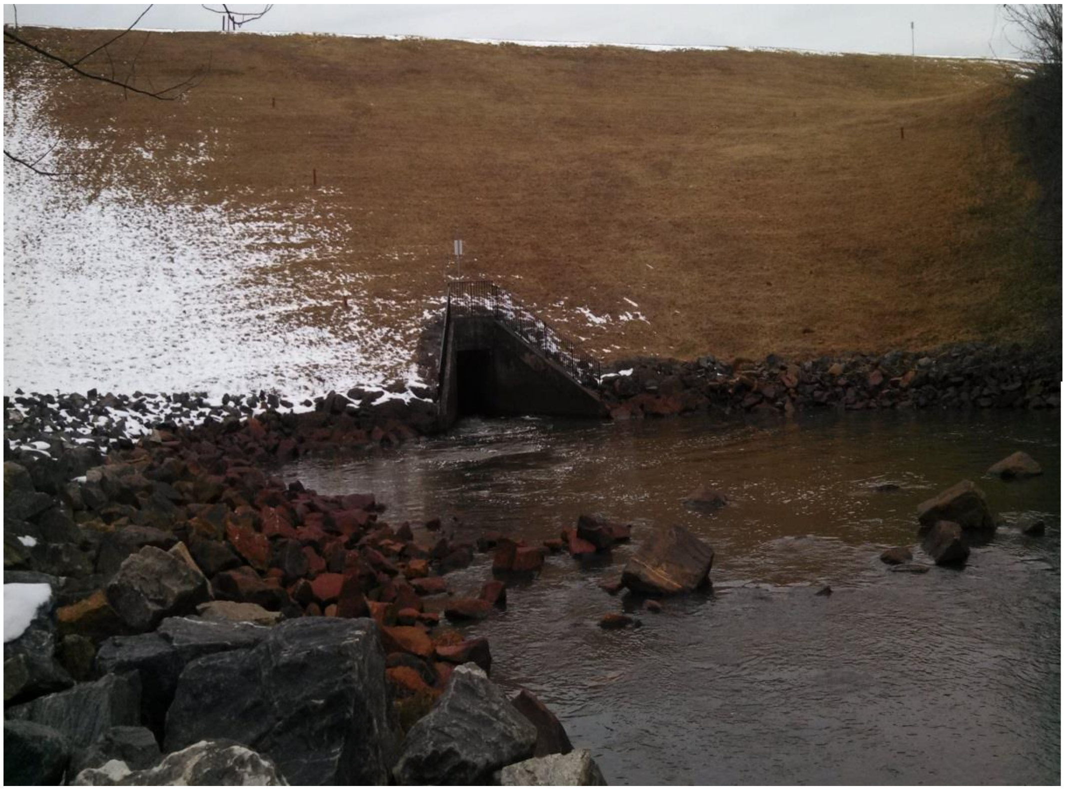

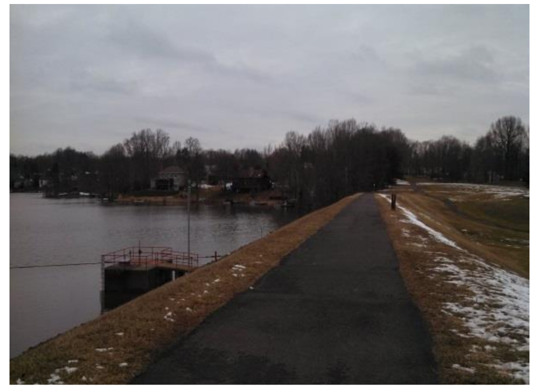

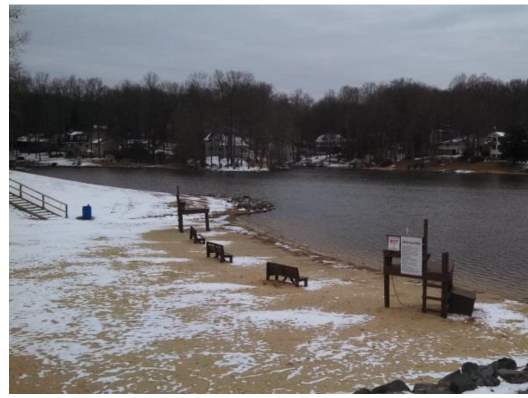

Report of Inundation Study
Montclair Dam
Inventory Number 15303
Dumfries, Virginia
F&R Record No. 62R-3350

Prepared for:

Montclair Property Owners Association

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Report of Inundation Study
Montclair Dam

Inventory Number 15303
Montclair, Virginia
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1.0 INTRODUCTION

1.1 Project Information

We understand that Montclair Property Owners Association is required to perform an inundation study for Montclair Dam (Inventory No. 15303) located in Montclair, Virginia. To meet this requirement Froehling & Robertson, Inc. (F&R) performed the below described inundation study in accordance with the Virginia Soil and Water Conservation Board regulation 4VAC50-20-54. Figure 1 in Appendix A (Study Area Map) illustrates the Montclair Dam watershed and the contributing downstream sub-watersheds utilized in our study. The project study area was defined as the drainage area encompassing Montclair Dam extending down Powells Creek to a termination point at the Potomac River 7.14 river miles from Montclair Dam.

