected water demands in Charles County have led to the consideration of increased water allocations from WSSC to CCG as an alternative water supply option.

Communications between CCG, the Hazen team and WSSC regarding increased water allocations were initiated via email on December 1, 2015 and continued at an in-person meeting held at WSSC on December 29, 2015. Following the in-person meeting, hydraulic and water quality data for the WSSC finished water system were provided by WSSC to CCG and the Hazen team. The hydraulic and water quality data pertained to two locations in the WSSC distribution system: 1) the existing CCG/WSSC connection site, located on Saw Mill Place in Waldorf, MD, and 2) a proposed new CCG/WSSC connection site, located at the intersection of Route 301 and Cedarville Road. The hydraulic data was provided to indicate the extent to which increased allocations could be supplied at the two locations; water quality data was provided to determine if additional treatment would be required at either of the locations between the two consecutive distribution systems.

Available Supply from WSSC

WSSC ran its in-house hydraulic model to determine the flow that could be provided to CCG under existing and future conditions from the WSSC distribution system at both the existing and proposed new connection points. Simulations of the system were performed under conservative low hydraulic grade conditions (i.e., maximum day demands, storage tanks low, pumps off).

At the existing connection site, approximately 1.65 to 2.0 mgd could be provided to CCG by WSSC at a hydraulic gradient level of 260 feet to 240 feet, respectively.[5] At the proposed new connection site, WSSC's published low hydraulic grade value is 326 feet in the WSSC system; WSSC has indicated that approximately 4.0 mgd could be provided to CCG without breaching this low hydraulic grade value. In the future, however, WSSC is planning several improvements for its 385A Pressure Zone that would increase the available supply capacity to CCG up to 12.9 mgd at the proposed new connection site.

For the purposes of this evaluation, it was assumed that a maximum of 1.4 mgd would continue to be available to CCG at the existing WSSC connection site and that a maximum of 10 mgd could be supplied to CCG at the proposed new WSSC connection site. The hydraulic data provided by WSSC are theoretical and do not imply that WSSC and the Commissioners have agreed to convey the quantities of water to CCG. WSSC has noted that if CCG wishes to pursue additional supply from WSSC, the specific amounts would need to be discussed with Executive Leadership. Consensus would then need to be reached on the details of any additional conveyances and associated costs during negotiations of an amendment to the 1987 agreement. The hydraulic implications of conveying water from the minimum hydraulic grade value in the WSSC system (published by WSSC) to the CCG Waldorf system's hydraulic grade line are discussed in the Water Supply Scenario 1 description (Scenario 1 – Increased Allocations from WSSC).

Water Quality from WSSC

WSSC provided water quality data for samples taken at locations close to the existing and proposed new connection sites. These data were provided to develop a more detailed understanding of water quality at the two connection sites, as concerns had been previously expressed by CCG regarding water age and high concentrations of disinfection byproducts (DBPs). As discussed in the Phase A-1 report, regulated DBPs include five haloacetic acid (HAA) compounds and four trihalomethane (THM) compounds. Using quarterly samples taken throughout the distribution system, National Primary Drinking Water Regulations require that the locational running annual average (LRAA) summation of the five HAA compounds remain below a maximum contaminant level of 60 μg/l and that the annual average summation of the four THM compounds remain below a maximum contaminant level of 80 μg/l at each monitoring station.

Figure 3 and Figure 4 show total THM and HAA concentrations for samples taken at the existing connection site and the proposed new connection site, respectively, between 2011 and 2016. The black horizontal line shows the regulatory limit under which the LRAA must remain in order to comply with National Primary Drinking Water Regulations; the grey horizontal line is 80% of this regulatory limit, which is a typical planning-level water quality goal.

[5] In the existing agreement, WSSC has committed to providing CCG with water at a hydraulic grade of approximately 240 feet. The published low hydraulic grade value for the WSSC system at the existing connection site is 260 feet.

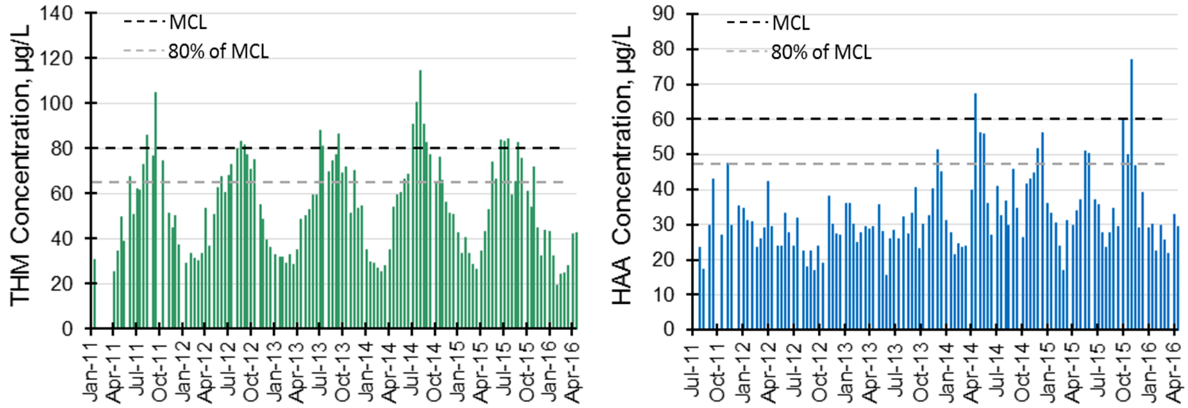


Figure 3: Total THM and HAA Concentrations at the Existing WSSC Connection Site (2011 – 2016)

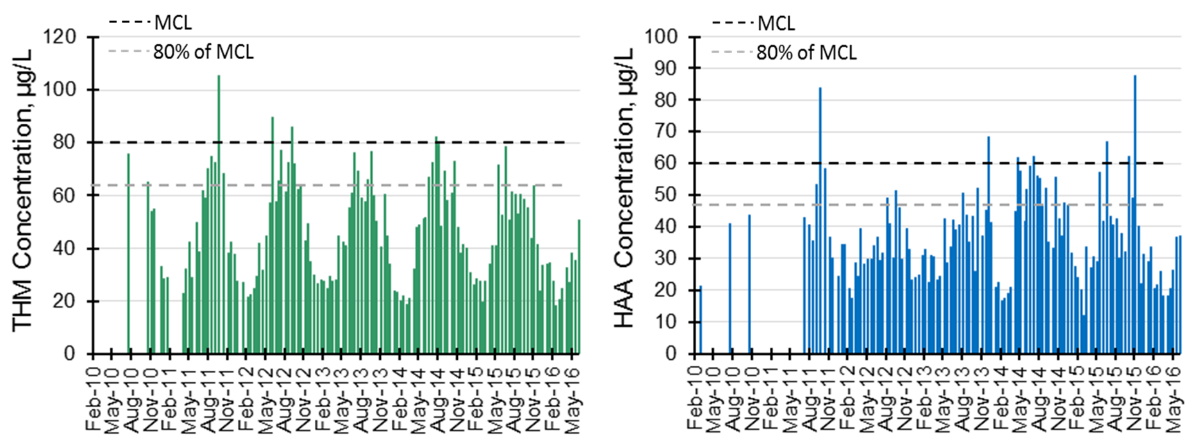


Figure 4: Total THM and HAA Concentrations at the Proposed New WSSC Connection Site (2011-2016)

In order to predict compliance, LRAA values were determined from the provided water quality data, as LRAAs are indicative of regulatory compliance at the two connection sites and not individual sample results. LRAAS were calculated as shown below. Because multiple samples were taken per quarter by WSSC, LRAAs were calculated using various values, such as the maximum, average, and minimum recorded value per quarter, to determine the range of expected LRAAs that would need to be reported to regulators.

$$Locational\ Running\ Annual\ Average\ (LRAA) = \frac{A+B+C+D}{4}$$

Where A = Total THM or HAA concentration for the current quarter
B = Total THM or HAA concentration for the previous quarter
C = Total THM or HAA concentration for the quarter before the previous quarter
D = Total THM or HAA concentration for the quarter before quarter C

Figure 5 and Figure 6 show the range of THM and HAA LRAAs calculated using data reported between 2011 and 2016 for the existing WSSC connection site and the proposed new site, respectively. The lower and upper boundaries of the shaded region represent the LRAAs that were calculated using the minimum and maximum recorded values per quarter, respectively. The calculated LRAAs never exceed the THM MCL (80 µg/L), nor the HAA MCL (60 µg/L), thus meaning the WSSC water is compliant with DBP regulations at both connection sites. However, it is important to note that within the CCG distribution system, WSSC water will require additional chlorine and will continue to travel and age, thus providing additional opportunity for DBP formation. At points within the distribution system WSSC water would also blend with other water supplies in the CCG system (e.g., treated groundwater), which may reduce DBP concentrations via dilution.

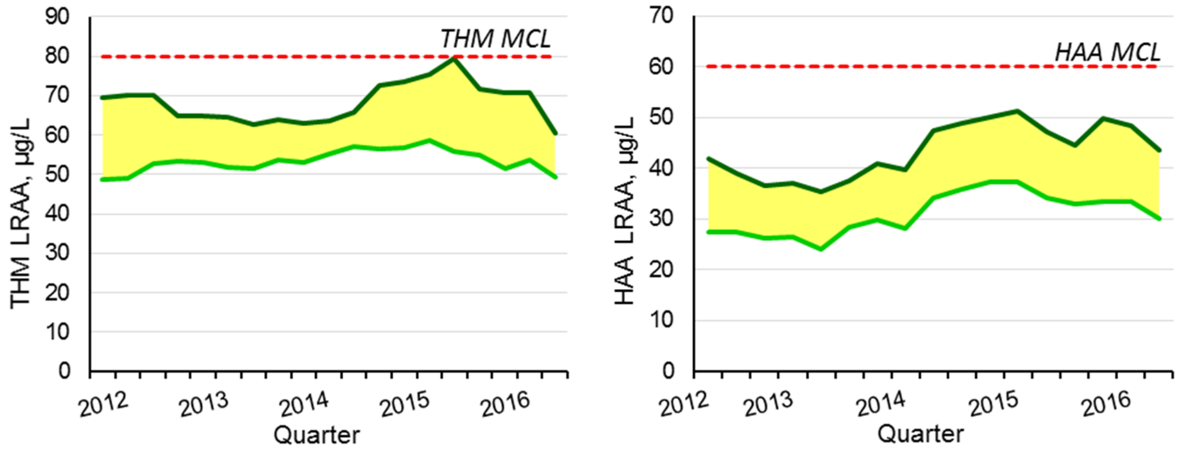


Figure 5: Range of Locational Running Annual Averages (LRAAs) for THM and HAA Concentrations Reported at the Existing WSSC Connection Site

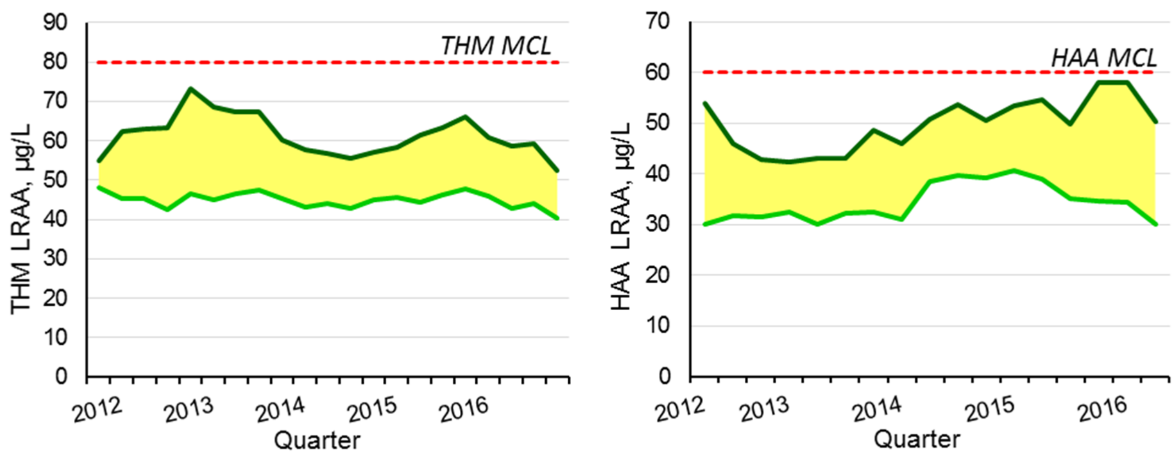


Figure 6: Range of Locational Running Annual Averages (LRAAs) for THM and HAA Concentrations Reported at the proposed new WSSC Connection Site

Based on the calculated LRAAs and flows at each of the WSSC connection sites, DBP treatment recommendations were made for the WSSC water supply component for each of the Water Supply Scenarios. Note that all WSSC supply options include additional disinfection to maintain the chlorine residual in the CCG distribution system.

- At the existing WSSC connection site, no intermediate treatment is included in the supply scenarios, because the limited supply is expected to be substantially diluted with other water supplies in the CCG system.
- At the proposed new WSSC connection site, no intermediate treatment is included for scenarios that utilize WSSC water to meet max day demands. DBP compliance is based on the annual average of concentrations, and it is assumed that infrequent, limited use of the supply would have minimal, short-term effects on DBPs in the CCG distribution system.
- At the proposed new WSSC connection site, treatment is recommended for scenarios that utilize WSSC water to meet average day demands. For these scenarios, a substantial fraction of the flow in the CCG distribution system would be from WSSC throughout the year, increasing the likelihood of exceeding the LRAA regulatory limits. Pressurized granular activated carbon (GAC) treatment is included in these scenarios to reduce HAA and THM concentrations[6] in WSSC water, while maintaining pressure from the WSSC system. Aeration may be used to remove THMs, but would not be effective for HAAs and would result in the loss of pressure from the WSSC system. Therefore, aeration is not recommended.

Treatment recommendations as part of this conceptual design are based on limited, existing data. It is recommended that additional evaluations be conducted to confirm the need and efficacy of intermediate treatment at both WSSC connection sites, depending on CCG's ultimate level of reliance on WSSC supplies. For example, additional water quality monitoring can be conducted at both sites to assess DBP variability; a distribution system tracer study can be conducted to evaluate the results of blending high DBP WSSC water with low DBP groundwater in the CCG distribution system; and Rapid Small-Scale Column Testing (RSSCT) can be used to determine the efficacy of THM and HAA removal via GAC, as well as the associated regeneration schedule.

Alternative S-5: Morgantown Generating Station

The Morgantown Generating Station, located in Morgantown, MD, is currently owned by NRG. The facility withdraws water from the Patapsco aquifer for potable uses and miscellaneous operational needs. Additionally, the facility withdraws water from the Potomac River for cooling and process water. Most of the water withdrawn from the Potomac River is minimally treated (sodium hypochlorite for biofouling control when necessary) and is used for cooling before being discharged back to the river. However, a portion of the Potomac River water withdrawal is treated with RO for use in the wet flue gas desulfurization scrubbers.

The Morgantown Generating Station is in the southern part of the county and is located away from major demand centers in the northern part of the County. Significant investment would be required for transmission of water from this source to the demand centers.

The draft report considered the following options:

[6] Data indicate DBPs are dominated by trichloracetic acid and chloroform in the WSSC system.

1. Purchase excess RO-treated water to augment CCG drinking water supplies in the southern portion of the County;
2. Purchase excess raw water from the Potomac River for use with a County-owned treatment plant (refer to Alternative S-2: Surface Water Treatment Plant – Potomac River lower reaches); and
3. Utilize the return flow to the Potomac River for dilution of desalination brine from a new County-owned treatment plant (refer to Alternative S-2: Surface Water Treatment Plant – Potomac River lower reaches).

Options 2 and 3 were eliminated from consideration during Phase 1 report based on the high cost of desalination and were not considered further. The Hazen team has reached out to the NRG, formerly the Mirant Corporation, to identify the feasibility of option 1 above. The Morgantown Generating Station representatives have not responded to the queries regarding possible purchase of water.

Therefore, water supply purchase from Morgantown Generating Station will be eliminated from further consideration due to multiple factors.

1. Lack of response from Morgantown representatives.
2. Long-term reliability issues regarding the existence of this facility in the future, as well as uncertainty regarding the amount and quality of water that could be provided to CCG as the needs of the Morgantown Generating Station change.
3. It may be difficult to obtain permits to supply drinking water from an industrial source of water without additional treatment.
4. The site is located away from the CCG population centers and would require substantial transmission infrastructure.

If new information is subsequently provided by NRG that indicates their willingness to discuss a water purchase agreement with the County, this option can be revisited in the future.

Alternatives B-2 and S-1: Riverbank Filtration and Surface Water Treatment Plant– Upper Reaches of the Potomac River

Riverbank filtration can be generally understood as a cross between a surface water source and a groundwater source. A large, reliable surface water source, such as the Potomac River, ensures an adequate water supply, while transport through the riverbank substrate provides water quality benefits. In the Phase A-1 report, it was concluded that riverbank filtration is a feasible alternative along the upper reaches of the Potomac River, but field investigations are necessary to confirm yield and whether additional costs relative to a conventional surface water withdrawal would be justified by improvements in water quality.

Overall, Alternatives B-2 and S-1 are expected to have similar implications due to these water supply options both relying upon the upper reaches of the Potomac River and including similar treatment processes and transmission requirements. At this point in the evaluation, Alternatives B-2 and S-1 are assumed to be similar, mutually exclusive options. In the Water Supply Scenarios presented herein, Alternatives B-2 and S-1 are collectively referred to as "Upper Reaches Potomac River Supply." Additional analyses are necessary to decide between riverbank filtration and a surface water intake based on ease of permitting, yield, land requirements, and water quality, as described in the triple bottom line results.

Alternative R-1: Non-Potable Reuse

To further evaluate the suitability of non-potable reuse for offsetting potable water demands, additional discussions with CCG were initiated to identify the types of customers that may be interested in non-potable reuse. It was indicated that current non-potable reuse customers include the Panda Power Plant and CPV for industrial cooling purposes. On average, approximately 0.7 mgd of reclaimed water is delivered to the Panda Power Plant, with a total allocation of 2.7 mgd in the CCG/Panda agreement; approximately 3.4 mgd of reclaimed water is delivered to CPV on average, with a total allocation of 5.4 mgd in the CCG/CPV agreement. The County did not identify any additional potential industrial users for reclaimed water and indicated that non-potable reuse would likely need to target residential and commercial end users.

Water use patterns in Waldorf were revisited to assess the amount of potable water that could be offset via irrigation with reclaimed water, as MDE's Class IV reclaimed water guidelines allow for irrigation in residential areas. Figure 7 shows the average daily water use on a monthly basis for the Waldorf community using historical data from 2013 to 2015. Indoor water use (the baseline) was assumed to be the average water use for November, December, January, February and March; any water use above this baseline was assumed to be outdoor water use. Using this approach, it was determined that Waldorf residents use approximately 0.4 mgd of water for outdoor purposes on an annual average basis, or 8% of the total water use. This quantification approach results in a high-level estimate of outdoor water use for planning purposes, although it should be noted that increased water use in April through October may also be a function of other factors, such as increased tourism during these months.

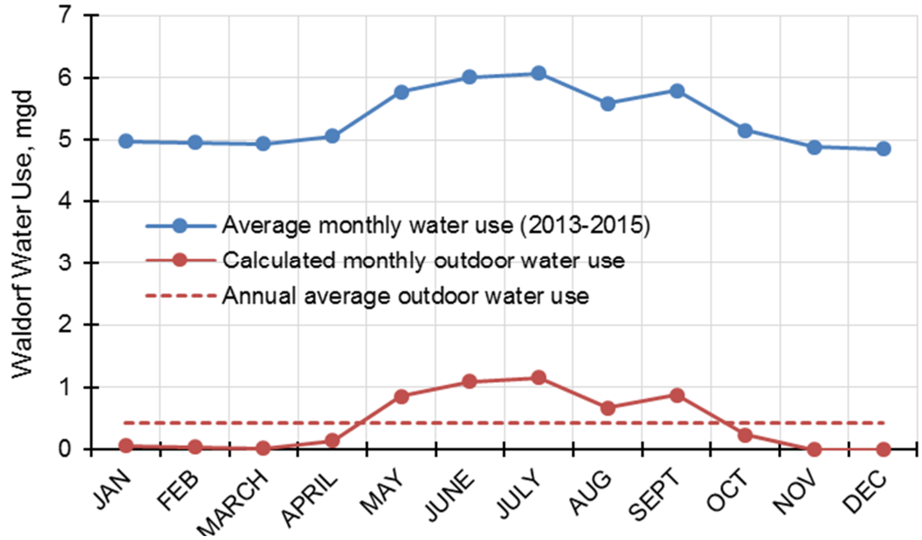


Figure 7: Reported Average Monthly Total Water Use and Calculated Average Monthly Outdoor Use in the Waldorf Community (2013 – 2015)

A 0.4 mgd increase in potable water supplies resulting from the use of reclaimed water for outdoor purposes by existing CCG end users would help address the projected maximum day deficits until the 2020 – 2025 timeframe. If combined with other near-term options (e.g., increased allocations from WSSC), non-potable reuse could be used as a near-term solution to increase water supplies until a long-term solution was implementable. As explained in the Development of Water Supply Scenarios section below, near-term solutions should address projected deficits until 2030, while long-term solutions may take longer to implement but should be able to address projected deficits between 2030 and 2045. However, achieving this level of potable water supply offset via non-potable reuse would require construction of an extensive reclaimed water distribution system to the vast majority of residential and commercial users in the Waldorf and Bryans Road service areas.

The anticipated costs, construction, and community impacts associated with distributing reclaimed water to all residential and commercial end users in the Waldorf and Bryans Road service areas led to the elimination of this water supply alternative from further consideration. The limited offset of potable water supplies that could be provided via non-potable reuse ultimately did not warrant the significant expenditures that would be required. However, it is recommended that CCG continue to consider non-potable reuse to offset potable water demands in new developments, as the construction of a reclaimed water distribution system in a new development is more cost effective than attempting to retrofit an existing residential area. Furthermore, CCG should continue to engage in conversations with large water users (industrial, institutional, or commercial) to identify new reclaimed water customers.

Alternative W-1: Countywide Agreement

The municipal and community water systems in Charles County, as well as the numerous individual, agricultural, and industrial wells, predominantly withdraw water from the same groundwater sources (Magothy, Patapsco, and Patuxent aquifers). CCG supply alternatives that reduce demands on the groundwater aquifers can benefit all water systems by reducing drawdown, increasing available supplies, and reducing pumping costs. A countywide agreement with other water systems might consist of investment in the development of an alternate water supply, treated water purchase agreements, or other cost-sharing measures. This would enable CCG to perhaps increase the size of the alternate supply(ies) to reduce demand on the groundwater aquifers without adversely affecting rates for CCG customers.

The potential benefits of a countywide agreement continue to support discussions between CCG and nearby municipalities. These discussions should cover the potential costs and benefits of agreeing to share the development of new water resources in the County, taking each stakeholder's perspective into consideration. However, for the Water Supply Scenarios proposed herein, it must be recognized that a countywide agreement does not constitute a water supply alternative per se. A countywide agreement would likely pertain to cost-sharing for a new surface water treatment plant, reuse program, or other water supply alternative. Thus, Alternative W-1 does not serve as a contributing water supply for the proposed Water Supply Scenarios.

If future agreements result in larger supply needs than estimated in this report, the same methodology can be used to update the analysis to ensure that increased supplies are consistent with the recommendations from this project.

Alternative C-1: Aquifer Storage and Recovery

Aquifer storage and recovery (ASR) is the process of injecting high-quality water (e.g., finished water from a surface water treatment plant, groundwater, reclaimed water, etc.) into an aquifer when demands on the aquifer are low (and/or when other supplies are plentiful) and then withdrawing from the same aquifer when demands are high (and/or when other supplies are low). The receiving aquifer essentially serves as a large storage vessel for any water supply that is deemed to be abundant during certain parts of the year and also compatible with the aquifer geology. Typically, ASR systems store water that has been treated to drinking water standards. The level of treatment needed when stored water is withdrawn is dependent on recovered water quality and applicable state regulations.

ASR (Alternative C-1) was not eliminated during the Phase A-1 evaluations and is included in the Water Supply Scenarios presented herein as being coupled with surficial aquifer withdrawal only. In theory, ASR could be coupled with any treated water supply; however, it only results in measurable benefits if the source of the recharge water is expected to benefit from storage for subsequent use. The surficial aquifer was identified as the only water supply option expected to benefit from ASR due to the surficial aquifer's seasonal variability and uncertainty in yield. The surficial aquifer is known to have water levels near the ground surface during the winter months and to experience drawdown in the summer months, thus suggesting that excess surficial aquifer withdrawals could be stored during the winter for subsequent use in the summer when surficial aquifer yields are low. Surficial aquifer wells are assumed to be distributed throughout the service area and would require microfiltration treatment systems due to the susceptibility of the surficial aquifer to contamination.

The benefits of ASR for the surface water treatment plant option were also considered, because of reduced Potomac River supply availability during intermittent high salinity events resulting from drought conditions. Based on preliminary correlations of salinity and flow conditions in the section of the Potomac River along the northwestern portion of Charles County, high salinity could range from a five-year recurrence to a 60-year recurrence interval.[7] Based on the anticipated infrequent nature of high salinity events, the preferred approach for addressing Potomac River salinity would be through conjunctive use that optimizes surface water and groundwater withdrawals based on quality and long-term sustainability (see below). Therefore, ASR is not considered as part of the baseline surface water treatment plant scenario, but could be considered based on subsequent salinity analysis and discussions with MDE.

For other water supplies that do not demonstrate prohibitive seasonality in terms of available supply, it would be more cost effective to treat and use supplies when needed and avoid added costs for permitting, monitoring, well construction, and pumping for an ASR system.

Alternative C-2: Conjunctive Use

In the Phase A-1 report, Alternative C-2 was described as operating one or more alternative water supplies with the existing network of groundwater wells in an optimized manner. The use of both sources would be balanced to minimize the undesirable economic and environmental effects from each individual source of supply, while maximizing the water demand/supply balance. An example of conjunctive use would be to use existing groundwater supplies only to the extent that does not result in further drawdown of the aquifer, coupled with a new surface water treatment plant that could address remaining demands (including peaks). With the same two water supplies, drought and other conditions that challenge surface water quantity/quality could be addressed by temporarily curtailing surface water withdrawals and relying more heavily on groundwater supplies. The supply mix would then be reversed following the end of drought conditions, allowing ground water aquifers to rebound.

Regardless of the alternative water source pursued by CCG, additional evaluation of conjunctive use of alternative supplies with existing supplies is recommended. Discussions with MDE may also be beneficial, to explore the structuring of groundwater appropriations such that they allow for occasional/temporary higher-than-normal withdrawals, similar to the current permit for Bryans Road wells in the Lower Patapsco aquifer (MDE permit CH1955G003(06)), which allows for withdrawals during water supply emergencies. However, similar to a countywide agreement, conjunctive use is not a source water in and of itself, and was therefore not included as a standalone option in the Water Supply Scenarios.

Other Surviving Alternatives from Phase A-1

Water supply alternatives G-4 (New Surficial Aquifer Wellfield), R-2 (Managed Aquifer Recharge), and P-3 (Wellfield Management Plan) were also included as surviving options at the conclusion of the Phase A-1 effort. No additional information for these alternatives was available after the Phase A-1 report, thus these alternatives are included in the Water Supply Scenarios discussed herein based on their Phase A-1 analyses.

[7] A high salinity event was based on exceeding a fresh water threshold of 500 mg/L total dissolved solids.

Development of Water Supply Scenarios

The final subset of surviving water supply alternatives was used to develop five Water Supply Scenarios. Individual alternatives were combined for some of the scenarios to improve supply reliability and cost-effectiveness. Each scenario described below is sized for an additional 10 mgd of supply capacity to meet projected maximum day demands, totaling approximately 20 mgd, when combined with the existing available supplies. Continued use of existing supplies, including groundwater and purchased water from WSSC, is assumed, with the addition of greensand filtration to existing groundwater wells to address concerns related to iron and manganese contamination.

Near-term Supply Needs

The scenarios described below are designed to meet long-term supply needs. However, based on the current supplies and demand projections, CCG could potentially face increasing difficulty and expense in meeting maximum day demands over the coming years. Average day demands are projected to be met until 2030 to 2035, except for the most conservative demand scenario, which would become an issue in 2025.[8] Given the cost and level of infrastructure investment needed for the Water Supply Scenarios described in this section, it is unlikely any scenario could be fully implemented by the time CCG could start to see supply problems. Therefore, it is necessary to plan for meeting near-term needs in order to provide adequate time to implement long-term water supply solutions.

The first shortfall is projected to be a potential max day demand deficit of between 0.18 and 1.15 mgd by 2020. WSSC's hydraulic analysis at the existing connection point indicates CCG could obtain between 0.25 and 0.6 mgd of additional supply with minimal infrastructure investment. Access to this water may require renegotiation of the current agreement between CCG and WSSC, which has a 1.4 mgd limit. However, WSSC may entertain short term exceedances of the current contract as a new agreement is negotiated. The maximum projected deficit cannot be met by WSSC alone, and the only other potential source that can be brought on-line in the next four years is assumed to be additional confined aquifer groundwater. Additional confined aquifer groundwater withdrawals would require permitted allocations, potentially justified with improved well management/consolidation and/or "down dip" lower Patapsco wells. MDE may be amenable to granting additional allocations to meet maximum day demands on an interim basis, if CCG has a suitable plan in place to bring permanent new supplies on-line for meeting long-term needs.

The potential average day demand deficit of 0.31 mgd by 2025 for the most conservative demand scenario could be met with additional supply from the existing WSSC connection. Between 2025 and 2030, CCG's average day supply needs will continue to increase above what could be supplied by the existing WSSC connection. However, it is assumed that between now and 2030 CCG will be able to bring sufficient permanent supplies on-line to begin to meet long-term demands. Implementation timeline is a category in the triple bottom line analysis described below; this parameter will therefore favor options that have a shorter lead time for implementation.

[8] It is unclear how the on-going implementation of the Watershed Conservation District will affect growth and demand projections. Once fully implemented, demand projections should be re-evaluated to confirm timelines for needed additional supply capacity.

Scenario 1: Increased Allocations from WSSC

Scenario 1 relies on the continued and increased provision of finished drinking water from WSSC to the CCG distribution system. Existing groundwater supplies and 5.0 mgd of WSSC water at the proposed new connection site are used to ultimately meet an average day demand of 11.2 mgd. To meet maximum day demands, WSSC water from the proposed new connection site is further relied upon up to 10.0 mgd, as well as WSSC water from the existing site. Hydraulic data provided by WSSC confirms the feasibility of these supplies given planned infrastructure improvements near the new proposed connection site. Water Supply Scenario 1 is summarized in Table 4.

Table 4: Scenario 1 Increased Allocations from WSSC

Source of Supply	Average Day Supply Mix (mgd)	Design Capacity (mgd)
Existing groundwater	6.2	9.33
Existing WSSC	0	1.42
New WSSC	5.0	10.0
Total	**11.2**	**20.75**

Implementation of Scenario 1 would require a new transmission main to connect the Bryans Road and Waldorf systems, as well as at the proposed new WSSC connection site. The proposed new WSSC connection site would include pressurized GAC treatment for the removal of DBPs; the existing transmission main near the proposed new WSSC connection would be upsized to connect to the Waldorf system. Figure 8 shows existing assets in and around Charles County, as well as the new major assets that would be required for Scenario 1. Figure 9 and Figure 10 show the pumping that would be needed to bring flows from the WSSC system at the existing and proposed new connection sites to the CCG system hydraulic grade line. The benefits of Scenario 1 include a minimal requirement for new infrastructure and a fairly high level of certainty regarding the quality and quantity of water that could be provided by WSSC. However, CCG would be highly sensitive to changes in WSSC rates due to heavy dependence on the use of WSSC supply to meet average day demands. Further, it is possible for supplies to be curtailed during water supply emergencies at WSSC.

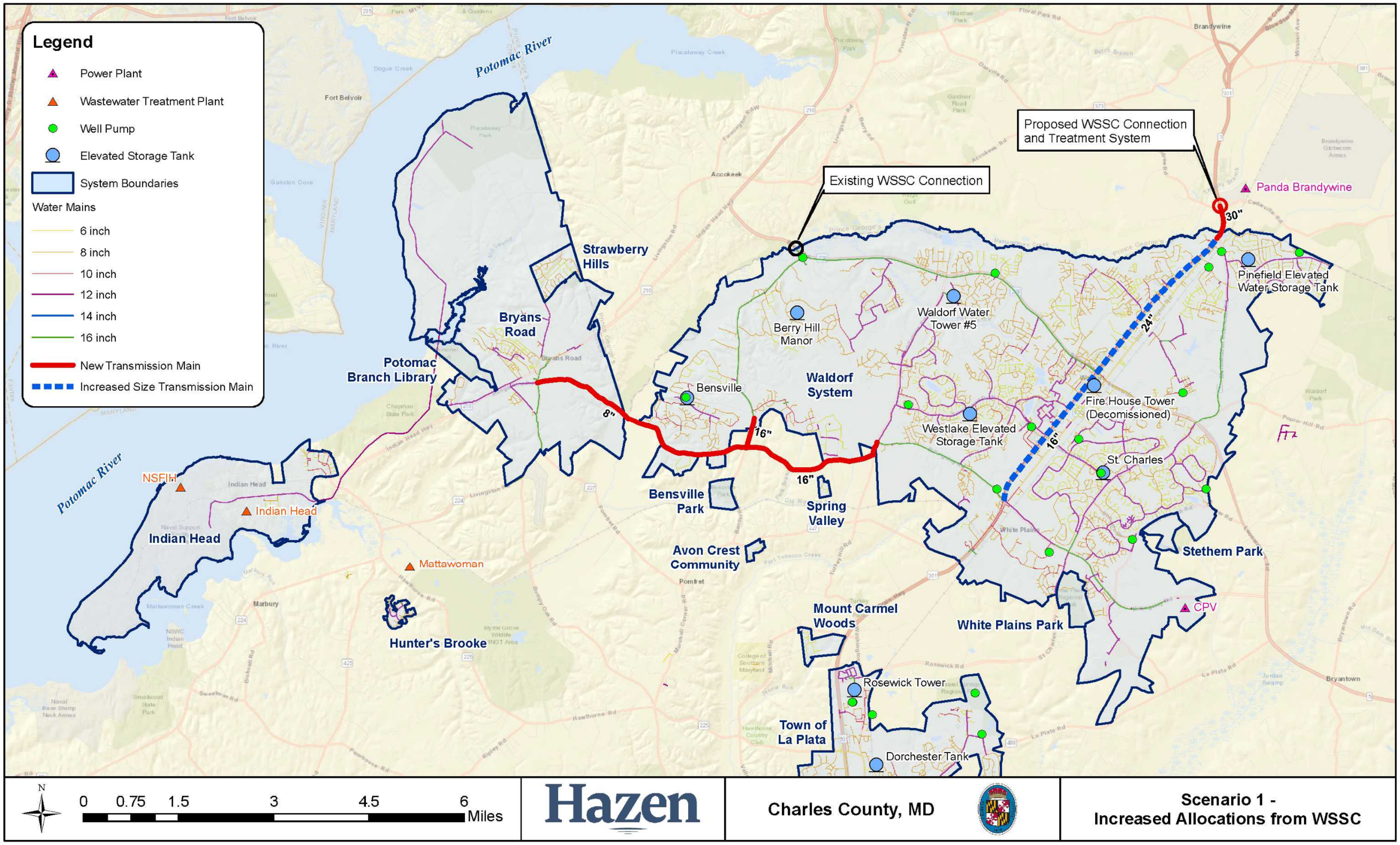


Figure 8: Water Transmission System Upgrade Layout for Water Supply Scenario 1

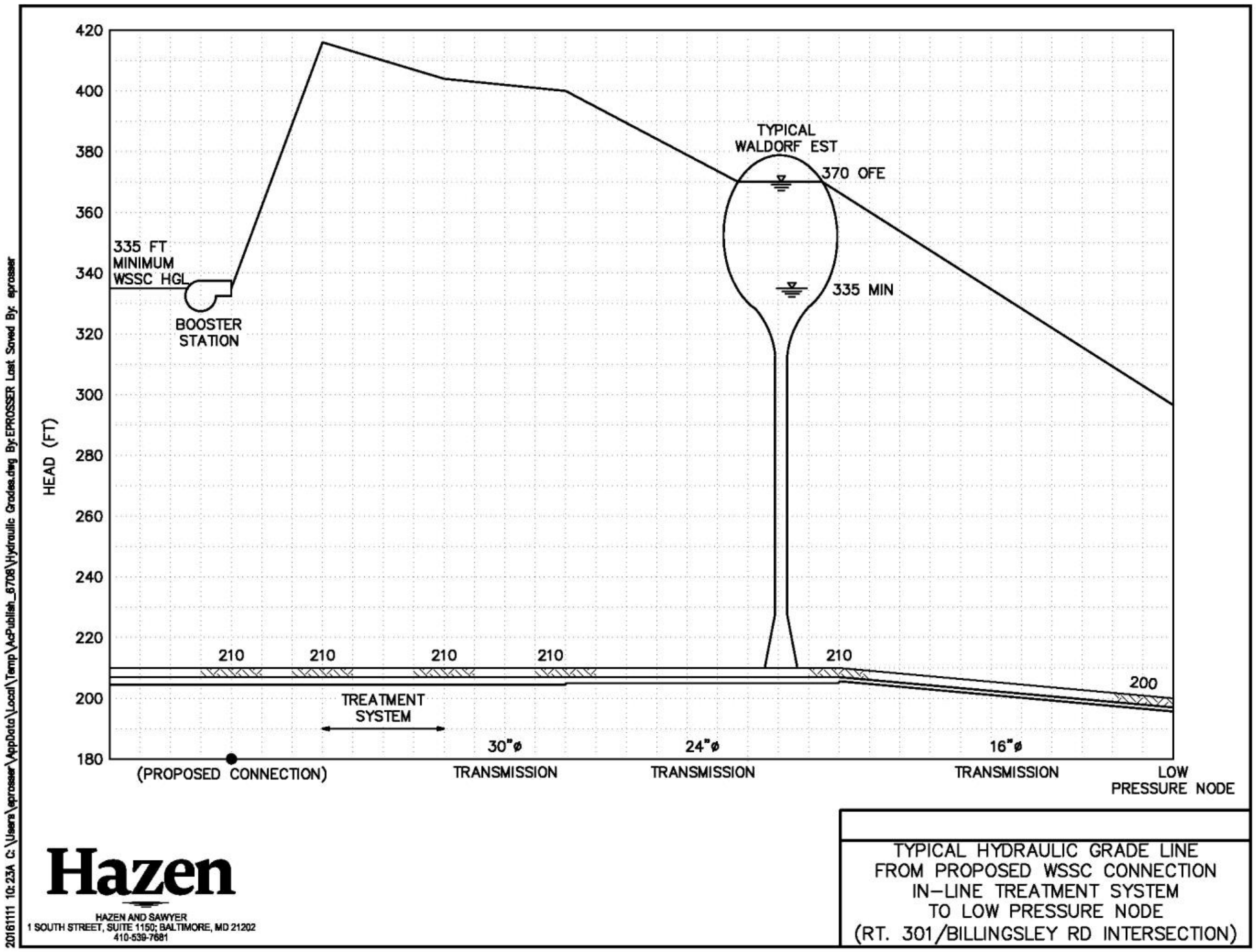


Figure 10: Typical Hydraulic Grade Line from Proposed WSSC Connection In-Line Treatment System to Low Pressure Node in CCG Distribution System

Scenario 2: Upper Reaches Potomac River Supply

Scenario 2 includes the continued use of existing groundwater allocations and a new upper reaches Potomac River supply (i.e., riverbank filtration or a surface water intake with a new treatment facility) for projected average day demands. Maximum day demands are met with additional dependence on the upper reaches Potomac River supply and existing WSSC allocations as necessary. Acceptable surface water options were limited to the upper reaches of the Potomac River to avoid the need for desalination. Water Supply Scenario 2 is summarized in Table 5.

Table 5: Scenario 2 Upper Reaches Potomac River Supply

Source of Supply	Average Day Supply Mix (mgd)	Design Capacity (mgd)
Existing groundwater	6.2	9.33
Existing WSSC	0	1.42
Upper reaches Potomac River supply	5.0	10.0
Total	**11.2**	**20.75**

As described in the Phase A-1 report, available water quality data for the upper reaches of the Potomac River would strongly suggest the use of advanced treatment processes to minimize DBP formation, achieve adequate pathogen reduction, and provide a barrier against organic contaminants. Furthermore, the proposed withdrawal location is downstream of the Blue Plains Advanced Wastewater Treatment Plant, and it is anticipated that MDE would require advanced drinking water treatment due to the significant wastewater influence. Other water quality parameters such as turbidity, alkalinity, and pH are within the typical range for conventional flocculation and sedimentation before the filtration process. Figure 11 presents a process schematic of a water treatment plant using the upper reaches of the Potomac River as a source of supply. If this option is selected for implementation, it will require detailed water quality data collection at the identified intake location and/or riverbank filtration well(s) along with pilot testing to confirm appropriate treatment process design. Another treatment consideration is the disposal of treatment plant residuals (e.g. backwash water, solids), which could be piped to a wastewater treatment plant or dewatered and disposed of by land application.

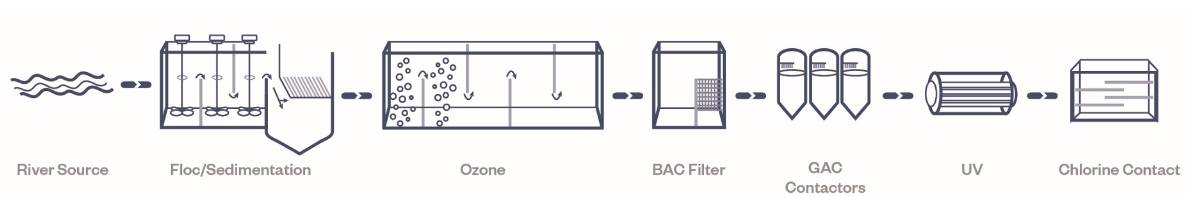


Figure 11: Water Treatment Plant Schematic for the Upper Reaches Potomac River Supply[9]

[9] Water treatment schematic shown is for a direct intake to the Potomac River. If RBF were used, the treatment plant would not require the floc/sedimentation basin treatment step, and UV treatment would be optional, depending on the level of pathogens in the raw water.

As described in the Phase A-1 report, existing data indicate the potential for infrequent high salinity events due to low flows in the Potomac River. Based on preliminary correlations of salinity and flow conditions in the section of the Potomac River along the northwestern portion of Charles County, high salinity could range from a five-year recurrence to a 60-year recurrence interval.[10] The preferred approach for addressing Potomac River salinity would be through conjunctive use that optimizes surface water and groundwater withdrawals based on quality and long-term sustainability. Selection of the best option to address intermittent salinity requires further water quality evaluation to determine frequency and duration of events, followed by consultation with MDE to confirm permitting requirements.

Figure 12 shows existing assets in and around Charles County, as well as the new major assets that would be required for Scenario 2. A new transmission line would be necessary to convey Potomac River supply to the Bryans Road and Waldorf systems. Additionally, an existing transmission main would be upsized as shown in the Waldorf system. Figure 13 shows the pumping that would be needed to bring new flows from the upper reaches Potomac River supply to the CCG system hydraulic grade line. The hydraulic grade line for the existing WSSC connection, shown in Figure 9, remains unchanged. Although Scenario 2 requires substantial capital investment for the establishment of a Potomac River supply, CCG would not be dependent on increased allocations from WSSC and thus less sensitive to changes in rates or supply availability from WSSC.

[10] A high salinity event was based on exceeding a fresh water threshold 500 mg/l total dissolved solids.

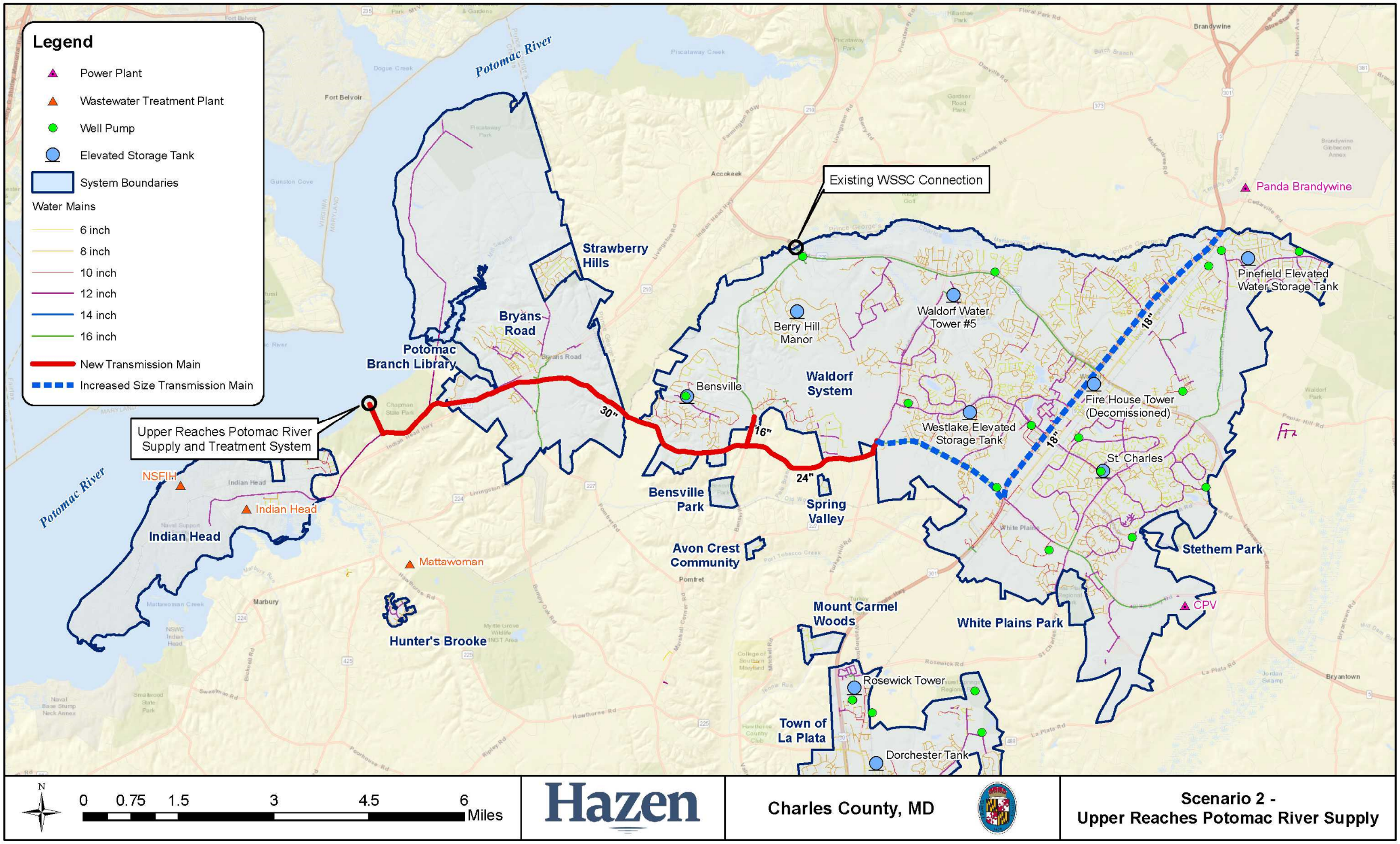


Figure 12: Water Transmission System Upgrade Layout for Water Supply Scenario 2

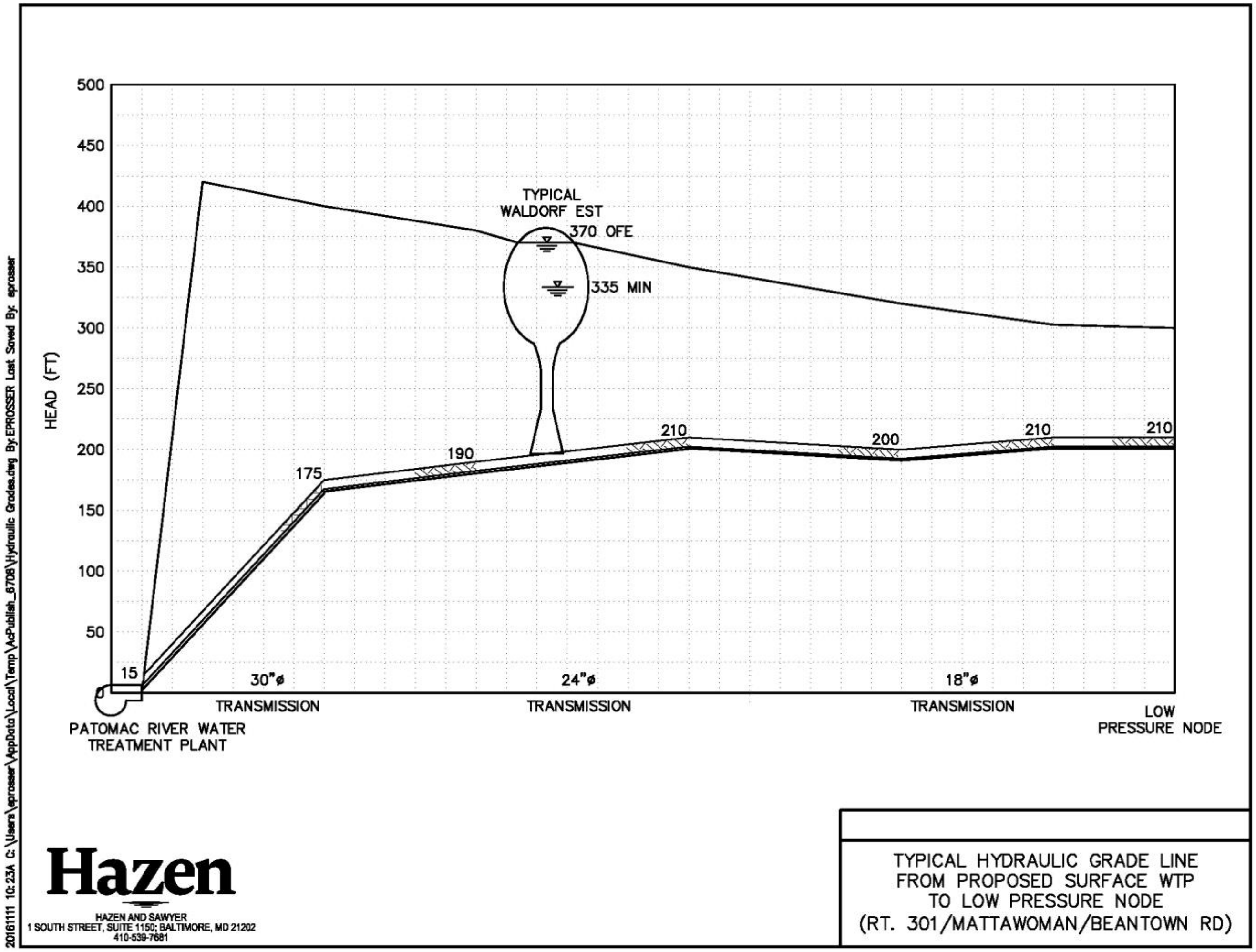


Figure 13: Typical Hydraulic Grade Line from Proposed Upper Reaches Potomac River Supply to Low Pressure Node in CCG Distribution System

Scenario 3: Upper Reaches Potomac River Supply and Increased Allocations from WSSC

Water Supply Scenario 3 involves a combination of existing groundwater, existing WSSC allocations, a new upper reaches Potomac River supply, and increased allocations from WSSC to meet projected average and maximum day demands (Table 6). The existing and proposed new WSSC connection sites are similar to Scenario 1, but are assumed to not require treatment for DBP removal due to WSSC water being blended with other supplies and only intermittently used for maximum day demands. The upper reaches Potomac River supply requires advanced treatment, as described for Scenario 2 (Figure 11). Water Supply Scenario 3 enables development of a long-term supply (Potomac River) that allows CCG to be more in control of its water supplies for meeting average day demands, while securing the availability of a known supply (WSSC) for maximum day demands. Further, the WSSC supply could be relied upon as an emergency alternative supply for CCG.

