Harrisonburg Public Utilities (HPU)

Raw Water System Management Plan

(RWSMP)

December 31, 2015

Table of Contents

I. EXECUTIVE SUMMARY SCORECARD:

An adequate raw water supply is an absolute requirement for communities such as Harrisonburg to:

- sustain its current land use;
- alter its current land use;
- bring into use the remaining undeveloped land;

The "Summary Section" of this document lists recommendations for the City of Harrisonburg to provide and to sustain its needed raw water supplies. This insight might well assure that the City can pursue various community goals that could otherwise be restricted by limited water supplies. A scorecard follows; it includes recommendations that the City should perform and also includes the status of the listed activities:

Plan Recommendation	Status
Dry River: The City should install a fourth pipe in the Route 33 corridor for purpose to maximize use of this priority raw water source and to simultaneously bring the lifecycle end to the oldest pipe in use.	**CIP Fund 910161-48621** **(Western Raw Water Supply):** 20,247 feet 30" pipe installed 34,753 feet 30" pipe to be installed 2015-2065
North River: The City should enhance the BWPS to include features that will: 1) Refine withdrawal rates to a higher resolution; 2) Add opportunities to efficiently manage power and energy;; 3) Provide improved mitigation and recovery from power failure events.	**CIP Project 473-12 -13** **(NRPS Upgrade 2013):** Project 90% completed ($1.7M)
Silver Lake: City should weigh its contingency dependency for Silver Lake against its cordial relationship with the Town of Dayton.	**Current Lease Agreement** The City's 99 year lease with first right of withdrawal to Dayton has expired. A short term lease now modifies the pricing structure and more importantly gives first rights of withdrawal to Harrisonburg. **Current Lease Agreement** Consideration to change conditions of the lease or to permanently use Silver Lake requires a better understanding and play out of forecasts set forth in the RWSMP.

Plan Recommendation	Status
South Fork Shenandoah River: City should undertake steps to make the project agile as follows: 1) Renew Virginia Water Withdrawal Permit#98-1672 as pertains to its future use of the Shenandoah River Source; 2) Finalize scope, cost, and schedule for the $32M project	**<u>Permit #98-1672</u>** Permit application is currently under review by DEQ; Harrisonburg Director of Public Utilities has refuted several conditions that DEQ has included in the first draft. See "VAC Local and Regional Water Supply Plan" (below"). **CIP Project 256-99-00** **<u>(Eastern Raw Waterline:</u>** $13.3M expended; $20.0M unfunded, project is not scheduled: Intake / Pump Station 87% completed; Booster Pump Station 65% completed; 90,000 feet 30" pipe 30% completed
VAC Local and Regional Water Supply Plan: The City must remain informed and responsive to DEQ actual implementation of the state mandated water supply plan.	**<u>Harrisonburg Plan Conditions</u>** By resolution of City Council, HPU submitted a regional plan that secured reliable drought supply to 15.0 MGD and included generally avoidable conservation triggers. **<u>Revisions:</u>** Under reissuance of Permit #98-1672, DEQ is attempting to reduce reliable drought supply to and to engage mandatory conservation.

II. BACKGROUND:

A strong supporting raw water supply has given the City Of Harrisonburg the opportunities to realize its current community, economical, social, cultural, and political status. The City's record for water supply planning has been quite impressive. The Harrisonburg journey began with the use of the "Big Spring" at Court Square. **Appendix A** of this document provides a chronology that recovers much of the history of this journey, an evolution to current day status that now brings greatest attention to:

- Reliability of raw water quantity and quality;
- Sustainability of existing assets and management of the energy and carbon footprint;
- Balance of raw water supply reliability versus environmental stewardship under drought;
- Emergency preparedness under risk management planning.

III. INTRODUCTION TO THE RWSMP:

The Harrisonburg Raw Water System Management Plan (HRWSMP) was drafted in the format to plan in terms of four components:

1) ***Water demand forecasting*** takes focus to how much reliable raw water supply that the City will need.

2) ***Optimized operations planning*** foretells the most probable use of water supply to sustain assets and to minimize the carbon footprint through electrical energy management.

3) ***Drought supply planning*** addresses environmental stewardship.

4) ***"What if" planning*** provides insight to mitigate the risk of a low probability / high consequence event that might incapacitate the reliability of one or more water sources (ie: contamination).

IV. OVERVIEW OF EXISTING RAW WATER SYSTEM

The City of Harrisonburg raw water system includes:

Dry River Source

North River Source

Silver Lake Source

South Fork Shenandoah River Source

- Primary source: **Dry River** provides approximately 50% of the annual raw water to the water treatment plant; Appendices B and C provide detailed information:

  Dry River preferred characteristics

  ✓ Soft and pristine water quality;
  ✓ Full range of delivery from 0.0 to 4.0 MGD
  ✓ Gravity delivery with zero energy requirements;
  ✓ Effectively and efficiently treated at the city water plant.

  Constraints to use of the Dry River Source include:

  ➢ Water quantity; during times of drought the in-stream flow can approach zero as would be reflective of the "Dry River" nomenclature;
  ➢ The City's raw water system maximum conveyance capacity is currently 4.0MGD.

- Secondary source: **North River provides** approximately 50% of the annual raw water to the water treatment plant; Appendix D provides information in detail.

  <u>North River preferred characteristics</u>

  ✓ Available 7.6 MGD supplement to Dry River

  <u>Constraints to use of the North River Source include:</u>

  ➢ Withdrawal quantity during drought is less than 7.6 MGD as in-stream flows are small and variable in the presence of high withdrawal demands;
  ➢ Water quality is subject to detrimental change due to agriculture in combination with the previously stated in stream flow characteristics;
  ➢ Requires power demand and electrical energy consumption.

- Inactive source: **Silver Lake;** Appendix D provides information in detail.

  <u>Silver Lake preferred characteristics</u>

  ✓ Available 1.5 MGD under drought to supplement Dry River and North River sources;
  ✓ Low threat of contamination; appears to be a contingency asset for loss of other sources;
  ✓ Lower energy usage compared to North River and future Shenandoah River.

  <u>Constraints to use of Silver Lake:</u>

  ➢ Town of Dayton's reliance on Silver Lake;
  ➢ Quality of water is characterized as groundwater under the influence of surface water and has an elevated level of hardness and algae growth;
  ➢ Higher energy consumption than Dry River;
  ➢ Permanent pump Station asset is nonfunctional.

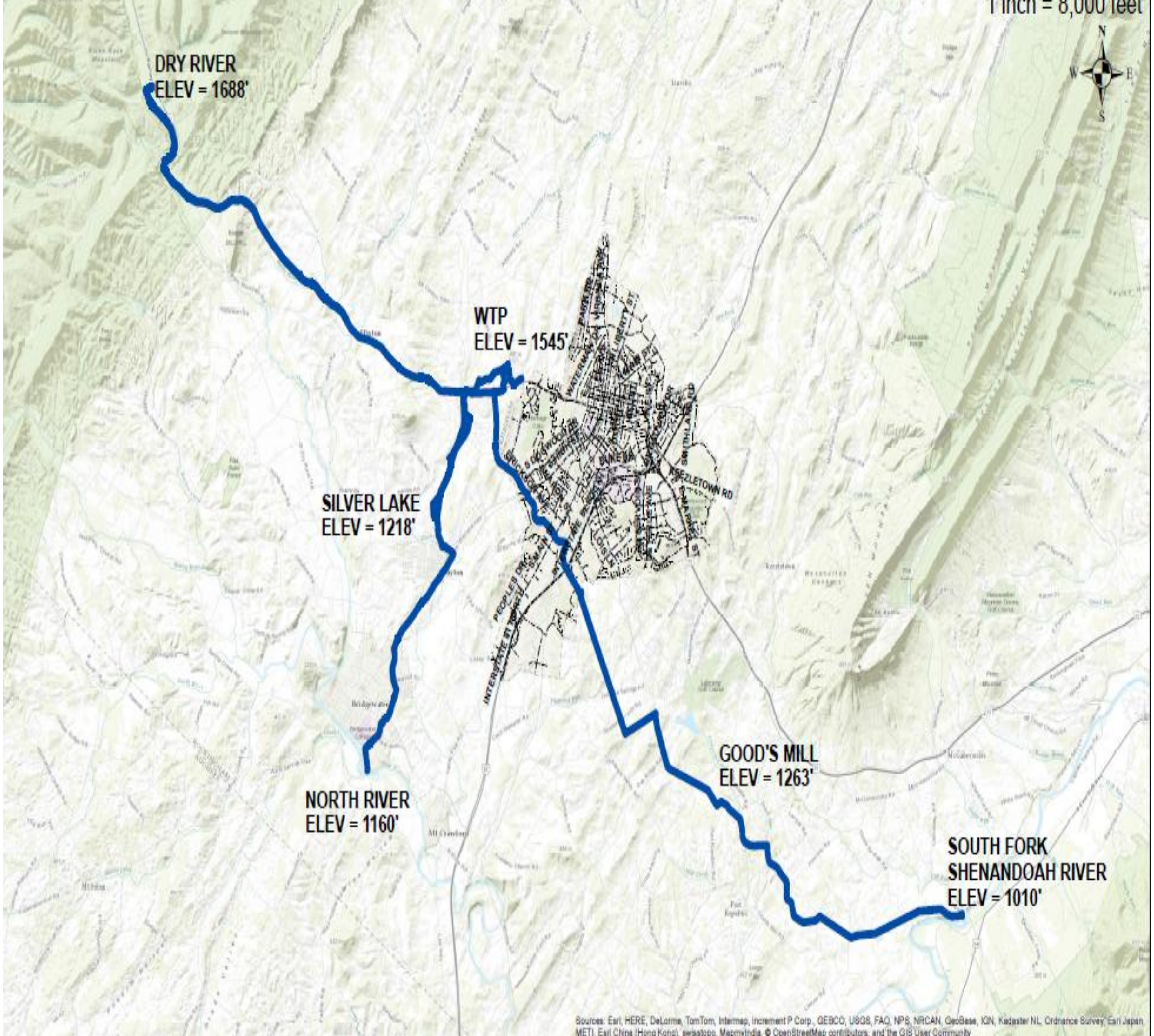
- Future source: **South Fork of the Shenandoah River;** refer to Appendix G for additional information.

  Shenandoah River preferred characteristics

  - ✓ Available 8.0 MGD to supplement all other sources of raw water;
  - ✓ In stream flow is highest of all sources with intake located downstream of HRRSA in the lower watershed; gives this source a highest grade for environmental stewardship.

  Constraints to use of Shenandoah River:

  - ➢ Highest energy consumption of all sources
  - ➢ Water quality is generally less desirable overall than other sources;
  - ➢ Withdrawal has been permitted under a Virginia Water Withdrawal Permit#98-1672.


1 inch = 8,000 feet
N
W
E
S
DRY RIVER
ELEV = 1688'
WTP
ELEV = 1545'
SILVER LAKE
ELEV = 1218'
NORTH RIVER
ELEV = 1160'
GOOD'S MILL
ELEV = 1263'
SOUTH FORK
SHENANDOAH RIVER
ELEV = 1010'
PEOPLES DR
INTERSTATE 81
KEEZLETOWN RD
Sources: Esri, HERE, DeLorme, TomTom, Intermap, Increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

V. WATER DEMAND FORECASTING:

Average Annual Daily Demand

Harrisonburg Public Utilities annually updates future water demand projections. The procedures use information collected from the most recent fiscal year of operations for actual water usages. In addition, information regarding land development is provided by the Harrisonburg Department of Community Development and is used to make future water growth projections.