Montclair Dam is a High Hazard dam that was constructed in 1964 as a recreational impoundment. It is situated on a Powells Creek approximately 0.28 miles upstream of Waterway Drive in Montclair, Virginia. The dam impounds Montclair Lake, an approximate 84 acre reservoir at normal pool. The drainage area to the Montclair Dam was calculated to be 10.72 square miles (6081 acres). The drainage area consists of predominately developed areas (see Montclair Dam Drainage Area – Figure 2 in Appendix A).

The dam is 72 feet tall with a top elevation that varies from 204.7 feet on the left end and 205.8 feet on the right. The spillway crest is at 193.5 allowing 11.2 feet of total flow depth to the lowest point on top of the dam. The normal pool elevation is at 187 feet. The elevation information used in our study was derived from a topographic survey performed by Nyfeler & Associates and VGIN topographic data. The North American Vertical Datum of 1988 was used as the vertical reference and the North American Datum of 1983 was used as the horizontal reference.

The principal spillway consists of a 12 foot by 20 foot rectangular concrete inlet tower with an 8 foot by 5-foot outfall conduit that discharges into the natural channel.

The auxiliary spillway is located on the right of the dam with a natural grade separating it from the dam embankment. The spillway has had many amenities built within it. The approach is 140 feet wide but is narrowed to an effective width of 100 feet at the control section. The spillway is reported to have a design capacity of the Probable Maximum Flood (PMF).

1.2 Scope of Services

The purpose of our involvement on the project was to perform a flood inundation study resulting in a hazard classification statement, flood inundation mapping, and an incremental damage assessment. We were also requested to perform a spillway stability analysis on the auxiliary spillway under the 100 year, ½ PMF, the Spillway Design Flood (SDF), and the PMF events. In order to accomplish these objectives the following services were performed.

Inundation Study

1) Made an initial visit to the dam and surrounding region with our engineers to observe existing conditions including review of records of previous studies, inspections and plans provided by the owner. Existing downstream bridges and houses were also observed in preparation of the Inundation Study.

2) Reviewed readily available mapping information relative to the impoundment and project site including, but not limited to, the following: United States Geological Survey (USGS) 1:24,000-scale topographic maps, Natural Resource Conservation Service (NRCS) soil survey, National Wetland Inventory (NWI), Federal Emergency Management Authority (FEMA) Flood Insurance Rate Map (FIRM) maps, USGS Color-Infrared (CIR) Aerial Photography, and Digital Elevation Model (DEM).

3) Subcontracted a licensed surveyor to perform a current survey of the existing dam and surrounding area. The physical survey was supplemented by VGIN 2007 digital orthophotography Triangular Irregular Network (TIN) files for contours outside of the surveyed area. The survey data was used as data input for both Part A of the RFP, the hydrologic and hydraulic flood model and Part B of the RFP, the stability analysis model.

4) Obtained terrain data for surrounding study area from VGIN 2007 full color, leaf-off, digital orthophotography Triangular Irregular Network (TIN) files for use as source-elevation data.

5) River reach information was derived from the National Hydrography Dataset (NHD) equivalent of USGS Topographic Map "blue lines".

6) Building outlines were digitized from the most recently available aerial photography or manually drawn in. The "best available" source for building elevations was used, derived from DTM analysis. Bridge structure information was obtained from VDOT, supplemented by our field observations and measurements.

7) Used the ESRI ArcMap extensions Arc Hydro and HEC Geo-RAS to "pre-process" GIS vector data, aerial photography, structure information, and terrain data. Data was manipulated to the extent where existing geometry could be imported into HEC-RAS Version 4. Included in this processing was the generation of elevation points, stream centerlines, cross-sectional cutlines, banklines, flowpath centerlines, bridge locations, and land use.

8) Performed HEC-HMS computer modeling of the dams' upstream watershed to develop runoff hydrographs. Rainfall data was obtained from NOAA-Atlas 14 data for Virginia and HMR-51. Stormwater run-off for a 100-year flood event up to a PMF rainfall event were developed from this data. Run-off data was calculated using the most recent available NRCS soil survey data. A calculated dam breach section was developed based on a selected failure depth, impoundment storage

volume, time of failure and bottom width. A "sunny day" breach was also analyzed based on a piping failure.

9) Performed HEC-RAS stream modeling for a 100-year flood event up to a PMF flood event as required. A stream model was developed from the dam outfall down to the end of the study area.

10) Upon HEC-RAS model processing and QA/QC of results, HEC-RAS model results were exported to ArcMap and HEC Geo-RAS was used to perform floodplain extent delineation using the DTM and HEC-RAS bounding polygons.

11) Output includes hard copy inundation maps and electronic shape files depicting flood hazard boundaries resulting from a possible dam break under each of the scenarios described above on a topographic map and readily available aerial photographs sourced from VGIN 2007 data or better as available. We have provided a table of flood elevations relative to each impacted structure for the various flood events.

12) Prepared a final inundation study report documenting our procedures and providing the inundation maps. A statement of the Hazard Classification was made. An incremental analysis was also made regarding the minimum required emergency spillway capacity of the dam (100-year up to 0.9 PMF). The capacity of the existing emergency spillway was determined.

