Enclosure 3

R. E. Ginna Nuclear Power Plant
Combined Events Flood Analysis
Revision 0

(221 Pages)

AREVA

CALCULATION SUMMARY SHEET (CSS)

Document No. 32 - 9190280 - 000 Safety Related: ☒ Yes ☐ No

Title Flood Hazard Re-evaluation - Combined Events Flood Analysis for R.E. Ginna Nuclear Power Plant

PURPOSE AND SUMMARY OF RESULTS:

The purpose of this calculation is to assess the effect of the combined-effect flood on Deer Creek and Lake Ontario at the R.E. Ginna Nuclear Power Plant (Ginna). This calculation supports the flood hazard re-evaluation of Ginna.

Combined effect flooding was evaluated as per guidance in Appendix H of NUREG/CR-7046. Combined effect flooding discussed in this calculation are the result of adding wave runup to the maximum stillwater elevation of the bounding riverine flood and the Probable Maximum Storm Surge on Lake Ontario, as discussed in Appendix H of NUREG/CR-7046. The results of the evaluation of the combined-effect flood at Ginna are as follows:

1. The bounding combined-effect flooding mechanism at Ginna is the combination of the PMF on the Deer Creek with the 25-year surge (with wind-wave activity) on Lake Ontario and the maximum controlled water level on the Lake. Under this scenario, waves overtop the stone revetment and discharge canal, increasing the PMF water surface elevations at the northern end of the site by 0.1 ft.

2. The Probable Maximum Water Elevation at Ginna including wave effects is calculated to be 272.4 ft, NGVD29 at the Reactor Containment Building, 272.6 ft, NGVD29 at the Auxiliary Building, 258.2 ft, NGVD29 at the Turbine Building, 272.4 ft, NGVD29 at the Control Building, 271.3 ft, NGVD29 at the All-Volatile Building, 272.8 ft, NGVD29 at the Standby Auxiliary Feedwater Pump Building, 273.5 ft, NGVD29 at the proposed Standby Auxiliary Feedwater Pump Building Annex, 258.2 ft, NGVD29 at the Screen House, and 258.4 ft, NGVD29 at the Diesel Generator Building.

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE/VERSION/REV	CODE/VERSION/REV
CEDAS-ACES v.4.03	USACE HEC-HMS v. 3.5
FLO-2D Version 2012.02 Professional (FLO-2D)	

THE DOCUMENT CONTAINS ASSUMPTIONS THAT SHALL BE VERIFIED PRIOR TO USE

☐ **YES**

☒ **NO**

AREVA

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Flood Hazard Re-evaluation - Combined Events Flood Analysis for R.E. Ginna Nuclear Power Plant

Review Method: ☒ Design Review (Detailed Check)
☐ Alternate Calculation

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1.0 PURPOSE

The purpose of this calculation is to assess the combined-effect flood mechanisms for the R.E. Ginna Nuclear Power Plant (Ginna). Ginna is located in Ontario, Wayne County, NY along the southern shore of Lake Ontario. Ginna is protected from flooding from Lake Ontario by a stone revetment. A concrete-lined discharge canal conveys flow from the site to Lake Ontario through the stone revetment. The confluence of two streams, Deer Creek (which generally flows west to east) and Mill Creek (which generally flows south to north) is located near the southwestern portion of the site. The streams flow along the southern portion of the site into Lake Ontario. For the purposes of this calculation, the portion of the stream from the confluence point of Mill Creek and Deer Creek to the discharge point into Lake Ontario will be referred to as Deer Creek. A locus map of the site is included as Figure 1. This calculation is to support the flood hazard re-evaluation for Ginna.

This calculation uses AREVA Document No. 32-9190273-000 "Probable Maximum Flood Flow in streams near R.E. Ginna" (Reference 1), AREVA Document No. 32-9190274-000 "Probable Maximum Flood Elevations at R.E. Ginna" (Reference 2), AREVA Document No. 32-9190276-000 "Probable Maximum Winds and Associated Meteorological Parameters at R.E. Ginna" (Reference 29), AREVA Document No. 32-9190277-000 "Probable Maximum Storm Surge at R.E. Ginna" (Reference 27) and AREVA Document No. 32-9190279-000 "Wind Generated Waves for R.E. Ginna" (Reference 28) as inputs.

This calculation was prepared by GZA GeoEnvironmental, Inc, under subcontract to AREVA, Inc.

Datum: All elevations in this calculation refer to NGVD29 vertical datum unless otherwise noted. Elevations in the Updated Safety Report (UFSAR) reference Mean Sea Level (MSL), which for areas distant from tidal fluctuations (i.e., Ginna) are considered to be the same as the NGVD29 vertical datum. To convert elevations from NAVD88 to NGVD29, add 0.69 feet to the NAVD88 elevations (Reference 3, see Appendix A).

2.0 ANALYTICAL METHODOLOGY

The calculation methodology is described below. Unless noted otherwise, the methodology used in the calculation is consistent with the following standards and guidance documents:

1. NRC Standard Review Plan, NUREG-0800, revised March 2007 (Reference 4);
2. NRC Office of Standards Development, Regulatory Guides:
    a. RG 1.102 – Flood Protection for Nuclear Power Plants, Revision 1, dated September 1976 (Reference 5);
    b. RG 1.59 – Design Basis Floods for Nuclear Power Plants, Revision 2, dated August 1977 (Reference 6).
3. NUREG/CR-7046 "Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America", publication date November 2011 (Reference 7).
4. American National Standard for Determining Design Basis Flooding at Power Reactor Sites (ANSI/ANS 2.8-1992) (Reference 8).

The Hierarchical Hazard Assessment (HHA) approach described in NUREG/CR-7046 (Reference 7) was used for the evaluation of the effects of the combined-effects flood on the Deer Creek at Ginna. The criteria for combined events are provided in NUREG/CR-7046, Appendix H. These criteria are:

1. Floods Caused by Precipitation Events

The criteria for floods caused by precipitation events were used as one input to the combined event result (NUREG/CR-7046, Appendix H, Section H.1). The criteria include the following:

- Alternative 1 - A combination of mean monthly base flow, median soil moisture, antecedent or subsequent rain, the PMP, and waves induced by 2-year wind speed applied along the critical direction;
- Alternative 2 - A combination of mean monthly base flow, probable maximum snowpack, a 100-year snow-season rainfall, and waves induced by 2-year wind speed applied along the critical direction; and
- Alternative 3 - A combination of mean monthly base flow, a 100-year snowpack, snow-season PMP, and waves induced by 2-year wind speed applied along the critical direction.

2. Floods Caused by Seismic Dam Failures

The criteria for floods caused by seismic dam failures (NUREG/CR-7046, Appendix H, Section H.2) were also considered. The criteria include:

- Alternative 1 – A combination of a 25-year flood, a flood caused by dam failure resulting from a safe shutdown earthquake (SSE), and coincident with the peak of the 25-year flood, and waves induced by 2-year wind speed applied along the critical direction;
- Alternative 2 – A combination of the lesser of one-half of Probable Maximum Flood (PMF) or the 500-year flood, a flood caused by dam failure resulting from an operating basis earthquake (OBE), and coincident with the peak of one-half of PMF or the 500-year flood, and waves induced by 2-year wind speed applied along the critical direction.

The alternatives presented under floods caused by precipitation events and floods caused by seismic dam failures are bounded by failure of all the dams in the watershed coincident with the PMF. The riverine flooding combination used for this analysis is therefore failure of dams during the PMF, and waves induced by 2-year wind speed applied along the critical direction.

3. Floods along the Shores of Open and Semi-Enclosed Bodies of Water

The criteria for floods along the shore of open or semi-enclosed bodies of water (NUREG/CR-7046, Appendix H, Section H.3) do not apply to Ginna since the site is not on an open or semi-enclosed body of water.

4. Floods along the Shores of Enclosed Bodies of Water

Ginna is located along the southern shore of Lake Ontario. Lake Ontario is an enclosed water body approximately 7,300 square miles in surface area. The criteria for floods along the shore of enclosed bodies of water (streamside location) (NUREG/CR-7046, Appendix H, Section H.4.2) was considered in this calculation. The criteria include:

- Alternative 1 – A combination of one-half of the PMF or the 500-year flood, surge and seiche from the worst regional hurricane or windstorm with wind-wave activity and the lesser of the 100-year or the maximum controlled water level in the enclosed body of water;
- Alternative 2 – A combination of the PMF in the stream, a 25-year surge and seiche with wind-wave activity and the lesser of the 100-year or the maximum controlled water level in the enclosed body of water;
- Alternative 3 – A combination of a 25-year flood in the stream, probable maximum surge and seiche with wind-wave activity and the lesser of the 100-year or the maximum controlled water level in the enclosed water body.

These alternatives were analyzed to determine the controlling combined-effect alternative at Ginna.

5. Floods Caused by Tsunamis

Combined event floods associated with tsunamis are included as part of the analyses required by NUREG/CR-7046 (Appendix H, Section H.5). Evaluation of the potential for tsunamis at the Ginna site (AREVA Document No. 51-9190872-000 "Tsunami Hazard Assessment at R.E. Ginna Nuclear Power Plant Site" - Reference 26) concluded that tsunamis are not a significant flood-causing mechanism. Therefore, no further analysis of tsunami-induced flooding combined with other mechanisms has been performed.

The combined event evaluation for Ginna used the following steps:

1. Calculate the maximum stillwater elevation (including dam failures) on the Deer Creek at Ginna using models developed for calculations 32-9190273-000 "Probable Maximum Flood Flow in Streams near R.E. Ginna" (Reference 1) and 32-9190274-000 "Probable Maximum Flood Elevations in Streams near R.E. Ginna" (Reference 2).
2. Calculate the wind wave effects and wave runup on Deer Creek at Ginna using the CEDAS-ACES v4.3 Computer Program (Reference 9);
3. Calculate the Probable Maximum Water Elevation at Ginna resulting from the combined-effect flood caused by the Precipitation;
4. Calculate the Probable Maximum Water Elevation at Ginna resulting from combined-effect floods along the Shores of Enclosed Bodies of Water based on AREVA Calculations 32-9190277-000 "Probable Maximum Storm Surge for R.E. Ginna" (Reference 27) and 32-9190279-000 "Wind Generated Waves for R.E. Ginna (Reference 28).
5. Determine controlling Probable Maximum Water Elevation at Ginna based on the results from the above analysis.

2.1 Calculate Maximum Stillwater Elevations on Deer Creek at Ginna

Failure of upstream dams during the PMF was analyzed to establish the maximum stillwater elevation at Ginna resulting from riverine flooding mechanism. The methodology used in this analysis is described in Sections 2.1.1 to 2.1.3.

2.1.1 Identify Upstream Dams

Upstream dams were identified using the New York State Inventory of Dams (NYSID), which is maintained by the Department of Environmental Conservation (Reference 10, see Appendix B). Dam characteristics (i.e. height, maximum storage, and dam type) were downloaded from the inventory. The dam locations were imported into ArcMap 10.0 and converted into a point shapefile.

2.1.2 Develop Dam Breach Hydrologic Simulations

A HEC-HMS model of the contributory watersheds at Ginna was developed. The model's hydrologic parameters were consistent with those used in AREVA Document No. 32-9190273-000 "Probable Maximum Flood Flow in Streams near R.E. Ginna" (Reference 1). Note that nonlinear adjustments to unit hydrographs were incorporated in this HEC-HMS model.

The identified dams were modeled as reservoir elements in HEC-HMS, and linked to the appropriate sub-basin element with reaches and junctions. Reservoir pool elevations prior to the breaching of the dams were conservatively assumed to be at the top of dam elevation. Dam breach parameters for the HEC-HMS model were selected based on published guidance (References 11, 12, and 13, see Appendix C).

Parameters for dams are described below:

a) Breach Method = Overtopping;

b) Top Elevation (ft) = Dam Height (ft);

c) Bottom Elevation (ft) = 0;

d) Side Slope = 0.5 (Reference 12, see Appendix C);

e) Average Breach Width = 3 x Dam Height (References 12 and 13, see Appendix C). Published references indicate typical dam breach widths are between one and five times the dam height (Reference 12) and often about 3 times the dam height for earthen dams (Reference 13);

f) Bottom Width (ft) = Average Breach Width – 2 x (Side Slope x ½ x Dam Height);

g) Development Time (hr) = 0.17 hours (Based on material composition of Dam and Reference 12);

h) Trigger Method = Specified Time;

i) Trigger Time = Selected such that initiation of the dam breach coincides with the peak PMF from the watershed in which the dam is located;

j) Progression Method = Linear;

k) Storage Method = Elevation-Area, based on surface area of reservoir and conical volume.

River reaches were incorporated in the HEC-HMS model to account for attenuation. The Muskingum-Cunge method was selected and it uses a combination of the conservation of momentum and conservation of mass to simulate river routing. "*Routing parameters are recalculated every time step based on channel properties and flow depths. It represents attenuation of flood waves and can be used in reaches with a small slope.*" (Reference 14)

Parameters for reaches are described below:

a) Reach cross-section = estimated based on the topographic survey of the site (Reference 15);

b) Length of reach = the total length of the reach in units of feet (Reference 16). Length was calculated using the "Calculate Geometry" function of ArcMap 10™;

c) Slope = based on the digital elevation model data within the watershed area (Reference 17, see Appendix D); and

d) Manning's roughness coefficient (Reference 20, see Appendix D) = selected based on visual interpretation of the ground conditions using available orthoimagery (Reference 18, see Appendix D) and land cover data (Reference 19, see Appendix D).

The all-season 72-hr PMP hyetograph used in AREVA Document No. 32-9190273-000 "Probable Maximum Flood Flow in Streams near R.E. Ginna" (Reference 1) was used for this calculation. The PMP consists of 3 days of 40-percent of the PMP, followed by 3 dry days and followed by 3 days of the full PMP, in accordance with NUREG/CR-7046 (Reference 7).

HEC-HMS internally calculates flow through the user-specified dam breach section based on the weir equation for overtopping dam failures (Reference 14).

2.1.3 Develop Hydraulic Simulations with Combined PMF and Dam Breach Outflow to calculate the probable maximum Stillwater elevation on Deer Creek

The FLO-2D model developed in AREVA Document 32-9190274-000 (Reference 2) was used in this calculation. The calculated, combined dam breach and PMF flows in the Deer Creek and Mill Creek at Ginna in Section 2.1 were used as inflows within the FLO-2D model to calculate the probable maximum stillwater elevation on the creek at Ginna.

2.2 Calculate Wind-Wave Effects on Deer Creek

Ginna would be susceptible to the formation of wind generated waves on both Lake Ontario and on Deer Creek. The wind generated waves on Lake Ontario were developed in Calculation No. 32-9190279-000 (Reference 28). This calculation estimates the wind generated waves on Deer Creek at the site. The calculation methodology includes the following steps, further described in Sections 2.2.1 through 2.2.4, below.

1. Calculate the straight line fetch;

2. Calculate Sustained Wind Speed:

   - Calculate the 2-year return period wind speed using the fastest 2-minute wind speed data from National Climatic Data Center (NCDC) Station GHCND:USW00014768 (Reference 21, see Appendix E), by applying the Gumbel Distribution to the observed data;

3. Calculate wave height and period using CEDAS-ACES v.4.03 wave prediction application;

4. Determine the wave runup using CEDAS-ACES v.4.03 wave runup.

2.2.1 Determine the Greatest Straight Line Fetch

The greatest over water fetch for the most conservative value for wind generated waves on the Deer Creek was determined from the FLO-2D model output showing the inundation extents (Figure 9). The fetch was considered to be the largest continuous wetted top width across Deer Creek in the vicinity of the main power block at Ginna.

2.2.2 Calculate the Sustained Wind Speed

The 10-meter, 2-year annual recurrence interval wind speed was required for the coincident wind wave calculations as part of the combined-effects flood analysis as per NUREG/CR-7046 (Reference 7). The fastest daily 10-meter, 2-minute duration wind speed from NCDC Station Global Historical Climatology Network-Daily (GHCND): USW00014768 (Greater Rochester International Airport, New York), was used and converted to the equivalent 10-meter, 30 minute duration average wind speed. Conversion of the raw data to the 2 year wind speed was done using the following steps:

1. The 2-minute wind speed data from NCDC Station GHCND: USW00014768 was downloaded and imported into Excel™ in tab delimited format. The period of record for this station was from 1996 to 2012, approximately 17 years. Station GHCND: USW00014768 is located at the Greater Rochester International Airport, New York (see Appendix E). The location is flat ground with no obstruction from trees and buildings and is therefore an appropriate station for use as wind input. This station was the closest station to the site with available data.

2. The greatest wind speed from each year during the period of record was selected. The annual maximum wind speeds were sorted in descending order. The Gumbel Distribution, a Generalized Extreme Value (GEV) Distribution, was used to calculate the 2 year recurrence wind speed.

2.2.3 Development of the Wave Height and Period

CEDAS-ACES v.4.03, developed by the U.S. Army Engineer Waterways Experiment Station, includes an application for determining wave growth over open-water and restricted fetches in deep and shallow water. The simplified wave growth formula predict deepwater wave growth in accordance to fetch and duration-limited criteria. These formulas are bounded (at the upper limit) by the estimates for a fully developed spectrum (Reference 22). The following variables were developed as input to the program to calculate wave height and period:

1. The elevation, duration, observation type, and speed of the observed wind speed from Section 2.2.2;
2. The air-sea temperature difference (See Appendix F);
3. Duration of the final wind speed (See Appendix F);
4. Latitude of the Observed Wind Speed (Appendix F); and
5. Wind fetch length, as determined through procedures described in Section 2.2.1.

2.2.4 Development of the Wave Runup

The runup on impermeable slopes application of the CEDAS-ACES v4.03 software program is based on an empirical runup equation developed by Ahrens and Titus as described in Reference 22. Wind generated waves on the Deer Creek will break and runup on the southern end of the power block (Contaminated Storage Building). The effect of wind generated waves on Deer Creek is therefore not expected to extend beyond the southern end of the plant.

2.2.4.1 Development of the Nearshore and Structure Slopes

Nearshore slopes were estimated from the site topographic survey plan (Reference 15). Because the water depths vary spatially, an average water depth along the fetch was calculated. Wave growth was determined to be governed by shallow open water conditions. The nearshore slope was determined based on the existing site grades along the selected fetch line.

In this calculation, the wave runup is calculated against the southern wall of the main power block (building labeled as "plant" in Figure 2). The structure slope was determined based on a vertical wall.

