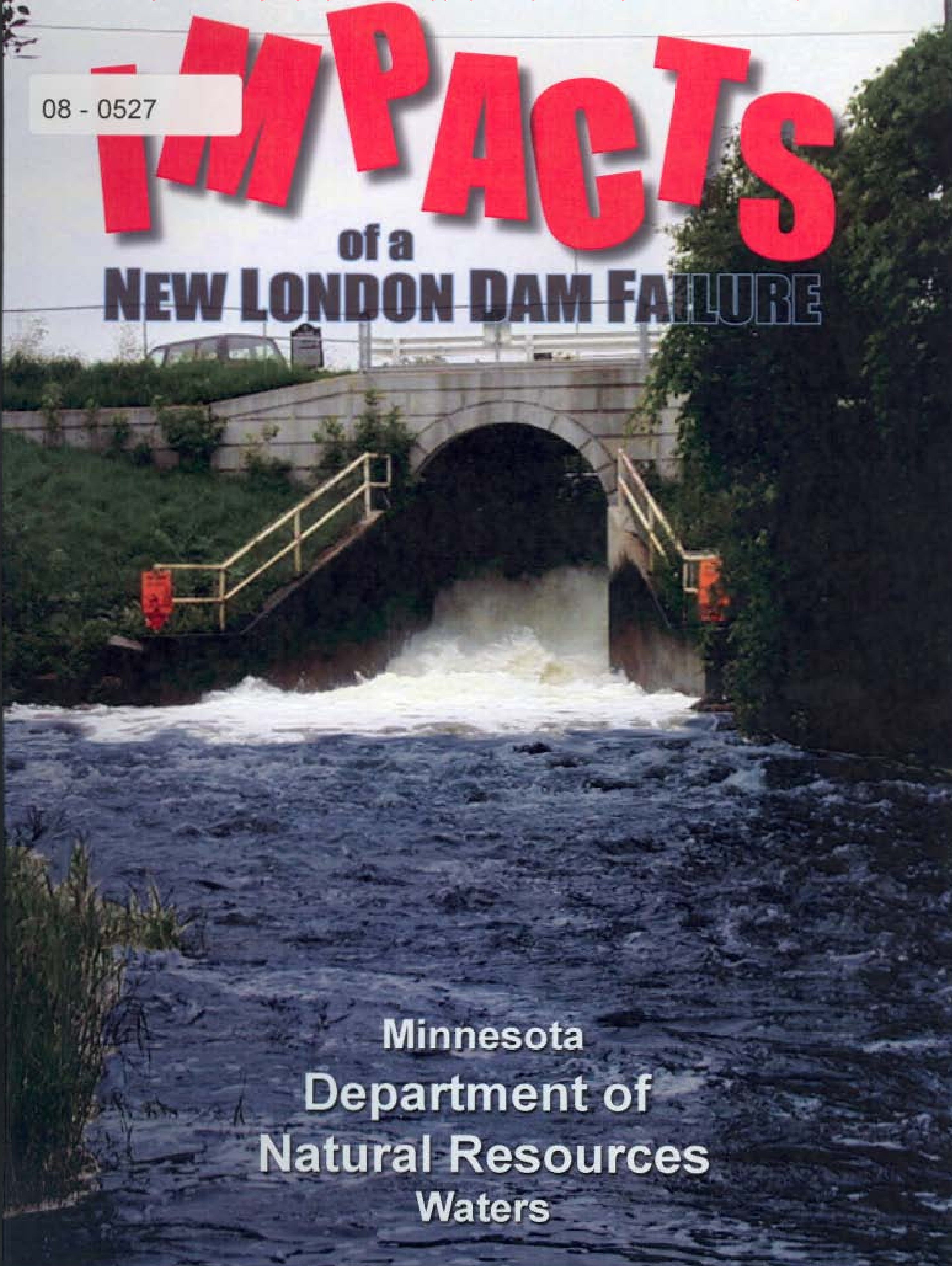
IMPACTS of a NEW LONDON DAM FAILURE



Minnesota
Department of
Natural Resources
Waters

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Impacts of a New London Dam Failure

Executive Summary

Observations

1. Failure of the New London Dam poses significant risk to anyone accidently driving into the breach area.

2. The overtopping of the roadway over the New London Dam poses significant risk to any vehicle driving on that roadway as the vehicle could be easily pushed off the roadway into deep and fast-flowing water downstream of the dam.

3. Several properties in the city of New London downstream of the Dam will be flooded by major flood events. A dam breach during those flood events will increase the depth of water in those properties. However, it appears that none of those properties are residential.

4. The spillway of the replacement dam should have the same capacity as the existing dam. Decreasing the capacity of the spillway will create additional high water problems on Lake Monongalia, while increasing the capacity of the spillway will create additional highwater problems downstream of the dam and on Nest Lake.

5. The water surface elevation for the 1% Flood Event (100-Year, 24-Hour Storm) was computed to be 1205.3 feet (NGVD-1929), with a flow of approximately 630 cfs. However, the peak flow may vary from 550 to 675 cfs while the peak water surface elevation may vary from 1204.5 to 1205.7 feet, depending on how the upper gate of the New London Dam is operated.

6. The New London Dam has the capacity to pass the 1% Flood Event (100-Year, 24-Hour Storm) using only the upper gate.

7. The Middle Fork Crow River would begin overtopping the roadway at the New London Dam at elevation 1206.7. With both gates fully open, the discharge at this elevation would be approximately 1650 cfs, or 1/3 Probable Maximum Flood.

8. At the New London Dam, the water surface elevation for the Probable Maximum Flood (PMF) was computed to be 1210.30 feet with a flow of approximately 5050 cfs, assuming normal operation of both gates. The PMF exceeded the capacity of the New London Dam, and with all gates fully open, would overtop the roadway by 3.6 feet at the lowest point on the roadway, if there were no areas of breakout flows.

9. During the Probable Maximum Flood scenario, high water levels would cause water problems at several lakeside residences. At two locations, sandbagging would be required to protect property and prevent breakout flows from the reservoir.

10. During modeled high flow events, Lake Monongalia would not respond as a large reservoir, responding instead as a group of smaller pools connected primarily in series.

11. During modeled dam breaches, the floodwave from Lake Monongalia would consist predominantly of water from the lower two pools (26.4 acres). Therefore, the initial dam breach floodwave would contain a relatively small volume of water.

12. After dam breach, the water surface elevation of the various pools comprising Lake Monongalia will stabilize at new levels varying from approximately two feet below normal on the upstream most pool, to approximately eight feet below normal at the New London Dam.

Recommendations

- When water overtops the roadway, there is a potential for a loss-of-life to any individual driving on the roadway over the New London dam by being pushed off the road and into deeper waters. Serious consideration should be given to eliminating or reducing this risk with the replacement dam.

- There is a potential for a loss-of-life due to a failure of the New London Dam to an individual driving on the roadway over the dam during failure, or driving into the breach area after the dam has collapsed. To reduce that risk, the roadway over the dam should be highly illuminated.

- The location of the New London Fire Department should be reevaluated as the building and equipment may be unavailable for use during a major flood (greater than a 1% Flood Event [100-Year, 24-Hour Storm]) and during a dam breach. The potential for a loss of life increases if an emergency response is delayed.

- There is a hydraulic constriction in the stream channel just downstream of the Fire Department. Reducing this constriction by channel modification and lowering the overbanks would increase conveyance and reduce water levels between the New London Dam and the Fire Department during flood events.

- The current New London Dam is classified as a "High Hazard Dam". The replacement dam should be designed, if possible, to meet the lower classification of "Significant Hazard".

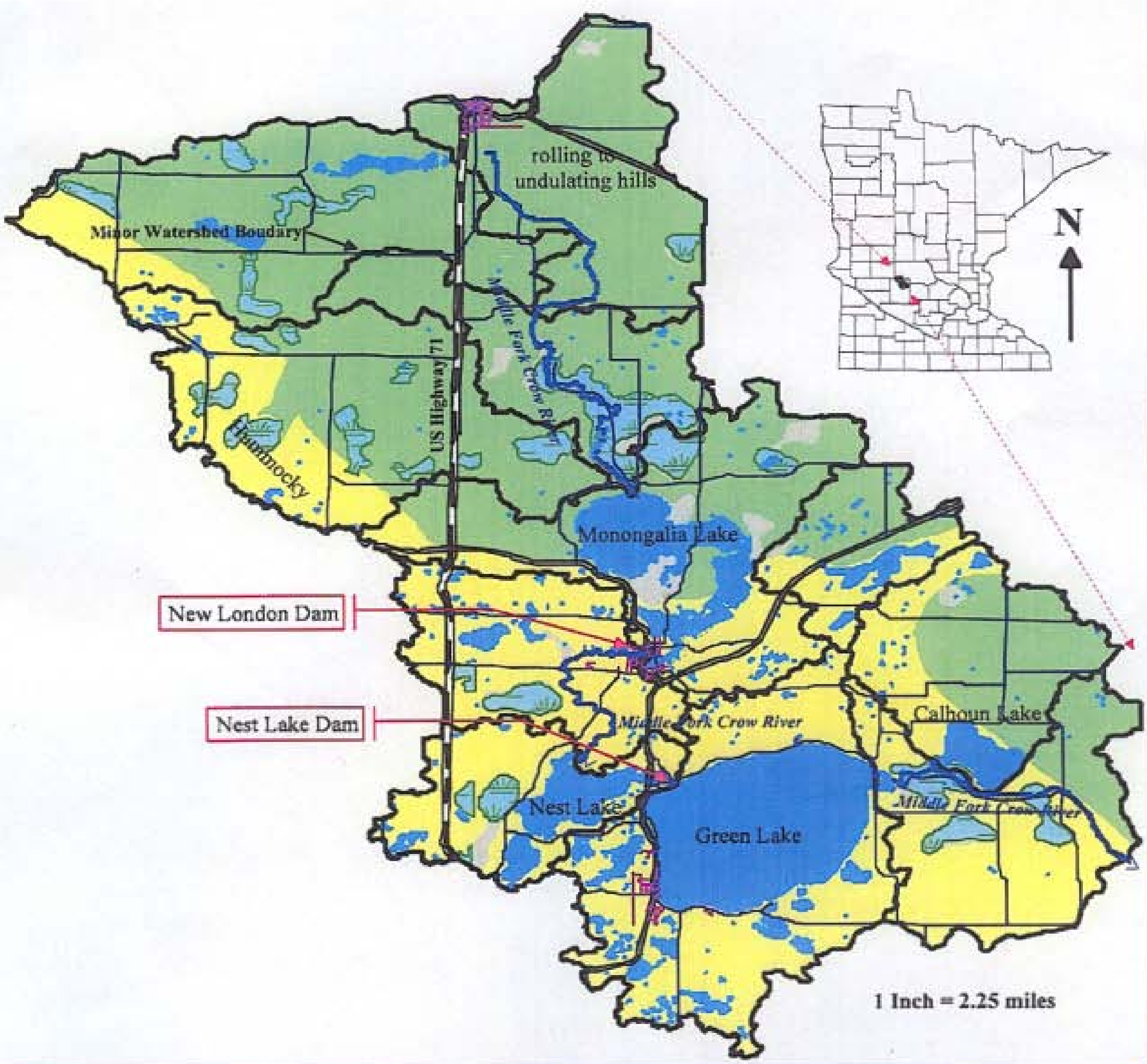
- Any proposed replacement dam should have a discharge capacity similar to the existing New London Dam. The replacement dam should also have a low-flow notch to maintain minimal flows in the channel downstream of the dam.

- With the redesign of the New London Dam, careful consideration of the impacts of the new dam on Nest Lake need to be evaluated. The new operation plan for the New London Dam must consider the manual operation of the Nest Lake Dam.