Auxiliary Spillway Stability Analysis

1) Conducted a subsurface exploration to determine subsurface profiles of the underlying soil and rock and obtain soil and rock properties data. A drill rig was mobilized to the site and four test borings were drilled in the auxiliary spillway and surrounding area. Samples of soil and rock were sent to our laboratory for analysis. Field data, boring logs, and laboratory data were summarized in the final report.

2) Performed a stability analysis using the NRCS SITES program using the material properties, subsurface profile, and the DCR approved hydrologic and hydraulic analysis. SITES analysis included model runs for the full PMF event, the SDF event, the ½ PMF, and 100 year events to help determine potential intermediate damage levels.

We note that an Emergency Action Plan (EAP) is not included in this report.

2.0 INFORMATION REVIEW

2.1 General

F&R reviewed appropriate information sources to identify Spatial Data depicting overall site conditions and to identify watershed characteristics. Spatial Data briefly described in this section was further utilized as input information for the hydrologic and hydraulic (H&H) models. Maps reviewed included some of the following: United States Geological Survey (USGS) 1:24,000-scale topographic maps, Natural Resource Conservation Service (NRCS) soil survey maps, Federal Emergency Management Authority (FEMA) Flood Insurance Rate Map (FIRM) maps, Digital Terrain Model (DTM) maps, Southeast Geospatial Analysis Project (SEGAP) maps and other relevant remote sensing data that could be freely obtained with coverage of the extent of the project site.

2.1.1 Field Data Collection

Field visits were performed to observe existing conditions along the downstream reach of the study area. Culvert and bridge profiles were measured to field-verify as-built information obtained from VDOT. These dimensions were then used in the subsequent hydraulic computer models to complete the described inundation study.

After survey and field verification we determined that the information found in the *Data Sheet – Operation and Maintenance Certificate*, relating to the Montclair Dam was not accurate for the application to this study. The reported spillway capacity and dimensions of the dam are not correct. We used the surveyed elevations and dimensions to model the breach events. It is our professional opinion that reliance on the above described field measurements combined with the use of available GIS DTM information (see Section 3.1) does not limit the precision of our described inundation study.

2.1.2 USGS Topographic Maps

The USGS 1:24,000-scale topographic map depicts moderate terrain variation within the project area watershed, with sloping topography throughout the project study area. The Montclair Dam and the study area are depicted on the Independent Hill, Occoquan, Joplin, and Quantico topographic maps. These maps were utilized to develop Figures 1 and 2 in Appendix A.

2.1.3 NRCS Soil Survey Maps

Soil map unit (SMU) polygon boundaries in ESRI shapefile format were obtained from the NRCS Spatial Data Gateway along with soils tabular data containing the equivalent of soils characteristics published in the printed soil survey. All data was imported into the spatial geodatabase schema supplied by the NRCS. The NRCS Soil Data Viewer, an ArcGIS extension for the analysis and reporting of soils information, was used to produce hydrologic soil group information.

2.1.4 Aerial Photography

Several years of aerial photography were reviewed to identify possible significant land use changes over time. The United States Geological Survey (USGS) 1994 Color Infrared (CIR), the Virginia Information Network (VGIN) Virginia Base Mapping Program (VBMP) 2007 Color, the NRCS National Aerial Imagery Program (NAIP) 2006 and 2008 all depict the dam watershed as primarily developed. Figure 3 (Montclair Dam Aerial Photo) in Appendix A shows the 2009 VGIN aerial photos of the dam drainage area.

Horizontal accuracy is not provided for the 2009 VGIN aerial photography used to develop cross-section information. Use constraints given by metadata as “Any person not licensed as a land surveyor preparing documentation pursuant to subsection C of 54.1-402 of the Code of Virginia shall note the following on such documentation: any determination of topography or contours, or any depiction of physical improvements, property lines or boundaries is for general information only and shall not be used for the design, modification, or construction of improvements to real property or for flood plain determination.”

The VBMP data was developed using procedures designed to produce data to National Standard for Spatial Data Accuracy (NSSDA) and is intended for use at 1" = 100' or 1" = 200' scale. It is requested that the Commonwealth of Virginia be cited for any use of the orthophotography as follows: "Imagery Courtesy of the Commonwealth of Virginia.”

In general, features shown on the 2009 VGIN aerial photography used in the preparation of inundation maps are assumed by F&R to represent true location.

2.1.5 Land Use/Land Cover

Data obtained from the Southeast Geospatial Analysis Project (SEGAP) depicts most of the watershed area as forested and open areas. Tables 1a and 1b (see Section 3.3.1) summarize Land Use/Land Cover (LULC) by acreage for the Montclair Dam watershed as well as the composite of the entire study area depicted by the SEGAP LULC database and reclassified into coarser classifications matching cover types provided in the NRCS Technical Release Manual TR-55.