2.2.4.2 Development of Wave Runup on Smooth Slopes

The equations for runup on a smooth slope were used. The general equation for runup (R) on smooth slopes is characterized by the following equation:

$$R = CH_i$$

The coefficient C is characterized by the surf similarity parameter ξ according to three wave structure regimes (Reference 22):

- ($\xi \leq 2$) waves plunging directly on the run-up slope.
- ($\xi \geq 3.5$) wave conditions that are nonbreaking and are regarded as standing or surging waves.
- ($2 < \xi < 3.5$) transition conditions where breaking characteristics are difficult to define

The recommended expressions for coefficient C corresponding to these regimes are defined by the following:

- Plunging wave conditions ($\xi \leq 2$)

$$C_p = 1.002\,\xi$$

- Nonbreaking wave conditions ($\xi \geq 3.5$)

$$C_{nb} = 1.181\left(\frac{\pi}{2\theta}\right)^{0.375} \exp\left[3.187\left(\frac{\eta_c}{H_i} - 0.5\right)^2\right]$$

Where:

η_c = crest height of the wave above the still-water level

H_i = incident wave height

- Transitional wave conditions ($2 < \xi < 3.5$)

$$C_t = \left(\frac{3.5-\xi}{1.5}\right)C_p + \left(\frac{\xi-2}{1.5}\right)C_{nb}$$

Where:

C_p = C coefficient corresponding to plunging wave conditions

C_{nb} = C coefficient corresponding to nonbreaking wave conditions

C_t = C coefficient corresponding to transitional wave conditions

2.3 Calculate the Probable Maximum Water Elevation at Ginna resulting from the combined-effect of floods caused by Precipitation Events.

Waves that strike structures will run up those structures, resulting in an increase in the height of the water at the face of the structure. The probable maximum stillwater elevation on Deer Creek at the southern end of the plant power block at Ginna resulting from the combined effect of floods caused by precipitation events was calculated by adding the predicted wave runup on the Deer Creek to the stillwater elevations resulting from the combination of upstream dam failure and the PMF.

2.4 Calculate the Probable Maximum Water Elevation resulting from the combined-effect of floods along the shores of Enclosed Bodies of Water.

The alternatives outlined under the criteria for floods along the shore of enclosed bodies of water (Streamside location) (NUREG/CR-7046, Appendix H, Section H.4.2) were analyzed to determine the controlling alternative at Ginna.

2.4.1 Combination of one-half of the PMF, worst regional surge with wind-wave activity and the maximum controlled water level in the Lake Ontario.

One-half of the PMF was calculated using the HEC-HMS model developed for AREVA Document No. 32-9190273-000 (Reference 1). One-half of the PMF was calculated as half the runoff generated from the PMP calculated in AREVA Document No. 32-9190273-000 (Reference 1). All other inputs to the HEC-HMS model were the same as those used in the HEC-HMS model in Reference 1. The worst regional surge on Lake Ontario was determined from water level data contained in AREVA Document No. 32-9190276-000 (Reference 29). See Appendix L. The maximum controlled water level in Lake Ontario was determined in AREVA Document No. 32-9190277-000 (Reference 27). Overtopping flow rates at the stone revetment resulting from the combination of the worst regional surge and seiche with wind-wave activity and the maximum controlled water level in Lake Ontario was calculated in AREVA Document No. 32-9190279-000 (Reference 28).

The calculated overtopping flow rates for the combination of the worst regional surge and seiche with wind-wave activity and the maximum controlled water level in Lake Ontario was combined with one-half the PMF on Deer Creek using the FLO-2D model developed in AREVA Document 32-9190274-000 (Reference 2) to determine the maximum water levels resulting from this alternative.

2.4.2 Combination of the PMF in Deer Creek, a 25-year surge with wind-wave activity and the maximum controlled water level in the Lake Ontario.

The PMF in the Deer Creek computed in Reference 1 was used in the analysis of this alternative. The 25-year surge on Lake Ontario was calculated from water level data contained in AREVA Document No. 32-9190276-000 (Reference 29, Appendix L) as described in Section 2.4.2.1. The maximum controlled water level in Lake Ontario was determined in AREVA Document No. 32-9190277-000 (Reference 27). Overtopping flow rates at the stone revetment and discharge canal resulting from the combination of the 25-year surge and seiche with wind-wave activity and the maximum controlled water level in Lake Ontario was calculated in AREVA Document No. 32-9190279-000 (Reference 28).

The calculated overtopping flow rates for the combination of the 25-year surge and seiche with wind-wave activity and the maximum controlled water level in Lake Ontario was combined with the PMF on Deer Creek using the FLO-2D model developed in AREVA Document 32-9190274-000 (Reference 2) to determine the maximum water levels resulting from this alternative.

2.4.2.1 Calculation of the 25-year Surge

The 25-year surge water level was calculated based on water level data for Rochester, NY (Reference 32) See Appendix L. The location of the Rochester water level station is shown in Figure 10. The maximum hourly water level in each year was obtained for the 50-year period of record and a frequency analysis was performed. The recommended distribution for data set transformations of this type is the log-Pearson Type III distribution (Reference 33). The 25-year surge water level was calculated as follows:

1. The hourly water level data for each complete year of data available was sorted to determine the yearly maximum hourly water level (HWL) for each year in the data set. The yearly maximums were transformed with (base 10) logarithm.

2. Sample statistics including mean, number of samples in the data set, standard deviation and skew coefficient were calculated using the following equations.

$$\overline{X} = \frac{\sum X}{N}$$

$$S = \left[\frac{\sum (X - \overline{X})^2}{(N-1)} \right]^{0.5}$$

$$G = \frac{N \times \sum \left(\frac{X - \overline{X}}{S} \right)^3}{(N-1)(N-2)}$$

where:

X = logarithm of annual peak water level
N = number of samples in the data set
$\overline{X}$ = mean of the sample data logarithms
S= standard deviation of the sample data
G= skew coefficient of logarithms

3. For skew coefficients from -9.0 to 9.0, the frequency factor coefficients (K) for exceedance probabilities from 0.9999 to 0.0001 were determined using the "Tables of K Values" in Appendix 3 of USGS Bulletin 17b (U.S. Dept. of the Interior, 1982). The log of the water levels corresponding to their respective exceedance probabilities are defined by the following equation:

$$Log(SurgeWaterLevel) = \overline{X} + K * S$$

where:

K = Frequency Factor Coefficient

4. The 25-year surge water level was calculated by taking the antilog of the log mean water level.

2.4.3 Combination of the 25-year flood in Deer Creek, the probable maximum surge with wind-wave activity and the maximum controlled water level in the Lake Ontario.

The 25-year flood in Deer Creek was calculated using the HEC-HMS model developed for AREVA Document No. 32-9190273-000 (Reference 1). The 25-year, 24-hour precipitation depth and distribution used in the HEC-HMS model were based on reference 31. All other inputs to the HEC-HMS model were the same as those used in the HEC-HMS model in Reference 1. The probable maximum surge on Lake Ontario was calculated in AREVA Document No. 32-9190277-000 (Reference 27). The maximum controlled water level in Lake Ontario was also determined in AREVA Document No. 32-9190277-000 (Reference 27). Overtopping flow rates at the stone revetment and discharge canal resulting from the combination of the probable maximum surge and seiche with wind-wave activity and the maximum controlled water level in Lake Ontario was calculated in AREVA Document No. 32-9190279-000 (Reference 28).

The calculated overtopping flow rates for the combination of the probable maximum surge and seiche with wind-wave activity and the maximum controlled water level in Lake Ontario was combined with the 25-year flood in Deer Creek to determine the maximum water levels resulting from this alternative.

2.5 Determine the controlling Probable Maximum Water Surface Elevations at Ginna

The results from the combined-effect flood alternatives for both floods caused by precipitation events and floods along the shores of enclosed bodies of water were analyzed to determine the probable maximum water surface elevations at Ginna. The alternative that results in the highest water surface elevations at Ginna was selected as the controlling combined-effect flood alternative.

3.0 ASSUMPTIONS

Unverified key assumptions are those requiring confirmation of applicability by users of the calculation and its results. There are no unverified key assumptions in this calculation. The following assumptions were used in the calculation:

- Potential for tsunamis at the Ginna to control flood elevations is not significant and bounded by flooding due to the combination of the PMF and dam breach within the contributory watershed at Ginna (Reference 26).
- Reservoir pool elevations prior to the breaching of the dams were at the top of dam elevation.
- Other assumptions used in calculations to support the combined effect flood evaluation are included in Sections 6.1 through 6.5. None of the assumptions require confirmation of applicability by users of the calculation prior to use of the calculation results.

4.0 DESIGN INPUTS

1. The HEC-HMS hydrologic model developed in AREVA Document No. 32-9190273-000 "Probable Maximum Flood Flow in Streams near R.E. Ginna" (Reference 1).
2. Elevation Datum Conversions – elevations in NAVD88 were converted to NGVD29, using VERTCON: North American Vertical Datum Conversion, by National Geodetic Survey (Reference 3, see Appendix A).
3. Dam and Reservoir Storage Characteristics – dam height and reservoir storage capacity of dams within the contributory watershed area at Ginna based on data provided by New York State Department of Environmental Protection (Reference 10, see Appendix B).
4. Digital Elevation Model (DEM) - the DEM used for the calculation is the National Elevation Dataset (NED) (1/3 arc second) provided by U.S. Geological Survey (USGS), published in 2011 (Reference 17, see Appendix D).
5. Land Use - the land use information for the watershed was obtained from the National Land Cover Database 2006 (NLCD2006) (Reference 19, see Appendix D).

6. Manning's roughness coefficients (Reference 20, see Appendix D).

7. The FLO-2D Model developed in AREVA Document No. 32-9190274-000 " Probable Maximum Flood Elevations near R.E. Ginna Nuclear Power Plant" (Reference 2)

8. Site Location: 41°16'39.34" N, 77°18'31.65" W, see Figure 1.

9. Ginna Site Layout (Reference 23).

10. NOAA National Climatic Data Center Fastest 2-minute wind speed (tenths of meters per second) Data: Verified Data, Greater Rochester International Airport, NY, Station ID GHCND:USW00001476889. Retrieved on March 19, 2013. (Reference 21, see Appendix E) Available at: http://www.ncdc.noaa.gov/cdo-web/review

11. 25-Year, 24-hour Precipitation depth and distribution at Ginna (Reference 31, see Appendix M).

12. 1-hour water level data for Lake Ontario at Rochester, NY (Reference 29, see Appendix K)

5.0 IDENTIFICATION OF COMPUTER PROGRAMS

1. ESRI® ArcMap™ 10.0, Service Pack 2 (Build 10.0.2.3200)

2. HEC-HMS v. 3.5, Build 1417 (USACE HEC, August, 2010)

3. FLO-2D Version 2012.02 Professional Model – Build No. 12.01.01

4. CEDAS-ACES v.4.03

ArcMap 10.0 was used to generate graphic outputs of the calculated results and is not subject to verification per AREVA Procedure 0902-30, Section 4.6.

Computer Software Certifications for HEC-HMS v.3.5, FLO-2D Version 2012.02 Professional Version and CEDAS-ACES v.4.03 are provided under separate cover (References 9, 24, and 25). The information contained in Appendix J, as part of the body of this calculation, lists the program version, hardware platform and operating system. HEC-HMS v.3.5, FLO-2D Version 2012.02 Professional Version and CEDAS-ACES v.4.03 are approved for use under the Microsoft Windows 7 operating system. No open software error notices were in effect at the time of software execution.

The CEDAS-ACES v.4.03 program is "Simple Use" per Section 4.7 of 0902-30. The program was executed on a GZA workstation as approved by AREVA.

HEC-HMS v.3.5 was tested on the computer used for this document by Kenneth Hunu on March 25, 2013. The inputs of the installation tests were the same as those used in the software verification report, and the outputs are documented in Appendix J. The results of the test were acceptable.

FLO-2D Version 2012.02 Professional Version was tested on the computer used for this document by Kenneth Hunu on April 4, 2013. The inputs of the installation tests were the same as those used in the software verification report, and the outputs are documented in Appendix J. The results of the test were acceptable.

CEDAS-ACES v.4.03 was tested on the computer used for this document by Bin Wang on March 25, 2013. The inputs of the installation tests were the same as those used in the software verification reports, and the outputs are documented in Appendix J. The results of the test were acceptable.

6.0 CALCULATIONS

6.1 Calculate Maximum Stillwater Elevations on Deer Creek at Ginna

6.1.1 Identify Upstream Dams

Based on a review of the data in the NYSID (Reference 10), three dams are within the contributory watershed. Maccines Marsh Dam is located in the Deer Creek Watershed, about 2.5 miles southwest of Ginna. Fruitland Mill Dam and William Daly Marsh Dam are located in the Mill Creek Watershed, about 4 and 7.5 miles southwest of Ginna, respectively. The dam coordinates were imported into ArcMap 10.0, and the dam locations are shown in Figure 3.

All three dams are classified as "Earth" in "Dam Type" according to the NYSID. Field observation and available information indicate the dams are likely non-engineered structures. Dam breach parameters for non-engineered earthen dams were therefore used for this calculation.

6.1.2 Perform Dam Breach Hydrologic Simulations

Dam breach parameters are summarized in Table 1 (see Appendix C for spreadsheet calculations). HEC-HMS reach parameters are summarized in Table 2 (see Appendix D for spreadsheet calculations). The HEC-HMS basin model is shown in Figure 4. The dams were modeled as reservoir elements. Junctions 2 and 3 were used to calculate the total corresponding resultant flow from runoff and dam failure for each subwatershed, and Junction 1 was used to calculate the total resultant flow from the entire contributory watershed.

The calculated total outflow from the Deer Creek Watershed with dam breach is 8,140 cfs, and the calculated total outflow from the Mill Creek Watershed with dam breach is 20,530 cfs. The resultant combined peak outflow at Ginna is 28,460 cfs. Breaching of the upstream dams within the Deer Creek and Mill Creek watersheds during the PMF resulted in no significant change in the peak PMF calculated in Reference 1. These results are presented in Table 3. The HEC-HMS calculated outflow hydrographs from the dam breach during the PMF simulation are shown in Figures 5 through 7.

Inputs and outputs from the HEC-HMS simulations are included in Appendix G.

6.1.3 Perform Hydraulic Simulations with Combined PMF and Dam Breach Outflow to calculate the probable maximum Stillwater elevation on Deer Creek

The FLO-2D model developed in AREVA Document 32-9190274-000 (Reference 2) was used to estimate the peak stillwater elevation resulting from the combination of upstream dam failures and the PMF. The HEC-HMS calculated flow hydrographs from Section 6.1.2 were used as inflows in the FLO-2D model.

The calculated probable maximum stillwater elevations at the site are shown in Table 4. The probable maximum stillwater elevation is 272.4 ft, NGVD29 at the Reactor Containment Building, 272.6 ft, NGVD29 at the Auxiliary Building, 258.1 ft, NGVD29 at the Turbine Building, 272.4 ft, NGVD29 at the

Control Building, 271.3 ft, NGVD29 at the All-Volatile Building, 272.8 ft, NGVD29 at the Standby Auxiliary Feedwater Pump Building, 273.5 ft, NGVD29 at the proposed Standby Auxiliary Feedwater Pump Building Annex, 258.1 ft, NGVD29 at the Screen House, and 258.3 ft, NGVD29 at the Diesel Generator Building.

FLO-2D inputs and outputs are included in Appendix H.

6.2 Results of Wind-Generated Wave Effects on Deer Creek

6.2.1 Determine the Greatest Straight Line Fetch

The inundation extent at Ginna due to the combination of upstream dam failures and the PMF in Deer Creek and Mill Creeks calculated in Section 6.1.3 was used to determine wetted top width for the fetch shown in Figure 9. The total length of the fetch was 870 ft and the average water depth was determined to be 15.7 ft.

6.2.2 Calculate the Sustained Wind Speed

Using the Gumbel Distribution on the 2-minute wind speed data (see Appendix F for Excel™ spreadsheet and formulas), the 2-year return period wind speed was determined to be 22.5 m/sec or 73.9 ft/sec.

The Gumbel Distribution yielded a conservative value for the calculated 2-year wind speed. The modeled values for selected return periods were plotted against the observed data. The calculated value for the 2-year wind speed is nearly the same as the "observed" approximate 2-year wind speed (see Figure F-1, Appendix F). The data from NCDC Station GHCND: USW000014687 is presented in Appendix E.

6.2.3 Calculate the Wave Height and Period

The wave prediction application of the CEDAS-ACES v.4.03 was used to determine the shallow water significant wave height and period.

The outputs from the model are provided in Appendix I. The wind duration of 120 minutes was conservatively used. The wave height was calculated to be 0.7 ft with a wave period of 1.2 seconds.

6.2.4 Determination of the Wave Runup

The wave runup on impermeable structures application was selected to calculate the wave runup at Ginna from the CEDAS-ACES v.4.03 program. The inputs for the wave runup calculation are presented in Table 4. Calculated results are shown in Appendix I. The results indicate maximum wave runup at the southern end of the power block at Ginna (south end of Contaminated Storage Building) of 0.9 feet.

6.3 Calculate the Probable Maximum Water Elevation at Ginna resulting from the floods caused by precipitation event

The probable maximum water elevation resulting from the combined-effect flood caused by precipitation event at Ginna is the combination of this Stillwater elevation and wave runup induced by the 2-year wind speed. Wave runup resulting from Deer Creek flooding is not expected to influence the stillwater elevations at the site with the exception of the southern end of the site. The probable maximum water surface elevations resulting from a precipitation event causing flooding in Deer Creek, in ft, NGVD29 are those stated in Section 6.1.3.

6.4 Calculate the Probable Maximum Water Elevation resulting from the combined-effect of floods along the shores of Enclosed Bodies of Water.

The results of the alternatives outlined under the criteria for floods along the shore of enclosed bodies of water (Streamside location) (NUREG/CR-7046, Appendix H, Section H.4.2) are discussed in Sections 6.4.1 to 6.4.3.

6.4.1 Combination of one-half of the PMF, worst regional surge with wind-wave activity and the maximum controlled water level in Lake Ontario.

The peak flow rate from one-half of the PMF at Ginna is calculated to be 14,230 cfs. The worst regional surge is calculated to be 1.3 ft (Appendix L) and the maximum controlled water level in Lake Ontario is calculated to be 248 ft, NGVD29 (Reference 27). The overtopping flow rates resulting from the combination of the worst regional surge with wind-wave activity and the maximum controlled water level in Lake Ontario are shown in Table 5 (Reference 28).

FLO-2D model results from the combination of one-half the PMF, and the overtopping flow rates resulting from the combination of the worst regional surge with wind-wave activity and the maximum controlled water level in Lake Ontario, is shown in Table 8. Flooding at Ginna from this alternative is limited to the Turbine Building, Proposed Auxiliary Feedwater Pump Building, Screen House and the Diesel Generator Building. Maximum Flood Elevations at the Turbine Building, Proposed Auxiliary Feedwater Pump Building, Screen House and the Diesel Generator Building are 255 ft, NGVD29, 270 ft, NGVD29, 254.9 ft, NGVD29 and 254.9 ft, NGVD29 respectively.

6.4.2 Combination of the PMF in Deer Creek, a 25-year surge with wind-wave activity and the maximum controlled water level in the Lake Ontario.

6.4.2.1 Calculation of the 25-year Surge

The 25-year surge elevation on Lake Ontario at Ginna was evaluated using the the recorded hourly water levels at NOAA Station 9052058 (Reference 32) in Rochester, NY for the period 1962 - 2012.

The results of the transformation are presented in Appendix L, Table L-1. The calculation of the 25-yr surge water level is presented in Appendix L, Table L-2.

The 25-year surge water level was calculated to be 0.95 feet.