Table 6: Scenario 3 Surface Water Treatment Plant plus Increased Allocations from WSSC

Source of Supply	Average Day Supply Mix (mgd)	Design Capacity (mgd)
Existing groundwater	6.2	9.33
Existing WSSC	0	1.42
New surface water treatment plant	5.0	5.0
New WSSC	0	5.0
Total	**11.2**	**20.75**

Figure 14 shows existing assets in and around Charles County, as well as the new major assets that would be required for Scenario 3. A new transmission line would be needed to convey Potomac River supply to the Bryans Road and Waldorf systems and an existing transmission main would be upsized as shown in the Waldorf system. Figure 9, Figure 10, and Figure 13 from the descriptions of Scenarios 1 and 2 show the pumping that would be needed to bring flows from the two WSSC connections and upper reaches Potomac River supply to the CCG system hydraulic grade line.

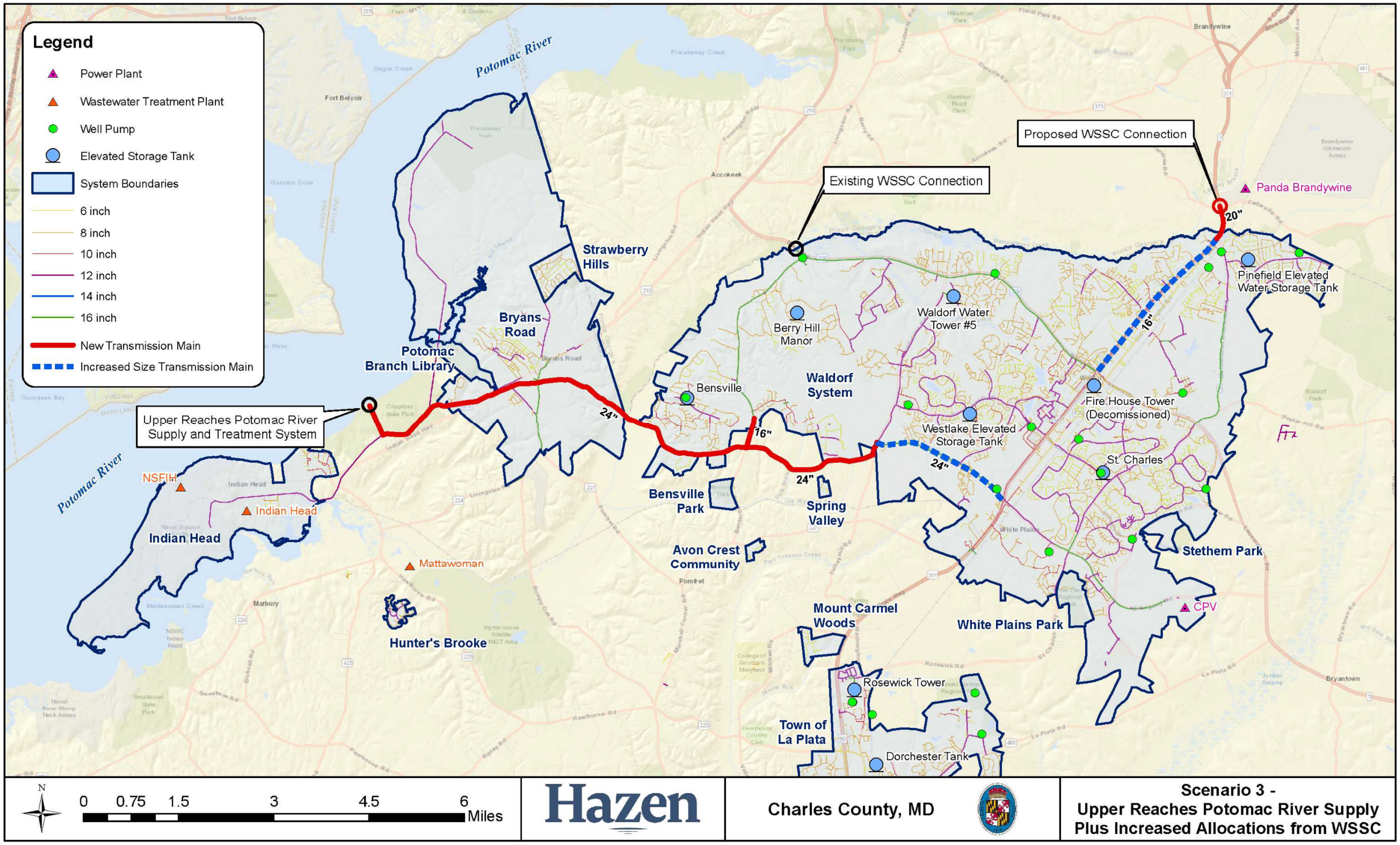


Figure 14: Water Transmission System Upgrade Layout for Water Supply Scenario 3

Scenario 4: Managed Aquifer Recharge and Increased Allocations from WSSC

In Water Supply Scenario 4, groundwater is maintained as the primary source of supply, and would consist of existing groundwater allocations in addition to increased groundwater allocations enabled by lower Patapsco aquifer recharge with highly treated reclaimed water from the Mattawoman Wastewater Treatment Plant. The injection of highly treated reclaimed water into one of Charles County's confined groundwater aquifers for subsequent withdrawal as potable water supply at a downgradient well is referred to here as managed aquifer recharge. Existing and increased WSSC allocations are used to meet maximum day demands (Table 7).

Table 7: Scenario 4: Managed Aquifer Recharge plus Increased Allocations from WSSC

Source of Supply	Average Day Supply Mix (mgd)	Design Capacity (mgd)
Existing groundwater	6.2	9.33
Existing WSSC	0	1.42
Managed aquifer recharge	5.0	5.0
New WSSC	0	5.0
Total	**11.2**	**20.75**

In the Phase A-1 report, it was determined that average flows for all public/municipal wastewater treatment plants operated by CCG totaled 10.6 mgd in 2015, the majority (> 95%) of which can be attributed to the Mattawoman Wastewater Treatment Plant. Considering a total effluent flow of approximately 10 mgd from the Mattawoman Wastewater Treatment Plant, with approximately 4 mgd being delivered to Panda Power Plant and CPV for cooling purposes on a daily basis, it was assumed that 6 mgd of effluent would be available for aquifer recharge. Based on aquifer recharge in other regions, it was assumed that only a portion of the injected water would result in an increased allocation for withdrawal. While the exact aquifer response would need to be verified with hydrogeological evaluations, the maximum available additional allocation from managed aquifer recharge is assumed to be 5.0 mgd based on current wastewater flows. It is noted that future wastewater flows available for injection, and thus allowable aquifer withdrawals associated with managed aquifer recharge, are anticipated to increase with demands (Table 7).

The benefits of managed aquifer recharge with highly treated reclaimed water from the Mattawoman Wastewater Treatment Plant, as compared with non-potable reuse, include the lack of return flows, minimal conveyance infrastructure, the potential to replenish diminishing groundwater supplies for the region, and the diversion of nutrients loads away from surface waters. Although precedent for producing indirect potable reuse quality water, as well as managed aquifer recharge, exists for other parts of the country, these practices are currently not in use in Maryland. Thus, determination of regulatory requirements (e.g., treatment standards, pilot-testing requirements, and permitting) may be a challenge.

Water Supply Scenario 4 assumes the use of the O_3-BAC-GAC-UF-UV treatment train shown in Figure 15. This treatment train, as well as a reverse osmosis-based treatment train, were evaluated in the Phase A-1 report, with both treatment options providing a multiple barrier approach to produce high quality reclaimed water. While both treatment trains have a range of operational, wastewater management, and monitoring requirements, the O_3-BAC-GAC-UF-UV treatment train was ultimately selected for this Phase A-2 effort due to difficulties associated with disposing of reverse osmosis brine and the fact that Mattawoman Wastewater Treatment Plant effluent is not expected to require reverse osmosis for the removal of total dissolved solids.

Figure 15: Managed Aquifer Recharge Treatment Train

Figure 16 shows existing assets in and around Charles County, as well as the new major assets that would be required for Scenario 4. A new transmission line would be necessary to connect the Bryans Road and Waldorf systems and an existing transmission main would be upsized to connect to the proposed new WSSC connection site. Figure 9 and Figure 10 from the description of Scenario 1 show the pumping that would be needed to bring flows from the existing and potential new WSSC connection to the CCG system hydraulic grade line.

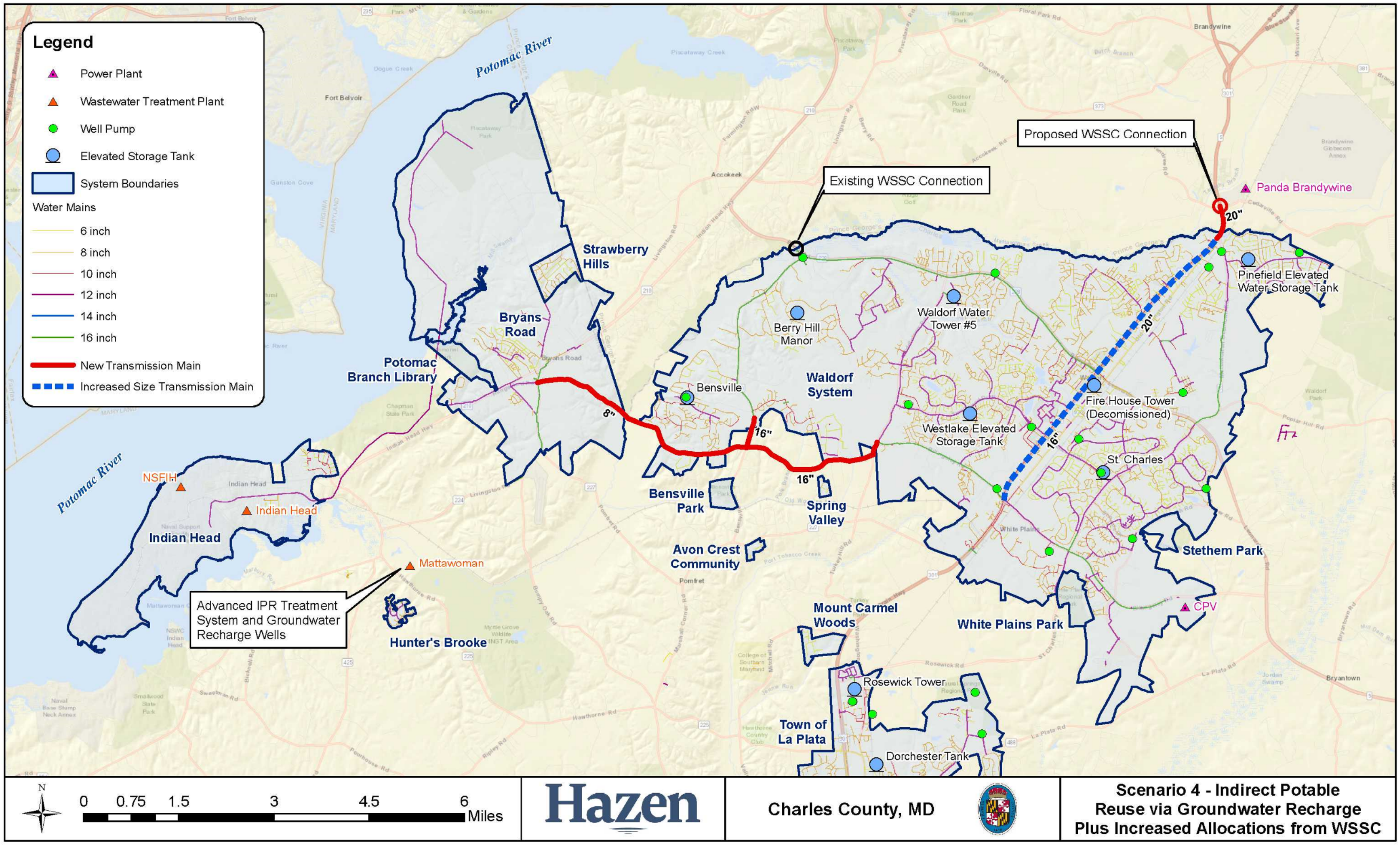


Figure 16: Water Transmission System Upgrade Layout for Water Supply Scenario 4

Scenario 5: Increased Groundwater Appropriations, Surficial Aquifer, and Increased Allocations from WSSC

Water Supply Scenario 5 is summarized in Table 8. In this scenario, average day demands are met with existing groundwater allocations in addition to new groundwater allocations from both the surficial and confined aquifers. The surficial aquifer withdrawals are assumed to be coupled with ASR due to the expected seasonal yield of the surficial aquifer, with aquifer levels being low in the summer and high in the winter. Groundwater withdrawals are augmented with expanded WSSC supplies for reliability and to meet maximum day demands. Overall, this Water Supply Scenario has the highest level of uncertainty, as the availability of adequate additional supplies from the surficial and confined aquifers must be further verified.

Table 8: Scenario 5: Increased Groundwater Appropriations plus Surficial Aquifer plus Increased Allocations from WSSC

Source of Supply	Average Day Supply Mix (mgd)	Design Capacity (mgd)
Existing groundwater	6.2	9.33
Existing WSSC	0	1.42
New confined aquifer withdrawals	2.5	2.5
New surficial aquifer withdrawals	2.5	2.5
New WSSC	0	5.0
Total	**11.2**	**20.75**

The new confined aquifer groundwater supply (total of 2.5 mgd) is expected to come from increased Magothy withdrawals (0.5 mgd) through improved wellfield management and “down dip” lower Patapsco wells (2.0 mgd). As described in the Phase A-1 report, the Magothy aquifer has a slightly declining to flat trend; however, conversations with MDE staff indicated potentially up to 0.5 mgd of additional allocation may not adversely affect aquifer drawdown. Aquifer levels in the “down dip” lower Patapsco aquifer are well above the 80% management limit, potentially allowing for additional allocation to CCG.[11] There is a risk that the Magothy aquifer cannot support additional withdrawals and that withdrawals in the “down dip” Patapsco aquifer would have an adverse impact on existing “up dip” wells. Consultation with MDE would be required to further assess the acceptability of this approach. If MDE consents to permitting additional allocations and CCG pursues this option, there is a risk that the wells may prove to be unsustainable in the long-term, requiring CCG to pursue a different alternative to meet needed supply capacity.

A maximum of 2.5 mgd is assumed to be available from the surficial aquifer with the use of an ASR system. At this time, the potential yield and water quality of the surficial aquifer are uncertain due to sparse data. Given the shallow depth of the aquifer, it is likely that wells would be categorized as GWUDI,[12] in which case withdrawals would need to be treated to meet drinking water regulations. In

[11] MDE suggested consolidation of “up dip” wells with the construction of new “down dip” wells, which would likely result in reduced aquifer drawdown per unit of withdrawal.
[12] Wells screened in unconfined aquifers at less than 50 feet depth is a potential indicator of GWUDI. A microscopic particulate analysis is required to confirm the quality of the water from the well.

this Water Supply Scenario, it is assumed that surficial aquifer withdrawals will require microfiltration or ultrafiltration membranes with chlorination (Figure 17).

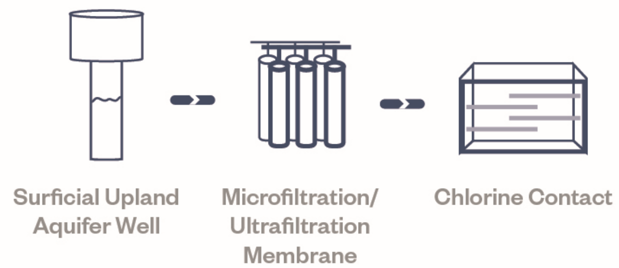


Figure 17: Surficial Aquifer Treatment Schematic

Figure 18 shows existing assets in and around Charles County, as well as the new major assets that would be required for Scenario 5. A new transmission line would be needed to connect the Bryans Road and Waldorf systems and an existing transmission main would be upsized to connect to the proposed new WSSC connection site. Figure 9 and Figure 10 from the description of Scenario 1 show the pumping that would be needed to bring flows from the existing and potential new WSSC connections to the CCG system hydraulic grade line.

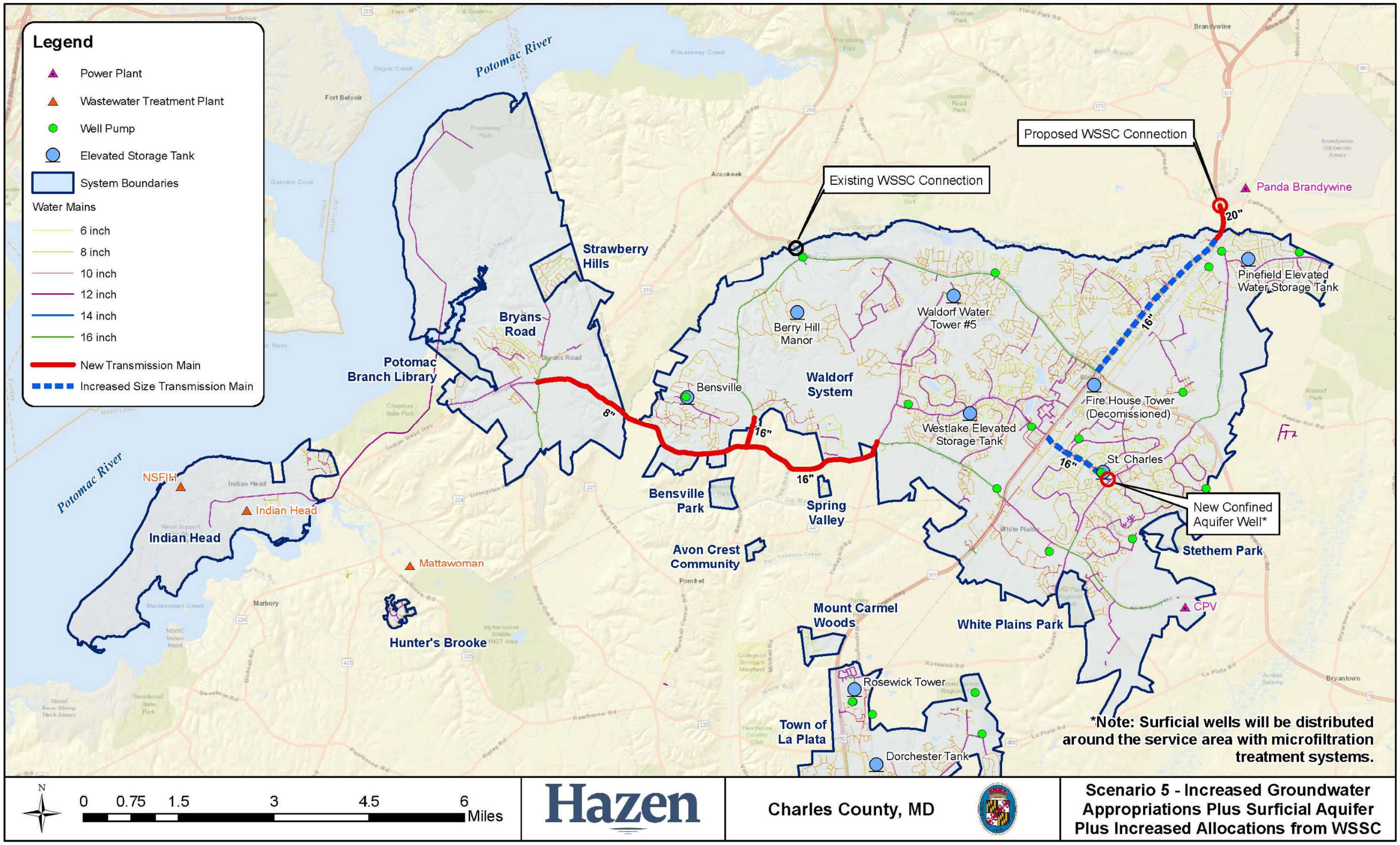


Figure 18: Water Transmission System Upgrade Layout for Water Supply Scenario 5

Preliminary Cost Comparison of Scenarios

Figure 19 and Table 9 shows the comparison of the net present values for each of the proposed Water Supply Scenarios, including capital costs and 30 years of annual operational costs for average day demands, at a 3% discount rate. The values are Class 5 Estimates, with an accuracy range of -30% to +50%, per the American Association of Cost Engineering, [13] which underscores the level of uncertainty in the cost estimates at this stage. However, there are some general conclusions that can be drawn from these estimates.

- Scenario 5 (Expanded Groundwater Appropriations + Surficial Aquifer + WSSC) is the lowest cost option under all assumptions due to its reliance on additional groundwater resources that require the lowest level of treatment.
- Scenario 3 (Upper Reaches Potomac River Supply + WSSC) is the second lowest cost option under all assumptions, because investing in increased capacity from WSSC to meet maximum day demands is more cost-effective than expanding a Potomac River water treatment plant from 5 mgd to 10 mgd.
- Scenario 2 (Upper Reaches Potomac River Supply) and Scenario 4 (Groundwater Recharge + WSSC) have relatively similar overall net present values, but have key differences in capital and O&M costs. Both have similar capital costs for treatment, but Scenario 2 has higher costs for transmission infrastructure, while Scenario 4 has higher costs for O&M. As a result, the rankings of these two scenarios are sensitive to the discount rate.
- Scenario 1 (WSSC) is the highest cost option under all assumptions due solely to the high cost of purchasing and treating water from WSSC.

Refer to Appendix A for detailed cost breakdowns of each scenario's preliminary cost estimate.

[13] American Association of Cost Engineering International Recommended Practice No. 18R-97 Cost Estimate Classification System–As Applied in Engineering, Procurement, and Construction for the Process Industries

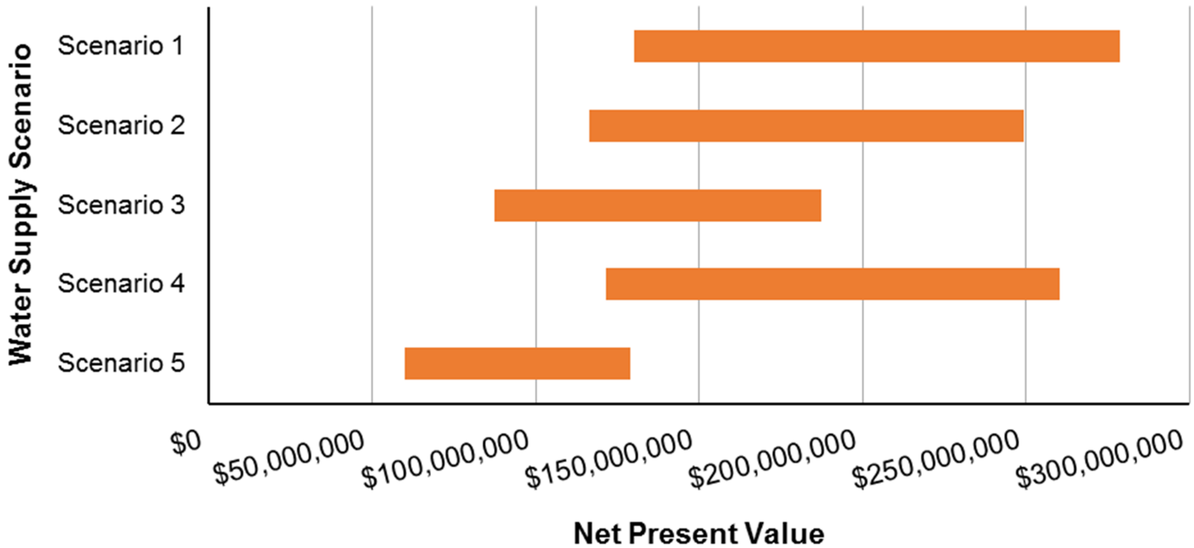


Figure 19: Range of Water Supply Scenario Net Present Values for Total Capital Costs and 30 Years of Annual Operation

Table 9: Range of Water Supply Scenario Net Present Values for Total Capital Costs and 30 Years of Annual Operation

Scenario	Total 30 Year Net Present Value Cost Range ($M)	Percent for Treatment/ Transmission/O&M Costs
Scenario 1: WSSC	$130 M to $279M	11% / 10% / 79%
Scenario 2: Upper reaches Potomac River WTP	$116 M to $249 M	61% / 23% / 16%
Scenario 3: Upper reaches Potomac River WTP and WSSC	$88 M to $188 M	55% / 23% / 22%
Scenario 4: Managed aquifer recharge and WSSC	$121 M to $260 M	63% / 9% / 27%
Scenario 5: New groundwater and WSSC	$60 M to $129 M	54% / 17% / 29%

Triple Bottom Line Framework

A triple bottom line assessment of the five Water Supply Scenarios was conducted in order to evaluate each scenario across a broad range of decision-making criteria, including those that pertain to cost estimates.

Triple Bottom Line Criteria

The five Water Supply Scenarios presented herein were compared using the sixteen triple bottom line criteria shown in Table 10. These criteria were selected to represent economic, environmental, and social factors that impact the favorability of a given Water Supply Scenario relative to the other scenarios under consideration. A thorough understanding of how the Water Supply Scenarios compare across TBL criteria is important in terms of selection, planning, and public communication. In addition, the criteria scores of a selected scenario can be used during implementation to make stakeholders aware of potential challenges and to guide various project activities.

All triple bottom line criteria were applied to the five Water Supply Scenarios. Qualitative criteria (e.g., public acceptance) were scored on a range from 0 to 1 based on best professional judgement, with 0 representing the least favorable score and 1 representing the most favorable score. Quantitative criteria (e.g., capital cost) scores were determined based on the metrics summarized in Table 10 and then normalized to a value ranging from 0 (least favorable) to 1 (most favorable). Figure 20 shows an example of the normalization procedure for quantitative criteria. These qualitative and normalized quantitative scores were compiled for all the five Water Supply Scenarios prior to applying criteria weights. These unweighted scores are referred to as "normalized raw scores".

Water Supply Scenario	Criterion Raw Score
Scenario 1	500,000
Scenario 2	130,000
Scenario 3	98,000
Scenario 4	900,000
Scenario 5	870,000

**Note: In this example, a higher criterion raw score is negatively correlated with favorability, e.g., capital cost or energy footprint*

$$Normalized\ Raw\ Score = \frac{Criterion\ Raw\ Score - Max\ Criterion\ Raw\ Score}{Min\ Criterion\ Raw\ Score - Max\ Criterion\ Raw\ Score}$$

Water Supply Scenario	Normalized Raw Score
Scenario 1	0.50
Scenario 2	0.96
Scenario 3	1.00
Scenario 4	0.00
Scenario 5	0.04

**Note: Normalized criterion scores can range from 0 to 1, with 0 representing the least favorable score and 1 representing the most favorable score. In this example, Scenario 3 has the most favorable normalized raw score because it had the lowest criteria raw score.*

Figure 20: Normalization Example for Triple Bottom Line Criteria Scores

Table 10: Criteria for Triple Bottom Line Comparison of Water Supply Scenarios

Criteria Category	Criteria	Description
Economic Criteria	Life cycle cost per unit of water ($/mgd)	Present value of costs over a selected timespan (within the anticipated life of the water source option); includes capital and operation/maintenance costs
	Capital cost per unit of water ($/mgd)	Capital expenditures including planning, design, permitting, construction, and commissioning of facilities required to access, treat, and convey the water source option to the closest connection point within the existing transmission and distribution system.
	Operation and maintenance cost per unit of water ($/year/mgd)	The annual costs to operate and maintain the infrastructure/facility, including labor, chemical costs, power costs, and equipment maintenance/replacements.
	Total available units of water (mgd)	Average daily amount of water available for the water supply option taking into account constraints, uncertainties, supply reliability, and potential for future expansion.
Environmental Criteria	Energy footprint per unit of water (kWh/mgd)	Direct energy consumption during operation of the water source option, including energy used at the water treatment facility and during water transmission
	Land footprint per unit of water (acres/mgd)	Measured as acres of land dedicated to use of the water source option
	Waste disposal cost per unit of water ($/mgd)	Quantity of waste byproduct generated during operation of the water source option (e.g., coagulation residuals, membrane filtrate concentrate) and associated cost of disposal
	Ease of waste disposal	The relative ease of waste disposal, considering its distribution of production, the type of waste(s), and locally available options
	Regional benefits (qualitative)	Long-term benefits of the water source option on water resource availability in the region
Social Criteria	Implementation timeline (months)	The amount of time necessary to bring the water source option on-line, including planning, design, permitting, construction, and commissioning of the facilities
	Public acceptance (qualitative)	Level of effort needed to obtain public consensus that the water source option is an acceptable way to provide the community with water
	Drought resiliency	Ability of the water source option to meet water demand during a drought event
	Local impacts of construction and operation (qualitative)	Anticipated level of noise, odor, traffic, and impedances to recreational space; assumed to be proportionate to capital costs
	Ease of permitting (qualitative)	The ease with which a water source option is expected to be deemed acceptable by Maryland Department of the Environment based on permitting precedents and discussions with regulators
	Ease of operation (qualitative)	The ease with which a source water option can be withdrawn, treated, and conveyed to customer after construction; operator training requirements, required monitoring, and anticipated adjustments to the treatment process are taken into consideration
	Control of destiny	The extent to which CCG controls its own destiny versus the required engagement of other stakeholders

Weighting of Triple Bottom Line Criteria

The unweighted triple bottom line results allow one to see how all the Water Supply Scenarios compare against each other for each individual criterion. The weighted triple bottom line results enable derivation of one single score for each Water Supply Scenario, thus allowing scenarios to be ranked in terms of favorability, taking all triple bottom line criteria and criteria weightings of importance into consideration.

The valuation structure used in this assessment is shown in Table 11. The criteria weighting scale ranges from 1 to 10, with 1 indicating a criterion with minimal importance in the decision-making process and 10 indicating a criterion with the highest importance in the decision-making process. The weights shown in Table 11 were developed based on discussions of water supply planning priorities with CCG. Overall, the triple bottom line evaluation approach allows for a wide range of factors to be taken into consideration, some of which ultimately drive the decision between the various Water Supply Scenarios and some of which help plan for a successful implementation of the selected Water Supply Scenario.

Table 11: Triple Bottom Line Criteria and Associated Weighting

Criteria Category	Criteria	Weighting (1 – 10)
Economic Criteria	Life Cycle Cost	6
	Capital Cost	1
	Operation and Maintenance Cost	1
	Total Water Availability	10
Environmental Criteria	Energy Footprint	2
	Land Footprint	1
	Waste Disposal Cost	1
	Ease of Waste Disposal	1
	Regional Benefits on Water Resources	5
Social Criteria	Implementation Timeline	1
	Public Acceptance	6
	Drought Resiliency	8
	Local Impacts of Construction and Operation	1
	Ease of Permitting	1
	Ease of Operation	6
	Control of Destiny	8

For each Water Supply Scenario, the normalized raw scores were coupled with their associated criteria weightings from Table 11 to determine a final weighted scenario score. The final weighted scenario score can range from 0 to 1, with 1 representing the most favorable Water Supply Scenario and 0 representing the least favorable scenario. The equation on the next page further explains the process for determining the final weighted score for each Water Supply Scenario using the sum of weighted averages. Criteria weightings were held constant for all Water Supply Scenarios.

$$Weighted\ Scenario\ Score = \frac{\sum_{i=1}^{14} r_i w_i}{\sum_{i=1}^{14} w_i}$$

$Where$:

$r_i = individual\ criterion\ normalized\ raw\ score\ for\ a\ given\ water\ supply\ scenario$

$w_i = individual\ criterion\ weighting$

Triple Bottom Line Results

Unweighted Triple Bottom Line Results

Unweighted, raw normalized scores for each Water Supply Scenario and TBL criterion are shown in Figure 21, Figure 22, and Figure 23. For every criterion, normalized scores range from 0 to 1, with 0 being the least favorable Water Supply Scenario and 1 being the most favorable Water Supply Scenario for the given criterion. Scores pertaining to economic criteria are presented in Figure 21; scores for environmental criteria are presented in Figure 22; and scores for social criteria are presented in Figure 23. The unweighted TBL results show that there is no clear ranking of favorability among the five Water Supply Scenarios across the criteria. For example, Water Supply Scenario 5 (increased groundwater appropriations) is the most favorable in terms of life cycle costs, but it is the least favorable in terms of the total availability of water and regional benefits.

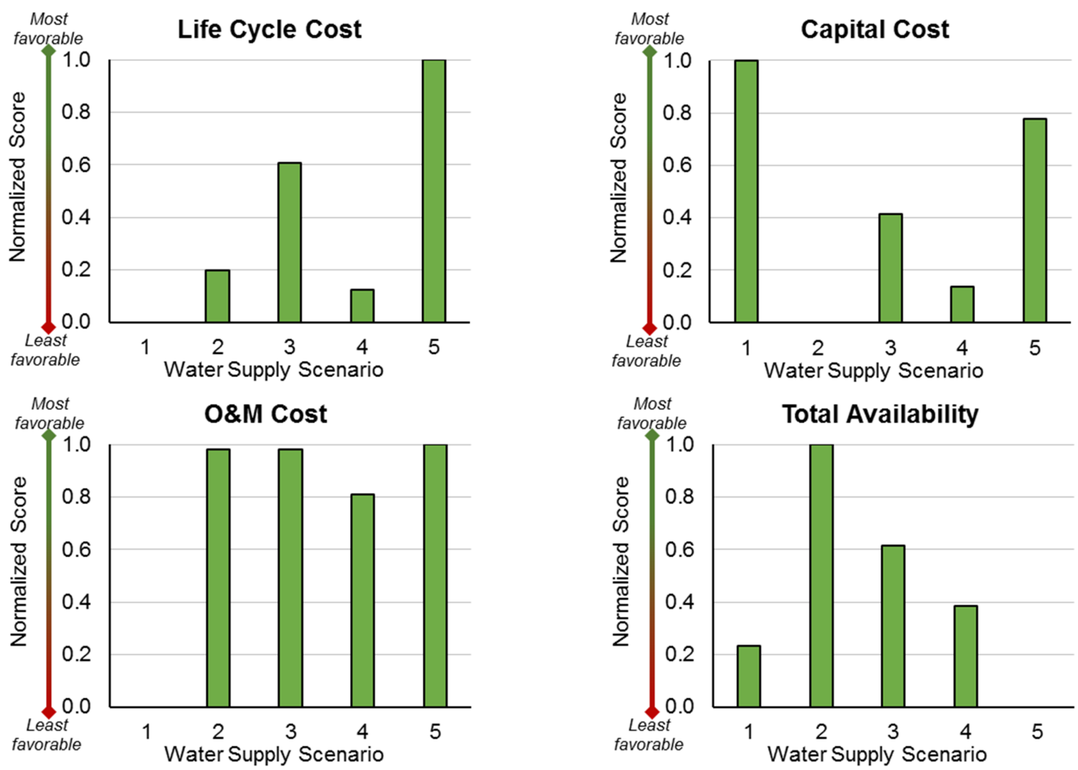


Figure 21: Unweighted Normalized Scores for Economic TBL Criteria

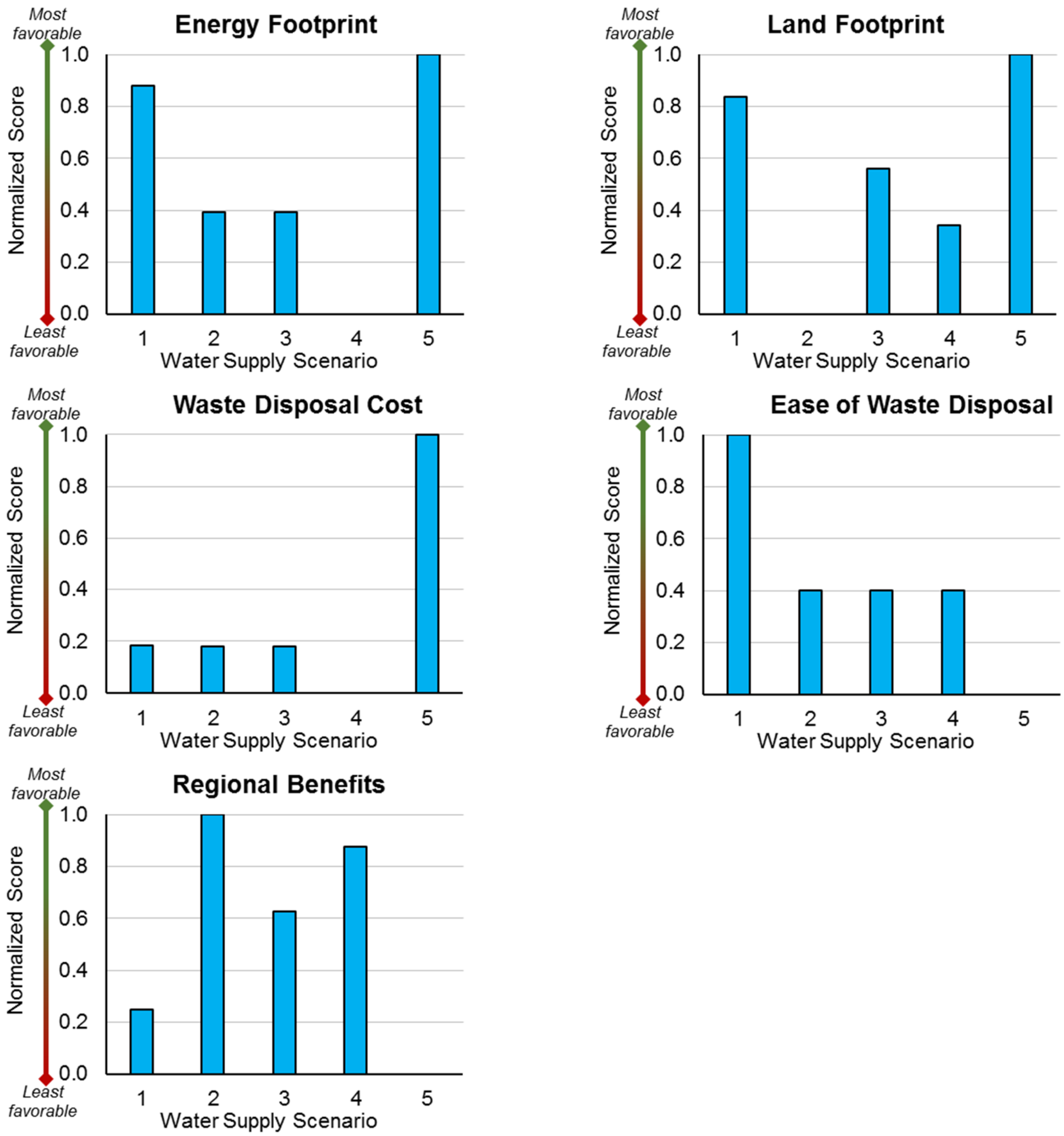


Figure 22: Unweighted Normalized Scores for Environmental TBL Criteria

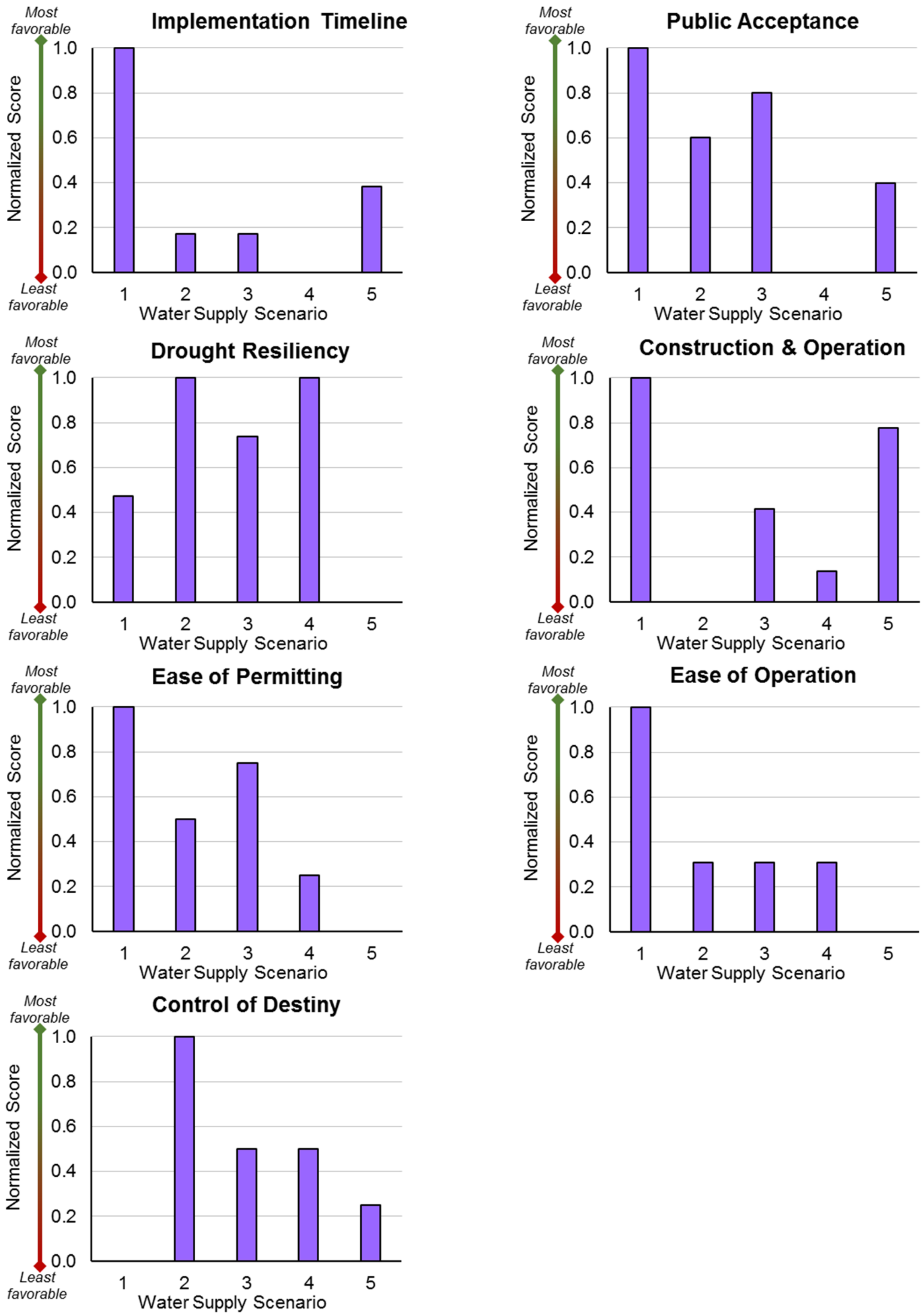


Figure 23: Unweighted Normalized Scores for Social TBL Criteria

Weighted Triple Bottom Line Results

Unweighted normalized scores were coupled with the criteria weightings presented in Table 11 to determine the overall weighted score for each Water Supply Scenario. The TBL results presented in Figure 24 show that Water Supply Scenario 2, an upper reaches Potomac River supply, is the most favorable, followed by Water Supply Scenario 3, an upper reaches Potomac River supply with increased allocations from WSSC. The least favorable option based on the weighted TBL score is Water Supply Scenario 5 (increased groundwater appropriations).

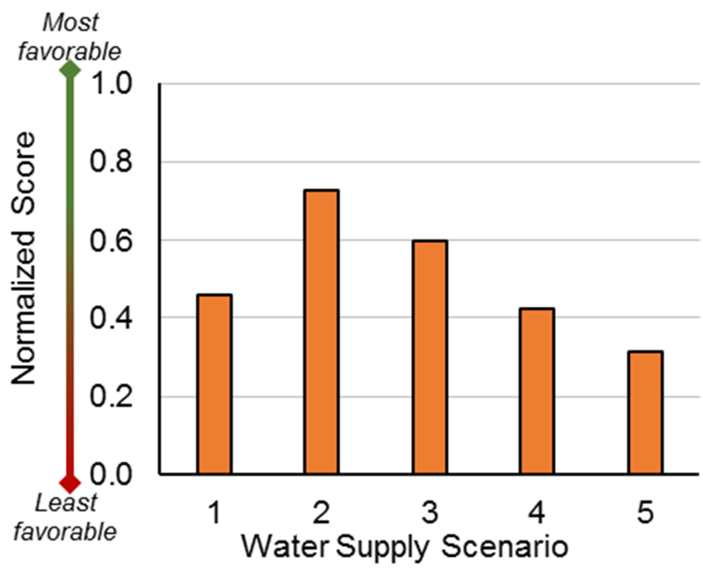


Figure 24: Overall Weighted TBL Score for Each Water Supply Scenario

The ranking of Water Supply Scenario 2 as the most favorable option is attributable to the fact that it scores well for the criteria that were most heavily weighted by CCG. In contrast, Water Supply Scenario 5 scored relatively poorly with respect to several of the highly weighted criteria, resulting in its bottom ranking of the five options.

Further comparison of Scenarios 2 and 3 with respect to differences in the weighted TBL scores for each criterion shows that four criteria (control of destiny, total water availability, drought resiliency, and regional benefits) favor Scenario 2, seven criteria are neutral between the two, and five criteria favor Scenario 3, with life cycle cost being the major contribution (Figure 25). Water Supply Scenario 3 has a more favorable life cycle cost than Scenario 2; however, Scenario 2 is favorable relative to Scenario 3 for the other criteria that CCG weighted as the most important decision-making factors; hence Scenario 2's overall weighted score is higher than that of Scenario 3.

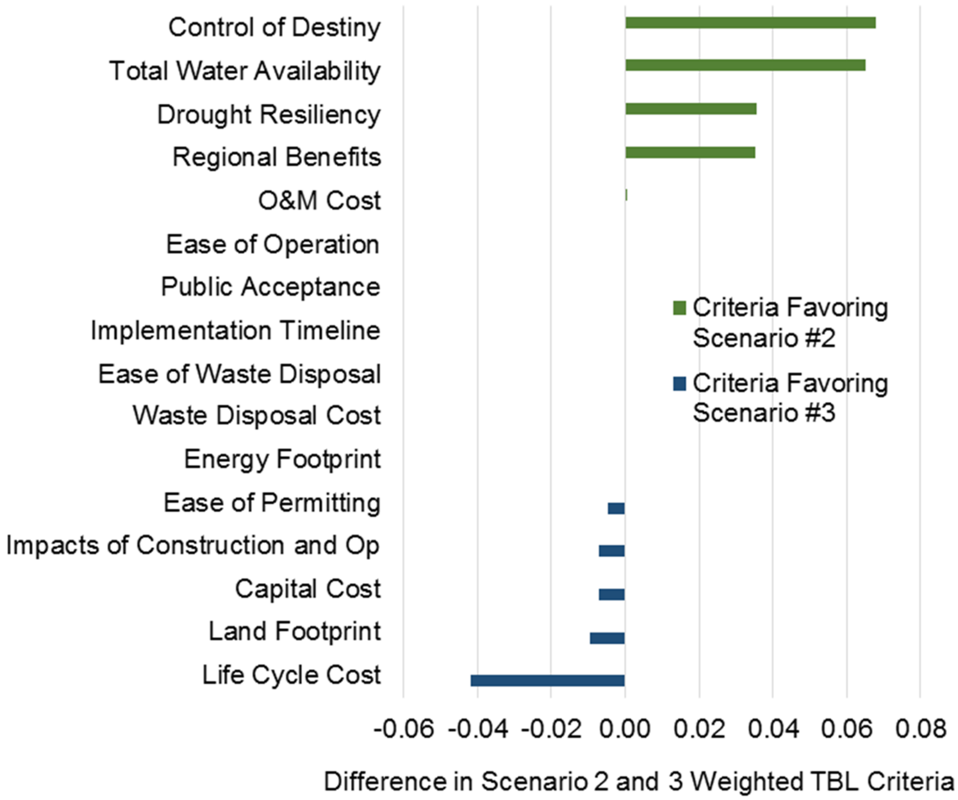


Figure 25: Comparison of Weighted TBL Criteria between Scenarios 2 and 3

Recommendations

Based on TBL analysis results, Water Supply Scenario 2 is the primary recommendation for CCG's long-term expansion of its water supply system to meet future demands. Scenario 2 includes the continued use of existing groundwater allocations and a new upper reaches Potomac River supply (i.e., riverbank filtration or a surface water intake with a new treatment facility) for projected average day demands. Maximum day demands would be met with additional dependence on the upper reaches Potomac River supply and existing WSSC allocations as necessary (Table 12). An important benefit from this option is that the Potomac River has the potential to supply significantly more water than CCG's planned needs. This provides additional options to CCG for an expanded intake and treatment plant, such as supplying water to neighboring communities, reducing WSSC purchases completely, or discontinuing withdrawals from poor quality wells.

However, Scenario 2 is not a final recommendation, because at this stage there remain substantial financial and engineering uncertainties for the water supply options. The County will be undertaking additional analyses to address many of these uncertainties. Further demands will continue to be monitored in order to compare with projections and project timing. Therefore, a roadmap was developed to identify the steps to be taken over the course of the program as the options are further refined by additional analyses. Refer to the Next Steps below.

As stated previously, there could potentially be a near-term supply deficit as a new surface water intake and treatment plant are brought on-line.[14] Additional water from WSSC via the existing connection and new confined aquifer wells were determined to be the best options to bridge the supply deficit. Further, if there were a major unforeseen obstacle that prevented the construction of a new Potomac River intake, a new connection to WSSC would be the next best option for CCG. As such, it is recommended that CCG continue negotiations with WSSC to confirm costs of additional supply and service reliability, as well as pursue the confined aquifer element of Scenario 5 to provide limited expansion of groundwater over the near-term to bridge any supply divide and ensure demands can be met prior to implementation of new long-term supplies.

[14] It is unclear how the on-going implementation of the Watershed Conservation District will affect growth and demand projections. Once fully implemented, demand projections should be re-evaluated to confirm timelines for needed additional supply capacity.

Table 12: Scenario 2 Upper Reaches Potomac River Supply

Source of Supply	Average Day Supply Mix (mgd)	Design Capacity (mgd)
Existing groundwater	6.2	9.33
Existing WSSC	0	1.42
Upper reaches Potomac River supply	5.0	10.0
Total	**11.2**	**20.75**

Next Steps

The Charles County Government Water Supply Roadmap shows the various steps and potential outcomes prior to initiating design of the new Potomac River supply and associated surface water treatment plant, as well as steps required for the exploration of additional supplies from WSSC and/or groundwater (Figure 26). The Potomac River Supply pathway is the dominant pathway for increased water supply availability, while updating demand projections, Additional Confined Aquifer Supply and Additional WSSC Supply pathways have the potential to impact the required timeline and capacity of the Potomac River supply.

In Figure 26, the baseline strategy is the anticipated pathway for each of the potential water supply options; however, alternative outcomes may arise, which would align CCG with the various off-ramps stemming from the baseline strategy. For example, while it is currently assumed that CCG will pursue a conventional surface water intake, riverbank filtration may prove to be feasible and beneficial with respect to water quality based on future field investigations and cost/benefit analyses. Therefore, riverbank filtration wells would be selected as the preferred alternative rather than a conventional surface water intake.

At the end of the Water Supply Roadmap, CCG will have determined the necessary implementation timeline and capacity of the new Potomac River water treatment plant. Subsequent tasks for the implementation of the new water treatment facility and associated finished water transmission to the existing CCG system are outlined in Figure 27 and Figure 28, as well as described in more detail as part of the implementation and Capital Improvement Plan schedule (CIP). Additional implementation steps and CIP elements are based on a baseline Scenario 2 path and do not account for any off-ramps or refinements that could occur during the Water Supply Roadmap.