3.0 INPUT DATA PREPARATION

3.1 Terrain Data

Terrain data from VGIN 2009 full color, leaf-off, digital orthophotography-derived Digital Terrain Model (DTM) files was obtained from the Commonwealth of Virginia with coverage of Prince William County Virginia. These data, originally created for the purpose of orthorectifying the VBMP aerial photography, were converted to raster (grid) format at a 10-foot horizontal cell resolution using ArcGIS 3D and Spatial Analyst. A Digital Terrain Model drawing of the Montclair Dam watershed (Figure 4) is provided in Appendix A. The raster dataset extent (x-min, y-min, x-max, y-max) was reduced to encompass the minimum spatial extent necessary to cover the Montclair Dam study area.

Virginia Geographic Information Network (VGIN) metadata for the VBMP TIN files used to generate the ten-foot resolution gridded DTM that served as the source for elevation data (NAVD 88) contains the following vertical accuracy statement: "Vertical Positional Accuracy Report: Vertical accuracy is untested. The data sources provided by VITA/VGIN were used "as-is," and were not tested for accuracy. The VBMP acceptance criteria require terrain data to be sufficiently accurate to produce orthoimagery meeting certain specifications." The elevation data depicted by the TIN data is referenced to the North American Vertical Datum of 1988 (NAVD 88) as its vertical reference and the North American Datum of 1983 (NAD83 HARN) Horizontal Datum and the Geodetic Reference System 80 (GRS80) Ellipsoid model as its horizontal reference.

In accordance with use constraints contained in the VGIN metadata, any determination of topography or contours, or any depiction of physical improvements, property lines or boundaries is for general information only and shall not be used for the design, modification, or construction of improvements to real property or for flood plain determination.

3.2 Watershed Processing

The ArcGIS hydrology extension (Arc Hydro) was used to generate digital watershed data. Watershed boundaries, artificial drainage lines, terrain derivatives, and flow path attributes for the Montclair Dam watershed and sub-watersheds were automatically generated in a consistent format in this manner. Data were then output for use in HEC-HMS analyses of watershed response to different rainfall events. Upon completion of input data generation for HEC-HMS, the same GIS data was utilized for generation of terrain and geometry data for input into HEC-RAS.

In addition to the dam watershed (drainage area at outflow of Montclair Dam), contributing sub-watersheds were characterized with regard to their contributory input to flow emanating from Montclair Dam during model rainfall events. We note that one sub-watershed was accounted for in our evaluation as illustrated on Figure 1 in Appendix A.

3.3 HEC-HMS Input Preparation

The ArcGIS hydrology extension, Arc Hydro was used to generate input data for analysis by HEC-HMS. Utilizing output from Arc Hydro, watershed response variables were automatically generated in a consistent manner for the Montclair Dam watershed and sub-watersheds.

3.3.1 Land Use/Land Cover Data

Land Use/Land Cover (LULC) classifications and percentages were determined for each respective watershed based on mapping values depicted by the SEGAP raster data. These SEGAP classifications (210 in number) were reclassified into coarser classifications that more resembled those used in the NRCS TR-55 manual. The coarser LULC classifications were visually checked using 2009 VGIN and 2011 NRCS NAIP aerial photography.

Table 1a (NRCS Land Use/Land Cover Data) provided below lists NRCS designations and the corresponding acreage for the Montclair Dam watershed used in our hydrological modeling. Table 1b lists the NRCS designations and the corresponding acreage for the entire Montclair Dam study area.

Table 1a: NRCS Land Use/Land Cover Data for Montclair Dam Watershed

NRCS Landuse	Acreage of Study Area
Clear Cut	384.2
Pine	3313.7
Developed - Dense	1850.2
Grass	179.8
Wetland	610.8
Row Crops	211.4
Pasture/Hay	54.0
Forested Hardwood	102.8
Developed	13.8
Water	85.6
Rock	50.5
Sand/Soil Mix	0.9
	6857.7

Table 1b: NRCS Land Use/Land Cover Data for the Entire Montclair Dam Study Area

NRCS Landuse	Acreage of Study Area
Clear Cut	538.5
Pine	4018.5
Developed - Dense	1975.9
Grass	198.3
Wetland	706.5
Row Crops	287.7
Pasture/Hay	75.2
Forested Hardwood	2215.9
Developed	1237.1
Back Water & Flood Plain	320.7
Marsh	136.8
Water	461.9
Rock	54.3
Sand/Soil Mix	2.4
Swamp	0.2
	12230.0

3.3.2 Curve Number Generation

The design curve numbers used in our study were based on the Runoff Curve Number tables provided in the NRCS TR-55 manual (Tables 2-2a through 2-2d) using a combination of the most recent NRCS soil survey data depicting hydrologic soil groups (A, B, C, and D) and the land use classifications shown in Tables 1a and 1b (Section 3.3.1). The NRCS soil survey data provided the hydrologic soil group designations and the percentage of each soil group within the respective components of each watershed. Soils mapped within the study area primarily consist of complexes which constitute a single mapping unit but contain two or more components that may belong to taxonomic classes other than that of the series. Hydrologic soil group information was taken to be the weighted average given by the NRCS for each component within each complex. We note that the primary NRCS land covers in the Montclair Dam study area is designated as Developed, followed by Pine. In addition, we note that we generally assumed the hydrologic condition to range between "fair" and "good" when using the TR-55 tables to estimate curve numbers for the individual ground cover types.