6.4.2.2 Combination of PMF in Deer Creek and overtopping flow rates from the combination of the 25-year surge with wind-wave activity and the maximum controlled water level in Lake Ontario

The Deer Creek PMF peak flow rate at Ginna was computed in Reference 1 to be 28,460 cfs. The 25-year surge on Lake Ontario is calculated to be 0.95 ft and the maximum controlled water level in Lake Ontario is calculated to be 248 ft, NGVD29 (Reference 27).

The overtopping flow rates resulting from the combination of the 25-year surge with wind-wave activity and the maximum controlled water level in Lake Ontario are listed in Table 6 (Reference 28).

FLO-2D model results from the combination of the PMF with upstream dam failures, and the overtopping flow rates resulting from the combination of the 25-year surge with wind-wave activity and the maximum controlled water level in Lake Ontario is shown in Table 9. The resulting maximum water surface elevations from this alternative are 272.4 ft, NGVD29 at the Reactor Containment Building, 272.6 ft, NGVD29 at the Auxiliary Building, 258.2 ft, NGVD29 at the Turbine Building, 272.4 ft, NGVD29 at the Control Building, 271.3 ft, NGVD29 at the All-Volatile Building, 272.8 ft, NGVD29 at the Standby Auxiliary Feedwater Pump Building, 273.5 ft, NGVD29 at the proposed Standby Auxiliary Feedwater Pump Building Annex, 258.2 ft, NGVD29 at the Screen House, and 258.4 ft, NGVD29 at the Diesel Generator Building.

6.4.3 Combination of the 25-year flood in Deer Creek, the probable maximum surge with wind-wave activity and the maximum controlled water level in the Lake Ontario.

The peak flow rate from the 25-year storm in Deer Creek at Ginna is calculated to be 3,000 cfs. The peak flow of 3,000 cfs results from a total precipitation depth of 3.79 inches over 24 hours. (Appendix M). The probable maximum surge is calculated to be 3.2 ft (Reference 27) and the maximum controlled water level in Lake Ontario is calculated to be 248 ft, NGVD29 (Reference 27). The overtopping flow rates resulting from the combination of the probable maximum surge with wind-wave activity and the maximum controlled water level in Lake Ontario are shown in Table 7 (Reference 28).

FLO-2D model results from the combination of the 25-year storm in Deer Creek at Ginna, and the overtopping flow rates resulting from the combination of the probable maximum surge with wind-wave activity and the maximum controlled water level in Lake Ontario are shown in Table 10. Flooding at Ginna from this alternative is limited to the Turbine Building, Screen House and the Diesel Generator Building due to wave activity (i.e., flooding in Deer Creek due to the 25-yr flood does not affect the site). Maximum Flood Elevations at the Turbine Building, Screen House and the Diesel Generator Building resulting from this alternative is 254.9 ft, NGVD29.

6.5 Determine the controlling Probable Maximum Water Surface Elevations at Ginna

The combination of PMF in the Deer Creek at Ginna with the 25-year surge with wind wave activity and the maximum controlled water level in Lake Ontario yields the highest water surface elevations at Ginna (Section 6.4.2). This alternative is therefore the controlling alternative in determining the probable maximum water surface elevations at Ginna. The Probable Maximum Water Surface Elevation at Ginna is 272.4 ft, NGVD29 at the Reactor Containment Building, 272.6 ft, NGVD29 at the Auxiliary Building, 258.2 ft, NGVD29 at the Turbine Building, 272.4 ft, NGVD29 at the Control Building, 271.3 ft, NGVD29 at the All-Volatile Building, 272.8 ft, NGVD29 at the Standby Auxiliary Feedwater Pump Building, 273.5 ft, NGVD29 at the proposed Standby Auxiliary Feedwater Pump Building Annex, 258.2 ft, NGVD29 at the Screen House, and 258.4 ft, NGVD29 at the Diesel Generator Building.

7.0 RESULTS AND CONCLUSIONS

NUREG/CR-7046 presents updated methodologies relative to Regulatory Guide 1.59 which are incorporated into this calculation. These include:

- Use of computerized hydrologic, hydraulic and wave height simulation models (i.e., HEC-HMS, FLO-2D and CEDAS-ACES v.4.03) to develop the dam breach outflow, maximum flood elevations and wave height;

- Identification of specific alternatives (i.e., Appendix H of NUREG/CR-7046) for evaluation in combined effect flooding.

The following summarizes the results and conclusions:

1. The bounding combined-effect flooding mechanism at Ginna is the combination of the PMF on the Deer Creek with the 25-year surge with wind-wave activity on Lake Ontario and the maximum controlled water level on the Lake. Under this alternative, waves overtop the stone revetment and discharge canal, increasing the PMF water surface elevations at the northern end of the site by 0.1 ft.

2. The Probable Maximum Water Elevation at Ginna including wave effects is calculated to be 272.4 ft, NGVD29 at the Reactor Containment Building, 272.6 ft, NGVD29 at the Auxiliary Building, 258.2 ft, NGVD29 at the Turbine Building, 272.4 ft, NGVD29 at the Control Building, 271.3 ft, NGVD29 at the All-Volatile Building, 272.8 ft, NGVD29 at the Standby Auxiliary Feedwater Pump Building, 273.5 ft, NGVD29 at the proposed Standby Auxiliary Feedwater Pump Building Annex, 258.2 ft, NGVD29 at the Screen House, and 258.4 ft, NGVD29 at the Diesel Generator Building.

8.0 REFERENCES

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TABLES

Table 1: Dam Breach Parameters

Dam Name	Height of Breach / Height of Dam (ft)	Top of Dam / Pool Elevation (ft)	Bottom of Breach[1] (ft)	Side Slope (--)	Average Breach Width (ft)	Bottom Width (ft)	Trigger Method	Breach Start Time[2]	Development Time[3] (hr)	Top of Dam Surface Area (acres)
Macinnes Marsh Dam	5	5	0	0.5	15	12.5	Specific Time	Jan 8 , 18:20	0.17	19
William Daly Marsh Dam	6	6	0	0.5	18	15		Jan 8, 19:10	0.17	5
Fruitland Mill Dam	10	10	0	0.5	30	25		Jan 8, 19:20	0.17	6

[1] Elevations are relative. Assigned all reservoir bottoms to be at elevation zero.

[2] Based on simulation beginning on January 1 at 00:00.

[3] Used development time of 0.17 hr for earthen dams.

Table 2: Muskingum-Cunge Parameters

Reach	Length (ft)	Average Bed Slope	Width (ft)	Manning's n
Macinnes Marsh Dam	14550	0.0026	40	0.04
William Daly Marsh Dam	56700	0.0041	40	0.04
Fruitland Mill Dam	30410	0.0024	40	0.04

Table 3: Peak Flow with Dam Breach and 72-hour PMP

HEC-HMS Element	Unit	72-hour PMP
Peak Outflow from Mill Creek Watershed	(cfs)	20,530
Peak Breach Outflow from William Daly Marsh Dam	(cfs)	480
Peak Breach Outflow from Fruitland Mill Dam	(cfs)	1,910
Total Discharge from Mill Creek Watershed	(cfs)	20,530
Peak Outflow from Deer Creek Watershed	(cfs)	8,140
Peak Breach Outflow from Maccines Marsh Dam	(cfs)	430
Total Discharge from Deer Creek Watershed	(cfs)	8,140
Combined Peak Outflow at Ginna Nuclear Station	(cfs)	**28,460**

Table 4: Probable Maximum Stillwater Elevations at Ginna from Riverine Flooding

Structure	Representative Grid Element Number	Design Basis Flood Levels (ft, NGVD29)	PMF Peak Elevation (ft,	Maximum Flow Depth (ft)	Maximum Flow Velocity (fps)
Reactor Containment	6193	272.0	272.4	2.2	1.1
Auxiliary Building	6651	272.0 to 273.8	272.6	2.1	2.8
Turbine Building	4364	256.6	258.1	4.1	3.1
Control Building	5740	272.0	272.4	2.1	2.1
All-Volatile-Treatment-Building	5286	272.0	271.3	0.7	5.3
Standby Auxiliary Feedwater Pump	6879	273.0	272.8	2.7	4.1
Proposed Standby Auxiliary Feedwater	7105	273.8	273.5	3.6	2.9
Screen House	3840	256.6	258.1	4.5	3.3
Diesel Generator Building	4014	256.6	258.3	4.7	4.3

Table 5: Overtopping Flow Rates for Worst Historic Surge with Wind-Wave Activity

Transect	Length (ft.)	Design Base Water Level (NGVD 29)	Depth at Structure Toe (Ft.)	T Peak (T_p)	H_s (Ft.)	H_o (Ft.) (CEDAS Calc.)	CEDAS Runup (Ft.)	Runup Elev. (NGV D29)	CEDAS Over-topping (cfs.)	Over-topping Reach (cfs)
1	60	249.2	5.40	10	4.20	3.0	6.55	255.75	0	0.0
2	88	249.2	5.50	10	4.29	3.0	6.67	255.87	0	0.0
3	245	249.2	7.30	10	5.69	4.3	8.49	257.69	0.015	3.7
4	47	249.2	7.70	10	6.00	4.6	14.6	263.8	5.53	259.9
5	233	249.2	8.20	10	6.39	5.0	9.37	258.57	0.019	4.4
6	110	249.2	7.30	10	5.69	4.3	8.50	257.7	0.003	0.3
7	105	249.2	5.70	10	4.44	3.2	6.87	256.07	0	0.0

See Figure 8 for Transect Locations

Table 6: Overtopping Flow Rates for 25-year Surge with Wind-Wave Activity

Transect	Length (ft.)	Design Base Water Level (NGVD29)	Depth at Structure Toe (Ft.)	T Peak (T_p)	H_s (Ft.)	H_o (Ft.) (CEDAS Calc.)	CEDAS Runup (Ft.)	Runup Elev. (NGVD29)	CEDAS Over-topping (cfs.)	Over-topping Reach (cfs)
1	60	248.8	5.00	10	3.85	2.7	6.08	254.88	0	0.0
2	88	248.8	5.10	10	3.95	2.8	6.21	255.01	0	0.0
3	245	248.8	6.90	10	5.38	4..0	8.10	256.90	0.005	1.2
4	47	248.8	7.30	10	5.68	4.3	14.15	262.95	4.13	194.1
5	233	248.8	7.80	10	6.07	4.7	8.97	257.77	0.007	1.6
6	110	248.8	6.90	10	5.38	4.0	8.10	256.9	0.001	0.1
7	105	248.8	5.30	10	4.13	2.9	6.46	255.26	0	0.0

See Figure 8 for Transect Locations

Table 7: Overtopping Flow Rates for Probable Maximum Surge with Wind-Wave Activity

Transect	Length (ft.)	Design Base Water Level (NGVD 29)	Depth at Structure Toe (Ft.)	T Peak (T_p)	H_s (Ft.)	H_o (Ft.) (CEDAS Calc.)	CEDAS Runup (Ft.)	Runup Elev. (NGV D29)	CEDAS Over-topping (cfs.)	Over-toppin g Reach (cfs)
1	60	251.1	7.3	10	5.7	4.3	8.4	259.5	0.07	4.2
2	88	251.1	7.4	10	5.8	4.3	8.5	259.6	0.08	7.0
3	245	251.1	9.2	10	7.2	5.7	10.2	261.3	0.33	80.9
4	47	251.1	9.6	10	7.5	6.0	16.7	267.8	15.8	742.6
5	233	251.1	10.1	10	7.9	6.3	11.1	262.2	0.34	79.2
6	110	251.1	9.2	10	7.2	5.7	10.2	261.3	0.14	15.4
7	105	251.1	7.6	10	5.9	4.5	8.7	259.8	0	0.0

See Figure 8 for Transect Locations

Table 8: Peak Water Surface Elevations resulting from the combination of the riverine PMF, worst historic surge with wind-wave activity and maximum controlled water level in Lake Ontario

Structure	Representative Grid Element Number	Design Basis Flood Levels (ft, NGVD29)	PMF Peak Elevation (ft, NGVD29)	Maximum Flow Depth (ft)	Maximum Flow Velocity (fps)
Reactor Containment	6193	272.0	-	-	-
Auxiliary Building	6651	272.0 to 273.8	-	-	-
Turbine Building	4364	256.6	255.0	1.0	1.2
Control Building	5740	272.0	-	-	-
All-Volatile-Treatment-Building	5286	272.0	-	-	-
Standby Auxiliary Feedwater Pump Building	6879	273.0	-	-	-
Proposed Standby Auxiliary Feedwater Pump Building Annex	7105	273.8	270.3	0.4	0.5
Screen House	3840	256.6	254.9	1.2	0.4
Diesel Generator Building	4014	256.6	254.9	1.2	1.0

Note: "-"implies that the flooding from the scenario does not impact the given location.

Table 9: Peak Water Surface Elevations resulting from the combination of the riverine PMF, 25-year surge with wind-wave activity and maximum controlled water level in Lake Ontario

Structure	Representative Grid Element Number	Design Basis Flood Levels (ft, NGVD29)	PMF Peak Elevation (ft, NGVD29)	Maximum Flow Depth (ft)	Maximum Flow Velocity (fps)
Reactor Containment	6193	272.0	272.4	2.2	1.1
Auxiliary Building	6651	272.0 to 273.8	272.6	2.0	2.8
Turbine Building	4364	256.6	258.2	4.2	3.1
Control Building	5740	272.0	272.4	2.0	2.1
All-Volatile-Treatment-Building	5286	272.0	271.3	0.7	5.3
Standby Auxiliary Feedwater Pump Building	6879	273.0	272.8	2.7	4.0
Proposed Standby Auxiliary Feedwater Pump Building Annex	7105	273.8	273.5	3.6	2.8
Screen House	3840	256.6	258.2	4.5	3.3
Diesel Generator Building	4014	256.6	258.4	4.7	4.4

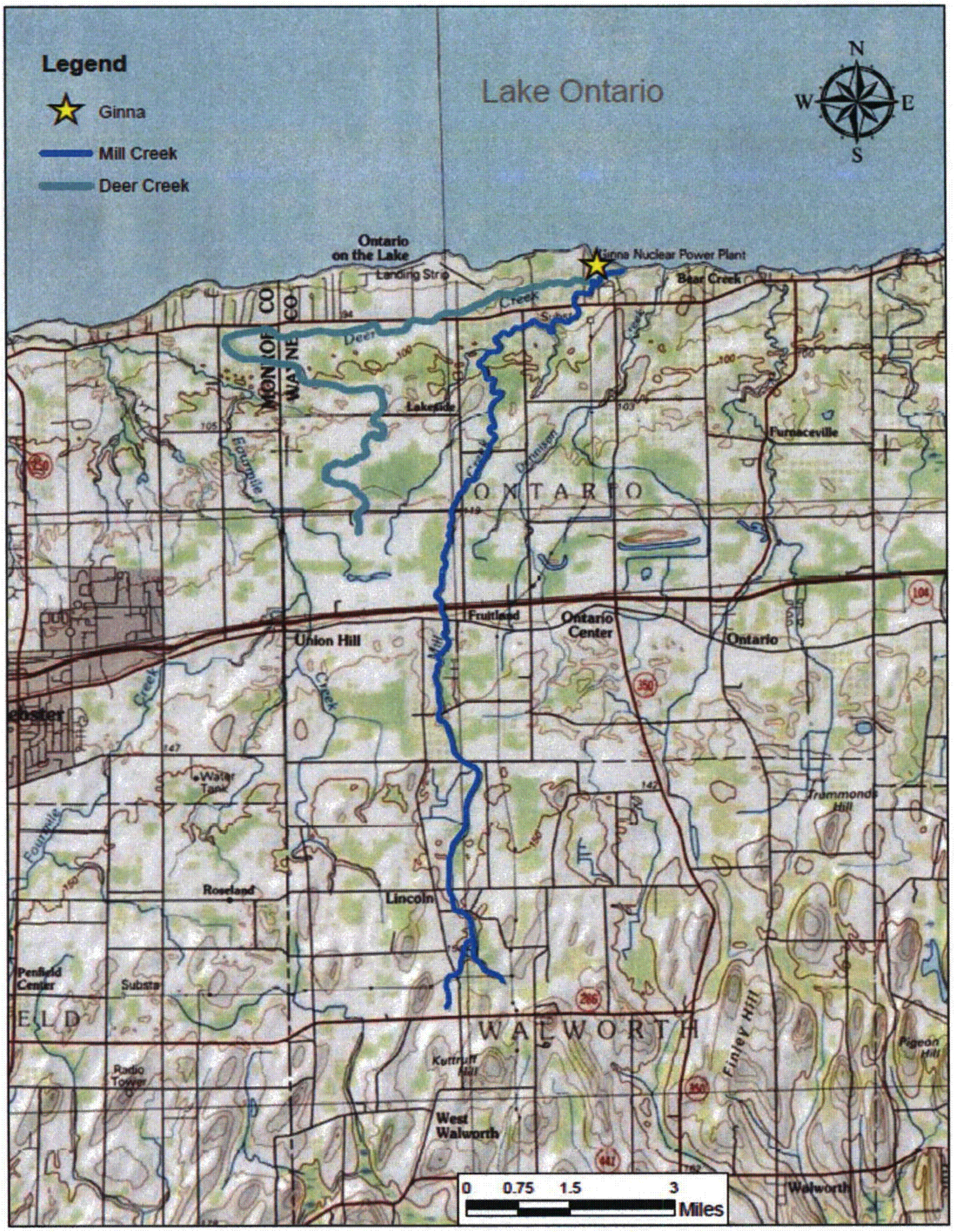
Table 10: Peak Water Surface Elevations resulting from the combination of the 25-year flood in Deer Creek, Probable Maximum Storm Surge with wind-wave activity and maximum controlled water level in Lake Ontario

Structure	Representative Grid Element Number	Design Basis Flood Levels (ft, NGVD29)	PMF Peak Elevation (ft, NGVD29)	Maximum Flow Depth (ft)	Maximum Flow Velocity (fps)
Reactor Containment	6193	272.0	-	-	-
Auxiliary Building	6651	272.0 to 273.8	-	-	-
Turbine Building	4364	256.6	254.9	0.9	0.8
Control Building	5740	272.0	-	-	-
All-Volatile-Treatment-Building	5286	272.0	-	-	-
Standby Auxiliary Feedwater Pump Building	6879	273.0	-	-	-
Proposed Standby Auxiliary Feedwater Pump Building Annex	7105	273.8	-	-	-
Screen House	3840	256.6	254.9	1.2	0.9
Diesel Generator Building	4014	256.6	254.9	1.2	0.8

Note: "-"implies that the flooding from the scenario does not impact the given location.