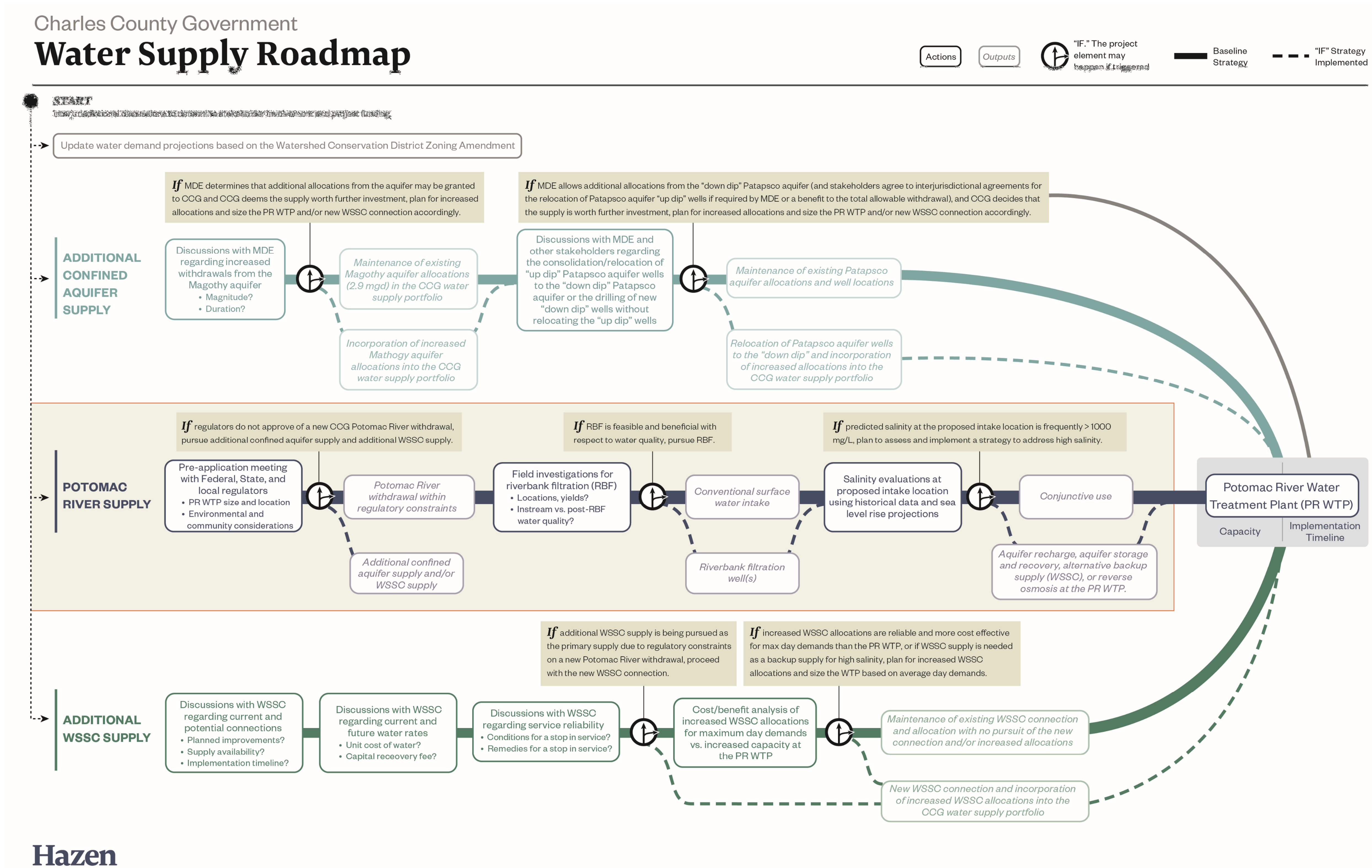


Figure 26: Charles County Roadmap for Increasing Water Supply Availability

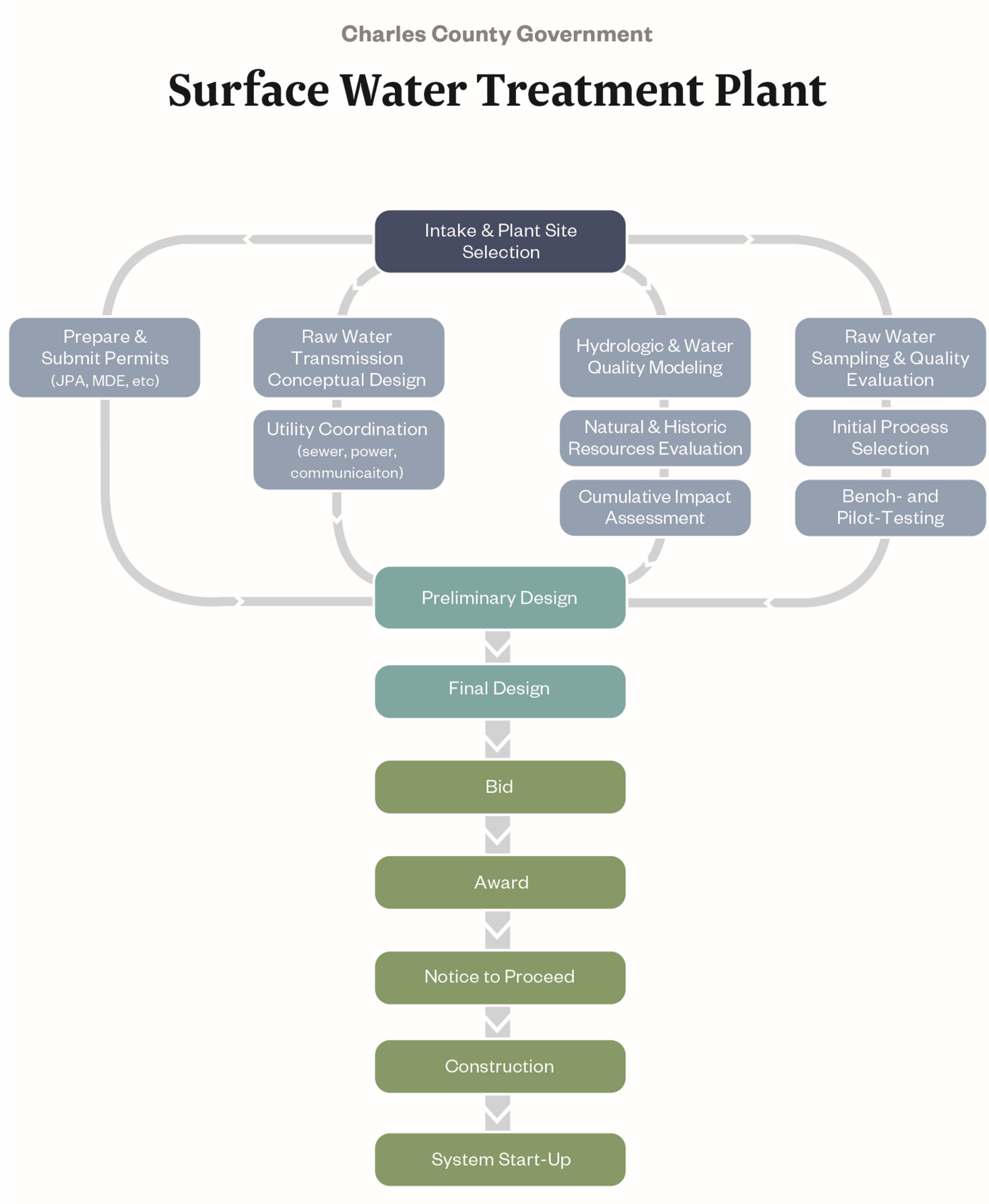


Figure 27: Tasks for Implementation of the Potomac River Supply and Treatment Facility (Scenario 2)

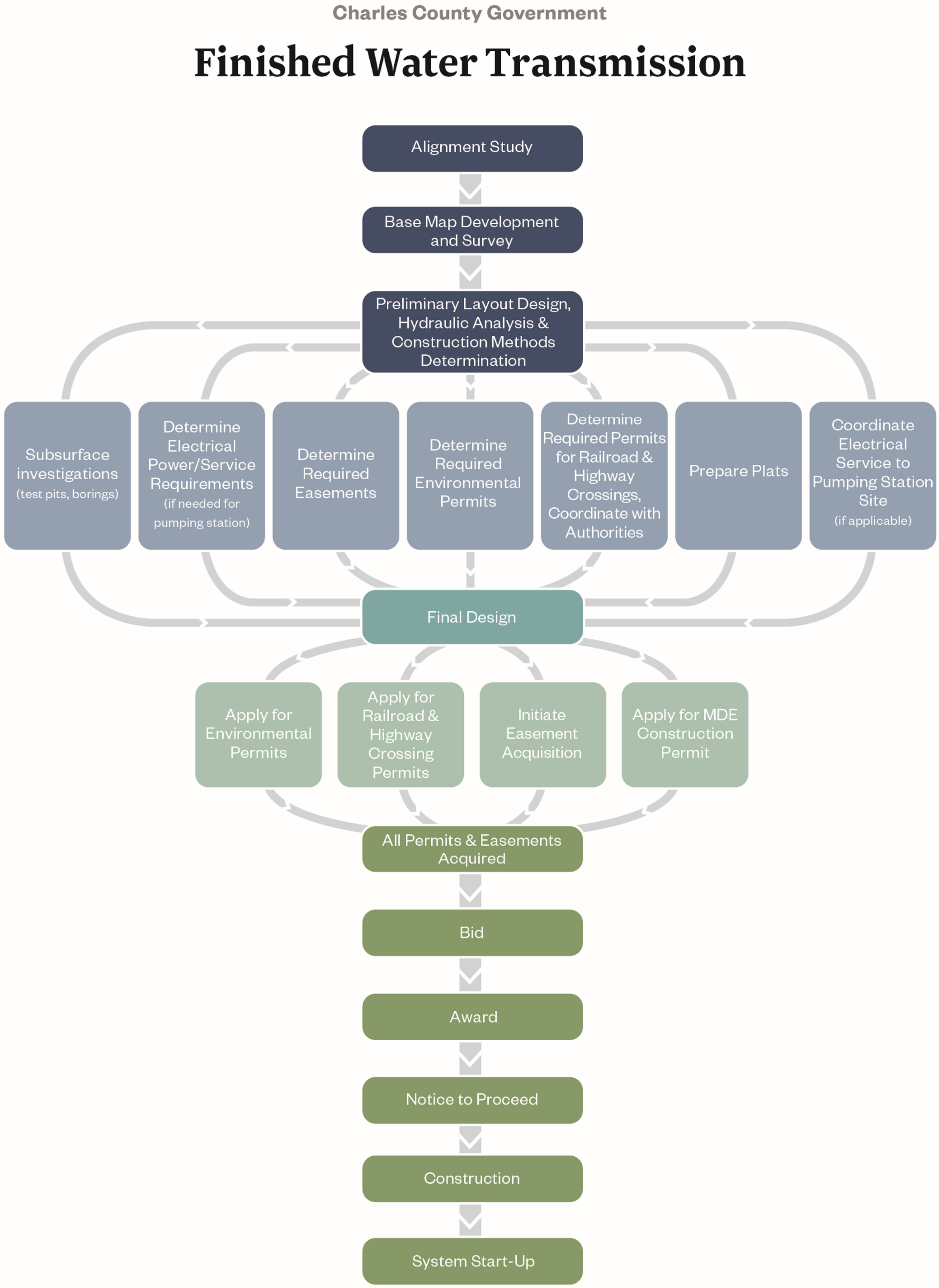


Figure 28: Tasks for Implementation of Finished Water Transmission from the Potomac River Supply and Treatment Facility (Scenario 2)

Preliminary Implementation Timeline and Cost Schedule

Preliminary Class 5 Estimates,[15] with an accuracy range of -30% to +50%, were prepared for the upfront planning, design, and implementation of water supply Scenario 2, a new surface water treatment plant along the upper reaches of the Potomac River and the associated transmission of finished water to the existing CCG system (Table 13). Preliminary cost estimates for Water Supply Scenario 2 (i.e., those presented in Appendix A) were further refined to more accurately reflect CCG methodologies for the derivation of program costs and to include the upfront actions required to ultimately construct a new surface water intake, treatment plant and transmission infrastructure.

Table 13: Class 5 Cost Estimates for the Implementation of Water Supply Scenario 2[a]

Maintenance of Existing Supplies				
	Engineering	**Administration**	**Construction**	**Total**
Greensand Filtration for Existing Groundwater Wells (9.3 mgd)	$1,210,000	$605,000	$12,100,000	$13,915,000
Surface Water Intake and Treatment Plant Planning				
	Engineering	**Administration**	**Construction**	**Total**
Pre-Application Meeting[b]	$30,000	$20,000	-	$50,000
Intake and Plant Site Selection	$200,000	-	-	$200,000
Raw Water Sampling and Quality Evaluation	$35,000	-	-	$35,000
Initial Process Selection	$30,000	-	-	$30,000
Bench- / Pilot-Testing	$1,000,000	-	$250,000	$1,250,000
Natural and Historic Resources Evaluation	$100,000			$100,000
Hydrologic and Water Quality Modeling	$200,000			$200,000
Cumulative Impact Assessment	$30,000	-	-	$30,000
Other Supporting Analyses	$80,000	-	-	$80,000
Prepare and Submit permits (JPA, MDE, etc.)	$120,000			$120,000
Finished Water Distribution Planning				
	Engineering	**Administration**	**Construction**	**Total**
Alignment Study	$300,000	$9,000	-	$309,000
Base map Development and Survey	$250,000	$7,500	-	$258,000

[15] American Association of Cost Engineering International Recommended Practice No. 18R-97 Cost Estimate Classification System–As Applied in Engineering, Procurement, and Construction for the Process Industries

Subsurface Investigations	$300,000	$9,000	-	$309,000
Surface Water Intake and Treatment Plant Implementation (10 mgd)				
	Engineering	**Administration**	**Construction**	**Total**
RFP/Award Engineering	-	$759,000	-	$759,000
Preliminary Design	$2,125,000	$797,000	-	$2,922,000
Determination of Required Easements and Permits	$152,000	-	-	
Final Design	$3,643,000	$1,480,000	-	$5,123,000
Acquisition of Required Easements and Permits	$152,000	-	-	
Bidding	$1,139,000	$759,000	-	$1,898,000
Construction	$7,590,000	$2,277,000	$75,900,000	$85,767,000
Finished Water Distribution Implementation (28,500 LF 18" DIP; 25,000 LF 24" DIP; 37,000 LF 30" DIP)				
	Engineering	**Administration**	**Construction**	**Total**
RFP/Award Engineering	-	$383,000	-	$383,000
Preliminary Design	$1,072,000	$402,000	-	$1,475,000
Determination of Required Easements and Permits	$77,000	$2,000	-	$79,000
Final Design of Improvements	$1,838,000	$747,000	-	$2,585,000
Acquisition of Required Easements and Permits	$77,000	$2,000	-	$78,898
Bidding	$574,000	$383,000		$958,000
Construction	$3,830,000	$1,149,000	$38,300,000	$43,279,000

[a] Scenario 2 cost estimates from Appendix A were further refined to more accurately reflect CCG methodologies for the derivation of program costs and to include the upfront actions required to ultimately construct a new surface water treatment plant and transmission.
[b] Pre-application Meeting with MDE and USACE may change critical assumptions affecting cost and schedule.

Using the cost estimates in Table 13 and estimated durations for each task, an implementation timeline and Capital Improvement Plan schedule were developed (Figure 29). The timeline shows that the overall program is estimated to span approximately eight years, resulting in Potomac River supply being brought on-line in 2026 assuming a program start date in early 2018. The overall estimated cost of the CCG Potomac River water supply program is $162 million.

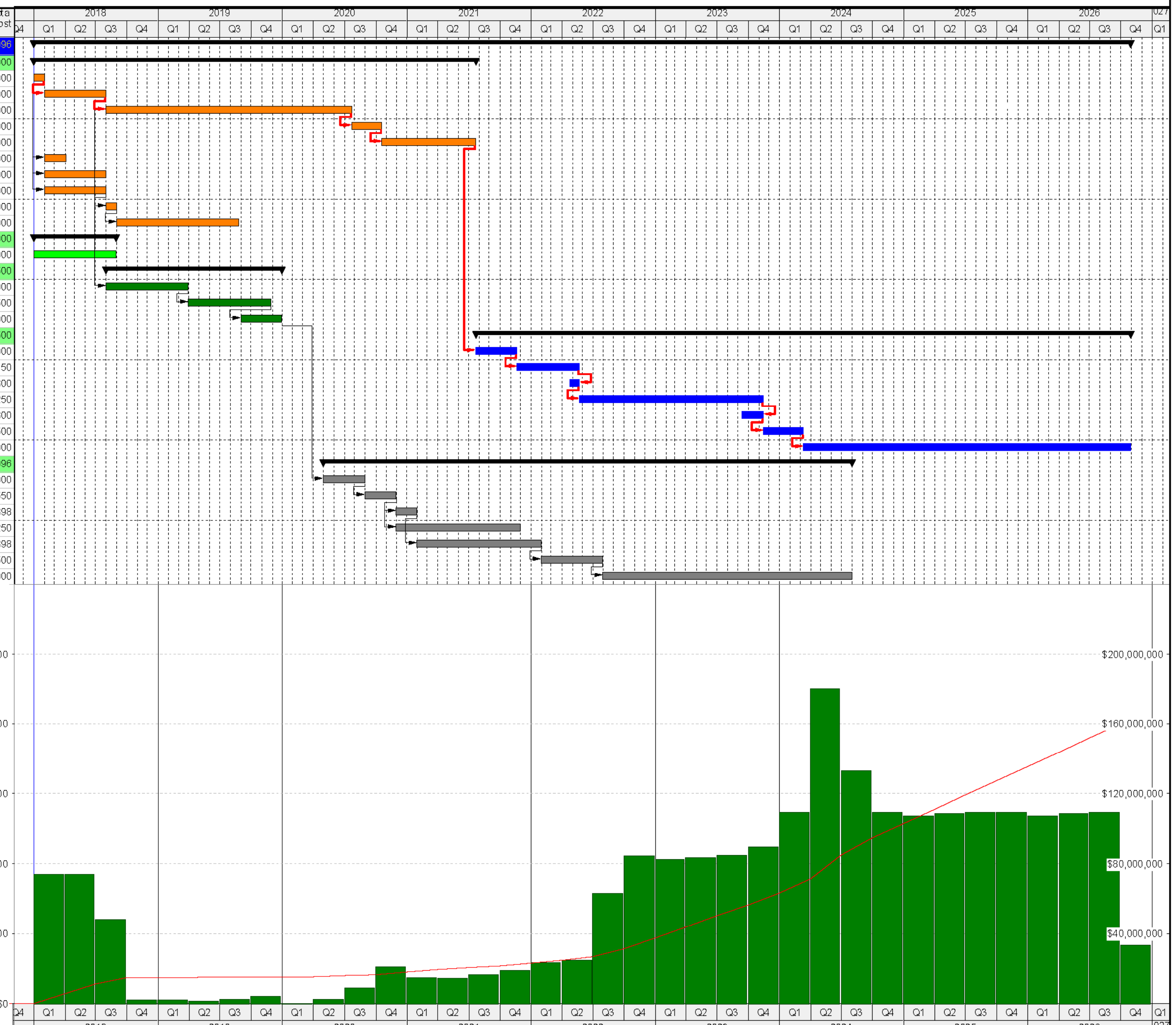
The first task, Maintenance of Existing Supplies, includes the addition of greensand filtration to the existing groundwater wells. Greensand filtration is anticipated to be required for continued use of the existing groundwater supply due to ongoing concerns related to iron and manganese contamination. The second group of tasks, Surface Water Intake and Treatment Plant Planning, represents the near-term regulatory and technical activities necessary to determine final design factors and permit requirements of a new surface water intake and treatment plant along the upper reaches of the Potomac River. This phase will include participation from multiple stakeholders, such as regulators, neighboring utilities, government agencies, and the public. Funding and time during this phase are primarily allocated to bench- and pilot-testing of proposed treatment processes for the new surface water supply, and the activities required to obtain permits from the primary regulators, MDE and the USACE, for an intake and water treatment plant.

The third group of tasks, Finished Water Distribution Planning, pertains to the upfront discussions and evaluations required for the delivery of finished water from the new surface water treatment plant to the existing CCG system. This second phase of work cannot begin until the intake and plant sites have been selected. The fourth and fifth groups of tasks pertain to the design and construction of the new surface water intake, treatment plant and finished water transmission. Tasks during these phases contribute significantly to the total duration and cost of the program.

The Water Supply Roadmap (Figure 26), task outlines (Figure 27 and Figure 28), and CIP schedule (Figure 29) provide CCG with a detailed, flexible pathway for increasing available water supply and meeting projected demands for many years in the future.

ESTIMATED CIP SCHEDULE FOR IMPLEMENTATION OF A NEW POTOMAC RIVER WATER SUPPLY AND ASSOCIATED TRANSMISSION INFRASTRUCTURE

Activity Name	Original Duration (Months)	Budgeted Total Cost
Est. CIP Schedule for Impl. of a New Potomac River Water Sup. and Assoc. Conv.	107	$162,495,096
Surface Water Treatment Plant Feasibility/Planning	43	$2,095,000
Pre-Application Meeting	1	$50,000
Intake and Plant Site Selection	6	$200,000
Raw Water Sampling and Quality Evaluation	24	$35,000
Initial Process Selection	3	$30,000
Bench- / Pilot-Testing	9	$1,250,000
Natural and Historic Resources Evaluation	2	$100,000
Hydrologic and water quality modeling	6	$200,000
Other supporting evaluations	6	$80,000
Cumulative Impact Assessment	1	$30,000
Prepare and Submit permits (JPA, MDE, etc.)	12	$120,000
Maintenance of Existing Water Supplies	8	$13,915,000
Greensand Filtration for Existing Groundwater Wells (9.3 mgd)	8	$13,915,000
Finished Water Distribution Feasibility/Planning	17	$875,500
Alignment Study	8	$309,000
Base Map Development and Survey	8	$257,500
Subsurface Investigations	4	$309,000
Surface Water Treatment Plant Implementation (10 mgd)	64	$96,772,500
RFP/Award Engineering	4	$759,000
Preliminary Design	6	$2,922,150
Determination of Required Easements and Permits	1	$151,800
Final Design	18	$5,123,250
Acquisition of Required Easements and Permits	2	$151,800
Bidding	4	$1,897,500
Construction	32	$85,767,000
Finished Water Distribution Implementation	52	$48,837,096
RFP/Award Engineering	4	$383,000
Preliminary Design	3	$1,474,550
Determination of Required Easements and Permits	2	$78,898
Final Design of Improvements	12	$2,585,250
Acquisition of Required Easements and Permits	12	$78,898
Bidding	6	$957,500
Construction	24	$43,279,000



FW IMP | FW PLAN | SW PLAN | MW PLAN | SW IMP | summary

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Print Date: 10-19-17
Data Date: 01-01-18

Figure 29: Estimated CIP Schedule and Implementation Timeline for a New Potomac River Water Supply and Transmission Infrastructure

Appendix A Conceptual Cost Estimates for Scenarios

The following text and tables provide background information on the scenario cost estimates presented in this report.

Cost Estimate Assumptions

All Scenarios

- Capital and O&M costs are American Association of Cost Engineering (Christensen & Dysert, 2005) Class 5 Estimates, with an accuracy range of -30% to +50%.
    - Christensen, P., & Dysert, L. R. (2005). AACE International Recommended Practice No. 18R-97 Cost Estimate Classification System–As Applied in Engineering, Procurement, and Construction for the Process Industries (TCM Framework: 7.3–Cost Estimating and Budgeting). AACE.
- Refer to capital cost detail section below for inclusions for the capital cost estimates.
- O&M costs for treatment processes are based on the references listed below and include media replacements, labor, chemicals, residuals handling, electricity, lab and field analysis, and equipment maintenance.
    - Plumlee, M. H., Stanford, B. D., Debroux, J. F., Hopkins, D. C., & Snyder, S. A. (2014). Costs of advanced treatment in water reclamation. *Ozone: Science & Engineering*, 36(5), 485-495.
    - U.S. Environmental Protection Agency. (2005). Technologies and Costs Document for the Final Long-term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule.
- All costs escalated to present values based on the Engineering News Record Construction Cost Index.
- Existing groundwater allocations for average day and month of maximum use remain unchanged and are included as part of each scenario.
- Pump efficiency is 75%. Pumping costs are based on average pump heads based on average aquifer levels and system HGL.
- Energy cost assumes 12 hour per day operation of pumps at $0.10/kW-hr.
- The 30-year present worth estimate is based on average day demands. No estimate is factored into the 30-year present worth for occasional max day demand costs.
- Average day supply values are approximate, distribution system hydraulics will affect actual contribution from each supply.

WSSC Supply Cost Estimate

- Waldorf HGL is 370 feet. Existing WSSC Connection HGL is 240 feet. Proposed WSSC connection HGL is 335 feet. Estimate includes pumping from WSSC HGL to Waldorf HGL.
- A pressure drop of 5 psi was assumed for WSSC GAC treatment system.
- Scenarios 3, 4, and 5 use WSSC connections solely for max day demands and as a backup supply. GAC treatment is not included for these scenarios.
- Scenario 1 uses WSSC connections for average day demands, max day demands, and as a backup supply. GAC treatment for DBP removal is only included at the proposed new WSSC connection site.

IPR Supply Cost Estimate

- IPR Assumes 6 mgd of injected reclaimed wastewater to augment the Patapsco aquifer.
- Assumes an 80% recovery on injected water to allow 5 mgd expansion of the Patapsco well system.
- IPR requires injection at the 6 mgd rate all year regardless of demand level

Upper Potomac River Supply Cost Estimate

- The Upper Potomac River Supply option would include either a Potomac River intake or riverbank filtration based on the results of subsequent water quality monitoring and pump tests.
- Treatment costs and transmission needs for a direct intake or a riverbank filtration system are similar enough to make these options interchangeable at this stage.

Groundwater Well Cost Estimate

- Costs for treatment (e.g. gross alpha, iron or other parameters) for new or existing confined aquifer groundwater supplies are not included in the cost estimates.
- Pump head for deep well aquifers is 350 feet below ground surface, for surficial well aquifer pump head is 50 feet below ground surface.
- Expanded groundwater options assume new wells.

Transmission Infrastructure Cost Estimate

- A skeletal model was built by using EPANET software. A Hazen-Williams friction factor of 120 was used in the model.
- Maximum day demand of 19.95 mgd for 2045 was distributed at demand nodes of the skeletal model to size pipelines.

- The hydraulics maintain a minimum pressure of 40 psi at maximum day demand at the lowest demand node elevation.
- Assuming a 35 feet operating range for elevated tanks, this corresponds to minimum pressure of 25 psi at minimum tank level.
- Node Elevations taken from Google Earth. Pipe lengths measured from Google Earth and approximated.
- Only indicated elevated tanks were included in the model. Well pumps were not included in the model.

Cost Estimate Summary

Charles County - Water Source Feasibility Study
Water Treatment and Transmission Cost Summary
Average Day Demands

Scenario 1: 10 mgd capacity from WSSC												
Water Source	Amount Supplied			Pump TDH	Pump BHP	Yearly Energy Cost for transmission pumping	Treatment O&M Costs	Water Purchase Costs	Total Annual Costs	Treatment/Well Capital Costs	Transmission Capital Costs	Total Capital Costs
	(gpm)	(%)	(MGD)	(ft)	(HP)	($)					($)	($)
Existing WSSC	0	0.0%	0.0	113	1	$0	$0	$0	$0	$0		
Proposed WSSC	3,472	44.5%	5.0	81	95	$31,041	$195,979	$6,591,900	$6,818,920	$9,000,000		
Groundwater	4,333	55.5%	6.2	720	1051	$343,412	$327,562	$0	$670,974	$12,090,840		
Surface WTP	0	0.0%	0.0	0	0	$0	$0	$0	$0	$0		
Surficial Aquifer	0	0.0%	0.0	0	0	$0	$0	$0	$0	$0		
Total	7,805	100.0%	11.2	914	1,147	$374,453	$523,541	$6,591,900	$7,489,894	$21,090,840	$17,863,000	$38,953,840

Scenario 2: 10 mgd capacity from upper reaches Potomac River WTP												
Water Source	Amount Supplied			Pump TDH	Pump BHP	Yearly Energy Cost	Treatment O&M Costs	Water Purchase Costs	Total Annual Costs	Treatment/Well Capital Costs	Transmission Capital Costs	Total Capital Costs
	(gpm)	(%)	(MGD)	(ft)	(HP)	($)					($)	($)
Existing WSSC	0	0.0%	0.0	150	1	$0	$0	$0	$0	$0		
Proposed WSSC	0	0.0%	0.0	0	0	$0	$0	$0	$0	$0		
Groundwater	4,333	55.5%	6.2	720	1051	$343,412	$327,562	$0	$670,974	$12,090,840		
Surface WTP	3,472	44.5%	5.0	355	416	$135,927	$547,935	$0	$683,862	$89,300,000		
Surficial Aquifer	0	0.0%	0.0	0	0	$0	$0	$0	$0	$0		
Total	7,805	100.0%	11.2	1,225	1,468	$479,339	$875,497	$0	$1,354,836	$101,390,840	$38,274,000	$139,664,840

Scenario 3: 5 mgd capacity from upper reaches Potomac River WTP and 5 mgd capacity from WSSC												
Water Source	Amount Supplied			Pump TDH	Pump BHP	Yearly Energy Cost	Treatment O&M Costs	Water Purchase Costs	Total Annual Costs	Treatment/Well Capital Costs	Transmission Capital Costs	Total Capital Costs
	(gpm)	(%)	(MGD)	(ft)	(HP)	($)					($)	($)
Existing WSSC	0	0.0%	0.0	123	1	$0	$0	$0	$0	$0		
Proposed WSSC	0	0.0%	0.0	55	1	$0	$0	$0	$0	$0		
Groundwater	4,333	55.5%	6.2	720	1051	$343,412	$327,562	$0	$670,974	$12,090,840		
Surface WTP	3,472	44.5%	5.0	405	474	$154,879	$547,935	$0	$702,813	$57,000,000		
Surficial Aquifer	0	0.0%	0.0	0	0	$0	$0	$0	$0	$0		
Total	7,805	100.0%	11.2	1,303	1,527	$498,291	$875,497	$0	$1,373,787	$69,090,840	$28,992,000	$98,082,840

Scenario 4: 5 mgd of add'l groundwater from IPR aquifer recharge and 5 mgd capacity from WSSC												
Water Source	Amount Supplied			Pump TDH	Pump BHP	Yearly Energy Cost	Treatment O&M Costs	Water Purchase Costs	Total Annual Costs	Treatment/Well Capital Costs	Transmission Capital Costs	Total Capital Costs
	(gpm)	(%)	(MGD)	(ft)	(HP)	($)					($)	($)
Existing WSSC	0	0.0%	0.0	104	1	$0	$0	$0	$0	$0		
Proposed WSSC	0	0.0%	0.0	53	0	$0	$0	$0	$0	$0		
Groundwater	7,805	100.0%	11.2	720	1893	$618,534	$590,035	$0	$1,208,569	$27,570,390		
Surface WTP	0	0.0%	0.0	386	1	$0	$0	$0	$0	$0		
Reuse Treatment	0	0.0%	0.0	0	1	$0	$1,225,287	$0	$1,225,287	$82,300,000		
Surficial Aquifer	0	0.0%	0.0	304	1	$0	$0	$0	$0	$0		
Total	7,805	100.0%	11.2	1,567	1,897	$618,534	$1,815,322	$0	$2,433,856	$109,870,390	$15,897,000	$125,767,390

Scenario 5: 5 mgd of add'l groundwater (surficial and confined aquifers) and 5 mgd capacity from WSSC												
Water Source	Amount Supplied			Pump TDH	Pump BHP	Yearly Energy Cost	Treatment O&M Costs	Water Purchase Costs	Total Annual Costs	Treatment/Well Capital Costs	Transmission Capital Costs	Total Capital Costs
	(gpm)	(%)	(MGD)	(ft)	(HP)	($)					($)	($)
Existing WSSC	0	0.0%	0.0	138	1	$0	$0	$0	$0	$0		
Proposed WSSC	0	0.0%	0.0	55	1	$0	$0	$0	$0	$0		
Groundwater	6,068	77.8%	8.7	720	1472	$480,973	$458,723	$0	$939,696	$20,230,615		
Surface WTP	0	0.0%	0.0	0	0	$0	$0	$0	$0	$0		
Surficial Aquifer w/ ASR	1,735	22.2%	2.5	223	131	$42,804	$271,263	$0	$314,066	$26,100,000		
Total	7,803	100.0%	11.2	1,136	1,605	$523,777	$729,985	$0	$1,253,762	$46,330,615	$14,946,000	$61,276,615

Treatment Capital Cost Detail Tables

Greensand Filtration Capital Cost Detail for Existing Groundwater Supplies

Process	Unit	Unit Cost ($)	Quantity	Cost Estimate
Decentralized Greensand Filtration Systems	MGD	0.50	9.33	$4,618,350
Subtotal process costs	***Process Subtotal***			**$4,618,350**
Ancillary Systems / Other Processes				
Chemical Feed and Storage (Chlorine)	As % of Process Subtotal		15%	$692,753
Yard Piping	As % of Process Subtotal		10%	$461,835
Sitework/Landscaping	As % of Process Subtotal		5%	$230,918
Electrical and I&C	As % of Process Subtotal		20%	$923,670
Constructability (geotech, environmental, permitting, etc.)	As % of Process Subtotal		5%	$230,918
	Subtotal 1			**$7,158,443**
Contingencies	As % of Subtotal 1		25%	$1,789,611
	Subtotal 2			**$8,948,053**
Contractor OH / Profit	As % of Subtotal 2		15%	$1,342,208
TOTAL ESTIMATED CONSTRUCTION COST				$10,290,261
Land Purchase	Lump Sum			
Engineering, Permitting, Legal, and Admin Costs	As % of Total Estimated Construction Cost		18%	$1,852,247
	TOTAL ESTIMATED COST (rounded)			**$12,100,000**

Surficial Groundwater Treatment Capital Cost Detail

Process	Unit	Unit Cost ($)	Quantity	Cost Estimate
Wells	MGD	0.6	2.5	$1,500,000
Raw Water Pumping	MGD	0.3	2.5	$750,000
Raw Water Transmission Piping	LF	150	2,000	$300,000
Microfiltration	MGD	1.3	2.5	$3,250,000
Clearwells	MG	1.0	0.6	$600,000
Finished Water Pumps	MGD	0.15	2.5	$375,000
ASR Injection Wells	Each	500,000	4	$2,000,000
Subtotal process costs	***Process Subtotal***			**$8,775,000**
Ancillary Systems / Other Processes				
Chemical Feed and Storage (All Chemical Systems)	As % of Process Subtotal		15%	$1,316,250
Residuals Handling (Solids Storage and Sewer Discharge)	As % of Process Subtotal		5%	$438,750
HVAC/Mechanical	As % of Process Subtotal		5%	$438,750
Yard Piping	As % of Process Subtotal		10%	$877,500
Sitework/Landscaping	As % of Process Subtotal		5%	$438,750
Electrical and I&C	As % of Process Subtotal		20%	$1,755,000
Constructability (geotech, environmental, permitting, etc.)	As % of Process Subtotal		5%	$438,750
	Subtotal 1			$14,478,750
Contingencies	As % of Subtotal 1		25%	$3,619,688
	Subtotal 2			$18,098,438
Contractor OH / Profit	As % of Subtotal 2		15%	$2,714,766
	TOTAL ESTIMATED CONSTRUCTION COST			$20,813,203
Land Purchase	Lump Sum			$1,500,000
Engineering, Permitting, Legal, and Admin Costs	As % of Total Estimated Construction Cost		18.00%	$3,746,377
	TOTAL ESTIMATED COST (rounded)			**$26,100,000**

References

Costs based on Water Treatment Plants Capacity and Siting Study May 2013 Summary of Technical Memoranda for Metro Water Services, Nashville TN developed by Hazen and Sawyer unless otherwise noted

EPA Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule, document 815-R-05-013 dated 2005

Plumlee, M. H., Stanford, B. D., Debroux, J. F., Hopkins, D. C., & Snyder, S. A. (2014). Costs of advanced treatment in water reclamation. *Ozone: Science & Engineering* , *36* (5), 485-495.

Note that contingecies and OH&P removed from all estimates to avoid double counting and all costs escalated to 2016 values per ENR CCI

Upper Reaches Potomac River Intake Water Treatment Plant Capital Cost Detail

Process	Unit	Unit Cost ($)	Quantity	Quantity	Cost Estimate (10 mgd)	Cost Estimate (5 mgd)
Raw Water Intake	MGD	0.5	10	5	$5,000,000	$2,500,000
Raw Water Pumping	MGD	0.3	10	5	$3,000,000	$1,500,000
Raw Water Transmission Piping	LF	150	2,000	2,000	$300,000	$300,000
Rapid Mix	Gallon	25	4,500	3,500	$112,500	$87,500
Flocculation	MG	5	0.3	0.2	$1,500,000	$1,000,000
Sedimentation	SF	180	5,500	3,000	$990,000	$540,000
Filtration (Ozone/BAC)	MGD	varies per cost curve	10	5	$11,400,000	$8,200,000
GAC (EBCT = 10 minutes, 360 day reactivation frequency)	MGD	varies per cost curve	10	5	$4,600,000	$3,100,000
UV (40 mJ/cm2)	MGD	varies per cost curve	10	5	$900,000	$600,000
Clearwells	MG	1.0	1.6	0.8	$1,600,000	$800,000
Finished Water Pumping	MGD	0.15	10	5	$1,500,000	$750,000
Subtotal process costs	***Process Subtotal***				**$30,902,500**	**$19,377,500**
Ancillary Systems / Other Processes						
Chemical Feed and Storage (All Chemical Systems)	As % of Process Subtotal		15%	15%	$4,635,375	$2,906,625
Residuals Handling (Solids Storage and Sewer Discharge)	As % of Process Subtotal		5%	5%	$1,545,125	$968,875
HVAC/Mechanical	As % of Process Subtotal		5%	5%	$1,545,125	$968,875
Admin/Lab Facilities	Lump Sum		1	1	$750,000	$750,000
Yard Piping	As % of Process Subtotal		10%	10%	$3,090,250	$1,937,750
Sitework/Landscaping	As % of Process Subtotal		5%	5%	$1,545,125	$968,875
Electrical and I&C	As % of Process Subtotal		20%	20%	$6,180,500	$3,875,500
Constructability (geotech, environmental, permitting, etc.)	As % of Process Subtotal		5%	5%	$1,545,125	$968,875
	Subtotal 1				$51,739,125	$32,722,875
Contingencies	As % of Subtotal 1		25%	25%	$12,934,781	$8,180,719
	Subtotal 2				$64,673,906	$40,903,594
Contractor OH / Profit	As % of Subtotal 2		15%	15%	$9,701,086	$6,135,539
TOTAL ESTIMATED CONSTRUCTION COST					$74,374,992	$47,039,133
Land Purchase	Lump Sum				$1,499,999	$1,500,000
Engineering, Permitting, Legal, and Admin Costs	As % of Total Estimated Construction Cost		18.00%	18.00%	$13,387,499	$8,467,044
	TOTAL ESTIMATED COST (rounded)				**$89,300,000**	**$57,000,000**

References

Costs based on Water Treatment Plants Capacity and Siting Study May 2013 Summary of Technical Memoranda for Metro Water Services, Nashville TN developed by Hazen and Sawyer unless otherwise noted

EPA Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule, document 815-R-05-013 dated 2005

Plumlee, M. H., Stanford, B. D., Debroux, J. F., Hopkins, D. C., & Snyder, S. A. (2014). Costs of advanced treatment in water reclamation. *Ozone: Science & Engineering* , *36* (5), 485-495.

Note that contingecies and OH&P removed from all estimates to avoid double counting and all costs escalated to 2016 values per ENR CCI

Upper Reaches Potomac River Riverbank Filtration Water Treatment Plant Capital Cost Detail

Process	Unit	Unit Cost ($)	Quantity	Quantity	Cost Estimate (10 mgd)	Cost Estimate (5 mgd)
RBF Wells	MGD	0.6	10	5	$6,000,000	$3,000,000
Raw Water Pumping	MGD	0.3	10	5	$3,000,000	$1,500,000
Raw Water Transmission Piping	LF	150	4,000	4,000	$600,000	$600,000
Filtration (Ozone/BAC)	MGD	varies per cost curve	10	5	$11,400,000	$8,200,000
GAC (EBCT = 10 minutes, 360 day reactivation frequency)	MGD	varies per cost curve	10	5	$4,600,000	$3,100,000
UV (40 mJ/cm2)	MGD	varies per cost curve	10	5	$900,000	$600,000
Clearwells	MG	1.0	1.6	0.8	$1,600,000	$800,000
Finished Water Pumps	MGD	0.15	10	5	$1,500,000	$750,000
Subtotal process costs	***Process Subtotal***				**$29,600,000**	**$18,550,000**
Ancillary Systems / Other Processes						
Chemical Feed and Storage (All Chemical Systems)	As % of Process Subtotal		15%	15%	$4,440,000	$2,782,500
Residuals Handling (Solids Storage and Sewer Discharge)	As % of Process Subtotal		5%	5%	$1,480,000	$927,500
HVAC/Mechanical	As % of Process Subtotal		5%	5%	$1,480,000	$927,500
Admin/Lab Facilities	Lump Sum		1	1	$750,000	$750,000
Yard Piping	As % of Process Subtotal		10%	10%	$2,960,000	$1,855,000
Sitework/Landscaping	As % of Process Subtotal		5%	5%	$1,480,000	$927,500
Electrical and I&C	As % of Process Subtotal		20%	20%	$5,920,000	$3,710,000
Constructability (geotech, environmental, permitting, etc.)	As % of Process Subtotal		5%	5%	$1,480,000	$927,500
	Subtotal 1				$49,590,000	$31,357,500
Contingencies	As % of Subtotal 1		25%	25%	$12,397,500	$7,839,375
	Subtotal 2				$61,987,500	$39,196,875
Contractor OH / Profit	As % of Subtotal 2		15%	15%	$9,298,125	$5,879,531
TOTAL ESTIMATED CONSTRUCTION COST					$71,285,625	$45,076,406
Land Purchase	Lump Sum				$1,500,000	$1,500,001
Engineering, Permitting, Legal, and Admin	As % of Total Estimated Construction Cost		18%	18%	$12,831,413	$8,113,753
	TOTAL ESTIMATED COST (rounded)				**$85,600,000**	**$54,700,000**

References

Costs based on Water Treatment Plants Capacity and Siting Study May 2013 Summary of Technical Memoranda for Metro Water Services, Nashville TN developed by Hazen and Sawyer unless otherwise noted

EPA Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule, document 815-R-05-013 dated 2005

Plumlee, M. H., Stanford, B. D., Debroux, J. F., Hopkins, D. C., & Snyder, S. A. (2014). Costs of advanced treatment in water reclamation. *Ozone: Science & Engineering* , *36* (5), 485-495.

Note that contingecies and OH&P removed from all estimates to avoid double counting and all costs escalated to 2016 values per ENR CCI

Indirect Potable Reuse (IPR) Treatment for Aquifer Recharge Capital Cost Detail

Process	**Unit**	**Unit Cost ($)**	**Quantity**	**Cost Estimate**
Raw Water Pumping	MGD	0.15	6	$900,000
Filtration (Ozone/BAC)	MGD	1.5	6	$9,000,000
GAC (EBCT = 10 minutes, 360 day reactivation frequency)	MGD	0.57	6	$3,400,000
Ultrafiltration	MGD	1.3	6	$7,800,000
UV (40 mJ/cm2)	MGD	0.1	6	$600,000
Clearwells	MG	1.0	0.8	$800,000
Finished Water Pumping	MGD	0.15	6	$900,000
Injection Wells	Each	500,000	10	5,000,000
Subtotal process costs	***Process Subtotal***			**$28,400,000**
Ancillary Systems / Other Processes				
Chemical Feed and Storage (All Chemical Systems)	As % of Process Subtotal		15%	$4,260,000
Residuals Handling (Solids Storage and Sewer Discharge)	As % of Process Subtotal		5%	$1,420,000
HVAC/Mechanical	As % of Process Subtotal		5%	$1,420,000
Admin/Lab Facilities	Lump Sum		1	$750,000
Yard Piping	As % of Process Subtotal		10%	$2,840,000
Sitework/Landscaping	As % of Process Subtotal		5%	$1,420,000
Electrical and I&C	As % of Process Subtotal		20%	$5,680,000
Constructability (geotech, environmental, permitting, etc.)	As % of Process Subtotal		5%	$1,420,000
	Subtotal 1			$47,610,000
Contingencies	As % of Subtotal 1		25%	$11,902,500
	Subtotal 2			$59,512,500
Contractor OH / Profit	As % of Subtotal 2		15%	$8,926,875
	TOTAL ESTIMATED CONSTRUCTION COST			$68,439,375
Land Purchase	Lump Sum			$1,500,000
Engineering, Permitting, Legal, and Admin Costs	As % of Total Estimated Construction Cost		18%	$12,319,088
	TOTAL ESTIMATED COST (rounded)			**$82,300,000**

References

Costs based on Water Treatment Plants Capacity and Siting Study May 2013 Summary of Technical Memoranda for Metro Water Services, Nashville TN developed by Hazen and Sawyer unless otherwise noted

EPA Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule, document 815-R-05-013 dated 2005

Plumlee, M. H., Stanford, B. D., Debroux, J. F., Hopkins, D. C., & Snyder, S. A. (2014). Costs of advanced treatment in water reclamation. *Ozone: Science & Engineering* , *36* (5), 485-495.