- The staff gage on the New London Dam does not accurately record the water surface elevation of high water events as the water surface elevation at the gage is impacted by the operation of the gates. This staff gage should be relocated away from the dam so as to not be impacted by the operation of the dam.

- The Emergency Action Plan (EAP) should be evaluated to verify it is current.

Figure 1 - **Drainage Area of the New London Dam and Downstream Areas Impacted by a Dam Breach**



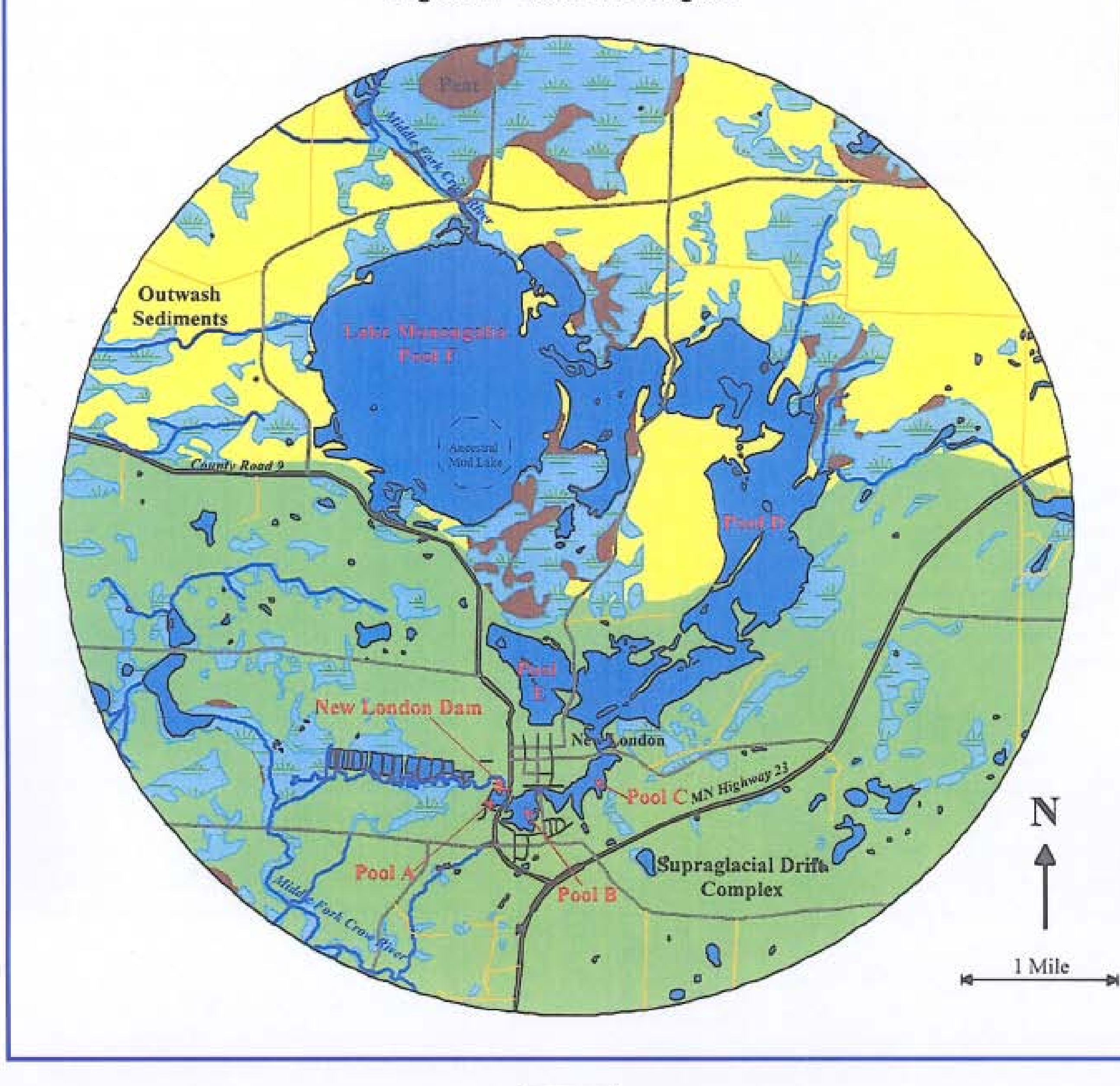
Introduction

The New London Dam is a High-Hazard[1] Dam located on the Middle Fork Crow River, in the city of New London, Minnesota. The current dam, constructed in 1958, no longer functions as designed due to problems with the gate stems. In addition, seepage is an ongoing source of concern. Due to the age and condition of the dam, a decision has been made by the owner, the Minnesota Department of Natural Resources, to rehabilitate the dam.

[1]A high-hazard dam is defined by Minnesota Rules (Minnesota Rules 6115.0340) as a dam that will likely result in the loss-of-life if the dam should fail.

The purpose of this report is twofold. First, in order to design a new dam, it is necessary to study the hydrology so that the replacement

Figure 2 - Lake Monongalia



dam has an appropriate capacity. Therefore, the Probable Maximum Flood (PMF) was computed for the Middle Fork Crow River at the New London Dam to assist in properly sizing the replacement dam. Second, due to the dam's classification as high hazard, several dam breach analyses were performed to determine the impacts on the city of New London and downstream areas if the New London Dam should fail.

Project Location and Description

The New London Dam is located on the Middle Fork Crow River in the town of New London, Kandiyohi County, Minnesota. The New London Dam forms an open water impoundment of approximately 2500 acres, or approximately 3.9 square miles. This impoundment was recently renamed Lake Monongalia (prior to December 2006, Lake Monongalia was referred to as Mud Lake). Including adjacent wetlands, this impoundment increases in size to approximately 3800 acres, or almost 6 square miles. At normal pool, Lake Monongalia has an average depth of 3.5 feet and a maximum depth of approximately 17 feet. At the New London Dam, the lake is approximately 8 feet deep. Figure 1 is a map of the project area showing the six watersheds that contribute water to Lake Monongalia and the New London Dam, and five watersheds downstream of the New London Dam. A map of Lake Monongalia and the surrounding area is shown in Figure 2.

The Middle Fork Crow River begins near the town of Belgrade in Stearns County and flows approximately 12 miles to the inlet of Lake Monongalia, and an additional 6.5 miles through Lake Monongalia to the New London Dam. Approximately 5.4 miles downstream of the New London Dam, the Middle Fork Crow River flows into Nest Lake. The Nest Lake Dam (Old Mill Dam), at the outflow of Nest Lake, is approximately 7.7 miles downstream of the New London Dam. The inlet to Green Lake is approximately 200 feet downstream of the Nest Lake Dam.

The drainage area of the Middle Fork Crow River at the New London Dam is approximately 98 square miles. Most of the drainage area is within Kandiyohi County, but a small portion of the upper reaches of the watershed extends into both Stearns and Pope Counties. Upstream of the New London Dam, six minor watersheds supply water to the Middle Fork Crow River. Four of these watersheds supply water to the river upstream of Lake Monongalia while the remaining two watersheds supply water directly to Lake Monongalia.

Topography of the project area is predominantly rolling and undulating hills resulting from the movement of the Des Moines Ice Lobe during the late Wisconsinan Glaciation (14,000 B.P.). Sediments north of Lake Monongalia are classified as predominantly glacial outwash, while sediments south of the lake are classified as Supraglacial Drift Complex. Soils are predominantly "B" type prairie soils that have a higher than average infiltration rate, and may be wet soils in parts of the project area. Localized peat deposits are common in the project area, especially north of Lake Monongalia.

Historical Information

The 1856 Public Land Survey of Kandiyohi County shows no water impoundment of the Middle Fork Crow River in the vicinity of the town of New London. Approximately 2 miles north of the current town of New London, Mud Lake was shown on that survey to be a small lake of approximately 250 acres, and is shown in Figure 2 as Ancestral Mud Lake. The area from Ancestral Mud Lake to the town of New London consisted of the Middle Fork Crow River flowing through a series of wetlands. With the building of the New London Dam, those wetlands flooded, forming the 2500 acre impoundment now referred to as Lake Monongalia.

The first New London Dam was constructed in 1861 for a mill to grind flour. That dam promptly failed. Reconstruction of the replacement dam began in 1862 and was completed in 1865. The second dam was built of granite block and mortar and had two operable gates. In 1897, a decision was made to remove the dam and restore the river to natural conditions, but that removal was stopped by legal action. By the mid-1920's the gates had become inoperable. Around 1938, ownership of the dam was transferred to the State of Minnesota in conjunction with the construction of a U.S. Fish and Wildlife Service fish hatchery downstream of the dam. In 1942, the inoperable gates were replaced by a stoplog structure to allow some manipulation of water levels. In 1958, the stoplog structure was removed from the dam and replaced by the existing system of two lift gates stacked vertically. Problems developed with the gate lift mechanisms almost immediately. Numerous repairs and modifications have been performed over the ensuing years.

Description of the New London Dam

The New London Dam consists of an earthen embankment with a concrete spillway. The concrete portion of the dam is approximately 12 feet wide by 10 feet tall and contains the gate structure and the two steel gates. Each steel gate is approximately 12 feet wide by 4 feet high and is stacked vertically. See Figure 3a. Above the two gates is a opening approximately 12 feet wide by 2.5 feet high to allow additional outflow from the dam. The roadway is above this opening.

In addition to the main dam structure, there is an 18-inch outlet culvert approximately 200 feet west of the main dam. This structure diverts water to the fish hatchery, primarily in the spring, to fill fish-rearing ponds.

Figure 3 **- New London Dam Lift-Gate Configurations**

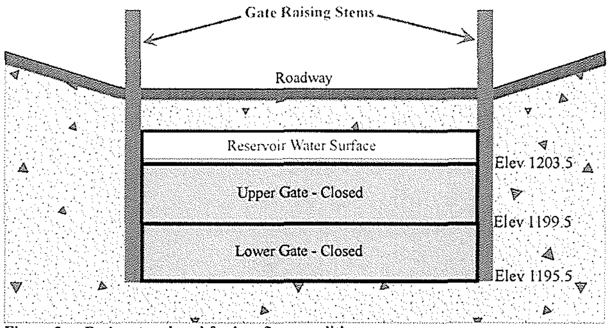


Figure 3a - Both gates closed for low flow conditions

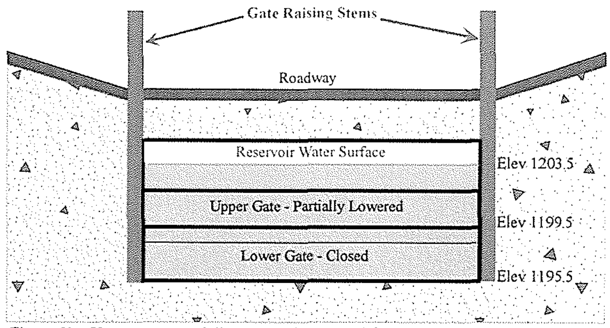


Figure 3b - Upper gate partially opened for normal flow conditions

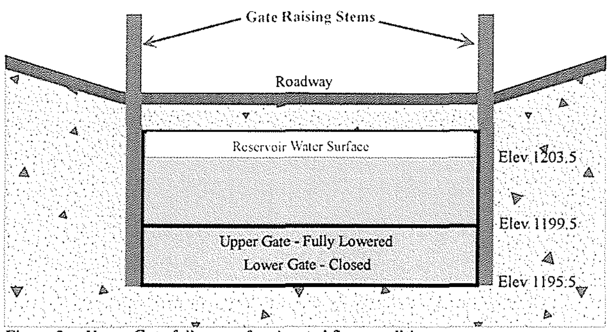


Figure 3c - Upper Gate fully open for elevated flow conditions

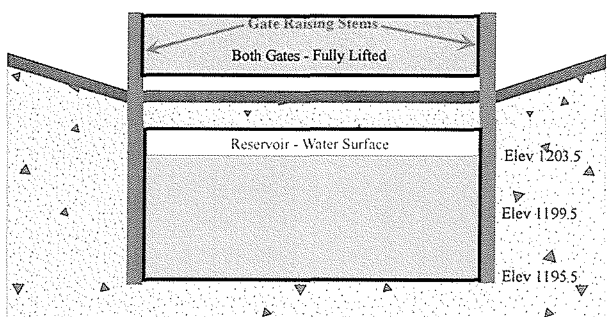


Figure 3d - Both gates opened for excessive flow conditions

Operating Procedures

The Operation, Inspection and Maintenance Plan calls for the New London Dam to be checked at least twice a week during the open water season. Upon arrival, the dam tender determines the water surface elevation from the lake gage on the side of the dam. If the water surface elevation exceeds the desired elevation of 1203.5[2] feet (NGVD, 1929), the Operation, Inspection and Maintenance Plan calls for the dam tender to lower the upper gate, thereby increasing the outflow from the dam The Operation, Inspection and Maintenance Plan calls for a maximum gate adjustment of 1 inch per hour to minimize downstream impacts. Therefore, during periods of rapidly rising water, it may be necessary to make hourly adjustments of the gate(s) over several hours to stop the rising water surface elevation.