HPU carefully selected a dual approach that delivered both an aggressive forecast and a conservative forecast; thus providing a forecast envelope. The aggressive approach is generally used for planning purposes whereas the conservative approach has been provided for comparison and understanding of the degree for margin of error (or safety margin) in planning.

Shown below is the most recent update from FY2015 for Annual Average Demands (AAD):

Water Projections for Harrisonburg : AAD FY2015

		Historical Criteria		Density Criteria	
Description	Existing MGD	Capacity MGD	% Maturity	Capacity MGD	% Maturity
City Residential	1,320,000	1,866,746	71%	2,672,181	49%
City Commercial	1,120,000	1,470,511	76%	1,667,452	67%
City Industrial	800,000	1,226,539	65%	2,327,243	34%
City Apartments	660,000	841,322	78%	841,322	78%
City Institutional	620,000	750,000	83%	750,000	83%
City Municipal	100,000	100,000	100%	100,000	100%
Subtotal City	**4,620,000**	**6,255,117**	**74%**	**8,358,197**	**55%**
Rural	780,000	1,000,000	78%	1,000,000	78%
Rockingham County	200,000	500,000	40%	1,000,000	20%
Michaels	-	90,000	0%	90,000	0%
Daley	-	170,000	0%	170,000	0%
Process Usage	160,000	210,000	76%	265,000	60%
Unaccounted Water	1,000,000	1,000,000	100%	1,000,000	100%
Total	**6,760,000**	**9,225,117**	**73%**	**11,883,197**	**57%**

- **FY2015 Annual Average Daily Water Demand was 6.76 MGD.**

  Included were 5.6 MGD sales, 1.0 MGD in unaccounted losses, and 0.16 MGD used in WTP processes.

- **The lower conservative estimate for future water demand was 9.23 MGD.**

  The projection of 9.23 MGD was determined as the sum of 6.76 MGD in existing demands plus 2.47 MGD in future growth demands. To obtain the latter, actual FY2015 water sales per user group were correlated to occupied land in the City; this allowed determination of historic water generation rates for respective land types. These rates were then applied to undeveloped land area for which the product was future sales growth.

- **The higher aggressive estimate for future water demand was 11.88 MGD.**

  The same format was used for the higher aggressive estimate; however, generation rates were determined from maximum land densities and published VDH per capita standards.

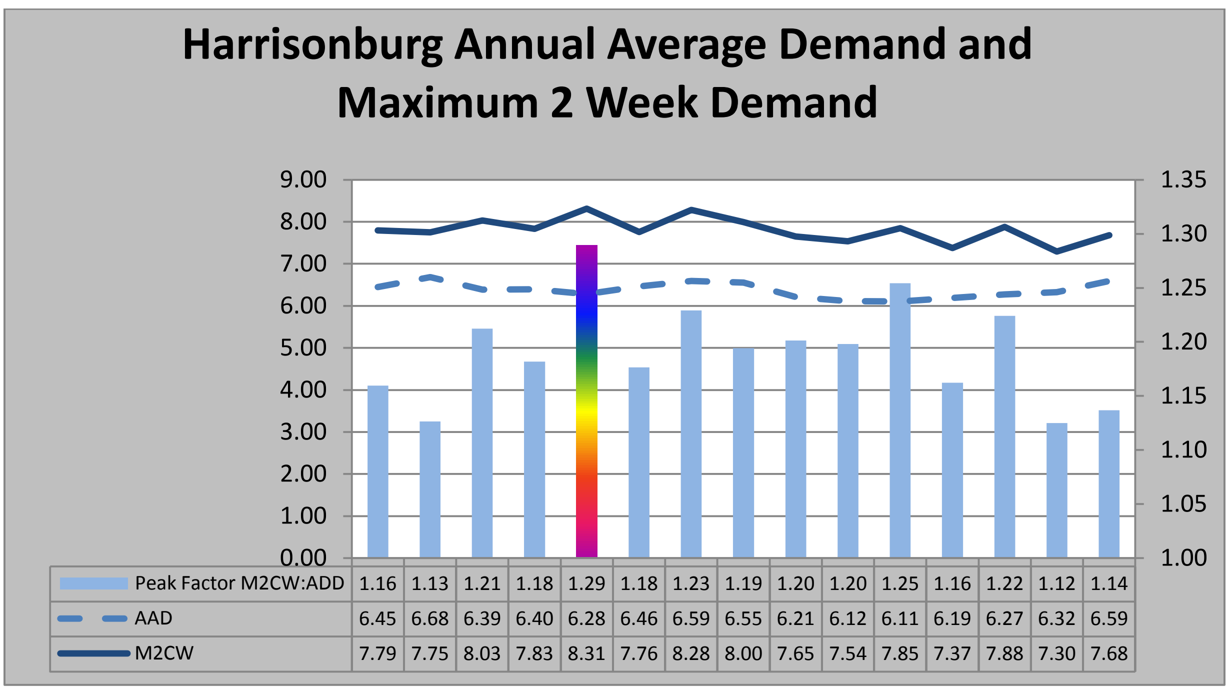
Shown below is a summary of the generation rates for historic versus maximum density criteria:

Customer Class	Historic Rates	Design Rates
Residential	488 gpd per acre	1,207 gpd per acre
Commercial	960 gpd per acre	1,500 gpd per acre
Industrial	698 gpd per acre	2,500 gpd per acre
Institutional	26 gpd per student	26 gpd per student
City	n/a	n/a
Apartments	428 gpd per acre	1,739 gpd per acre

Water Treatment and Raw Water Capacities

To relate AAD to needed water supply requires recognition that the treatment plant must produce a volume of water in sufficient quantities to refill the potable water system storage reserves at the completion of two consecutive cycles of operations. This is much like the analysis that is typically performed for reservoir routing and sizing, except that the storage volume is fixed and the effort solves for input and output parameters (which are equal in this case).

The period of choice for this study is the maximum two consecutive week duration. The relationship between AAD and consecutive two peak week demand is the benchmark parameter for sizing raw water supply capacities. Using the 2001 to 2015 period as shown below, HPU has determined the relationship for Raw Water Capacity to AAD is 1.29.



Peak Factor M2CW:ADD	1.16	1.13	1.21	1.18	1.29	1.18	1.23	1.19	1.20	1.20	1.25	1.16	1.22	1.12	1.14
AAD	6.45	6.68	6.39	6.40	6.28	6.46	6.59	6.55	6.21	6.12	6.11	6.19	6.27	6.32	6.59
M2CW	7.79	7.75	8.03	7.83	8.31	7.76	8.28	8.00	7.65	7.54	7.85	7.37	7.88	7.30	7.68

Raw Water Supply Required = Annual Average Daily Demand x 1.29
Raw Water Supply Required @ 9.23 MGD= 11.91 MGD
Raw Water Supply Required @ 11.88 MGD= 15.33 MGD: HRWSMP Target

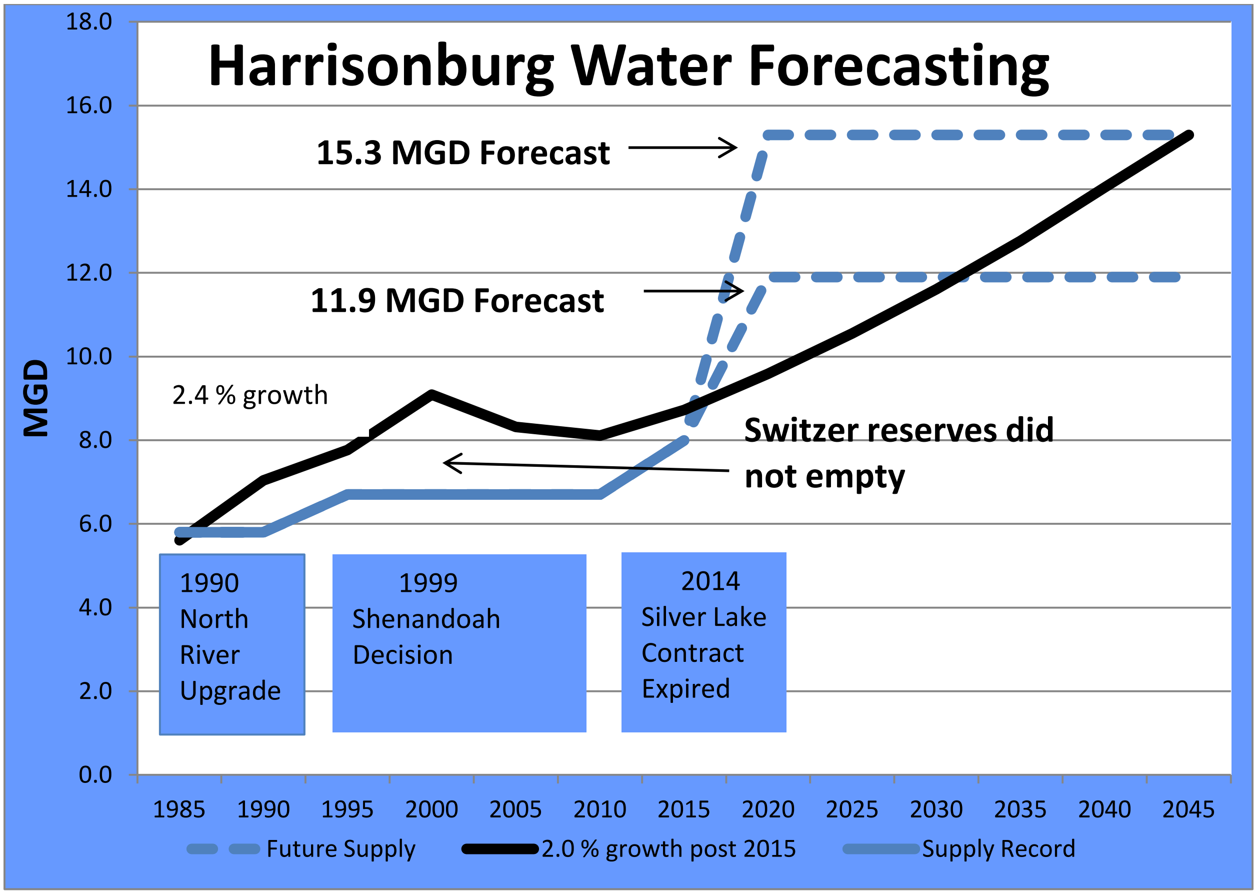
The table as follows summarizes current and future average annual demand (AAD) and water supply requirements. Current AAD is 6.76 MGD that requires 8.72 MGD in water supplies. In the future, AAD will increase to 9.23 to 11.88 MGD; required water supply will be 11.91 to 15.33 MGD, respectively.

Harrisonburg Water Supply Forecast Summary

	FY 2015	Build-out	Build-out
AAD	6.76 MGD	9.23 MGD	11.88 MGD
WATER SUPPLY	8.72 MGD	11.91 MGD	15.33 MGD

__Water Supply Scheduling__

The graph as follows shows both historic and future water forecasting:



- The drought of 1988 created near significant impact to customers; the issue was resolved by adding 1.0 MGD from North River with pipe installation.
- Decision was made to pursue Shenandoah River in 1999; project schedule was delayed with decrease in water usage. Customers were not significantly impacted as Switzer reserves did not empty but were close on several occasions.
- In 2014 Silver Lake became available; it is in an emergency use status.
- A future water supply to 15.3 MGD is necessary to avoid investments at Silver Lake and dependency on chance that Switzer reserves will not empty.