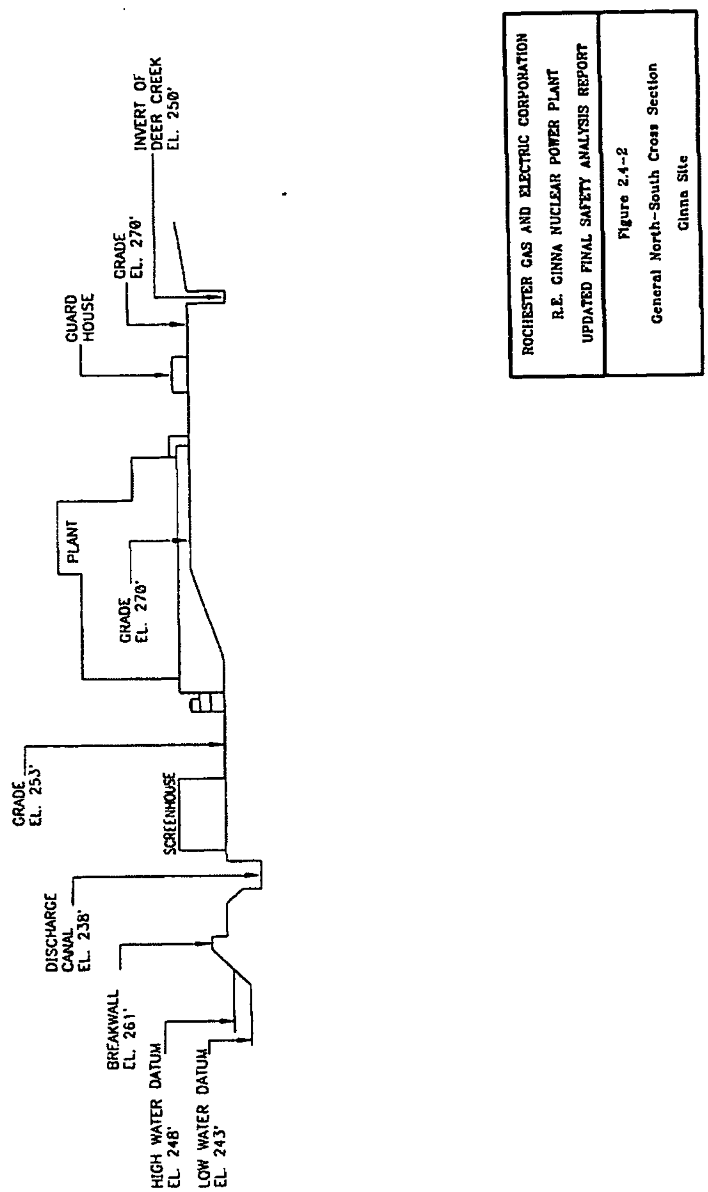
FIGURES

Figure 1: Locus Map



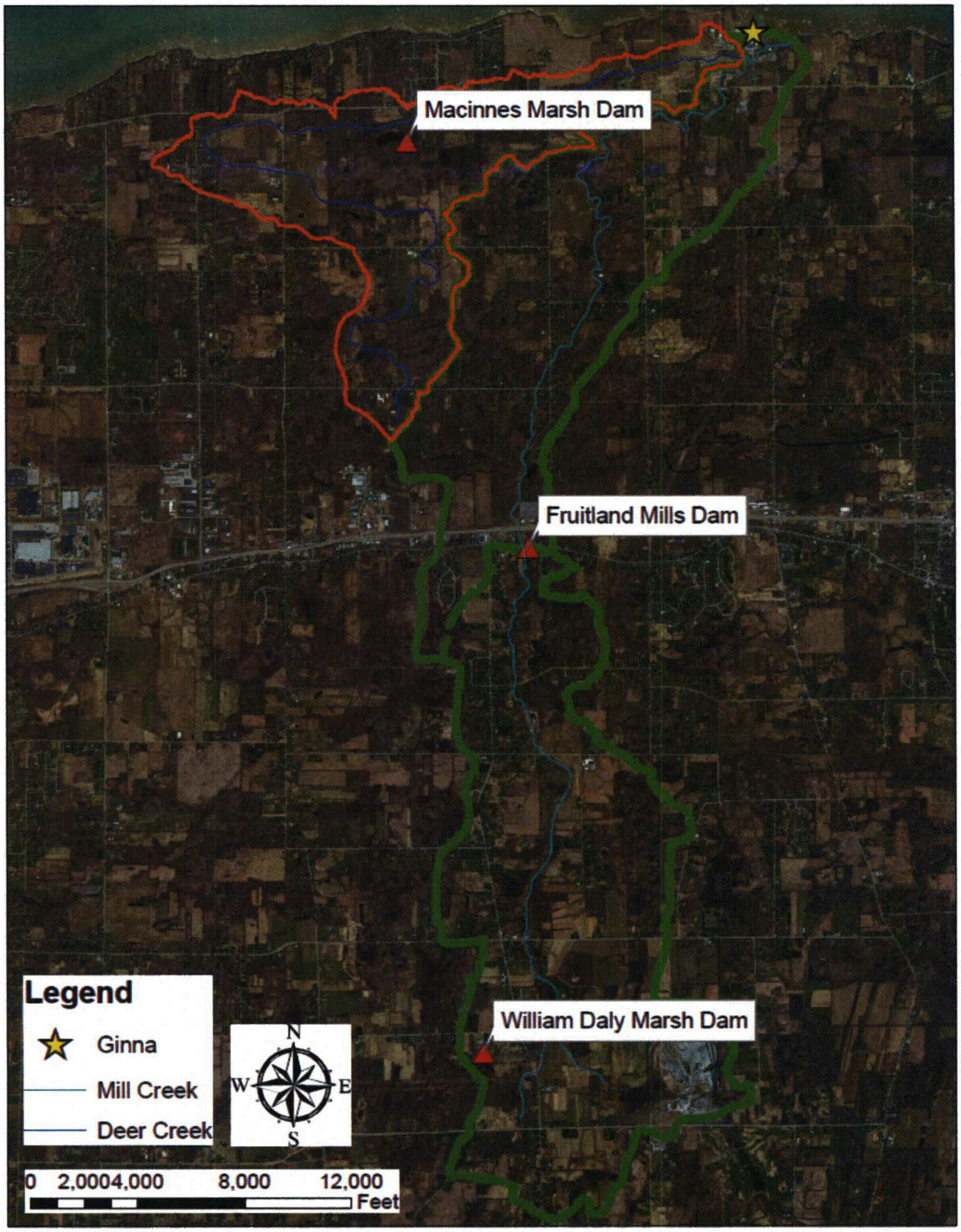
Note: Illegible text or features in this figure are not pertinent to the technical purposes of this document

Figure 2: Site Layout (Reference 23)



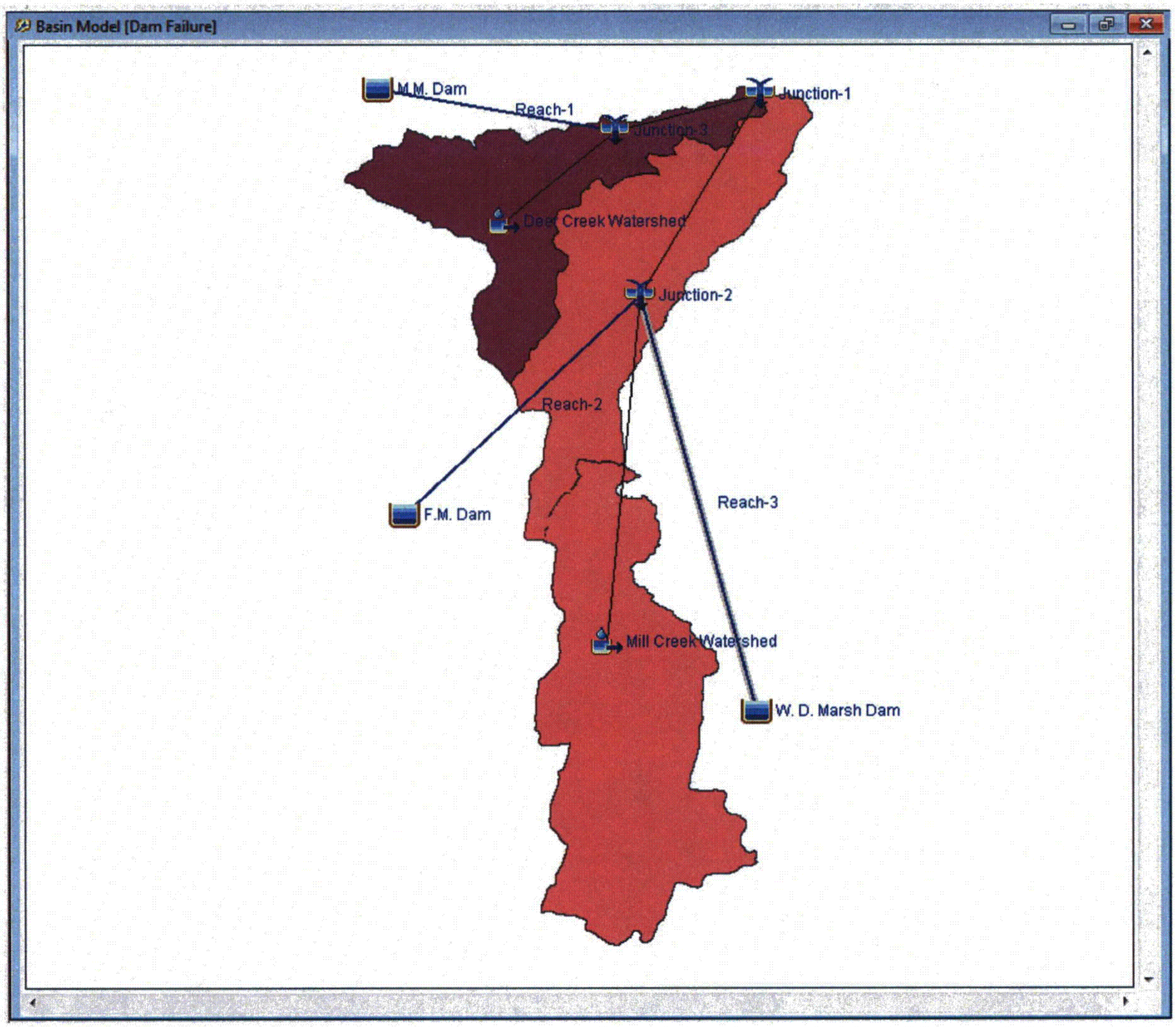
Note: Illegible text or features in this figure are not pertinent to the technical purposes of this document

Figure 3: Dam Locations



Note: Illegible text or features in this figure are not pertinent to the technical purposes of this document

Figure 4: HEC-HMS Basin Model



Note: Illegible text or features in this figure are not pertinent to the technical purposes of this document

Figure 5: Total Contributory Watershed Hydrograph with Dam Breach

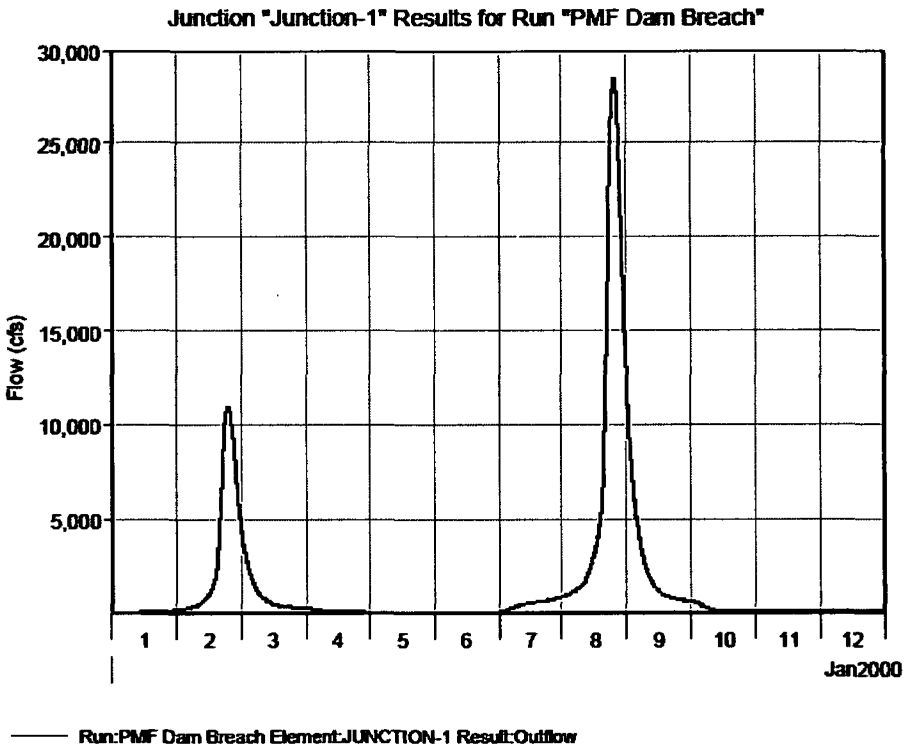


Figure 6: Mill Creek Watershed Hydrograph with Dam Breach

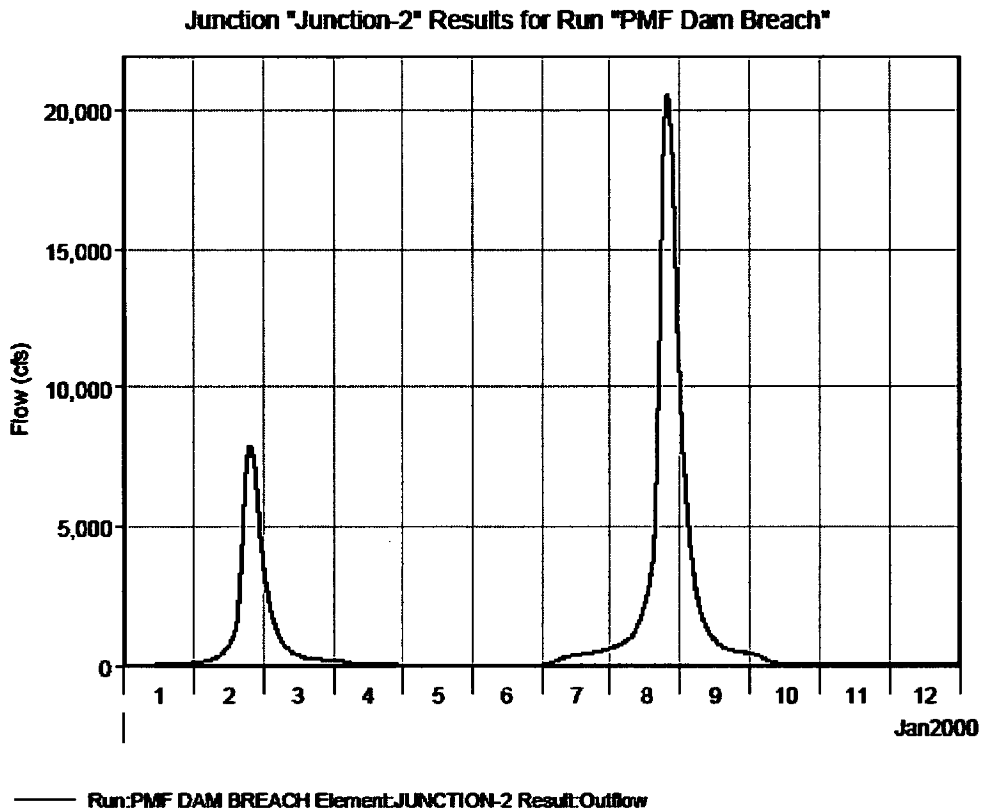


Figure 7: Deer Creek Watershed Hydrograph with Dam Breach

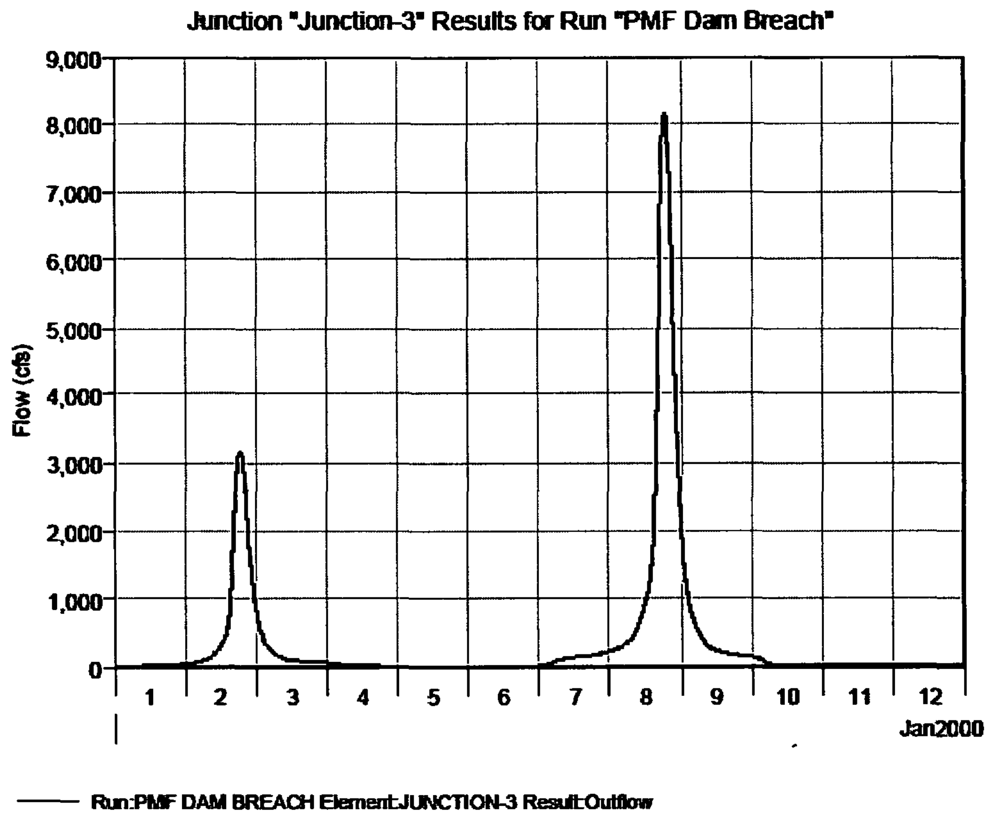
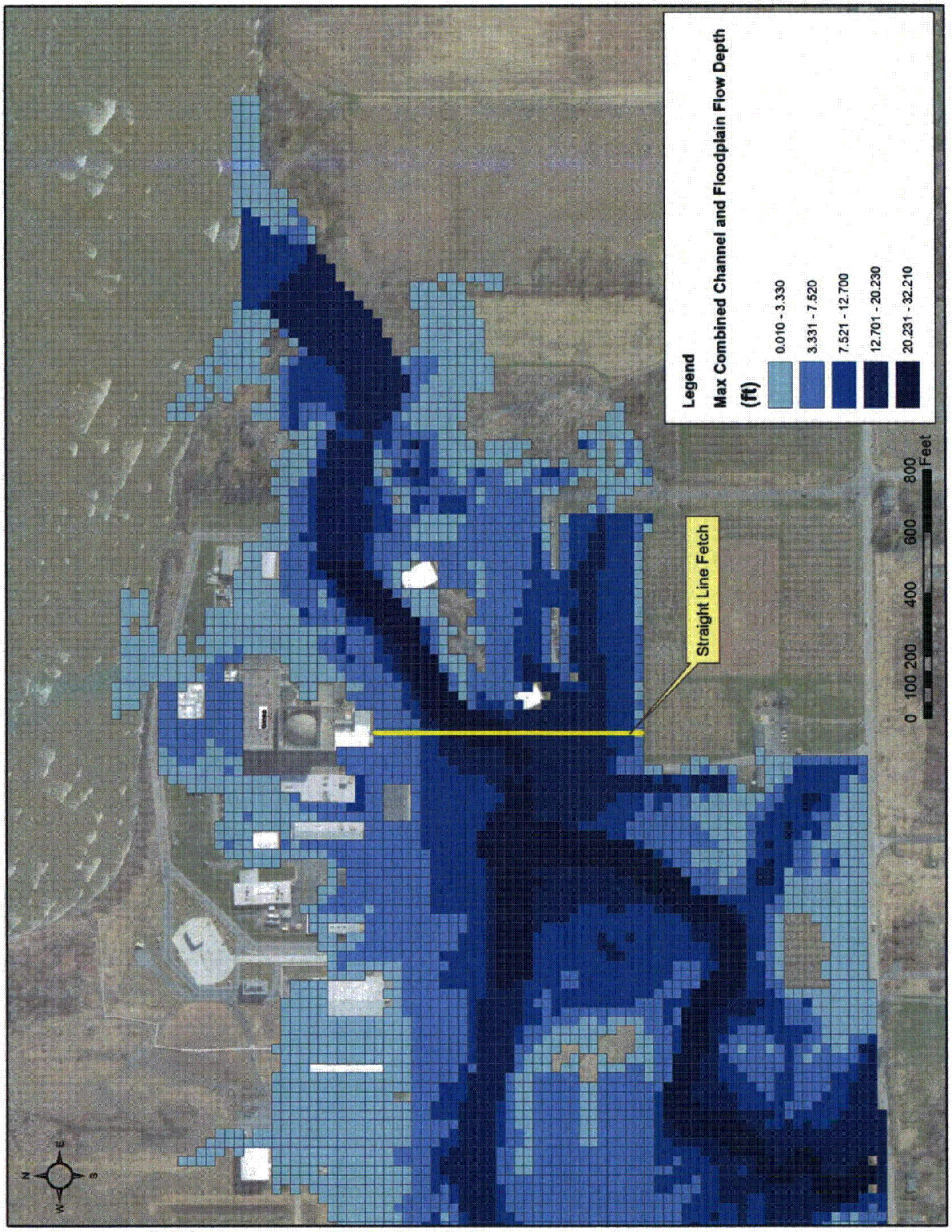