During low-flow conditions, both gates will likely be closed. As flows increase, the upper gate will be lowered as needed to maintain a reservoir elevation of 1203.5 feet. See Figure 3b. If conditions warrant, the upper gate may be lowered to the bottom of the sill, which lowers the runout to an elevation of 1199.5 (Figure 3c).

If the upper gate is completely lowered and the water level in the reservoir continues to rise above elevation 1205.2[3] feet, the Operation, Inspection and Maintenance Plan calls for both gates to be raised until water levels stop rising or the gates are lifted completely out of the water (see Figure 3d). Currently, there is concern that the gate stems have deteriorated from age and wear, and that if the lower gate is raised, it may not be possible to lower this gate back into place. Therefore, only the upper gate is currently being used for water-level control. However, at very high water levels, attempts would be made to raise the lower gate. If the lower gate could not be lowered back into place after a high-flow event, the upper gate could be lowered to the bottom of the sill to reduce outflows from Lake Monongalia. With both gates fully lifted, the spillway has an outflow capacity of approximately 1260 cubic feet per second (cfs), or 1/4 Probable Maximum Flood. When flows exceed 1260 cfs, the excess water will cause the water surface elevation of Pool A will rise above the elevation of the gate structure. Water levels will continue to rise above the gate structure until inflows decrease. If the water surface elevation of Pool A rises above 1206.7, water will overtop the embankment rendering the road impassible.

Hydrologic Model Description (HEC-HMS)

The Probable Maximum Precipitation (PMP) was computed for the project area using procedures described in *Design of Small Dams* (1977). From that manual, the 48-hour PMP was computed to be 28.0 inches. The 28.0 inches of precipitation was then distributed over 48 hours using procedures described in that manual.

For the 1% Flood Event, a precipitation value of 5.8 inches was obtained from the National Weather Service's Technical Paper 40 (1961). As this 5.8 inches is representative of a 10-square mile storm, the depth of precipitation was reduced 6.8% to 5.4 inches for a 98-square mile storm using procedures described in the *Hydrology Guide for Minnesota* (1981). This 5.4 inches of precipitation was then distributed over 24 hours following the distribution of a Soil Conservation Service[4] Type II storm.

A precipitation runoff model of the project area was then created using the U.S. Army Corps of Engineers program HEC-HMS (Hydrologic Engineering Center - Hydrologic Modeling System). The purpose of the HMS model is to determine the volume of water running off the land from the respective storms and the shape of the runoff hydrographs for each of the minor watersheds.

[2] All elevations in this report are assumed to be in the National Geodetic Vertical Datum (NGVD) datum plane of 1929.

[3] The water surface elevation gage for Lake Momongalia is located on the New London Dam. It has been observed that during high water events, the water surface elevations recorded on the lake gage are lower than the actual water surface elevation of Pool A due to the drawdown effects of the spillway and the size of the gate openings.

[4] The Soil Conservation Service has been renamed the Natural Resources Conservation Service (NRCS).

Two HMS models were created to compute stormwater runoff in the project area and the associated minor watersheds. The first HMS model was used to compute the Probable Maximum Flood while the second HMS model was used to compute the runoff from the 1% Flood Event (100-Year, 24-Hour Storm).[5] Both models were set to begin computation at a simulation time of July 1 with precipitation beginning on July 2. Starting the models 24 hours before the precipitation events allowed the models to stabilize in the established baseflow conditions.

At some locations, the six minor watersheds in the project area were further subdivided into subwatersheds. Minor watersheds or subwatersheds that contained large lakes, such as Monongalia, Nest or Green, were further reduced into smaller watersheds so that direct precipitation on these large lakes could be computed with no losses. Watersheds were further analyzed to determine the contributing and noncontributing drainage area. The drainage areas of the watersheds in the two models are slightly different because several areas that were determined to be noncontributing during the 1% Flood Event were assumed to contribute water to the Middle Fork Crow River during the Probable Maximum Flood.

The Initial and Constant Loss method was used in HEC-HMS to determine the volume of water infiltrating the soil and the volume of water running off the land. Normally, the initial infiltration is assumed to be 10% to 20% of the total precipitation. For the 100-Year, 24-Hour Precipitation Event, the initial loss was set at 15% of 5.4 inches, or 0.81 inches. For the PMP, the initial loss was set at 10%, or 2.8 inches. Using the lower value of 10% for the PMP computed a greater runoff than using an average value of 15%. The lower value was used to compute a maximum expected runoff for the Probable Maximum Flood.

The constant loss is determined by the soil type. In the project area, soils are predominantly "B" type prairie soils, which have an infiltration rate of 0.15 to 0.30 inches per hour. For the 100-Year, 24-Hour Precipitation Event, an average value of 0.225 inches per hour was used for the constant infiltration rate. For the PMP, the lower value of 0.15 inches per hour was chosen to compute the highest likely runoff from the land. The time of concentration was computed for each minor watershed. The time of concentration from the furthest most upstream point in the project area to the New London Dam was computed to be approximately 52 hours.

[5]The 1% Flood Event is computed from the 100-Year, 24-Hour Precipitation Event, and will often be referred to as simply the 1% Flood Event. No other time duration was used in this report for the 1% Flood Event.

Information that was not incorporated into the HMS models included baseflow values, evaporation and transpiration losses, the influence of groundwater, vegetation and other parameters.

After runoff hydrographs were computed for each of the minor watersheds, subwatersheds, and lakes in the project area, the resulting hydrographs were imported into the U.S. Army Corps of Engineers River Analysis Program HEC-RAS (Hydraulic Engineering Center - River Analysis System) to perform hydraulic routing of the water through the Middle Fork Crow River in the project area.

Hydraulic Model Description (HEC-RAS)

Three HEC-RAS models of the project area were created to model the Probable Maximum Flood, the 1% Flood Event and the Sunny Day Dam Breach scenarios. The HEC-RAS models are of the Middle Fork Crow River from its source near Belgrade and extending approximately 34 miles downstream through Lake Monongalia, Nest Lake and Green Lake, to a point approximately 3 miles downstream of the outlet of Green Lake. Cross sections of the river were interpolated from United States Geological Survey (USGS) 7.5-minute quadrangle topographic maps and entered into the model. Actual cross sections and bridge information were obtained from bridge plans supplied by the Minnesota Department of Transportation, Kandiyohi County and Stearns County.

The many tributary streams and ditches that merge into the Middle Fork Crow River and Lake Monongalia were represented by lateral hydrographs. Many of the larger wetland complexes in the project area were incorporated into the model as storage areas. These areas store water during high flow events and release water back into the river as the river stage falls. Storage area was determined by digitizing the estimated area and depths from quadrangle topographic maps. The storage areas were connected to the Middle Fork Crow River using lateral weirs. The size and shape of the lateral weirs were interpolated from the quadrangle topographic maps.

The gates in the New London Dam are manually operated. To simulate the manual operation of the gates during the 1% Flood Event, the upper gate was lowered (opened) at a rate of 0.085 feet (1.02 inch) per hour during rising lake levels. During the Probable Maximum Flood, the upper gate was rapidly lowered to the fully open position while the lower gate remained closed until the water surface elevation exceeded 1205.20. As the water surface elevation exceeded 1205.20, both gates were raised out of the water and water passed freely though the dam. It was assumed that during the Probable Maximum Flood, it is more important to reduce water levels than to follow the Operation, Inspection and Maintenance Plan. During the Sunny Day scenario, no gate adjustments are made.

In addition, the type of gates available in HEC-RAS does not include lift gates like those at the New London Dam. The lower lift gate at the New London Dam behaves like a sluice gate while the upper gate, when lowered, operates in a manner opposite a sluice gate. As a rating curve exists for the upper gate based on field measurements, the weir coefficient of the upper gate was adjusted so that discharges from the dam when the upper gate is lowered matched the discharges on the measured rating curve.

Dam Breach

Upon completion of computing the Probable Maximum Flood and the 1% Flood Event, the models were modified to perform a dam breach analysis at the peak of the respective flood scenario events. To simulate worst case conditions, a fast breach time of 15 minutes was used. A slower breach time would result in a smaller dam breach floodwave. The breach depth was set at elevation 1194.00 feet, which is the approximate elevation of the base of the concrete gate structure. The breach elevation of 1194.00 is approximately 2 feet lower than the bottom elevation of Pool A, yet approximately 10 feet higher than the tailwater of the dam. Erosion will eventually cut a channel through the lake and embankment sediments, lowering the runout after dam breach to well below 1194.00, but it is assumed that this erosion occurs after the peak of the dam breach floodwave has passed.