VI. RAW WATER OPTIMIZATION STRATEGY:

Under future conditions that incur the fullest availability of targeted raw water supplies and city asset capacities, the City's withdrawal scheme will operate to optimize operations considering the following:

1) Water Quality
2) Electrical power and energy requirements
3) Effectiveness and efficiency of treatment
4) Sustainability in terms of frequency for sustaining 100% needed supply

The following graph is a decision matrix for optimizing raw water use.

RAW WATER OPTIMIZATION STRATEGY

	Water Quality	Electrical Efficiency	Treatability	Sustainability
Dry River	Pristine	0 KWHRS/ MG 0 kW	Caustic	65.2% > 13.5 MGD
North River	Variable	2,150 KWHRS/ MG 530 kW	Caustic & Alum	99.8%>5.5 MGD
Shenandoah River	Lower Watershed	3,108 KWHRS/ MG 708 kW	Caustic & Alum	99.6%>12.2 MGD
Silver Lake	Hard & Algae	1,805 KWHRS/ MG 137 kW	Caustic & Alum Algae Control	

Best option available   Intermediate option   Least preferred option

Conclusions from the matrix are:

1) Maximize the Dry River:	**1.0 - 4.0 MGD**
(complete 30" pipe project)	**1.0 - 13.5 MGD**
2) Minimize the Shenandoah River:	**2.0 - 8.0 MGD (12.2)**
3) Gap fill with North River:	**1.5 - 5.7 MGD**
4) Silver Lake is contingency	**0.0 - 1.5 MGD**

Considerations behind selection of the optimization scheme are as follows:

- Dry River: Current conveyance capacity of the Dry River system is 4.0 MGD; current Best Management Practice (BMP) seeks to maximize use of this source. With repeated consistency, all future schemes to optimize energy management begin with the requirement to maximize water use at Dry River. Capital Improvement Plans include progressive installation of 30” pipe to replace existing aging 10”pipe; this will expand conveyance capacity to 13.5 MGD. Due to the hydraulic characteristics of the Dry River System, significant increase in conveyance capacity will not be realized until the upgrade approaches near completion near 50 years out.

- North River: The future scheme to optimize energy management recognizes that North River is the second most efficient raw water source (considers that Silver Lake Pump Station will not become a permanent water source). A 2015 upgrade project adds variable speed drives to the North River Pump Station; this will allow the City to operate any pump at the most optimum output of 2.3 MGD. With the station being equipped with three pumps, the optimum electrical consumption in terms of kW-hrs/MG correlates to output at 2.3 MGD, 4.6 MGD, and 6.9 MGD with 1, 2, and 3 pumps in parallel operation, respectively.

- Silver Lake: The City’s withdraw capacities of Silver Lake are assumed to be constrained to mobilizing temporary pumps; therefore the Silver Lake source is not considered as a viable permanent source under the normal scheme of operations.

- Shenandoah River: The Shenandoah River is the least energy efficient raw water source available to the City. Completion and commissioning of the Shenandoah Project is undecided but is foremost in the Harrisonburg’s Capital Improvement Plan. The pump stations are currently under design and therefore the energy use parameters for the pumps are not yet available. As such, there are several issues to consider in the aforementioned design.

1. The pumps will be installed with variable speed drives such that full range of output can be selected. This correlates with a wide range of power demand and energy usage efficiencies;
2. The pumps will have a minimum output determined by the characteristics of the pump that is selected;
3. The pumps will be designed with a maximum that matches the limits of the Virginia's Water Withdrawal Permit that is applicable to this source;
4. Actual operation will be dependent upon the power / energy cost relationship at the Shenandoah River in combination with the same at North River. An algorithm program may be needed to define this relationship with electrical rate schedules that are effective at the time of operations.

VII. RAW WATER DROUGHT MANAGEMENT STRATEGY

To meet water reliability goals and environmental stewardship responsibilities, the City gives its greatest attention to water supply during drought conditions.

Under this plan the City pursues adequate water supply volume, under the most extreme low in-stream flow conditions, such to limit the need for imposed water restrictions to customers. The City has targeted 15.3 MGD of reliable water source for its long term build-out water supply.

For environmental stewardship, the responsible actions that are needed from Harrisonburg were defined within the VAC Local Regional Water Supply Plan as adopted by City Council and submitted by HPU to fulfill the requirements of the applicable state statute. The requirements for protecting the South Fork of the Shenandoah River were included in the original Virginia Water Withdrawal Permit (VWWP) #98-1672; requirements for other sources were not addressed. More recently under reissuance of the expired VWWP, DEQ is positioning to supersede the aforementioned "in permit" responsibilities. These proposed revisions for the City's responsibilities are not compatible with the City original plans for sustainability during drought. The Harrisonburg Director of Public Utilities is in collaboration with DEQ to pursue a mutually acceptable arrangement to the differences as denoted.

For itemization of withdrawal privileges, the table below summarizes the allowable withdrawals that would be available to Harrisonburg under four conditions: 1) currently with available water supplies, 2) upon completion of the Shenandoah River Project and the conditions of the original VWWP #98-1672, 3) upon completion of the Shenandoah River Project but with DEQ added conditions that were proposed under the first draft to reissue the expired VWWP, and 4) under item 3 but with DEQ acceptance of the arguments as presented by the City.

RAW WATER DROUGHT MANAGEMENT STRATEGY

	FY 2015	Original VWWP #1972	Draft VWWP #1972	Collaborated VWWP #1972
North River (1)	5.5 MGD	5.5 MGD	2.1 MGD	2.1 MGD
Dry River (2)	1.0 MGD	1.0 MGD	1.0 MGD	1.0 MGD
Shenandoah River (3)	0.0 MGD	8.0 MGD	5.4 MGD	12.2 MGD
Silver Lake (4)	1.5 MGD	0.5 MGD	1.5 MGD	0.0 MGD
TOTAL	8.0 MGD	15.0 MGD	10.0 MGD	15.3 MGD

Acceptable to Plan **Work Around** **Non supporting limit**

1. North River set at 15% in-stream flow in revised permit
2. Dry River supply is evaluated after exhaust of Switzer Dam reserves
3. Shenandoah is set at 10% in-stream in revised permit; City pursing recycle effect
4. Silver Lake requires mobilization of temporary pumps

Conclusions to the City's drought management strategy are as follows:

- The City recognizes that North River is a target for water protection; this effort began with the proposed Surface Water Management Area (SWMA) in the 1990s and takes even greater focus under the Local and Regional Water Supply Plan (VAC) that is relevant today. The withdrawal limitation has progressively decreased from the 1Q10 criteria of 13.6 MGD prior to the 1990s, to 5.5 MGD with the SWMA, to 2.1 MGD with the VAC.

- The City's raw water supply will decrease to 1.0 MGD when the reserve at Switzer Dam is exhausted. Such an occurrence would be infrequent as a 132 days drought would be necessary; however, this event is on record to have occurred during the 20^{th} century.

- The addition of Silver Lake would increase the drought raw water supply from 1.5 MGD. As a minimum, this would require access to the Silver Lake Spring (included in current agreement negotiations with the Town of Dayton) and a connection to the City raw water pipe in the vicinity of Silver Lake. Permanent pumps assets are not proposed.

- The addition of the Shenandoah Project appeared to provide water supply to reach the target of 15.0 MGD. The new criterion for City withdrawal not to exceed 10% of in-stream flow now jeopardizes this value. Negotiations continue with this important condition of withdrawal. The City is pursuing a withdrawal greater than 8.0 MGD such to obtain its goal. The argument for this privilege pertains to a water recycle effect (City withdrawals at Island Ford and discharges upstream at HRRSA.)

VIII. RAW WATER RISK MANAGEMENT PLAN

Causes for failure to meet reliability for water supply include the potentials for loss of a given sources. These causes would most likely be contamination, effects from flood or other natural disasters, mechanical failures, electrical failures, or control system failures. The appendices of this document further articulate the potential for each of the City's source waters to incur such conditions. The table as follows shows the degree of mitigation that the City will enjoy upon completion of the recommendations in the RWSMP.

Raw Water System Risk Matrix

(Withdrawals in MGD; Optimized and Drought Shown)

	North River	Dry River	Shenandoah River	Silver Lake
North River		**5.5** **2.1**	**5.5** **2.1**	**5.5** **2.1**
Dry River	**13.5** **1.0**		**13.5** **1.0**	**13.5** **1.0**
Shenandoah River	**12.2** **12.2**	**12.2** **12.2**		**12.2** **12.2**
Silver Lake	**1.5** **1.5**	**1.5** **1.5**	**1.5** **1.5**	
Total Supply	**15.3+** **14.7+**	**15.3+** **15.3+**	**15.3+** **4.6+**	**15.3+** **15.3+**

From the matrix above the conclusion is:

- Loss of the Shenandoah River source under drought conditions is the only scenario that presents concerns for inadequate water supply.

IX. <u>SUMMARY</u>

Effective integration of raw water assets will have value in terms of general operations efficiency, selections in water quality, reliability and continuity during drought, and risk mitigation / recovery in the event of catastrophic loss of a water source. The challenges that confront the City of Harrisonburg are summarized as follows:

- **Quantification and qualification of the City's need for raw water supplies**
- **Dry River as the primary and preferred raw water source;**
- **North River as the second existing raw water source;**
- **South Fork of Shenandoah River as a future raw water source;**
- **Silver Lake as a re-emerging option for raw water supply;**
- **Virginia Water Withdrawal Permit #1972 (issued for the South Fork Shenandoah Water Withdrawal) as a RWSMP management tool;**
- **"The Upper Shenandoah Basin Water Supply Plan" as a RWSMP management tool.**

- **DRY RIVER**:
    1) CIP planning must direct the installation of a new parallel 30" diameter pipe that will be efficient and effective in the life cycle management of existing pipe while simultaneously expanding the delivery capacity from 4.0 MGD to 13.5 MGD.
    2) Future expanded use of the Dry River source will require the City to better understand its management options in how to control releases from Switzer Dam Reservoir. This will also include retaining a reserve in the reservoir, establishing a minimum release from Switzer Dam, and maintaining a minimum in-stream bypass around the Dry River intake.

- **NORTH RIVER**
  1) The BWPS is currently under construction for electrical upgrade including variable speed pumps; the City must use these new assets to enhance electrical energy management and to better facilitate the integration with the Shenandoah River source.

- **SILVER LAKE:**
  1) The City will consider long term extension of lease or sale of rights to the Town of Dayton but in doing so it must consider the value of Silver Lake in terms of advantages toward energy efficiency, supplemental supply during drought, and contingency during catastrophic loss of one of its other sources.

- **SOUTH FORK SHENANDOAH RIVER:**
  1) The VWWP#98-1672 is up for renewal and DEQ is requesting understanding of the City's comprehensive plan for water withdrawals; the concepts in this document may be shared to facilitate a good understanding of the topics. Whereas this permit may carry conditions implied to the other City sources of water, consideration should be made to expanding the withdrawal limits at the Shenandoah intake under the permit.
  2) The City should consider when it will target commencement of the remaining project construction such to commission this source.
  3) The commissioning of the Shenandoah source will bring with it a need to manage a sophisticated integration of sources such to optimize power demand and energy usage.