Note that contingecies and OH&P removed from all estimates to avoid double counting and all costs escalated to 2016 values per ENR CCI

WSSC Connection Treatment (Future) Capital Cost Detail

Process	Unit	Unit Cost ($)	Quantity	Cost Estimate
Pressurized GAC for DBP removal	MGD	0.42	5	$2,100,000
Finished Water Pumping	MGD	0.15	5	$750,000
Subtotal process costs	***Process Subtotal***			**$2,850,000**
Ancillary Systems / Other Processes				
Chemical Feed and Storage (Chlorine)	As % of Process Subtotal		15%	$427,500
Yard Piping	As % of Process Subtotal		10%	$285,000
Sitework/Landscaping	As % of Process Subtotal		5%	$142,500
Electrical and I&C	As % of Process Subtotal		20%	$570,000
Constructability (geotech, environmental, permitting, etc.)	As % of Process Subtotal		5%	$142,500
	Subtotal 1			**$4,417,500**
Contingencies	As % of Subtotal 1		25%	$1,104,375
	Subtotal 2			**$5,521,875**
Contractor OH / Profit	As % of Subtotal 2		15%	$828,281
	TOTAL ESTIMATED CONSTRUCTION COST			$6,350,156
Land Purchase	Lump Sum			$1,500,000
Engineering, Permitting, Legal, and Admin Costs	As % of Total Estimated Construction Cost		18%	$1,143,028
	TOTAL ESTIMATED COST (rounded)			**$9,000,000**

Well Construction Capital Cost Detail Tables

Injection Well Capital Cost Detail

Item Description	Estimated Quantity	Units	Unit Price	Total Amount
Mobilization/Demobilization	1	LS	$60,000	$60,000
Test boring & Formation Sampling	1400	LF	$25	$35,000
Geophysical Logging	1	LS	$3,000	$3,000
Test Boring Backfill/Sealing	200	LF	$25	$5,000
Monitoring Well Construction	1000	LF	$25	$25,000
Monitoring Well Completion	1	LS	$1,500	$1,500
Furnish/Install Surface Casing	20	LF	$280	$5,600
14-inch Drilling	1200	LF	$50	$60,000
Furnish/Install 10-inch Well Screen	200	LF	$280	$56,000
Furnish/Install 10-inch Screen Blank	200	LF	$75	$15,000
Furnish/Install 10-inch Well Casing	1200	LF	$50	$60,000
Well Development	200	HR	$325	$65,000
Furnish/Install/Remove Test Pump	1	LS	$5,000	$5,000
Pump/Generator Rental (Step Test/48-hr Test)	1	LS	$3,500	$3,500
48-Hr Test Discharge Hose install/removal	1	LS	$40,000	$40,000
Well Disinfection	1	LS	$1,500	$1,500
Constant Rate Test Monitoring	48	HR	$150	$7,200
Pump Purchase and Installation	1	LS	$25,000	$25,000
Wellhead Completion	1	LS	$15,000	$15,000
As-Built Records/Well Completion Report	1	LS	$150	$150
	Calculated Total Amount per Well			**$500,000**

Magothy Aquifer Well Capital Cost Detail

Item Description	Estimated Quantity	Units	Unit Price	Total Amount
Mobilization/Demobilization	1	LS	$59,597	$59,597
Test boring & Formation Sampling	600	LF	$25	$14,766
Geophysical Logging	1	LS	$2,998	$2,998
Test Boring Backfill/Sealing	100	LF	$25	$2,453
Monitoring Well Construction	500	LF	$22	$10,765
Monitoring Well Completion	1	LS	$1,350	$1,350
Furnish/Install Surface Casing	20	LF	$262	$5,235
14-inch Drilling	585	LF	$48	$27,852
Furnish/Install 10-inch Well Screen	100	LF	$269	$26,949
Furnish/Install 10-inch Screen Blank	100	LF	$65	$6,527
Furnish/Install 10-inch Well Casing	400	LF	$48	$19,364
Well Development	50	HR	$316	$15,790
Furnish/Install/Remove Test Pump	1	LS	$4,641	$4,641
Pump/Generator Rental (Step Test/48-hr Test)	1	LS	$3,240	$3,240
48-Hr Test Discharge Hose install/removal	1	LS	$37,395	$37,395
Well Disinfection	1	LS	$1,490	$1,490
Constant Rate Test Monitoring	48	HR	$141	$6,782
Pump Purchase and Installation	1	LS	$23,338	$23,338
Wellhead Completion	1	LS	$12,960	$12,960
As-Built Records/Well Completion Report	1	LS	$150	$150
Well Abandonment, Well 1 and Well 2	2	LS	$8,150	$16,300
	Calculated Total Amount per Well			**$300,000**
Ancillary Systems / Other Processes				
Chemical Feed and Storage (All Chemical Systems)	As % of Process Subtotal	15%		$45,000
Sitework/Landscaping	As % of Process Subtotal	5%		$15,000
Electrical and I&C	As % of Process Subtotal	20%		$60,000
Constructability (geotech, environmental, permitting, etc.)	As % of Process Subtotal	5%		$15,000
	Subtotal 1			$ 435,000.00
Contingencies	As % of Subtotal 1	25%		$108,750.00
	Subtotal 2			$543,750
Contractor OH / Profit	As % of Subtotal 2	15%		$81,562.50
	TOTAL ESTIMATED CONSTRUCTION COST			$625,313
Land Purchase	Lump Sum			$75,000
Engineering, Permitting, Legal, and Admin Costs	As % of Total Estimated Construction Cost	18%		$112,556.25
	TOTAL ESTIMATED COST (rounded)			**$800,000**

Patapsco Aquifer Well Capital Cost Detail

Item Description	Estimated Quantity	Units	Unit Price	Total Amount	
Mobilization/Demobilization	1	LS	$60,000	$60,000	
Test boring & Formation Sampling	1400	LF	$25	$35,000	
Geophysical Logging	1	LS	$6,000	$6,000	
Test Boring Backfill/Sealing	200	LF	$25	$5,000	
Monitoring Well Construction	1000	LF	$25	$25,000	
Monitoring Well Completion	1	LS	$3,000	$3,000	
Furnish/Install Surface Casing	20	LF	$280	$5,600	
14-inch Drilling	1200	LF	$50	$60,000	
Furnish/Install 10-inch Well Screen	200	LF	$280	$56,000	
Furnish/Install 10-inch Screen Blank	200	LF	$75	$15,000	
Furnish/Install 10-inch Well Casing	1200	LF	$50	$60,000	
Well Development	200	HR	$325	$65,000	
Furnish/Install/Remove Test Pump	1	LS	$10,000	$10,000	
Pump/Generator Rental (Step Test/48-hr Test)	1	LS	$7,000	$7,000	
48-Hr Test Discharge Hose install/removal	1	LS	$40,000	$40,000	
Well Disinfection	1	LS	$3,000	$3,000	
Constant Rate Test Monitoring	48	HR	$300	$14,400	
Pump Purchase and Installation	1	LS	$50,000	$50,000	
Wellhead Completion	1	LS	$30,000	$30,000	
As-Built Records/Well Completion Report	1	LS	$300	$300	
	Calculated Total Amount per Well			**$550,300**	
				2 mgd capacity	5 mgd capacity
			subtotal	**$1,650,900**	**$4,402,400**
Ancillary Systems / Other Processes					
Chemical Feed and Storage (All Chemical Systems)	As % of Process Subtotal	15%		$247,635	$660,360
Sitework/Landscaping	As % of Process Subtotal	5%		$82,545	$220,120
Electrical and I&C	As % of Process Subtotal	20%		$330,180	$880,480
Constructability (geotech, environmental, permitting, etc.)	As % of Process Subtotal	5%		$82,545	$220,120
	Subtotal 1			$2,393,805	$6,383,480
Contingencies	As % of Subtotal 1	25%		$598,451	$1,100,600
	Subtotal 2			$2,992,256	$7,484,080
Contractor OH / Profit	As % of Subtotal 2	15%		$448,838	$660,360
TOTAL ESTIMATED CONSTRUCTION COST				$3,441,095	$8,144,440
Land Purchase	Lump Sum			$75,000	$75,000
Engineering, Permitting, Legal, and Admin Costs	As % of Total Estimated Construction Cost	18%		$619,397	$792,432
	TOTAL ESTIMATED COST (rounded)			**$4,100,000**	**$9,000,000**

Transmission Capital Cost Detail Tables

PROJECT: Charles County - Water Source Feasibility Study	HAZEN AND SAWYER
ALTERNATIVE: Scenario1: 10 mgd capacity from WSSC	Environmental Engineers & Scientists
DATE: October 2016	One South Street, Suite 1150
DESCRIPTION: Water Transmission Capital Cost Detail	Baltimore, Maryland 21202
PREPARED BY: AA	Tel: (410) 539-7681 • Fax: (410) 539-7682

Description	Quantity	Units	Unit Cost	Total Cost	References/Comments
DIVISION 1					
General Conditions (12 %)	1	LS	$1,363,847	$1,363,847	
Mobilization	1	LS	$30,000	$30,000	
		Division #1 Subtotal =		**$1,393,847**	
DIVISION 2					
Traffic Control (assume 160 LF/day installation)	400	DAYS	$1,000	$400,000	
Erosion and Sedimentation Control (assume $1/LF)	64000	LF	$2	$128,000	
Environmental Mitigation	1	LS	$61,000	$61,000	
Landscape restoration	1	LS	$30,500	$30,500	
Dewatering	400	Days	$250	$100,000	Means 312319200010
Utility Relocations	1	LS	$305,000	$305,000	(Assume 10 % of pipe length at $50/LF)
Easements	12800	SF	$4	$51,200	Assume $4/SF
8 inch DIP main					
8" DIP, restrained gasket joint (American Fastite or equal)	20000	LF	$38.71	$774,200	
8" Fittings (Assume 1 fitting per 250 ft)	80	EA	$1,106	$88,480	
Trench Excavation	10206	CY	$35.00	$357,202	
Hauling Excavated Material	259	CY	$10.00	$2,586	
Backfill - On Site Material	7972	CY	$4.21	$33,562	
Pipe Bedding	1975	CY	$32.81	$64,810	
Backfill Compaction	2469	CY	$13.80	$34,074	
Seeding and mulching	11111	SY	$2.61	$29,000	
16 inch DIP main					
16" DIP, restrained gasket joint (American Fastite or equal)	26000	LF	$60.47	$1,572,220	
16" Fittings (Assume 1 fitting per 250 ft)	104	EA	$2,077	$216,008	
Trench Excavation	18724	CY	$35.00	$655,350	
Hauling Excavated Material	4554	CY	$10.00	$45,544	
Backfill - On Site Material	14170	CY	$4.21	$59,655	
Pipe Bedding	3210	CY	$32.81	$105,316	
Backfill Compaction	17712	CY	$13.80	$244,430	
Seeding and mulching	14444	SY	$2.61	$37,700	
24 inch DIP main					
24" DIP, restrained gasket joint (American Fastite or equal)	15000	LF	$87.60	$1,314,000	
24" Fittings (Assume 1 fitting per 250 ft)	60	EA	$11,018	$661,080	
Trench Excavation	14444	CY	$35.00	$505,556	
Hauling Excavated Material	3968	CY	$10.00	$39,676	
Backfill - On Site Material	10477	CY	$4.21	$44,108	
Pipe Bedding	2222	CY	$32.81	$72,911	
Backfill Compaction	13096	CY	$13.80	$180,726	
Seeding and mulching	8333	SY	$2.61	$21,750	
30 inch DIP main					
30" DIP, restrained gasket joint (American Fastite or equal)	3000	LF	$120.00	$360,000	
30" Fittings (Assume 1 fitting per 250 ft)	12	EA	$25,000	$300,000	
Trench Excavation	3500	CY	$35.00	$122,500	
Hauling Excavated Material	1045	CY	$10.00	$10,454	
Backfill - On Site Material	2455	CY	$4.21	$10,334	
Pipe Bedding	500	CY	$32.81	$16,405	
Backfill Compaction	3068	CY	$13.80	$42,342	
Seeding and mulching	1667	SY	$2.61	$4,350	
Pavement Repair					
Pavement Removal	7111	SY	7.04	$50,062	Assume 20 % of main length requires pavement removal
Pavement Repair - Aggregate Base	7111	SY	10.71	$76,160	
Pavement Repair - Base Course	7111	SY	41.01	$291,627	
Pavement Repair - Surface Course	7111	SY	30.21	$214,827	
Jack and Bore - Highway-Railroad-Stream					
Jack and Bore	1000	LF	$323.50	$323,500	
Jacking Pits	10	EA	$15,000	$150,000	
Air Release Valves (located at 3000 ft intervals)					
Valve	22	EA	$1,629	$35,827	
Valve Vault	22	EA	$6,276	$138,061	
Blow-off Valves (located at 3000 ft intervals)					
Valve	22	EA	$1,629	$35,827	
Valve Vault	22	EA	$6,276	$138,061	
Pressure reducing valve					
Valve and appurtenances	0	EA	$10,000	$0	
Valve Vault	0	EA	$6,276	$0	
Isolation Valves (located at 2000 ft intervals)					
8 inch gate valve with valve box and cover	11	EA	$2,741	$30,151	
8 inch valve joint restraint	22	EA	$84	$1,848	
Isolation Valves (located at 2000 ft intervals)					
16 inch gate valve with valve box and cover	14	EA	$19,687	$275,618	
16 inch valve joint restraint	28	EA	$158	$4,410	
Isolation Valves (located at 2000 ft intervals)					
24 inch gate valve with valve box and cover	8	EA	$48,486	$387,888	
24 inch valve joint restraint	16	EA	$258	$4,128	
Isolation Valves (located at 2000 ft intervals)					
30 inch gate valve with valve box and cover	2	EA	$51,886	$103,772	
30 inch valve joint restraint	4	EA	$400	$1,600	
		Division #2 Subtotal =		**$11,365,393**	
			Subtotal =	**$12,759,000**	
Contractor Overhead & Profit	15%			$1,914,000	
Contingency	25%			$3,190,000	
			TOTAL =	**$17,863,000**	

PROJECT: Charles County - Water Source Feasibility Study	HAZEN AND SAWYER
ALTERNATIVE: Scenario 2: 10 mgd capacity from upper reaches Potomac River WTP	Environmental Engineers & Scientists
DATE: October 2016	One South Street, Suite 1150
DESCRIPTION: Water Transmission Capital Cost Detail	Baltimore, Maryland 21202
PREPARED BY: AA	Tel: (410) 539-7681 • Fax: (410) 539-7682

Description	Quantity	Units	Unit Cost	Total Cost	References/Comments
DIVISION 1					
General Conditions (12 %)	1	LS	$2,925,877	$2,925,877	
Mobilization	1	LS	$30,000	$30,000	
		Division #1 Subtotal =		**$2,955,877**	
DIVISION 2					
Traffic Control (assume 160 LF/day installation)	566	DAYS	$1,000	$565,625	
Erosion and Sedimentation Control (assume $1/LF)	90500	LF	$2	$181,000	
Environmental Mitigation	1	LS	$90,500	$90,500	
Landscape restoration	1	LS	$45,250	$45,250	
Dewatering	566	Days	$250	$141,406	Means 312319200010
Utility Relocations	1	LS	$452,500	$452,500	(Assume 10 % of pipe length at $50/LF)
Easements	18100	SF	$4	$72,400	Assume $4/SF
18 inch DIP main					
18" DIP, restrained gasket joint (American Fastite or equal)	28500	LF	$67.40	$1,920,900	
18" Fittings (Assume 1 fitting per 250 ft)	114	EA	$4,796	$546,744	
Trench Excavation	22167	CY	$35.00	$775,833	
Hauling Excavated Material	1865	CY	$10.00	$18,653	
Backfill - On Site Material	16607	CY	$4.21	$69,915	
Pipe Bedding	3694	CY	$32.81	$121,215	
Backfill Compaction	4618	CY	$13.80	$63,729	
Seeding and mulching	15833	SY	$2.61	$41,325	
24 inch DIP main					
24" DIP, restrained gasket joint (American Fastite or equal)	25000	LF	$87.60	$2,190,000	
24" Fittings (Assume 1 fitting per 250 ft)	100	EA	$11,018	$1,101,800	
Trench Excavation	24074	CY	$35.00	$842,593	
Hauling Excavated Material	6613	CY	$10.00	$66,126	
Backfill - On Site Material	17461	CY	$4.21	$73,513	
Pipe Bedding	3704	CY	$32.81	$121,519	
Backfill Compaction	21827	CY	$13.80	$301,211	
Seeding and mulching	13889	SY	$2.61	$36,250	
30 inch DIP main					
30" DIP, restrained gasket joint (American Fastite or equal)	37000	LF	$120.00	$4,440,000	
30" Fittings (Assume 1 fitting per 250 ft)	148	EA	$25,000	$3,700,000	
Trench Excavation	43167	CY	$35.00	$1,510,833	
Hauling Excavated Material	12893	CY	$10.00	$128,935	
Backfill - On Site Material	30273	CY	$4.21	$127,450	
Pipe Bedding	6167	CY	$32.81	$202,328	
Backfill Compaction	37842	CY	$13.80	$522,213	
Seeding and mulching	20556	SY	$2.61	$53,650	
Pavement Repair					
Pavement Removal	10056	SY	7.04	$70,791	Assume 20% of main length req's pavement removal
Pavement Repair - Aggregate Base	10056	SY	10.71	$107,695	
Pavement Repair - Base Course	10056	SY	41.01	$412,378	
Pavement Repair - Surface Course	10056	SY	30.21	$303,778	
Jack and Bore - Highway-Railroad-Stream					
Jack and Bore	1000	LF	$323.50	$323,500	
Jacking Pits	10	EA	$15,000	$150,000	
Air Release Valves (located at 3000 ft intervals)					
Valve	31	EA	$1,629	$50,484	
Valve Vault	31	EA	$6,276	$194,541	
Blow-off Valves (located at 3000 ft intervals)					
Valve	31	EA	$1,629	$50,484	
Valve Vault	31	EA	$6,276	$194,541	
Pressure reducing valve					
Valve and appurtenances	0	EA	$10,000	$0	
Valve Vault	0	EA	$6,276	$0	
Isolation Valves (located at 2000 ft intervals)					
18 inch gate valve with valve box and cover	15	EA	$23,686	$355,290	
18 inch valve joint restraint	30	EA	$179	$5,355	
Isolation Valves (located at 2000 ft intervals)					
24 inch gate valve with valve box and cover	13	EA	$48,486	$630,318	
24 inch valve joint restraint	26	EA	$258	$6,708	
Isolation Valves (located at 2000 ft intervals)					
30 inch gate valve with valve box and cover	19	EA	$51,886	$985,834	
30 inch valve joint restraint	38	EA	$400	$15,200	
		Division #2 Subtotal =		**$24,382,311**	
			Subtotal =	**$27,338,000**	
Contractor Overhead & Profit	15%			$4,101,000	
Contingency	25%			$6,835,000	
			TOTAL =	**$38,274,000**	

PROJECT: Charles County - Water Source Feasibility Study	HAZEN AND SAWYER
ALTERNATIVE: Scenario 3: 5 mgd capacity from upper reaches Potomac River WTP and 5 mgd capacity from WSSC	Environmental Engineers & Scientists
DATE: October 2016	One South Street, Suite 1150
DESCRIPTION: Water Transmission Capital Cost Detail	Baltimore, Maryland 21202
PREPARED BY: AA	Tel: (410) 539-7681 • Fax: (410) 539-7682

Description	Quantity	Units	Unit Cost	Total Cost	References/Comments
DIVISION 1					
General Conditions (12 %)	1	LS	$2,215,583	$2,215,583	
Mobilization	1	LS	$30,000	$30,000	
		Division #1 Subtotal =		**$2,245,583**	
DIVISION 2					
Traffic Control (assume 160 LF/day installation)	500	DAYS	$1,000	$500,000	
Erosion and Sedimentation Control (assume $1/LF)	80000	LF	$2	$160,000	
Environmental Mitigation	1	LS	$77,000	$77,000	
Landscape restoration	1	LS	$38,500	$38,500	
Dewatering	500	Days	$250	$125,000	Means 312319200010
Utility Relocations	1	LS	$385,000	$385,000	(Assume 10 % of pipe length at $50/LF)
Easements	16000	SF	$4	$64,000	Assume $4/SF
8 inch DIP main					
8" DIP, restrained gasket joint (American Fastite or equal)	0	LF	$38.71	$0	
8" Fittings (Assume 1 fitting per 250 ft)	0	EA	$1,106	$0	
Trench Excavation	0	CY	$35.00	$0	
Hauling Excavated Material	0	CY	$10.00	$0	
Backfill - On Site Material	0	CY	$4.21	$0	
Pipe Bedding	0	CY	$32.81	$0	
Backfill Compaction	0	CY	$13.80	$0	
Seeding and mulching	0	SY	$2.61	$0	
16 inch DIP main					
16" DIP, restrained gasket joint (American Fastite or equal)	15000	LF	$60.47	$907,050	
16" Fittings (Assume 1 fitting per 250 ft)	60	EA	$2,077	$124,620	
Trench Excavation	10802	CY	$35.00	$378,086	
Hauling Excavated Material	2628	CY	$10.00	$26,276	
Backfill - On Site Material	8175	CY	$4.21	$34,416	
Pipe Bedding	1852	CY	$32.81	$60,759	
Backfill Compaction	10219	CY	$13.80	$141,017	
Seeding and mulching	8333	SY	$2.61	$21,750	
20 inch DIP main					
20" DIP, restrained gasket joint (American Fastite or equal)	3000	LF	$72.45	$217,350	
20" Fittings (Assume 1 fitting per 250 ft)	12	EA	$6,609	$79,308	
Trench Excavation	2512	CY	$35.00	$87,932	
Hauling Excavated Material	650	CY	$10.00	$6,498	
Backfill - On Site Material	1863	CY	$4.21	$7,841	
Pipe Bedding	407	CY	$32.81	$13,367	
Backfill Compaction	2328	CY	$13.80	$32,129	
Seeding and mulching	1667	SY	$2.61	$4,350	
24 inch DIP main					
24" DIP, restrained gasket joint (American Fastite or equal)	62000	LF	$87.60	$5,431,200	
24" Fittings (Assume 1 fitting per 250 ft)	248	EA	$11,018	$2,732,464	
Trench Excavation	59704	CY	$35.00	$2,089,630	
Hauling Excavated Material	16399	CY	$10.00	$163,992	
Backfill - On Site Material	43304	CY	$4.21	$182,312	
Pipe Bedding	9185	CY	$32.81	$301,366	
Backfill Compaction	54131	CY	$13.80	$747,002	
Seeding and mulching	34444	SY	$2.61	$89,900	
Pavement Repair					
Pavement Removal	8889	SY	7.04	$62,578	Assume 20 % of main length requires pavement removal
Pavement Repair - Aggregate Base	8889	SY	10.71	$95,200	
Pavement Repair - Base Course	8889	SY	41.01	$364,533	
Pavement Repair - Surface Course	8889	SY	30.21	$268,533	
Jack and Bore - Highway-Railroad-Stream					
Jack and Bore	500	LF	$323.50	$161,750	
Jacking Pits	5	EA	$15,000	$75,000	
Air Release Valves (located at 3000 ft intervals)					
Valve	26	EA	$1,629	$42,341	
Valve Vault	26	EA	$6,276	$163,163	
Blow-off Valves (located at 3000 ft intervals)					
Valve	26	EA	$1,629	$42,341	
Valve Vault	26	EA	$6,276	$163,163	
Pressure reducing valve					
Valve and appurtenances	0	EA	$10,000	$0	
Valve Vault	0	EA	$6,276	$0	
Isolation Valves (located at 2000 ft intervals)					
8 inch gate valve with valve box and cover	0	EA	$2,741	$0	
8 inch valve joint restraint	0	EA	$84	$0	
Isolation Valves (located at 2000 ft intervals)					
16 inch gate valve with valve box and cover	8	EA	$19,687	$157,496	
16 inch valve joint restraint	16	EA	$158	$2,520	
Isolation Valves (located at 2000 ft intervals)					
20 inch gate valve with valve box and cover	2	EA	$32,787	$65,574	
20 inch valve joint restraint	4	EA	$204	$816	
Isolation Valves (located at 2000 ft intervals)					
24 inch gate valve with valve box and cover	32	EA	$48,486	$1,551,552	
24 inch valve joint restraint	64	EA	$258	$16,512	
		Division #2 Subtotal =		**$18,463,189**	
			Subtotal =	**$20,709,000**	
Contractor Overhead & Profit	15%			$3,106,000	
Contingency	25%			$5,177,000	
			TOTAL =	**$28,992,000**	

PROJECT: Charles County - Water Source Feasibility Study	HAZEN AND SAWYER
ALTERNATIVE: Scenario 4: 5 mgd of add'l groundwater from IPR aquifer recharge and 5 mgd capacity from WSSC	Environmental Engineers & Scientists
DATE: October 2016	One South Street, Suite 1150
DESCRIPTION: Water Transmission Capital Cost Detail	Baltimore, Maryland 21202
PREPARED BY: AA	Tel: (410) 539-7681 • Fax: (410) 539-7682

Description	Quantity	Units	Unit Cost	Total Cost	References/Comments
DIVISION 1					
General Conditions (12 %)	1	LS	$1,213,346	$1,213,346	
Mobilization	1	LS	$30,000	$30,000	
		Division #1 Subtotal =		**$1,243,346**	
DIVISION 2					
Traffic Control (assume 160 LF/day installation)	400	DAYS	$1,000	$400,000	
Erosion and Sedimentation Control (assume $1/LF)	64000	LF	$2	$128,000	
Environmental Mitigation	1	LS	$64,000	$64,000	
Landscape restoration	1	LS	$32,000	$32,000	
Dewatering	400	Days	$250	$100,000	Means 312319200010
Utility Relocations	1	LS	$320,000	$320,000	(Assume 10 % of pipe length at $50/LF)
Easements	12800	SF	$4	$51,200	Assume $4/SF
8 inch DIP main					
8" DIP, restrained gasket joint (American Fastite or equal)	20000	LF	$38.71	$774,200	
8" Fittings (Assume 1 fitting per 250 ft)	80	EA	$1,106	$88,480	
Trench Excavation	10206	CY	$35.00	$357,202	
Hauling Excavated Material	259	CY	$10.00	$2,586	
Backfill - On Site Material	7972	CY	$4.21	$33,562	
Pipe Bedding	1975	CY	$32.81	$64,810	
Backfill Compaction	2469	CY	$13.80	$34,074	
Seeding and mulching	11111	SY	$2.61	$29,000	
16 inch DIP main					
16" DIP, restrained gasket joint (American Fastite or equal)	26000	LF	$60.47	$1,572,220	
16" Fittings (Assume 1 fitting per 250 ft)	104	EA	$2,077	$216,008	
Trench Excavation	18724	CY	$35.00	$655,350	
Hauling Excavated Material	4554	CY	$10.00	$45,544	
Backfill - On Site Material	14170	CY	$4.21	$59,655	
Pipe Bedding	3210	CY	$32.81	$105,316	
Backfill Compaction	17712	CY	$13.80	$244,430	
Seeding and mulching	14444	SY	$2.61	$37,700	
20 inch DIP main					
20" DIP, restrained gasket joint (American Fastite or equal)	18000	LF	$72.45	$1,304,100	
20" Fittings (Assume 1 fitting per 250 ft)	72	EA	$6,609	$475,848	
Trench Excavation	15074	CY	$35.00	$527,593	
Hauling Excavated Material	3899	CY	$10.00	$38,989	
Backfill - On Site Material	11175	CY	$4.21	$47,048	
Pipe Bedding	2444	CY	$32.81	$80,202	
Backfill Compaction	13969	CY	$13.80	$192,772	
Seeding and mulching	10000	SY	$2.61	$26,100	
Pavement Repair					
Pavement Removal	7111	SY	7.04	$50,062	Assume 20 % of main length requires pavement removal
Pavement Repair - Aggregate Base	7111	SY	10.71	$76,160	
Pavement Repair - Base Course	7111	SY	41.01	$291,627	
Pavement Repair - Surface Course	7111	SY	30.21	$214,827	
Jack and Bore - Highway-Railroad-Stream					
Jack and Bore	800	LF	$323.50	$258,800	
Jacking Pits	8	EA	$15,000	$120,000	
Air Release Valves (located at 3000 ft intervals)					
Valve	22	EA	$1,629	$35,827	
Valve Vault	22	EA	$6,276	$138,061	
Blow-off Valves (located at 3000 ft intervals)					
Valve	22	EA	$1,629	$35,827	
Valve Vault	22	EA	$6,276	$138,061	
Pressure reducing valve					
Valve and appurtenances	0	EA	$10,000	$0	
Valve Vault	0	EA	$6,276	$0	
Isolation Valves (located at 2000 ft intervals)					
8 inch gate valve with valve box and cover	11	EA	$2,741	$30,151	
8 inch valve joint restraint	22	EA	$84	$1,848	
Isolation Valves (located at 2000 ft intervals)					
16 inch gate valve with valve box and cover	14	EA	$19,687	$275,618	
16 inch valve joint restraint	28	EA	$158	$4,410	
Isolation Valves (located at 2000 ft intervals)					
20 inch gate valve with valve box and cover	10	EA	$32,787	$327,870	
20 inch valve joint restraint	20	EA	$204	$4,080	
		Division #2 Subtotal =		**$10,111,216**	
			Subtotal =	**$11,355,000**	
Contractor Overhead & Profit	15%			$1,703,000	
Contingency	25%			$2,839,000	
			TOTAL =	**$15,897,000**	

PROJECT: Charles County - Water Source Feasibility Study	HAZEN AND SAWYER
ALTERNATIVE: Scenario 5: 5 mgd of add'l groundwater (surficial and confined aquifers) and 5 mgd capacity from WSSC	Environmental Engineers & Scientists
DATE: October 2016	One South Street, Suite 1150
DESCRIPTION: Water Transmission Capital Cost Detail	Baltimore, Maryland 21202
PREPARED BY: AA	Tel: (410) 539-7681 • Fax: (410) 539-7682

Description	Quantity	Units	Unit Cost	Total Cost	References/Comments
DIVISION 1					
General Conditions (12 %)	1	LS	$1,140,688	$1,140,688	
Mobilization	1	LS	$30,000	$30,000	
		Division #1 Subtotal =		**$1,170,688**	
DIVISION 2					
Traffic Control (assume 160 LF/day installation)	403	DAYS	$1,000	$403,125	
Erosion and Sedimentation Control (assume $1/LF)	64500	LF	$2	$129,000	
Environmental Mitigation	1	LS	$64,500	$64,500	
Landscape restoration	1	LS	$32,250	$32,250	
Dewatering	403	Days	$250	$100,781	Means 312319200010
Utility Relocations	1	LS	$322,500	$322,500	(Assume 10 % of pipe length at $50/LF)
Easements	12900	SF	$4	$51,600	Assume $4/SF
8 inch DIP main					
8" DIP, restrained gasket joint (American Fastite or equal)	20000	LF	$38.71	$774,200	
8" Fittings (Assume 1 fitting per 250 ft)	80	EA	$1,106	$88,480	
Trench Excavation	10206	CY	$35.00	$357,202	
Hauling Excavated Material	259	CY	$10.00	$2,586	
Backfill - On Site Material	7972	CY	$4.21	$33,562	
Pipe Bedding	1975	CY	$32.81	$64,810	
Backfill Compaction	2469	CY	$13.80	$34,074	
Seeding and mulching	11111	SY	$2.61	$29,000	
16 inch DIP main					
16" DIP, restrained gasket joint (American Fastite or equal)	41500	LF	$60.47	$2,509,505	
16" Fittings (Assume 1 fitting per 250 ft)	166	EA	$2,077	$344,782	
Trench Excavation	29887	CY	$35.00	$1,046,039	
Hauling Excavated Material	7270	CY	$10.00	$72,696	
Backfill - On Site Material	22617	CY	$4.21	$95,219	
Pipe Bedding	5123	CY	$32.81	$168,101	
Backfill Compaction	28272	CY	$13.80	$390,148	
Seeding and mulching	23056	SY	$2.61	$60,175	
20 inch DIP main					
20" DIP, restrained gasket joint (American Fastite or equal)	3000	LF	$72.45	$217,350	
20" Fittings (Assume 1 fitting per 250 ft)	12	EA	$6,609	$79,308	
Trench Excavation	2512	CY	$35.00	$87,932	
Hauling Excavated Material	650	CY	$10.00	$6,498	
Backfill - On Site Material	1863	CY	$4.21	$7,841	
Pipe Bedding	407	CY	$32.81	$13,367	
Backfill Compaction	2328	CY	$13.80	$32,129	
Seeding and mulching	1667	SY	$2.61	$4,350	
Pavement Repair					
Pavement Removal	7167	SY	7.04	$50,453	Assume 20 % of main length requires pavement removal
Pavement Repair - Aggregate Base	7167	SY	10.71	$76,755	
Pavement Repair - Base Course	7167	SY	41.01	$293,905	
Pavement Repair - Surface Course	7167	SY	30.21	$216,505	
Jack and Bore - Highway-Railroad-Stream					
Jack and Bore	800	LF	$323.50	$258,800	
Jacking Pits	8	EA	$15,000	$120,000	
Air Release Valves (located at 3000 ft intervals)					
Valve	22	EA	$1,629	$35,827	
Valve Vault	22	EA	$6,276	$138,061	
Blow-off Valves (located at 3000 ft intervals)					
Valve	22	EA	$1,629	$35,827	
Valve Vault	22	EA	$6,276	$138,061	
Pressure reducing valve					
Valve and appurtenances	0	EA	$10,000	$0	
Valve Vault	0	EA	$6,276	$0	
Isolation Valves (located at 2000 ft intervals)					
8 inch gate valve with valve box and cover	11	EA	$2,741	$30,151	
8 inch valve joint restraint	22	EA	$84	$1,848	
Isolation Valves (located at 2000 ft intervals)					
16 inch gate valve with valve box and cover	21	EA	$19,687	$413,427	
16 inch valve joint restraint	42	EA	$158	$6,615	
Isolation Valves (located at 2000 ft intervals)					
20 inch gate valve with valve box and cover	2	EA	$32,787	$65,574	
20 inch valve joint restraint	4	EA	$204	$816	
		Division #2 Subtotal =		**$9,505,734**	
			Subtotal =	**$10,676,000**	
Contractor Overhead & Profit	15%			$1,601,000	
Contingency	25%			$2,669,000	
			TOTAL =	**$14,946,000**	

Treatment O&M Cost Detail Table

Treatment O&M Cost Detail Table

			Annual Process/supply O&M					Totals
Treatment Alternative	**Supply (mgd)**	**Major Processes**	**MF(2 Exhibit 4.29**	**O3-BAC(1)**	**GAC(2 exhibit 4.46)**	**UV(2 exhibit 4.13)**	**Greensand**	
Alternative G-4 (Surficial aquifer wellfield)	2.5	MF	$271,263					$271,263
Alternative S-1 (Upper reach Potomac)	10	O3_BAC_GAC_UV		$581,967	$331,210	$34,424		$947,601
Alternative S-1 (Upper reach Potomac)	5	O3_BAC_GAC_UV		$328,518	$195,979	$23,437		$547,935
Alternative B-2 (Riverbank filtration)	10	O3_BAC_GAC_UV		$581,967	$331,210	$34,424		$947,601
Alternative B-2 (Riverbank filtration)	5	O3_BAC_GAC_UV		$328,518	$195,979	$23,437		$547,935
Alternative R-2 (IPR treatment train #2)	6	O3_BAC_GAC_UF_UV	$593,777	$381,807	$223,336	$26,367		$1,225,287
Alternative P-1 (Increased WSSC Allocation)	10	GAC			$331,210			$331,210
Alternative P-1 (Increased WSSC	5	GAC			$195,979			$195,979
All Alternatives (Existing Groundwater)	9.3	Greensand					$327,562	$327,562

(1) Plumlee, M. H., Stanford, B. D., Debroux, J. F., Hopkins, D. C., & Snyder, S. A. (2014). Costs of advanced treatment in water reclamation. *Ozone: Science & Engineering* , *36* (5), 485-495.
(2) EPA Technologies and Costs Document for the Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule dated 2005

Note: Pumping costs calculated separately

Appendix B Charles County Water Source Feasibility Study – Phase A-1 Report

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Charles County Water Source Feasibility Study – Phase A-1

Technical Memorandum
February 18, 2016

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List of Acronyms

Abbreviation	Definition
AOP	Advanced Oxidation Processes
BAC	Biologically active carbon
CAT	Corrective action thresholds
CBP	Chesapeake Bay Program
CCG	Charles County Government
CCL	Contaminant Candidate List
CFR	Code of Federal Regulations
Cl_2	Chlorine
CPV	Competitive Power Ventures
CT	Contact time
DBP	Disinfection byproduct
DOC	Dissolved organic carbon
DPR	Direct potable reuse
GAC	Granular activated carbon
GIS	Geographical information system
g/mol	Grams per mole
gpm	Gallons per minute
GWUDI	Groundwater under the direct influence of surface water
H_2O_2	Hydrogen peroxide
HAA5	The sum of 5 haloacetic acid concentrations (monochloroacetic acid, monobromoacetic acid, dichloroacetic acid, trichloroacetic acid, and dibromoacetic acid)
HGL	Hydraulic grade line
IPR	Indirect potable reuse
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
MCL	Maximum contaminant level
MDE	Maryland Department of Environment
MF	Microfiltration
mg/L	Milligrams per liter
mgd	Million gallons per day
MGS	Maryland Geological Survey
mL	Milliliter
MPN	Most probable number
NA	Not applicable
NOM	Natural organic matter
NSWC	Naval Surface Warfare Center

NTU	Nephelometric Turbidity Units
O&M	Operation and maintenance
O_3	Ozone
PAC	Powdered activated carbon
pCi/L	Picocuries per liter
RBF	Riverbank filtration
RO	Reverse osmosis
SWTR	Surface Water Treatment Rule
TAZ	Traffic Analysis Zones
TDS	Total dissolved solids
TOC	Total organic carbon
TTHM	Total trihalomethanes (the sum of bromoform, chloroform, bromodichloromethane, and chlorodibromomethane concentrations)
UCMR	Unregulated Contaminant Monitoring Rule
UF	Ultrafiltration
USEPA	United States Environmental Protection Agency
UV	Ultraviolet irradiation
WMA	Washington DC metropolitan area
WSSC	Washington Suburban Sanitary Commission
WTP	Water treatment plant
WWTP	Wastewater treatment plant
µg/L	Micrograms per liter

Executive Summary

The Charles County Government (CCG) has commissioned a Water Source Feasibility Study in response to projected population growth, declining water levels in regional aquifers, and requirements laid out by the Maryland Department of the Environment. The main objective of this study is to evaluate potential options for meeting the Waldorf and Bryans Road water systems' future demand. However, due to the fact that nearly all water for domestic, industrial, and agricultural use in the County is withdrawn from the same confined aquifers, the scope of the study is not limited to these CCG systems.

The results of Phase A-1 of the evaluation are presented here, including a comprehensive review of all potential water sources in the County, such as increased allocations from the Washington Suburban Sanitary Commission, development of a surface water supply, new wells in confined and unconfined aquifers, water reuse, water conservation, and a combination thereof. The majority of the water supply alternatives available in Charles County require more treatment and monitoring than existing groundwater supplies. Thus, an overview of water quality considerations pertaining to various source waters, as well as the treatment processes that address these water quality considerations, is provided. Successful diversification of the CCG water supply portfolio will depend on selecting treatment technologies that adequately addresses raw water quality, as well as thoroughly anticipating and addressing the potential impacts of blending source waters in the distribution system.

Water source alternatives were evaluated based on the preliminary screening criteria shown in Table ES-1, which were developed to assess multiple aspects of each option. The preliminary screening criteria served to provide a concept development roadmap for all identified water source alternatives, as well as a means by which to identify potential critical flaws. Ultimately, these criteria and their associated pass/fail assessments for each water source alternative enabled removal of options from further consideration that had notable conceptual weaknesses, such as unproven performance or reliability, high cost, or insurmountable regulatory issues. The information and data used to assess each water source alternative originated from multiple sources, including water resource monitoring databases, federal and state publications, peer reviewed literature, and professional experience.

Table ES-1: Phase A-1 Preliminary Screening Criteria

Preliminary Screening Criteria
Capital Cost
Operation and Maintenance Cost
Water Quality
Supply Reliability
Ease of Operation
Constructability
Ease of Permitting
Environmental Stewardship
Public Acceptance
Regional Benefits

The results of the screening analysis identified twelve alternatives that will be included in the Phase A-2 analysis (Figure ES-2). Critical flaws for the water source alternatives that were eliminated during this preliminary screening ranged from lack of supply reliability to exorbitant capital cost to lack of regulatory and public acceptance. The options being carried forward include surface water and groundwater sources, riverbank filtration, reuse, as well as a variety of policy and management opportunities. The major factors that influenced whether an alternative was accepted or screened out are described below:

Groundwater sources: Based on available drawdown data in the Magothy, Patapsco, and Patuxent aquifers, there is currently low confidence in the long term reliability of increased withdrawals from these groundwater sources. However, updated modeling of the Coastal Plain Aquifer system could improve the County's ability to utilize existing wells, plan new well development, and support permitting appropriations for confined aquifer withdrawals. In addition to the confined aquifers, the Surficial Upland aquifer may be a potential source that would require a relatively low level of treatment, but yields would need to be confirmed through field investigations.

Surface water sources: From a water supply standpoint the Potomac and Patuxent Rivers are reliable options, but water quality would require substantial treatment. While treatment would be expensive, it is feasible. Acceptable surface water options were limited to the upper reaches of the Potomac River in order to avoid the need for desalination.

Riverbank filtration sources: Riverbank filtration can be generally understood as a cross between a surface water source and a groundwater source. A large, reliable surface water source, such as the Potomac River, ensures an adequate water supply, while transport through the riverbank substrate provides water quality benefits. Riverbank filtration is a feasible alternative along the upper reaches of the Potomac River, but field investigations would be required to confirm yield and water quality.

Reuse sources: Non-potable reuse is currently practiced in the County and could be expanded if additional customers are identified. While indirect potable reuse is untried in Maryland, it has been successfully implemented in many states. Therefore, it may be a suitable source for aquifer recharge from a permitting and public acceptance standpoint. There are few precedents in the U.S. for direct potable reuse, and it was determined to be too drastic of a change from current practice from both a permitting and public acceptance perspective to be carried forward for further analysis.

Policy options: Policy options evaluated in this study were varied. Accepted alternatives include expanding purchased water from WSSC, developing a wellfield management plan using modeling of the Coastal Plain Aquifer system, and creating county-wide agreements for sharing costs of developing new sources of supply. A demand management program was rejected based on current usage trends in the County.

Combined options: Two feasible options were identified that could be combined with the development of an alternative source of supply: 1) addition of an aquifer storage and recovery system, which could expand the yield of the alternate source if there are seasonal constraints; and 2) operation of the existing (or expanded) groundwater wells and an alternate source of supply as a conjunctive use system to maximize overall yield.

Capital costs were estimated for the water source alternatives requiring new treatment infrastructure, which included planning, design, permitting, construction, and commissioning of facilities required to access, treat, and convey the water source to the closest connection point within the existing transmission and distribution system. Because of the early stage of the project, the cost estimates are characterized as Class 5, indicating there is a high level of uncertainty. Costs were based on published data, prior projects recently constructed in the region, and typical rates for contingencies. Some of the factors that can have a major impact on final costs include land acquisition, intake or well construction, raw water and finished water pipeline lengths, investigations and studies, and permitting. Figure ES-1 presents a summary of the range of costs estimated for treatment alternatives being further evaluated in Phase A-2. Other alternatives that will also be further evaluated in Phase A-2 (but are not included in Figure ES-1) require additional effort to identify costs in Phase A-2 (e.g. expanded WSSC allocations and non-potable reuse).

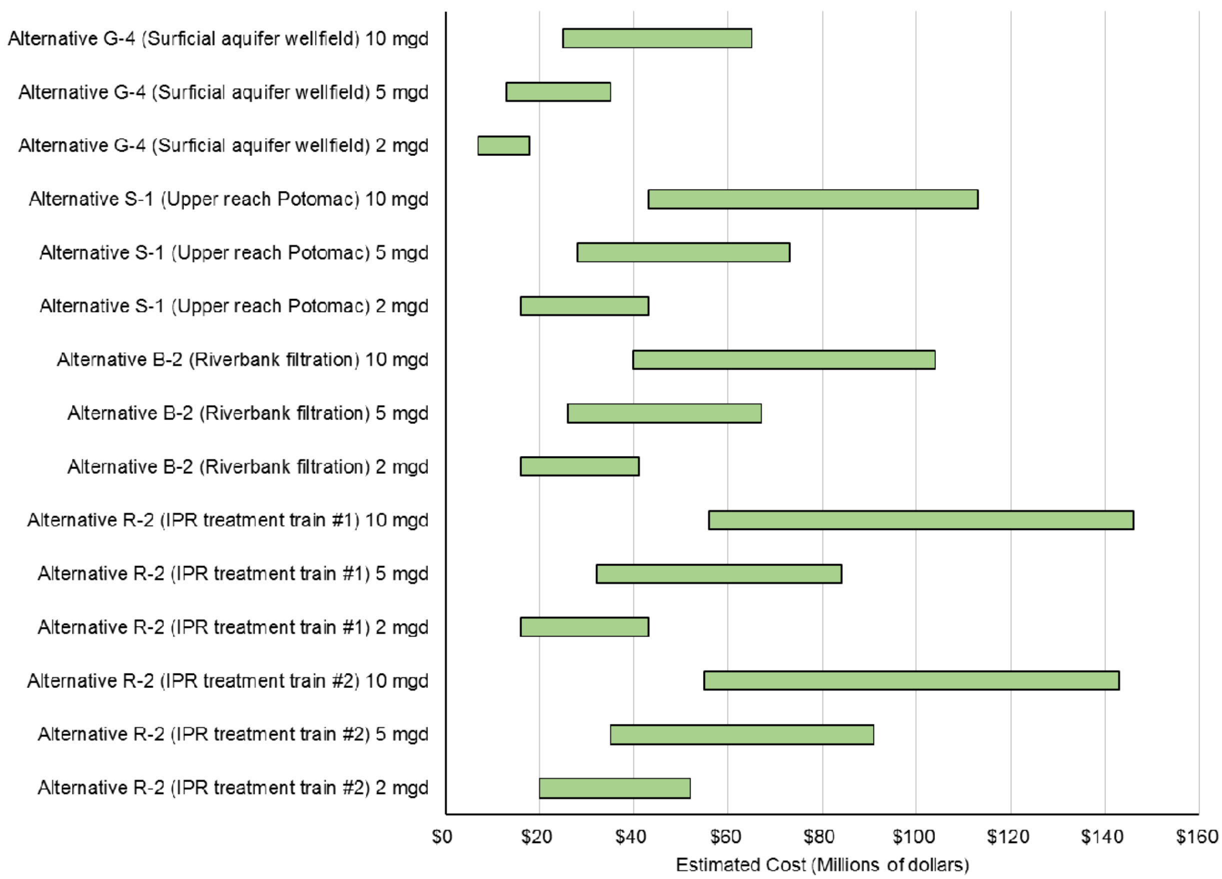

Figure ES-1: Range of Costs for Each Treatment Option Estimated for 2, 5, And 10 mgd Plant Capacities

While many of these alternatives are necessarily long-term solutions, due to additional work needed to confirm feasibility or long lead times for permitting and construction, a number of the alternatives could be implemented in the near term (e.g. increased allocations from Washington Suburban Sanitary Commission). Further, based on the demand analysis, a supply deficit is not projected to occur for a number of years. Supply needs can also likely be met by existing groundwater appropriations in the near term without reaching the regulated 80% management limit at CCG wells; however, increased pumping by other users that increases the rate of drawdown or new occurrences of gross alpha contamination at Patapsco aquifer wells could substantially limit currently available groundwater resources for the County.

In phase A-2 of the project, the feasibility and infrastructure requirements of the options will be further explored, and high-level system modeling will be conducted to assess the mix of options (i.e. percentage supply from one or more alternatives) that can best serve the County's needs. Phase A-2 will also include the triple bottom line evaluation of feasible alternatives to develop a comprehensive ranking of the alternatives.

However, in advance of Phase A-2, the Hazen team recommends a bridging phase to address specific issues identified in this study to further confirm feasibility of alternatives. For example, property acquisition is a critical component of nearly every alternative and requires further discussion with the County. Other suggested tasks for each alternative include the following:

- Alternative G-4: New Surficial aquifer wellfield
    - Conduct field investigations to identify potential wellfield locations and confirm yields of the Surficial Upland aquifer
- Alternative S-1: Surface Water Treatment Plant – Potomac River upper reaches
    - Discuss permitting with the Army Corps of Engineers for a new surface water intake in the Potomac River to identify constraints on size, location, etc.
- Alternative B-2: Riverbank Filtration – Potomac River upper reaches
    - Conduct field investigations to identify potential RBF locations and confirm yields
- Alternative R-1: Non-potable Reuse
    - Conduct a detailed evaluation of potential non-potable reuse customers and the implications for operations of the Mattawoman WWTP
- Alternative R-2: Indirect Potable Reuse with Confined Aquifer Recharge
    - Facilitate discussions with MDE and present experience with IPR from other states to confirm feasibility of permitting IPR in Maryland
- Alternative P-3: Wellfield Management Plan
    - Work with the Maryland Geological Survey to identify costs and timeframe for updating County or regional modeling of the coastal plain aquifers system
- Alternative W-1: Countywide Agreements
    - Facilitate discussions with other Charles County municipalities the benefits and costs of joint agreements to share the development of new water resources in the County
- Alternative C-1: Aquifer Storage and Recovery
    - Discuss permitting ASR with MDE to confirm treatment, monitoring, and water quality requirements

In conclusion, the results of the preliminary screening assessment indicate that CCG has numerous potential options available to meet current and future water demands reliably and safely. Additional work is required to better identify the most feasible and cost-effective options for future investment among the alternatives carried forward from Phase A-1.

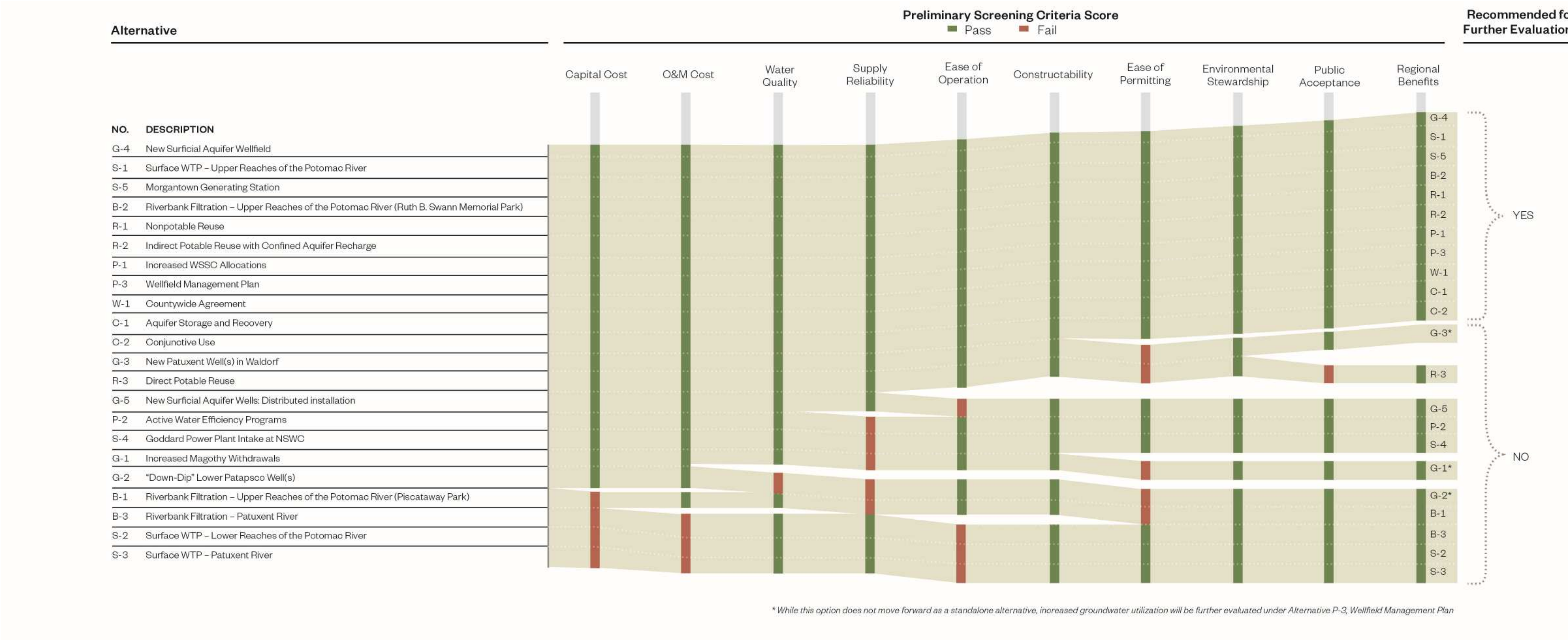

Figure ES-2: Summary of Evaluated Water Source Alternatives and Preliminary Screening Assessment Results

Introduction

The Charles County Government (CCG) is the primary water utility for the County, operating 31 of the approximately 52 water systems serving Charles County residents in addition to approximately 6,000 customers in Prince George's County. The County's water supply system consists of multiple individual systems, some of which are connected and others that are standalone. The largest system is the Waldorf system, which comprises nearly 90% of the demands for the overall CCG system. The County has historically relied on groundwater as the primary source of supply, supplemented with purchased finished water from the Washington Suburban Sanitary Commission (WSSC). Over the years, as the population has grown, groundwater resources have become constrained, requiring the County to shift to deeper aquifers. While current average daily demands of approximately 5.3 mgd for the Waldorf system are within the permitted allocation of approximately 7.07 mgd, the system may reach capacity by 2020 and is projected to exceed the current capacity by 2.5 mgd by 2040. In light of projected growth and in response to continued water level decline (i.e. drawdown) of the regional aquifers, the Maryland Department of the Environment (MDE) is requiring the County to perform this Water Alternatives Analysis Study[1] to evaluate potential options for supplying the CCG Waldorf water system's future demand. However, due to the fact that nearly all water for domestic, industrial, and agricultural use in the County is withdrawn from the same confined aquifers and that the CCG Bryans Road system and a number of other smaller systems are also projected to experience a shortfall by 2040, the scope of the study is not limited to one CCG system in order to comprehensively assess supply options county-wide.

The purpose of the study is therefore to evaluate the feasibility of developing, treating, and distributing alternative water sources for public drinking water supply for the Charles County Public Water System. Because nearly all water for domestic, industrial, and agricultural use in the County is withdrawn from the same confined aquifers, options considered in this report are not strictly limited to the Waldorf system. The evaluation is a comprehensive review of all potential water sources in the County and includes increasing the quantity of water purchased from WSSC; developing a surface water supply; developing new wells in the confined aquifers; developing new withdrawals from the unconfined aquifer; water re-use; and water conservation, or a combination of options. Several of these options could involve collaboration and future partnership with the local incorporated towns, which can be further assessed in the subsequent phase of the project.

The results of this study will be used to formulate a plan for developing future water resources for the County and will accordingly help to shape the future of drinking water supply in the region. Phase A-1 of this study, provided herein, is to conduct an initial screening analysis of the full range of potential options in order to screen out those with fatal flaws. The surviving, feasible options will be carried forward into Phase A-2 for system modeling analysis and full triple bottom line[2] analysis.

The scope of the screening assessment for Phase A-1 includes the following components:

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[1] Condition No. 20 in permit CHI970G009(14)

[2] A triple bottom line analysis is an assessment of the economic, social, and environmental implications (i.e. costs and benefits) of a project.

- Identify alternative water sources
- Collect available data on surface water and groundwater resources (water quality, aquifer characteristics, etc.)
- Collect available data on countywide demands (both potable and non-potable), and estimate future demands for drinking water
- Collect GIS data on and conduct site visits to County water supply infrastructure
- Summarize water treatment processes to address water quality of potential sources of supply
- Conduct outreach to stakeholders across the County about the availability of shared resources (e.g. WSSC, Town of Indian Head, Town of La Plata, Naval Surface Warfare Center, Morgantown Generating Station, etc.)
- Develop criteria for comparing and screening options
- Evaluate feasibility of each option based on preliminary screening criteria
- Identify alternative water sources for further evaluation based on feasibility screenings
- Identify technical tasks to further evaluate alternatives and develop recommendations for next steps

This report summarizes the important considerations for developing alternate water resources in the County (e.g. sources of supply, demands, water quality considerations, etc.) and presents evaluations of each alternative based on the screening criteria. Results are summarized and recommendations are provided to guide work in the forthcoming Phase A-2 of the project, which includes a more in-depth Triple Bottom Line Analysis of the feasible options identified herein.

Water Transmission and Distribution

The MDE indicates there are 52 community and municipal water systems in Charles County (MDE, 2015). Many of these systems are small neighborhoods or businesses with a single well, or systems that purchase water from a CCG system. The primary systems in the County include the CCG, Town of Indian Head, Town of La Plata, and the Naval Support Facility Indian Head (Table 1 and Figure 1). The systems operated by the CCG are grouped into large systems with capacities greater than 50,000 gpd and small systems with capacities less than 50,000 gpd. In addition to the systems listed on Table 1, the CCG has taken ownership of developer-constructed communities and added them to the Waldorf system over the years. These communities include Bensville, Quiet Acres, Dutton's Addition, Foxhall Estates, Laurel Branch and Eutaw Forest.

Table 1: Charles County Government and Other Municipal Water Systems in Charles County

Category	Subgroup	System
Large CCG Systems (Capacity larger than 50,000 gpd)		Waldorf
		Bryans Road
		Swan Point
		Hunters Brooke
		Clifton-on-the-Potomac
Small CCG Systems (Capacity smaller than 50,000 gpd)	South Communities	Ellenwood
		Mariellen Park
		Newtown Village
		Chapel Point Woods including Jude House
		Bel Alton Estates
	Other Small Communities	Avon Crest
		Beantown Park
		Benedict
		Brookwood Estates
		Laurel Branch
		Mt. Carmel Woods
		Oakwood
		Spring Valley
		Strawberry Hill Estates
		Port Tobacco Complex
	Small communities with capacities less than 2,000 gpd	White Plains Park
		Laurel Springs Park
		Oak Ridge Park
		Bryantown Park
		Gilbert Run Park
		Nanjemoy Community Center
		Potomac Branch Library
		Pisgah Park
Other Municipal Systems		The Town of Indian Head
		The Town of La Plata
		Naval Support Facility Indian Head

Existing CCG water transmission and distribution system infrastructure mainly consists of wells and well supply pumps, elevated or ground storage tanks, hydropneumatic tanks and water transmission and distribution system pipelines serving individual communities. There is no countywide transmission and distribution system. Major demand centers are listed in Table 2. Water storage capacities and elevated tank overflow elevations of major communities are listed in Table 3.