Utilizing the ground cover classifications with corresponding curve number recommendations provided in the TR-55 tables and the land use/land cover and hydrologic soil group breakdown, a weighted design curve number value based on the percentage of acreage for each Land Use/Soil Group combination was established. The resulting output was converted to a continuous grid with a 40-foot pixel resolution (each pixel representing a discrete curve number value). Potential storage and Initial Abstraction (IA) were derived from the curve number grid, also at 40-foot pixel resolution. Soil Moisture Deficit Value (S), Initial Abstraction (IA), and Lag Time (TL) for each pixel were computed using the equations shown below. The design curve numbers and initial abstraction values for each watershed were derived by computing the zonal mean of each grid data set using the watershed boundary as the zone definition within the ArcGIS Zonal Statistics tool. The resulting design curve numbers utilized in the HEC-HMS modeling of the Montclair Dam watershed and the sub-watersheds are provided in Table 2.

$$\text{Soil Moisture Deficit Value (S)} = (1000/CN)-10$$

$$\text{Initial Abstraction (IA)} = 0.2S$$

$$\text{Lag Time (TL)} = L^{0.8}*(S+1)^{0.7}/1900*Y^{0.5}$$

3.3.3 Watershed Characteristics

Stream/river centerlines, longest flowpath parameters, and watershed characteristics were derived from the watershed characterization tools provided by ArcHydro. The watershed values used in our modeling included drainage basin areas (in square miles), hydraulic flow lengths (longest flow path), an average of watershed side slopes, current land use (noted in Tables 1a and 1b), and hydrologic soil groups (A, B, C or D soils). The watershed characteristics assumed in our modeling are provided in Table 2.

Table 2: Watershed Hydrology Characteristics

Watershed	Drainage Area (sq. mi)	Longest Flow Path (ft.)	Average Watershed Slope (%)	Initial Abstraction (in.)	Hydrologic Curve Number (CN)	Lag Time (hr.)
Dam Watershed	10.72	24,985	8	0.9	70	1.9
W100	8.13	45,327	12	1.5	64	3.1

*Values shown are an average of the watersheds that make up the junction
**Values shown are the sum of the watersheds that make up the junction

3.3.4 Precipitation

Rainfall amounts representing Probable Maximum Precipitation (PMP) events for a 6-hour, a 12-hour, and a 24-hour duration storm over the Montclair Dam drainage basin area were obtained from Hydrometeorological Report (HMR) 51, developed by the National Weather Service (NWS). Contributing sub-watersheds were evaluated based on 100-year rainfall data that was obtained from the NOAA (National Oceanic and Atmospheric Administration) Atlas 14 database. The distribution of each rainfall event modeled was developed based on consideration of the 24-hr distribution of rainfall reported in the Atlas 14 database for the 100 to 1000 year precipitation events and is provided in Appendix C. The rainfall depths used to simulate precipitation runoff in our modeling are provided below.

- 100-year Event = 8.2 inches
- PMP 6-Hour Event = 28 inches
- PMP 12-hour Event = 33 inches
- PMP 24-hour Event = 37 inches

3.4 HEC-RAS Input Preparation

The HEC-RAS (Hydrologic Engineering Center River Analysis System) computer model output requires the accumulation of a significant amount of data. This includes the following:

- pre-calculated stream/river hydrograph and flow data (cubic feet per second),
- topographic information of the below dam stream/river systems,
- horizontal cross-sections from the dam to a long distance downstream,
- stream/river crossing bridge and bridge dimension data,
- Manning’s roughness factors for the stream/river bed and side channel cover (also known as “n” values),
- stream bed slope as well as other boundary conditions.

The ArcGIS hydrology extension, HEC-GeoRAS was used to generate input data for analysis by HEC-RAS. Utilizing output from Arc Hydro, terrain and geometry data were generated in a format allowing for direct import into HEC-RAS. HEC-GeoRAS automates the production of cross-section geometry, channel and overbanks, and bank stations.

3.4.1 Stream/River Centerline

The stream/river centerline was taken to be the stream/centerline of the drainage path generated by the extraction tool in Arc Hydro. The "start" of the river was taken to be the point at which flow emanates at Montclair Dam and the study area was terminated approximately 7.14 miles downstream of Montclair Dam.

3.4.2 Stream/River Banks

Left and right stream banks distinguish the main channel from the overbank floodplain, and based on field observations, were taken initially from either the VGIN 2009 breaklines depicting "top of bank" or field observations of select cross-sections. Stream bank stations were later manually adjusted in HEC-RAS based upon field observations due to the inconsistency of the remotely-sensed terrain data to depict stream bank location.

3.4.3 Flowpaths

Left and right flowpaths, side channel and overbank flow locations were digitized by hand using a combination of aerial photography and 2-foot interval contour lines (generated using the DTM and ArcGIS Spatial Analysis Contour Tool) to guide in determining appropriate placement. Channel flowpaths were taken to be the same geometry as the stream/river centerline.