- **9VAC 25-780 Local and Regional Water Supply Planning:**
  1) Denoted under South Fork Shenandoah, VWWP#98-1672, above.

APPENDIX A: HARRISONBURG WATER SUPPLY CHRONOLOGY

History of Harrisonburg Water Supply:

- 1779 - Thomas Harrison deeds the "Big Spring" for public use.
- 1798 - Town Council commits $35.00 to wall the Big Spring. (See Spring House replica at Court Square)
- 1890's - Ten miles of hand laid 10" cast iron pipe supplies pristine waters from Dry Run, Gum Run and Rocky Run surface water dams.
- 1914 – Construction of a 5 million gallon reservoir at Tower Street improves service reliability to town customers.
- 1920's – Two projects significantly enhance water supply
  1. A 12" cast iron waterline was constructed in parallel to the previous 10" pipe.
  2. Construction of a 16 million gallon reservoir at Tower Street increases storage to 21 million gallons
- 1930's – the Research Service in Washington D.C. designs and oversees town forces to construct a unique below ground collection gallery at Rawley Springs.
- 1950's – A 16" cast iron waterline is constructed parallel to the 10" and 12" pipes from Rawley Springs.
- 1960's – A pump station and pipeline for use of Silver Lake water is implemented as the auxiliary drought supply option.

<u>Clean Water Act mandates filtration technology: City targets 5.0 MGD</u>

- 1970's – A 7.5 mile pipeline to the North River in Bridgewater and the city's first filtration plant are placed in operation. Switzer dam is constructed as a flood control dam but the City pays to increase the capacity for water supply purposes.
- 1980's – The City's filtration capacity is increased from 5.0 MGD to 7.7 MGD by operation management practices and without capital dollars; this is the first plant in the state to operate at 6 gpm/sf filtration.

<u>Annexation: City targets 10.0 MGD interm to 15.0 MGD</u>

- 1989 – 1991: The City upgraded its water supply line from Silver Lake to Grandview Drive and then upgraded its North River Pump Station capacity rating to 7.6 MGD from VDH
- 1990 – 1993: The city's filtration capacity is increased to 10.0 MGD, again without capital dollars. The plant remains today as the only 8 gpm/sf filtration plant in Virginia.

. <u>Annexation: City targets 10.0 MGD interm to 15.0 MGD</u>

- 1991-1993: City considers a pipeline to Switzer Dam for long term planning agenda; this alternative was rejected due to environmental constraints and limitations with the determined yield of Switzer Dam given overland flow from the dam to the Dry River Intake.
- 1993-1997: Bridgewater requests designation of the North River Surface Water Management Area; concludes with Harrisonburg statement to reject a supporting role. However, Harrisonburg established agenda to pursue an alternative source of water such that future needs can be met with no greater than 5.5 MGD withdrawls from the North River.
- 1993-1997: Harrisonburg pursues groundwater in the Dry River and North River corridors as an alternative to the Riven Rock to Switzer pipeline. This alternative was abandoned due to the small yields of recommended well sites.
- 1995: Harrisonburg proposes to participate in Rockingham County's construction of its "Three Springs Water Treatment Plant"; joint proposal rejected by Rockingham County.
- 1996-1999: City studies South Fork of Shenandoah River as an alternative raw water source.
- 2000: City studies optimum location for WTP for Shenandoah water source
- 2001: Groundwater source evaluated on South Fork of Shenandoah River as an augmentation source to the river intake for purposes that would address temporary concerns for water quality and for environmental stewardship (the latter if needed).
- 2002: Harrisonburg pursues evaluation of an alternative to enhance Dry River Dam for water supply; alternative abandoned due to environment objections and cost.
- 2002: Shenandoah pipeline easement acquision begins
- 2004: Remenant of old hydroelectric dam removed on South Fork of Shenandoah River
- 2005: City constructs intake in South Fork of Shenandoah River
- 2005: Shenandoah project organized into 20 different suprojects which are in various phases of planning, design, construction, managerial and closure.
- 2015: Bridgewater Pump Station Upgrade

APPENDIX B: DRY RIVER SOURCE

Longitude 78.971 Latitude 38.371

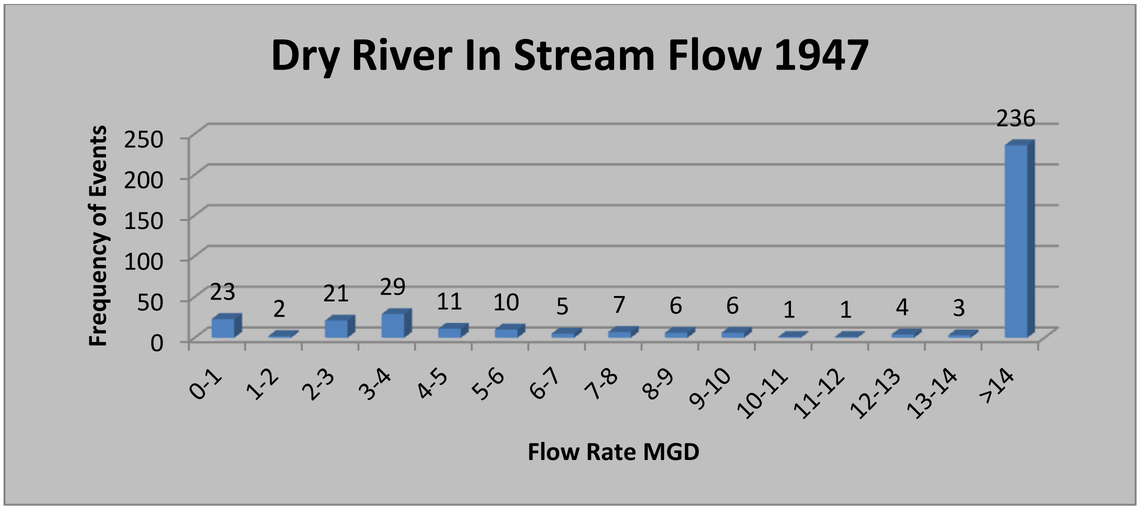
Intake Capacity 4.0 MGD

Dry River Source:

The **Dry River** was Harrisonburg's original viable raw water source when commissioned in the late 1890's. M*aximizing the use of the Dry River source water remains an inherent priority to the City's past, current, and future raw water management strategies.* Use patterns for this source are typically constant and at 100% capacity (4.0 MGD) under all scenarios of normal operations. Harrisonburg's withdrawal is a grandfathered activity as compared to a Virginia Water Withdrawal permit. There are no formal privileges or restrictions upon the City's withdrawals; however, in an effort of environmental stewardship, the City bypasses a minimum of 0.5 MGD around its intake to maintain an in-stream flow. The bypass originated through a handshake agreement with local Verona based DGIF staff during the drought in the late 1990's.

DEQ has not rated the Dry River for a safe yield; however, records from a long removed stream gage station, as well as common observations, suggested the flow approached nearly zero on many occasions. The following graph displays the frequency of stream flow quantities from 1947; this was a drought type year that was selected arbitrarily from the limited data that is available. Significant to the graph is the following frequency of low flow events.

- 23 days throughout the year the flow was less than 1.0 MGD;
- 75 days the flow was below the City's current system conveyance capacity of 4.0 MGD;
- On 129 days the flow was below (thus 236 days the flow was above), the future expanded raw water pipe network conveyance capacity at 13.5 MGD.



Harrisonburg Assets:

The City obtained access to the Dry River in the 1890s by installing 55,000 feet of 10" pipe that began at Dry River/Rocky Run/Gum Run intakes at Rawley Springs and extended to the reservoirs that were located within the City borders. Near the years of 1923 and 1947, 12" and 16" diameter pipes were respectively installed in parallel to the 10" diameter pipe. Along the way in 1934, a unique combined surface water / subsurface alluvial groundwater intake structure was installed; later to be upgraded in the early 2000's. The structure consisted of a concrete dam, a bar screen, underground collection pipe and a collection gallery. See 1934 ENR Article that follows.

Until 1970 the pipe system conveyed potable water until the addition of the water treatment plant at Grand View Drive. At that time all pipes were converted to raw water conveyance from Rawley Springs to the new water treatment plant; exception was the 10" diameter pipe that was retained to convey potable water, but in the direction from the new water treatment plant to Rawley Springs. Since early 2000s, the City has embarked a concept to install a new 30" diameter pipe, accompanied by conversion of the 12" and 16" pipes to potable water. This provides a progressive engagement of life cycle management approach to retire older assets and to simultaneously expand raw water conveyance capacity to 13.5 MGD when completed. The current Dry River Raw Water System currently includes the following assets:

- 30” pipe: 17,805 feet
- 30 pipe: 7,405 feet
- 16” pipe: 45,036 feet
- 12” pipe: 25,108 feet

Zero energy consumption is a primary advantage to maximizing the Dry River source as follows:

system:	143 feet TDH
energy:	0 kW-hrs/MG by gravity delivery
power:	0 kW

Dry River Risk:

Harrisonburg’s Dry River source is most susceptible to natural disaster and contamination whereas mechanical, electrical, and control failures are not as prominent with the inherent gravity intake features. In recent history, the hurricane flood of 1985 saw the pipe conveyance system lost for a substantial period of time. In contrast, no major contamination has been incurred from the Dry River; however, five miles of river bed in the upstream watershed can in some places be easily contaminated by a vehicular accident along the highly traveled Route 33 corridor. The frequent small in-stream flow in the presence of a contaminant poses special attention to this concern.

Groundwater Cutoff Wall Provides New Water Supply

Harrisonburg, Va., adds to its supply by building concrete wall in valley from surface to bedrock to intercept underflow

By A. B. McDaniel
Consulting Engineer, Washington, D. C.

LED BY the water shortage that developed during the great drought of 1930 to give consideration to an addition to its water-supply facilities, Harrisonburg, Va., has built an unusual groundwater-supply system, comprising essentially a concrete cutoff wall to intercept the underflow in the valley of the Dry River. Directly behind the wall there was built a collecting gallery, from which the water is conveyed by pipe line to the existing supply mains.

The city of Harrisonburg is situated in the Shenandoah Valley about 6 miles west of the southern extremity of Massanutten Mountain and about 12 miles east of the easterly slope of the North Mountain Range. The business section of the city lies at an elevation of 1,320 ft. above sea level, and the principal residential district is located on the eastern slope of a hill that rises to a height of about 100 ft. above Main Street. On this ridge above the city are the two distribution reservoirs, one having a capacity of 6,000,000 gal. and the other 15,000,000 gal.

In 1921 the city constructed a concrete dam 100 ft. long and 10 ft. high in the channel of Dry River, 15 miles west of the city. About a quarter of a mile below the dam and on the west side of the valley is the intake works, the construction of which was begun in 1899. It consists of a concrete flume and a pool or collecting basin that receives the flow from a spring-fed stream along the west side of the valley. A 12-in. pipe carries the water during the low-flow period of the summer months from a small collecting basin behind the dam in the river channel to a 12-in. cast-iron main that is one of two parallel supply lines from the intake pool to the city. The other supply line is a 10-in. cast-iron main. The 10-in. main is also supplied with water from the bed of the main river channel during low-water periods by an 8-in. cast-iron pipe which runs to a sump in the bed of the river about 800 ft. below the dam. The general layout of the intake works, dam and pipe lines are shown in Fig. 2. The watershed area above the intake works is about 57 square miles.