Table 2: Major Charles County Municipal and Community System Domestic Water Use[3]

System	Use (gal)	% of Total Use
CCG (Waldorf)	5,300,000	64.4%
Naval Support Facility Indian Head	1,150,000	14.0%
Town of La Plata	725,000	8.8%
CCG (Bryans Road)	375,000	4.6%
CCG Standalone Communities Cumulative Use	360,000	4.4%
Town of Indian Head	315,000	3.8%
Total Domestic Demand	**8,225,000**	**100.0%**

Table 3: Domestic Water Storage Capacities of Major Charles County Municipal and Community Systems

Community	No	Name	Capacity (Gallon)	Ground Elevation (feet)	Low Level Elevation (feet)	Overflow Elevation (feet)
Waldorf	1	Bensville (Elevated)	500,000	189.50	332.50	370.00
	2	Berry Hill Manor (Elevated)	250,000	212.50	341.67	370.00
	3	Pinefield (Elevated)	1,000,000	217.00	335.00	370.00
	4	St. Charles (Elevated)	2,000,000	205.00	335.00	370.00
	5	Waldorf No.5 (Elevated)	2,000,000	212.00	336.00	371.00
	6	Westlake (Elevated)	2,000,000	217.00	336.00	371.00
	7	Firehouse (not in service)	200,000	216.00	336.00	365.38
		Total Waldorf Capacity (Tanks in service)	7,750,000			
La Plata	1	Wills Park (Elevated)	300,000	185.30	282.45	307.45
	2	Dorchester (Elevated)	750,000	202.58	269.08	307.58
	3	Rosewick (Elevated)	250,000	196.62	282.62	313.62
	4	Box Elder (Ground Storage)	750,000	180.57	180.57	211.57
		Total La Plata Capacity	2,050,000			
Bryans Road	1	Bryans Road Tower	1,000,000	(1)	(1)	(1)
	2	Bryans Road No 2 (Hydropneumatic)	20,000	(1)	(1)	(1)
	3	Strawberry Hills No 2 (Ground storage, not in service)	200,000	(1)	(1)	(1)
		Total Bryans Road (Tanks in service)	1,020,000	(1)	(1)	(1)
Indian Head						
Naval Support Facility Indian Head	1	Tank 1	500,000	NA	NA	263.00
	2	Tank 2	500,000	NA	NA	268.00
	3	Tank 3	500,000	NA	NA	257.00
		Total Domestic Use Storage Capacity	(1)	(1)	(1)	(1)

(1) Data have been requested, but have not been received.

A transmission main ("South County Main") is in the concept planning stage to serve the South Communities (Ellenwood, Mariellen Park, Newtown Village, Chapel Point Woods, Jude House and Bel Alton) from the Town of La Plata and with an ultimate connection to Waldorf. Therefore, these small systems to the south of the Town of La Plata are grouped together in Table 1. The planned transmission

[3] MDE exempts many uses from Water Appropriation and Use Permits, including individual domestic use, agricultural withdrawals less than 10,000 gpd, and most other non-potable uses less than 5,000 gpd. Therefore, it is not possible to track the source or rate of these withdrawals.

mains are intended not only to serve the South Communities but to connect Waldorf and La Plata, providing system reliability and redundancy, and potentially a backbone for a countywide transmission system that can be used to transmit water from water supply sources evaluated in this study. The CCG is also planning to provide a connection between the Waldorf and Bryans Road systems to support additional redundancy and reliability.

In addition to water supplied from groundwater resources, the CCG can purchase up to 1.4 mgd of treated water from WSSC. The WSSC supply is connected to the Waldorf system at the northwest side of the Waldorf system. The connection point is at 2250 Sawmill Place. WSSC water is supplied from the Accokeek Elevated Storage Tank with an overflow elevation of 345 feet. The overflow elevation of the Waldorf elevated tank system is at 370 feet elevation. A 10 inch transmission main supplies water from the Accokeek tank to a booster station that lifts the WSSC supply to the Waldorf hydraulic grade line of 370 feet.

Water transmission alignments from supply alternatives to the demand centers will be evaluated once the locations of feasible water supply alternatives are determined. Initially the following transmission main alignments have been identified for transmission of water from sources to the demand centers and for providing interconnection between communities:

1. Indian Head Highway (Route 210) and Route 228 for transmission in the East-West direction that can connect communities including Town of Indian Head, Bryans Road and Waldorf
2. Route 301, St. Charles Parkway and Route 6 for transmission in North South direction that can connect communities including Waldorf, Town of La Plata and South Communities

Figure 1 shows the communities served by CCG and potential interconnections and alignments, as well as potential water transmission alignments to communities that are near proposed mains (including Hunters Brooke, Gilbert Run Park, Oak Ridge Park) and that are remote (including Doncaster, Benedict, Cliffton and Swan Point).

Figure 1: Communities Served By The Charles County Water Supply and Distribution System

Charles County Water Resources

Charles County faces significant challenges as demand growth outstrips the capacity of current water supplies. However, while the citizens of Charles County have historically relied on groundwater resources to meet potable water demands, the region benefits from plentiful water resources, including two major rivers, the Potomac and the Patuxent; seasonally reliable rainfall recharge; multiple confined and unconfined aquifers; a neighboring water supply with large capacity; and high quality wastewater effluent that is already meeting water demands for power production cooling water. While none of these potential water sources is without technical, financial and/or policy challenges, overall they provide a positive outlook for the County's search for a safe, reliable, and sustainable set of options to support continued regional growth with high quality water.

Groundwater Resources

There are five primary aquifers that underlie Charles County (Figure 2), Surficial Upland, Aquia, Magothy, Patapsco, and Patuxent. State regulations allow withdrawals from confined aquifers so long as it does not result in drawdown below the "80% Management Level," which represents 80% of the drawdown from the pre-pumping potentiometric surface (well water-level) to the top of the aquifer on an individual well basis (MDE 2013). Wells operated by CCG in the Magothy and Patapsco aquifers have come close to this regulated limit in the recent past. MDE has, therefore, adjusted CCG's appropriation to maintain the aquifers above this limit. Table 4 presents a summary of appropriations permitted by MDE for each aquifer compiled by MGS based on 2011 data and current CCG appropriations.

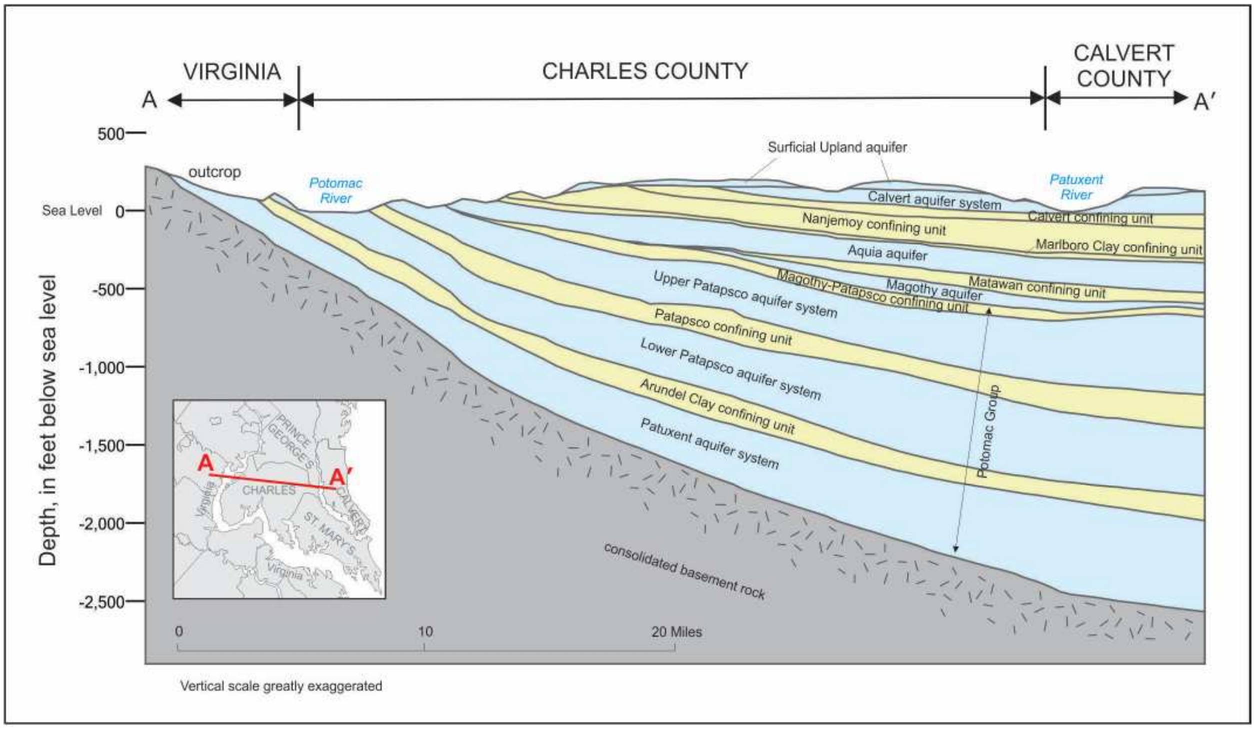

Figure 2: Schematic Hydrogeologic Cross Section Showing Relation of Aquifers through Northern Charles County (reprinted from Staley, 2015).

Table 4: Average Annual Permitted Groundwater Appropriations for Coastal Plain Aquifers in Charles County

Aquifer	Total Permitted Appropriation in Charles County, 2011 (mgd) (MGS, 2015)[4]	Permitted Appropriation for CCG (mgd)[5]	Percent of Total Appropriations by CCG
Surficial	2.9	0	0%
Aquia	0.75	0.036	5%
Magothy	3.3	2.9	88%
Patapsco (lower and upper)	15.0	3.55	24%
Patuxent	1.5[6]	0.57	38%
Total	**25.0**	**7.06 (7.20)[7]**	

The following text summarizes the five primary aquifers in Charles County based on the Maryland Geological Survey (MGS) *Report of Investigations No. 76: Water-Supply Potential of the Coastal Plain Aquifers in Calvert, Charles, and St. Mary's Counties, Maryland, With Emphasis On The Upper Patapsco and Lower Patapsco Aquifers*, dated August 2007 and the Charles County Comprehensive Plan, Water Resources Element, adopted in 2011.

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[4] Table lists permitted appropriations, actual withdrawals may be less. Uses that are exempt from Water Appropriation and Use permits (e.g. individual domestic wells, agricultural withdrawals less than 10,000 gpd, etc.) are not included.
[5] Based on available data
[6] Appropriations for the Chalk Point Generating Station in Prince George's County add approximately 1.5 mgd to the total appropriation from the Patuxent aquifer.
[7] Value in parenthesis includes permitted appropriations for wells that formation data is not available

Surficial Upland Aquifer: The unconfined, water-table aquifer on the western shore in southern Maryland is referred to as the Surficial Upland aquifer. The Surficial Upland aquifer is associated with deposits consisting of gravel, sand silt and clay found at elevations above 40 feet above mean sea level. Less significant water-table aquifers are found at lower elevations, and tend to be finer grained and less productive.

The Surficial Upland aquifer is exposed at the land surface, and receives recharge directly from precipitation. Hydrogeologic processes such as evaporation, transpiration to plants, and base flow to streams occur within the Surficial Upland aquifer. It provides recharge to deeper aquifers, either as leakage through intervening confining units or as direct infiltration where it directly contacts an underlying aquifer. The Surficial aquifer is tapped by some irrigation wells and older farm and domestic wells, but is not widely used for potable water supply because of its vulnerability to contamination and reduced dependability during droughts.

Water levels in the Surficial Upland aquifer fluctuate seasonally due primarily to cyclic variations in evapotranspiration and interannual precipitation variations. On average, seasonal precipitation is fairly constant throughout the year in Maryland. During the growing season, plants consume water within their root zones reducing the available recharge from precipitation, and the water table declines. When the growing season is over, recharge from precipitation goes into storage, and the water table rises. The water table also varies from year to year, with a higher water table in years with abundant precipitation. Water levels in the Surficial Upland aquifer will generally decline without recharge from precipitation as groundwater flows from upland areas to topographic lows where groundwater discharges to seeps, springs or streams. Hydrographs from shallow wells open to the Surficial Upland aquifer typically do not show long-term water level trends although reduced recharge resulting from changes in land use or pumping may result in a locally depressed the water table. Limited data on water quality is available on the Surficial Upland aquifer.

An additional noteworthy feature of the Surficial Upland aquifer is a paleochannel,[8] which has been mapped in northern Charles County near the Potomac River that is likely to be unconfined or semi-confined and contain potentially productive basal coarse grained sand and gravel deposits. The location of the Paleochannel is identified in the vicinity of Indian Head, generally following Mattawoman Creek and crossing the Indian Head peninsula west of Potomac Heights (Hiortdahl, 1997). The paleochannel may extend on land further to the north in Charles County based on mapping in Virginia (Froelich et al, 1978). The paleochannel eroded into the Patapsco formation to approximately 75 feet below sea level at Indian Head and the infill deposits are likely hydraulically connected to the Potomac River. The paleochannel deposits are interpreted to be potentially favorable for the development a water supply using induced riverbank infiltration (Hiortdahl, 1997).

Aquia aquifer: The Aquia aquifer underlies the surficial aquifer and is comprised of sandy sediments of the Aquia Formation in eastern Charles County. The Aquia aquifer is used extensively for domestic and major-user supplies in Southern Maryland, as well as in Virginia and the Eastern Shore of Maryland. Utilization by CCG is limited to the eastern portion of the

[8] A remnant of a river or stream channel that has been either filled or buried by younger sediment.

county (Table 5) and is not generally used for water supply west of U.S. Route 301 in the County. It outcrops or subcrops in a southwest to northeast trending band, roughly 10 miles wide, from Virginia through northern Charles County to Prince George's and Anne Arundel Counties, and the Eastern Shore of Maryland. Since 1975, water levels have declined in the Aquia aquifer on the order of 50 to 100 feet in areas of Calvert and St Mary's counties where the aquifer is heavily pumped for public supplies and other uses. Individual domestic wells also utilize the Aquia aquifer in this area, and declining water levels have caused failures in some wells.

Table 5: CCG Wells in the Aquia Aquifer

System	Number of Wells	MDE Water Appropriation and Use Permit		
		Number	Annual Average Daily Use (gpd)	Max Month Daily Average (gpd)
Benedict	2	CH1980G020(05)	36,000	54,000

Water quality in the Aquia aquifer is generally good; however, arsenic concentrations in some places exceed the United States Environmental Protection Agency's (USEPA) Maximum Contaminant Level (MCL) of 10 micrograms per liter (μg/L) for public water supplies (Drummond 2007). Because of these considerations, water-supply managers in Calvert and St. Mary's Counties are seeking to shift some ground-water usage from the Aquia aquifer to the deeper Patapsco aquifers.

Magothy aquifer: The Magothy aquifer underlies the Aquia aquifer, and is separated from it by the Brightseat confining unit. The Magothy aquifer primarily comprises the sandy portion of the Magothy Formation. The Magothy aquifer "pinches out" (decreases to zero thickness) in central Charles County (Figure 3), but is used extensively for domestic and public supplies in northeastern Charles County (Table 6). The Magothy aquifer crops out only in central Anne Arundel County, and does not receive recharge directly within Charles County.

The potentiometric surface of the Magothy aquifer shows a cone-of-depression in the Waldorf area. The Magothy aquifer is heavily pumped in this area for the public-supply system. Hydrographs of two wells screened in the Magothy aquifer located south of Waldorf show a significant drawdown over the past several decades. In recent years, a reduction of the withdrawals from the Magothy aquifer by increasing withdrawals from the Upper Patapsco, Lower Patapsco, and Patuxent aquifers, has resulted in stabilized water levels in the Magothy aquifer near Waldorf. CCG is currently permitted to withdraw up to 2.87 mgd from the Magothy aquifer for the Waldorf water system, which is approximately 50% less than that which was previously allocated in the late 1990's.

CCG has multiple wells completed in the Magothy aquifer and relies heavily on the aquifer to supply the Waldorf system (Table 6). Permit CH1970G009(14) allocates an annual average daily use of 2,870,000 gpd and 4,150,000 gpd maximum month use from the Magothy aquifer from nine wells in Waldorf in addition to smaller allocations from the Spring Valley and Brookwood wells.

Table 6: CCG Wells in the Magothy Aquifer

System	Well Name	MDE Water Appropriation and Use Permit		
		Number	Annual Average Daily Use (gpd)	Max Month Daily Average (gpd)
Waldorf	Billingsley Road - M	CH-04-2573	2,870,000	4,150,000
Waldorf	Cleveland Park – M	CH-73-1518		
Waldorf	John Hanson	CH-73-1750		
Waldorf	Mattawoman – Beantown	CH-04-2572		
Waldorf	Pinefield	CH-73-2423		
Waldorf	Piney Church	CH-73-2889		
Waldorf	St. Charles	CH-70-0087		
Waldorf	Towne Plaza	CH-81-0135		
Waldorf	Westwood Drive – M	CH-81-2310		
Spring Valley		CH1973G001(05)	9,600	16,000
Brookwood		CH1967G009(08)	5,000	30,000

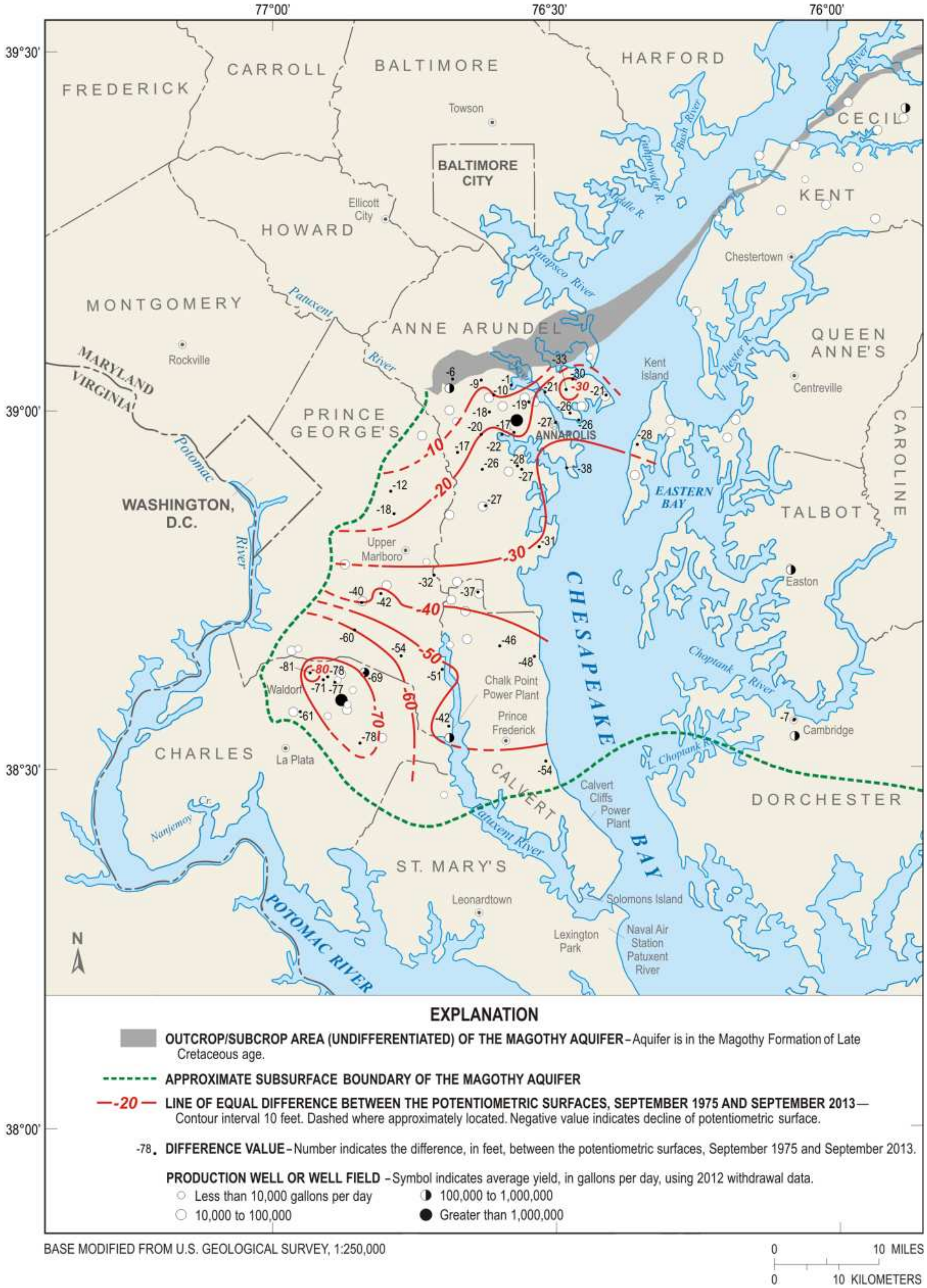

Figure 3: Extent of the Magothy aquifer in Charles County and the Current Estimated Drawdown between 1975 and 2013 (Staley, Andreasen & Curtin 2014)

Patapsco aquifer: The Patapsco Formation is divided into the Upper and Lower aquifers based on hydraulic and structural characteristics. While the two aquifers are physically similar, well data indicate that they are hydraulically disconnected. Water quality across the two aquifers is characterized as good; however, some wells, which are screened in both the Upper and Lower Patapsco aquifer systems, have exceeded the Maximum Contaminant Level (MCL) of 15 picocuries per liter for gross alpha-particle activity as a result of naturally occurring polonium 210. Elevated gross alpha radiation has required wells to be taken offline (e.g. Jude House) or wellhead treatment installed (e.g. Chapel Point). At this time there are insufficient data to determine which vertical strata are contributing to the observed polonium 210 concentrations. MGS has a number of studies planned to refine their understanding of polonium 210 occurrence in the Patapsco aquifer.[9]

The Upper Patapsco aquifer underlies the Magothy aquifer where the Magothy is present, and underlies the Aquia aquifer where the Magothy is absent. The Upper Patapsco aquifer includes sandy beds in the upper part of the Patapsco Formation, which appear to be sufficiently interconnected at the regional scale to form a single aquifer. The Upper Patapsco aquifer extends to the northeast through Prince George's and Anne Arundel Counties, and beneath the Chesapeake Bay to the Eastern Shore of Maryland. It extends southwest across the Potomac River, into Virginia. The bluffs along the Potomac River in northwestern Charles County contain outcrops of the upper part of the Potomac Group, and the Upper Patapsco aquifer outcrops and subcrops in this area. It also subcrops beneath the Potomac River, and river-water intrusion has occurred in the Indian Head area from the tidal part of the river (Hiortdahl, 1997). Outcrop and subcrop areas provide recharge to the aquifer. The Upper Patapsco aquifer is used for public supply and domestic users in Charles County. It is also pumped heavily by major users in Prince George's and Anne Arundel Counties to the north. A few major users pump the Upper Patapsco aquifer in Calvert and St. Mary's Counties, and it is used on the Eastern Shore of Maryland as far south as Crisfield, in Somerset County. Table 7 presents the available data on CCG wells completed in the Upper Patapsco aquifer.

Water levels have declined significantly in the Upper Patapsco aquifer since pumping began in northwestern Charles County. A cone-of-depression has formed in the Upper Patapsco aquifer, centered in the La Plata area, which was 136 feet below sea level in 2002. This cone-of-depression probably extends northwest to the Potomac River, where it may induce river-water intrusion. It may extend southeast to the Lexington Park area, where withdrawals for public supply began in the early 2000's.

[9] David Andreasen, personal communication on 1/7/16).

Table 7: CCG Wells in the Upper Patapsco Aquifer

System	Number of Wells	MDE Water Appropriation and Use Permit		
		Number	Annual Average Daily Use (gpd)	Max Month Daily Average (gpd)
Chapel Point Woods	3	CH1976G011 (05) CH1976G011 (06)	80,000	120,000
Ellenwood	2	CH1975G002 (06)	27,000	38,000
Bel Alton	2	CH1974G010 (07)	26,000	37,000
Port Tobacco Complex	1	CH1977G016(04)	3,000	5,000

The Lower Patapsco aquifer underlies the Upper Patapsco aquifer, and is comprised of sandy units in the lower part of the Patapsco Formation. Like the Upper Patapsco aquifer, the Lower Patapsco aquifer is composed of numerous sandy beds, which may be hydraulically separated locally, but coalesce on a regional scale to form a single aquifer. The extent of the Lower Patapsco Aquifer is considered to be smaller than the Upper Patapsco Aquifer. Water levels have declined significantly in the Lower Patapsco aquifer, especially in the northwestern Charles County area where a cone-of-depression is present. This cone-of-depression extends northwest to the Potomac River, and probably to the outcrop area in Virginia and Prince George's County. Table 8 presents the available data on CCG wells completed in the Lower Patapsco aquifer.

Permit CH 1989G032(05) allocates an annual average daily use of 200,000 gpd and 400,000 gpd maximum month use from the Lower Patapsco aquifer for the wells at Bensville, Laurel Branch and Duttons Addition. Permit CH1983G012(08) allocates an annual average daily use of 2,600,000 gpd and 4,000,000 gpd maximum month use from the Lower Patapsco aquifer for the remaining seven wells in Waldorf. In addition to the wells that are completed in either the Upper or Lower Patapsco aquifers, Table 9 presents data on wells that are lacking specific formation details.

Table 8: CCG Wells in the Lower Patapsco Aquifer

System	Well Name	MDE Water Appropriation and Use Permit		
		Number	Annual Average Daily Use (gpd)	Max Month Daily Average (gpd)
Waldorf	St. Pauls	CH-81-0738	2,800,000	4,400,000
Waldorf	Smallwood West	CH-81-1194		
Waldorf	White Oak	CH-81-1195		
Waldorf	Billingsley Road – P	CH-88-0341		
Waldorf	Cleveland Park – P	CH-94-0464		
Waldorf	Westwood Drive – P	CH-94-3965		
Waldorf	St. Charles Tower	CH-94-6686		
Waldorf	Bensville No.1	CH-94-0724		
Waldorf	Bensville No.2	CH-94-0037		
Waldorf	Laurel Branch	CH-88-0124 CH-88-0765		
Waldorf	Duttons Addition	CH-03-0385		
Cliffton	Two wells	CH1983G014(04)	85,000	130,000
Brookwood		CH1967G109(05)	52,500	52,500
Bryans Road	South Hampton #3 South Hampton #1	CH1955G003(06)	44,400	270,000
Strawberry Hills		CH1966G005(09)	17,000	200,000
Mt. Carmel Woods	Two wells	CH1966G108(03)	15,000	22,000
Oakwood		CH1964G004(06)	5,000	7,000

Table 9: CCG Wells in the Patapsco Aquifer (unspecified)

System	Number of Wells	MDE Water Appropriation and Use Permit		
		Number	Annual Average Daily Use (gpd)	Max Month Daily Average (gpd)
Bensville Park	4	CH1989G032(04)	299,400	500,000
Swan Point	2	CH1972G002(05)	60,000	100,000
Mariellen Park	3	CH1965g011 (05)	18,000	23,000
Newtown Village	3	CH1967G002 (05)	14,700	24,500
Jude House	2		NA	NA

Patuxent aquifer:

The Patuxent aquifer underlies the Lower Patapsco aquifer, and is separated from it by the Arundel confining unit. The Patuxent aquifer is the deepest Coastal Plain aquifer in the study area, and rests on the bedrock surface. The top of the Patuxent aquifer is approximately 400 feet below sea level in northwestern Charles County and approximately 1,800 feet below sea level in the eastern portion of the County. The well yields from the Patuxent aquifer are highly variable due to the variable thickness, number, and lateral extent of the individual sand intervals intersected. A recent hydrogeological investigation (Staley, 2015) of the Patuxent aquifer in northern Charles County indicated that development of the aquifer in this region may be constrained by deep drilling depths, declining water levels, and relatively low transmissivity. The aquifer thickens to the southeast, although the proportion of sand intervals was interpreted to decrease as the aquifer thickens. The Patuxent aquifer is used for public water supply by a few wells in northwestern Charles County and for cooling water at the Chalk Point Generating Station. Water quality is characterized as good, but some wells can have elevated iron and manganese levels.

Table 10: CCG Wells in the Patuxent Aquifer

System	Well Name	MDE Water Appropriation and Use Permit		
		Number	Annual Average Daily Use (gpd)	Max Month Daily Average (gpd)
Bryans Road	SH-2 FH-6	CH1996G123(02)	570,000	781,000

Surface Water Resources

Surface water hydrology in Charles County is dominated by the Potomac River, which is a major river with a watershed of over 12,000 square miles. The Potomac River is located along Charles County's western boundary. The County abuts the river along approximately 60 river miles of its length. The Patuxent River along the eastern boundary of the County is a sizable waterbody, but with a substantially smaller watershed, approximately 937 square miles. Charles County has approximately five miles of river frontage along the Patuxent River.

In addition to these two major river systems that are adjacent to the County, there are a number of smaller drainages that flow through the County (Table 11). The drinking water supply potential of these surface water sources is limited primarily by their small watersheds, which significantly limits typical flows. Any substantial yield would require the construction of a reservoir to capture inflows from peak flow events. Further, generally low relief topography and the presence of sensitive environments (Zekiah Swamp Natural Environment Area, Zekiah Watershed Rural Legacy Area, Nanjemoy Creek Preserve, etc.) would be obstacles to the development of local surface water resources.

Table 11: Charles County Watersheds

Watershed	Watershed area (square miles)	Watershed Organization
Pomonkey Creek	42	
Nanjemoy Creek	73	
Mattawoman Creek	94	Mattawoman Watershed Society
Port Tobacco River	47	Port Tobacco River Conservancy
Zekiah Swamp/Wicomico River	110	Wicomico Scenic River Commission

The Potomac and Patuxent rivers comprise the most promising surface water sources for new County drinking water supplies. However, water quality of these sources poses a challenge. Both rivers are tidal tributaries of the Chesapeake Bay and, depending on location, can have salinity levels well above levels that would require desalination to make the water potable (CBP, 2008). Further, because Charles County is downstream of the Washington DC metropolitan area (WMA), both rivers receive substantial contributions of treated wastewater effluent and are at risk for urban, non-point source pollution, which increases pathogens, nutrients, and organic matter in the rivers. The Potomac River in the vicinity of Charles County can thus be susceptible to harmful algal blooms, particularly in summer months when water temperatures are high and natural flows are low (Figure 4) (MWCOG 2014). Algae is also a problem in the Patuxent River, but the location of blooms relative to the County has not been mapped. Water quality issues in the rivers would not preclude the ability to use the resources for drinking water, but these challenges would require more sophisticated and potentially more costly treatment to manage water quality.

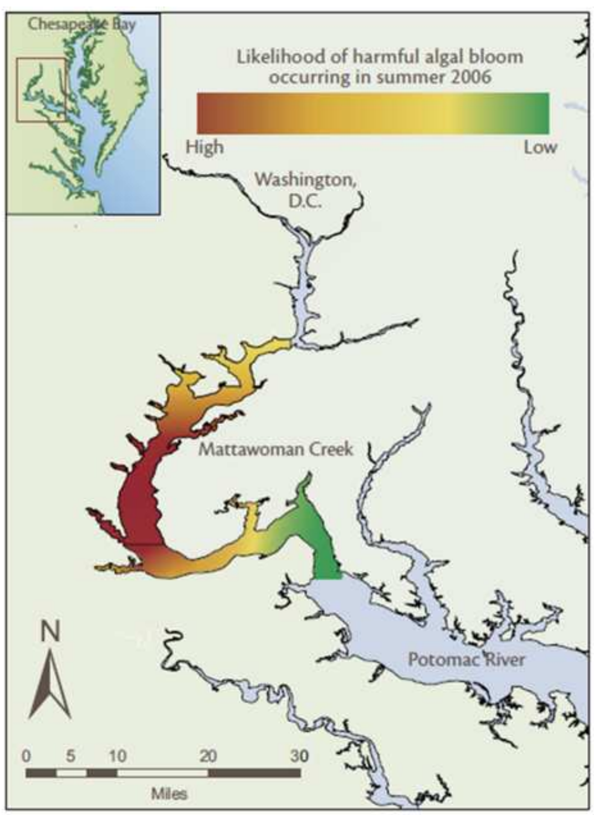

Figure 4: Harmful Algal Bloom Forecast, Potomac River, summer 2006 (CBP, 2006)

Charles County Demand Analysis

In order to understand the current demands and project future demands for planning purposes, the Hazen team reviewed CCG documents (e.g. the Charles County Comprehensive Plan, the Waldorf Water Capacity Management Plan, and the Water and Sewer Allocation system Modification) and production data from Monthly Operating Reports from January 2013 through October 2015.

The Charles County Comprehensive Plan (August 2015 Draft) projects water supply deficits by 2040 for the Waldorf, Bryans Road, and Clifton-on-the-Potomac systems (Table 12). Projections are based on a dwelling units demand of 208 gallons per day for CCG systems. Additionally, the Comprehensive Plan projects deficits for the Town of La Plata of between 0.86 to 0.94 mgd on an annual average. The Town of Indian Head and NSFIH are not showing deficits by 2040.

Table 12: Current and Projected Annual Average Daily Demands for Select CCG Systems[10]

System	Scenario	Existing permitted production, MGD	2013 – 2014 daily demand, MGD	CCG 2040 projected demand, MGD	2040 projected system capacity, MGD	2040 available capacity (deficit), MGD
Benedict	A	0.056	0.019	0.027	0.056	0.029
	B	0.056	0.019	0.026	0.056	0.030
Bryans Road	A	0.57	0.40	0.80	0.57	-0.23
	B	0.57	0.40	0.77	0.57	-0.20
Clifton-on-the-Potomac	A	0.085	0.054	0.095	0.09	-0.005
	B	0.085	0.054	0.092	0.09	-0.002
Hunter's Brooke	All	0.116	0.046	0.046	0.116	0.070
Swan Point	A	0.50	0.061	0.161	0.50	0.34
	B	0.50	0.061	0.161	0.50	0.35
Waldorf System	A	7.07	5.30	9.61	7.07	-2.54
	B	7.07	5.30	9.61	7.07	-2.54

The Waldorf system Capacity Management Plan dated 2015 indicates that annual average daily drought demand[11] will reach the available capacity (permitted groundwater appropriations plus 1.4 mgd of purchased water from WSSC) by approximately 2020. The Capacity Management Plan estimate for future growth uses an estimate of 185 gpd per dwelling unit. The Capacity Management Plan projections are limited to 2024 and indicate a deficit for the Waldorf system between 0.42 and 0.84 mgd.

The water and Sewer Allocation Modification Report included a ten year flow analysis from 2001 to 2010 to identify water demands and sewer loadings. The report indicated there was a steady decline in residential consumption per dwelling unit from approximately 190 gpd to approximately 170 gpd. Current

[10] Source of these projections is the Charles County Comprehensive Plan (August 2015 Draft), the Hazen team is continuing to analyze county data to develop an updated demand projection. As stated in the Plan, "2040 projected system capacity" incorporates ongoing, planned, and recommended upgrades and expansions.
[11] Annual average daily drought demand is calculated based on the maximum annual average daily demand over the last five years multiplied by an additional 10%.

analyses of water billing data suggest the downward trend in water use per dwelling unit has continued through the end of 2015.

Recent production data from operating reports for January 2013 through October 2015 exhibit a very small positive trend. Daily production is highly variable seasonally, peaking in the summer months. At the system level, the trend for the Waldorf system matches the overall system, mostly likely because it represents a majority of the overall production. Bryans Road water production behaves differently and has a less distinct seasonal pattern than those of Waldorf and the County overall. The estimated linear trend for Bryans Road production is positive and has a higher slope than for Waldorf or the county overall. However, average Bryans Road production flattens at the end of the period for which data are available. It should be noted that the limited extent of these data make it difficult to extrapolate long term trends.

As part of the data analysis, the CCG's data on water production and billing were compared to identify percentage of non-revenue or unaccounted for water from the system. The results indicate that CCG's unaccounted for water percentage is low (Table 13) and would not be a candidate for addressing future water supply needs.

Table 13: Production and Billed Water Use Comparison with Percent Unaccounted For (UA) Water (MG)

	2010	2011	2012	2013	2014	2015
Production	-	-	-	2202.7	2195.7	1102.7
Billed	2249.0	2161.3	2228.5	2141.7	2158.9	1012.9
Difference	-	-	-	61.0	36.8	89.8
Percent UA	**-**	**-**	**-**	**2.8%**	**1.7%**	**8.1%**

* Dash signifies unavailable data. 2015 data are for Jan. - June. Data exclude 8" sewer flow meter.

Accurate and robust estimates for growth projections, daily average demands and seasonal peaking factors are critical to sizing major infrastructure potentially required by CCG over the next five to 25 years. The Hazen team is continuing to analyze data provided by CCG to develop updated estimates of future demands. At this stage of the feasibility evaluation, specific demand projections are not needed. However, for cost estimates, a range of capacities are presented in order to provide an order of magnitude to guide subsequent discussions with the County.

Overview of Water Quality Considerations and Treatment Strategies

Water demand projections and increasing drawdown of regional aquifers in Charles County suggest that diversification of Charles County's water supply portfolio may be required to meet future demands. The majority of the water supply alternatives available in Charles County require more treatment and monitoring than existing groundwater supplies. Thus, the purpose of this section is to provide an overview of water quality considerations pertaining to various source waters, as well as the treatment processes that address these water quality considerations. Upon selection of potential water sources, it will also be critical to address the impacts of blending new water sources with existing water sources in the distribution system. One must consider the quality of all contributing water sources and the resulting combined quality when blended, the current condition of piping, and how all of these components interact. The overall goal is to produce high quality finished water at the water treatment facility and promote continued stability in the distribution sytem in order to ultimately deliver water at the point of use that meets or exceeds drinking water standards.

Water Quality Considerations

The level of treatment required to produce a safe, high quality, and aesthetically pleasing potable water that meets or exceeds all primary and secondary regulatory standards depends on the raw water quality and the extent to which treatment is needed. Primary drinking water standards are legally enforceable limits for public water systems that serve to protect public health. Secondary standards are non-mandatory guidelines that aim to minimize aesthetic, cosmetic, and technical effects (although states may elect to enforce secondary standards, which Maryland has not).

The following sections summarize contaminant types that fall under primary and secondary standards, as well as "contaminants of emerging concern" that may be regulated in the future, including background information and regulatory limits. In general, surface water sources are subject to stricter treatment and monitoring requirements than groundwater sources due to increased susceptibility to contamination and greater variability in water quality. It should be noted that the USEPA reviews and updates both the regulated parameters and the MCLs periodically to ensure the regulations are up to date with the current science on toxicity of various compounds. Accordingly, it is important when reviewing treatment options to consider the robustness of different processes for controlling contaminants that could face future regulatory limits.

Primary Drinking Water Contaminants

Microorganisms

Microorganisms in drinking water are monitored and subject to regulatory limits in order to reduce illness caused by pathogens. Pathogenic microorganisms are found naturally in the environment, and can originate from human and animal fecal waste. Thus, microorganisms are typically more of a concern in surface waters and groundwaters under the direct influence of surface water (GWUDI) due to the increased susceptibility of surface waters to contamination from upstream wastewater discharges, runoff, and spills, as opposed to confined groundwater aquifers. Under the USEPA's Surface Water Treatment Rule (SWTR), systems using surface water or groundwater under the direct influence of surface water (GWUDI) are required to disinfect and filter their water to achieve 2-log removal of *Cryptosporidium* oocysts, 3-log removal of *Giardia lamblia*, and 4-log removal of viruses (log removal values express percent removals in factors of 10; see Table 14). Additionally, USEPA's Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) requires that surface water treatment facilities conduct a monitoring program to assess the prevalence of *Cryptosporidium* in their source waters.[12] Monitoring results dictate the water treatment facility's bin classification, thus indicating the level of additional treatment required for *Cryptosporidium* removal in addition to the 2-log minimum (Table 15). The LT2ESTWR includes a "Microbial Toolbox" of technologies that can be used in combination to achieve the total required log removal.

Table 14: Log Removals and Corresponding Percent Removals

Log Removal	Percent Removal
0.5-log	68.4%
1-log	90%
1.5-log	96.8%
2-log	99%
2.5-log	99.7%
3-log	99.9%
4-log	99.99%
5-log	99.999%

Table 15: *Cryptosporidium* Bin Classification and Additional Treatment Requirements for Filtered Systems (adapted from USEPA's Long Term 2 Enhanced Surface Water Treatment Rule)

Observed *Cryptosporidium* Concentration (oocysts/L)	Bin Classification	Additional Treatment Requirements for Alternative Filtration Approaches		
		Conventional Filtration	Direct Filtration	Alternative Filtration Technologies
< 0.075	1	No additional treatment	No additional treatment	No additional treatment
≥ 0.075 and <1.0	2	1-log additional treatment[1]	1.5-log additional treatment[1]	As determined by the state
≥ 1.0 and <3.0	3	2-log additional treatment[2]	2.5-log additional treatment[2]	As determined by the state
≥ 3.0	4	2.5-log additional treatment[2]	3-log additional treatment[2]	As determined by the state

[1]Systems can use any combination of technologies from the Microbial Toolbox.
[2]Systems must achieve at least 1 log of total treatment using ozone, chlorine dioxide, UV, membranes, bag/cartridge filters, or bank filtration.
[3] LT2ESTWR: 40 CFR 141.710 and 40 CFR 141.711

Additionally, indicators of microbial pathogens, such as turbidity, total coliforms, and Heterotrophic Plate Counts, must be routinely monitored to ensure the microbial safety of finished water. Groundwater treatment systems must comply with microbial pathogen regulations outlined in the Groundwater Rule,

[12] Filtered water systems can forgo the source water monitoring and agree to provide the maximum 5.5 log treatment.

such as compliance monitoring to ensure 4-log removal of viruses and routine sanitary surveys. National Primary Drinking Water Regulations pertaining to microorganisms are summarized in Table 16 below. Microorganism removal from drinking water may be achieved by physical removal and/or inactivation.

Table 16: National Primary Drinking Water Regulations Pertaining to Microorganisms

Contaminant Group	Contaminant/Indicator Name	Monitoring/Treatment Requirements
Microorganisms	*Cryptosporidium*	Minimum 2-log removal required. Treatment effectiveness demonstrated by monitoring turbidity of the combined filter effluent at least every four hours and continuous monitoring of turbidity at individual filters.
	Giardia lamblia	Minimum 3-log removal required.
	Heterotrophic plate count	No limit. Lower bacteria concentration indicates better maintained water system.
	Legionella	No limit. Rule assumes if virus and *Giardia lamblia* limits are met, *Legionella* will be controlled.
	Total coliforms	The total number and location of samplings is based on the size of the population served. No more than 5% samples total coliform-positive in a month for systems that collect at least 40 samples per month. No more than one coliform-positive sample in a month for systems that collect less than 40 samples per month.
	Turbidity	<0.3 NTU at least 95% of time. Indicator of filter effectiveness, i.e., whether disease-causing organisms are present. Higher turbidity levels are often indicative of higher levels of disease-causing microorganisms. Grab samples every four hours or continuous monitoring.
	Viruses (enteric)	Minimum 4-log removal required.

[1]National Primary Drinking Water Regulations: 40 CFR 141

Disinfectants and Disinfection Byproducts

Disinfectants are added to drinking water to remove microbes from source water and control the regrowth of microbes in the distribution system. The term "disinfectant residual" refers to the concentration of readily available disinfectant in a water as it travels through the distribution system in order to prevent microbial contamination of water between the water treatment plant and the point of use. Although minimum disinfectant residuals are critical for conveyance of safe drinking water, maximum residual disinfectant levels must also be observed in order to avoid unintended consequences of delivering water with too much disinfectant (e.g., eye/nose irritation, upset stomach, anemia, nervous system impacts).

Additionally, disinfection processes can result in the formation of disinfection byproducts (DBPs), which have been linked to increased risk of cancer. Two classes of regulated disinfection byproducts, haloacetic acids (HAAs) and trihalomethanes (THMs), form when natural organic matter (NOM) in water reacts with free chlorine; bromate is a result of bromide interaction with ozone; chlorite occurs when chlorine dioxide is used. The formation of DBPs is controlled by the removal of DBP precursors (e.g., dissolved organic matter), disinfectant selection, and minimizing water age. In some cases it is feasible to remove DBPs after formation in the distribution system, such as through air stripping of volatile compounds. DBPs in drinking water are regulated through the USEPA's Stage 1 and Stage 2 Disinfectants and Disinfection Byproducts Rules. Table 17 summarizes the National Primary Drinking Water Regulations pertaining to disinfectants and disinfectant byproducts.

Table 17: National Primary Drinking Water Regulations Pertaining to Disinfectants and Disinfectant Byproducts

Contaminant Group	Contaminant/Indicator Name	Monitoring/Treatment Requirements
Disinfectants	Chloramines (as Cl_2)	Maximum residual disinfectant level of 4 mg/L. Daily samples at distribution system entry point. Frequent sampling throughout distribution system; frequency depends on size of system.
	Chlorine (as Cl_2)	
	Chlorine dioxide (as ClO_2)	Maximum residual disinfectant level of 0.8 mg/L. Daily sample at distribution system entry point. Four quarterly samples throughout the distribution system.
Disinfection byproducts	Bromate	Maximum contaminant level of 0.010 mg/L. If the system includes an ozone treatment step, one monthly sample.
	Chlorite	Maximum contaminant level of 1.0 mg/L. If the system includes chlorine dioxide addition, daily sample at distribution system entry point.
	Haloacetic acids (HAA5)	Maximum contaminant level of 0.06 mg/L (summation of HAA species). Four quarterly samples throughout distribution system.
	Total trihalomethanes (TTHMs)	Maximum contaminant level of 0.08 mg/L (summation of THM species). Four quarterly samples throughout the distribution system.

[1]National Primary Drinking Water Regulations: 40 CFR 141

Inorganic Chemicals

Inorganic chemicals on the National Primary Drinking Water Regulations list originate from a wide range of sources. Inorganic contaminants can be naturally occurring and end up in potable water sources through the erosion of natural deposits (e.g., arsenic, asbestos, barium, cadmium, chromium, and others). Industrial discharges can also be sources of inorganic contamination in source waters, such as fluoride emissions from fertilizer factories, cyanide from plastic factories, and mercury from refineries and landfills. The health effects associated with inorganic contamination of drinking water show the same breadth, ranging from kidney damage (cadmium) to blue-baby syndrome (nitrate, nitrite) to circulatory problems (selenium). Table 18 summarizes the National Primary Drinking Water Regulations pertaining to inorganic chemicals. For the majority of the listed contaminants, testing is only required once per year for surface water systems and once every three years for groundwater systems. Less frequent testing is required for groundwater systems due to groundwater typically being more consistent in quality than surface water. Most of the inorganic chemicals are elemental in nature, thus indicating that water treatment processes must operate based on physical removal versus destruction.

Table 18: National Primary Drinking Water Regulations Pertaining to Inorganic Chemicals

Contaminant Group	Contaminant/Indicator Name	Monitoring/Treatment Requirements
Inorganic chemicals	Antimony	Maximum contaminant level of 0.006 mg/L. Testing once a year for surface water systems; once every three years for groundwater systems.
	Arsenic	Maximum contaminant level of 0.010 mg/L. Testing once a year for surface water systems; once every three years for groundwater systems.
	Asbestos	Maximum contaminant level of 7 million fibers per liter. Testing once every nine years.
	Barium	Maximum contaminant level of 2 mg/L. Testing once a year for surface water systems; once every three years for groundwater systems.
	Beryllium	Maximum contaminant level of 0.004 mg/L. Testing once a year for surface water systems; once every three years for groundwater systems.
	Cadmium	Maximum contaminant level of 0.005 mg/L. Testing once a year for surface water systems; once every three years for groundwater systems.
	Chromium (total)	Maximum contaminant level of 0.1 mg/L. Testing once a year for surface water systems; once every three years for groundwater systems.
	Copper	Action level of 1.3 mg/L. Required to treat the corrosivity of treated water.
	Cyanide (as free cyanide)	Maximum contaminant level of 0.2 mg/L. Testing once a year for surface water systems; once every three years for groundwater systems.
	Fluoride	Maximum contaminant level of 4 mg/L. Testing once a year for surface water systems; once every three years for groundwater systems.
	Lead	Action level of 0.015 mg/L. Required to control the corrosivity of treated water.
	Mercury (inorganic)	Maximum contaminant level of 0.002 mg/L. Testing once a year for surface water systems; once every three years for groundwater systems.
	Nitrate (as N)	Maximum contaminant level of 10 mg/L. Four quarterly samples for surface water systems; once a year for groundwater systems.
	Nitrite (as N)	Maximum contaminant level of 1 mg/L. Sampling required during first three year compliance period; frequency determined by state.
	Selenium	Maximum contaminant level of 0.05 mg/L. Testing once a year for surface water systems; once every three years for groundwater systems.
	Thallium	Maximum contaminant level of 0.002 mg/L. Testing once a year for surface water systems; once every three years for groundwater systems.

[1]National Primary Drinking Water Regulations: 40 CFR 141

Organic Chemicals

Similar to inorganic chemicals, organic chemicals regulated under the National Primary Drinking Water Regulations originate from a wide variety of sources and result in a range of health effects. Organic chemical contamination of potable source waters can mostly be attributed to industrial discharges (e.g., benzene in factory discharge, and runoff/leaching of land applied chemicals, such as pesticides). Table 19 provides a summary of the National Primary Drinking Water Regulations pertaining to organic chemicals, all of which have the same corresponding compliance protocol. The organic chemicals are all compounds, as opposed to the aforementioned elemental inorganic compounds, thus indicating that water treatment processes that address organic contaminants may operate under the mode of physical removal (e.g., filtration) and/or destruction (e.g., oxidation).

Table 19: National Primary Drinking Water Regulations Pertaining to Organic Chemicals

Contaminant Group	Contaminant/Indicator Name	Monitoring/Treatment Requirements	
Organic chemicals	Acrylamide	Depends on if acrylamide and epichlorohydrin are used to treat water. If so, third-party certification required to verify specified levels are not exceeded.	Four consecutive quarterly samples during first compliance period. Compliance is based on annual average of quarterly samples. If no detections are found during initial round of sampling, two quarterly samples are required each year for systems serving > 3,300 connections and one sample is required every three years for smaller systems.
	Alachlor	Maximum contaminant level of 0.002 mg/L.	
	Aldicarb	Maximum contaminant level of 0.003 mg/L.	
	Aldicarb sulfoxide	Maximum contaminant level of 0.004 mg/L.	
	Aldicarb sulfone	Maximum contaminant level of 0.002 mg/L.	
	Atrazine	Maximum contaminant level of 0.003 mg/L.	
	Benzene	Maximum contaminant level of 0.005 mg/L.	
	Benzo(a)pyrene (PAHs)	Maximum contaminant level of 0.0002 mg/L.	
	Carbofuran	Maximum contaminant level of 0.04 mg/L.	
	Carbon tetrachloride	Maximum contaminant level of 0.005 mg/L.	
	Chlordane	Maximum contaminant level of 0.002 mg/L.	
	Chlorobenzene	Maximum contaminant level of 0.1 mg/L.	
	2,4-D	Maximum contaminant level of 0.07 mg/L.	
	Dalapon	Maximum contaminant level of 0.2 mg/L.	
	1,2-Dibromo-3-chloropropane (DBCP)	Maximum contaminant level of 0.0002 mg/L.	
	o-Dichlorobenzene	Maximum contaminant level of 0.6 mg/L.	
	p-Dichlorobenzene	Maximum contaminant level of 0.075 mg/L.	
	1,2-Dichloroethane	Maximum contaminant level of 0.005 mg/L.	
	1,1-Dichloroethylene	Maximum contaminant level of 0.007 mg/L.	
	cis-1,2-Dichloroethylene	Maximum contaminant level of 0.07 mg/L.	
	trans-1,2-Dichloroethylene	Maximum contaminant level of 0.1 mg/L.	
	Dichloromethane	Maximum contaminant level of 0.005 mg/L.	
	1,2-Dichloropropane	Maximum contaminant level of 0.005 mg/L.	
	Di(2-ethylhexyl) adipate	Maximum contaminant level of 0.4 mg/L.	
	Di(2-ethylhexyl) phthalate	Maximum contaminant level of 0.006 mg/L.	
	Dinoseb	Maximum contaminant level of 0.007 mg/L.	
	Dioxin (2,3,7,8-TCDD)	Maximum contaminant level of 3×10^{-8} mg/L.	
	Diquat	Maximum contaminant level of 0.02 mg/L.	
	Endothall	Maximum contaminant level of 0.1 mg/L.	
	Endrin	Maximum contaminant level of 0.002 mg/L.	
	Epichlorohydrin	Depends on if acrylamide and epichlorohydrin are used to treat water. If so, third-party certification required to verify specified levels are not exceeded	
	Ethylbenzene	Maximum contaminant level of 0.7 mg/L.	
	Ethylene dibromide	Maximum contaminant level of 5×10^{-5} mg/L.	
	Glyphosphate	Maximum contaminant level of 0.7 mg/L.	
	Heptachlor	Maximum contaminant level of 4×10^{-4} mg/L.	
	Heptachlor epoxide	Maximum contaminant level of 2×10^{-4} mg/L.	