Table 1 shows the breach parameters used for the Probable Maximum Flood, the 1% Flood

Table 1. Dam Breach Parameters - New London Dam

	Sunny Day	1% Flood Event - 100-Year, 24-Hour	Probable Maximum Flood (PMF)
Type of Failure	Piping	Piping	Overtopping
Water Surface Elevation	1203.50	1205.30	1210.3
Bottom Elevation	1194.00	1194.00	1194.00
Average Breach Width	33.25	39.55	57.02
Bottom Breach Width	26.125	32.31	44.80
Side Slopes	0.75	0.75	0.75
Time to Full Breach	15 minutes	15 minutes	15 minutes

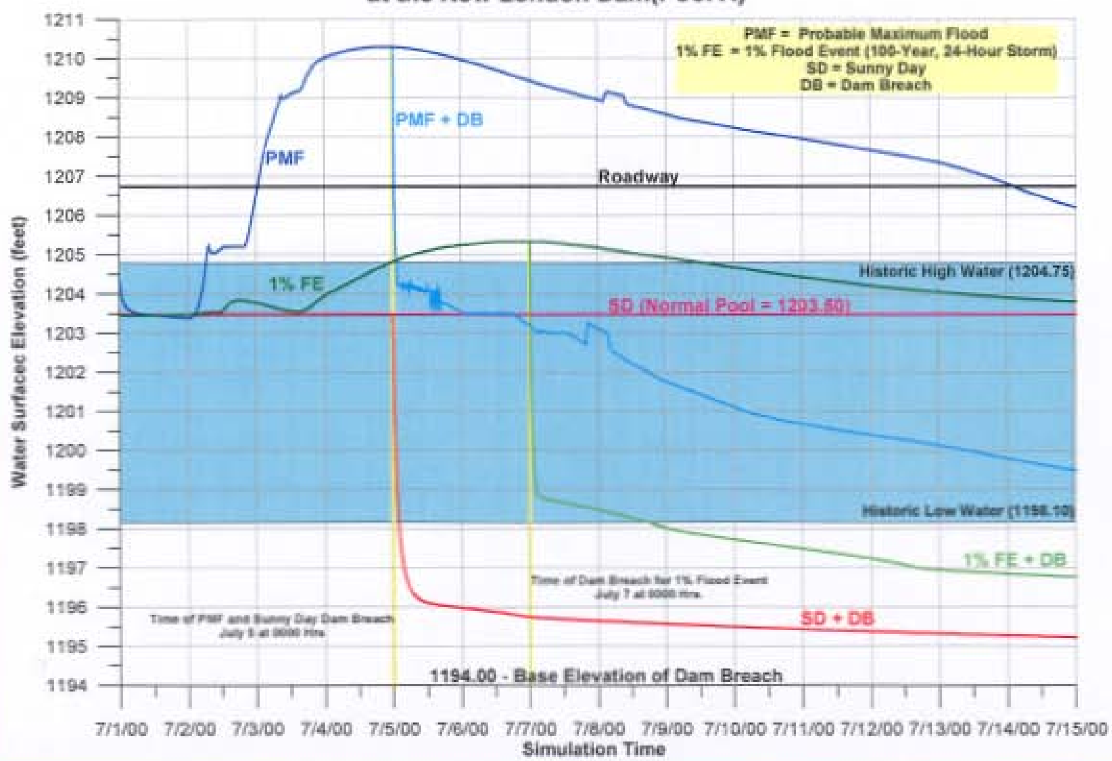
Event, and the Sunny Day Dam Breach. The water surface elevation listed is the maximum water surface elevation of the reservoir prior to dam breach. An average breach width of 3.5 times the breach height was determined by subtracting 1194.00 from the peak water surface elevation.

Research on dam breaches has shown that the sideslopes of a breached dam vary from near vertical (90 degrees) for highly compacted dams constructed with cohesive soils, to approximately 45 degrees (1 foot horizontal to 1 foot vertical) for poorly compacted dams, dams containing large amount of clay, and dams constructed of noncohesive soils. For the New London Dam, it is assumed that the embankment is well compacted, cohesive, and lacks a large volume of clay. Those assumptions dictate near vertical sideslopes for the models. However, shallower sideslopes of 0.75 foot horizontal to 1 foot vertical were chosen to represent worst case conditions.

Two different types of dam failures were modeled. The Sunny Day scenario and the 1% Flood Event were modeled as piping failures. Piping failures occur when water flows through voids in the embankment, eventually leading to the collapse of the embankment. For the Probable Maximum Flood, an overtopping failure was modeled. An overtopping failure is a result of water flowing over the top of the dam and eroding or scouring the downstream face of the dam. For the New London Dam, the overtopping failure during the Probable Maximum Flood is assumed to occur when the water surface in the reservoir reaches maximum elevation. The dam will not be overtopped during the Sunny Day or 1% Flood Event.

Figure 4 shows the computed water surface elevations of Lake Monongalia at the New London Dam for the Probable Maximum Flood, the 1% Flood Event and the Sunny Day scenarios.

Figure 4 **- Lake Monongalia Water Surface Elevations at the New London Dam(Pool A)**



Also shown on Figure 4 are the computed water surface elevations of Pool A at the New London Dam following dam breach. For the Probable Maximum Flood and the Sunny Day scenarios, the simulated dam breach occurred at 0000 hours on 7/5/00. This was a randomly chosen simulation time. For the 1% Flood Event, the simulated dam breach occurred at 0000 hours on 7/7/00. The dam breach was delayed an additional two days for the 1% Flood Event as the water surface elevation of Pool A did not reach a maximum value as quickly as during the Probable Maximum Flood. During the Probable Maximum Precipitation, the 28 inches of precipitation falling directly on Lake Monongalia and the nearby land areas results in a rapid rise in the water surface elevation. Water falling on the upland portions of the watersheds arrives after the initial precipitation and is distributed over a longer time interval. For the 1% Flood Event, the initial precipitation falling on or adjacent to Lake Monongalia can be easily passed through the New London Dam, but the later arriving water from the upstream portions of the watersheds causes the water surface elevation to rise.

It was assumed that the bridges upstream of the New London Dam would not fail. Bridge failure is possible due to the increased water levels and flow velocities at the bridges, especially after dam breach. However, it was assumed that bridge failure, if it did occur, would occur after dam breach, and that the peak water surface elevation due to any bridge failure will be less than the peak water surface elevation from the original dam breach floodwave. Failure of an upstream bridge prior to dam breach may also partially block the channel, thereby reducing outflows from the dam breach.

The geometry of the bridges incorporated into the HEC-RAS models is based on surveyed bridge plans. Replacing an existing bridge with a new bridge will cause slight changes in the modeled results. Replacing a bridge upstream on the New London Dam with a bridge with more conveyance may result in a slightly large dam breach floodwave.

Model Results - Probable Maximum Flood

After construction of the HEC-RAS models, one model was run to compute the maximum water surface elevation and discharge at the New London Dam for the Probable Maximum Flood. That model computed a maximum water surface elevation of 1210.30 feet and a maximum discharge of approximately 5050 cfs at the New London Dam.

Probable Maximum Flood: Both Gates Fully Open

1 PMF:	5050 cfs	≈	1210.3 feet
3/4 PMF:	3790 cfs	≈	1209.5 feet
1/2 PMF:	2525 cfs	≈	1208.5 feet
1/3 PMF:	1650 cfs	≈	1206.7 feet (Top of Dam)
1/4 PMF:	1260 cfs	≈	1204.5 feet

Due to concerns about the condition of the gate stems and potential problems with the lower gate, the model was also run simulating the lower gate as inoperable and jammed in place. In this scenario, the maximum water surface elevation was computed to be 1210.80 feet with a maximum discharge of approximately 5100 cfs.

Probable Maximum Flood: Lower Gate Inoperable

5100 cfs ≈ 1210.8 feet

During the Probable Maximum Flood, water will overtop the dam and roadway. Two additional areas have been identified where water will potentially break out from Pools A and B and bypass the New London Dam. These areas are shown on Figure 5. Both of these potential break outs are in residential areas. The assumption was made that these areas would be protected with sandbags during the Probable Maximum Flood, and that breakout flows will be prevented.


Figure 5
New London
PMF Inundation Map
PMF + Dam Breach
Middle Fork Crow River
New London Dam
Lake Monongalia
WSEL = 1210.3
Breakout Flows
Breakout Flows
Breakout Flows
0
0.5 Miles
N
E
S
W

A common parameter used in studying overtopping failures is when the water surface elevation exceeds the top of the dam by 1 foot. For the New London Dam, the minimum elevation of the roadway was surveyed to be 1206.70 feet. Therefore, the 1 foot level corresponds to an elevation of 1207.70. From the HEC-RAS model, with both gates being operable and fully open, the discharge was computed to the top of the road deck to be approximately 1650 cfs, or 1/3 Probable Maximum Flood. For a depth of 1 foot over the roadway, the discharge was computed to be approximately 1900 cfs. The time from the beginning of roadway overtopping to a water depth of 1 foot over the roadway was computed to be just under 2 hours and 30 minutes.

Roadway Overtopped by 1 foot of Water (PMF)

	Road Deck	**+1 Foot**
Stage:	1206.70	1207.70
Flow:	1650 cfs	1900 cfs
Time:		2 Hrs 30 Min.

Figure 5 is an inundation map for the city of New London. Upstream of the New London Dam, Figure 5 shows the areas that would be inundated by the Probable Maximum Flood. Downstream of the New London Dam, Figure 5 shows the approximate areas of inundation due to the Probable Maximum Flood with Dam breach. Downstream of the New London Dam, the Dam breach floodwave will rapidly dissipate into the Probable Maximum Flood, going from a maximum height of approximately 3 feet at the base of the dam to less than 1 foot by the time the floodwave reaches the fish hatchery. Therefore, analysis of the impacts of a dam breach during the PMF was not taken further downstream through the fish hatchery.

During the Probable Maximum Flood, all bridges over Lake Monongalia will be overtopped except the Main Street Bridge (County Road 9). At the Main Street Bridge, water will approach, but not reach the elevation of the road deck.

Table 2 shows the surveyed elevation of properties downstream of the New London Dam. This table includes the location of the properties (addresses), the surveyed elevation of the first floor, and the expected water surface elevations (WSEL) at the respective property due to the Probable Maximum Flood and the Probable Maximum Flood with Dam breach. The duration of flooding was determined by how long the elevation of the floodwave exceeded the first floor elevation at the given location. The height of the Dam breach floodwave is the difference in the water surface elevation between the Probable Maximum Flood and the Probable Maximum Flood with Dam breach. The parameters shown in Table 2 are also shown in Table 3 and Table 4 for the 1% Flood Event and the Sunny Day scenarios, respectively.

Table 2 shows that flooding due to the Probable Maximum Flood will affect eight buildings in the city of New London downstream of the New London Dam. No additional buildings will be flooded with a Dam breach, though the water surface elevations and depth of water in those eight buildings will be greater than the Probable Maximum Flood alone. It is believed that none of the properties flooded by the Probable Maximum Flood or the Probable Maximum Flood with Dam breach are residential. However, one of the properties that will experience the worst flooding is the Fire Department. Upstream of the New London Dam, the Probable Maximum Flood will cause flooding and high water problems on many properties on Lake Monongalia.

Other impacts not shown in Table 2 include road flooding. Downstream of the New London Dam, water from the Probable Maximum Flood and Probable Maximum Flood with Dam breach will overtop both the County Road 40 and the County Road 9 Bridges, as well as the township bridge downstream of County Road 9. The Probable Maximum Flood and the Probable Maximum Flood with Dam breach will also overtop the roadway at the Nest Lake Dam. Even with all stoplogs removed from that dam, the Nest Lake

Table 2. Probable Maximum Flood and Probable Maximum Flood with Dam Breach

Inundation Depths in Downstream Properties

		Probable Maximum Flood			Probable Maximum Flood with Dam Breach			
Address	**1st Floor Elev.**	**WSEL (ft.)**	**Depth (ft.)**	**Duration HR:MN**	**WSEL (ft.)**	**Depth (ft.)**	**Duration HR:MN**	**Height of DB Floodwave (ft.)**
Garage at Alley 14 Main St	1195.81	1196.33	0.52	56:11	1199.17	3.36	59:36	+2.84
Building Basement 24 Main St	1195.35	1196.17	0.82	70:25	1198.99	3.64	72.51	+2.82
Pottery Shop 17 Central Ave	1193.06	1195.97	2.91	8+ Days	1198.70	5.64	9+ Days	+2.73
Garage	1190.75	1195.97	5.22	8+ Days	1198.70	7.95	9+ Days	+2.73
Fire Department	1191.31	1195.32	4.01	8+ Days	1197.79	6.48	9+ Days	+2.47
Telecom Building 24 Central Ave	1194.01	1194.13	0.12	32:02	1195.39	1.38	37.58	+1.26
Banner Oak 98 Central Ave	1193.30	1194.05	0.75	81:14	1195.18	1.88	82.09	+1.13
Construction Co 102 Central Ave	1192.64	1194.02	1.38	118:04	1195.11	2.47	119:06	+1.09
Residence 108 Central Ave	1200.69	1193.90	---	---	1194.77	---	---	+0.87
Residence 112 Central Ave	1197.63	1193.84	---	---	1194.61	---	---	+0.77
Residence 118 Central Ave	1199.01	1193.75	---	---	1194.36	---	---	+0.61