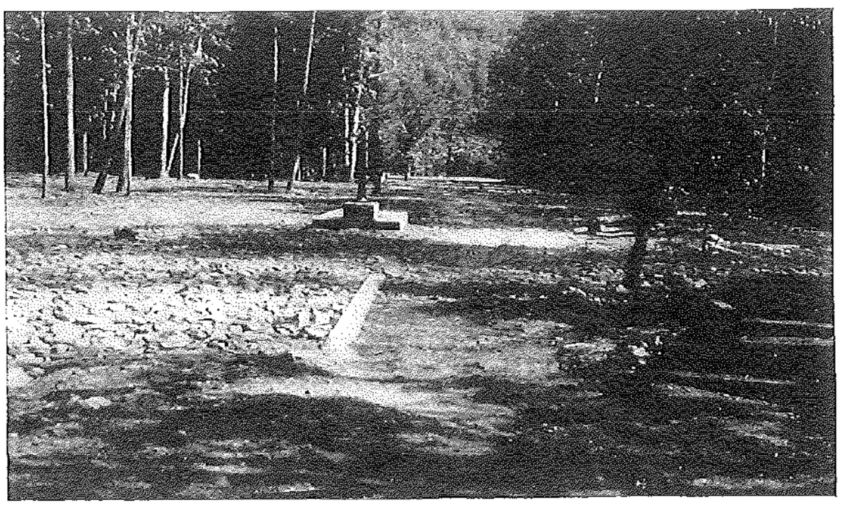


FIG. 1—TOP OF THE COLLECTING GALLERY and a portion of the top of the cutoff wall in new groundwater supply of Harrisburg, Va.

Due to the great deficiency of flow in the Dry River Basin during the summer of 1930, the city found it necessary to secure an auxiliary supply. This supply was provided by an 8-in. cast-iron pipe line 2 miles long from Silver Lake to the 12-in. main at Dale Enterprise. The water was pumped from the lake at the rate of 600,000 gal. a day for 133 days, at an operating expense of $10,305. Early in January, 1931, the surface-water supply at Rawley Springs picked up sufficiently to do away with the auxiliary supply, which was objectionable both for domestic and industrial use on account of its high total hardness of 251.

Preliminary investigation

At the request of the city council, the author's firm began a field investigation and study for the improvement of and addition to the water supply of the city. A survey was made of all existing sources of water supply, including springs, spring-fed lakes, surface-water streams, wells and storage. It was recommended that further investigation be made of the economic practicability of building an impounding and regulatory reservoir in the Skidmore Fork Basin in the headwaters of the Dry River watershed.

A field investigation was made that included core drill holes, churn drill borings and test pits at proposed dam sites in the Skidmore Fork and Gum Run basins, and in the territory adjacent to the city's intake. These investigations showed the economic impracticability of constructing a dam at either of the two proposed locations in the Skidmore Fork and Gum Run basins and of securing water from wells near the city's intake.

Geologic studies and pumping tests in the pits across the valley from the dam in the river channel clearly indicated the presence of groundwater flow over the valley floor in many isolated streams and the practicability of intercepting this flow by an underground dam extending across the valley. Recommendation was made to the city council to construct a system of groundwater intercepting and collecting works comprising a reinforced-concrete wall or dam extending from the old dam in the river channel to the rock cliff on the west side of the valley, a distance of about 900 ft. These works would be located 1,200 ft. up the valley from the city's intake and would make possible the diversion of the underflow from a collecting gallery in a natural gorge on the west side of the valley through a supply main by gravity flow to the existing intake works. The city council approved of this project. In November 1933, authorization was given for the preparation of an application on behalf of the city for a PWA loan and grant of $50,000. This application was approved by the state PWA engineer, but was indefinitely held up in Washington on account of the overallotment of funds for the state of Virginia for PWA projects. In March, 1934, the city council authorized the construction of the proposed ground-

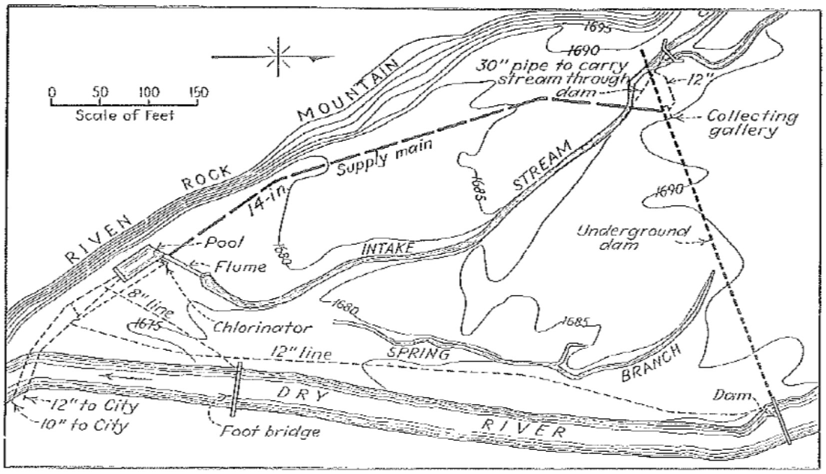


FIG. 2—UNDERFLOW down the valley of the Dry River is intercepted by the underground dam and is conveyed to the existing supply mains.

water collecting works with funds secured from local banks, the work to be done by local labor forces under the immediate supervision of the city engineer.

Construction of project

During the last week of March the city engineer initiated the construction work with the building of a small office building, tool house, blacksmith shop and cement sheds adjacent to the site of the proposed submerged dam. During the latter part of April, actual construction was begun with the excavation of the trench and the laying of 600 ft. of 14-in. cast-iron pipe at the intake end of the proposed supply line and 100 ft. of 30-in. cast-iron pipe and headwall for carrying the intake stream through the submerged dam. During the month of May the remaining 576 ft. of the 14-in. supply line were laid.

The excavation for the submerged dam was begun at the west side of the valley early in May. The first 150 ft. of this excavation was done entirely by hand labor. West of the 30-in. pipe line an excavator equipped with a 43-ft. boom and ½-yd. clamshell bucket excavated the trench to a top width of about 20 ft. and a depth of 10 to 12 ft. The lower section of the trench was excavated by hand labor. The trench prism was so located as to provide sufficient space on the upstream side of the dam for the handling of the groundwater, which was largely confined in a channel along the upstream face of the trench. Along the west side of the valley especially there was some groundwater flow out of the downstream face of the trench, which was largely backflow from the intake stream. Every effort was made to confine this backflow to a minimum by carrying the intake stream in a wooden flume about 150 ft. below the downstream end of the 30-in. pipe.

The excavation of the footing trench

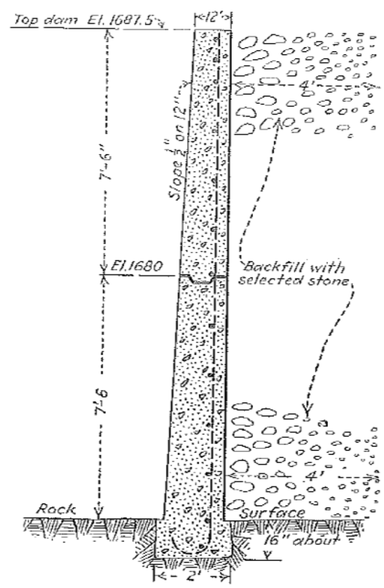


FIG. 4—THE CUTOFF WALL was built in two sections, the first extending from rock to within 7½ ft. of the top. The top is level with the spillway of the existing dam in Dry River.

in the valley floor was done largely by quarrying, using a pavement breaker operated by a portable air compressor. In one or two sections it was necessary to blast out short lengths of the rock trench. This was done with center holes and light charges of 40 per cent dynamite, so as not to open up adjacent seams or contact planes in the valley floor.

The results of the excavation of the trench across the valley fully confirmed the indications made by the test pits and the reports of the consulting geologists, Charles Butts and Irving Crosby, who cooperated in the preliminary investigation of 1931-32. The valley floor consists of a fine-grained, closely cemented, hard sandstone, the Pocono sandstone. At the west side of the valley the narrow gorge exposed a narrow stratum of a hard, dark-colored, indurated shale. The preliminary investigation and subsequent excavation showed that this shale is as tight and impervious to the flow of water as is the sandstone.

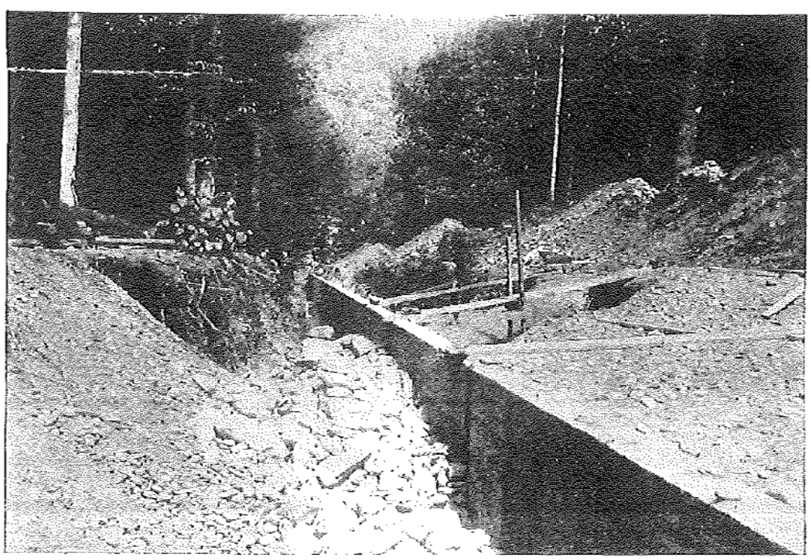


FIG. 3—SELECTED STONE from the excavated material was used as backfill on the upstream side of the wall and around the collecting gallery.

About twelve large underground streams were encountered across the valley. Between these major streams there were minor flows through the overburden or drift. The flow of these streams varied from about 150 to 300 gal. per minute, as nearly as could be estimated. The most difficult part of the construction work was the intercepting of these streams, especially during the pouring of the footing sections of the concrete wall. The pumping requirements were taken care of by one 4-in. and one 6-in. centrifugal pump, and a gasoline-engine-driven diaphragm pump. The total pumping capacity of this equipment was about 800 gal. per minute.

To secure a fairly accurate estimate of the amount of groundwater flow during the construction period, three series of measurements were made by an engineer of the state water resources and power office. These measuremnts were made on July 19, Aug. 27 and Sept. 26, 1934. The following data give the essential results:

1. Flow in intake stream at upper end of 30-in. pipe on upstream side of submerged dam:
   1,467 g.p.m. on July 19.
   1,260 g.p.m. on Aug. 27.
   1,395 g.p.m. on Sept. 26.
2. Flow in intake stream at concrete flume of intake works:
   1,350 g.p.m. on July 19.
   1,170 g.p.m. on Aug. 27.
   1,620 g.p.m. on Sept. 26.
3. Groundwater flow collected along submerged dam at exit end of pipe at intake works:
   594 g.p.m. on July 19.
   590 g.p.m. on (includes estimated amount of about 10 per cent of total) Aug. 27.
   1,125 g.p.m. on (about 10 per cent of which was from extraneous sources) Sept. 26.