Contaminant Group	Contaminant/Indicator Name	Monitoring/Treatment Requirements
	Hexachlorobenzene	Maximum contaminant level of 0.001 mg/L.
	Hexachlorocyclopentadiene	Maximum contaminant level of 0.05 mg/L.
	Lindane	Maximum contaminant level of 2×10^{-4} mg/L.
	Methoxychlor	Maximum contaminant level of 0.04 mg/L.
	Oxamyl (vydate)	Maximum contaminant level of 0.2 mg/L.
	Polychlorinated biphenyls (PCBs)	Maximum contaminant level of 5×10^{-4} mg/L.
	Pentachlorophenol	Maximum contaminant level of 0.001 mg/L.
	Pichloram	Maximum contaminant level of 0.5 mg/L.
	Simazine	Maximum contaminant level of 0.004 mg/L.
	Styrene	Maximum contaminant level of 0.1 mg/L.
	Tetrachlorethylene	Maximum contaminant level of 0.005 mg/L.
	Toluene	Maximum contaminant level of 1 mg/L.
	Toxaphene	Maximum contaminant level of 0.003 mg/L.
	2,4,5-TP (Silvex)	Maximum contaminant level of 0.05 mg/L.
	1,2,4-Trichlorobenzene	Maximum contaminant level of 0.07 mg/L.
	1,1,1-Trichloroethane	Maximum contaminant level of 0.2 mg/L.
	1,1,2-Trichloroethane	Maximum contaminant level of 0.005 mg/L.
	Trichloroethylene	Maximum contaminant level of 0.005 mg/L.
	Vinyl chloride	Maximum contaminant level of 0.002 mg/L.
	Xylenes (total)	Maximum contaminant level of 10 mg/L.

[1]National Primary Drinking Water Regulations: 40 CFR 141

Radionuclides

Elevated levels of radionuclides in drinking water are expected to cause increased risk of cancer, as well as kidney toxicity (uranium). All of the radionuclides listed in Table 20 result from the erosion of natural deposits, as well as the decay of natural and manmade deposits. Alpha particles, beta particles and photon emitters do not refer to specific elements or compounds, but rather groups of constituents with similar radioactive properties. For example, the USEPA does not specifically regulate polonium 210 in drinking water; however, polonium 210 emits alpha particles and the maximum contaminant level for alpha radioactivity in drinking water is 15 pCi/L. The alpha particle MCL shown below excludes both radon and uranium. There is currently no drinking water standard for radon, although the USEPA did propose the Radon in Drinking Water Rule in 1999, which included a proposed maximum contaminant level of 300 pCi/L and an alternative maximum contaminant level of 4,000 pCi/L. The rule is currently still in the proposal stage.

Table 20: National Primary Drinking Water Regulations Pertaining to Radionuclides

Contaminant Group	Contaminant/Indicator Name	Monitoring/Treatment Requirements
Radionuclides	Alpha particles	Maximum contaminant level of 15 picocuries per liter (pCi/L). Four consecutive quarterly samples must be taken at all sample points.
	Beta particles and photon emitters	Maximum contaminant level of 4 millirems per year. Vulnerable systems must be identified. Once identified, quarterly samples required for beta emitters and annual samples for Tritium and Strontium-90 at entry to distribution system.
	Radium 226 and Radium 228 (combined)	Maximum contaminant level of 5 pCi/L. Four consecutive quarterly samples must be taken at all sample points.
	Uranium	Maximum contaminant level of 0.03 mg/L. Four consecutive quarterly samples must be taken at all sample points.

[1]National Primary Drinking Water Regulations: 40 CFR 141

Secondary Drinking Water Contaminants

The USEPA has set 15 secondary drinking water standards with the goal of minimizing aesthetic, cosmetic, and technical effects of water. The effects are defined by the USEPA as follows: aesthetic effects are undesirable tastes or odors; cosmetic effects are effects that do not damage the body but are undesirable; technical effects cause damage to water equipment or reduced effectiveness of treatment for other contaminants. For example, chloride, copper, iron, manganese, and sulfate are all water constituents related to odor and taste; aluminum, copper, and total dissolved solids pertain to color; high concentrations of silver can cause skin discoloration; corrosion and related staining can be caused by chloride, copper, iron, manganese, pH, and zinc. Table 21 summarizes secondary drinking water regulations in terms of the recommended secondary maximum contaminant level and the resulting effect if recommended concentrations are exceeded.

It should be noted that in addition to primary and secondary standards, the USEPA provides guidelines for other unregulated contaminants. One notable example is recommendations provided by the USEPA for the management of cyanobacteria and associated cyanotoxins in drinking water. These recommendations are driven by established Health Advisory levels for the cyanotoxins microcystin and cylindrospermopsin. The ten-day health advisory level for total microcystins is 0.3 µg/L for young children and 1.6 µg/L for all other ages, meaning that these are the drinking water concentrations below which ten days of exposure is not expected to cause any adverse non-carcinogenic effects. The ten-day health advisory level for cylindrospermopsin is 0.7 µg/L for young children and 3.0 µg/L for all other ages.

The USEPA recommends a stepwise approach for ensuring cyanotoxin concentrations in finished drinking water do not exceed health advisory levels: 1) conduct a system-specific evaluation for vulnerability to blooms, 2) execute suggested activities for preparing and observing for potential blooms, 3) monitor to determine presence of cyanotoxins and initiate appropriate communication and treatment activities if confirmed, 4) monitor to determine presence of cyanotoxins in finished water and initiate appropriate communication and treatment activities if so, and 5) continue monitoring, treatment, and communication if cyanotoxins are found in finished water above acceptable levels (EPA 815-R-15-010).

Table 21: National Secondary Drinking Water Regulations

Contaminant	Secondary Maximum Contaminant Level	Effects Above Secondary Maximum Contaminant Level
Aluminum	0.05 to 0.2 mg/L	Colored water
Chloride	250 mg/L	Salty taste
Color	15 color units	Visible tint
Copper	1 mg/L	Metallic taste; blue-green staining
Corrosivity	Non-corrosive	Metallic taste; corroded pipes/fixtures staining
Fluoride[2]	2 mg/L	Tooth discoloration
Foaming agents	0.5 mg/L	Frothy, cloudy; bitter taste; odor
Iron	0.3 mg/L	Rusty color, sediment; metallic taste; reddish or orange staining
Manganese	0.05 mg/L	Black to brown color; black staining; bitter metallic taste
Odor	3 threshold odor number (TON)	Odor, musty or chemical smell
pH	6.5 to 8.5	Low pH: bitter metallic taste; corrosion; high pH: slippery feel; soda ash; deposits
Silver	0.1 mg/L	Skin and eye discoloration
Sulfate	250 mg/L	Salty taste
Total dissolved solids (TDS)	500 mg/L	Hardness; deposits; colored water and staining; salty taste
Zinc	5 mg/L	Metallic taste

[1]Secondary Maximum Contaminant Levels: 40 CFR 143.3
[2]Fluoride has a primary and secondary maximum contaminant level of 4 mg/L and 2 mg/L, respectively

Future Regulations

Despite the extensive list of regulated pathogens and chemicals listed in Table 15 through Table 21, there remain millions of unregulated chemicals with potential to end up in potable source waters. The term "contaminants of emerging concern" typically refers to unregulated pharmaceuticals, personal care products, endocrine disruptors, and other micropollutants that the drinking water sector has become increasingly aware of due to improvements in analytical capabilities and continued anthropogenic influences on natural environments. Contaminants of emerging concern are often affiliated with drinking water sources downstream of known wastewater effluent discharge locations because of the prevalence of these compounds in municipal wastewater and the fact that conventional wastewater treatment facilities are not designed to remove them. Thus, drinking water treatment facilities downstream of wastewater discharge locations should address the potential for emerging contaminants in raw water through technical means as well as public outreach in order to ensure public health and acceptance.

Although millions of contaminants of emerging concern are currently not included in primary or secondary drinking water standards, additional chemical and microbial contaminants may be regulated in the future. Under the 1996 amendments to the Safe Drinking Water Act, the USEPA uses the Contaminant Candidate List (CCL) and Unregulated Contaminant Monitoring Rule (UCMR) programs to determine whether additional national primary drinking water regulations are needed in order to significantly benefit public health. The CCL is published every five years by the USEPA and includes contaminants that may require future regulation based on health effects and occurrence in drinking water sources. Contaminants included on the most recently published draft CCL (CCL 4) were selected based on previous CCLs, nominations from the public, and new available data for any CCL 1 or CCL 2 contaminants that had been previously deemed undeserving of a primary drinking water standard. The draft CCL 4 includes 100 chemical contaminants and 12 microbial contaminants. Publication of a final CCL requires the USEPA to determine whether or not to regulate at least five of the listed contaminants in the Regulatory Determinations Process; the contaminant's determination must be based on health effects, occurrence in public water systems, and the expectation that regulation of the contaminant will result in a meaningful reduction in public health risk. The Announcement of Final Regulatory Determinations for Contaminants on the Third Drinking Water Contaminant Candidate List (CCL 3) was published by the USEPA on January 4, 2016, in which it was decided to not regulate dimethoate, 1,3-dinitrobenzene, terbufos, and terbufos sulfone. A decision pertaining to strontium is being delayed in order to consider additional data (40 CFR 141).

As previously mentioned, one of the criteria that a contaminant's regulatory decision must be based on is occurrence in public water systems, as regulatory agencies do not want to regulate and require monitoring of constituents that do not actually occur in public water systems. The UCMR program is one method for measuring occurrence. The UCMR program allows the USEPA to require monitoring of up to 30 contaminants every five years in large systems and a representative sample of small systems serving less than 10,000 people. UCMR contaminants are based on previous UCMR lists and the CCL. The proposed current UCMR 4 includes ten cyanotoxins, two metals, eight pesticides, one pesticide manufacturing byproduct, three brominated HAAs, three alcohols, and three semivolatile organic chemicals (80 FE 76897). All UCMR analyses must be conducted at USEPA approved laboratories and results are stored in the National Contaminant Occurrence Database. A thorough understanding of CCL and UCMR developments is important for anticipating new regulations and assessing the adequacy of treatment.

Treatment Strategies

Several treatment strategies are available for addressing the contaminants listed in Table 15 through Table 21 if source water characterization determines that removal is needed. The discussion below is divided into three sections, the first section relating to conventional and advanced treatment processes typically found onsite at centralized drinking water treatment facilities. The removal of formed disinfection byproducts in the distribution system (i.e., away from the water treatment facility) is also discussed due to implications for Alternative P-1 (Increased WSSC Allocations). Lastly, information is included to specifically address potential treatment options for the removal of polonium 210 (alpha particle emitter) due to the significant role polonium has played, and may continue to play, with respect to withdrawals from the Patapsco aquifer. The text below provides general information on treating for the various classes of contaminants, specific treatment process recommendations are provided for each alternative evaluated.

Conventional and Advanced Treatment Processes

Table 22 provides a summary of several conventional and advanced treatment processes available for addressing one or a combination of contaminant categories. According to the USEPA, conventional treatment consists of the following unit processes: coagulation, flocculation, clarification, and filtration, followed by disinfection. Advanced treatment includes all water treatment processes that further enhance (but do not necessarily replace) conventional treatment. Advanced processes operate under the mode of particle separation (e.g., filtration), dissolved compound removal (e.g., ion exchange), or oxidation (e.g., ozone). Some treatment processes benefit from combined modes of operation, such as biofiltration in which organic contaminants are sorbed onto media and/or biomass, as well as consumed by the biomass.

Processes employing physical separation of particles and dissolved compounds result in a waste stream that must ultimately be disposed of, such as sludge, concentrate (brine), and exhausted media. Oxidation processes typically do not produce waste streams; however, oxidation byproducts can be a concern. Combinations of the water treatment processes listed in Table 22 are used to address a wide variety of water quality considerations and to provide multiple barriers for any one given contaminant. For example, at a surface water treatment facility, microorganism control does not simply include chlorination but rather a combination of removal and inactivation processes in what is termed a multi-barrier approach. Microorganisms in raw water can be removed at multiple stages, such as sedimentation, media filtration, membrane filtration, UV irradiation, and chemical oxidation, thus minimizing the potential for microbial contamination in finished water even if one process is not at optimal performance.

Table 22: Summary of Common Water Treatment Processes and Targeted Contaminants

Water Treatment Process	Water Quality Consideration[1]								
	Turbidity, particles	Microorganisms	Organic contaminants, emerging contaminants	Taste and odor compounds	Iron and manganese	Hardness	Salinity	Algal cells	Algal toxins
Conventional treatment	Green	Green	Green	Yellow	Green	Red	Red	Green	Red
Microfiltration/ ultrafiltration	Green	Green	Yellow	Red	Green	Yellow	Red	Green	Yellow
Nanofiltration	Yellow	Green	Green	Green	Green	Green	Red	Green	Green
Reverse osmosis	Yellow	Green	Green	Green	Green	Green	Green	Green	Green
Powdered activated carbon	Red	Red	Green	Green	Red	Red	Red	Red	Yellow
Granular activated carbon	Red	Red	Green	Green	Red	Red	Red	Red	Green
Ozone/ biofiltration	Yellow	Yellow	Green	Green	Green	Red	Red	Yellow	Green
Ion exchange	Red	Red	Green	Yellow	Red	Green	Red	Red	Yellow
Lime softening	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Red	Yellow	Yellow
UV irradiation	Red	Green	Red	Red	Red	Red	Red	Red	Red
UV advanced oxidation	Red	Green	Green	Green	Red	Red	Red	Red	Green
Chlorination	Red	Green	Yellow	Red	Green	Red	Red	Yellow	Yellow

[1]*Green: controllable removal and purpose of treatment process; yellow: incidental/ancillary removal possible, but not the purpose of treatment process; red: no removal and not the purpose of the treatment process*

Disinfection Byproduct Removal in the Distribution System

The County and WSSC have discussed concerns related to elevated DBP concentrations in finished water that would be provided to Charles County by WSSC.[13] These concerns stem from CCG recollection of previous sampling events, known DBP precursors in the source water (Potomac River), and the tendency for DBP concentrations to increase throughout chlorinated distribution systems due to the continued reaction between free chlorine and organic matter. Typically, DBPs are primarily addressed at the water treatment plant via precursor removal (i.e., dissolved organic carbon removal) or modifications to the disinfection processes. DBP levels can also be controlled via management of hydraulic flow and storage to minimize residence time in the distribution system. However for purchased finished water, these in-plant and distribution system management strategies are largely within the realm of WSSC and outside the control of CCG. If DBP concentrations at the existing and/or potential future CCG/WSSC connection site(s) are a concern, CCG cannot modify WSSC operations, but CCG can opt to employ additional treatment prior to blending WSSC water into the CCG distribution system. This scenario is often referred to as a localized treatment approach.

The selection of appropriate treatment technologies for the connection site(s) depends on the speciation of formed DBPs, space constraints, and operational preference. If THMs are above or approaching the regulatory limit, then aeration/air stripping can be effective due to the volatility of THM species. Aeration/air stripping is most effective when the total THM concentration is dominated by the more volatile species with lower molecular weights.[14] While the removal of brominated THMs via aeration/air stripping is more challenging, it is feasible. Previous bench-, pilot-, and full-scale investigations of aeration/air stripping in storage tanks have reported significant reductions in THMs, the extent of which depends on THM concentration and speciation, temperature, flow rate, spray configuration, and other design factors (Cecchetti, Roakes, & Collins 2014; Schneider et al., 2015). It should be noted that adding treatment would result in the loss of head from the WSSC Accokeek Tank, requiring additional pumping to reach the HGL of the CCG distribution system.

HAAs tend to be more soluble and less volatile than THMs; therefore aeration/air stripping would not be recommended as a localized treatment approach for DBPs dominated by HAAs. These minimally volatile DBPs are biodegradable and can be better removed by biofiltration using granular activated carbon (GAC) media. HAA removal via biofiltration can reach high levels (70 to >99%) without the need for frequent GAC regeneration (Johnson et al., 2009).

Radionuclide Removal

Water treatment processes that specifically target polonium 210 are not widespread. Previous research and evaluations mostly pertain to analytical methods for measuring polonium 210 in various matrices and quantifying the health effects associated with exposure. However, there are treatment processes available

[13] CCG is working with WSSC to obtain additional data on DBPs in the Accokeek portion of the WSSC system.
[14] Chloroform (molecular weight of 119.38 g/mol) is more volatile than bromoform (molecular weight 252.73 g/mol).

that have demonstrated polonium 210 removal. It should be noted that management of the resulting water treatment residuals containing polonium 210 may be a challenge depending on the quantity and radioactive strength of the residuals.

The Center for Disease Control suggests that private wells with polonium 210 levels that exceed the National Primary Drinking Water Regulation (15 pCi/L) install a properly functioning reverse osmosis (RO) membrane system to treat water prior to all uses, as polonium 210 is a radiation hazard by way of inhalation, ingestion, and contact with open skin. Polonium 210 removal via RO would result in the production of a concentrate stream with increased levels of polonium 210. Polonium 210 removal via RO is currently practiced by CCG at the Chapel Point water system, which withdrawals water from the Patapsco aquifer. The resulting RO concentrate is transported and disposed of at the Mattawoman Wastewater Treatment Plant. Increased monitoring has been implemented at the facility to ensure that radionuclide levels in treated effluent and biosolids meets regulatory requirements. The sustainability of this RO concentrate disposal strategy will depend on the extent to which polonium 210 affects additional CCG wells, and the resulting production of RO concentrate relative to other influent flows at the Mattawoman Wastewater Treatment Plant.

GAC filtration and ion exchange could potentially achieve moderate polonium 210 removal (likely greater than 35%); however, the elevated radioactivity of the filter or regeneration brine over time may be a concern. The filter/brine vessel would likely require shielding to attenuate gamma radiation in order to maximize the loading capacity of the carbon and regenerating capability of the ion exchange brine while also protecting those in the surrounding area (Annanmaki and Turtiainen, 2000). Polonium 210 removal by conventional surface water treatment has also been found to be effective at a full-scale facility in Sweden. A sampling campaign at the facility showed that coagulation, flocculation, and sedimentation with ferric chloride and aluminum sulfate resulted in 94% and >99% removal of polonium 210, respectively (Gafvert et al., 2002). Prior to installation of GAC, ion exchange, or any other process for the removal of polonium 210, the costs and constraints of disposing of the residuals (concentrate, exhausted media, sludge, etc.) must be identified.

Description of Preliminary Screening Criteria

The feasibility of incorporating an alternative water source(s) into CCG's water supply portfolio depends on a range of factors, including the water source's quality, available quantity relative to demand, cost, environmental considerations, technical considerations, and customer perceptions. In order to incorporate these factors into the decision-making process, preliminary screening criteria were developed to specifically assess various aspects of each alternative water source. The overall purpose of these preliminary screening criteria was to provide a concept development roadmap for all identified water source alternatives, as well as a means by which to identify potential critical flaws from multiple perspectives. Ultimately, these criteria and their associated pass/fail assessments enabled removal of alternatives from further consideration that have notable conceptual weaknesses, such as unproven performance or reliability, high cost, or insurmountable constructability or regulatory issues, thus limiting the "world of options" to those alternatives without critical flaws. Descriptions for each preliminary screening criterion are provided below. For all criteria, assessment outputs were either pass or fail, with a fail designation indicating the identification of a critical flaw as described in the alternative evaluation sections. Options were removed from further consideration in Phase A-2 only when a critical flow was identified. However, the feasibility of several remaining options is currently uncertain due to lacking data. Additional investigations will facilitate further determinations of feasibility, which may ultimately result in the identification of new fatal flaws.

Capital Cost

The immediate capital expenditure includes the planning, design, permitting, construction, and commissioning of facilities required to access, treat, and convey the water source to the closest connection point within the existing transmission and distribution system. Because of the early stages of the project, the cost estimates are characterized as class 5, indicating there is a high level of uncertainty, and are presented as a range herein. Costs are based on published data (e.g., Plumlee et al., 2014), prior projects recently constructed in the region, and typical rates for contingencies. Some of the factors that can have a major impact on final costs include land acquisition, intake or well construction, raw water and finished water pipeline lengths, investigations and studies, and permitting. Alternatives were assessed as a "fail" if initial capital costs based on best professional judgement were expected to far exceed the costs of other potentially viable options utilizing the same source. For example of the five surface water options evaluated, only the lowest cost option(s) of the feasible alternatives were selected for further evaluation.

Operation and Maintenance Cost

The annual costs to operate and maintain the infrastructure/facility, including labor, chemical costs, power costs, and equipment maintenance/replacements (e.g., GAC, membranes, etc.). For this feasibility study O&M costs were qualitative. Alternatives were assessed as a "fail" if initial operation and maintenance costs based on best professional judgement were expected to far exceed the costs of other potentially viable options utilizing the same source.

Water Quality

Source water quality in comparison with current and projected drinking water regulatory limits determines the level of treatment needed. This criterion is intended to assess the overall quality of each source water option taking average concentrations into account. Water quality parameters of particular interest include those related to salinity, dissolved organic matter, algal bloom conditions (e.g., wastewater influence, nutrients, flow), and microbial safety (e.g., wastewater influence, pathogenic indicators). Water quality deemed as untreatable would warrant a "fail" assessment.

Supply Reliability

If a source water's availability in terms of quantity is inconsistent, highly sensitive to outside influences (e.g., drought), and/or requires frequent monitoring to determine its usability, then it should be considered less reliable than other alternatives. Less reliable source water options are less desirable than water sources with consistent availability. A water source option with availability that is expected to meet projected water supply deficits should be given a "pass." Options with inherently unreliable characteristics that cannot be mitigated would warrant a "fail" assessment.

Ease of Operation

This criterion is intended to assess the ease with which a source water option can be withdrawn, treated, and conveyed to customers. If the requirements of a source water option are similar to those pertaining to the average existing groundwater well, then the source water is deemed easy to operate and maintain, thus deserving a "pass." If a source water requires treatment processes that are new to Charles County and/or involve many instances of moving parts, required monitoring, or frequent adjustments, then the source water is considered more difficult to operate, but a "fail" is only assigned if this difficulty is perceived as insurmountable.

Constructability

Constructability pertains to the sequence of events that must take place in order for the infrastructure needed to access, treat, and convey a source water to be constructed. This criterion takes into consideration land acquisition, construction timelines, and upsets to other systems. If a source water option can be accessed, treated, and conveyed using land that is already owned or accessed by the County, then it would be given a favorable ("pass") constructability assessment. If a source water option requires the use of land that is currently owned by a historically unwilling stakeholder and/or negatively impacts other currently operating systems (e.g., other drinking water systems, high traffic recreational space) to the point where constructability is outside the realm of possibility, then an unfavorable ("fail") constructability assessment would be assigned.

Ease of Permitting

The feasibility of using a water source as a drinking water resource ultimately depends on its ability to be permitted. The ease with which a water source is permitted depends on its associated water quality (to protect consumer health) and available quantity (to protect human and environmental health), as well as the existence of any similar precedents. If a similar water source (or the water source itself) is already considered a standard drinking water resource by the MDE, then it would most likely be considered an easily permitted option. Water source options that have been previously used as drinking water resources in the State of Maryland should be given a "pass." Water source options with no existing precedent or with expected regulatory opposition should be given a "fail," if deemed insurmountable. With regard to quantity, increased allocations of an accepted drinking water resource (in terms of quality) that has shown evidence of depletion/overuse would be a permitting challenge, which may result in a "fail" depending on the extent to which depletion has been documented (e.g., federal/state reports) and/or acted upon (e.g., withdrawal restrictions).

Environmental Stewardship

This criterion speaks to the environmental impacts of using a water source option as a drinking water resource. Environmental impacts span those related to withdrawal (e.g., flows and levels of the source water), treatment inputs (e.g., land, chemicals, energy), and treatment outputs (e.g., wastes, brine, sludge). Water source options requiring treatment with minimal chemical and energy inputs would be deserving of a "pass", especially when compared to more chemically/energy intense options. Water source options that require pulling water from an already strained resource and/or active habitat are not favorable in terms of environmental stewardship, which may result in a "fail" depending on the extent to which the resource and/or habitat has been given protection (e.g., critical habitat, approved shellfish harvesting area).

Public Acceptance

Public acceptance of a new water source option plays a critical role in its successful implementation. Water source options that are similar to the status quo (e.g., additional groundwater wells) are expected to garner higher levels of public acceptance than those viewed as a radical change (e.g., direct potable reuse). Findings related to the impacts of various factors (e.g., environmental buffers, media coverage, community structure, etc.) must be taken into account when assigning public acceptance pass/fail designations for each water source option. Anticipation of inherent public acceptance of a water source option is important because it helps plan for the extent of utility outreach and communication efforts that should take place concurrent with technical planning and construction.

Regional Benefits

Optimal use of existing water sources and potential new water sources depends on recognizing the regional nature of water demand and distribution in Charles County. This criterion pertains to a water source alternative's potential for providing regional benefits (i.e., provision of water to multiple systems). Water source options that result in water availability for multiple systems, such as La Plata or small communities in southern Charles County in addition to the major systems of interest (Waldorf and Bryans Road), would be deserving of a strong "pass." Water source options that result in additional water for only the Waldorf or Bryans Road system are not ideal, but would also be deserving of a "pass." However, water source options that are expected to adversely affect water supply availability elsewhere would be given a "fail."

Evaluation of Alternatives

This section presents the results of the alternatives evaluation based on the screening criteria. Alternatives requiring treatment include conceptual treatment plant process schematics based on available water quality data. As discussed in the Treatment Strategies section, multiple treatment processes are typically employed for water treatment in order to target a wide range of contaminants and to provide multiple barriers for contaminant removal. The selected treatment train for a given source water depends on the raw water quality, operational preferences, available resources, and cost. Examples of water treatment trains provided in this section were developed to be fully protective of public health based on the available water quality data in order to meet or exceed drinking water regulations. Treatment process selection for the water supply alternative(s) will ultimately require detailed source water quality characterization coupled with bench- and/or pilot-scale testing to confirm appropriate treatment process trains and support infrastructure design. Additionally, the location of each water source alternative relative to CCG demand centers was considered because the cost, constructability, ease of permitting, and public acceptance of an alternative can be highly dependent on location (e.g., conveyance costs, easements, community impacts from construction, crossing of jurisdictional boundaries etc.). Table 23 presents full list of options considered in the study.

Table 23: Summary of Water Source Alternatives Evaluated in Phase A-1

Water Source Alternative Type	Water Source Alternative
Groundwater	G-1: Increased Magothy Withdrawals
	G-2: “Down-Dip” Lower Patapsco Well(s)
	G-3: New Patuxent Well(s) in Waldorf
	G-4: New Surficial Aquifer Wellfield
	G-5: New Surficial Aquifer Wells – Distributed Installation
Surface Water	S-1: Surface Water Treatment Plant – Potomac River Upper Reaches
	S-2: Surface Water Treatment Plant – Potomac River Lower Reaches
	S-3:Next Patuxent Water Treatment Plant
	S-4: Goddard Power Plant Intake at the Naval Surface Warfare Center at Indian Head, MD
	S-5: Morgantown Generating Station at Morgantown, MD
Riverbank Filtration	B-1: Riverbank Filtration – Potomac River Upper Reaches (Piscataway Park)
	B-2: Riverbank Filtration – Potomac River Upper Reaches (Ruth B. Swann Memorial Park)
	B-3: Riverbank Filtration – Patuxent River
Reuse	R-1: Non-potable Reuse
	R-2: Indirect Potable Reuse with Confined Aquifer Recharge
	R-3: Direct Potable Reuse
Policy	P-1: Increased WSSC Allocations
	P-2: Demand Management
	P-3: Wellfield Management Plan
Countywide	W-1: Countywide Agreements
Combined Alternatives	C-1: Aquifer Storage and Recovery
	C-2: Conjunctive Use

Groundwater

Alternative G-1: Increased Magothy withdrawals

The Magothy aquifer was heavily used in the 1970's and into the mid 1980's as the primary source of water for the CCG public water system. As total withdrawals approached four million gallons per day, the rate of decline of the aquifer began to increase dramatically. As a result, MDE reduced CCG permitted allocation, and CCG shifted pumping to the deeper Patapsco aquifers. As of 2011 total permitted withdrawals for all large users in Charles County equaled 3.3 mgd (Table 4), 87% of which is permitted to CCG. In 2014 the CCG withdrew an average of approximately 2.4 million gallons per day (mgd) of water from the Magothy aquifer. According to the Charles County Observation-Well Network, water levels in the Magothy aquifer continue to show flat to slightly declining trends (Figure 5). Water levels have generally not recovered and the aquifer remains depressed by 60 to 80 feet throughout its extent in Charles County (Figure 3).

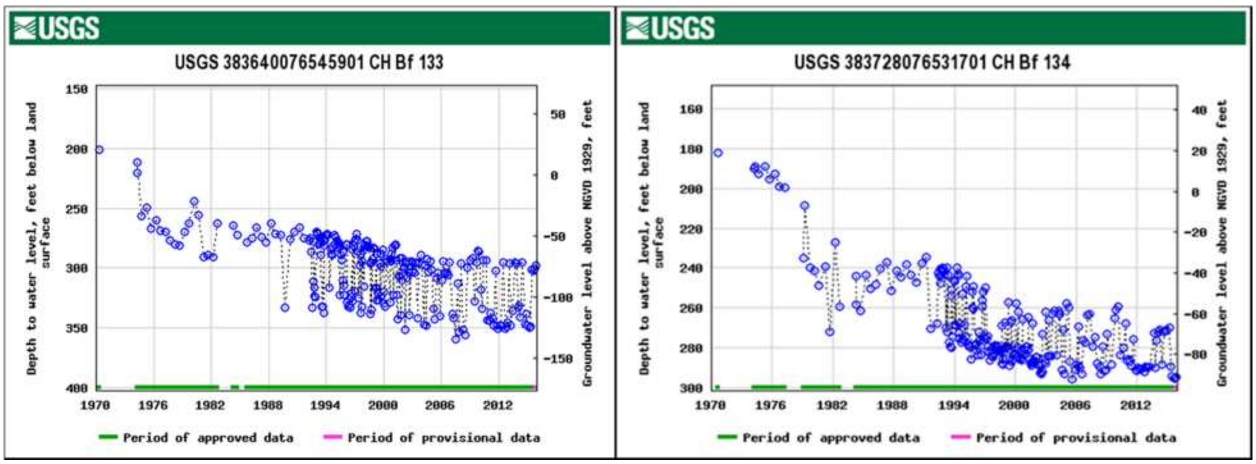

Figure 5: Charles County Observation Wells CH Bf133 and CH Bf134 for Magothy Aquifer (USGS 2015)

Withdrawals from the Magothy aquifer resulted in significant water level decline in the aquifer and nearly reached the 80% management level in 2002. Because the aquifer has not recovered substantially, additional pumping is likely to result in further water level decline. Therefore, it is unlikely that additional pumping from the aquifer would provide a sustainable source of supply or be approved by MDE. Further, because the aerial extent of the Magothy Aquifer is limited and depressed water levels are observed across most of the County, limited benefit to water levels is anticipated by redistributing withdrawals in this aquifer. Given these current trends, additional wells and/or pumpage would be unsustainable for maintaining the aquifer above the 80% management level long term.

The poor long term reliability and the difficulty of permitting new Magothy aquifer wells are judged to be fatal flaws for this option as a standalone alternative (Table 24). However, there may be opportunities to better utilize existing wells and increase yield. Refer to Alternative P-3 for a discussion of the wellfield management plan. Additional withdrawals could potentially be used for short term or intermittent operation in conjunction with the development of a permanent alternate supply. Consultation with MDE would be required to further assess the acceptability of this approach.

Table 24: Preliminary Screening Assessment for Alternative G-1

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws
Supply Reliability	✗	Long term sustainability of increased pumping is low
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✗	Permitting of increased withdrawals is unlikely as a standalone option
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Alternative G-2: "Down-Dip" Lower Patapsco well(s)

At one time, Charles County supplied approximately 50% of its demands with water from the Lower Patapsco aquifer. However, in 2007 MDE raised concerns that water levels in the area of Potomac Heights were nearing the 80% management limit. The County shifted a substantial portion of its pumping in the Bryans Road area to the Patuxent aquifer. Water levels in the Lower Patapsco aquifer in wells in the far northern and northwestern parts of the County have either begun to recover or have held steady since 2012. Lower Patapsco water levels at St. Charles, La Plata, Chapel Point Woods, and Douglas Point continue to show a flat to slightly declining trend. There remains a large cone of depression in the Lower Patapsco aquifer that underlies most of Charles County.

The deepest portion of the cone of depression encompasses the area to the north and west of La Plata (Figure 6). While the drawdown in the cone of depression is less in the southern and eastern portions of the County (the “down-dip” areas), additional withdrawals from the Lower Patapsco in the “down-dip” area may impact the water level trend in the “up-dip” portion of the aquifer. Additional withdrawals located in the “down-dip” region are likely to be permitted by the MDE as the available drawdown in the aquifer is greater than the shallower “up-dip” regions, and would not exceed the 80% management limit. While additional withdrawals from the “down-dip” Lower Patapsco may be feasible, management of withdrawals from the aquifer may be required regionally based on water level trends in the “up-dip” and “down-dip” regions.

It is not currently possible to predict drawdown impacts in the aquifer with high confidence based on available modeling tools, but it is expected that additional withdrawals from new wells located “down-dip” may modify water level trends in the Lower Patapsco aquifer. Investment in new wells, as well as the pipeline infrastructure needed to connect down-dip wells to the Waldorf system, would require an assessment of probable yields and predicted water level trends. An additional complication is that water quality of new wells is uncertain and may require treatment for gross alpha radiation related to polonium 210.

The poor long term reliability, risk of gross alpha contamination, and the difficulty of permitting new Lower Patapsco aquifer wells are judged to be fatal flaws for this option as a standalone alternative (Table 25). However, development of additional groundwater withdrawals in the Lower Patapsco aquifer should be included in the wellfield management approach as part of Alternative P-3. Additional withdrawals could potentially be used for short term or intermittent operation in conjunction with the development of a permanent alternate supply. Consultation with MDE would be required to further assess the acceptability of this approach.

Table 25: Preliminary Screening Assessment for Alternative G-2

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✗	Potential for gross alpha contamination
Supply Reliability	✗	Long term sustainability of increased pumping is low
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✗	Permitting of increased withdrawals is unlikely as a standalone option
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

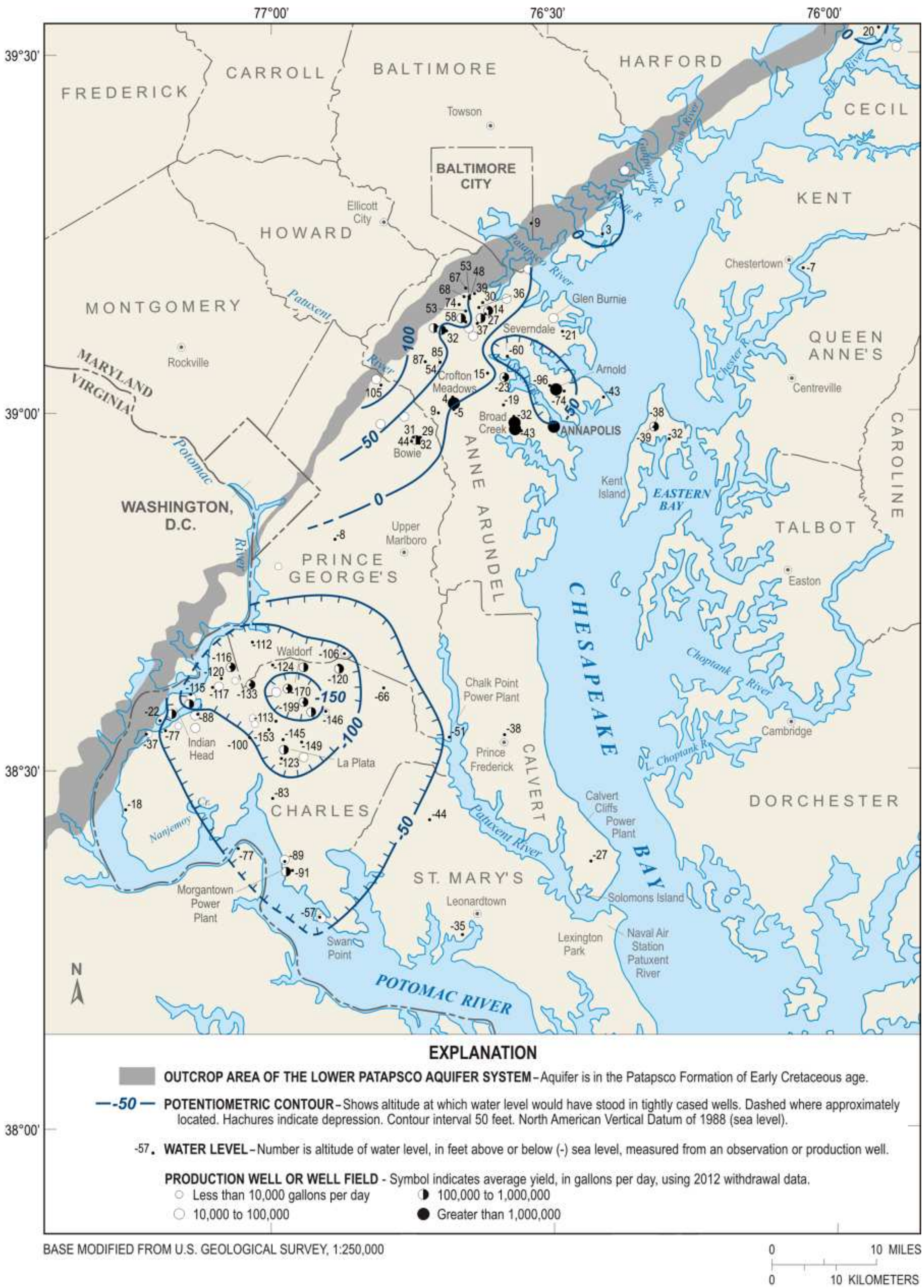

Figure 6: Potentiometric Surface of the Lower Patapsco Aquifer System in Southern Maryland and Maryland's Eastern Shore, September 2013 (Staley, Andreasen & Curtin 2014)

Alternative G-3: New Patuxent well(s) in Waldorf

Charles County increased development of the Patuxent aquifer for public water supply in approximately 2007. Average withdrawals currently range between 1.0 and 1.5 mgd for the Bryans Road and Indian Head area. Since 2010, the Chalk Point Generating Station has pumped approximately 0.5 to 1.0 mgd from the Patuxent aquifer (Staley 2015). Water levels in the Patuxent aquifer are declining at a rate ranging from two to seven feet per year. The most rapid declines are located near the Bryans Road and Chalk Point pumping centers. The cones of depression associated with the withdrawals do not currently overlap (Figure 7).

While the rate of water level decline is significant in some regions of Charles County, there is substantial available drawdown in the aquifer, ranging from approximately 600 feet in the northwest of the County near Bryans Road to 1,400 feet near Chalk Point in the east. The additional development of the Patuxent aquifer is feasible, although deep drilling depths, low aquifer transmissivity, additional development costs and the declining water levels may limit the long term sustainability of developing new wells and additional withdrawals (Staley 2015).

The poor long term sustainability of new Patuxent aquifer wells is judged to be a fatal flaw for this option as a standalone alternative (Table 26). However, development of additional groundwater withdrawals in the Patuxent aquifer should be included in the wellfield management approach as part of Alternative P-3. Additional withdrawals could potentially be used for short term or intermittent operation in conjunction with the development of a permanent alternate supply. Consultation with MDE would be required to further assess the acceptability of this approach.

Table 26: Preliminary Screening Assessment for Alternative G-3

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws
Supply Reliability	✗	Long term sustainability of increased pumping is low
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

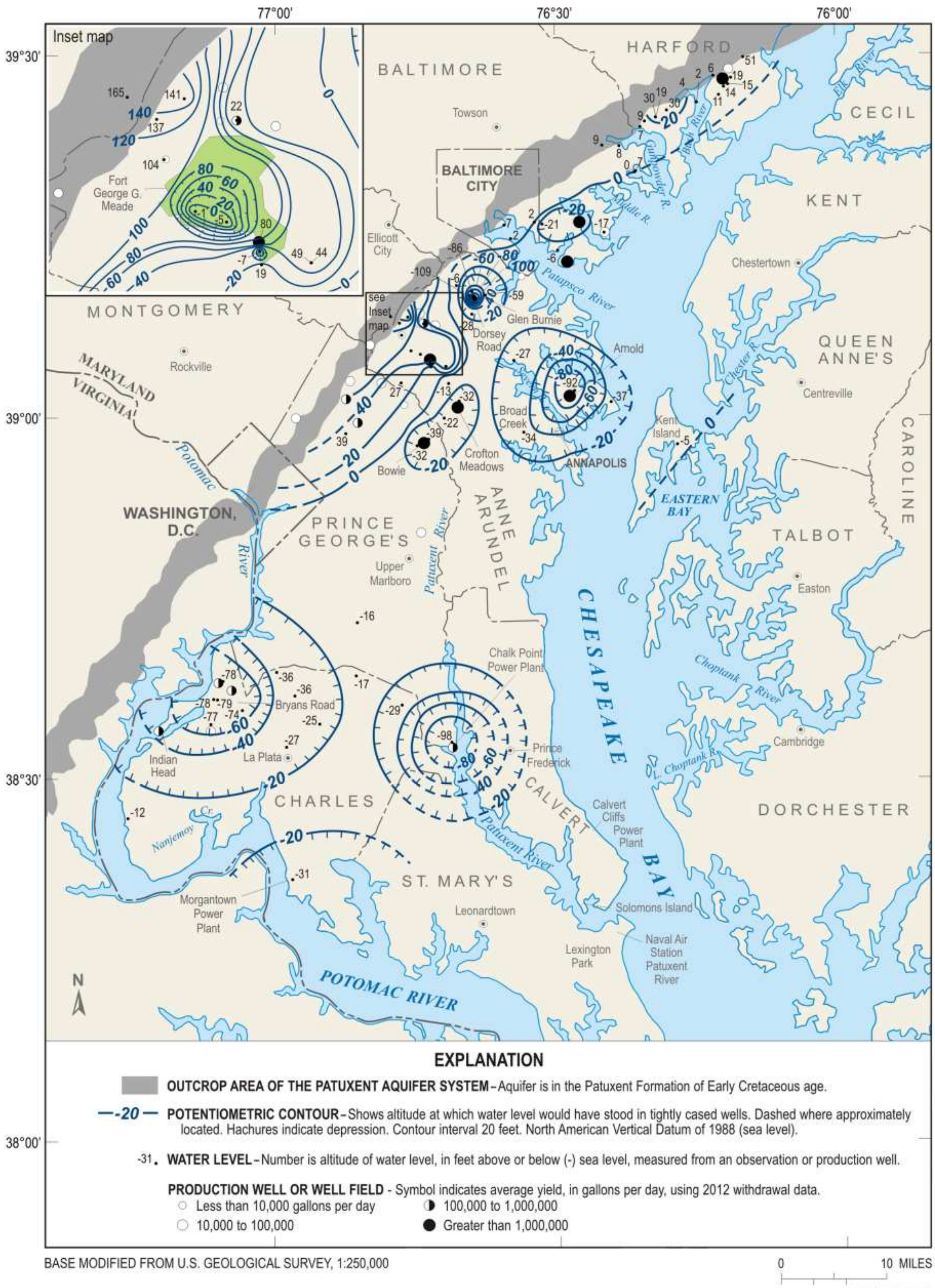

Figure 7: Potentiometric Surface of the Patuxent Aquifer System in Southern Maryland and Maryland's Eastern Shore, September 2013 (Staley, Andreasen & Curtin 2014)

Alternative G-4: New Surficial aquifer wellfield

The Surficial Upland aquifer is a relatively minor aquifer used for domestic and farm supply in the County. The aquifer is present over much of southern Maryland, although locally the extent and thickness are controlled by topography and elevation, resulting in a very irregular distribution of the aquifer. The Surficial Upland aquifer is thickest in the upland areas (generally above 40 feet in elevation). The average thickness of the Surficial Upland aquifer is 30 feet in Charles County and may exceed this where in-filled paleochannels have incised the older sediment (i.e. near Indian Head) (Hiortdahl, 1997).

At this time the potential yield and water quality are uncertain due to sparse data. Given the shallow depth of the aquifer, it is likely wells would be categorized as GWUDI,[15] in which case withdrawals would need to be treated to meet drinking water regulations. For the purposes of this screening assessment, it is assumed a combination of microfiltration and ultrafiltration membranes would be required with chlorination (Figure 8). Depending on contact time, UV disinfection could be added to ensure the required log removal of pathogens. Estimated costs are presented in Table 27 for the surficial aquifer treatment train shown in Figure 8.

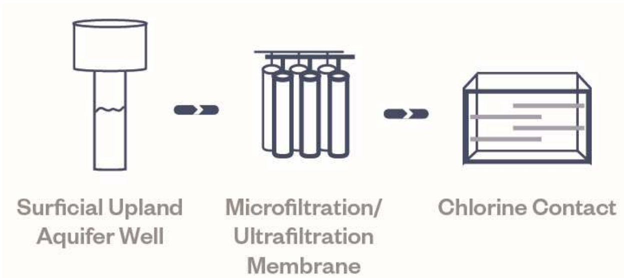

Figure 8: Surficial Upland Aquifer Treatment Schematic

Table 27: Summary of Estimated Capital Costs for the Surficial Aquifer Treatment Train G-4 in Millions of Dollars as a Function of Plant Capacity

Capacity (mgd)	Treatment train: Surficial well-MF/UF-Chlorine	
	Total estimated capital cost ($M)	Unit capital cost ($M/mgd)
2	$7 – 18	$4 – 9
5	$13 – 35	$3 – 7
10	$25 – 65	$3 – 7

In addition to water quality concerns, yield is limited by aquifer thickness and is heavily influenced by precipitation, making the surficial aquifer wells unreliable during droughts. Further, substantial withdrawals may result in a localized reduction of discharge to nearby streams. The development of a shallow surficial aquifer typically requires multiple wells, or the development of high capacity horizontal collectors to obtain sufficient yields. The potential well yields decrease during dry periods as the aquifer

[15] Wells screened in unconfined aquifers at less than 50 feet depth is a potential indicator of GWUDI. A microscopic particulate analysis is required to confirm the quality of the water from the well.

dewaters without recharge from precipitation. Yields may be increased substantially by utilizing artificial recharge from infiltration ponds that may also be utilized for storage, along with the additional storage provided in the normally unsaturated underlying aquifer material. Infiltration ponds may collect local runoff or store water diverted from surface water sources. Infiltration ponds also increase the reliability of surficial aquifer water supplies during dry periods. Infiltration ponds have been used in conjunction with shallow wells for water systems in New Jersey, Florida, and California.

The key considerations for this alternative are 1) identification of a location suitable for a wellfield and/or infiltration pond, 2) the acquisition of property (larger areas if infiltration ponds are anticipated) 3) sufficient, reliable yield from wells installed at the selected location, 4) understanding of the potential impacts to surface water recharge and the local environment, and 4) treatment requirements for surface water sources. The ultimate location of a surficial aquifer wellfield would determine the infrastructure required to connect it with the existing distribution system.

The following tasks are recommended to determine the suitability of the surficial aquifer in Charles County for public water supply, to identify the preferred location for development of the resource, and to determine the potential utility of infiltration ponds; 1) Identify suitable locations in the Surficial Upland Aquifer, 2) assess site-specific aquifer properties and stratigraphy, and 3) determine site-specific infiltration and storage capacity.

While cost or other factors (e.g. reliability or property acquisition) may ultimately be prohibitive, there are no identified fatal flaws for this option that would exclude it from the list of potential alternatives to be examined in the Phase A-2 analysis (Table 28).

Table 28: Preliminary Screening Assessment for Alternative G-4

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws
Supply Reliability	✓	No fatal flaws
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Alternative G-5: New Surficial aquifer wells: Distributed installation

A second alternative for utilizing the Surficial Upland aquifer yield would be to install wells distributed around the County to augment demands at many of the smaller standalone systems. However, given the strong possibility that filtration would be required at each well due to the influence of surface water recharge, it may become impractical to maintain numerous small treatment systems around the County. Supplemental recharge using engineered infiltration ponds would be even less practical as a distributed option. The development of the Surficial Upland aquifer would likely be applicable only in the upland areas with sufficient saturated aquifer thickness, and where the aquifer is not dissected by surface drainage features (e.g. creeks, streams, springs, etc.). Typically, yields are dependent on saturated aquifer thickness and likely would decrease as the water table declines during dry conditions.

An alternative approach to supplying standalone systems would be to implement supply alternatives that reduce demand on the confined aquifers, which would benefit standalone water systems by reducing drawdown, increasing groundwater availability, and reducing pumping costs.

Alternative G-4, focusing on a single wellfield location, is a more practical option for withdrawing from the Surficial Upland aquifer. Therefore, the difficulty and potentially inconsistent yields of distributed surficial aquifer wells are judged to be fatal flaws for this option (Table 29). Similar hydrogeologic investigations would be required to determine the feasibility of this option and the suitability of potential wellfield locations. If the Surficial aquifer is determined to be productive at multiple locations during hydrogeologic testing, this distributed option could be revisited.

Table 29: Preliminary Screening Assessment for Alternative G-5

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws
Supply Reliability	✓	No fatal flaws
Ease of Operation	✗	Maintaining numerous small treatment plants would be impractical and costly
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Surface Water

Alternative S-1: Surface Water Treatment Plant – Potomac River upper reaches

From a water quantity standpoint, the Potomac River is an attractive option. Charles County is at the lower end of the river, which has a drainage area of over 12,000 square miles. Average flows are on the order of 7,000 mgd, and even during low flow conditions, there is sufficient flow to supply the anticipated demands for Charles County. The major drawback to this source is water quality, due to wastewater effluent discharged from the Washington, DC area upstream of Charles County; the risk of non-point pollution from upstream rural and urban sources; and the high salinity from the Chesapeake Bay downstream.