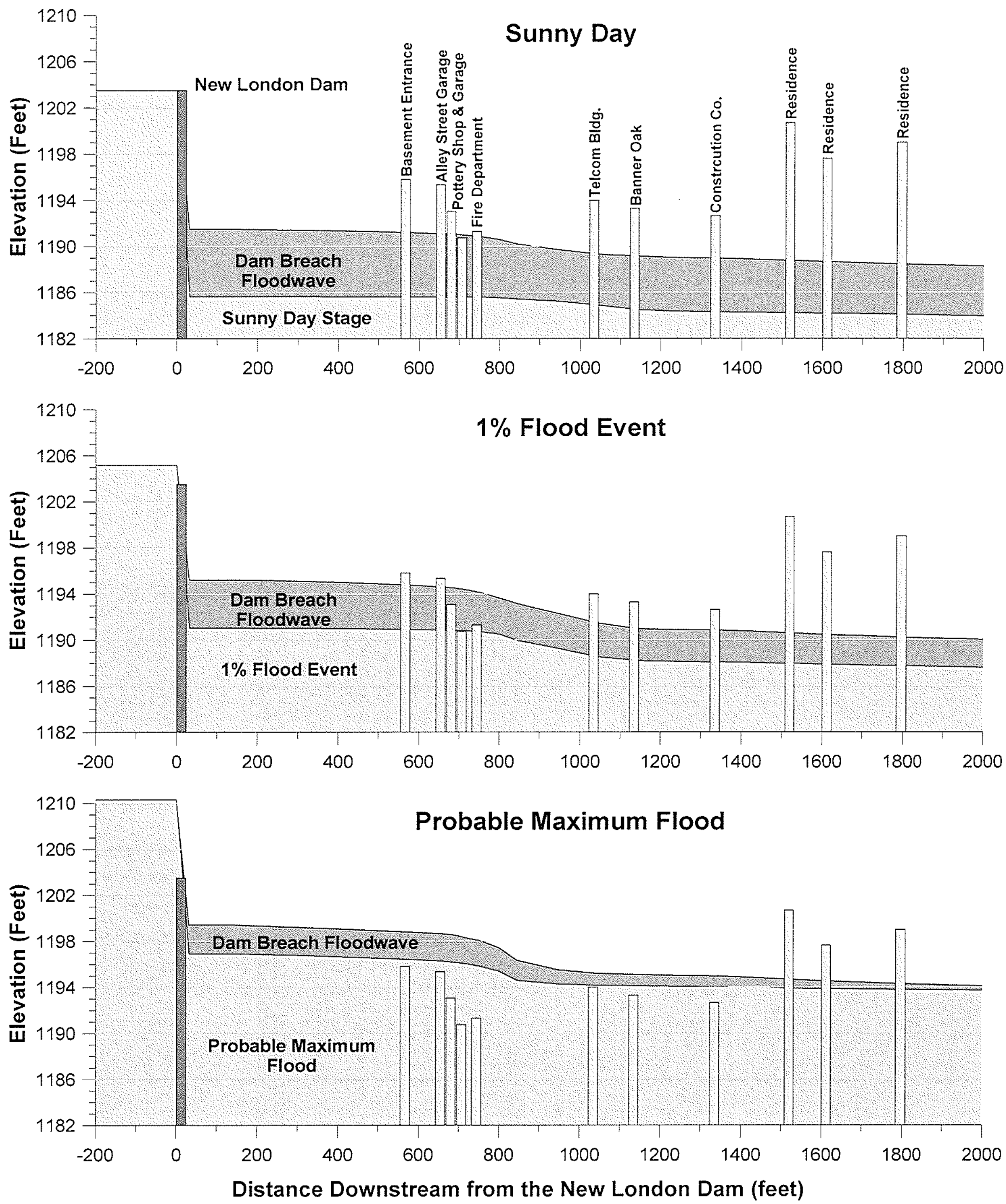
Dam has insufficient capacity to pass the Probable Maximum Flood. Considering the poor condition of the tailrace below the Nest Lake Dam spillway, the overtopping of the Nest Lake Dam may lead to failure of that spillway and ultimately the Nest Lake Dam.

Probable Maximum Flood and the Probable Maximum Flood with Dam breach will also overtop the roadway at the Nest Lake Dam. Even with all stoplogs removed from that dam, the Nest Lake Dam has insufficient capacity to pass the Probable Maximum Flood. Considering the poor condition of the tailrace below the Nest Lake Dam spillway, the overtopping of the Nest Lake Dam may lead to failure of that spillway and ultimately the Nest Lake Dam.

The tabular data shown in Table 2 is shown graphically in Figure 6c. Figure 6 shows a profile of the Middle Fork Crow River extending from approximately 200 feet upstream of the New London Dam, to the approximately 2000 feet downstream of the dam, which is near the corporate limit of the city. Figure 6 includes the computed water surface elevations for the various flood

Figure 6

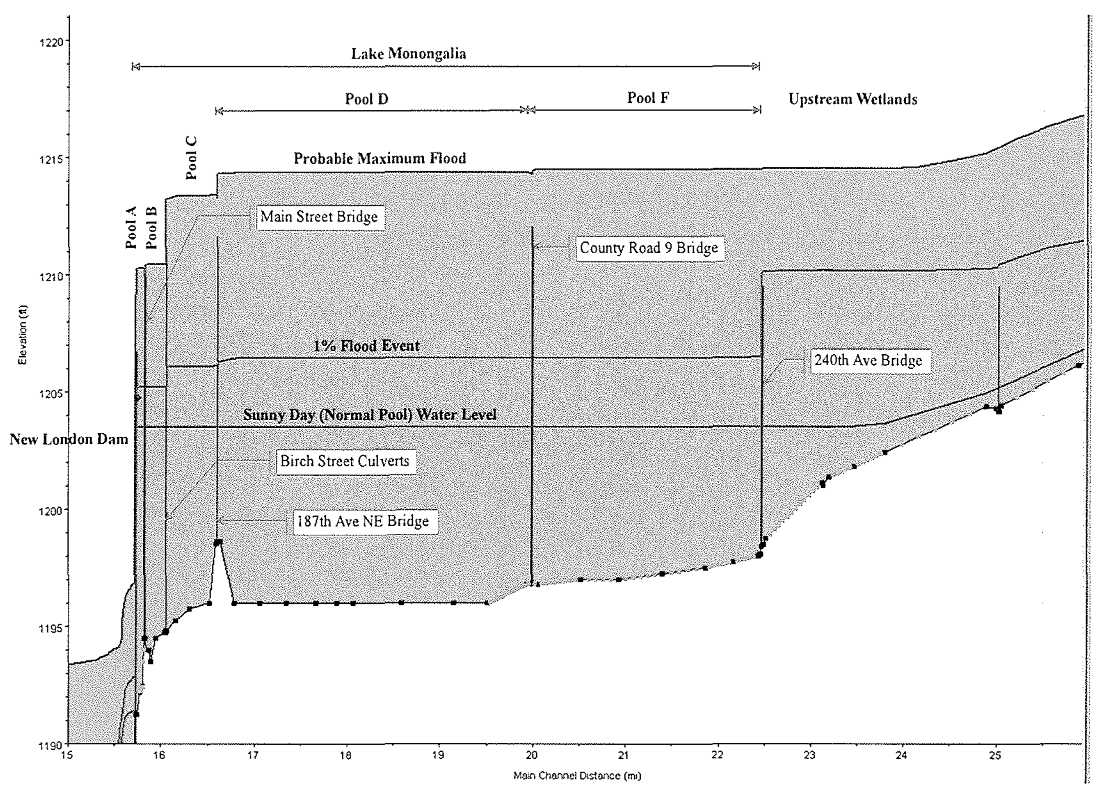
Water Surface Elevations of the Middle Fork Crow River from New London Dam downstream 2000 feet for the three scenarios



scenarios, the computed water surface elevations due to a dam breach, the approximate location of properties downstream of the dam, and elevation of the first floor of those properties.

Figure 7 shows the profile of the Middle Fork Crow River from just upstream of Lake Monongalia, through the lake to just downstream of the New London Dam. Included in Figure 7 are the calculated water surface elevations for the Probable Maximum Flood, the 1% Flood Event, and the Sunny Day scenarios. One of the surprising results observed in the Probable Maximum Flood model was the variation in water surface elevations in the different segments or pools that constitute Lake Monongalia. Note the bridges and the changes in water surface elevations associated with the different pools between the bridges. Normally, on a lake with a river flowing through it, there is a very slight decrease in the water surface elevation from where the river enters the lake to where the river exits the lake. During dry or low-flow conditions, the lake is essentially flat. This is also true of Lake Monongalia. However, during the Probable Maximum Flood, the model indicates that the difference in the water surface elevation from the upstream end of the lake to the dam would be more than 4 feet. This effect can also be seen during the 1% Flood Event, though in that scenario, the change in the water surface elevation would be less than 1 foot. It was found during modeling that, in most cases, the water surface elevation in each of the pools that constitute the lake would be controlled by the hydraulics of the nearest downstream bridge. The only exception was the Main Street Bridge (old U.S. Highway 71 bridge), which has sufficient capacity so that hydraulic control in Pool B is provided by the New London Dam.

***Figure 7.* Computed Lake Monongalia Water Surface Elevations**
Probable Maximum Flood, 1% Flood Event and Sunny Day



A similar effect can also be seen on Nest Lake where a stepped water surface elevation can be seen at several bridge crossings during the Probable Maximum Flood. As the Middle Fork Crow River flows through Nest Lake, the lake constricts as the river approaches a bicycle trail bridge (former railroad bridge), the Minnesota Highway 23 bridge, and then the Nest Lake Dam. During the Probable Maximum Flood, the model indicates that the water surface elevation where the Middle Fork Crow River enters Nest Lake is approximately 1-3/4 feet higher than at the Nest Lake Dam. For the 1% Flood Event, the difference in water surface elevation is approximately 1 inch. All Nest Lake water surface elevations used in this report are at the Nest Lake Dam.

Model Results - 1% Flood Event (100-Year, 24-Hour Storm)

A second HEC-RAS model was created using output from the HMS model for the 1% Flood Event. In this scenario, gates were adjusted in accordance with the procedures described in the Operation, Inspection and Maintenance Plan. That plan calls for the gates to be opened in increments of one inch per hour as the water surface elevation of the reservoir rises from 1203.50 feet. For the 1% Flood Event, this adjustment rate of one inch per hour resulted in three adjustments in the first nine hours, and then hourly adjustments for 41 consecutive hours to move the upper gate to the fully open position. This gate operation resulted in a computed discharge of approximately 630 cfs and a computed water surface elevation of 1205.30 feet. In this scenario, the lower gate was not opened even though the Operation, Inspection and Maintenance Plan calls for the opening of the lower gate once the water surface elevation exceeds 1205.20 feet. The Operation, Inspection and Maintenance Plan for the New London Dam (Ayres, 1990) lists the water surface elevation of the 1% Flood Event as 1205.2 feet, with a discharge of 550 cfs.

As the New London Dam has manually operable gates, computing an exact water surface elevation and discharge for the 1% Flood Event is difficult as it is possible to exchange discharge for water surface elevation. Therefore, the model was run several times with different gate settings. For example, recognizing that a 100-Year, 24-Hour Precipitation Event is occurring, the dam tender could preemptively move the upper gate to the fully open position. This preemptive action would reduce the discharge of the 1% Flood Event to 550 cfs with a maximum water surface elevation of 1204.50. Conversely, a delayed response, such as allowing the reservoir to rise to an elevation of 1204.00 before making a gate adjustment, would allow the water surface elevation of the reservoir to rise to approximately 1205.7 feet, with a discharge of approximately 675 cfs.