3.4.4 Cross Sections

Cross sections were drawn (from river left to right) using the cross section editor tool in HEC-GeoRAS. Aerial photography, planimetric GIS data, 2 foot contour lines, and shaded-relief terrain rendering were used to aid the appropriate placement of GIS cross sections. The locations of the cross sections are shown on Cross Section Maps (1, 2, and, 3) provided in Appendix B.

3.4.5 Manning's "n" Value

HEC-RAS attributes some of the energy losses in a particular system to friction. The amount of friction that exists in any given geometry is associated with a specific Manning's frictional coefficient. The Manning's n-values chosen were taken from Table 3-1 of the HEC-RAS user manual. These values are placed along each cross-section to represent the frictional resistance in both the stream and the floodplain. The value is changed when the topography or land cover changes.

3.4.6 Dam Storage

The available storage above the reported normal pool elevation for the dam was determined using elevation information provided in the VGIN 2009 DTM data. The normal pond elevation, emergency crest elevation, dam crest elevation, and resulting available storage volume for the dam is provided in Table 3. Our calculated stage / storage curve is in Appendix C.

Table 3: Dam Available Storage

Description	Normal Pond Elevation (ft.)	Emergency Spillway Crest Elevation (ft.)	Dam Crest Elevation (ft.)	Available Storage At Dam Crest (acre-ft.)
Montclair Dam	187	193.5	204.7	4891.2

3.4.7 Bridges and Structures

The culvert and bridge locations were digitized using the bridge editor tool in HEC-GeoRAS. As GIS is unable to capture the necessary data to represent culvert and bridge profiles in HEC-RAS, the structures were field-checked to measure, document, and photograph structure openings and other pertinent data. Culvert and bridge plans were obtained from VDOT when available. This information was manually entered into HEC-RAS using the HEC-RAS Bridge Deck Editor. GIS bridge information only served as a guide as to where (stationing) to enter bridge data in HEC-RAS.

Structure outlines (houses, barns, sheds, garages, etc.) that are directly impacted by the flood boundaries were digitized using the 2007 VGIN aerial photography. Property boundaries and ownership of land and buildings were not synthesized.

3.4.8 HEC-RAS Geometry

Upon completion of the planimetric data generation using the HEC-GeoRAS editing tools, River/Reach names, Topology, Lengths/Stations, Elevations, and Downstream Reach Lengths were all automatically calculated by HEC-GeoRAS. An export file was created by HEC-GeoRAS for direct import into HEC-RAS.

4.0 HEC-HMS AND HEC-RAS ANALYSES AND RESULTS

4.1 HEC-HMS Analyses and Results

The USCOE engineering computer program HEC-HMS (Hydrologic Modeling System) was used to simulate the precipitation-runoff processes for the Montclair Dam watershed and the previously described contributing sub-watersheds for various rainfall events. The precipitation-runoff model was developed utilizing the SCS Curve Number and SCS unit hydrograph methods and the data discussed in Section 3.3 for determining runoff.

HEC-HMS was used for simulating the storage, overtopping, and breaching of Montclair Dam. The resulting breach hydrographs (Appendix C) were routed approximately 7.14 miles down Powell Creek to the Potomac River using HEC-RAS as described in section 4.2.

A dam breach section was developed for "sunny day," PMF, and spillway design flood (SDF) failure scenarios. The breach sections are shown in Table 4 and based on the Froehlich (2008) method using the following input parameters: selected failure depth, calculated impoundment storage volume, and the dam dimensions. We note that the "sunny day" breach scenario was initiated near the toe of the dam as a piping failure. The "sunny day" scenario was initiated with the water level at normal pool elevation of 187.0 feet. The PMF dam breach scenario was initiated as an overtopping failure. The PMF breach event was initiated at its maximum water surface elevation of 208.4 feet. The spillway design flood events were breached following the same procedures. All of the modeled breach events resulted in the near emptying of the pool and used the breach parameters shown in Table 4.

Table 4: Breach Parameters

Description	Breach Bottom Width (ft)	Breach Bottom Elevation (ft.)	Side Slopes (H:V)	Failure Time (hours)
PMF Breach	126.8	133	1:1	0.65
SDF Breach	125.5	133	1:1	0.64
Sunny Day Breach	61.0	133	0.7:1	0.40

Per the Virginia Soil and Water Conservation Board's Impounding Structure Regulations (Chapter 20), a Probable Maximum Flood (PMF) outflow for the Montclair Dam watershed was determined based on the peak flow resulting from a 6-hour, 12-hour, and 24-hour PMP event. Flows in downstream sub-watersheds were estimated based on a percentage of the 100-year peak flow. The peak flows determined during our HEC-HMS evaluation for each watershed are provided in Table 5. The HEC-HMS outputs for Montclair Dam (6-hour, 12-hour, and 24-hour) and the sub-watersheds are provided in Appendix C.

Table 4: Peak Runoff Flows (cubic-feet per second)

Dam Watershed	6-hour	12-hour	24-hour
PMF – Inflow	39507	37498	29770
PMF - Outflow	35552	34376	29511

Sub-Watersheds	6-hour	12-hour	24-hour
W100 (100-Year)	-	-	2651

4.2 HEC-RAS Analyses

The computer program HEC-RAS is used to evaluate stream network and flood surface elevations and calculate water surface profiles for varied flow in natural or man-made channels. The HEC-RAS model output includes storm water runoff totals for the different storm events, stream/river bottom elevations, water surface elevations for each event, water flow velocities, water travel times, stream flow areas and top widths of the various storm events.