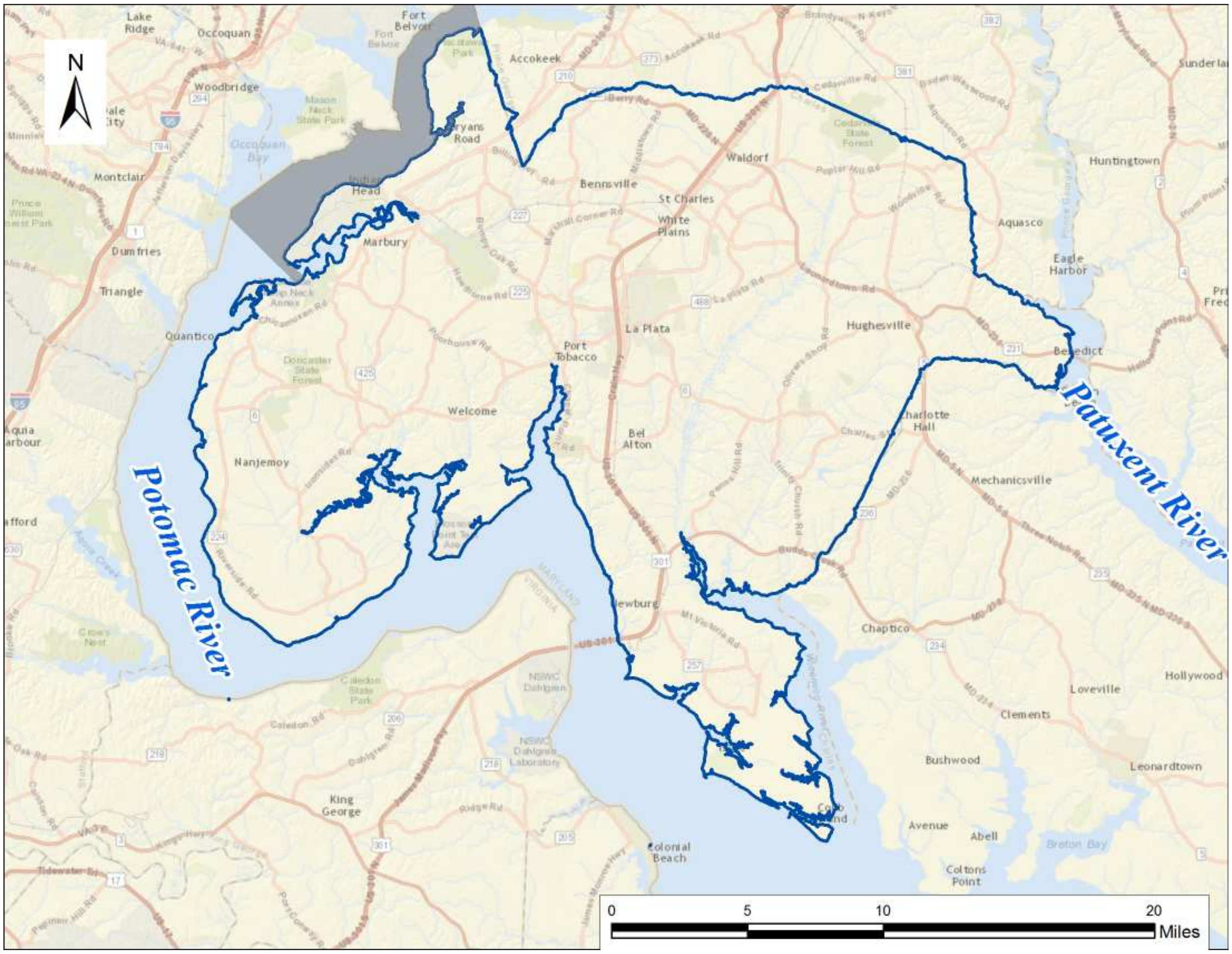

Figure 9: Upper Reaches of the Potomac River adjacent to Charles County (shaded gray)

For the purposes of this study, the upper reach of the Potomac River for Charles County is defined as the twelve-mile section of the River that extends from the northern boundary of the County south to the confluence with the Mattawoman Creek (Figure 9). This section of river receives flow from the Middle Potomac-Anacostia-Occoquan Watershed, hydrologic unit code (HUC) 02070010. Available water quality data within this section of the river (extended further north to ensure adequate spatial and seasonal coverage) were reviewed to identify the level of treatment that would be required for a WTP. A summary of important water quality data is provided in Table 30. Note that detailed water quality measurements, obtained through a well-designed sampling program, would be needed at specific potential WTP intake locations in order to design the treatment processes needed to efficiently and cost effectively meet drinking water quality regulations and supply needs.

Salinity, quantified in terms of total dissolved solids (TDS) and chlorides, varies substantially with location and flow rate along the Potomac River in the vicinity of Charles County. For example, TDS at Indian Head is typically less than 500 mg/L and chlorides are typically less than 250 mg/L, which are the secondary drinking water standards for these constituents.[16] However, peak TDS concentrations of up to 3,500 mg/L, the lower end for brackish water, occur for short periods during low flow conditions in this section of the river Potomac River. For the Middle Potomac River HUC (02070010), monthly average TDS between 1986 and 2015 did not exceed 100 mg/L (8,765 readings from the main stem of the river in total). For a WTP at this location, desalination would most likely not be needed to maintain TDS and chloride levels within the secondary drinking water standards. However, a management plan would be recommended to address infrequent, short-term elevated salinity concentrations. These periods could be addressed through blending with lower salinity sources (e.g. groundwater), short-term use of RO desalination units, or temporarily curtailing WTP production until salinity levels decrease.

Table 30: Potomac River Water Quality in the Middle Potomac-Anacostia-Occoquan River HUC (02070010)

Water Quality Parameter	Average	Year Range
Total dissolved solids (mg/L)	50	1986 – 2015
Fecal coliforms (MPN/100 mL)	240	2000 – 2007
Organic carbon (mg/L)	3.6	1986 – 2014
Turbidity (NTU)	29	2000 – 2014
Alkalinity (mg/L)	80	1986 – 2014
pH	7.8	1976 – 2014

Another important water quality concern is the high proportion of wastewater effluent in the river below Washington DC (Figure 10), which results in high concentrations of organic matter, nutrients, and emerging contaminants in the upper reach of the Potomac River, particularly during low streamflow conditions. Substantial wastewater influence in this section of the river results in high levels of fecal coliform (overall average of 240 MPN/100 mL) and organic carbon (overall average of 3.6 mg/L). High concentrations of nutrients increase the probability of algal blooms. With respect to contaminants of emerging concern, there is no data currently available for this section of the river, but DC Water recently began a monitoring program on its effluent from the Blue Plains Wastewater Treatment Plant (DC Water 2015). DC Water data combined with site specific monitoring can help identify specific compounds and concentrations of emerging contaminants in the Potomac River. In order to ensure sufficient protection of public health, available water quality data would strongly suggest the use of advanced treatment processes such as ozone, BAC, UV disinfection, GAC or RO to address DBP formation, achieve log removal of pathogens, and provide barriers to emerging contaminants.

[16] While secondary drinking water standards are non-mandatory guidelines and not enforceable, salinity at levels higher than the secondary standards may result in objectionable taste to consumers.

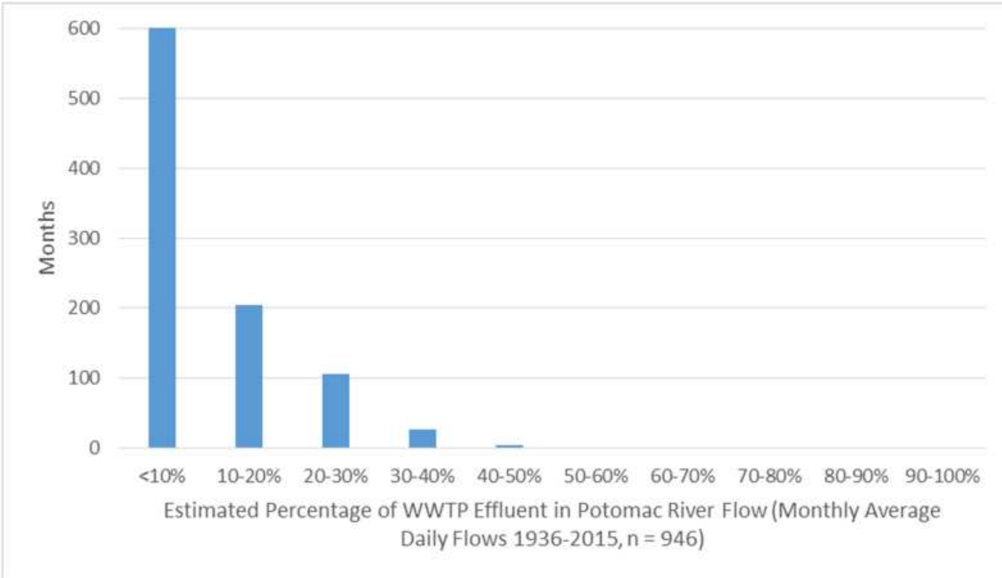

Figure 10: Cumulative Months for Estimated Percentages of Washington DC Area Wastewater Flows in the Potomac River near Charles County[17]

Other water quality parameters such as turbidity, alkalinity, pH, etc. are within the typical range for conventional flocculation and sedimentation before the filtration process. Figure 11 presents a process schematic of a WTP using the upper reaches of the Potomac River as a source of supply based on the available water quality data. If this option is selected for implementation, it will require detailed water quality data collection at the identified intake location along with pilot testing to confirm appropriate treatment process design. Another treatment consideration is the disposal of treatment plant residuals (e.g. backwash water, solids), which could be piped to a wastewater treatment plant or dewatered and disposed of by land application. A conceptual level cost estimate is provided for construction (capital) costs in Table 31. Refined cost estimates, including operation and maintenance, will be developed in Phase A-2.

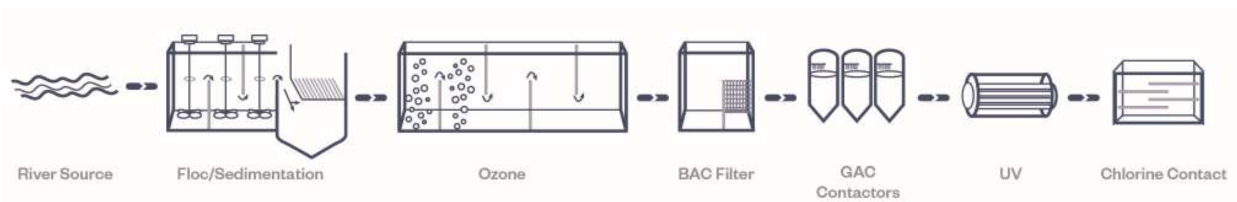

Figure 11: WTP Process Schematic for the Upper Reach Potomac River Source of Supply

[17] Tidal effects also provide dilution of wastewater flows, but is difficult to quantify.

Table 31: Summary of Estimated Capital Costs for Surface Water Treatment Train S-1 in Millions of Dollars as a Function of Plant Capacity

Capacity (mgd)	Treatment train S-1: Floc/sed-O3-BAC-GAC-UV-Chlorine	
	Total estimated capital cost ($M)	Unit capital cost ($M/mgd)
2	$16 – 43	$8 - 22
5	$28 – 73	$6 – 15
10	$43 - 113	$4 – 11

In addition to water quality and process selection, other considerations for this alternative include acquisition of property and/or easements for the WTP facility itself, an intake in the Potomac River, and pipelines connecting the intake, WTP, and distribution system. A potential property for an intake/WTP is the Ruth B. Swann Memorial Park, which is a County park just south of the confluence of the Pomonkey Creek and Potomac River. The site is relatively close to the Indian Head and Bryans Road areas and has waterfront access. In addition to the typical permits for municipal drinking water infrastructure (e.g. state water appropriation and constructions permits, local building permits, etc.), construction of an intake in the Potomac River will require a Joint Permit Application through the U.S. Army Corps of Engineers (ACOE) for work in the waters of the U.S. Property acquisition and intake permitting have the potential to be fatal flaws due to cost, lead time, permit constraints, or other factors. Therefore it is recommended the County begin to identify sites as soon as possible and explore the permit process with the ACOE in advance of subsequent phases of this study.

While cost or other factors (e.g. property acquisition, intake permitting, etc.) may ultimately prove prohibitive, there are no identified fatal flaws for this option that would exclude it from the list of potential alternatives to be examined in the Phase A-2 analysis (Table 32).

Table 32: Preliminary Screening Assessment for Alternative S-1

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws
Supply Reliability	✓	No fatal flaws
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Alternative S-2: Surface Water Treatment Plant – Potomac River lower reaches

For the purposes of this study, the lower reach of the Potomac River for Charles County is defined as the section of the river that extends approximately 48 miles from the Mattawoman Creek outlet to the confluence with the Wicomico River (Figure 12). This section of river is defined by the USGS as the Lower Potomac Watershed, hydrologic unit code (HUC) 02070011. Available water quality data within this section of the river were reviewed to identify the level of treatment that would be required for a WTP. Note that detailed water quality measurements, obtained through a well-designed sampling program, would be needed at specific potential WTP intake locations in order to design the treatment processes needed to efficiently and cost effectively meet drinking water quality regulations and supply needs.

As in the upper reach, salinity varies substantially with location and flow rate in the lower reach of the Potomac River adjacent to Charles County. Salinity increases from upstream to downstream, and overall concentrations are typically in the moderate to high range for brackish water treatment. For the Lower Potomac River HUC, monthly averages ranged from ~4,500 (May) to 9,000 mg/L (October) (data from 2000 to 2013; 1,083 readings from the main stem of the river in total). A WTP at this location would require desalination to maintain TDS and chloride levels within secondary drinking water quality standards.

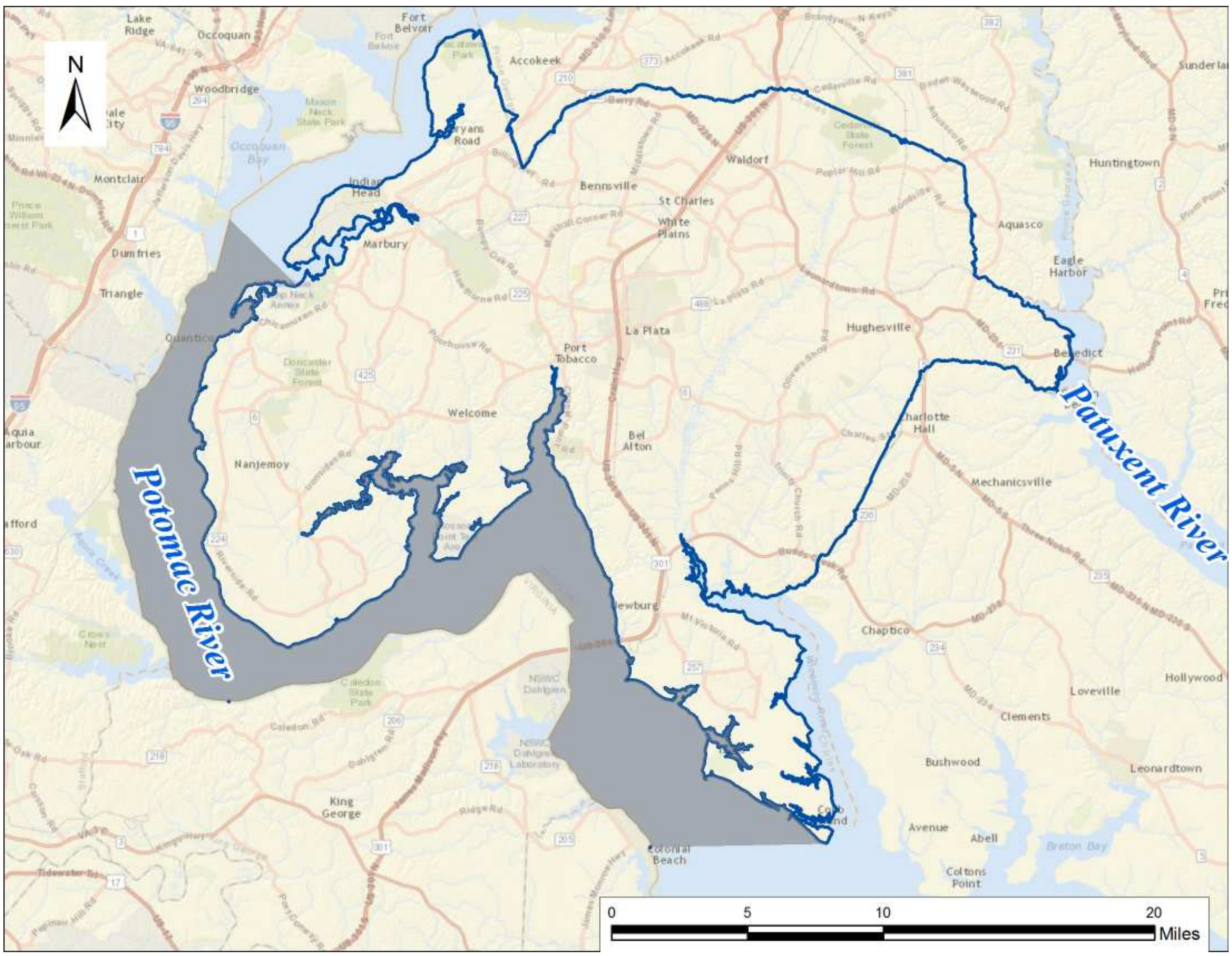

Figure 12: Lower Reaches of the Potomac River adjacent to Charles County (shaded gray)

Table 33: Potomac River Water Quality in the Lower Potomac River HUC (02070011)

Water Quality Parameter	Average	Year Range
Total dissolved solids (mg/L)	7,100	2000 – 2013
Fecal coliforms (MPN/100 mL)	15	2000 – 2013
Organic carbon (mg/L)	2.4	2000 – 2013
Turbidity (NTU)	20	2009 – 2013
Alkalinity (mg/L)	75	2013 – 2013
pH	7.9	1978 – 2013

While the lower reach of the Potomac River receives substantial wastewater effluent and non-point pollution from upstream sources similar to the upper reaches, dilution and natural attenuation reduce the presence of indicator organisms (fecal coliforms average 15 MPN) and the potential for algal blooms. A conceptual treatment train for this source consists of coagulation/flocculation, microfiltration and reverse osmosis membranes and advanced oxidation (UV/H_2O_2) (Figure 13). However, the design would depend on specific water quality conditions at the location of an intake along the lower reaches of the Potomac River, and would require additional water quality monitoring and pilot testing to confirm the most appropriate treatment processes. A conceptual level cost estimate is provided for construction (capital) costs in Table 34.

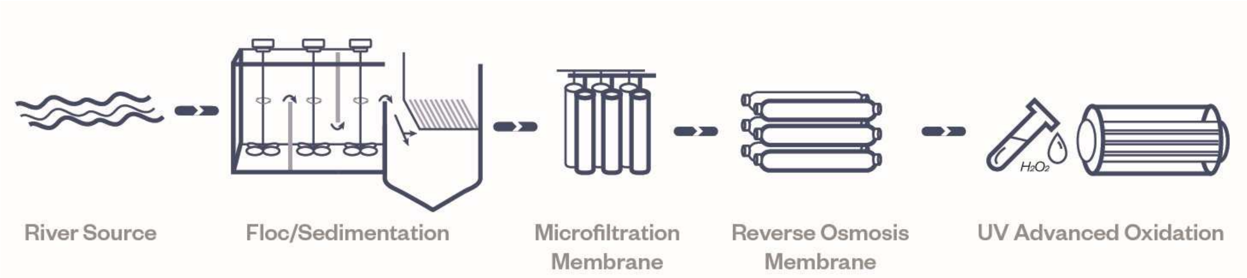

Figure 13: WTP Process Schematic for the Lower Reach Potomac River Source of Supply

Table 34: Summary of Estimated Capital Costs for Surface Water Treatment Train S-2 in Millions of Dollars as a Function of Plant Capacity

Capacity (mgd)	Treatment train S-2: Floc/sed-MF-RO-UV/AOP	
	Total estimated capital cost ($M)	Unit capital cost ($M/mgd)
2	$19 – 49	$10 – 25
5	$38 – 99	$8 – 20
10	$66 – 173	$7 – 17

Another treatment consideration is the disposal of treatment plant residuals, which for brackish water desalination can be significant. Water recovery at the range of salinities for the lower Potomac River can range from 50% to 80% (Harvey 2008). Disposal of RO process wastewater would require sufficient dilution before being discharged to the Potomac River. Existing WWTPs in proximity to the lower reaches of the Potomac River would most likely be too small to receive a substantial volume of RO process wastewater. Therefore the only feasible brine disposal option for this alternative would be to mix the RO process wastewater with the return flow from a thermo-electric generating station, such as the facility at Morgantown (refer to Alternative S-5).

If GenOn Energy Holdings (owner of the Morgantown Generating Station) is amenable to mixing RO process wastewater with the return flows from the generating station, this option could become feasible. However, it is unlikely to be cost effective relative to Alternative S-1 due to treatment costs and further distance from population centers. Therefore, this option is screened out of further consideration based on cost of desalination, difficulty of disposing of treatment residuals, and cost to connect to the distribution system (Table 35).

Table 35: Preliminary Screening Assessment for Alternative S-2

Criteria	Assessment	Explanation
Capital Cost	✘	High cost of desalination and distance from population centers of the County
Operation and Maintenance Cost	✘	High energy cost of desalination
Water Quality	✓	No fatal flaws
Supply Reliability	✓	No fatal flaws
Ease of Operation	✘	Difficulty disposing of the RO process wastewater
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Alternative S-3: New Patuxent WTP

While substantially smaller than the Potomac River, flows in the Patuxent River, which average over 100 mgd, would be sufficient to be a source of supply for Charles County. However, as with the Potomac River, the Patuxent River water quality would be an issue (e.g. salinity, non-point source pollution, and wastewater discharges). Charles County frontage along the Patuxent is approximately five miles,[18] which is also substantially less than for the Potomac River. Water quality within this section of the river was reviewed to identify the level of treatment that would be required for a WTP.

This analysis is based on available water quality data for the section of the Patuxent River in proximity to the County. Detailed water quality measurements would be needed at specific potential WTP intake locations in order to design the treatment processes needed to efficiently and cost effectively meet drinking water quality regulations and supply needs. Historical monthly average salinity ranged from ~4,000 to 6,000 mg/L, reaching as high as 10,000 mg/L. These levels are in the moderate to high range for brackish desalination. A WTP at this location would require desalination to maintain TDS and chloride levels within the secondary drinking water quality standards.

[18] Includes waterfront length at Charles Cove and Indian Creek Cove, which accounts for approximately half of the waterfront length.

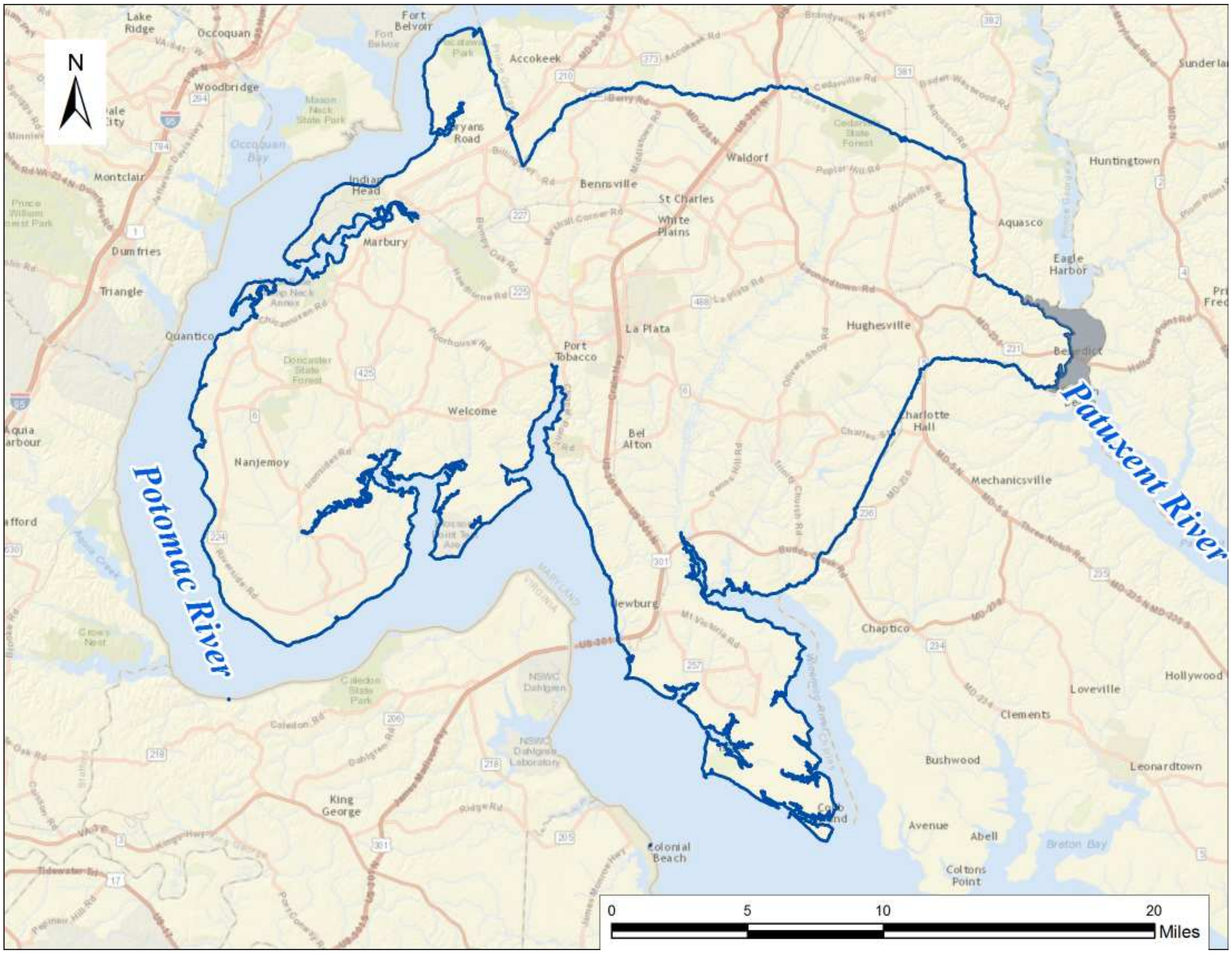

Figure 14: Patuxent River adjacent to Charles County (shaded gray)

Table 36: Patuxent River Water Quality in the Patuxent River HUC (02060006)

Water Quality Parameter	Average	Year Range
Total dissolved solids (mg/L)	4,700	1985 – 2013
Fecal coliforms (MPN/100 mL)	33	2004 – 2013
Organic carbon (mg/L)	4.4	1985 – 2013
Turbidity (NTU)	No data	No data
Alkalinity (mg/L)	48	1986 – 1990
pH	7.6	1985 – 2013

A conceptual treatment train for this source would be similar to a WTP along the lower reaches of the Potomac River and consist of coagulation/flocculation, microfiltration and reverse osmosis membranes, and advanced oxidation (UV/H_2O_2) (Figure 15). However, the design would depend on specific water quality conditions at the location of an intake along the lower reaches of the Patuxent River, and would require additional water quality monitoring and pilot testing to confirm the most appropriate treatment processes. A conceptual level cost estimate is provided for construction (capital) costs in Table 37.

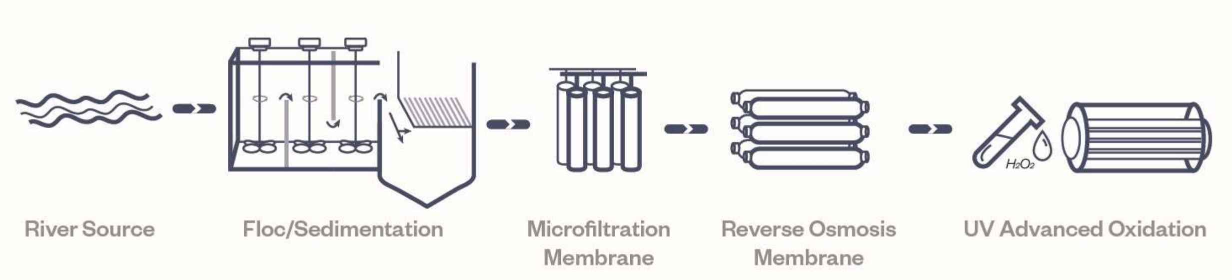

Figure 15: WTP Process Schematic for the Patuxent River Source of Supply

Table 37: Summary of Estimated Capital Costs for Surface Water Treatment Train S-3 in Millions of Dollars as a Function of Plant Capacity

Capacity (mgd)	Treatment train S-2: Floc/sed-MF-RO-UV/AOP	
	Total estimated capital cost ($M)	Unit capital cost ($M/mgd)
2	$19 – 49	$10 – 25
5	$38 – 99	$8 – 20
10	$66 – 173	$7 – 17

Another treatment consideration is the disposal of treatment plant residuals, which for brackish water desalination can be significant. Water recovery at the range of salinities for the Patuxent River can range from 50% to 80% (Harvey 2008). Disposal of RO process wastewater would require sufficient dilution before being discharged to the Potomac River. There are no existing WWTPs in proximity to the Patuxent River in Charles County for disposal. Therefore disposal of RO process wastewater would be a major issue. Therefore the only feasible brine disposal option for this alternative would be to mix the RO process wastewater with the return flow from a thermo-electric generating station. The Chalk Point Generating Station, which is owned by NRG Energy, Inc., is located across Charles Cove in Prince George's County. NRG Energy, Inc. has not been approached about the possibility of mixing RO process water with return flow from the plant.

If NRG Energy, Inc. is amenable to mixing RO process wastewater with the return flows from the generating station, this option could become feasible. However, it is unlikely to be cost effective relative to Alternative S-1 due to treatment costs (similar to those presented for Alternative S-2 in Table 34) and further distance from population centers. Therefore, this option is screened out of further consideration based on cost of desalination, difficulty of disposing of treatment residuals, and cost to connect to the distribution system (Table 39).

Table 38: Preliminary Screening Assessment for Alternative S-2

Criteria	Assessment	Explanation
Capital Cost	✗	High cost of desalination and distance from population centers of the County
Operation and Maintenance Cost	✗	High energy cost of desalination
Water Quality	✓	No fatal flaws
Supply Reliability	✓	No fatal flaws
Ease of Operation	✗	Difficulty disposing of the RO process wastewater
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Alternative S-4: Goddard Power Plant Intake at the Naval Surface Warfare Center at Indian Head, MD

The Naval Surface Warfare Center (NSWC) at Indian Head, MD withdraws water for potable use from the Patapsco and Patuxent aquifers, and withdraws water for fire suppression and cooling water from the Potomac River. The NSWC recently decommissioned the 60-year old Goddard coal-fired power plant in October 2015. The new plant being constructed will require 75% less water. The Naval Support Facility Indian Head was contacted to explore the potential for CCG to purchase excess intake capacity available from the original plant. Facility staff responded that excess withdrawal capacity was re-allocated at the facility and is not available for purchase from the Federal government.

Unavailable Potomac River intake capacity at the NSWC is a fatal flaw for this option and it is removed from further consideration.

Alternative S-5: Morgantown Generating Station at Morgantown, MD

The Morgantown Generating Station, located in Morgantown, MD, is currently owned by GenOn Energy Holdings. The facility withdraws water from the Patapsco aquifer for potable uses and miscellaneous operational needs. Additionally, the facility withdraws water from the Potomac River for cooling and process water (Table 39). The majority of the water withdrawn from the Potomac River is minimally treated (sodium hypochlorite for biofouling control when necessary) and is for cooling before being discharged back to the river. A portion of the Potomac River water is, however, treated with RO for use in the wet flue gas desulfurization scrubbers.

Table 39: Permitted Allocations for the Morgantown Generating Facility

Source	MDE Water Appropriation and Use Permit		
	Permit Number	Annual Average Daily Use (gpd)	Max Month Daily Average (gpd)
Lower Patapsco aquifer	CH1967G011 (12)	700,000	1,000,000
Potomac River	CH1956S003(10)	1,500,000	2,400,000
Potomac River	CH1967S111(04)	3,440,000	4,680,000

There are a few potential options associated with this alternative:

1. Purchase excess RO-treated water to augment CCG drinking water supplies in the southern portion of the County;
2. Purchase excess raw water from the Potomac River for use with a County-owned treatment plant (refer to Alternative S-2: Surface Water Treatment Plant – Potomac River lower reaches); and
3. Utilize the return flow to the Potomac River for dilution of desalination brine from a new County-owned treatment plant (refer to Alternative S-2: Surface Water Treatment Plant – Potomac River lower reaches).

Options 2 and 3 above screen out based on the reasons that make Alternative S-2 undesirable and are not considered further. The Hazen team has reached out to the GenOn Energy Holdings, formerly the Mirant Corporation, to identify feasibility of option 1 above. The individuals contacted have forwarded our queries to facility management for consideration.

While cost and other factors (e.g. inability to reach agreement with GenOn Energy Holdings) may ultimately be prohibitive, at this time there are no identified fatal flaws for purchasing RO-treated water that would exclude it from the list of potential alternatives for further study during Phase A-2 (Table 40).

Table 40: Preliminary Screening Assessment for Alternative S-5

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws
Supply Reliability	✓	No fatal flaws
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Riverbank Filtration

Riverbank Filtration (RBF) is the process by which surficial aquifer recharge is induced from a surface water source (typically a river) by pumping from wells located in proximity to the surface water source (Figure 16). Physical, chemical, and biological processes within the streambed and aquifer, along with dilution from local, surficial groundwater, can provide reductions in critical water quality parameters relative to the river source. Thus reducing the amount of engineered treatment required for use as drinking water source. This can lead to substantial reductions in capital costs, land requirements, as well as operations and maintenance costs (e.g. chemicals, residuals handling).

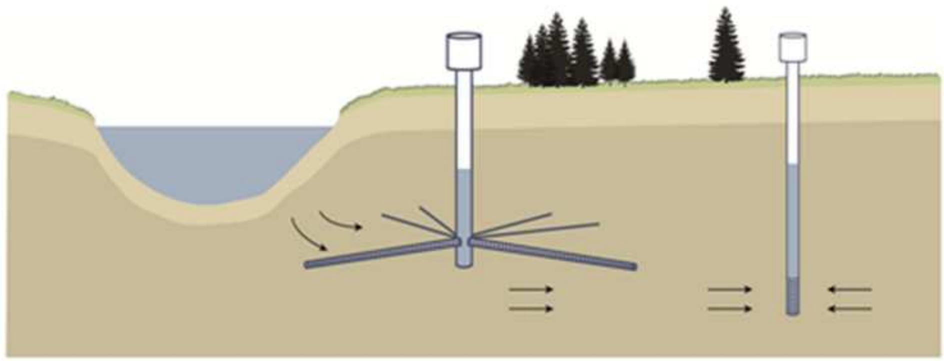

Figure 16 : Example Riverbank Filtration System with Horizontal Collector (Ranney) Well (Left) and Vertical Well (Right)

A RBF system can be generally understood as a cross between a surface water source and a groundwater source. The proximity to a large, reliable surface water source such as the Potomac River ensures an adequate supply over most conditions, while transport through the surficial aquifer provides water quality benefits and can serve as a buffer to mitigate shock loadings of contaminants in the river, such as a chemical spill or WWTP overflow; and large, seasonal fluctuations in river water quality. It should also be noted that for a utility like CCG, with extensive experience in operating groundwater wells, O&M requirements for RBF wells will be familiar to staff.

RBF has been extensively utilized in Europe for more than 100 years (Kuehn and Mueller, 2000). The European experience has revealed a number of water quality improvements associated with RBF, including removal of organic matter, suspended solids, tastes and odors, and coliform, as well as attenuation of shock loads of chemical contaminants (Doussan et al, 1997; Juttner, 1995; Cosovic et al, 1996; Miettinen et al, 1994). Experience with RBF in the U.S. is more limited but interest in the process picked up in the late 1990s due to concerns over DBPs and pathogens, and recognition that RBF could be a low-cost way to minimize subsequent treatment requirements while meeting DBP and microbial regulations (Weiss et al., 2002; Weiss et al., 2003 a, b; Weiss et al., 2005).

Today there are at least 25 major RBF systems operating in the U.S. with system capacities ranging from less than 1 to more than 100 mgd; and likely many more systems officially classified as GWUDI that are essentially unrecognized RBF systems. Data reported from these systems indicate typically high removals of total and dissolved organic carbon (TOC/DOC), disinfection by-product precursor compounds, turbidity, and microorganisms (Wang et al., 2002; Weiss et al., 2003 a, b; Gollnitz et al., 2003; Weiss et al., 2005; Partinoudi, 2007). Under certain conditions, some pharmaceutically active compounds that are biologically degradable have demonstrated high potential for removal (Snyder et al., 2007; Heberer et al., 2008). However, non-biodegradable compounds of low molecular size should not be expected to be readily removed during RBF.

The most common well type in the U.S. is the horizontal collector well, or radial collector well, since it generally can provide higher withdrawal capacity than a single vertical well, reducing the need for construction of multiple wells. RBF is typically practiced in the surficial aquifer surrounding a river, but there are also examples of lake-bank filtration and some water utility use of infiltration galleries, in which surface water is delivered to a large pond and drawn through the subsurface and collected via wells. Performance of a RBF facility, with regard to both yield and water quality, is very site specific but tends to be stable, with river scour and biological processes minimizing the build-up of clogging material within the riverbed. The aquifer material and hydraulic connection between the surface water and the aquifer generally determines the hydraulic yield of an RBF system as well as the magnitude of water quality benefits.

As with a surface water intake, the required level of subsequent treatment will depend on the baseline water quality and treatability testing. At a minimum, RBF can be used as a pretreatment process to reduce subsequent treatment requirements and provide an additional buffer against many surface water contaminants (e.g. natural organic matter, turbidity, microorganisms). In some cases, RBF may provide high quality water such that minimal additional treatment is necessary. In the case of the Potomac River, it is likely that some level of additional treatment would be needed due to the presence of substantial wastewater treatment plant effluent upstream.

As described previously for Alternative S-1, the Potomac River can occasionally high concentrations of salinity above the secondary regulatory standards. The impacts of transient elevated salinity events are reduced for RBF compared to surface water intakes sources due to the extended travel time of water from the river to the well, which may range from months to years (Navoy et al, 2004). However RBF alternatives may benefit from a management plan to address the potential for infrequent, short-term elevated salinity as described for Alternative S-1.

The EPA has recognized the ability of RBF to reduce concentrations of pathogenic microorganisms and included RBF as part of the LT2ESWTR "Microbial Toolbox," as described above under Water quality Considerations. Wells that are located at a setback distance of 25 feet between the riverbed and the closest well screen are given 0.5 log (68%) removal credit for *Cryptosporidium*, while wells located at a setback distance of 50 feet are given 1.0 log (90%) removal credit. In both cases, the aquifer material must be unconsolidated silt, clay, sand, and gravel containing at least 10% fine material (defined as <0.1 mm in diameter).

Alternatively, for a utility employing filtration in addition to RBF, source water monitoring can be performed on the extracted well water as opposed to the surface water source for determining bin classification for the LT2ESTWR. This could potentially result in a lower bin classification with less additional treatment required; however, the utility would not be eligible for the 0.5-log or 1.0-log treatment credits for bank filtration given in the Microbial Toolbox. Finally, there have been cases in which utilities using RBF have successfully obtained additional treatment credits as an alternative filtration technology by conducting a demonstration of performance study (Gollnitz et al., 2003, 2004, 2005). However, given the presence of major wastewater treatment plant outfalls and other potential sources of contamination upstream, it is expected that filtration and advanced treatment following extraction would be desirable as additional barriers to prevent contamination of the CCG water supply system.

If RBF were chosen as a preferred alternative for implementation, additional study would be required to evaluate the hydraulic connection between the river and the aquifer, estimate site-specific yields, and characterize the aquifer material and associated potential for removing water quality contaminants and achieving log removal credits under the LT2ESWTR. While some fine-grained material is desirable to provide adequate depth filtration for contaminant removal (and 10% fines are required for log removal credit for *Cryptosporidium*), an excess amount of fine material can reduce the hydraulic conductivity of the aquifer, cause clogging, and reduce the yield and long-term reliability of the system. Aquifer particle size distributions should be compared against values from the literature, such as those compiled for a number of RBF systems in Hubbs et al. (2006).

Components of a site characterization should include:

- Full characterization of Potomac River and surficial groundwater quality in the vicinity of the selected site;
- River and surface geophysical investigations to characterize the aquifer media and river/aquifer hydraulic connection prior to more costly drilling techniques;
- Soil borings to further characterize aquifer sediment characteristics;
- Pump testing to estimate aquifer volume, induced infiltration rates, transmissivity, and hydraulic conductivity; and
- Seasonal water quality modeling under pumping conditions.

Three RBF alternatives were evaluated under this screening analysis, including two possibilities along the Potomac River and one along the Patuxent River.

Alternative B-1: Riverbank Filtration – Potomac River upper reaches (northern Bryans Road at Piscataway Park)

A system of three Ranney collector wells was installed in the northwest corner of the County near Marshall Hall for the U.S. Navy's Indian Head Naval Surface Warfare Center during World War II. Anecdotally, two of the wells (Well 2 and Well 3) were used only briefly (several months) before being permanently shut down. The third well (Well 1), closest to the Potomac River and likely having the highest amount of bank filtered Potomac River water, rather than surficial groundwater, was reported to have been used until 1960 to provide water to the Marshall Hall Amusement Park (Slaughter and Laughlin, 1966). Yields for Wells 2 and 3 were reported to range from 200 to 350 gpm (~0.3 to 0.5 mgd), and were described as penetrating "saturated material of relatively low permeability," a description supported by the low apparent yields (Bennett and Meyer, 1952; Otton, 1955). Yield data for Well 1 could not be found.

Communications with Henry Hunt (Layne, formerly Ranney) indicate that while Ranney provided consulting and advice regarding the construction of the collector wells, the company was not the contractor for installing the caissons, did not perform any site characterization, and was not part of the decision on well locations. Mr. Hunt stated that he was told by a Ranney employee from that era that senior Navy personnel simply chose three locations on a map, and that one of the wells was described to Mr. Hunt as "technically dry." During site visits conducted during for this study, the Hazen team found no surviving aboveground infrastructure at Well 1 and derelict aboveground infrastructure at the site of Well 3. Well 2 could not be located during the site visit but communication from Ed Gorham with CCG on 12/21/2015 indicated that it may have been built as a bunker, with most of the infrastructure below grade. This region may potentially be underlain by paleochannel deposits with permeable sand and gravel deposits mapped at the base of the paleochannel to the north, in Virginia (Froehling, 1997). It is not known if the collector wells intersected any paleochannel deposits.

Review of the tax parcel records for the former well locations indicates that Well 1 and Well 3 are currently located on National Park Service property within the bounds of the Piscataway Park. Well 2 is located further south on River Road and is on private property. Review of quit claim deeds and property records granted to CCG from the Navy indicates the easements for the former pipeline were transferred to the County, but no deeded property ownership was transferred. Development of water supply infrastructure on National Park Service property is considered to be unlikely, because one of the key functions of Piscataway Park is to maintain the viewshed from George Washington's Mount Vernon on the opposite side of the Potomac River. Further, based on previous experience, even if Charles County did own the parcel containing the well head, obtaining permits for easements and construction access in a protected Federal park would be a significant challenge.

The condition of the aboveground infrastructure, the 50+ year lack of use, the documented low yields, lack of adequate site characterization prior to installation, uncertain ownership status, and proximity to the Piscataway Park are all fatal flaws for this alternative (Table 41). Therefore, use of the abandoned RBF system at any of the former Naval Center well sites, either using the existing infrastructure or installing new infrastructure, is not recommended for further consideration.

Table 41: Preliminary Screening Assessment for Alternative B-1

Criteria	Assessment	Explanation
Capital Cost	✗	Existing infrastructure would need to be investigated and rehabbed or removed
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws
Supply Reliability	✗	Sites of existing RBF wells of questionable suitability and low reported yields
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✗	Uncertainty regarding land ownership status; obtaining permits, easements, and construction access on or adjacent to federal park land would be a significant challenge
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Alternative B-2: Riverbank Filtration – Potomac River upper reaches

The development of RBF would be feasible if permeable sediments are encountered along the Potomac River, which could include sediments associated with paleochannel deposits. The search for alternative sites along the Potomac River for a RBF system was driven by the need to stay in the upper reaches to avoid desalination and consideration of property acquisition and easements (see discussion of Alternative S-1). As described for Alternative S-1, the Ruth B. Swann Memorial Park, just south of the confluence of the Potomac River and Pomonkey Creek, offers a possible location for which CCG has ownership. While there may be challenges related to public acceptance of using park lands for a water facility, the system could be designed to minimize impacts on the existing land use. The use of high capacity horizontal collector wells would limit the amount of land disturbance; and because RBF offers a level of pretreatment, subsequent treatment requirements would be less than for a surface water treatment plant, thereby reducing the amount of land required for treatment facilities. While the use of the park is a possibility, the primary consideration would be sediment character and well yield. Other sites along the upper reaches of the Potomac River should be considered based on hydrogeological evaluation.

The major treatment benefit of RBF over a surface water intake at this location (Alternative S-1) is that RBF pretreatment would preclude the need for conventional coagulation, flocculation, and sedimentation. For this screening analysis, the Hazen team proposes an approach similar to Alternative S-1, but without coagulation, flocculation, and sedimentation processes, as a possible treatment scenario for cost estimation purposes (Figure 17). Specifically, the extracted water would undergo ozonation and biologically active filtration for additional removal of organics, taste and odor compounds, and protection against algal toxins; optional GAC adsorption to protect against upstream contaminant sources; optional UV disinfection to control microorganisms; and chlorine contact to provide disinfection residual (refer to Table 22). A conceptual level cost estimate is provided for construction (capital) costs in Table 42. Refined cost estimates, including annual operation and maintenance, will be developed in Phase A-2.

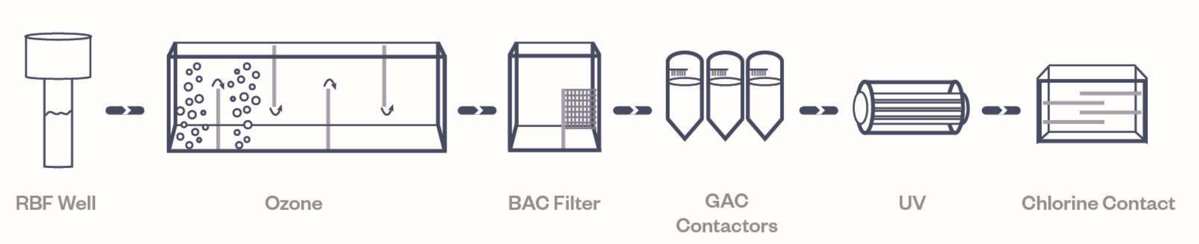

Figure 17: WTP Process Schematic for a Potomac River RBF Source of Supply

Table 42: Summary of Estimated Capital Costs for Riverbank Filtration Treatment Train B-2 in Millions of Dollars as a Function of Plant Capacity

Capacity (mgd)	Treatment train B-2: RBF-O3-BAC-GAC-UV-Chlorine	
	Total estimated capital cost ($M)	Unit capital cost ($M/mgd)
2	$16 – 41	$8 – 21
5	$26 – 67	$5 – 13
10	$40 – 104	$4 – 10

Similar to the case for a surface water intake, treatment or operational solutions should be investigated to ensure uninterrupted water supply during infrequent periods of elevated salinity that could increase salinity from RBF wells. As described above, the suitability of this location for a RBF system and the level of subsequent treatment required would be based on water quality sampling, aquifer characterization, hydraulic testing, and estimation of yield. Based on this screening evaluation, there are no fatal flaws at this point for a RBF system in the upper reaches of the Potomac River that would exclude it from the list of potential alternatives to be examined in the Phase A-2 analysis (Table 43).

Table 43: Preliminary Screening Assessment for Alternative B-2

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws
Supply Reliability	✓	No fatal flaws
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Alternative B-3: Riverbank Filtration – Patuxent River

Similar to Alternative S-3, the Patuxent River was also considered for a RBF system. However, the major drawback of the Patuxent River for a surface water intake, high salinity, is also a drawback for a RBF system since aquifer passage is not expected to sufficiently dilute chlorides or other components of TDS. Desalination by RO would be recommended for RBF along the Patuxent River. One benefit of RBF over a surface water intake along the Patuxent River is that RBF would provide some pretreatment to reduce fouling of RO membranes. Further, since RBF is a mixture of groundwater and surface water, some dilution of surface water TDS would occur. Nevertheless, as with Alternative S-3, the cost of desalination, difficulty of disposing of treatment residuals, and cost to connect to the distribution system are fatal flaws for this alternative (Table 44). A RBF system along the Patuxent River is, therefore, not recommended for further study.

Table 44: Preliminary Screening Assessment for Alternative B-3

Criteria	Assessment	Explanation
Capital Cost	✗	High cost of desalination and distance from population centers of the County
Operation and Maintenance Cost	✗	High energy cost of desalination
Water Quality	✓	No fatal flaws
Supply Reliability	✓	No fatal flaws
Ease of Operation	✗	Difficulty disposing of the RO process wastewater
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Reuse

Water reuse is a long-standing and established practice in many areas of the United States and globally, and it is being increasingly embraced in the State of Maryland from a regulatory and operational standpoint. The recovery of water from wastewater effluent is typically motivated by stress on water supplies resulting from a combination of climatic conditions, population growth, increased agricultural needs, urbanization, and industrialization. Water reuse is also an alternative to discharging high quality wastewater effluent into the environment, where there is no direct economic benefit to the wastewater facility, especially as increasingly stringent wastewater standards become a reality. In some cases, water reuse can also be used as a means to comply with environmental discharge limits (e.g., diverting nutrient load away from surface waters to comply with nutrient waste load allocations). Water reuse has the potential to increase potable water supplies relative to demand by substituting reclaimed water for potable water in non-potable applications (non-potable reuse) or through the direct augmentation of potable water supplies with reclaimed water (potable reuse).

Currently, there are no federal regulations for water reuse, so states have adopted their own water reuse regulations. Guidelines across the U.S. range from minimal treatment with restricted use to applications such as creating potable water supplies by blending with groundwater in the aquifer, with surface waters in lakes/reservoirs, or supplying water directly to drinking water treatment plants for treatment and distribution. In Maryland, the basis for water reuse is contained in Maryland code and two sets of guidelines written by MDE pertaining to specific Classes of reclaimed water. The Class designation of a reclaimed water refers to the degree to which water is treated, corresponding to specific reuse applications for which that class is authorized. Class I is the lowest quality reclaimed water designation and therefore Class I water has the most restricted use, while Class IV is the highest quality reclaimed water designation and thus Class IV reclaimed water is more widespread in its allowable uses. Guidelines pertaining to Class IV reclaimed water were the most recently released and apply to reuse applications with high potential for human contact. Reclaimed water regulatory language and guidelines are provided in the following documents:

- Annotated Code of Maryland, § 9-303.1 – Use of reclaimed water
    - MDE is directed to "encourage use of reclaimed water as an alternative to discharging treated sewage effluent to surface waters of the State"
- MDE-WMA-001-04/10 Guidelines for Land Application/Reuse of Treated Municipal Wastewaters
    - Pertains to Class I, II and III reclaimed water generated from a centralized wastewater treatment works
- MDE-WMA-002-07/15 Guidelines for Use of Class IV Reclaimed Water: High Potential for Human Contact
    - Pertains to Class IV reclaimed water generated from a centralized wastewater treatment works

Table 45 summarizes the water quality parameters and allowable reuse categories that apply to each of the four reclaimed water designations. In terms of volumetric flow, water reuse in Maryland is dominated by spray irrigation, followed by industrial cooling. Drip irrigation is also practiced, but to a much lesser extent. It should be noted that existing guidelines only address non-potable reuse and make no specific mention of indirect or direct potable reuse.