Figure 8: Transect Locations for Wave Overtopping

Note: Illegible text or features in this figure are not pertinent to the technical purposes of this document

Figure 9: Straight Line Fetch over Deer Creek

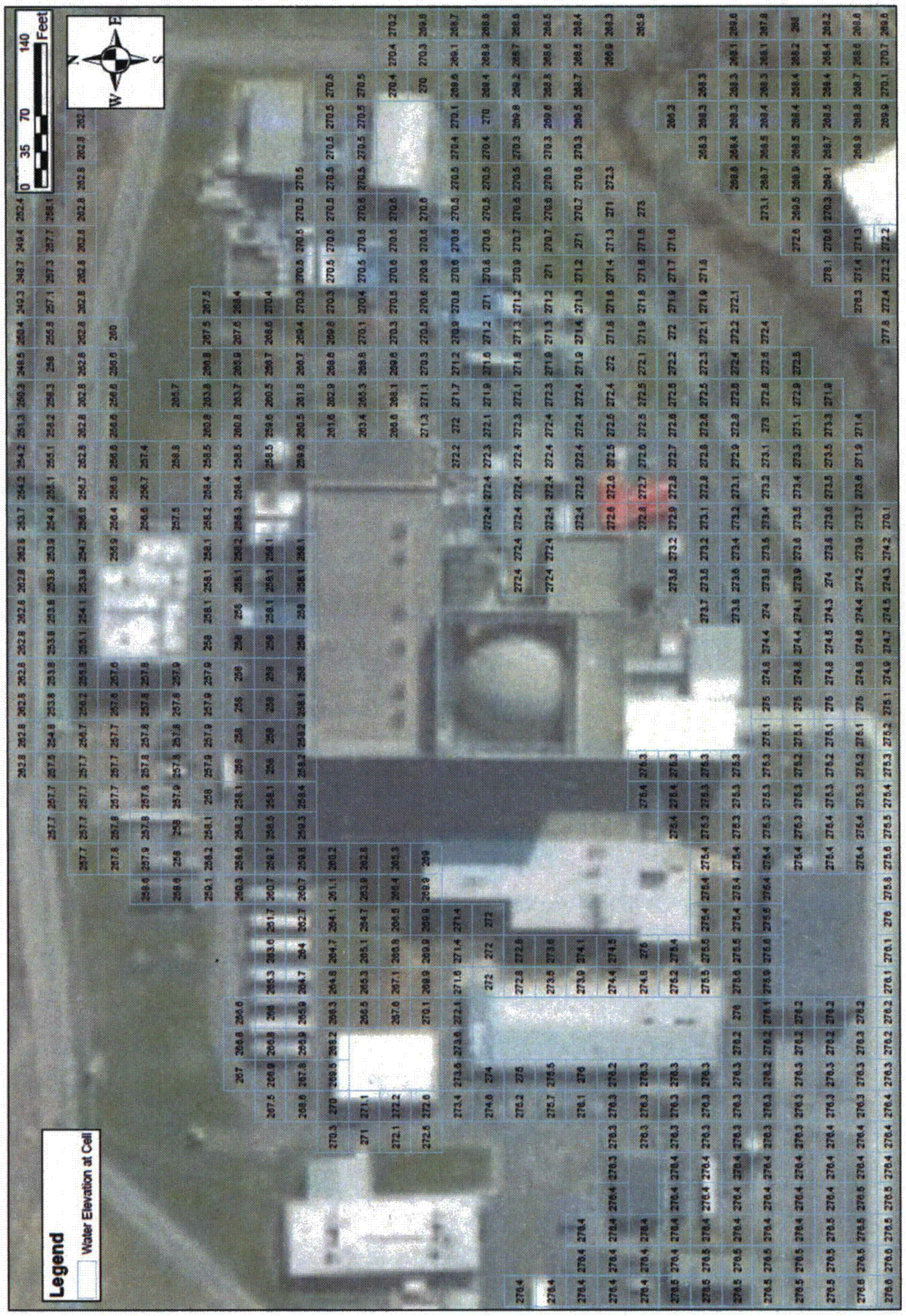


Note: Illegible text or features in this figure are not pertinent to the technical purposes of this document

Figure 10: NOAA Station Location Map

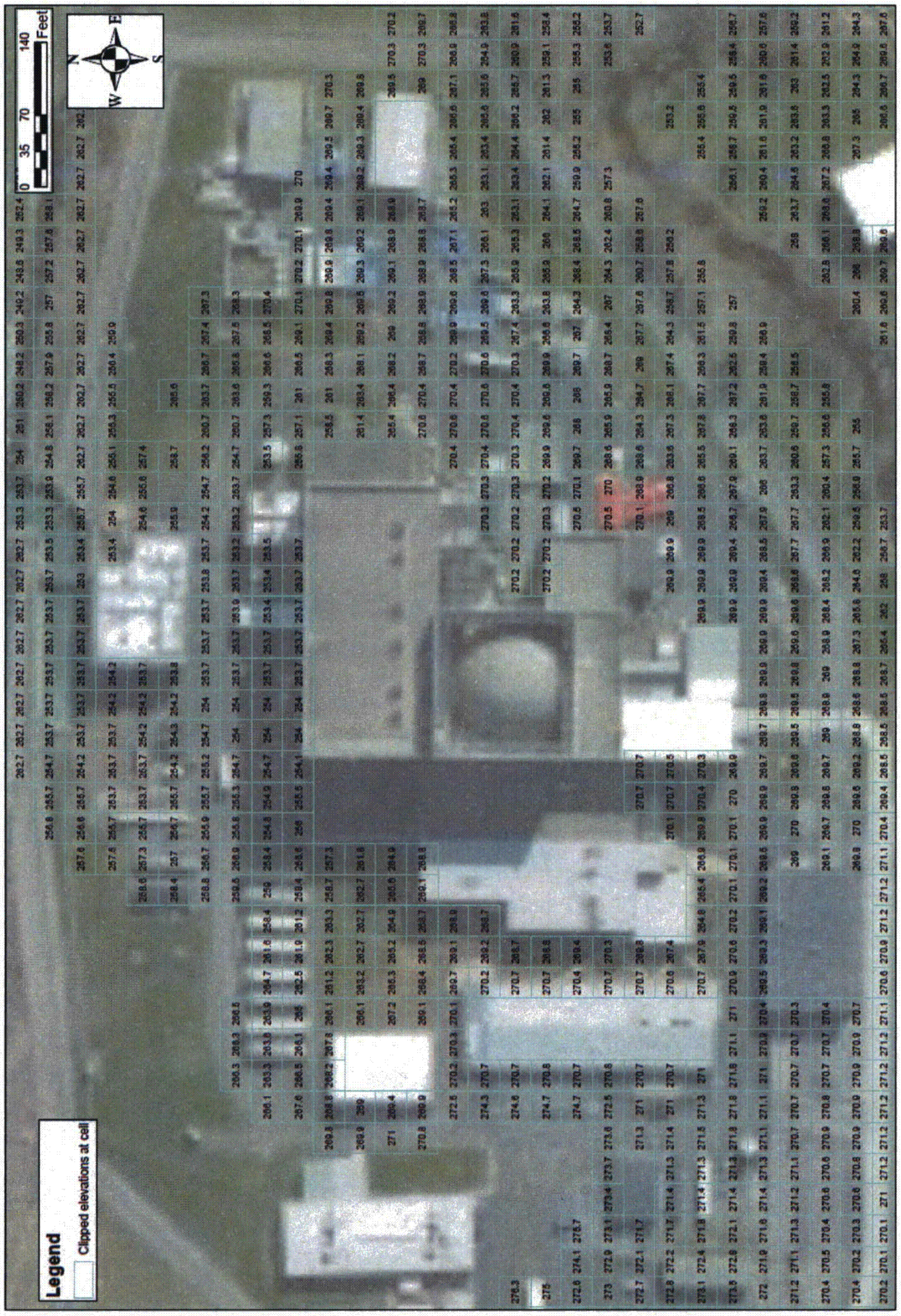
Note: Illegible text or features in this figure are not pertinent to the technical purposes of this document

Figure 11: Probable Maximum Water Surface Elevations at Ginna (ft, NGVD29) (Combination of PMF on Deer Creek and 25-year Surge with wind-wave activity and the maximum controlled water level in Lake Ontario)



Note: Illegible text or features in this figure are not pertinent to the technical purposes of this document

Figure 12: Elevation at Grid Cell (ft, NGVD29)



Note: Illegible text or features in this figure are not pertinent to the technical purposes of this document

AREVA

Figure 13: Probable Maximum Flow Depths at Ginna (ft, NGVD29) (Combination of PMF on Deer Creek and 25-year Surge with wind-wave activity and the maximum controlled water level in Lake Ontario)

Note: Illegible text or features in this figure are not pertinent to the technical purposes of this document

APPENDIX A: DATUM CONVERSION

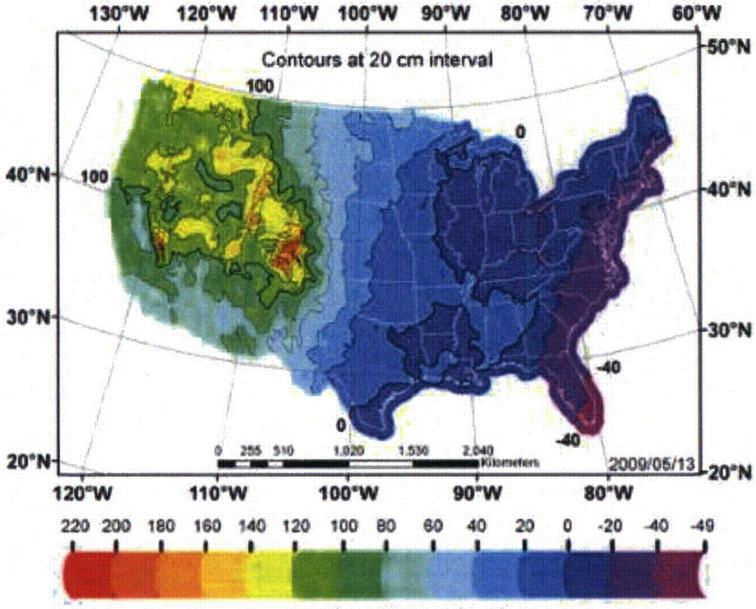
VERTCON - North American Vertical Datum Conversion

National Geodetic Survey

Method
Sign conventions
Questions ?
Height Conversion

VERTCON

NAVD 88 minus NGVD 29 Datum Shift Contours



See the text version of an **article** about VERTCON that appeared in the *Professional Surveyor* magazine, March 2004 Volume 24, Number 3

Questions concerning the VERTCON process may be mailed to NGS

Latitude: 43 16 40.00

Longitude: 77 18 32.00

NAVD 88 height: 0.00 FT

Datum shift(NAVD 88 minus NGVD 29): **-0.689 feet**

Converted to NGVD 29 height: 0.689 feet

APPENDIX B: NEW YORK STATE INVENTORY OF DAM

Google Maps and Earth

Some of DEC's map data can be viewed in Google Maps or Google Earth. To use Google Maps, simply click on any of the Google Maps icons below and the map will open an offsite link in your browser window. To use Google Earth, users must first download the software from Google (see link in right column under Links Leaving DEC's Website). Then, simply click on a Google Earth icon below to open or save the map (as a kmz file). Users new to Google Earth can also refer to DEC's tutorial (also in the right column).

Recreational Maps

Data Set	Google Earth	Google Maps (offsite links)	Description
Accessible Recreation Destinations			Accessible recreation destinations throughout New York State that are owned, maintained, or jointly managed by DEC offer a variety of recreational opportunities for people with disabilities.
Bird Conservation Areas			Bird Conservation Areas (BCA) offer excellent opportunities to observe birds and natural resources while supporting the integration of bird conservation interests into agency planning, management and research projects.
Boat Launch Sites			DEC-owned or operated boat launch sites offer public facilities for launching boats onto New York State waters.
Campgrounds			DEC campgrounds offer hiking trails, beaches, picnic areas, and a variety of other recreational activities.
Cross-Country Ski Trails			Cross-Country Skiing Trails are DEC trails that are approved for cross-country skiing.
DEC Lands			Lands under the care, custody, and control of DEC, include state forests, forest preserves, unique areas, and wildlife management areas.
DEC Roads			DEC Roads are roads located on DEC Lands that are approved for motor vehicle use. Please note: due to funding reductions, some temporary road closures are in effect.
Hiking Trails			Hiking Trails are DEC trails that are approved for foot travel.
Horse Trails			Horse Trails are DEC trails that are approved for horse travel.
Lake Contour Maps			The New York State lake contour map series provides information on depth contours, water surface area, mean depth, and available fish species for selected state waters.

Important Links
Google Earth instructions (PDF, 1.8 mB)
Links Leaving DEC's Website
Download Google Earth
Contact for this Page
Division of Public Affairs and Education
625 Broadway
Albany, NY 12233-4500
518-402-8013
Send us an email
This Page Covers
All of New York State

75%

NEW YORK STATE
DEPARTMENT OF
ENVIRONMENTAL CONSERVATION

New York State Inventory of Dams

Name of Dam: Macinnes Marsh Dam

State ID: 045-2684

Hazard Code: A

See below for hazard code definition

Year Completed: 1958

Most Recent Inspection: 1/16/2002

Location Information:				
County	Municipality	River or Stream	Latitude	Longitude
Wayne	Town of Ontario	TR-DEER CREEK	43° 16' 0.001" N	77° 21' 29.999" W

Type:	
Type of Construction	Purpose
RE - Earth	Other

Technical Information:	
Federal ID Number	NY11010
Dam Length (feet)	0
Dam Height (feet)	5
Spillway Width (feet)	8
Maximum Discharge (cubic feet per second)	139
Maximum Storage (acre-feet)	0
Normal Storage (acre-feet)	43
Reservoir Surface Area (acres)	19
Drainage Area (square miles)	0.22
Basin	CENTRAL LAKE ONTARIO
Date of Data Update	7/6/2009

Note -- The Hazard Code denotes the downstream hazard potential in the event of a dam failure:

- **C** = High Hazard
- **B** = Intermediate Hazard
- **A** = Low Hazard
- **0** = Null; No hazard code assigned

ery Date: 5/9/2011 43°13'45.16" N 77°

NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

New York State Inventory of Dams

Name of Dam: William Daly Marsh Dam

State ID: 045-1903

Hazard Code: A
See below for hazard code definition

Year Completed: 1953
Most Recent Inspection: 1/16/2002

Location Information:				
County	Municipality	River or Stream	Latitude	Longitude
Wayne	Town of Walworth	TR-MILL CREEK	43° 10' 18.001" N	77° 20' 48.001" W

Type:	
Type of Construction	Purpose
RE - Earth	Other

Technical Information:	
Federal ID Number	NY11001
Dam Length (feet)	0
Dam Height (feet)	6
Spillway Width (feet)	0
Maximum Discharge (cubic feet per second)	87
Maximum Storage (acre-feet)	18
Normal Storage (acre-feet)	8
Reservoir Surface Area (acres)	5
Drainage Area (square miles)	0.06
Basin	CENTRAL LAKE ONTARIO
Date of Data Update	7/6/2009

Note -- The Hazard Code denotes the downstream hazard potential in the event of a dam failure:

C = High Hazard
B = Intermediate Hazard
A = Low Hazard
0 = Null; No hazard code assigned

Also Note -- This data was exported from DEC's database on 08/30/11. Updates to data that occurred after 08/30/11 are not reflected here.