A maximum water surface elevation of 1204.75 was recorded at the New London Dam on September 18, 1991. Surveyed elevations greater than 1204.75 have been recorded at other locations on Lake Monongalia on several occasions, including a maximum value of 1205.42 on September 20, 1991.

1% Flood Event at the New London Dam

630 cfs ≈ 1205.3 feet	Normal Gate Operations
550 cfs ≈ 1204.5 feet	Preemptive Gate Operations
675 cfs ≈ 1205.7 feet	Delayed Gate Operations

Table 3 shows the computed water surface elevation at 11 buildings downstream of the New London Dam for the 1% Flood Event and the 1% Flood Event with Dam breach. From the calculated water surface elevation and property elevation, the expected depth and duration of flooding was computed as a result of the Dam breach floodwave. The height of the Dam breach floodwave, which is the difference in water surface elevation between the 1% Flood Event and the 1% Flood Event with Dam breach, is also shown. The data shown in Table 3 is also shown graphically in Figure 6b.

Table 3 shows that only one building, the Pottery Shop garage, would be slightly impacted by the 1% Flood Event. However, with Dam breach, flooding would be expected in three properties, with a duration of flooding of less than 90 minutes for two of the properties and approximately three days for the third property. The reason for the three days of flooding at the Pottery Shop garage is that the 1% Flood Event exceeds the elevation of the garage for almost 2 days, and when combined with the water from the dam breach, the elevation of the garage floor is exceeded for a third day. For the other two properties, the

Table 3. 1% Flood Event and 1% Flood Event with Dam Breach Inundation Depths in Downstream Properties

		1% Flood Event		1% Flood Event with Dam Breach			
Address	**1st Floor Elev.**	**WSEL (ft.)**	**Depth (ft.)**	**WSEL (ft.)**	**Depth (ft.)**	**Duration HR:MN**	**Height of DB Floodwave (ft.)**
Garage at Alley 14 Main St	1195.81	1190.90	---	1194.57	---	---	3.67
Building Basement 24 Main St	1195.35	1190.84	---	1194.41	---	---	3.57
Pottery Shop 17 Central Ave	1193.06	1190.78	---	1194.24	1.18	0:30	3.46
Garage	1190.75	1190.78	0.03	1194.24	3.49	3+ Days	3.46
Fire Department	1191.31	1190.50	---	1193.60	2.29	1:21	3.10
Telecom Building 24 Central Ave	1194.01	1188.42	---	1191.12	---	---	2.70
Banner Oak 98 Central Ave	1193.30	1188.28	---	1190.98	---	---	2.70
Construction Co 102 Central Ave	1192.64	1188.09	---	1190.83	---	---	2.70
Residence 108 Central Ave	1200.69	1187.94	---	1190.57	---	---	2.63
Residence 112 Central Ave	1197.63	1187.88	---	1190.45	---	---	2.57
Residence 118 Central Ave	1199.01	1187.74	---	1190.22	---	---	2.48

Pottery Shop and the Fire Department, the floodwave would quickly pass through the area, resulting in the water surface elevation dropping below the floor elevation in 30 minutes and 81 minutes, respectively. The County Road 9 bridge southwest of New London would be the only bridge overtopped by the combined 1% Flood Event and the dam breach floodwave.

Table 4. Sunny Day and Sunny Day with Dam Breach Inundation Depths in Downstream Properties

		Sunny Day		Sunny Day with Dam Breach			
Address	**1st Floor Elev.**	**WSEL (ft.)**	**Depth (ft.)**	**WSEL (ft.)**	**Depth (ft.)**	**Duration HR:MN**	**Height of DB Floodwave (ft.)**
Garage at Alley 14 Main St	1195.81	1185.59	---	1192.45	---	---	6.86
Building Basement 24 Main St	1195.35	1185.58	---	1192.28	---	---	6.70
Pottery Shop 17 Central Ave	1193.06	1185.57	---	1192.13	---	---	6.56
Garage	1190.75	1185.57	---	1192.13	1.38	1:00	6.56
Fire Department	1191.31	1185.50	---	1191.58	0.27	0:13	6.08
Telecom Building 24 Central Ave	1194.01	1184.68	---	1189.95	---	---	5.27
Banner Oak 98 Central Ave	1193.30	1184.54	---	1189.83	---	---	5.29
Construction Co 102 Central Ave	1192.64	1184.27	---	1189.59	---	---	5.32
Residence 108 Central Ave	1200.69	1184.25	---	1189.57	---	---	5.32
Residence 112 Central Ave	1197.63	1184.17	---	1189.25	---	---	5.08
Residence 118 Central Ave	1199.01	1184.17	---	1189.09	---	---	4.92

Model Results - Sunny Day with Dam Breach

Table 4 shows the computed water surface elevation of properties at risk due to the Sunny Day scenario with Dam breach. The tabular data shown in Table 4 is shown graphically in Figure 6a. A baseline Sunny Day flow of 10 cfs was chosen, representing a moderately dry or low-flow condition. As expected, no properties would be flooded by a Sunny Day flow. However, the Sunny Day scenario with Dam breach produced minor flooding in the Pottery Shop garage and at the Fire Department. At the Pottery Shop garage, water may rise to a maximum depth of approximately 1.40 feet, and water would be above the concrete base of the garage for up to one hour. At the Fire Department, the maximum water surface elevation of up to 0.3 foot of water for a duration of approximately 17 minutes would be expected. No other flooding would be expected in this Sunny Day with Dam breach scenario.

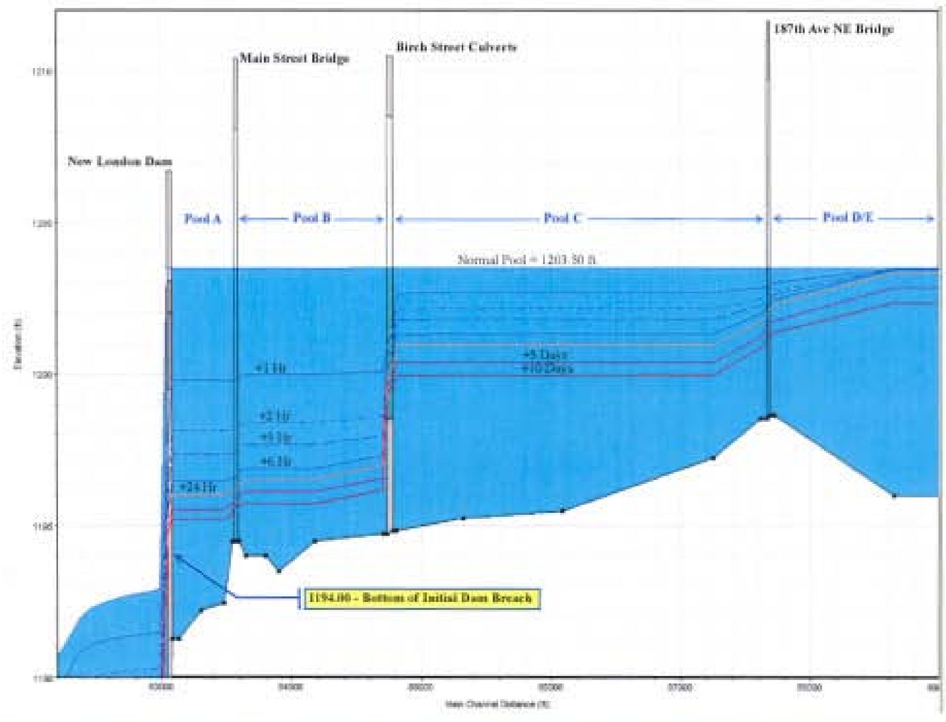
An additional concern at the Fire Department is that the road is approximately 2 feet lower than the main floor of the building. Flooding at the Fire Department may be minimal, or not even occurring, yet it may not be possible to remove equipment from the building due to a flooded roadway.

Flows from a Sunny Day scenario with Dam breach would not overtop any of the downstream bridges. Even with all stoplogs inplace, the Nest Lake Dam would pass the Sunny Day scenario with Dam breach without overtopping the roadway.

Figure 8 is a profile of Lake Monongalia showing the impacts of a Dam breach during a Sunny Day scenario. In this scenario, a constant inflow to the dam of 10 cfs would be maintained prior to dam breach. At dam breach, water would rapidly flow out of Pools A and B into the downstream reaches of the Middle Fork Crow River.

Figure 8 **- Profile of Lake Monongalia - Sunny Day Dam Breach**

Water Surface Elevation at Breach, +2 Hours, +4 Hours, +6 Hours, + 24 Hours, +5 Days, +10 Days



One hour after Dam breach, water levels in Pools A and B would drop approximately 3.5 feet. Two hours after Dam breach, the water levels in Pools A and B would drop approximately five feet. In Pool C, the water level would fall approximately 1.5 feet two hours after Dam breach. In the remaining upstream pools, the drop in water surface elevations would be small and gradual. Figure 8 also shows the computed water surface elevation 3 hours, 6 hours, 24 hours, 5 days and 10 days after dam breach.

Assuming no changes in inflow, water levels in Lake Monongalia would drop quickly in the first 24 hours after dam breach. However, 24 hours after dam breach, the water surface elevation in the various pools of the lake would fall at a much slower rate. After dam breach, outflow from the New London Dam would now be a function of the breach geometry and the water surface elevation in Pools A and B. After the initial dam breach and loss of water in Pools A and B, outflow from the New London Dam would stabilize at approximately 225 cfs and then slowly decrease as the water surface elevations in the upstream pools drops. This assume that no emergency action has been taken to temporarily repair or reduce outflows from the dam.

For the 1% Flood Event and the Probable Maximum Flood, the water surface elevation of Lake Monongalia would be higher than in the Sunny Day scenario due to increased flow in the Middle Fork Crow River. However, after dam breach, a stepped pattern similar to that shown in Figure 8 for the Sunny Day will occur, though the water surface elevations will be higher than the Sunny Day scenario.