Table 45: Summary of Maryland Department of the Environment Guidelines for Water Non-potable Reuse

Parameter	Quality Requirement[1]			
	Class I	Class II	Class III	Class IV
Biochemical oxygen demand (monthly average)	70 mg/L	10 mg/L	10 mg/L	10 mg/L
Turbidity/suspended solids	90 mg/L (monthly average)	10 mg/L (monthly average)	2 NTU (daily average) Not to exceed 5 NTU at any time	2 NTU (daily average) CAT > 5 NTU (at any time)
E. coli (monthly median)	N/A	NA	N/A	1 MPN/100 mL Or meeting the fecal coliform limit below CAT > 23 MPN/100 mL (monthly maximum)
Fecal coliform	200 MPN/100 mL (monthly geometric mean) Or 3 MPN/100 mL (monthly geometric mean) for use on golf courses	3 MPN/100 mL (monthly geometric mean)	2.2 MPN/100 mL (monthly geometric mean)	2.2 MPN/100 mL (monthly median) CAT > 23 MPN/100 mL (monthly maximum)
pH (any time)	6.5 – 8.5	6.5 – 8.5	6.5 – 8.5	6. 5- 8.5
Total nitrogen (monthly average)	Case by case	Case by case	Case by case	10 mg/L
Total residual chlorine (measured at the treatment system outlet)	N/A	N/A	N/A	1.5 – 4.0 mg/L (any time) CAT < 1. 5 mg/L or > 4.0 mg/L
Total residual chlorine (measured at designated sampling locations in the distribution system)	N/A	N/A	N/A	0.5 – 4.0 mg/L (any time) CAT < 0.5 mg/L or > 4.0 mg/L
Allowable reuse categories	Irrigation with restricted access and applicable buffer zone	Irrigation with restricted access and applicable buffer zone	Irrigation with restricted access and applicable buffer zone; non-residential irrigation	Irrigation with restricted access and applicable buffer zone; non-residential irrigation; commercial, industrial, and government owned facilities; other industrial; residential outdoor irrigation

CCG has already implemented non-potable reuse and an expansion of the existing program is under construction. Currently, non-potable reuse by CCG involves the delivery of Class IV reclaimed water from the Mattawoman Wastewater Treatment Plant to the Panda Power Plant in Prince George's County for use in its cooling towers. The expanded reuse program will include continued provision of additional reclaimed water to the Panda Power Plant (0.66 mgd), as well as reclaimed water flow to Competitive Power Ventures (CPV) (3.40 mgd), both for cooling purposes. The water source alternatives discussed in this section pertain to expanding the use of reclaimed water in Charles County even further, with reclaimed water serving as either an offset for potable water demands (non-potable reuse) or an augmentation of potable water supplies (indirect potable reuse, direct potable reuse). The three reuse options below focus on the Mattawoman Wastewater Treatment Plant as the source of reclaimed water due to its capacity and current effluent flows relative to other local facilities. Additionally, it should be noted that the feasibility of all three reuse options below is expected to be impacted by how CCG elects to manage wells contaminated with polonium 210. Continued and increased disposal of water treatment residuals containing polonium 210 at the Mattawoman Wastewater Treatment Plant has the potential to adversely affect the actual and perceived quality of treated effluent, thus potentially requiring treatment that specifically addresses polonium 210 and gross alpha radiation, alternative disposal methods for residuals contaminated with polonium 210, and/or limited opportunities for water reuse.

Alternative R-1: Non-potable Reuse

Non-potable reuse, in which wastewater is treated and reused for non-potable applications in lieu of effluent disposal, is the most common form of water reuse in Maryland. Non-potable reuse applications not only offset potable water demands, but also reduce effluent discharges into surface water bodies. The MDE has been directed to encourage water reuse as an alternative to discharging treated effluent into surface waters of the State due to the sensitivity of receiving waters to wastewater constituents (e.g., nutrients).

Based on Monthly Operating Reports from 2015, average flows for all public/municipal wastewater treatment plants operated by Charles County totaled to 10.6 mgd, the majority (> 95%) of which can be attributed to the Mattawoman Wastewater Treatment Plant. Increased non-potable reuse would likely involve increased allocations of treated effluent from the Mattawoman Wastewater Treatment Plant to new reclaimed water end users in order to build reclaimed water infrastructure where there is the most abundant supply of wastewater. As indicated by the Mattawoman Wastewater Treatment Plant's current allocation of reclaimed water to the Panda Power Plant and CPV for cooling purposes, reclaimed water produced at the Mattawoman Wastewater Treatment Plant can be characterized as Class IV. Class IV labeling allows reclaimed water to be used for all non-potable applications currently regulated by the Maryland Department of the Environment, including high human contact applications. Importantly, the current understanding is also that the Mattawoman Wastewater Treatment Plant is not subject to any minimum environmental discharge flow at the existing discharge site in Mattawoman Creek, thus indicating that the diversion of additional effluent flow away from the Potomac River Basin and to reclaimed water customers would be favorably received from a regulatory standpoint.

Further investigation of non-potable reuse opportunities in Charles County as a method for reducing potable water consumption is recommended. This pathway requires a better understanding of the current distribution of water demand throughout Charles County, as well as any developments on the planning horizon. For example, high density residential users, agricultural customers, industrial customers, and any other customers with significant water demand attributed to non-potable applications are all important potential end users for non-potable reclaimed water. Phase A-2 evaluations will weigh potential non-potable reclaimed water demand against the capital and operational costs required to deliver the supply. The expected variability in demand, as a function of customer stability, seasonal influences, and reclaimed water quality thresholds, will be taken into account, as this can impact onsite storage requirements and realized revenue.

The costs associated with increased non-potable reuse will mostly pertain to conveyance because existing treatment at the Mattawoman Wastewater Treatment Plant is already sufficient to achieve Class IV reclaimed water status, with the one caveat being chlorination. Planned operations at the Mattawoman Wastewater Treatment Plant include UV disinfection of all effluent flow to be discharged to Mattawoman Creek and chlorination (without UV disinfection) of all reclaimed water. These operations are motivated by the requirement that all effluent flow to the environment must carry no disinfection residual, while reclaimed water must maintain a disinfection residual at the treatment system outlet, in the distribution system, and at the point of use. Increased non-potable reuse would require the chlorination unit to be sized appropriately for the entire reclaimed water flow. Costs for non-potable reclaimed water conveyance will depend on the distribution of identified customers (i.e., density and distance from the Mattawoman Wastewater Treatment Plant) as well as the required pipe size to convey the demanded flow.

In addition to determining the potential for the Mattawoman Wastewater Treatment Plant to serve reclaimed water customers, the extent to which reclaimed water customers have the potential to impact operations at the plant will also be explored. More specifically, it is known that the Mattawoman Wastewater Treatment Plant currently operates at a lean food-to-microorganisms ratio, which has recently required the addition of supplemental carbon. In order to avoid exacerbating this situation, attention must be paid to the types of influent flow received by the Mattawoman Wastewater Treatment Plant and how water reuse customers may impact these flows. For example, some non-potable reuse applications (e.g., industrial cooling) will result in a return flow back to the Mattawoman Wastewater Treatment Plant containing high concentrations of salts and recalcitrant nutrients, as well as low concentrations of carbon (i.e., food). The sustainability and extent to which non-potable reuse can be practiced is expected to depend on achieving a balance in the reclaimed water customer base in terms of consumptive and non-consumptive users. If promising non-potable reuse customers are identified, a headworks analysis would be required to quantify influent loadings of various contaminants from existing and potential influent flows in comparison with thresholds of importance (e.g., total dissolved solids limits for irrigation, industrial cooling, and in-plant operations).

A summary of the preliminary screening assessment is provided in Table 46. There were no fatal flaws identified for Alternative R-1, and the alternative is recommended for further evaluation in Phase A-2.

Table 46: Preliminary Screening Assessment for Alternative R-1

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws, but capital costs depend on identification of potential customers and corresponding conveyance requirements
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws; Class IV reclaimed water quality already achieved at the Mattawoman Wastewater Treatment Plant
Supply Reliability	✓	No fatal flows
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws, but constructability depends on identification of potential customers and corresponding conveyance requirements
Ease of Permitting	✓	No fatal flows; non-potable reuse precedent already established
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws; non-potable reuse precedent already established
Regional Benefits	✓	No fatal flaws

Alternative R-2: Indirect Potable Reuse with Confined Aquifer Recharge

Indirect potable reuse, or IPR, is defined as the augmentation of a drinking water source (surface or groundwater) with reclaimed water followed by an environmental buffer that precedes drinking water treatment. Indirect potable reuse is considered planned and purposeful, whereas *de facto* reuse is a situation in which reuse of treated wastewater is in fact practiced, but not officially recognized (e.g., where a drinking water supply intake is located downstream from a wastewater treatment plant discharge point). Indirect potable reuse has been extensively and safely practiced for decades in other areas of the country, such as California's West Basin and Orange County Water District Groundwater Replenishment System and the Upper Occoquan Service Authority in Virginia. Environmental buffers for indirect potable reuse may include rivers, lakes, reservoirs, and aquifers, the most likely of which for Charles County is an aquifer. The injection of highly treated reclaimed water into one of Charles County's confined groundwater aquifers for subsequent withdrawal as potable water supply at a downgradient well is referred to here as indirect potable reuse with confined aquifer recharge. The result is additional water supply in the selected confined aquifer. Implementation of indirect potable reuse requires available/unallocated wastewater flows, advanced treatment to achieve adequate water quality, confirmation of aquifer stability with reclaimed water injection, regulatory approval, and public acceptance. The following paragraphs discuss each of these factors individually.

Average flows provided in Monthly Operating Reports for 2015 show that total public/municipal wastewater flows are 10.6 mgd, most of which is attributed to the Mattawoman Wastewater Treatment Plant (> 95%). Indirect potable reuse in Charles County would involve further intensifying treatment at the Mattawoman Wastewater Treatment Plant to achieve adequate water quality, followed by redirection of all or a portion of the treated effluent flow away from Mattawoman Creek to a groundwater injection well. Taking existing allocations to the Panda Power Plant and CPV Power Plant into account, as well as the assumption that there is no minimum flow requirement for discharges to Mattawoman Creek, Mattawoman Wastewater Treatment Plant could potentially provide approximately 6 mgd to potable water supplies via confined aquifer recharge.

MDE does not currently provide regulatory guidance on indirect potable reuse, thus required water standards must be inferred based on other installations across the U.S. and confirmed in future conversations with MDE. For reference, water quality and treatment requirements for indirect potable reuse via subsurface groundwater replenishment in California are directed by Title 22 of the California Code of Regulations, which were most recently revised in July 2014 (Division 4, Chapter 3, Article 5.2 – Indirect Potable Reuse: Groundwater Replenishment – Subsurface Application). Water quality and treatment requirements mostly pertain to pathogenic microorganisms, nitrogen compounds, and regulated contaminants and physical characteristics (Table 47). Additionally, under California's Title 22, the selected treatment train must prove that it meets the definition and operational requirements of "full advanced treatment" through the use of reverse osmosis, oxidation treatment, upfront performance testing, and the development of an on-going performance monitoring plan including appropriate surrogate parameters (e.g., conductivity for reverse osmosis, indicator compounds for oxidation). Potable reuse guidelines have also been developed outside of California, such as in Florida, Georgia, Virginia, Pennsylvania, and other western states, with guidelines pertaining to each state's unique drivers and circumstances.

Table 47: Summary of California Water Quality Requirements for Indirect Potable Reuse via Groundwater Replenishment with Subsurface Application

Contaminant Category	Treatment and/or Monitoring Requirements
Pathogenic microorganisms	A function of both treatment and storage time in environmental buffer; compliance is 12-log enteric virus reduction, 10-log Giardia cyst reduction and 10-log Cryptosporidium oocyst reduction
Nitrogen compounds	Weekly testing for total nitrogen; compliance is total nitrogen < 10 mg/L
Regulated contaminants and physical characteristics	Quarterly testing for inorganic chemicals, radionuclide chemicals, organic chemicals, disinfection byproducts, lead and copper[1]; yearly testing for secondary drinking water contaminants; compliance based on primary and secondary contaminant maximum contaminant levels or action levels (lead and copper, NDMA)

[1]National primary drinking water contaminants plus nickel, 1,1-dichloroethane, 1,3-dichloropropene, methyl-tert-butyl ether, 1,1,2,2-tetrachloroethane, trichlorofluoromethane, 1,1,2-trichloro-1,2,2-trifluoroethane, bentazon, molinate, and thiobencarb
[2]Lead and copper has a national action level, NDMA has a California action level but no federal action level

Existing (and currently under construction) reclaimed water treatment at the Mattawoman Wastewater Treatment Plant includes primary clarification, enhanced nutrient removal, secondary clarification, sand filtration, and chlorination. Effluent total nitrogen concentrations reported in 2015 Monthly Operating Reports ranged from 0 to 57 mg/L, with an average value of 7.6 mg/L and an interquartile range of 1.5 to 14 mg/L. While we are not suggesting that the CA Title 22 regulations are the only means of moving forward, they are the most conservative regarding potable reuse and provide no credit for disinfection performance at the wastewater treatment plant. Discussions of risk reduction strategies and evaluations of process performance at the Mattawoman Wastewater Treatment Plant would likely need to be a collaborative process between CCG, MDE, and project engineers. Specifically, methodologies such as Hazard Analysis and Critical Control Points (HACCP) can be used to identify and manage risks in potable reuse systems (Walker, Stanford, et al., 2016 in press). With regard to regulated contaminants and physical characteristics, additional effluent sampling is required to compare current effluent water quality to primary and secondary maximum contaminant levels. Existing treatment processes and reported effluent quality suggest that production of indirect potable reuse quality water at the Mattawoman Wastewater Treatment Plant will require additional treatment processes. Options for safe, reliable production of IPR water include processes such as MF-RO-UV/H_2O_2 in addition to other options such as ozone-biofiltration with GAC and subsequent disinfection.

The treatment trains shown in Figure 18 and Figure 19 represent two options for the production of indirect potable reuse quality reclaimed water. Both trains are expected to be equivalent in terms of the quality of the reclaimed water produced if salinity levels in combined influent municipal flows and return flows from non-potable reuse customers (e.g., industrial cooling) are below the 500 mg/L secondary maximum contaminant level. At salinity levels greater than 500 mg/L, reverse osmosis may be desired to remove the salty taste. In addition to salinity considerations, there are important tradeoffs between the two treatment trains (e.g., chemical inputs vs. energy inputs vs. operational complexity), which ultimately determine which option would be recommended if both were acceptable in terms of salinity. Both indirect potable reuse trains provide a multiple-barrier approach for the minimization of contamination in reclaimed water. Estimated capital costs for RO-based treatment train #1 (Figure 18) and non-RO based treatment train #2 (Figure 19) are presented in Table 48. The two treatment trains are comparable in terms of capital cost, thus highlighting the potential importance of other factors that would influence which train is preferred for CCG (e.g., footprint, operational complexity, operation and maintenance). More refined cost estimates specific to CCG will be developed for Phase A-2, including those pertaining to annual operation and maintenance costs. Operation and maintenance costs will be a critical factor considering the energy intensity and residuals disposal requirements associated with reverse osmosis.

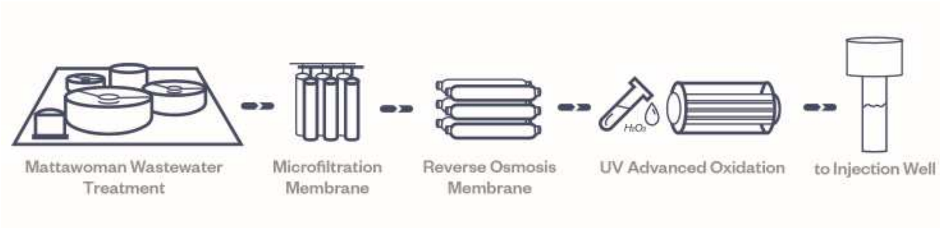

Figure 18: Indirect Potable Reuse Treatment Train #1

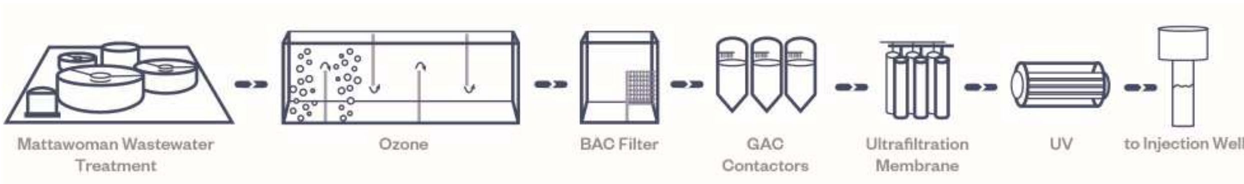

Figure 19: Indirect Potable Reuse Treatment Train #2

Table 48: Summary of Estimated Capital Costs for IPR Treatment Trains #1 And #2 in Millions of Dollars as a Function of Plant Capacity

Capacity (mgd)	Treatment train #1: MF-RO-UV/H_2O_2		Treatment train #2: O_3-BAC-GAC-UF-UV	
	Total estimated capital cost ($M)	Unit capital cost ($M/mgd)	Total estimated capital cost ($M)	Unit capital cost ($M/mgd)
2	$16 – 43	$8 – 22	$20 – 52	$10 – 26
5	$32 – 84	$6 – 17	$35 – 91	$7 – 18
10	$56 – 146	$6 – 15	$55 – 143	$5 – 14

In addition to producing water suitable for potable purposes, indirect potable reuse with confined aquifer recharge requires that the finished reclaimed water also be compatible with aquifer geology. The details of subsurface water injection for subsequent withdrawal as potable water supply are further discussed in the section pertaining to Alternative C-1 (Aquifer Storage and Recovery). It should be noted that California regulations grant subsurface injection of reclaimed water with additional log-removal credits for pathogenic microorganism control (up to 1/1/1-log reduction per month of travel time). Injection and withdrawal wells must be located in different locations and one of several methods (e.g., tracer study, numerical modeling, analytical modeling) can be used to estimate the retention time between the injection well and the nearest downgradient drinking water well, taking both municipal and private wells into consideration.

Although precedents for producing indirect potable reuse quality water, as well as aquifer storage and recovery, exist for other parts of the country, these practices are untried in Maryland. Thus, determination of regulatory requirements (e.g. treatment standards, pilot-testing requirements, and permitting) may be a challenge. However, the lack of highly concentrated return flows, the potential to replenish diminishing groundwater supplies, and the diversion of nutrients away from surface waters resulting from indirect potable reuse suggest that this alternative should be further investigated in Phase A-2. Furthermore, the subsurface injection of highly treated reclaimed water at the Mattawoman Wastewater Treatment Plant for confined aquifer recharge maximizes the regional benefit of replenishing groundwater available to the entire County, while also minimizing the infrastructure required for conveyance.

Phase A-2 evaluations will include two indirect potable reuse treatment trains as additions to existing treatment at the Mattawoman Wastewater Treatment Plant: MF-RO-UV/H_2O_2 and O_3-BAC-GAC-UF-UV, both of which will end of subsurface injection (See Figure 18 and Figure 19). These two indirect potable reuse trains were selected to ensure a multiple barrier approach to producing high quality reclaimed water, as well as to represent two options with a range of operational complexity, waste management, and monitoring requirements. Space constraints, capital costs, operation and maintenance costs, and expected resulting water quality will all be taken into consideration. It should be noted that public acceptance of potable reuse is critical for its successful implementation and that there are several available resources to help guide public outreach efforts. Furthermore, the inclusion of the aquifer as an environmental buffer is expected to facilitate public acceptance of indirect potable reuse, as compared with direct potable reuse. A summary of Alternative R-2's preliminary screening assessment is shown in Table 49.

Table 49: Preliminary Screening Assessment for Alternative R-2

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws; however, required water quality has yet to be defined by Maryland Department of the Environment
Supply Reliability	✓	No fatal flaws
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws; however, a precedent for indirect potable reuse with confined aquifer recharge has not yet been established in Maryland, so permitting may a challenge
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws; resource allocation for public outreach is required; public acceptance facilitated by the environmental buffer
Regional Benefits	✓	No fatal flaws; benefits all those withdrawing water from the selected aquifer without requiring conveyance to specific users

Alternative R-3: Direct Potable Reuse

Direct potable reuse, or DPR, is defined as the introduction of reclaimed water (with or without retention in an engineered storage buffer) directly into a drinking water treatment plant, either co-located or remote from the advanced wastewater treatment system. DPR differs from more established indirect approaches to potable water recycling by the absence of an environmental buffer (e.g., aquifer, reservoir, lake). Implementation of direct potable reuse requires wastewater flows that are available and unallocated, as well as advanced treatment. The resulting high quality water can conceivably be blended into the water supply at three locations in a drinking water treatment and distribution system, including at the head of the water treatment plant, within the treatment plant, or in the distribution system (clearwell to far reaches of the distribution system). However, blending of DPR product water at the head of the water treatment plant or in the distribution system are the only two options that are expected to be used by water utilities.

Several potential benefits of direct potable reuse relative to indirect potable reuse have been identified related to costs and ability to control water quality within engineered buffer systems.

DPR is not currently practiced in Maryland and there are no existing regulations or guidelines for its implementation. The most recently released MDE guidance on reuse pertains to Class IV reclaimed water, and it specifically states that Class IV reclaimed water does not meet the standards for potable water. If other nearby states are looked to for additional examples, Virginia has a long-standing example of indirect potable reuse in the Occoquan Reservoir, but Virginia's water reuse and reclamation regulations list DPR as prohibited.

Considering the lack of historical and regulatory precedent for potable reuse in Maryland, DPR is not recommended for further evaluation as an alternative water source for Charles County (Table 50). Although direct potable reuse is being investigated and pursued in other areas of the country, MDE is not expected to view the current water supply and demand situation in Charles County as one necessitating DPR. Furthermore, public acceptance is critical for its successful implementation. This is a major challenge for the region due to the lack of exposure to similar reuse applications and the lack of an environmental buffer which typically helps minimize public concerns. Additionally, DPR would require a new or expanded drinking water distribution system in order to convey finished reclaimed water from the Mattawoman Wastewater Treatment Plant to customer demand centers, while IPR involves natural conveyance from the Mattawoman Wastewater Treatment Plant to drinking water wells via aquifer flow.

Table 50: Preliminary Screening Assessment for Alternative R-3

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws; however, piping to convey finished reclaimed water from the Mattawoman Wastewater Treatment Plant to customers is an added capital cost relative to IPR
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws; however, required water quality has yet to be defined by Maryland Department of the Environment
Supply Reliability	✓	No fatal flaws
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws; however, piping to convey finished reclaimed water from the Mattawoman Wastewater Treatment Plant to customers is an added construction challenge relative to IPR
Ease of Permitting	✗	No local precedent and very few national precedents; currently only practiced in the U.S. in response to severe drought
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✗	No local precedent and very few national precedents; no environmental buffer to help ameliorate public concerns
Regional Benefits	✓	No fatal flaws; benefits all those withdrawing water from the selected aquifer without requiring conveyance to specific users

Policy

Alternative P-1: Increased WSSC Allocations

CCG’s groundwater supplies are currently supplemented with purchased, finished potable water provided by WSSC. The existing CCG/WSSC connection site is located at 2250 Saw Mill Place, Waldorf, MD, where WSSC water is supplied to the Waldorf Water System when needed (Figure 20). The connection site is currently outfitted with chlorine and phosphate dosing capabilities. Average monthly purchases of WSSC water by CCG have ranged from 0 to 0.68 mgd based on Monthly Operating Reports for the Waldorf Water System from January 2013 to November 2015. The overall average monthly withdrawal (i.e., average of monthly averages) was 0.17 mgd in 2013, 0.02 mgd in 2014, and 0.12 mgd in 2015; the maximum daily withdrawal was 1.88 mgd in 2013 (8/13/2013), 1.69 mgd in 2014 (7/3/2014), and 1.55 mgd in 2015 (10/31/2015).

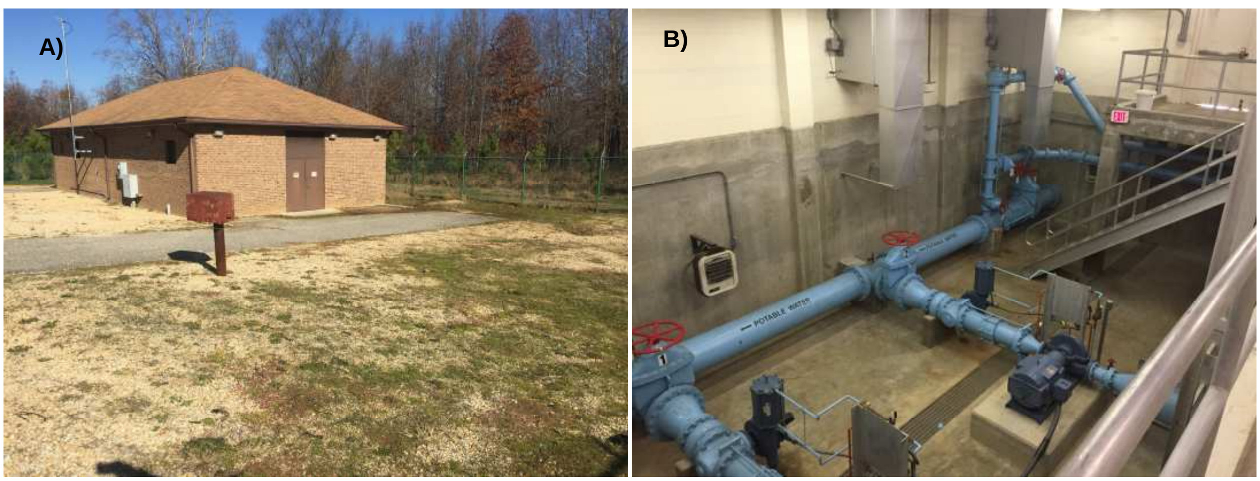

Figure 20: A) Exterior and B) Interior Views of the CCG/WSSC Connection Site in Waldorf, MD

The existing Agreement between Charles County and WSSC was signed in 1987, in which it is stated that *“WSSC agrees to sell to the Commissioners up to 1,400,000 gallons of potable water per day.”* It is also stated that the Commissioners (Charles County Government) agree to pay WSSC monthly for the amount of water metered at a rate equal to *“70% of the prevailing rate WSSC charges a customer having an average daily consumption of 240 gallons.”* The rate of payment from Charles County to WSSC has remained at this level for the duration of the Agreement. Furthermore, the Agreement states that parties *“understand that the projected potable water demand for Charles County is such that in the future further extension of the WSSC water system to furnish additional potable water may be desirable.”* As predicted, existing groundwater supplies and existing/projected water demands in Charles County have led to the consideration of increased water allocations from WSSC to Charles County as an alternative water supply option.

Communications between CCG, The Hazen team, and WSSC regarding increased water allocations were initiated via email on December 1, 2015 and continued in-person at a meeting held at WSSC on December 29, 2015. Existing water and wastewater agreements between WSSC and the County were discussed, as well as the fact that these arrangements have resulted in a long-standing successful working relationship between the parties. WSSC staff were receptive to increasing water allocations to Charles County by an additional five mgd, and indicated that their Master Plan accounts for this potential future allocation. The additional five mgd allocation from WSSC to CCG would not be supplied via the existing connection site, but rather delivered by a new 42-inch water main currently under construction along Maryland Route 5. Extension of the Waldorf Water System to connect with the 42-inch main would be required and would fall within the responsibilities of CCG. Preliminary indications are that WSSC would likely require CCG to pay a capital “recovery fee” for the 42-inch water main in addition to rates for metered water usage. However, no specific costs have been determined and doing so would necessitate further discussion with the WSSC Finance Department.

The existence of some required infrastructure and a positive working relationship between CCG and WSSC supports the use of increased WSSC allocations as an alternative water supply for CCG. Additionally, the use of WSSC’s long-standing water supply lends itself to high ease of operability, ease of permitting, and strong public acceptance for CCG. CCG would also benefit from WSSC’s existing water intake location on the Potomac River, not only in terms of capital costs, but also with respect to actual and perceived water quality. A new water intake location on the Potomac River in proximity to Charles County would be downstream of significant wastewater treatment plant inputs from the Washington, DC area, whereas the WSSC Potomac River water intake is located upstream of these major wastewater inputs. While WSSC has proven to be a reliable source of supply for CCG, the agreement between WSSC and CCG includes clauses that allow WSSC to reduce the amount of water provided to CCG during water supply emergencies. These reductions could be problematic with increased reliance on WSSC in the future.

Potential challenges of further augmenting the water supplies in Charles County with purchased, finished potable water from WSSC must also be addressed. The Hazen team has requested documentation and data from WSSC to develop a more detailed understanding of the water quality and minimum/maximum pressures that would be delivered to the Charles County connection site(s) and also the consistency with which water would be made available. Current concerns pertain primarily to WSSC water age and the resulting disinfection byproduct formation potential. If water quality data suggest that DBP precursor concentrations or formed DBP concentrations are a concern, the feasibility of adding an appropriate water treatment process at the connection site(s) will be evaluated.

Treatment selection for a new interconnection will depend on the compounds being targeted for removal prior to entering the CCG distribution system (e.g., dissolved organic carbon, THMs, HAAs). WSSC staff noted that challenges with water quality tend to occur during warmer months due to the impacts of temperature on DBP formation. Accordingly, seasonal variability in WSSC water quality and the potential to use WSSC water seasonally based on water quality will be evaluated. The potential improvements in water quality realized through blending of WSSC water with existing groundwater supplies in the Charles County distribution system will also be quantified as an alternative to treatment at the connection site(s). Continuous blending of WSSC water with CCG groundwater has the potential to benefit overall water quality due to the high quality of existing groundwater resources in CCG and the potential for continuous withdrawals from WSSC to decrease WSSC water age in the far reaches of the WSSC distribution system. In addition to DBPs and water age, WSSC treatment process or source water quality changes in the future could adversely impact the quality of water delivered to CCG. Therefore, as the volume of water purchased by CCG increases, it will be necessary for CCG to maintain communication with WSSC regarding changes to the WSSC water supply system.

Increased allocations of purchased, finished potable water from WSSC to Charles County is recommended for continued evaluation as an alternative water supply (Table 51). This recommendation stems from the confirmed current and future availability of WSSC allocations for Charles County, the existing relationship between WSSC and Charles County, existing infrastructure, and availability of multiple approaches for addressing water quality challenges. Table 52 summarizes the current understanding of Alternative P-1, as well as the information needs that have been discussed between Charles County, WSSC, and the Hazen team for further determination of feasibility relative to other water supply options.

Table 51: Summary of Alternative P-1 (Increased WSSC Allocations

Parameter		Value or Information
Current CCG use of WSSC water (average of monthly averages)	2013	0.17 mgd
	2014	0.02 mgd
	2015	0.12 mgd
Current CCG use of WSSC water (maximum daily withdrawal)	2013	1.88 mgd
	2014	1.69 mgd
	2015	1.55 mgd
Current WSSC allocation to Charles County		1.40 mgd
Total potential estimated future WSSC allocation to Charles County		6.40 mgd
Requested information for further evaluation of Alternative P-1 feasibility		• WSSC water quality at current and proposed connection sites, e.g., DOC, DBPs, chlorine residual • Planned new WSSC infrastructure • Current demands on WSSC system vs future demand projections • Terms regarding suspensions in service • Costs, e.g., capital recovery fees and metered water rate

Table 52: Preliminary Screening Assessment for Alternative P-1

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws
Supply Reliability	✓	No fatal flaws
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Alternative P-2: Demand Management

Demand management is the purposeful manipulation of the level and timing of water usage within a system or community. Demand management utilizes various techniques for conserving water and improving the efficient use of water by end users. Managing demand can complement traditional supply development to balance available supplies and need.

Demand management involves measures that promote the efficient use of water, including load management and load reduction or conservation. Water conservation also can be understood as the economically and/or socially beneficial reduction of water withdrawals, water use, or water waste. Demand management can forestall future supply-capacity needs; it can be implemented on the supply side as well as the demand side; and it can consist of both temporary measures used during emergencies (conservation) and more permanent measures used to improve long-term efficiency. Long-term efficiency improvements can be facilitated by utility-sponsored programs (active efficiency). Increases in efficiency can also occur naturally, as inefficient plumbing fixture get replaced by water customers with more efficient fixtures and as new development conforms to plumbing standards (passive efficiency). Regardless of the source, reductions in water usage can be beneficial to both water utilities and wastewater utilities in terms of flow reduction and lower long-term costs.

For the CCG, current demand data on a per dwelling unit basis indicate a decreasing trend, which is likely explained in part by passive efficiency improvements. The current forecasting activities will evaluate scenarios where passive efficiency improvements continue. It is likely that the cost-effectiveness of implementing active efficiency programs will be low, given natural plumbing fixture replacement rates. The potential incremental benefits of active demand management programs are expected to be small and are not recommended at this time as a measure to stretch current water supplies. However, as additional County data is analyzed by the Hazen team, this finding can be revisited if data indicate potential for supply benefits.

Table 53: Preliminary Screening Assessment for Alternative P-3

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws
Supply Reliability	✗	Not expected to provide substantial benefit over passive efficiency improvements
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Alternative P-3: Wellfield Management Plan

Charles County Government has well locations distributed throughout much of the County that tap the Magothy, Patapsco, and Patuxent aquifers. Previously, the County has modified the apportionment of withdrawals from the Magothy and Patapsco aquifers to limit drawdown impacts in the aquifers and maintain water levels above the 80% management level. It may be beneficial to manage withdrawals of the existing wells in conjunction with developing wells at new locations (e.g. down-dip Lower Patapsco aquifer and/or additional Patuxent aquifer wells) in order to proactively manage water levels in the aquifers. The purpose of this approach would be to maintain the ability to withdraw groundwater at specific locations without potential restrictions associated with the 80% management requirements, and to increase pumping capacity in areas with depressed water levels that may be limited by the available drawdown. Other operational factors include evaluating well performance and maximizing well efficiency.

This option may be useful as a standalone alternative or could also serve as a component of an alternative that adds an alternate source of supply to the CCG's water resources portfolio. In order to effectively plan improved well management and/or new well development, an updated groundwater model is needed to simulate withdrawal scenarios. The Hazen team discussed the status of the current modeling tools to address the information needed for this option. The current MGS modeling tools for the County require updating based on recent groundwater studies in the region. Further, it was previously recommended that a regional model of the Coastal Plain Aquifer system be developed (which includes Delaware and the northern part of Virginia) to assist MDE with groundwater appropriations decisions. This model is currently in the early stages of development, and the completion date for the model will be based on availability of funding from the State. If the County were to invest in additional modeling, a regional model might be the preferred option for providing comprehensive information on sustainable yield from the aquifers.

A potential approach to supplying standalone CCG systems would be to implement supply alternatives that reduce demand on the confined aquifers, which would benefit the standalone water systems by reducing drawdown, increasing groundwater availability, and reducing pumping costs. Improved modeling could help identify the level of reduction needed for each aquifer in order to maximize water availability across the county.

While cost or other factors may ultimately be prohibitive, there are no identified fatal flaws for this option that would exclude it from the list of potential alternatives for inclusion in the Phase A-2 analysis (Table 54).

Table 54: Preliminary Screening Assessment for Alternative P-3

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws
Supply Reliability	✓	No fatal flaws
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Countywide Options

Alternative W-1: Countywide Agreements

The municipal and community water systems in Charles County, as well as the numerous individual, agricultural, and industrial wells, predominantly withdraw water from the same groundwater sources (Magothy, Patapsco, and Patuxent aquifers). CCG supply alternatives that reduce demands on the groundwater aquifers can benefit all water systems by reducing drawdown, increasing available supplies, and reducing pumping costs.

A County-wide agreement with other water systems might consist of investment in the development of an alternate water supply, treated water purchase agreements, or other cost-sharing measures. This would enable CCG to perhaps increase the size of the alternate supply(ies) to take more demand off of the groundwater aquifers without adversely affecting rates for CCG customers.

Alternatively, if CCG limited its alternate supply capacity to just cover the current CCG water supply system projected future need, groundwater resources would continue to be constrained for other systems in the County. Therefore, there is merit to a system that is planned to address County-wide demands through explicit agreements to share costs. There is a precedent with CCG and the Town of La Plata exploring the “South County Main Project” as a means of inter-jurisdictional agreement and cooperation to achieve mutual benefits. While the ability to obtain agreements with other systems in the County may ultimately be infeasible, there are no identified fatal flaws for this option that would exclude it from the list of potential alternatives for inclusion in the Phase A-2 analysis (Table 55).

Table 55: Preliminary Screening Assessment for Alternative W-1

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws
Supply Reliability	✓	No fatal flaws
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Combined Alternatives

Alternative C-1: Aquifer Storage and Recovery

Aquifer Storage and Recovery (ASR) is the process of injecting water from another source of supply (e.g. surface water treatment plant, different aquifer, wastewater reuse, etc.) when demands are low (and/or other supplies plentiful); and withdrawing from the aquifer when demands are high (and/or other supplies are low). The receiving aquifer essentially serves as a large storage vessel. Because ASR requires a different source of supply (i.e. the same aquifer cannot be used for both withdrawal and injection), it can be combined with any of the supply alternatives described previously.

Typically, ASR systems store water that has been treated to drinking water standards. When recovered from storage, this water usually requires only disinfection before being sent to the distribution system. However, this is a major uncertainty for Charles County, because ASR has yet to be implemented in Maryland, and the design parameters and criteria are not fully known. The following text describes the potential sources of water for ASR in Charles County.

> **Groundwater:** Groundwater as a source for ASR would consist of withdrawing from one aquifer and injecting into another aquifer. Groundwater as a source for ASR is practiced, but it is uncommon. The few systems that use groundwater as a source for ASR typically withdraw from an unconfined aquifer that has substantial annual variability, and inject into a confined aquifer (e.g. San Antonio Water System and Miami-Dade County Water & Sewer Department). Confined aquifers in the vicinity of Charles County would not be candidates for withdrawal for ASR, given the current long term trends of those aquifers (see Alternatives G-1 to G-3), which are largely driven by pumping and not seasonal recharge. The unconfined surficial aquifer may be a candidate for withdrawal, refer to Alternative G-4 above. The key considerations for developing the surficial aquifer as a source for ASR would be the same as for developing the surficial aquifer for direct use: 1) the acquisition of property 2) sufficient, reliable yield from wells installed at the selected location, 3) understanding of potential impacts to surface water discharge, and 4) surface water influence on the aquifer that will dictate treatment requirements.
>
> **Surface Water/Riverbank Filtration:** One of the more common applications of ASR is to store excess capacity from a surface water treatment plant seasonally when natural stream flows are high and demands low. Therefore, ASR could be combined with one of the surface water or RBF

options described previously. The utility of ASR in combination with surface water or RBF treatment would depend on the presence of a seasonal driver. For example, if CCG could withdraw sufficient water from the Potomac River or RBF to meet full maximum day demands under all conditions, there would be no benefit from the added costs of storing water in an ASR system. Alternatively, if seasonal water quality (e.g. summertime algal blooms or elevated salinity levels) or other factors were expected to result in reduced production from a surface water treatment plant on a regular basis, ASR could be a beneficial add-on option. This option may also be assessed for reducing treatment costs if ASR storage is utilized to meet peak demands.

Indirect Potable Reuse: Indirect potable reuse requires that highly treated reclaimed water be discharged to an environmental buffer for subsequent withdrawal as a potable water supply. In the case of Charles County, the aquifer could serve as a storage location for IPR-quality reclaimed water, while also providing additional treatment benefits (e.g., up to 1-log pathogenic microorganism reduction credit for each month water is retained underground according to California regulations). Unlike ASR involving the use of potable water for injection, reclaimed water as part of indirect potable reuse cannot use the same well for injection and withdrawal, because travel through the aquifer provides necessary treatment as water flows through the aquifer substrate.

Several methods can be used to estimate the retention time between the injection well and the nearest downgradient drinking water well (e.g., tracer study, numerical modeling, analytical modeling). While indirect potable reuse in conjunction with aquifer and surface water environmental buffers has been practiced in other areas of the country (e.g., Texas, California, and Florida), Maryland has not developed regulations or a precedent for indirect potable reuse or ASR. Therefore, permit constraints for IPR-ASR are uncertain. Additional information on indirect potable reuse as a source of supply is provided under Alternative R-2.

Increased WSSC Allocations: ASR could potentially be used in conjunction with increased WSSC allocations. The driver for this application would be if there was a substantial difference pertaining to the use of WSSC during one part of the year versus another. For example, WSSC water quality is expected to be more of a challenge during the warmer months due to the formation of DBPs, so Charles County may opt to only rely on WSSC water during cooler months. In this scenario, purchases of WSSC water in excess of demand during the cooler months could be stored in the aquifer for subsequent use during the summer. ASR may also be utilized for reducing disinfection byproducts, which is practiced by other utilities (Centennial WSD, Colorado and Thames Water Utilities, England). Seasonal variability in the cost of WSSC water could also be a driver for ASR, with excess water being purchased and stored during low cost times for later withdrawal and use at high cost times.

Important factors to consider for the aquifer that water is injected into are the ability to inject water and the potential for chemical reactions between the formation and the recharge water. The recharge rates will depend on aquifer properties and the aquifer water levels. Recharge may be possible by gravity feed or may require injection under pressure. The recharge rates and aquifer properties would be determined from aquifer tests. Water chemistry issues would be evaluated by conducting extended injection/recovery tests. Chemical reactions in the aquifer may occur, which may be mitigated by pre-treatment, reducing reactions within the storage zone by treatment or repeated recharge/recovery cycles, and by developing a buffer zone between successive injection/recharge cycles. Any potential for chemical reactions may reduce the recovery volume. Suitable aquifers for ASR may include the confined Magothy, Patapsco or Patuxent aquifers, depending on the source and native water chemistry and site specific aquifer properties.

In addition to the suitability of an aquifer for injection or source for supply, other considerations include location of system components in relation to one another and the distribution system, and the difficulty in permitting ASR. No ASR projects have been completed in Maryland, although ASR programs in similar hydrogeological environments are operating in New Jersey, Delaware, and Virginia. While cost or other factors (e.g. suitable source of supply or aquifer for injection) may ultimately be prohibitive, there is not enough information to exclude this option from the list of potential alternatives for inclusion in the Phase A-2 analysis (Table 56).

Table 56: Preliminary Screening Assessment for Alternative C-1

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws
Supply Reliability	✓	No fatal flaws
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Alternative C-2: Conjunctive Use

Local groundwater resources have been and will most likely continue to be a mainstay of the drinking water supply for the County. While many wells have experienced drawdowns over the past decades, most wells continue to have substantial depth before reaching the 80% management level. This alternative would combine the operations of one or more of the alternate supply options described above with the existing (or expanded) network of groundwater wells. The use of both sources of water would be balanced to minimize the undesirable economic and environmental effects from each individual source of supply in order to optimize the water demand/supply balance.

One example for this alternative would be to develop an alternate supply (e.g. surface water or RBF) with some capacity redundancy that could be used to offset some groundwater use as needed. Under normal conditions the groundwater system would be operated at baseline levels so as not to result in further drawdown of the aquifer, and the alternate system would fluctuate to supply the remaining demands. Under drought conditions, when water availability or quality from the alternate supply required curtailing production, groundwater production would be ramped up to meet demands. Once the drought ends, alternate supply production would be increased and groundwater pumping reduced to allow the aquifer levels to recover. Baseline groundwater production would resume once aquifer levels reached the target elevation.

This alternative would require an alternate supply of sufficient capacity, and may require discussions with MDE to structure appropriations permits to allow for occasional higher-than-normal withdrawals, similar to current permit for the Bryans Road wells in the Lower Patapsco aquifer (MDE permit# CH1955G003(06)). No fatal flaws were identified for this option that would exclude it from the list of potential alternatives for inclusion in the Phase A-2 analysis (Table 57).

Table 57: Preliminary Screening Assessment for Alternative C-2

Criteria	Assessment	Explanation
Capital Cost	✓	No fatal flaws
Operation and Maintenance Cost	✓	No fatal flaws
Water Quality	✓	No fatal flaws
Supply Reliability	✓	No fatal flaws
Ease of Operation	✓	No fatal flaws
Constructability	✓	No fatal flaws
Ease of Permitting	✓	No fatal flaws
Environmental Stewardship	✓	No fatal flaws
Public Acceptance	✓	No fatal flaws
Regional Benefits	✓	No fatal flaws

Recommendations Summary

The results of the screening analysis identified eleven alternatives from the original 22 that will be included in the Phase A-2 analysis (Table 58). The options include surface water and groundwater sources, riverbank filtration, reuse, as well as a variety of policy and management opportunities. While many of these alternatives are necessarily long-term solutions, due to additional work needed to confirm feasibility or long lead times for permitting and construction, a number of the alternatives could be implemented in the near term (e.g. increased WSSC allocations[19] and demand management). Further, based on the demand analysis, a supply deficit is not projected to occur for a number of years. Supply needs can also likely be met by existing groundwater appropriations in the near term without reaching the regulated 80% management limit at CCG wells; however, increased pumping by other users that increases the rate of drawdown could substantially limit available groundwater resources for the CCG system. Another critical uncertainty is the potential for new occurrences of gross alpha contamination at Patapsco aquifer wells in the near term that could require RO treatment or taking the wells offline.

Table 58: Summary of Alternatives Recommended for Further Evaluation

ımber	Description
G-4	w Surficial Aquifer Wellfield
S-1	face Water Treatment Plant – Upper Reaches of the Potomac River
S-5	rgantown Generating Station
B-2	erbank Filtration – Upper Reaches of the Potomac River (Ruth B. Swann morial Park)
R-1	n-potable Reuse
R-2	irect Potable Reuse with Confined Aquifer Recharge
P-1	reased WSSC Allocations
P-3	llfield Management Plan*
W-1	untywide Agreement*
C-1	uifer Storage and Recovery*
C-2	njunctive Use*

* These options are not new sources of supply, but are options for increasing supply reliability and efficient utilization of current and future supplies

Based on available information about drawdown trends in the Magothy, Patapsco, and Patuxent aquifers, there is currently low confidence in the long term reliability of increased withdrawals from these groundwater sources. While it is unclear whether it could be complete solution to meet the County's objectives, a recommended option (Alternative P-3) would be to invest in updated modeling tools to improve the County's ability to utilize existing wells, plan new well development, and support permitting appropriations for confined aquifer withdrawals. Other recommended supply options (surficial aquifer

[19] Even without increasing WSSC allocations, CCG is currently not purchasing up to the limit of the current agreement, and has 1+ mgd of available capacity for purchase from WSSC based on recent usage.

withdrawals, riverbank filtration, surface water, and non-potable or indirect potable reuse) would all most likely require a significantly higher level of treatment than the County's confined well supplies. No one of these alternate supply options is currently preferred, as significant strengths and weaknesses have been identified for each. Surficial aquifer wells, for example, are expected to have lower treatment costs, but sustainable and reliable yields are uncertain without additional hydrogeologic investigations. Yields from surface water treatment and reuse are more certain, but treatment costs are expected to be significantly higher. Riverbank filtration may be an attractive option, but yields and costs are uncertain without further investigation. Other alternatives require additional effort to identify costs, including expanded WSSC allocations, non-potable reuse, and purchasing treated water from the Morgantown Generating Station. Figure 21 shows a summary of the range of capital costs for each treatment option that will be further evaluated in Phase A-2, all of which were estimated for 2, 5, and 10 mgd plant capacities.

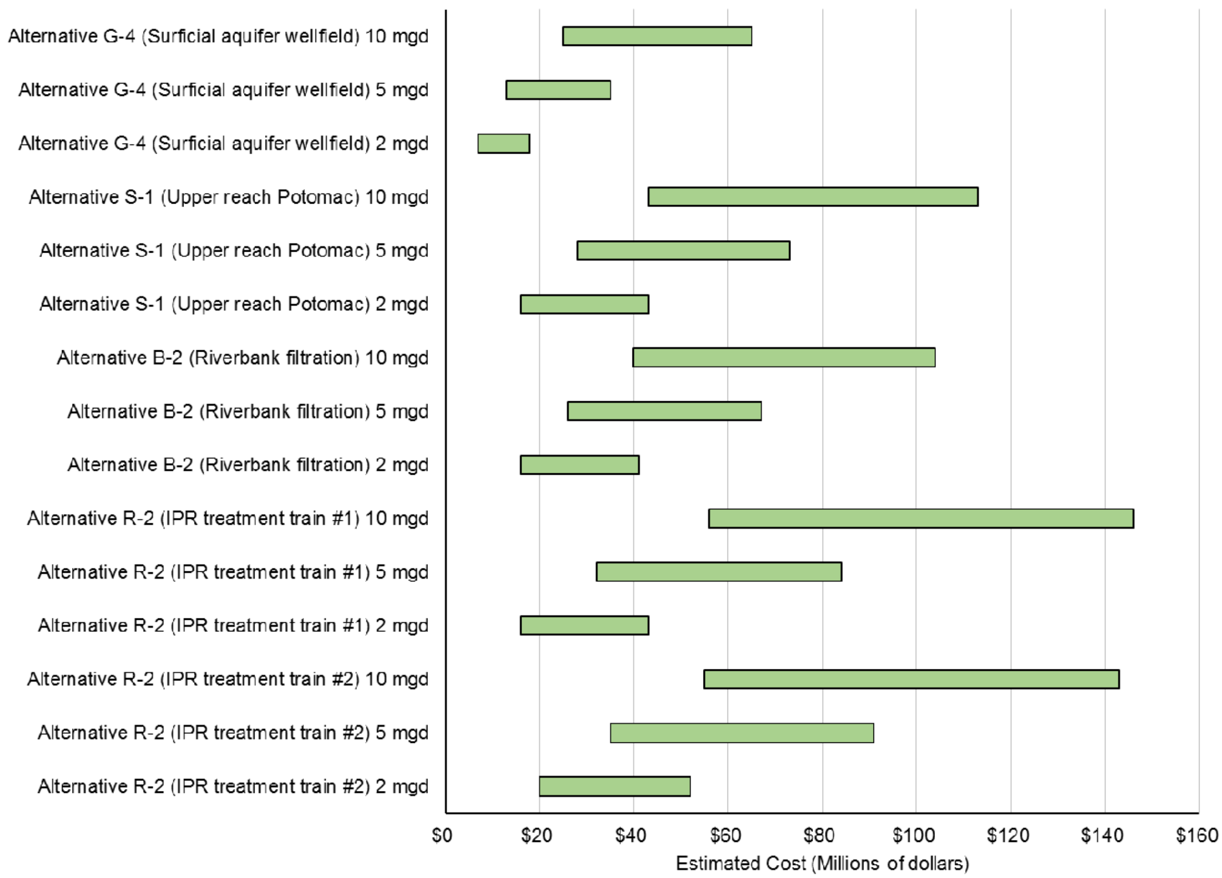

Figure 21: Range of Capital Costs for Each Treatment Option Estimated For 2, 5, and 10 mgd Plant Capacities

In phase A-2 of the project the feasibility and infrastructure requirements of the options will be further explored, and high-level system modeling will be conducted to assess the mix of options (i.e. percentage supply from one or more alternatives) that can best serve the County's needs. Phase A-2 will also include the triple bottom line evaluation of feasible alternatives to develop a comprehensive ranking of the alternatives.

However, in advance of Phase A-2, the Hazen team recommends a bridging phase to address specific issues identified in this study to further confirm feasibility of alternatives. For example property acquisition is a critical component of nearly every alternative and requires further discussion with the County. Other suggested tasks for each alternative include the following:

- Alternative G-4: New Surficial aquifer wellfield
    - Conduct field investigations to identify potential wellfield locations and confirm yields of the Surficial Upland aquifer
- Alternative S-1: Surface Water Treatment Plant – Potomac River upper reaches
    - Discuss permitting with the Army Corps of Engineers for a new surface water intake in the Potomac River to identify constraints on size, location, etc.
- Alternative B-2: Riverbank Filtration – Potomac River upper reaches
    - Conduct field investigations to identify potential RBF locations and confirm yields
- Alternative R-1: Non-potable Reuse
    - Conduct a detailed evaluation of potential non-potable reuse customers and the implications for operations of the Mattawoman WWTP
- Alternative R-2: Indirect Potable Reuse with Confined Aquifer Recharge
    - Facilitate discussions with MDE and present experience with IPR from other states to confirm feasibility of permitting IPR in Maryland
- Alternative P-3: Wellfield Management Plan
    - Work with the Maryland Geological Survey to identify costs and timeframe for updating County or regional modeling of the Coastal Plain Aquifer system
- Alternative W-1: Countywide Agreements
    - Facilitate discussions with other Charles County municipalities the benefits and costs of joint agreements to share the development of new water resources in the County
- Alternative C-1: Aquifer Storage and Recovery
    - Discuss permitting ASR with MDE to confirm treatment, monitoring, and water quality requirements

In conclusion, the results of the preliminary screening assessment indicate that CCG has numerous potential options available to meet current and future water demands reliably and safely. Additional work is required to better identify the most feasible and cost-effective options for future investment among the alternatives carried forward from Phase A-1.

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