Several different storm events were included in our analysis for the Montclair Dam watershed: a “sunny day” breach scenario, a PMF routed through the dam with dam failure, a PMF routed through the dam without failure, and the spillway design flood routed through the dam with and without breach. The PMF used in our HEC-RAS evaluation was based on a 6-hour PMP event (28 inches of rain) which produced the maximum outflow runoff from the Montclair Dam impoundment.

To account for contributing flow into downstream reaches of Powell Creek resulting from the downstream sub-watersheds, a uniform flow based on a percentage of the 100-year rain event peak flows shown in Table 4 was used. For our “sunny-day” model we assumed an approximate percentage of 8 percent of the 100-year peak flow to simulate a creek that is running at top of bank. For the PMF and Spillway Design Flood events an approximate percentage of 75 percent of the 100-year peak flow was used to simulate the flood event that would likely surround the dam watershed storm event.

4.3 HEC-RAS Results

A tabulated report of the HEC-RAS outputs (“sunny day” dam failure, PMF with dam failure, SDF with dam failure, and SDF without dam failure) listing water surface elevations, stream velocities, discharge amounts, top widths, and other information is provided in Appendix D for the different storm events. The results of the HEC-RAS analyses were used to determine what structures, if any, below the dam would be endangered by flood waters. We note that a convergence of one foot between the PMF with and without dam failure is not reached prior to the confluence with the Potomac River where it does finally dissipate. No further impacts were detected downstream of cross-section 2758.4.

We note that no consideration was given to the effect of debris dams at the culverts and bridges or other locations. The potentially inundated roads were indicated as inundated without this consideration.

4.4 Hazard Classification

Virginia Soil and Water Conservation Board's Impounding Structure regulations (Chapter 20) state that if the failure of the impounding structure causes a probable loss of life or serious economic damage to downstream areas, the impounding structure shall be classified as a High Hazard Potential dam. The term "probable loss of life" means that impacts that are likely to cause a loss of human life, including but not limited to impacts to residences, businesses, other occupied structures, major roadways, interstates, and primary roadways.

Based on our study of the Montclair Dam, there are three hundred and fifty-four occupied structures (nineteen of which are multi-family dwellings), three interstate bridges, and four secondary road bridges impacted by a breach event. The structures were determined to be impacted based on the depths of water during the PMF event routed through the dam with and without failure.

A summary table (developed based on readily available information) of inundated bridges and dwellings resulting from the four modeled events ("Sunny Day" dam failure, PMF with dam failure, 0.9 PMF with dam failure, and 0.9 PMF without dam failure) is provided in Appendix G.

4.5 Incremental Damage Assessment

Current dam safety regulations require that High Hazard impoundments have an emergency spillway capacity equal to at least a 0.9 PMF, unless it can be shown by an incremental damage assessment that increasing the emergency spillway to that size provides no additional protection to downstream facilities or roads. The minimum spillway design designated in the regulations for a High Hazard structure is a 100 year storm event.

Accordingly, we have evaluated the application of an incremental damage assessment for Montclair Dam. We evaluated the effects from a 100 year event up to a PMF event to determine at what point a dam break would cause damage to a structure. We found that the PMF with dam break event impacts more structures than the PMF without dam break. Therefore, based on our evaluation and the current regulations, no reduction to the spillway capacity may be allowed through an incremental damage analysis and the dam will need to have a spillway capacity equal to at least a 0.90 PMF flood event. No further incremental damage assessment is warranted nor required.

Our analysis showed that the current auxiliary spillway plus the principal spillway have the capacity to pass a 0.41 PMF event when the storm is routed through the dam. Therefore, the dam does not have the capacity to pass the spillway design flood (0.90 PMF). We note that the current spillways were used in the analysis of the "Sunny Day" with dam break, PMF with dam break, 0.90 PMF flood with dam break, and 0.90 PMF flood without dam break events. A spillway design to increase capacity will be required

5.0 INUNDATION MAPS AND PROFILES

Flood events modeled with HEC-RAS were imported into the ArcMap interface using the HEC-GeoRAS extension. Bounding polygons, water surface elevation rasters, and floodplain boundary were all generated in GIS-format based upon the HEC-RAS geometry data output from the HEC-RAS interface.

Following inundation boundary delineation mapping tasks using HEC-GeoRAS, planimetric maps were produced depicting the location of structures, roads, and other property that would be endangered should the impounding structure fail. The resulting Inundation Maps that graphically display downstream inhabited areas and structures, roads, and other pertinent structures within the identified inundation areas are provided in Appendix E. The ten foot topographic maps generated using the Digital Terrain Model (DTM) and the ArcGIS Spatial Analysis Contour Tool are also located in Appendix E.

A general profile plot illustrating the water surface elevations of the modeled breach events for the Montclair Dam study area is provided in Appendix F (General Profile Plots). Individual cross-section profiles providing a more detailed look at the water surface elevations determined from the Sunny Day and PMF with and without dam breach events at selected cross-sections are also provided in Appendix F (Cross-Section Profiles).