It will be noted that the groundwater flow on July 19 and Aug. 27 was about the same—namely, about 850,000 gal. per day. The surface flow decreased during this five-week period about 300,000 gal. per day, while the groundwater flow remained nearly constant. This condition is accounted for by the normal summer drop of surface flow and the increase in groundwater flow due to the extension of the excavation for the trench and the resulting addition of several underground streams. The considerable increase in both surface and groundwater flows shown by the Sept. 26 measurements was due to the excessive rainfall during the month of September. It should be noted in this connection that the rainfall shown by the records of the Dale Enterprise Weather Bureau station, for the first six months of 1934, indicate a subnormal condition. During July and August the rainfall was about that of the 54-year average.

The groundwater collecting works comprise a reinforced-concrete dam or wall and a collecting gallery on the upstream face of the wall in the gorge near the western side of the valley. The wall has a top width of 12 in.; the upstream face is vertical, and the downstream face has a slope of ½ in. to the foot.

The wall was built in two sections, a footing section and a wall section, the former stopping at El. 1680. The wall section has a constant height of 7½ ft., and the top is level with the top of the dam in the river channel.

The collecting gallery is a rectangular chamber 25 ft. long, 5 ft. wide and 16.5 ft. high inside. At the ends of the gallery, about 2 ft. above the floor, are the intake openings, which are 3 ft. square and protected with cast-iron gratings. The water is carried from the collecting gallery in a 14-in. cast-iron outlet pipe, which is provided with a gate valve at its intake end in the chamber. The water in the intake stream flows through the 30-in. line and can be diverted to the collecting gallery through a 12-in. main. Such a diversion will be made during low water or drought periods, to avoid loss through seepage and evaporation. The intake openings are controlled by sluice gates operated by stands at the top of the collecting gallery, which extends about 3 ft. above the adjacent ground surface.

For drainage, a perforated concrete pipe line was laid along the upstream toe of the dam. Opposite each of the major underground streams, a tee was placed in the pipe line, and a line of smaller pipe extended to the outpouring of the stream at the upstream face of the trench.

On the upstream side of the dam the trench was backfilled over the drainage pipe with rock graduated from the large-sized stone on the bottom and against the wall to the smaller stone and sand at the top and along the outer face of the trench. Back of the wall the trench was backfilled with earth and small stone. About 8,300 cu.yd. of material was handled at an average unit cost of 37¢. per cu.yd.

The total cost of the project was $37,567, of which $17,624 was spent for labor and $14,875 for materials. Miscellaneous expenditures included $2,025 for the rental of the excavator, $30 for office expenses, $542 for workmens' compensation insurance, and $2,470 for engineering, testing and inspection. The estimated cost of the project, based on handling the work two years ago by competitive bids and lump-sum contract, was $35,000. Assuming a 20 per cent increase in the cost of executing the work during the summer of 1934 on the competitive contract basis, it is possible that the city of Harrisonburg may have effected a saving of about $4,500 by doing the work by force account—utilizing its available resources of labor, materials, equipment and machinery as far as practicable.

The field surveys, studies and design were made largely by the writer. He also supervised the later stages of the construction. Valuable assistance in the preparation of the working drawings and early supervision of construction was rendered by Harry W. Thompson. William G. Myers, city engineer of Harrisonburg, was in direct charge of construction.

ENGINEERING NEWS-RECORD

Volume 113, No. 24

EDITOR—F. E. Schmitt. EDITORIAL STAFF—V. T. Boughton, W. G. Bowman, F. W. Herring, C. S. Hill, H. W. Richardson, J. I. Ballard, W. W. De Berard, N. A. Bowers.
Editorial and Publishing Offices at 330 West 42d Street, New York

December 13, 1934

Sta

at

Below the Surface

GEOLOGICAL CONDITIONS in the valleys of streams frequently result in extensive subsurface flows. Understood and appreciated by geologists, this condition should not be overlooked by those communities which have developed surface supplies and subsequently find them inadequate in the normal process of expanding demand. The intercepting of the underflow of a stream from which the surface flow has been utilized may provide an economic supplemental supply, as in the case of Harrisonburg, Va., where an expenditure of $37,500 for a subsurface dam and collecting system developed 850,000 gal. per day, as described on another page in this issue. There is also the fundamental advantage that the use of underflow provides for complete development of a stream before another water supply resource must be sought. The possibilities for this type of inexpensive

APPENDIX C: SWITZER DAM ON DRY RIVER SOURCE

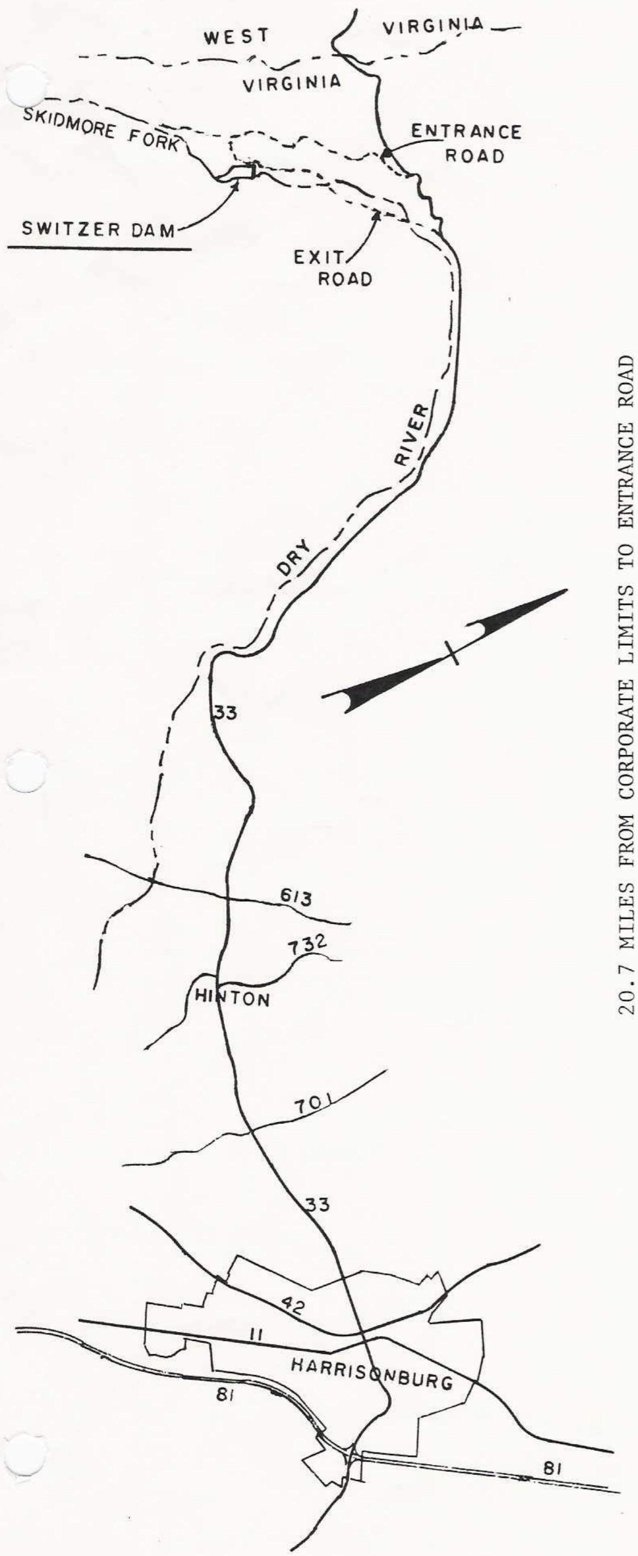
Dry River Source with Switzer Dam

Unlike conditions of 1947 in Dry River, the in-stream flow can be influenced by operations of a reservoir located upstream. Approximately five miles upstream of the City's Dry River intake is the aforementioned reservoir known as Switzer Dam. In the 1970s, the City added water supply functions to the original designed flood control dam. Switzer Dam was designed and constructed to hold 1.6 billion gallons of water; it has been rated by DEQ to have a safe yield of 8.3 MGD. Initially, the City could not use the water supply privileges until financing bond payments had been completed; a status which has now long passed (1990). There are currently no formal restrictions to the City's use of the dam.

Through the wetter part of the annual season the dam is at overflow level where flow out of the dam nearly equals flow into the dam (exception for precipitations and evaporation). During other times when the water is below overflow level, actions to control releases from the dam would be through one of the five gates in the outlet tower. One gate is a drain gate and two others are below a significant benchmark of 400,000,000 gallon reserve storage level. The remaining two gates are strategically placed above the 400,000,000 level. Controls for the gates are not readily usable and therefore it is somewhat infeasible for the City to make adjustments to the gate settings.

Informally, the City has engaged two environmental stewardship activities; the first to maintain a minimum 400,000,000 gallons in reserve and the second to maintain a release of water from the reservoir. The reserve storage concept was initiated by informal discussion with DGIF staff in the 1990s for purpose of protecting aquatic life in the lake. The release was is in recognition of certain local groups who expect the City to maintain a minimum release from Switzer Dam for the purpose of sustaining fish and aquatic life in the immediate downstream reaches of Skidmore Fork, a tributary to Dry River. The City generally leaves the second highest gate at a partially opened position and thereby allows the discharge to vary from approximately 8.0 MGD when water level is at overflow to 0.0 MGD when water level is at the open gate level. The stationary positioning of the gates, plus some escape of water from outlet structure leakage, generally provided environmental stewardship for both in lake and downstream aquatic protection.

In the fall season of a dry 1999, the City evaluated the dam release and intake capture relationship during the peak season for evaporation / transpiration. General conclusion was that a release of 8.3 MGD maintained a capture of 5.5 MGD at the City's intake located five miles downstream. During the study the water reservoir above 400,000,000 gallons was exhausted in 132 days. The Switzer Dam release – City intake recapture relationship must be recognized and refined in the RWSMP.



SWITZER DAM

Joint Water Storage-Flood Control

Water Surface Area	119 acres
Drainage Area	9,414 acres
Storage to Emergency Spillway	2,255,000,000 gals.
Storage at Normal Ht.	1,600,000,000 gals.
Height of Dam	138 feet
Length of Dam Crest	1,500 feet
Thickness of Dam Base	720 feet
Width of Dam Top	40 feet
Volume of Fill	2,137,000 cu. yds.
Flood Storage Above Permanent Pool	27 feet
Concrete Riser Height	101 feet
Length of 42" Pipe Through Dam	720 feet
Sandstone Spillway-Ridge Cut	139,000 cu. yds.
Service Road Constructed	2 miles

Cost

U. S. Soil Conservation Service	$1,900,000
City of Harrisonburg	$1,600,000
Total	$3,500,000

APPENDIX D: NORTH RIVER SOURCE

Longitude 80.847 Latitude 37.662

Intake Capacity 7.6 MGD

North River Source

The **North River** source was commissioned in the early 1970s. *The North River has given Harrisonburg a significant tool to adjust for daily and seasonal variations in demand.* Harrisonburg's Bridgewater Pump Station (BWPS) withdraws raw water from the North River; the withdrawal is a grandfathered application as compared to a Virginia Water Withdrawal permit. DEQ has rated North River to have a safe yield of 13.6 MGD. The source water has been under demand from Harrisonburg, Bridgewater, and irrigation practices such that a "Surface Water Management Declaration" was considered in the 1990s. The declaration did not move forward but Harrisonburg informally declared that its intention was not to use the North River beyond 5.7 MGD in times of drought.