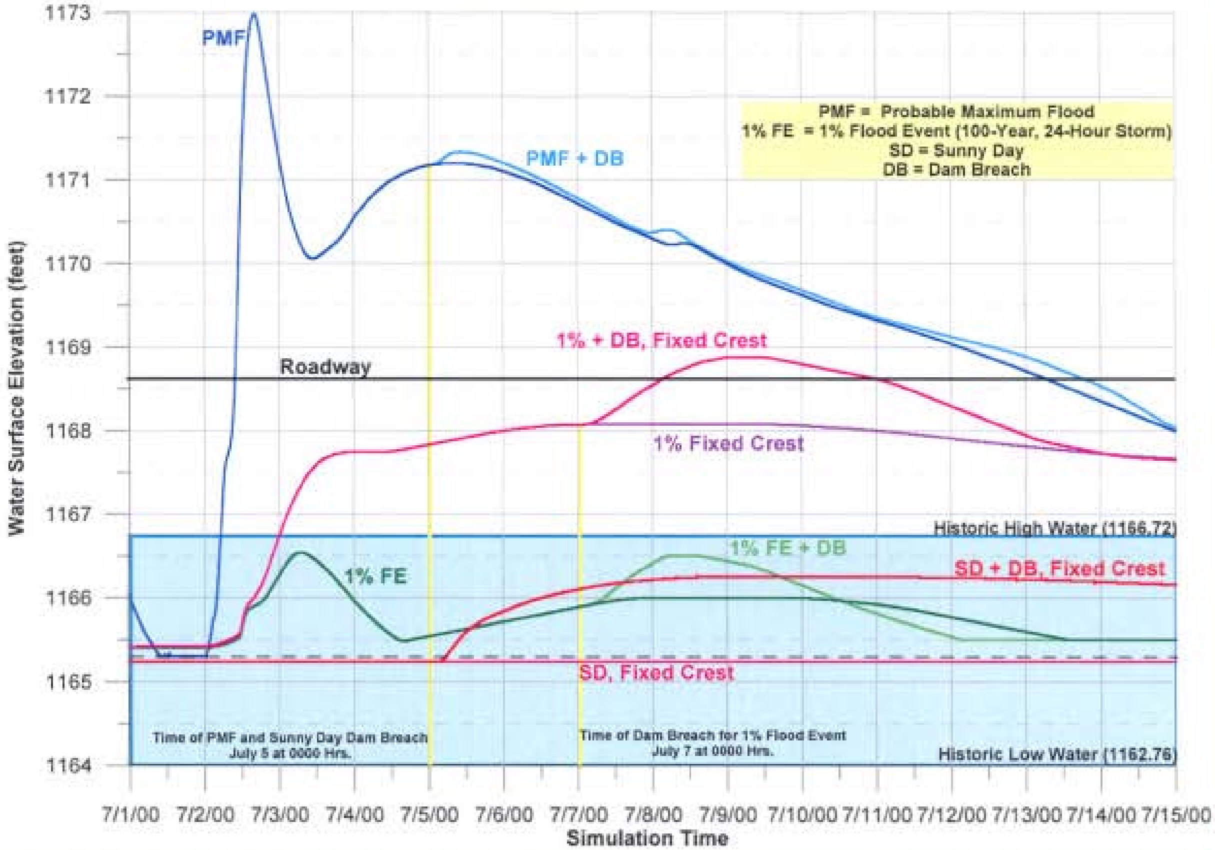
Impacts of a Dam Breach on Nest Lake and Green Lake

With hundreds of residential properties located downstream of the New London Dam on Nest Lake and Green Lake, it is also important to determine if there are any impacts of a dam breach on these two lakes. Flood events greater than the 100-Year Flood Event will cause damage to some residential properties on both lakes. A flood event approaching the Probable Maximum Flood, will cause damage to many residential properties. However, the models indicate that the impacts of a New London Dam breach on Nest Lake and Green Lake during one of these flood events would be relatively minor, as the volume of water from the respective flood events is significantly greater than the volume of water from the dam breach.

Figure 9 shows the computed water surface elevations on Nest Lake for the Probable Maximum Flood, the 1% Flood Event and the Sunny Day scenarios with and without dam breach. For the Probable Maximum Flood, the peak water surface elevation on Nest Lake is a result of the combination of direct precipitation on the lake, runoff from the local watersheds, and inflow from Lake Monongalia. The peak water surface elevation occurs approximately 16 hours after the beginning of precipitation and then drops rapidly as direct precipitation on the lake ceases and runoff from the local watershed diminishes.

A second peak water surface elevation occurs 3 days later on July 5 and is a result of the peak water surface elevation on Lake Monongalia and a maximum discharge from the New London Dam. Approximately 2-1/2 hours after dam breach, water levels on Nest Lake start to rise with the arrival of the leading edge of the dam breach floodwave. However, the increase in water surface elevation on Nest Lake due to dam breach was computed to be slightly less than two inches as the dam breach floodwave is attenuated by the channel between the New London Dam and

Figure 9 - **Nest Lake Water Surface Elevation at the Nest Lake Dam**



Nest Lake, and further reduced as the inflowing water spreads out into Nest Lake. Note that the water surface elevation for both peaks overtops the roadway at the Nest Lake Dam. It was assumed that during the Probable Maximum Flood, all stoplogs in the Nest Lake Dam are either rapidly removed or fail due to high water pressures. If the stoplogs could not be removed, the water surface elevation on Nest Lake would be noticeably higher.

The 1% Flood Event was modeled in two different configurations for the Nest Lake Dam. The first condition assumes aggressive operation of the Nest Lake Dam to maintain a water surface elevation of 1165.4 feet. The second configuration assumes that the stoplogs could not be removed from the dam and that the dam is essentially a fixed crest dam.

With the removal of the stoplogs at the Nest Lake Dam, the 1% Flood Event results in a peak water surface elevation of approximately 1166.55 feet, or approximately 1.20 feet above normal lake level. Similar to the Probable Maximum Flood scenario, the initial peak in water surface elevation results from a combination of direct precipitation on the lake, runoff from the local watersheds and inflow from Lake Monongalia via the Middle Fork Crow River. With the stoplogs removed from the Nest Lake Dam, the water surface elevation on the lake falls rapidly. As water levels approach normal pool, stoplogs are added to the dam to stop the fall in the water surface elevation. At the same time, inflows start increasing from Lake Monongalia as that lake is approaching the second peak in water surface elevations. Stoplogs are again removed from the Nest Lake Dam to bring the water surface elevation of Nest Lake back to 1165.40 feet.

Approximately four hours after dam breach (0410 hours 7/7/00 simulation time), the water surface elevations of Nest Lake will begin rising with the arrival of the dam breach floodwave. The dam breach floodwave will result in a peak water surface elevation of approximately 1166.50 feet, slightly lower than the elevation of the first peak, but approximately 0.5 foot higher than the water surface elevation without dam breach. With the arrival of the dam breach floodwave and rising water surface elevations, stoplogs are again removed from the dam to bring the water surface elevation back to 1165.40 feet. As the breach floodwave moves through Nest Lake, the water surface elevation of Nest Lake will drop to a lower level than if the dam breach had not occured. This drop in water surface elevation is a result of the reduced discharges from the failed New London Dam.

An additional simulation for the 1% Flood Event on Nest Lake was run based on the assumption that the Nest Lake Dam stoplogs could not be removed. In this simulation, the water surface elevation of Nest Lake increased approximately 2-1/2 feet as a result of direct precipitation on the lake, runoff from the local watersheds, and inflow from Lake Monongalia. Adding dam breach to this scenario resulted in an additional increase in the water surface elevation of approximately 0.80 feet to 1166.88 feet. This water surface elevation is approximately two inches higher than the lowest point on the roadway over the Nest Lake dam, resulting in some flow on the roadway.

The Nest Lake Dam has sufficient capacity that aggressive operation of the dam during the 1% Flood Event will result in relatively minor changes in water surface elevation, while a lack of operation can result in significant changes in water surface elevation. As the Nest Lake Dam is a manually operated dam, the actual water surface elevation for the 1% Flood Event would likely fall between these two operational extremes.

Note on Figure 9 that the starting water surface elevation on Nest Lake is near the normal water surface elevation of 1165.40 feet. Starting at a different water surface elevation or changing the time of the stoplog adjustments would result in minor changes in the lake level hydrograph.

The Sunny Day Scenario is also shown of Figure 9. In this scenario, a constant flow of 10 cfs maintains the elevation of 1165.24 feet, or approximately two inches lower than normal. With dam breach, it is assumed that minor adjustments to the stoplogs could be made to maintain the lake level. If no changes are made in the Nest Lake Dam, the water surface elevation would increase 1.01 feet to a maximum water surface elevation of 1166.25 feet.

Figure 10 shows the computed water surface elevations on Green Lake for the various scenarios. For the Probable Maximum Flood and the 1% Flood Events, it was assumed that the water surface elevation of Green Lake was near the historical average of 1156.31 feet. However, in the Sunny Day scenario, a constant inflow of 10 cfs resulted in a significantly lower starting water surface elevation as this ten cfs is significantly lower than the normal outflow from Green Lake. Also note that in the Sunny Day scenario, the water surface elevation of Green Lake slowly declines as the outflow exceeds ten cfs.

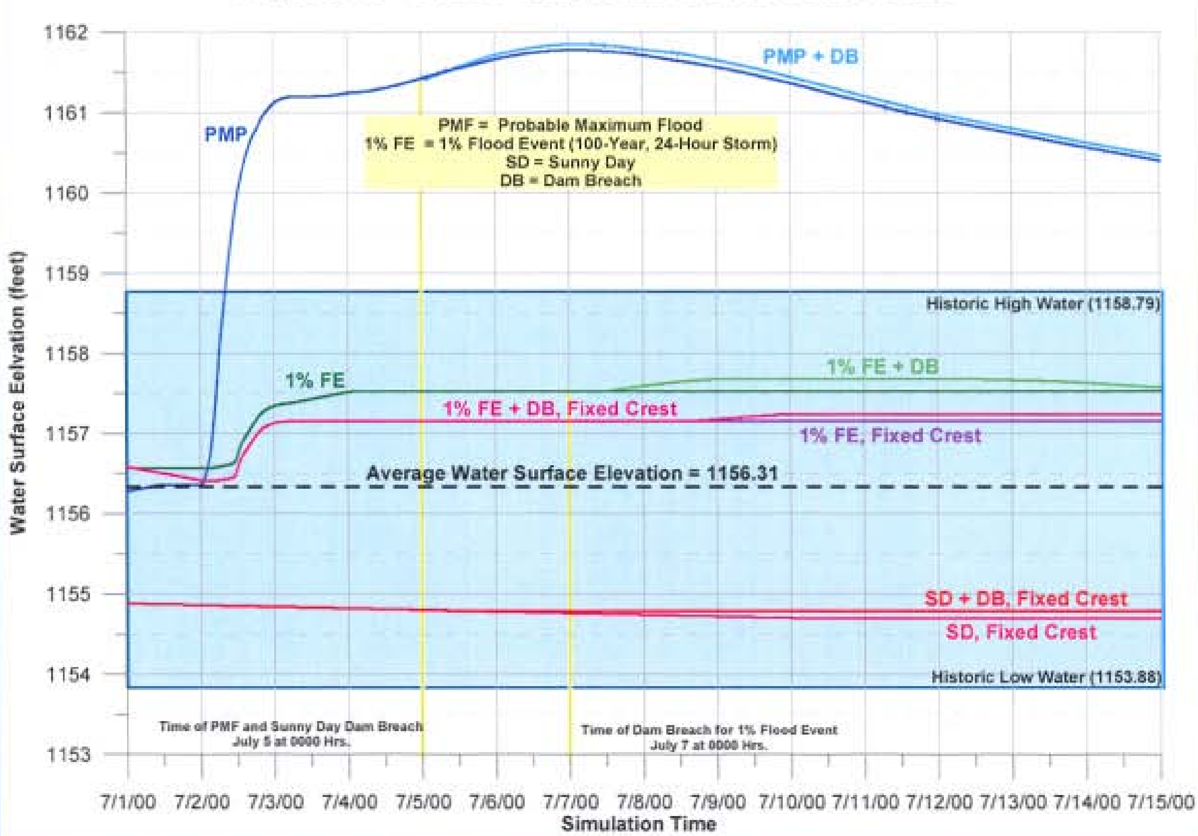
For the Probable Maximum Flood, the peak water surface elevation occurred approximately six days after the start of precipitation. The maximum computed water surface elevation for the Probable Maximum Flood was computed to be 1161.78 feet while the maximum water surface elevation of the Probable Maximum Flood with dam breach was computed to be 1161.85 feet. The increased water surface elevation on Green Lake due to a failure of the New London Dam during the Probable Maximum Flood is approximately one inch.

For the 1% Flood Event, the dam breach floodwave increased the water surface elevation of Green Lake approximately two inches with aggressive operation of the Nest Lake Dam. However, if the stoplogs of the Nest Lake Dam could not be removed, the dam breach floodwave would increase the water surface elevation of Green Lake by approximately one inch. Comparing Figures 9 and 10, note that jammed gates resulted in a higher water surface elevation on Nest Lake but a lower water surface elevation on Green Lake. With all stoplogs in place, more water would be held back or contained in Nest Lake and inflow into Green Lake would be reduced.