6.0 EMERGENCY ACTION PLAN CONSIDERATIONS

As previously noted, an Emergency Action Plan (EAP) and corresponding field reconnaissance are not included in this report. Concerning our study and the resulting inundation maps provided, we note the following items that should be considered in subsequent EAP.

Our study found three hundred and fifty-four occupied structures that will have portions inundated by water (see Appendices E, F, and G). The structural elevation was used to determine if the dwelling lies within the specified inundation zone. The structural elevation refers to the lowest adjacent corner of the structure. These structures will be noted in a subsequent EAP.

Our study indicates that the road bridges provided in Appendix G and roadways as shown in Appendix E will have portions inundated by water due to a dam failure. These bridges and roadways will be addressed accordingly in the subsequent EAP

7.0 AUXILIARY SPILLWAY STABILITY ANALYSIS

The SITES model is a software tool developed by NRCS for use on their flood control dams across the country and is accepted by VA DCR for analysis of earthen spillways in Virginia. It is most commonly used to determine stability during the Spillway Design Flood (SDF). Due to the variability of the surface within the Montclair auxiliary spillway and the limitations of the SITES software, we needed to perform several erosion models to obtain a complete SITES analysis.

The control section appears to have been originally designed to be 140 feet wide, but landscaping has been constructed that impedes the outflow down to an effective width of 100 feet. The landscaping has been in place since at least 1979 as it was shown in drawings developed by Greiner Engineering Sciences for a previous project. There is a beach area extending from the water’s edge up to and including the control section at the spillway crest with many recreational features built into it. The loose sand at the control section is of particular concern for spillway stability. Below the control section is a paved parking lot constructed across the spillway channel. The asphalt surface is another concern for spillway stability as it is susceptible to damage under flowing water. This is followed by a grass control section down the slope that reduces to a minimum width of 80 feet which then drops off a steep grade into a side channel. The severe grade change is another stability concern.

SITES is a model for predicting the erosion potential of a spillway. The spillway surface material properties are programmed into the model as is a surface profile showing the changes in slopes. Then the hydrograph for the desired storm event is modeled through the spillway showing the flow rate and depth over the storm duration. Erosion can happen within the spillway at any point along the surface profile and the upstream progression of the erosion is called headcut. Erosion in the spillway is allowed and may be significant but it is not considered a failure until the headcut crosses through the control section. Once the control section is breached the program stops. Otherwise the spillway is considered to be stable.

The SITES model is unable to model all the different surface material properties that exist in the Montclair spillway simultaneously. As mentioned previously the sand material located through the control section is of particular concern because it has no cohesive properties and erodes almost immediately under flow. Any earth directly below the sand would have no vegetative cover and would also be susceptible to erosion early in the storm. This condition alone is enough to show the spillway does not meet stability requirements and corrective measures would need to be implemented. However, this particular condition could be remedied relatively easily in the new spillway design.

We also performed simulations by treating the spillway as if it were a continuous grassed surface using the material properties determined from the core samples that were taken. For grassed spillways the erosion is usually initiated at some distance downslope where the flow velocities are greater. Greater velocity applies greater shear stresses and strips the vegetative cover exposing the natural soils to the flow. In this case we did not find an intermediate location for the initiation of erosion, erosion was initiated at the outlet end of the grassed section approximately 500 feet downstream of the control section.

Abrupt changes in slopes are also common locations for the initiation of the erosion because the shear stresses are focused at that point. In this case erosion is initiated at the end of the grassed spillway where it does drop off significantly into the deeper channel leading to the outfall stream. At this location the grassed spillway slope of approximately 5% changes to approximately 33% as it drops into the channel. SITES shows this erosion progression all the way back to the top of the spillway, but does not quite breach the control section. Since the current spillway does not have adequate capacity, this very near to failure condition will need to be checked during the subsequent design process. For example, if the additional capacity is achieved by raising the top of dam or lowering the control section thus deepening the flow, the stress from the additional flow depth may be enough to cause it to fail through the spillway.

Additionally we ran simulations for other selected storm events including the 100 year storm, the ½ PMF storm, and the PMF storm to predict the extent of erosion damage for each event. The 100 year storm did not show any significant erosion. The 0.5 PMF, 0.9 PMF, and 1.0 PMF showed significant erosion damage, but did not show failure of the spillway.

8.0 LIMITATIONS

This report has been prepared for the exclusive use of The Montclair Property Owners Association or their agent, for specific application to the Montclair Dam (Montclair, Virginia) Inundation Study, in accordance with generally accepted engineering practices. No other warranty, express or implied, is made. Our conclusions and recommendations are based on information made available to us, the data obtained during the previously described study, and generally accepted engineering practice.

F&R obtained GIS data in vector and raster format from numerous sources. F&R did not perform consistency or accuracy analysis of the data. F&R assumes that the logical consistency and vertical and horizontal accuracy of GIS data used in the preparation of maps and figures conform to GIS production "best practices."

If this inundation study is copied or transmitted to a third party, it must be copied or transmitted in its entirety, including text, attachments, and enclosures. Interpretations based on only a part of this report may not be valid.