NEW YORK STATE
DEPARTMENT OF
ENVIRONMENTAL CONSERVATION

New York State Inventory of Dams

Name of Dam: Fruitland Mill Dam

State ID: 045-0330

Hazard Code: 0

See below for hazard code definition

Year Completed: 1800

Most Recent Inspection: 12/31/1901

Location Information:				
County	Municipality	River or Stream	Latitude	Longitude
Wayne	Town of Ontario	FISH CREEK	43° 13' 27.998" N	77° 20' 26.999" W

Type:	
Type of Construction	Purpose
ER - Rockfill	Other

Technical Information:	
Federal ID Number	NY10993
Dam Length (feet)	128
Dam Height (feet)	10
Spillway Width (feet)	0
Maximum Discharge (cubic feet per second)	0
Maximum Storage (acre-feet)	0
Normal Storage (acre-feet)	0
Reservoir Surface Area (acres)	0
Drainage Area (square miles)	0
Basin	CENTRAL LAKE ONTARIO
Date of Data Update	7/6/2009

Note -- The Hazard Code denotes the downstream hazard potential in the event of a dam failure:

C = High Hazard
B = Intermediate Hazard
A = Low Hazard
0 = Null: No hazard code assigned

Inventory of Dams - New York State (NYSDEC)

Metadata also available as

Metadata:

Identification_Information:
  Citation:
    Citation_Information:
      Originator: New York State Department of Environmental Conservation
      Originator: Division of Water
      Originator: Dam Safety Section
      Publication_Date: 20091125
      Title: Inventory of Dams - New York State (NYSDEC)
      Geospatial_Data_Presentation_Form: vector digital data
      Publication_Information:
        Publication_Place: Albany, NY
        Publisher: New York State Department of Environmental Conservation
      Online_Linkage:
        <http://www.nysgis.state.ny.us/gisdata/inventories/details.cfm?DSID=1130>
  Description:
    Abstract:
      A point file to show the location of dams in the New York State Inventory of Dams.
    Purpose:
      This dataset is used to show the location of dams in New York State's inventory of dams, and lists selected attributes of each dam.
    Supplemental_Information:
      1. While we try to maintain an accurate inventory, this data should not be relied upon for emergency response decision-making. We recommend that critical data, including dam location and hazard classification, be verified in the field. The presence or absence of a dam in this inventory does not indicate its regulatory status. Any corrections should be submitted to the Dam Safety Section with supporting information.
      2. There are approximately 17 dams in this dataset that do not have X Y locations.
  Time_Period_of_Content:
    Time_Period_Information:
      Single_Date/Time:
        Calendar_Date: 20110912
    Currentness_Reference: publication date

Status:
Progress: Complete
Maintenance_and_Update_Frequency: Annually
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -79.982799
East_Bounding_Coordinate: -72.112362
North_Bounding_Coordinate: 45.006295
South_Bounding_Coordinate: 40.426335
Keywords:
Theme:
Theme_Keyword_Thesaurus: ISO 19115 Topic Category
Theme_Keyword: environment
Theme_Keyword: 007
Theme_Keyword: inlandWaters
Theme_Keyword: 012
Theme_Keyword: structure
Theme_Keyword: 017
Theme_Keyword: utilitiesCommunication
Theme_Keyword: 019
Theme:
Theme_Keyword_Thesaurus: None
Theme_Keyword: custodial
Theme_Keyword: dam
Theme_Keyword: watercourse
Theme_Keyword: flood
Theme_Keyword: hydroelectric
Theme_Keyword: storm water
Theme_Keyword: recreation
Theme_Keyword: water supply
Place:
Place_Keyword_Thesaurus:
Geographic Names Information System
<http://geonames.usgs.gov/pls/gnispublic>
Place_Keyword: New York State
Access_Constraints: N/A
Use_Constraints:
1. The NYS DEC asks to be credited in derived products. 2. Secondary Distribution of the data is not allowed. 3. Any documentation provided is an integral part of the data set. Failure to use the documentation in conjunction with the digital data constitutes misuse of the data. 4. Although every effort has been made to ensure the accuracy of information, errors may be reflected in the data supplied. The user must be aware of data conditions and bear responsibility for the appropriate use of the information with respect to possible errors, original map scale, collection methodology, currency of data, and other conditions.
Point_of_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: New York State Department of Environmental Conservation
Contact_Person: Division of Water, Dam Safety Section
Contact_Address:

Address_Type: mailing and physical address
Address: 625 Broadway
Address: 4th Floor
City: Albany
State_or_Province: NY
Postal_Code: 12233-3504
Country: USA
Contact_Voice_Telephone: 518-402-8151
Data_Set_Credit: NYS DEC, Div. of Water, Dams Section
Security_Information:
Security_Classification_System: None
Security_Classification: Unclassified
Security_Handling_Description: None
Native_Data_Set_Environment:
Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 2; ESRI ArcCatalog 9.3.1.3500

Data_Quality_Information:
Logical_Consistency_Report: None
Completeness_Report: None
Lineage:
Process_Step:
Process_Description:
A feature class is created from data extracted from the Divison of Water's Dam Safety Section database. Latitude/Longitude in decimal degrees is calculated from the latitude/longitude degrees, minutes, seconds fields extracted from the database. Data is then projected to NAD83, NYTM Zone 18 from GCS, WGS 1984..
Process_Date: 20070501
Process_Step:
Process_Description:
Updated feature class created from updated data, using latittude and longitude coordinates from the dataset, converted into decimal degrees.
Process_Date: 20081027
Process_Step:
Process_Description:
Updated feature class with newest data set from Dam Safety. New data set consisted of various changes in field names and field structure. Metadata was updated accordingly.
Process_Date: 20091125
Process_Step:
Process_Description:
Updated feature class with newest data set from Dam Safety. New data set consisted of various changes in field names and field structure. Projected the data to UTM Zone 18. Metadata was updated accordingly.
Process_Date: 20110912

Spatial_Data_Organization_Information:
  Direct_Spatial_Reference_Method: Vector
  Point_and_Vector_Object_Information:
    SDTS_Terms_Description:
      SDTS_Point_and_Vector_Object_Type: Entity point
      Point_and_Vector_Object_Count: 6906

Spatial_Reference_Information:
  Horizontal_Coordinate_System_Definition:
    Planar:
      Grid_Coordinate_System:
        Grid_Coordinate_System_Name: Universal Transverse Mercator
        Universal_Transverse_Mercator:
          UTM_Zone_Number: 18
          Transverse_Mercator:
            Scale_Factor_at_Central_Meridian: 0.999600
            Longitude_of_Central_Meridian: -75.000000
            Latitude_of_Projection_Origin: 0.000000
            False_Easting: 500000.000000
            False_Northing: 0.000000
      Planar_Coordinate_Information:
        Planar_Coordinate_Encoding_Method: coordinate pair
        Coordinate_Representation:
          Abscissa_Resolution: 0.000100
          Ordinate_Resolution: 0.000100
        Planar_Distance_Units: meters
    Geodetic_Model:
      Horizontal_Datum_Name: North American Datum of 1983
      Ellipsoid_Name: Geodetic Reference System 80
      Semi-major_Axis: 6378137.000000
      Denominator_of_Flattening_Ratio: 298.257222
  Vertical_Coordinate_System_Definition:
    Altitude_System_Definition:
      Altitude_Datum_Name: NA
      Altitude_Resolution: 1.000000
      Altitude_Distance_Units: NA
      Altitude_Encoding_Method:
        Explicit elevation coordinate included with horizontal coordinates

---

Entity_and_Attribute_Information:
  Detailed_Description:
    Entity_Type:
      Entity_Type_Label: Inventory of Dams - New York State (NYSDEC)
      Entity_Type_Definition: Point Feature Class
      Entity_Type_Definition_Source: ESRI
    Attribute:
      Attribute_Label: OBJECTID

Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain:
Sequential unique whole numbers that are automatically generated.

Attribute:
Attribute_Label: COUNTY_NAM
Attribute_Definition: Name of New York State county in which the dam is located.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Unrepresentable_Domain: Names.

Attribute:
Attribute_Label: NAME_ONE
Attribute_Definition: Official dam name.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Unrepresentable_Domain: Names.

Attribute:
Attribute_Label: FEDERAL_ID
Attribute_Definition:
The National Dam Inspection Program ID Number in the Inventory of Dams. The first two characters are NY followed by a five digit serial number.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Codeset_Domain:
Codeset_Name: ID Number
Codeset_Source: National Dam Inspection Program

Attribute:
Attribute_Label: NAME_TWO
Attribute_Definition: Alternate dam name.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Unrepresentable_Domain: Names.

Attribute:
Attribute_Label: STATE_ID
Attribute_Definition:
Unique identifier incorporating quad sheet number and serial number of dam separated by a hyphen.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Unrepresentable_Domain: Unique identifier.

Attribute:
Attribute_Label: LAT_DEGREE
Attribute_Definition: Degrees latitude of dam location.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 90
Attribute_Units_of_Measure: degrees

Attribute:

Attribute_Label: LAT_MIN
Attribute_Definition: Minutes latitude of dam location.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 60
Attribute_Units_of_Measure: minutes

Attribute:
Attribute_Label: LAT_SEC
Attribute_Definition: Seconds latitude of dam location.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 60
Attribute_Units_of_Measure: seconds

Attribute:
Attribute_Label: LONG_DEGREE
Attribute_Definition: Degrees longitude of dam location.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 180
Attribute_Units_of_Measure: degrees

Attribute:
Attribute_Label: LONG_MIN
Attribute_Definition: Minutes longitude of dam location.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 60
Attribute_Units_of_Measure: minutes

Attribute:
Attribute_Label: LONG_SEC
Attribute_Definition: Seconds longitude of dam location.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 60
Attribute_Units_of_Measure: seconds

Attribute:
Attribute_Label: MUNI
Attribute_Definition:
The name of the municipality in which the dam is located. May accommodate more than one municipality, each one separated by a comma.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:

Unrepresentable_Domain: Names.
Attribute:
Attribute_Label: RIVER_STRE
Attribute_Definition:
The official name of the watercourse on which the dam is located. If the stream is not named, enter as a tributary to first larger, named stream in form: TR-stream name.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Unrepresentable_Domain: Names.
Attribute:
Attribute_Label: NR_CITY_NA
Attribute_Definition: Official name of the nearest downstream community.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Unrepresentable_Domain: Names.
Attribute:
Attribute_Label: NR_CITY_DI
Attribute_Definition:
Distance, to the nearest mile, from the dam to the nearest downstream community.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 9999999999
Attribute_Units_of_Measure: miles
Attribute:
Attribute_Label: CONSTR_TYP
Attribute_Definition:
Type of dam construction. Field can accommodate more than one construction type, each one separated by a comma.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: OT - Other
Enumerated_Domain_Value_Definition: Some other construction type.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: CB - Buttress
Enumerated_Domain_Value_Definition: The dam is a buttress construction type.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: CN - Concrete Gravity
Enumerated_Domain_Value_Definition: The dam is a concrete gravity construction type.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:

Enumerated_Domain:
Enumerated_Domain_Value: ER - Rockfill
Enumerated_Domain_Value_Definition: The dam is a rockfill construction type.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: LS - Laid Up Stone
Enumerated_Domain_Value_Definition: The dam is a laid up stone construction type.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: MS - Masonry
Enumerated_Domain_Value_Definition: The dam is a masonry construction type.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: MV - Multi-Arch
Enumerated_Domain_Value_Definition: The dam is a multi-arch construction type.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: RE - Earth
Enumerated_Domain_Value_Definition: The dam is an earth construction type.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: ST - Stone
Enumerated_Domain_Value_Definition: The dam is a stone construction type.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: TC - Timber Crib
Enumerated_Domain_Value_Definition: The dam is a timber crib construction type.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: VA - Arch
Enumerated_Domain_Value_Definition: The dam is an arch construction type.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute:
Attribute_Label: PURPOSES
Attribute_Definition:
The purpose for which the dam is used. Field may accommodate more than one

purpose, each one separated by a comma.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Water Supply - Other
Enumerated_Domain_Value_Definition: The dam is used for water supply other than primary source.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Debris Control
Enumerated_Domain_Value_Definition: The dam is used to control debris.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Fish & Wildlife Pond
Enumerated_Domain_Value_Definition: The dam is used to create fish and wildlife pond.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Hydroelectric
Enumerated_Domain_Value_Definition: The dam is used to produce hydroelectric power.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Irrigation
Enumerated_Domain_Value_Definition: The dam is used to supply water for irrigation.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Navigation
Enumerated_Domain_Value_Definition: The dam is used to supply water for navigation.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Other
Enumerated_Domain_Value_Definition: The dam is used for some other purpose.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Fire Protection, Livestock, or Farm Pond
Enumerated_Domain_Value_Definition:
The dam is used to supply water for fire protection, livestock,irrigation, or is a farm pond dam.
Enumerated_Domain_Value_Definition_Source: NYSDEC

Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Recreation
Enumerated_Domain_Value_Definition: The dam is used to contain water for recreation.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Water Supply - Primary
Enumerated_Domain_Value_Definition: The dam is used as a primary source water supply.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Tailings
Enumerated_Domain_Value_Definition: The dam is used to contain tailings waste.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Flood Control/Storm Water Management
Enumerated_Domain_Value_Definition:
The dam is used for flood control or for storm water management.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute:
Attribute_Label: YEARBUILT
Attribute_Definition:
The year original construction was completed, or the year of the latest major reconstruction.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Unrepresentable_Domain: Dates.
Attribute:
Attribute_Label: DAM_LENGTH
Attribute_Definition:
Crest length, in feet, of the dam. Total horizontal distance measured along the axis at the elevation of the top of the dam between the ends of the dam. This includes spillways, power house sections, and navigation locks where they form part of the dam retaining structure.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 9999999999
Attribute_Units_of_Measure: feet
Attribute:
Attribute_Label: DAM_HEIGHT
Attribute_Definition:
Height, in feet to the nearest foot, of the vertical distance of the dam from the lowest point on the crest of the dam to the lowest point in the original streambed.

Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 9999999999
Attribute_Units_of_Measure: feet

Attribute:
Attribute_Label: MAX_DISCHR
Attribute_Definition:
The number of cubic feet per second which the spillway is capable of discharging when the reservoir is at its maximum designed water surface elevation.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 9999999999
Attribute_Units_of_Measure: cubic feet per second

Attribute:
Attribute_Label: MAX_STORAG
Attribute_Definition:
Volume impounded by the dam, in acre feet, at the maximum attainable water surface elevation.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 9999999999
Attribute_Units_of_Measure: acre feet

Attribute:
Attribute_Label: NORMAL_STO
Attribute_Definition:
Volume impounded by the dam, in acre feet, at the elevation of a single or service spillway.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 9999999999
Attribute_Units_of_Measure: acre feet

Attribute:
Attribute_Label: SURFACE_AR
Attribute_Definition:
Reservoir surface area, in acres, at pool elevation of a single or service spillway.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 9999999999
Attribute_Units_of_Measure: acres

Attribute:
Attribute_Label: DRAINAGE_A
Attribute_Definition:
The area that draws to the dam on a river or stream, in square miles.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 9999999999
Attribute_Units_of_Measure: square miles
Attribute:
Attribute_Label: OWNERS
Attribute_Definition:
The name of the owner(s). Field can accommodate more than one owner, each one separated by a comma.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Unrepresentable_Domain: Names.
Attribute:
Attribute_Label: P1_INSP_DE
Attribute_Definition:
Army Corps of Engineers Phase I Inspection Report program results description.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Unsafe Stability
Enumerated_Domain_Value_Definition:
Phase I Inspection rated the dam unsafe due to inadequate stability.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Unsafe Spillway Capacity
Enumerated_Domain_Value_Definition:
Phase I Inspection rated the dam unsafe due to inadequate spillway capacity.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Unsafe Emergency
Enumerated_Domain_Value_Definition: Phase I Inspection rated the dam "Unsafe - Emergency"
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: OK
Enumerated_Domain_Value_Definition: Phase I Inspection found that the dam met safety criteria.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:

Enumerated_Domain_Value: None
Enumerated_Domain_Value_Definition: No Phase I inspection report present.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Null/Blank
Enumerated_Domain_Value_Definition: No Phase I inspection report present
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute:
Attribute_Label: LST_INSP_D
Attribute_Definition:
Date of the most recent NYSDEC Dam Safety Section inspection of the dam.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Unrepresentable_Domain: Dates.
Attribute:
Attribute_Label: HAZARD_COD
Attribute_Definition: The hazard classification code of the dam.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: A
Enumerated_Domain_Value_Definition:
Class "A" or "Low Hazard" dam: A dam failure is unlikely to result in damage to anything more than isolated or unoccupied buildings, undeveloped lands, minor roads such as town or county roads; is unlikely to result in the interruption of important utilities, including water supply, sewage treatment, fuel, power, cable or telephone infrastructure; and/or is otherwise unlikely to pose the threat of personal injury, substantial economic loss or substantial environmental damage.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: B
Enumerated_Domain_Value_Definition:
Class "B" or "Intermediate Hazard" dam: A dam failure may result in damage to isolated homes, main highways, and minor railroads; may result in the interruption of important utilities, including water supply, sewage treatment, fuel, power, cable or telephone infrastructure; and/or is otherwise likely to pose the threat of personal injury and/or substantial economic loss or substantial environmental damage. Loss of human life is not expected.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: C
Enumerated_Domain_Value_Definition:
Class "C" or "High Hazard" dam: A dam failure may result in

widespread or serious damage to home(s); damage to main highways, industrial or commercial buildings, railroads, and/or important utilities, including water supply, sewage treatment, fuel, power, cable or telephone infrastructure; or substantial environmental damage; such that the loss of human life or widespread substantial economic loss is likely.

Enumerated_Domain_Value_Definition_Source: NYSDEC

Attribute_Domain_Values:

Enumerated_Domain:

Enumerated_Domain_Value: D

Enumerated_Domain_Value_Definition:

Class "D" or "Negligible or No Hazard" dam: A dam that has been breached or removed, or has failed or otherwise no longer materially impounds waters, or a dam that was planned but never constructed. Class"D" dams are considered to be defunct dams posing negligible or no hazard. The department may retain pertinent records regarding such dams.

Enumerated_Domain_Value_Definition_Source: NYSDEC

Attribute_Domain_Values:

Enumerated_Domain:

Enumerated_Domain_Value: 0

Enumerated_Domain_Value_Definition: Hazard Code has not been assigned

Enumerated_Domain_Value_Definition_Source: NYSDEC

Attribute:

Attribute_Label: QUAD

Attribute_Definition:

A letter (A, B, C, D) to designate on which 7.5 quad of the original 15 minute quad the dam is located.

Attribute_Definition_Source: NYSDEC

Attribute_Domain_Values:

Enumerated_Domain:

Enumerated_Domain_Value: A

Enumerated_Domain_Value_Definition: Top left.

Enumerated_Domain_Value_Definition_Source: NYSDEC

Attribute_Domain_Values:

Enumerated_Domain:

Enumerated_Domain_Value: B

Enumerated_Domain_Value_Definition: Top right.

Enumerated_Domain_Value_Definition_Source: NYSDEC

Attribute_Domain_Values:

Enumerated_Domain:

Enumerated_Domain_Value: C

Enumerated_Domain_Value_Definition: Bottom left.

Enumerated_Domain_Value_Definition_Source: NYSDEC

Attribute_Domain_Values:

Enumerated_Domain:

Enumerated_Domain_Value: D

Enumerated_Domain_Value_Definition: Bottom right.

Enumerated_Domain_Value_Definition_Source: NYSDEC

Attribute:

Attribute_Label: BASIN_NAME
Attribute_Definition: Name of drainage basin in which the dam is located.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Unrepresentable_Domain: Names.

Attribute:
Attribute_Label: REGION_NAM
Attribute_Definition: DEC region in which the dam is located.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Unrepresentable_Domain: Names.

Attribute:
Attribute_Label: DIKE_LENGT
Attribute_Definition:
Crest length, in feet, of all closures, retaining or diversion dikes not directly attached to main dam.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 9999999
Attribute_Units_of_Measure: feet

Attribute:
Attribute_Label: SPILLWY_T1
Attribute_Definition: Single or service spillway.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Uncontrolled Overflow
Enumerated_Domain_Value_Definition: Uncontrolled Overflow.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Drop Inlet or Riser
Enumerated_Domain_Value_Definition: Drop Inlet or Riser.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Drop Structure
Enumerated_Domain_Value_Definition: Drop Structure.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Culvert - No Control
Enumerated_Domain_Value_Definition: Culvert - No Control.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Gated
Enumerated_Domain_Value_Definition: Gated.
Enumerated_Domain_Value_Definition_Source: NYSDEC

Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Uncontrolled Overflow with flashboards
Enumerated_Domain_Value_Definition: Uncontrolled Overflow with flashboards.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Stop Log sluice
Enumerated_Domain_Value_Definition: Stop Log sluice.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Taintor Gate
Enumerated_Domain_Value_Definition: Taintor Gate.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Other
Enumerated_Domain_Value_Definition: Other.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Null/Blank
Enumerated_Domain_Value_Definition: Single or service spillway information is not available
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: None
Enumerated_Domain_Value_Definition: Single or service spillway information is not available
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute:
Attribute_Label: SPILLWY_WD
Attribute_Definition: Total width, in feet, of all spillway facilities.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 9999999999
Attribute_Units_of_Measure: feet
Attribute:
Attribute_Label: SCS
Attribute_Definition: Dam designed or financed by USDA Soil Conservation Service.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Y
Enumerated_Domain_Value_Definition: Dam designed or financed by USDA Soil Conservation Service.

Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: N
Enumerated_Domain_Value_Definition: Dam not designed or financed by USDA Soil Conservation Service.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute:
Attribute_Label: EAP_DOC_DA
Attribute_Definition:
Date on which the dams' emergency action plan was instituted or revised. Required of all high hazard dams.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Unrepresentable_Domain: Dates.
Attribute:
Attribute_Label: LAST_MODIFI
Attribute_Definition: The most recent date information was edited.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Unrepresentable_Domain: Dates.
Attribute:
Attribute_Label: LAT2
Attribute_Definition: Decimal Degrees latitude of dam location.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 180
Attribute_Units_of_Measure: decimal degrees
Attribute:
Attribute_Label: LONG2
Attribute_Definition: Decimal Degrees longitude of dam location.
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: 0
Range_Domain_Maximum: 180
Attribute_Units_of_Measure: decimal degrees
Attribute:
Attribute_Label: SHAPE
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
Attribute:
Attribute_Label: SPILLWY_T2
Attribute_Definition_Source: NYSDEC
Attribute_Definition: Auxillary or emergency spillway.
Attribute_Domain_Values:
Enumerated_Domain:

Enumerated_Domain_Value: Grassed Earth Channel
Enumerated_Domain_Value_Definition: Grassed Earth Channel.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Channel cut in rock
Enumerated_Domain_Value_Definition: Channel cut in rock.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Concrete Overflow
Enumerated_Domain_Value_Definition: Concrete Overflow.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Concrete Overflow with Flashboards
Enumerated_Domain_Value_Definition: Concrete Overflow with Flashboards.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Other
Enumerated_Domain_Value_Definition: Other.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: None
Enumerated_Domain_Value_Definition: Dam does not have an auxiliary or emergency spillway
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Null/Blank
Enumerated_Domain_Value_Definition: Auxiliary or emergency spillway information is not available
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute:
Attribute_Label: EAP_STATUS
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: On file
Enumerated_Domain_Value_Definition: EAP is on file
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Definition: Emergency Action Plan Status
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: None
Enumerated_Domain_Value_Definition: There is no EAP on file.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute:

Attribute_Label: EAP_LST_EX
Attribute_Definition_Source: NYSDEC
Attribute_Definition: Last time an EAP was exercised.
Attribute_Domain_Values:
Unrepresentable_Domain: Dates.
Attribute:
Attribute_Label: EAP_REQ
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Y
Enumerated_Domain_Value_Definition: Yes. An EAP is required.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Definition: An EAP is required for this dam.
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: N
Enumerated_Domain_Value_Definition: No. An EAP is not required.
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute:
Attribute_Label: LST_INSP_D
Attribute_Definition_Source: NYSDEC
Attribute_Definition: Last time a dam was inspected.
Attribute_Domain_Values:
Unrepresentable_Domain: Dates.
Attribute:
Attribute_Label: LAST_DEFIC
Attribute_Definition_Source: NYSDEC
Attribute_Definition: Last deficiencies noted during the last inspection.
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: BR
Enumerated_Domain_Value_Definition: Man made breach
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: FA
Enumerated_Domain_Value_Definition: Natural failure, breached, or cause unknown
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: MA
Enumerated_Domain_Value_Definition: Dam has maintenance issues
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: NA
Enumerated_Domain_Value_Definition: No dam stability analysis
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:

Enumerated_Domain:
Enumerated_Domain_Value: NC
Enumerated_Domain_Value_Definition: Incompleted/not built
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: NL
Enumerated_Domain_Value_Definition: Dam no longer exists
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: None
Enumerated_Domain_Value_Definition: No deficiencies were observed
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: NS
Enumerated_Domain_Value_Definition: No spillway capacity analysis
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: SA
Enumerated_Domain_Value_Definition: Dam has inadequate structural stability
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: SC
Enumerated_Domain_Value_Definition: Dam has insufficient spillway capacity
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: SE
Enumerated_Domain_Value_Definition: Dam has seepage
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: SR
Enumerated_Domain_Value_Definition: Dam has structural issues
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute:
Attribute_Label: FERC_STATU
Attribute_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: A
Enumerated_Domain_Value_Definition: Application submitted
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:

Enumerated_Domain_Value: E
Enumerated_Domain_Value_Definition: FERC Licensed Exempt Dam
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: L
Enumerated_Domain_Value_Definition: FERC Licensed Dam
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute_Definition: Federal Energy Regulatory Commission status, if applicable
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: Null
Enumerated_Domain_Value_Definition: Not Applicable
Enumerated_Domain_Value_Definition_Source: NYSDEC
Attribute:
Attribute_Label: FERC_INFO
Attribute_Definition_Source: NYSDEC
Attribute_Definition: FERC Project Number
Attribute_Domain_Values:
Unrepresentable_Domain: Unique Identifier
Overview_Description:
Entity_and_Attribute_Overview:
The names of fields listed in the Attribute Table are the exact column headings in the DAMS Point Attribute Table. Originally, ArcGIS only allowed use of ten characters for field names. The layerfile is running off of aliases. The longer more descriptive names follow some of the field names in the definition.
Entity_and_Attribute_Detail_Citation: Dam Safety Section

Distribution_Information:
Distributor:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: New York State Department of Environmental Conservation
Contact_Person: Division of Information Services, GIS Unit
Contact_Address:
Address_Type: mailing and physical address
Address: 625 Broadway
Address: 3rd Floor
City: Albany
State_or_Province: NY
Postal_Code: 12233-2750
Country: USA
Contact_Voice_Telephone: (518) 402-9860
Contact_Facsimile_Telephone: (518) 402-9031
Contact_Electronic_Mail_Address: enterpriseGIS@gw.dec.state.ny.us
Resource_Description: New York State Inventory of Dams
Distribution_Liability:
New York State Department of Environmental Conservation (NYSDEC) provides these

geographic data "as is". NYSDEC makes no guarantee or warranty concerning the accuracy of information contained in the geographic data. NYSDEC further makes no warranty, either expressed or implied, regarding the condition of the product or its fitness for any particular purpose. The burden for determining fitness for use lies entirely with the user. Although these data have been processed successfully on a computer system at NYSDEC, no warranty expressed or implied is made regarding the accuracy or utility of the data on any other system or for general or scientific purposes. This disclaimer applies both to individual use of the data and aggregate use with other data. It is strongly recommended that careful attention be paid to the contents of the metadata file associated with these data. NYSDEC shall not be held liable for improper or incorrect use od the data described and/or contained herein.

Standard_Order_Process:
- *Digital_Form:*
  - *Digital_Transfer_Information:*
    - *Format_Name:* SHP
    - *Format_Version_Date:* 20080912
    - *Transfer_Size:* 0.183
  - *Digital_Transfer_Option:*
    - *Online_Option:*
      - *Computer_Contact_Information:*
        - *Network_Address:*
          - *Network_Resource_Name:* unknown
- *Fees:* none

Metadata_Reference_Information:
- *Metadata_Date:* 20111012
- *Metadata_Contact:*
  - *Contact_Information:*
    - *Contact_Organization_Primary:*
      - *Contact_Organization:* New York State Department of Environmental Conservation
      - *Contact_Person:* Division of Information Services, GIS Unit
    - *Contact_Address:*
      - *Address_Type:* mailing and physical address
      - *Address:* 625 Broadway
      - *Address:* 3rd Floor
      - *City:* Albany
      - *State_or_Province:* NY
      - *Postal_Code:* 12233-2750
      - *Country:* USA
    - *Contact_Voice_Telephone:* (518) 402-9860
    - *Contact_Facsimile_Telephone:* (518) 402-9031
    - *Contact_Electronic_Mail_Address:* enterpriseGIS@gw.dec.state.ny.us
- *Metadata_Standard_Name:* FGDC Content Standards for Digital Geospatial Metadata
- *Metadata_Standard_Version:* FGDC-STD-001-1998
- *Metadata_Time_Convention:* local time
- *Metadata_Extensions:*
  - *Online_Linkage:* <http://www.esri.com/metadata/esriprof80.html>
  - *Profile_Name:* ESRI Metadata Profile

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APPENDIX C: BREACH PARAMETER CALCULATIONS

FERC
FEDERAL ENERGY REGULATORY COMMISSION

Engineering Guidelines for the Evaluation of Hydropower Projects

Updated: June 28, 2010

Preface

These engineering guidelines have been prepared by the Office of Energy Projects (OEP) to provide guidance to the technical Staff in the processing of applications for license and in the evaluation of dams under Part 12 of the Commission's regulations. The Guidelines will also be used to evaluate proposed modifications or additions to existing projects under the jurisdiction of the Federal Energy Regulatory Commission (Commission). Staff technical personnel consist of the professional disciplines (e.g. professional engineers and geologists) that have the responsibility for reviewing studies and evaluating designs prepared by owners or developers of dams.

The guidelines are intended to provide technical personnel of the Office of Energy Projects, including the Regional Office and Washington Office personnel, with procedures and criteria for the engineering review and analysis of projects over which the Commission has jurisdiction. In addition, these guidelines should be used by staff in the evaluation of consultant or licensee/exemptee conducted studies. The guidance is intended to cover the majority of studies usually encountered by Staff. However, special cases may require deviation from, or modification of, the guidelines. When such cases arise, Staff must determine the applicability of alternate criteria or procedures based upon their experience and must exercise sound engineering judgment when considering situations not covered by the guidelines. The alternate procedures, or criteria, used in these situations should be justified and accompanied by any suggested changes for incorporation in the guidelines. Since every dam site and hydropower related structure is unique, individual design considerations and construction treatment will be required. Technical judgment is therefore required in most analytical studies.

These guidelines are not a substitute for good engineering judgment, nor are the procedures recommended herein to be applied rigidly in place of other analytical solutions to engineering problems encountered by staff. Staff should keep in mind that the engineering profession is not limited to a specific solution to each problem, and that the results are the desired end to problem solving.

These guidelines are primarily intended for internal use by OEP staff, but also provide licensees, exemptees, and applicants with general guidance that should be considered when presenting any studies presented to the Commission under Parts 4 and 12 of the Regulations (18 CFR, Parts 4 and 12). When any portions of the Guidelines becomes outdated, obsolete, or needs revision for any reason, it will be revised and supplemented as necessary. Comments on, or recommended changes, in these Guidelines should be forwarded to the Director of the Division of Inspections for consideration and possible inclusion in future updates. New pages will be prepared and issued with instructions for page replacements.

CHAPTER II

SELECTING AND ACCOMMODATING INFLOW DESIGN FLOODS FOR DAMS

October 1993

TABLE 1
SUGGESTED BREACH PARAMETERS
(Definition Sketch Shown in Figure 1)

Parameter	Value	Type of Dam
Average width of Breach (BR) (See Comment No. 1)*	$\bar{BR}$ = Crest Length	Arch
	$\bar{BR}$ = Multiple Slabs	Buttress
	$\bar{BR}$ = Width of 1 or more Usually $\bar{BR} \le 0.5$ W	Masonry, Gravity Monoliths,
	HD $\le \bar{BR} \le$ 5HD .... (usually between .... 2HD & 4HD)	Earthen, Rockfill, Timber Crib
	$\bar{BR} \ge$ 0.8 x Crest .... Length	Slag, Refuse
Horizontal Component of Side Slope of Breach (Z) (See Comment No. 2)*	$0 \le Z \le$ slope of valley walls ...	Arch
	Z = O	Masonry, Gravity Timber Crib, Buttress
	$\frac{1}{4} \le Z \le 1$	Earthen (Engineered, Compacted)
	$1 \le Z \le 2$	Slag, Refuse (Non-Engineered)
Time to Failure (TFH) (in hours) (See Comment No. 3)*	TFH $\le$ 0.1	Arch
	0.1 $\le$ TFH $\le$ 0.3	Masonry, Gravity, Buttress
	0.1 $\le$ TFH $\le$ 1.0	Earthen (Engineered, Compacted) Timber Crib
	0.1 $\le$ TFH $\le$ 0.5	Earthen (Non Engineered Poor Construction)
	0.1 $\le$ TFH $\le$ 0.3	Slag, Refuse

Definition:

HD - Height of Dam
Z - Horizontal Component of Side Slope of Breach
BR - Average Width of Breach
TFH - Time to Fully Form the Breach
W - Crest Length

Note: See Page 2-A-12 for definition Sketch

**Comments: See Page 2-A-10 - 2-A-11*

STATE OF COLORADO
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DIVISION OF WATER RESOURCES

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(See Figures 1&2)

$\boldsymbol{H_b}$ = Height of breach in feet, which is the vertical distance between the dam crest and breach invert.

$\boldsymbol{H_w}$ = Maximum depth of water stored behind the breach in feet (usually depth from emergency spillway crest down to breach invert for a full, fair-weather breach)

$\boldsymbol{V_w}$ = Reservoir volume stored corresponding to H_w in acre-feet (AF)

BFF (Breach Formation Factor) = H_wV_w in acre-feet^2 – used for MacDonald & Langridge-Monopolis and Washington State methods only.

$\boldsymbol{V_{er}}$ = Volume of dam eroded in cubic yards during a breach. Used for MacDonald & Langridge-Monopolis and Washington State methods only. This is the same as $B_{avg}W_{avg}$ for a full breach or D^2L for a piping only failure (variables defined below).

$\boldsymbol{B_{avg}}$ = Average breach width in feet. For a trapezoidal section, this is the width of the breach at the mid-point, $H_b/2$.

$\boldsymbol{Z_b}$ = Side slopes of breach (Z_b Horizontal: 1 Vertical).

$\boldsymbol{Z_d}$ = slopes of downstream face of the embankment (Z_d Horizontal: 1 Vertical).

$\boldsymbol{Z_u}$ = slope of the upstream face of the embankment (Z_u Horizontal: 1 Vertical).

$\boldsymbol{Z_t}$ = sum of the upstream and downstream embankment slopes, $Z_u + Z_d$

$\boldsymbol{B_b}$ = breach bottom width in feet: $B_{avg} - H_bZ_b$

$\boldsymbol{W_{avg}}$ = Average width of dam in direction of flow (feet). This is the width at the mid-point of H_b: $W_{avg} = C + H_b\frac{(Z_u+Z_d)}{2}$

$\boldsymbol{T_f}$ = breach development time in hours.

$\boldsymbol{C}$ = width of the dam crest in feet.

$\boldsymbol{g}$ = acceleration due to gravity, which equals 32.2 feet/sec^2

SI= Storage Intensity = V_w/H_w acre-feet/foot

ER = Erosion Rate = B_{avg}/T_f feet/hour

$\boldsymbol{L}$ = Length of piping hole, feet

$\boldsymbol{D}$ = Piping hole height/width (assumed square), feet

$\boldsymbol{H_p}$ = Height from center of piping hole to dam crest = $H_b - \frac{D}{2}$

$\boldsymbol{A_s}$ = Surface area of reservoir (acres) at reservoir level corresponding to H_w

$\boldsymbol{Q}$ = Discharge in cfs

$\boldsymbol{Q_p}$ = Peak dam break discharge at the dam in cfs

$\boldsymbol{Q_r}$ = Routed peak discharge in cfs at a certain distance, X, downstream of the dam

$\boldsymbol{X}$ = Distance downstream from the dam along the floodplain in miles

$\boldsymbol{D_{50}}$ = Mean soil particle diameter in millimeters

$\boldsymbol{A}$ = Area of the piping hole in square feet: D^2

$\boldsymbol{C_p}$ = Piping orifice coefficient

$\boldsymbol{C_w}$ = Weir coefficient

$\boldsymbol{f}$= Darcy friction factor

γ = Instantaneous flow reduction factor = 23.4 A_s/B_{avg}

$\boldsymbol{K_o}$ = Froehlich Failure Mode Factor

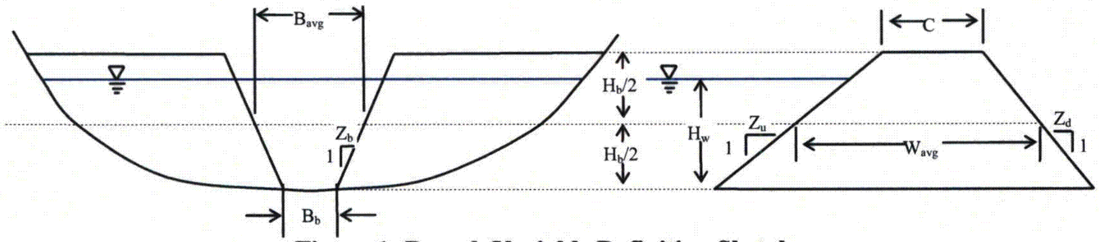

Figure 1- Breach Variable Definition Sketch

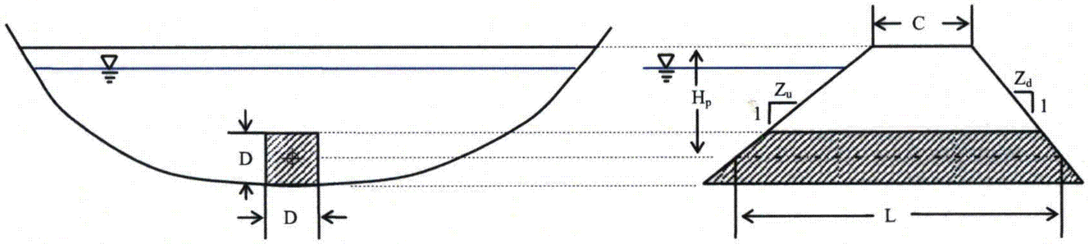

Figure 2 – Piping Hole Variable Definition Sketch

estimate of flood magnitude and velocity at critical locations. HEC-RAS is the most widely used hydraulic model for dam safety analyses in the United States and can be utilized for steady and unsteady flow analyses. The latest versions of HEC-RAS (since version 3.0) have a parametric dam breach routine that can calculate a breach outflow hydrograph within an unsteady flow simulation.

Another hydraulic model that has been widely used for unsteady flow analyses is the NWS DAMBRK model. The BOSS Corporation has added a graphical user interface while keeping the same numeric algorithm to make the model more user-friendly. This version is called BOSS DAMBRK. The model is based upon the same basic unsteady routing hydraulic principles as HEC-RAS, but DAMBRK was specifically developed for modeling dam failures. The cross-section input requirements for routing dam break floods require the same number of points to represent every cross section, which limits its usefulness.