In the Sunny Day scenario, the dam breach resulted in an increase in water surface elevation of approximately 0.10 foot. In the Sunny Day scenario, no floodwave or peak in the water surface was observed.

It is important to note that the computed water surface elevations for Nest Lake and Green Lake are specific to the parameters of the models used. While significant effort was made to produce the most accurate models, it is extremely unlikely for all of the modeled parameters to exactly match all of the actual parameters for a given event. The road and bridge downstream of Green Lake, which was incorporated into the model from surveyed road and bridge plans, will be overtopped during the Probable Maximum Flood. However, Green Lake has a history of reduced outflows due to downstream flooding and backwater conditions caused by Calhoun Lake and other downstream wetlands. Increased vegetation in the channel and adjacent wetlands may further reduce outflows and increase water surface elevations in the summer months. Therefore, the computed water surface elevations on Green Lake should be considered course calculations. The purpose of including Nest Lake and Green Lake into the models was primarily to show how these lakes are impacted by a New London Dam breach.

Figure 10 **- Green Lake Water Surface Elevations**



Conclusion

The impacts of a failure of the New London Dam are highly variable. A Sunny Day failure, or a failure during periods of low flow, will have relatively minor, if any, impacts downstream of the dam, including Nest and Green Lakes. Upstream of the dam, the failure of the dam will result in lower water surface elevations on Lake Monongalia with a potential loss or reduction in recreational opportunities such as fishing or boating, until the dam is repaired.

A failure of the New London Dam during a major flood event is unlikely to cause flooding in any residential properties in the city of New London. However, several commercial properties downstream of the dam are at risk. A dam breach during a major flood event would increase the damage to any property being flooded, and may cause minor flooding at properties that are not being flooded. The duration that a property is experiencing flooding will be relatively short due to a dam breach as the dam breach floodwave will rapidly flow downstream and dissipate. However, some of the lowest properties will experience flooding of an extended duration caused by the respective flood event.

The potential exists for the loss-of-life if the New London Dam should fail. Possible causes of a loss-of-life include driving over the dam during failure, or being washed off the dam during an overtopping event. A potential also exists for a loss-of-life downstream of the dam. However, with no residential properties impacted by a dam breach, the potential for a loss-of-life is not probable.

The models indicate that there is a hydraulic constriction in the river channel just downstream of the Fire Department. Increasing the conveyance of the river at this location by modifying the stream channel and lowering the overbank would result in a lower water surface elevation at the Fire Department and other nearby properties.

References

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List of Figures

Appendix: 1/3 Probable Maximum Flood

As this report approached completion, a request was received to perform the dam breach analysis when the water surface elevation of Lake Monongalia reached the top of the dam. Due to time constraints, it was decided to add this analysis as an appendix rather than inserting it into the existing document.

The top of the New London dam is the roadway over the embankment and concrete gate structure. The lowest point on the embankment is at elevation 1206.70 feet. With the water surface elevation at the top of the dam/roadway (1206.70 feet), and both gates fully open, the discharge was computed to be approximately 1650 cfs, which is approximately 1/3 Probable Maximum Flood.

For the 1/3 Probable Maximum Flood, the height of the dam breach was determined to be 11.7 feet, extending from the base of the concrete gate structure at the approximate elevation of 1194.00 feet, to the top of the dam at elevation 1206.70. The average breach width was computed to be 40.95 feet, which is 3.5 time the height of the breach. However, in this scenario, breach times of 1-minute, 15-minutes and 30-minutes was used to compute the water surface elevations so as to allow a comparison of the computed water surface elevations for the different breach times.

Table 5 shows the computed water surface elevations for the 1/3 Probable Maximum Flood and the 1/3 Probable Maximum Flood with Dam Breach. Only two properties, the Pottery Shop garage and the Fire Department will experience minor flooding due to the 1/3 Probable Maximum Flood. With Dam breach, minor flooding can be expected in the Pottery Shop, the Pottery Shop garage, the Fire Department and at the construction company. After dam breach, the dam breach floodwave will quickly pass through the area downstream of the dam. However, flooding in several properties will continue for an extended period of time due to the low elevation of those properties and the large volume of water associated with the 1/3 PMF.

Figure 11 shows computed water surface elevations of the Middle Fork Crow River extending from approximately 200 feet upstream of the New London Dam to approximately 2000 feet downstream. The downstream limit of the profile is near the west corporate limit of the city of New London. The computed water surface elevations include the 1/3 Probable Maximum Flood, and the 1/3 Probable Maximum Flood with dam breach. The 1st floor elevation of several properties and the approximate downstream distance from the dam are also shown on Figure 11. An important feature to note on Figure 11 (and Figure 6) is the rapid change in water surface elevation between 700 and 1000 feet downstream of the dam. This indicates that there is a constriction or hydraulic control in the channel at this location. This is also near the point where the Middle Fork Crow River makes a 90 degree turn to the west. Reducing the size of this constriction, including lowering the overbanks, would be an inexpensive method to reduce water levels in the vicinity of the Pottery shop and Fire Department during high stage events.

The three breach times did not result in significantly different water surface elevations. The difference in water surface elevation from a 1-minute breach time to a 30-minute breach time was approximately 0.50 feet at the dam and approximately 0.1 feet 2000 feet downstream of the dam. The water surface elevations for the three breach times is shown on Figure 11. A breach time of several hours would result in water surface elevations only slightly greater than that of the 1/3 Probable Maximum Flood.

Table 5. 1/3 Probable Maximum Flood and Probable Maximum Flood with Dam Breach

Inundation Depths in Downstream Properties

		1/3 Probable Maximum Flood			1/3 Probable Maximum Flood with Dam Breach			
Address	**1st Floor Elev.**	**WSEL (ft.)**	**Depth (ft.)**	**Duration HR:MN**	**WSEL (ft.)**	**Depth (ft.)**	**Duration HR:MN**	**Height of DB Floodwave (ft.)**
Garage at Alley 14 Main St	1195.81	1192.94	---	---	1196.13	0.32	0:10	+3.19
Building Basement 24 Main St	1195.35	1192.81	---	---	1195.96	0.61	0:15	+3.15
Pottery Shop 17 Central Ave Garage	 1193.06 1190.75	 1192.70 1192.70	 --- 1.95	 --- +12 Days	 95.73 95.73	 2.67 4.98	 1:25 +12 Days	 +3.03 +3.03
Fire Department	1191.31	1192.53	1.22	+10 Days	1194.42	3.11	+10 Days	+1.89
Telecom Building 24 Central Ave	1194.01	1191.12	---	---	1193.00	---	---	+1.88
Banner Oak 98 Central Ave	1193.30	1191.06	---	---	1192.91	---	---	+1.85
Construction Co 102 Central Ave	1192.64	1191.01	---	---	1192.85	0.21	0:15	+1.84
Residence 108 Central Ave	1200.69	1190.94	---	---	1192.68	---	---	+1.74
Residence 112 Central Ave	1197.63	1190.91	---	---	1192.60	---	---	+1.69
Residence 118 Central Ave	1199.01	1190.85	---	---	1192.47	---	---	+1.62

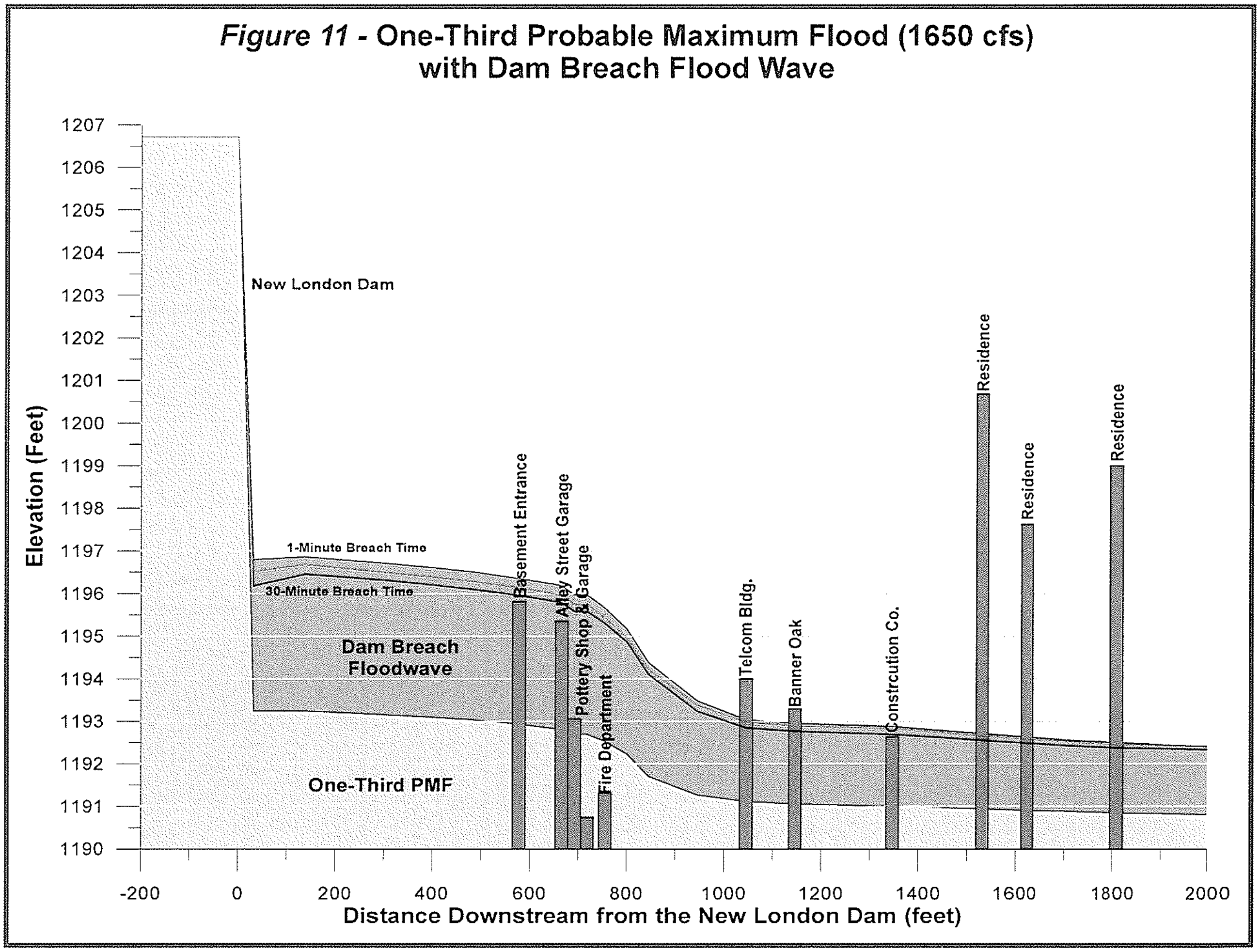
Figure 11 - One-Third Probable Maximum Flood (1650 cfs)
with Dam Breach Flood Wave
Elevation (Feet)
1207
1206
1205
1204
1203
1202
1201
1200
1199
1198
1197
1196
1195
1194
1193
1192
1191
1190
New London Dam
1-Minute Breach Time
30-Minute Breach Time
Dam Breach
Floodwave
One-Third PMF
Basement Entrance
Alley Street Garage
Pottery Shop & Garage
Fire Department
Telcom Bldg.
Banner Oak
Constrcution Co.
Residence
Residence
Residence
-200
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance Downstream from the New London Dam (feet)