Harrisonburg Assets

The City obtained access to the North River in 1970. The Bridgewater Pump Station / Intake and 20" pipe to adjoin the Silver Lake System (see Appendix F) were constructed. In the early 1990s, a 24" pipe was constructed in parallel to the pipe system from Silver Lake to Route 33. In the early 2000s, another 24" pipe was extended in the Route 33 corridor to the water treatment plant. These latter additions were made to accommodate growth from the 1983 City annexation by increasing North River capacity to 7.6MGD.

The current North River Raw Water System includes:

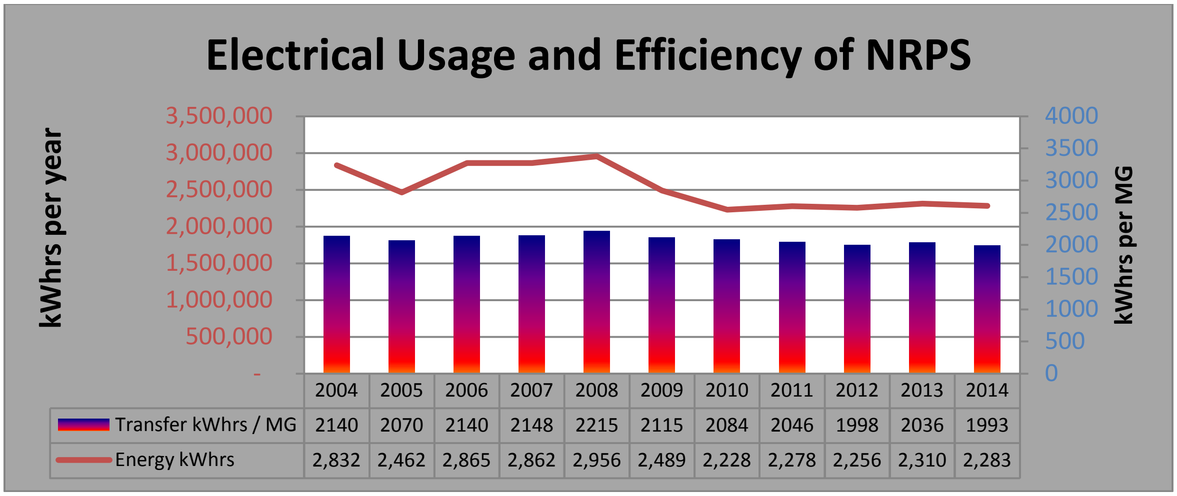
- 20” pipe: 26,312 feet
- 24” pipe: 12,591 feet
- 24” pipe: 3,969 feet
- Pump Station and Intake

A check valve in the 24” diameter pipe at the North River Valve Vault (NRVV) provides risk reduction from back flow and from the introduction of higher pressures during static conditions. As a second risk management effort, the pipe network was isolated and separated to convey only North River water until it adjoins with the Dry River network at the water treatment plant. These arrangements provided risk reduction through prevention, mitigation, and enhanced recovery toward potential pipe ruptures.

The Virginia Department of Health rates the pump station at 7.6 MGD. At the intake is an in stream concrete structure where bar screens provide protection from debris entering into two parallel pipes that route water to the pump station wet well. From 1970 until mid 2015, the station had three vertical turbine pumps in active service; each pump driven by a 350 horsepower motor. The pumps and motors were started with across the line configurations and then operated at full speed for any and all individual pumps and motors. Output performances with one, two, and three pumps in parallel operations provided the City wastewater treatment plant with 3.7 MGD, 5.7 MGD, and 7.6 MGD, respectively.

Electrical power and energy usage are constraints to using this source. The Bridgewater Pump Station at the North River is the single biggest demand for electricity for HPU as it accounted for 2,283,200 kW-hrs of usage or 63% of the total water system energy usage in FY 2014. The associated power demand was 530+ kW.

system:	3,950 gpm @ 514 feet TDH @ 79% PE & 90% ME
energy:	2,150 kW-hrs/MG
power:	530 kW plus house load



North River Risk

Harrisonburg's North River source is most susceptible to several potential causes of risk.

- The hurricane flood of 1985 inundated the pump station with severe impacts upon electrical equipment.
- As for contamination, recent alerts have been issued due to contamination from agricultural activities which are intense along the banks of the North River and upstream tributaries of Dry River and Mossy Creek. As similar to Dry River, the frequent small in-stream flow in the presence of a contaminant poses special attention to the concern.
- And finally, the Bridgewater Pump Station has potential for mechanical, electrical and instrumentation failure. Generally, the City has in place some abilities to operate one pump under most causes of mechanical, electrical, and instrumentation duress.

POTOMAC RIVER BASIN

01622000 NORTH RIVER NEAR BURKETOWN

LOCATION: LATITUDE 382025 LONGITUDE 0785450 HYDROLOGIC UNIT: 02070005 COUNTY: ROCKINGHAM

PERIOD OF RECORD: OCT 1925 TO SEP 1972
MAY 1975 TO SEP 1986
DRAINAGE AREA: 379 MI^2. AVERAGE DISCHARGE: 372 CFS

REMARKS: THE HIGH FLOW MONTHS ARE NOT CONTIGUOUS. THE HIGH FLOW 7 DAY 10 YEAR FLOW CANNOT BE CALCULATED.

JANUARY - MAY CORRECT

********** FLOW STATISTICS (CFS) **********

7 DAY 10 YR FLOW:	40
HIGH FLOW 7 DAY 10 YR FLOW:	NONE 65

1 DAY 30 YR FLOW:	27
HARMONIC MEAN:	142

********** MONTHLY FLOW (CFS) **********

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
MINIMUM	87	107	140	174	213	263	251	182	128	93	85	79
MEAN	253	289	327	392	524	693	605	476	325	199	237	185
MAXIMUM	1486	1478	1388	1384	1786	2567	1981	1860	1623	685	1129	847

********** DAILY FLOW DURATION (CFS) **********

PERCENT OF TIME FLOW EXCEEDS INDICATED VALUE									
5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
1251	809	604	440	406	348	300	265	231	200
174	150	130	113	98	84	73	63	52	---
55%	60%	65%	70%	75%	80%	85%	90%	95%	---

486

74 CFS = 20%

********** LOW FLOW FREQUENCY (CFS) **********

RECURRENCE IN YRS	DURATION IN DAYS: 1	3	7	14	30	60	90	183	365
100	23	26	29	31	32	35	36	38	111
50	25	29	32	33	35	38	39	44	133
40	26	30	33	34	36	39	40	47	141
25	28	32	35	36	38	41	42	53	161
20	29	33	36	37	39	42	44	56	172
10	33	37	40	41	44	47	49	70	211
5	39	43	45	47	50	54	58	91	263
2	54	58	60	63	67	75	86	152	373

EXPLANATION

Recent daily or average flow values
95th percentile to maximum daily flow
90th percentile to 95th percentile
75th percentile to 90th percentile
25th percentile to 75th percentile
10th percentile to 25th percentile
5th percentile to 10th percentile
Minimum daily flow to 5th percentile

Median flow
Instantaneous minimum flow

Streamflow Statistics based on average flows

Daily | 7-Day | 14-Day | 28-Day

Duration-plot description

Percentile Definition

Duration Table of Daily Streamflow

Flow values in cubic feet per second

01622000 NORTH RIVER NEAR BURKETOWN, VA

	Minimum daily flow	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile	Maximum daily flow		Years of record
January	28.0	58.0	71.2	147	271	479	888	1,370	13,700		85
February	35.0	78.0	108	194	326	588	1,020	1,530	6,230		85
March	52.0	142	187	293	477	820	1,400	2,090	13,600		85
April	80.0	154	188	258	396	703	1,250	1,780	10,000		85
May	84.0	118	144	210	328	572	1,010	1,460	14,500		85
June	49.0	83.0	96.0	130	182	308	627	1,030	29,900		87
July	30.0	55.0	66.8	90.0	123	190	340	566	6,300		87
August	32.0	44.0	52.0	71.0	105	196	413	772	12,700		87
September	22.0	46.0	53.0	66.0	95.0	171	379	687	32,000		87
October	25.0	48.0	54.0	66.0	99.0	190	430	747	20,100		86
November	24.0	48.0	57.0	76.0	128	297	631	965	30,000		85
December	25.0	52.0	60.0	106	225	403	772	1,150	14,800		85

Instantaneous minimum flow for period of record = 16.0 cubic feet per second.

The current daily value for 12/06/2015 is 730 cubic feet per second.

---- Provisional Data Subject to Revision ----

APPENDIX E: SOUTH FORK SHENANDOAH RIVER SOURCE

Longitude 78 43.8’ Latitude 38 20.2’

Intake Capacity TBD MGD

South Fork of the Shenandoah River Source

Harrisonburg’s Power Dam Road Pump Station will withdraw raw water from the South Fork of the Shenandoah River; the withdrawal is permitted under Virginia Water Withdrawal Permit #98-1672. The lower reaches of the water shed lends to a lesser quality of raw water as compared to other available sources. A submerged structure is located in stream where bar screens provide protection from debris entering into two parallel pipes that route water to the pump station wet well. At the same location, DEQ has rated the in stream safe yield at 78.0 MGD.

Harrisonburg Assets

The intake structure and pump wet well are a unique collaboration between the City, DEQ, and various agencies responding under the input format of the Virginia Marine Resources Commission. The City pump station is located in an abandoned hydroelectric canal at the site of the original turbines; the initial intake design proposed to somewhat resurrect the hydroelectric concept that used a flow through side stream to bring source water to the turbines (pumps). The concept was also planned to facilitate boat access through the canal to overcome the hindrances to float travel caused by the in-stream dam remnants.

Through collaboration previously mentioned, an alternative concept was chosen. The concept avoided placement of difficult to maintain small screens into the mainstream river. The in stream hydroelectric dam remnants were removed, an intake with debris screen was installed at an alternative in stream location, and a flow through pump station wet well was installed at the site of the original turbines. The latter was a unique installation that allowed water to flow continuously from the in-stream structure to the pump wet well and then back into the original canal as it returns to the mainstream of the river. This unique design retained provisions to avoid the intake and impingements of aquatic organisms by pumps and upon smaller screens, respectively, while allowing the City to have its 2 millimeter micro-screens located for easy access and repair.

The pump station housing structure has been constructed on the old turbine support structures. The pumps to this facility are expected to be three units with 500 horsepower motors. The operation and control configuration will be much similar to the North River Pump Station as the latter's 2015 upgrade will serve as a model for the final design at Power Dam Road Pump Station. The Power Dam and Goods Mill Pump Stations have not yet been commissioned but have the following characteristics:

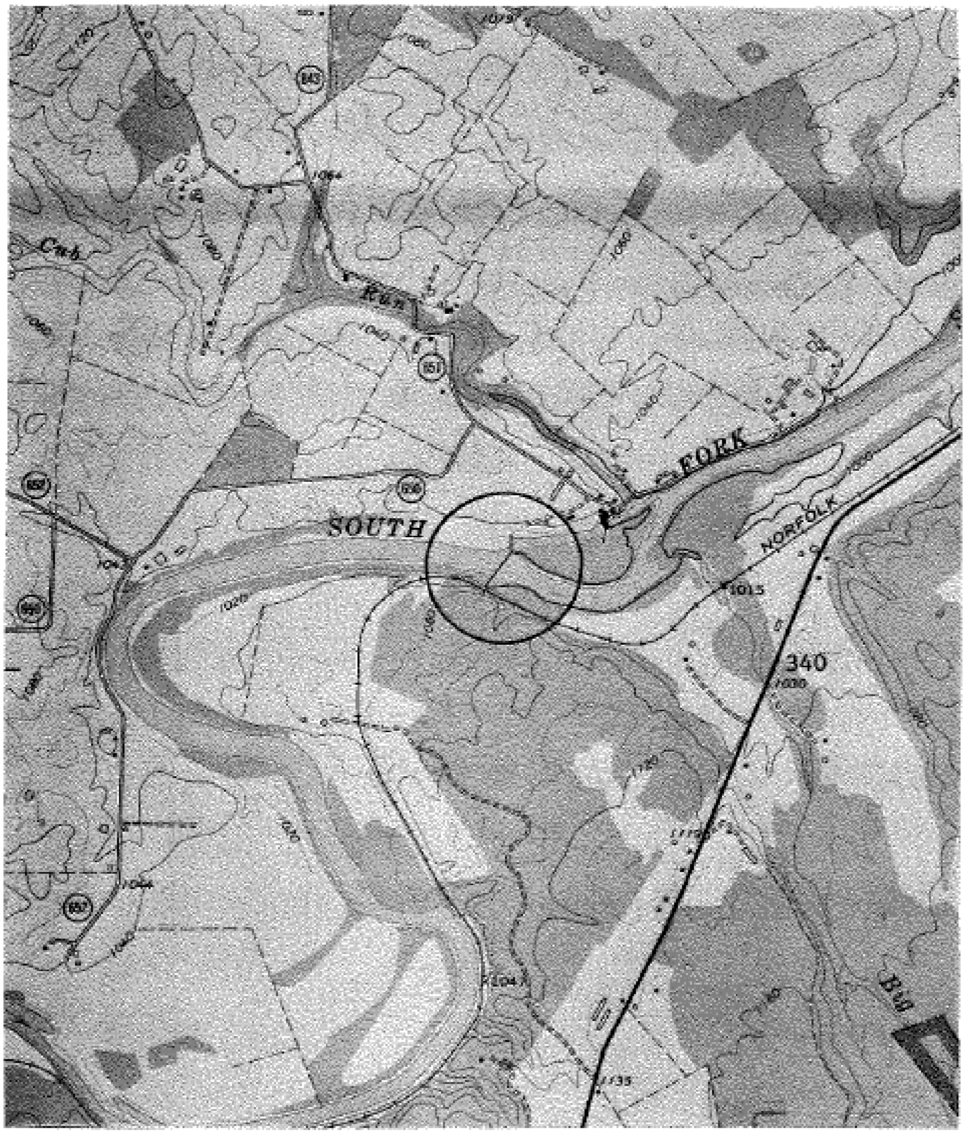
system	2,778 gpm @ 651 feet TDH @ 72% PE & 90% ME
energy:	3,108 kW-hrs/MG
power:	705 kW

Shenandoah River Source Risks:

In contrast to the Dry River and North River, the Shenandoah River has a much higher in-stream flow pattern with characteristics that are typical of its location in the lower drainage basin. Changes in flow rate and water quality generally occur over longer durations. More pollution and more dilution are prevalent; the latter has significant mitigation influence. And finally, the future Power Dam Road Pump Station will have potential for mechanical, electrical and instrumentation failure. Future design will attempt to mitigate these risks.

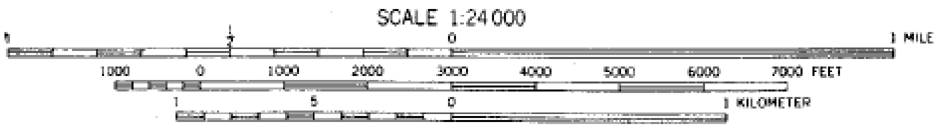
DAM LOCATION MAP

McGAHEYSVILLE DAM



McGAHEYSVILLE QUADRANGLE

7.5 MINUTE SERIES (TOPOGRAPHIC)



STREAM FLOW DATA

South Fork Shenandoah River near Lynnwood
Gaging Station 1-6285

Location: 1.2 miles northeast of Lynnwood, Rockingham County and 3.3 miles downstream from confluence of North and South rivers.

Drainage Area: 1,084 square miles

Average Discharge: 977 cfs

Length of Record: 46 years

Flow Duration Data

Percent Exceedance	Flow in C.F.S.
99.8	120
97.7	170
94.0	200
87.5	240
81.1	280
73.5	340
66.8	400
58.4	480
50.8	570
43.2	680
35.7	810
28.9	960
24.0	1100
17.1	1400
14.0	1600
10.5	1900
7.5	2300
4.1	3200
2.0	4600

EXPLANATION

Recent daily or average flow values
95th percentile to maximum daily flow
90th percentile to 95th percentile
75th percentile to 90th percentile
25th percentile to 75th percentile
10th percentile to 25th percentile
5th percentile to 10th percentile
Minimum daily flow to 5th percentile

Median flow
Instantaneous minimum flow

Streamflow Statistics based on average flows

Daily | 7-Day | 14-Day | 28-Day

Duration-plot description

Percentile Definition

Duration Table of Daily Streamflow

Flow values in cubic feet per second

01628500 SOUTH FORK SHENANDOAH RIVER NEAR LYNNWOOD, VA

	Minimum daily flow	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile	Maximum daily flow		Years of record
January	130	218	267	462	798	1,370	2,460	3,430	39,300		84
February	133	270	390	600	952	1,600	2,690	3,940	21,100		84
March	148	449	532	817	1,250	2,080	3,570	5,220	52,400		84
April	292	452	550	726	1,040	1,760	3,060	4,250	30,800		84
May	250	388	451	593	880	1,350	2,270	3,170	22,400		84
June	134	267	310	411	560	840	1,440	2,360	41,500		84
July	84.0	206	240	310	407	562	886	1,310	7,720		84
August	84.0	174	204	259	348	533	973	1,600	32,600		84
September	95.0	175	192	235	315	499	994	1,800	63,500		84
October	100	178	190	237	318	539	1,210	2,090	42,700		84
November	114	185	220	268	405	792	1,630	2,540	60,000		84
December	129	193	225	332	650	1,100	2,040	3,040	31,200		84

Instantaneous minimum flow for period of record = 32.0 cubic feet per second.

The current daily value for 12/06/2015 is 1750 cubic feet per second.

---- Provisional Data Subject to Revision ----

APPENDIX F: SILVER LAKE SOURCE

Longitude 79.057 Latitude 38.521

Intake Capacity 0.0 MGD

Silver Lake Source

Harrisonburg owns **Silver Lake**. DEQ has rated Silver Lake to have a safe yield of 1.5 MGD. The City's withdrawal is a grandfathered activity as compared to a Virginia Water Withdrawal permit. The feed location to Silver Lake is an underground spring opening from which the groundwater enters into Silver Lake. The Town of Dayton has installed horizontal well screens into the spring by which raw water is routed through a manifold and suction pipe to the Town's pump station. In contrast, the City's intake pipe lays supported on wooden cross ties from the pump station structure to a location just outside the spring / lake interface. The City's intake location is not ideal from the perspectives of both water quality and water quantity. As for water quality, City intake water is subject to high algae contents which have significant deleterious effects to water treatment filter operations. As for water quantity, the availability of water is subject to withdraw activities by the Town of Dayton.

Formal privileges and restrictions upon the City's withdraws are relevant to a contractual relationship with the Town of Dayton. The Silver Lake source was purchase by the City in 1947 as a drought supplement to the Dry River source. The purchase, however, came with significant restrictions in the format of first rights of withdrawal to the Town of Dayton. The Town has held a ninety nine year lease of first rights to water withdrawal under a contract that preceded the City's1947 purchase. The lease ran from 1915 to 2014.

Harrisonburg Assets

Upon purchase, the City immediately constructed a pump station plus 10,854 feet of 16" pipe from Silver Lake to adjoin the Dry River pipe system at Route 33. Silver Lake Pump Station is inactive but has the following characteristics:

system:	929 gpm @ 378 feet TDH @72% PE & 90% ME
energy:	1,805 kW-hrs/MG
power:	137 kW

As the need for water grew, the City operated the pump station as a significant component for water supply, but not without careful respect to the Town of Dayton. Beginning with mild drought conditions, the City's raw water supply from the Silver Lake source would come into unreliable status that depended upon the relationship between the available water and the unrestricted withdrawals made by the Town of Dayton. This constraint prevailed as significant in the City's water management operations until the North River source became available in 1970.

From 1970 until 1990, the City used Silver Lake under limited application except for the catastrophic effects of the hurricane of 1985 which disabled both the Dry River and North River sources for a short period of time. As the 1990's approached, the pump station needed consideration for an upgrade as it had reached the end of its useful life and became non-functional. Given the City's longer term raw water supply needs, the smaller safe yield of Silver Lake, the water quality and quantity issues, and contractual obligations / future considerations to the Town of Dayton, the City opted not to invest at Silver Lake but to undertake efforts to the South Fork of the Shenandoah River. In conclusion, the decision to upgrade the Silver Lake Pump Station was delayed until the City could consider its own first rights to the water and with perspective to the progress made towards the Shenandoah project.

Silver Lake Risks:

The Silver Lake source is fed from groundwater feed that is under the influence of surface water. Although the surface water influence is a concern for contamination, its risk for exposure is far less than any other Harrisonburg raw water source. The Silver Lake Pump Station is currently out of operations and considered to be in non-salvageable status.

Obligations and Considerations

The Town of Dayton lease agreement for Silver Lake expired in 2014. Going forward, Harrisonburg intends to work with the Town of Dayton to allow them to maintain their viability through this water supply but also wishes to maintain flexibility for its own use. The potential values that the City must consider include Silver Lake's respective position among other sources within the optimized, drought, and risk mitigation strategies for water supply.

It should be noted and addressed that the City has little ability to effectively capture raw water from Silver Lake unless it gains access to the spring. Two options can achieve this goal. Harrisonburg can either share the current infrastructure owned by the Town of Dayton or the City can obtain sole ownership of the infrastructure by purchase or new installation.

APPENDIX G: VAC LOCAL AND REGIONAL WATER SUPPLY PLAN

The Commonwealth of Virginia is comparatively a water rich state; however, following the drought of 1999-2002 the state engaged a statute (9VAC25-780) calling for Local and Regional Water Supply Planning. Under this statute each locality was required to submit a plan that identified their water needs throughout 2040. The City was one of 48 plans submitted by the 2011 deadline. The City optioned to submit the plan using a regional approach that culminated by action of Harrisonburg City Council to adopt the "Upper Shenandoah River Basin Water Supply Plan"

The information from 48 plans has been under review by the Department of Environmental Quality (DEQ) with purpose to develop a State Water Resources Plan (SWRP). The purpose is to make recommendations that will protect all beneficial uses to the maximum. DEQ has analyzed the data and has forecasted that the daily statewide water usage will increase by 32% to 450 MGD by 2040. In a proactive approach, DEQ has published a list of 12 recommendations that reflects how they plan to meet the intent of the statute base on the data in the SWRP. DEQ's intentions toward Harrisonburg are on display in the reissuance of VWWP #98-1672.