6.0 A Tiered Dam Breach Analysis Structure

Given the wide range of conditions that could exist at a dam and in its failure path, and the modeling options available, there are many choices to be made while performing a dam breach analysis for a hazard classification study or to develop inundation maps for emergency preparedness documents. Because dam breach analyses will not always require the most sophisticated tools available, a tiered approach is recommended. The tiered approach matches the appropriate level of analysis with a given situation. The goal is to make the most efficient use of time and available tools while producing results that are appropriately conservative.

Table 1 shows a matrix of the tiered dam breach analysis structure. As shown, various tools can be utilized in part or all together, depending on the nature of the analysis that is required. Rows in the table represent the level of analysis and the columns represent a four-step breach analysis process. In general, as the level of analysis increases, so does the level of effort (time) needed to complete it. However, as the analysis increases in complexity, less conservative assumptions can be used, and the results are considered more accurate.

6.1 Screening

Assuming that a presumptive determination (by inspection) of hazard classification is not practical, the first level of analysis is Screening. Screening is meant to be a cursory, yet conservative level of analysis that can be performed rapidly. The analysis ignores dam break hydrograph development. The breach parameters determined from empirical methods are calculated and used for input into the SMPDBK peak discharge equation, or an orifice equation assuming instantaneous piping hole formation.

Empirical routing equations or nomographs can be used to estimate the attenuation of the flood wave downstream of the dam. One empirical routing equation was developed by the USBR in 1982 "Guidelines for Defining Inundation Areas Downstream from Bureau of Reclamation Dams". This equation follows:

$$Q_r = 10^{log(Q_p)-0.01X}$$

Where:

X = distance in miles downstream of the dam measured along the flood plain.
Q_r= peak discharge in cfs corresponding to distance X.
Q_p= peak dam break discharge at the dam in cfs.

Table 1 - Tiered Dam Breach Analysis Structure

Level of Analysis	Breach Parameter Estimation (Size/Shape and Failure Time)	Breach Hydrograph Estimation	Breach Hydrograph Routing	Hydraulics at Critical Section(s)
Screening	Empirical Equations	Peak Breach Discharge from SMPDBK	Empirical Routing Equations or Nomographs	Normal Depth
Simple	Empirical Equations	Parametric Model (HEC-1 or HEC-HMS)	Hydrologic Model (HEC-1 or HEC-HMS)	Steady-State Hydraulics (HEC-RAS)
Intermediate	Empirical Equations	Parametric Model HEC-1 or HEC-HMS	Unsteady Hydraulic Model (HEC-RAS)	Peak Water Surface Profile (Unsteady HEC-RAS)
Advanced	Empirical Equations	Parametric Model (HEC-RAS or DAMBRK)	Unsteady Hydraulic Model (HEC-RAS)	Peak Water Surface Profile (Unsteady HEC-RAS)

The hydraulic conditions at critical locations downstream of the dam can usually be determined with normal depth calculations as long as steady, uniform flow is a valid assumption (i.e. no significant backwater effects in the vicinity of the section).

Because the screening level of analysis is very conservative, it can be used to determine if further analysis is required. It is expected that, if the hydraulics calculated at critical locations indicate a specific hazard classification with a screening-level analysis, then more sophisticated analyses would not likely result in a higher hazard classification. So if a screening analysis indicates a Low Hazard, no further analysis is required. If the screening analysis indicates High or Significant Hazard, a more accurate, less conservative approach may show a lower hazard classification and additional analysis may be warranted to demonstrate this depending on the situation.

Note that the screening level of analysis does not lead to inundation maps which are required for Significant and High Hazard dams. The minimum level of analysis required to develop inundations maps is the next level: Simple.

6.2 Simple

The Simple level of analysis is slightly more sophisticated than the screening analysis. Results of the Simple level of analysis may provide the necessary conclusion, or may indicate that the intermediate or advanced approach is warranted. This analysis uses the recommended empirical methods to determine the breach parameters and then uses a hydrologic parametric model (HEC-HMS or HEC-1) to compute a breach hydrograph. The hydrologic tool can then be used to route the flood downstream to critical locations. At that point, a steady-state hydraulic model can be used to calculate the hydraulic conditions where required.

The Simple approach is considered moderately conservative. In most cases, it is not as conservative as the Screening level because the breach hydrograph typically has a smaller peak due to the parametric modeling of the breach formation, and the hydrologic routing typically results in flood wave attenuation by the time it reaches critical locations. A steady-state hydraulic model can then be used to accurately predict hydraulic conditions at critical locations. The results of the steady-state hydraulic model can be used to create inundation mapping for Emergency Action Plans. If this method results in a borderline situation, it may be necessary to employ a more advanced approach.

6.3 Intermediate

The Intermediate approach lies between the simple approach and advanced approach in accuracy and sophistication. Similar to the simple approach, it uses empirical equations to determine the breach parameters (geometry and failure time). Those dimensions are then input into a hydrologic parametric model (HEC-HMS or HEC-1) to calculate the breach flood hydrograph which is then input into a hydraulic model (HEC-RAS) in an unsteady flow simulation to route the flood downstream and calculate the hydraulic conditions at critical locations.

This approach may not be as accurate as the advanced approach for piping failures of smaller dams because the usage of HEC-1 and HEC-HMS to develop the dam break hydrographs may not model this process as accurately as HEC-RAS or DAMBRK. However, it may be just as accurate as the advanced approach for overtopping scenarios or for piping failures of larger dams. This approach is a viable option for developing flood inundation mapping for Emergency Action Plans.

6.4 Advanced

The Advanced approach is the most rigorous level of analysis. Similar to the Simple approach, it uses empirical equations to determine the breach parameters (geometry and failure time). Those dimensions are then input into a hydraulic parametric model (HEC-RAS or DAMBRK) to calculate the breach flood For DAMBRK the hydrograph is then input into (HEC-RAS) in an unsteady flow simulation to route the flood downstream and calculate the hydraulic conditions at critical locations. For HEC-RAS, the dam failure simulation and downstream routing is performed in the same simulation.

The increased accuracy of the Advanced approach comes at the expense of more time required to develop, debug and refine the unsteady hydraulic model. This level of analysis can be time consuming, particularly if the downstream drainage is complex and critical sections are located well downstream.

7.0 Recommendations for Dam Breach Analysis

The recommendations presented herein for modeling dam breaches are intended to provide the most realistic dam breach flood estimates while still being appropriately conservative. For the purposes of these recommendations, the term "conservative" means an analysis that tends to overestimate the magnitude and impacts of the dam breach flood. For example, an increase in the estimate of average breach width for a given development time leads to an increase in the peak breach discharge and associated impacts downstream. Being appropriately conservative at this time is warranted because of the need for better physically-based modeling of the erosion processes of dam failures, which is still in the developmental stage. These recommendations are based on case studies performed on a range of dams within Colorado. A summary of the case study results is presented in Appendix A.

Uncertainty of Predictions of Embankment Dam Breach Parameters

Tony L. Wahl[1]

Abstract: Risk assessment studies considering the failure of embankment dams often require the prediction of basic geometric and temporal parameters of a breach, or the estimation of peak breach outflows. Many of the relations most commonly used to make these predictions were developed from statistical analyses of data collected from historic dam failures. The prediction uncertainties of these methods are widely recognized to be very large, but have never been specifically quantified. This paper presents an analysis of the uncertainty of many of these breach parameter and peak flow prediction methods. Application of the methods and the uncertainty analysis are illustrated through a case study of a risk assessment recently performed by the Bureau of Reclamation for a large embankment dam in North Dakota.

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CE Database subject headings: Dam failure; Uncertainty analysis; Peak flow; Erosion; Dams, embankment; Risk management.

Introduction

Risk assessment studies considering the failure of embankment dams often make use of breach parameter prediction methods that have been developed from analysis of historic dam failures. Similarly, predictions of peak breach outflow can also be made using relations developed from case study data. This paper presents an analysis of the uncertainty of many of these breach parameter and peak flow prediction methods, making use of a previously compiled database (Wahl 1998) of 108 dam failures. Subsets of this database were used by other investigators to develop many of the relations examined.

The paper begins with a brief discussion of breach parameters and prediction methods. The uncertainty analysis of the various methods is presented next, and finally, a case study is offered to illustrate the application of several breach parameter prediction methods and the uncertainty analysis to a risk assessment recently performed by the Bureau of Reclamation for a large embankment dam in North Dakota.

Breach Parameters

Dam-break flood routing models [e.g., *DAMBRK* (Fread 1984) and *FLDWAV* (Fread 1993)] simulate the outflow from a reservoir and through the downstream valley resulting from a developing breach in a dam. These models focus their computational effort on the routing of the breach outflow hydrograph. The development of the breach is not simulated in any physical sense, but rather is idealized as a parametric process, defined by the shape of the breach, its final size, and the time required for its development (often called the failure time). Breaches in embankment dams are usually assumed to be trapezoidal, so the shape and size of the breach are defined by a base width and side slope angle, or more simply by an average breach width.

The failure time is a critical parameter affecting the outflow hydrograph and the consequences of dam failure, especially when populations at risk are located close to a dam so that available warning and evacuation time dramatically affect loss of life. For the purpose of routing a dam-break flood wave, breach development begins when a breach has reached the point at which the volume of the reservoir is compromised and failure becomes imminent. During the breach development phase, outflow from the dam increases rapidly. The breach development time ends when the breach reaches its final size; in some cases, this may also correspond to the time of peak outflow through the breach, but for relatively small reservoirs the peak outflow may occur before the breach is fully developed. The breach development time as described above is the parameter intended to be predicted by most failure time prediction equations.

The breach development time does not include the potentially long preceding period described as the breach initiation phase (Wahl 1998), which can also be important when considering available warning and evacuation time. This is the first phase of an overtopping failure, during which flow overtops a dam and may erode the downstream face, but does not create a breach through the dam that compromises the reservoir volume. If the overtopping flow were quickly stopped during the breach initiation phase, the reservoir would not fail. In an overtopping failure, the length of the breach initiation phase is important, because breach initiation can potentially be observed and may thus trigger warning and evacuation. Unfortunately, there are few tools presently available for predicting the length of the breach initiation phase.

During a seepage-erosion (piping) failure, the delineation between breach initiation and breach development phases is less apparent. In some cases, seepage-erosion failures can take a great deal of time to develop. In contrast to the overtopping case, the

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Note. Discussion open until October 1, 2004. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on June 25, 2002; approved on September 25, 2003. This paper is part of the ***Journal of Hydraulic Engineering***, Vol. 130, No. 5, May 1, 2004. ©ASCE, ISSN 0733-9429/2004/5-389–397/$18.00.

loading that causes a seepage-erosion failure cannot normally be removed quickly, and the process does not take place in full view, except that the outflow from a developing pipe can be observed and measured. One useful way to view seepage-erosion failures is to consider three possible conditions:

1. Normal seepage outflow, with clear water and low flow rates;
2. Initiation of a seepage-erosion failure with cloudy seepage water that indicates a developing pipe, but flow rates are still low and not rapidly increasing. Corrective actions might still be possible that would heal the developing pipe and prevent failure.
3. Active development phase of a seepage-erosion failure in which erosion is dramatic and flow rates are rapidly increasing. Failure cannot be prevented.

Only the length of the last phase is important when determining the breach hydrograph from a dam, but both the breach initiation and breach development phases may be important when considering warning and evacuation time. Again, as with the overtopping failure, there are few tools available for estimating the length of the breach initiation phase.

Predicting Breach Parameters

To carry out a dam-break flood routing simulation, breach parameters must be estimated and provided as inputs to the dam-break and flood routing simulation model. Several methods are available for estimating breach parameters; a summary of the available methods was provided by Wahl (1998). The simplest methods (Johnson and Illes 1976; Singh and Snorrason 1984; Bureau of Reclamation 1988) predict the average breach width as a linear function of either the height of the dam or the depth of water stored behind the dam at the time of failure. Slightly more sophisticated methods predict more specific breach parameters, such as breach base width, side slope angles, and failure time, as functions of one or more dam and reservoir properties, such as storage volume, depth of water at failure, depth of breach, etc. All of these methods are based on regression analyses of data collected from actual dam failures. The database of dam failures used to develop these relations is relatively lacking in data from failures of large dams, with about 75% of the cases having a height less than 15 m (Wahl 1998).

Physically based simulation models are available to aid in the prediction of breach parameters. None are widely used at this time, but the most notable is the National Weather Service (NWS)-BREACH model (Fread 1988). These models simulate the hydraulic and erosion processes associated with flow over an overtopping dam or through a developing piping channel. Through such a simulation, an estimate of the breach parameters may be developed for use in a dam-break flood routing model, or the outflow hydrograph at the dam can be predicted directly. The primary weakness of the NWS-BREACH model, and other similar models, is the fact that they do not adequately model the headcut-type erosion processes that dominate the breaching of cohesive-soil embankments (e.g., Hanson et al. 2002). Recent work by the Agricultural Research Service (e.g., Temple and Moore 1997) on headcut erosion in earth spillways has shown that headcut erosion is best modeled with methods based on energy dissipation.

Predicting Peak Outflow

In addition to the prediction of breach parameters, many investigators have proposed simplified methods for predicting peak outflow from a breached dam. These methods are used for reconnaissance-level work and for checking the reasonability of dam-break outflow hydrographs developed from estimated breach parameters. This paper considers the relations by Kirkpatrick (1977), SCS (1981), Hagen (1982), Bureau of Reclamation (1982), MacDonald and Langridge-Monopolis (1984), Singh and Snorrason (1984), Costa (1985), Evans (1986), Froehlich (1995b), and Walder and O'Connor (1997).

All of these methods, except Walder and O'Connor, are straightforward regression relations that predict peak outflow as a function of various dam and/or reservoir parameters, with the relations developed from analyses of case study data from real dam failures. In contrast, Walder and O'Connor's method is based upon an analysis of numerical simulations of idealized cases spanning a range of dam and reservoir configurations and erosion scenarios. An important parameter in their method is an assumed vertical erosion rate of the breach; for reconnaissance-level estimating purposes, they suggest that a range of reasonable values is 10 to 100 m/h, based on an analysis of case study data. The method makes a distinction between so-called large-reservoir/fast-erosion and small-reservoir/slow-erosion cases. In large-reservoir cases, the peak outflow occurs when the breach reaches its maximum depth, before there has been any significant drawdown of the reservoir. In this case, the peak outflow is insensitive to the erosion rate. In the small-reservoir case, there is a significant drawdown of the reservoir as the breach develops, and thus the peak outflow occurs before the breach erodes to its maximum depth. Peak outflows for small-reservoir cases are dependent on the vertical erosion rate and can be dramatically smaller than for large-reservoir cases. The determination of whether a specific situation is a large- or small-reservoir case is based on a dimensionless parameter incorporating the embankment erosion rate, reservoir size, and change in reservoir level during the failure. Thus, so-called large-reservoir/fast-erosion cases can occur even with what might be considered "small" reservoirs and vice versa. This refinement is not present in any of the other peak flow prediction methods.

Developing Uncertainty Estimates

In a typical risk assessment study, a variety of loading and failure scenarios are analyzed. This allows the study to incorporate variability in antecedent conditions and the probabilities associated with different loading conditions and failure scenarios. The uncertainty of key parameters (e.g., material properties) is sometimes considered by creating scenarios in which analyses are carried out with different parameter values and a probability of occurrence assigned to each value of the parameter. Although the uncertainty of breach parameter predictions is often very large, there have previously been no quantitative assessments of this uncertainty, and thus breach parameter uncertainty has not been incorporated into most risk assessment studies.

It is worthwhile to consider breach parameter prediction uncertainty in the risk assessment process because the uncertainty of breach parameter predictions is likely to be significantly greater than all other factors, and could thus dramatically influence the outcome. For example, Wahl (1998) used many of the available relations to predict breach parameters for 108 documented case studies and plot the predictions against the observed values. Prediction errors of ±75% were not uncommon for breach width, and prediction errors for failure time often exceeded one order of magnitude. Most relations used to predict failure time are conser-

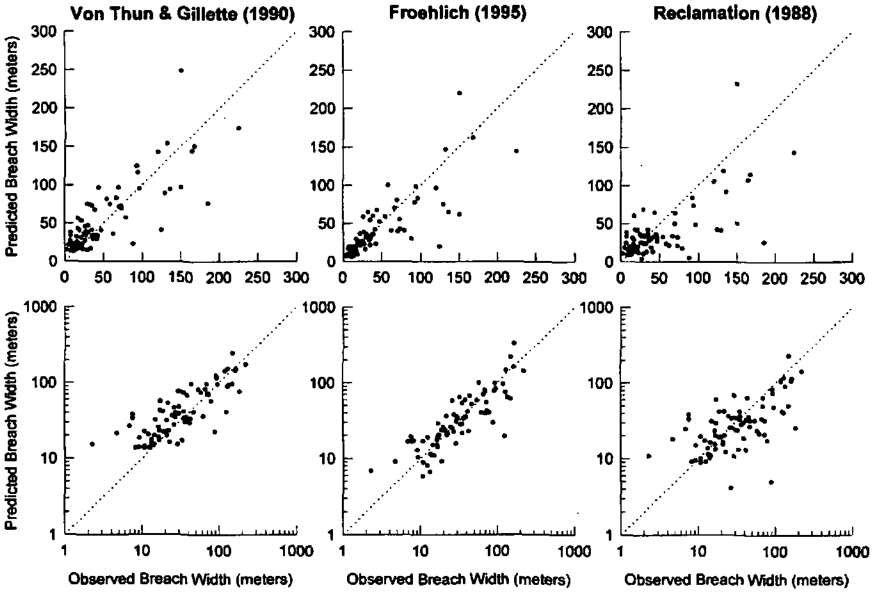

Fig. 1. Predicted and observed breach widths (Wahl 1998), plotted arithmetically (top) and on logarithmic scales (bottom)

vatively designed to underpredict the reported time more often than they overpredict, but overprediction errors of more than one-half of an order of magnitude did occur several times.

The first question that must be addressed in an uncertainty analysis of breach parameter predictions is how to express the results. The case study datasets used to develop most breach parameter prediction equations include data from a wide range of dam sizes, and thus, regressions in log–log space have been commonly used. Fig. 1 shows the observed and predicted breach widths as computed by Wahl (1998) in both arithmetically scaled and log–log plots. In the arithmetic plots, it would be difficult to draw in upper and lower bound lines to define an uncertainty band. In the log–log plots, data are scattered approximately evenly above and below the lines of perfect prediction, suggesting that uncertainties would best be expressed as a number of log cycles on either side of the predicted value. This is the approach taken in the analysis that follows.

The other notable feature of the plots in Fig. 1 is the presence of some significant outliers. Possible sources of these outliers include the variable quality of the case study parameter observations being used to test the predictions and the potential for misapplication of some of the prediction equations in the analysis described here due to lack of detailed firsthand knowledge of each case study situation. Such problems should not affect a careful future application of these prediction equations to a specific case, and we do not wish for them to affect the present analysis of the uncertainties of the methods themselves. Admittedly, much of the scatter and the appearance of outliers are probably due to the inherent variability of the data caused by the variety of factors that influence dam breach mechanics, and this variability should be preserved as we analyze the uncertainties of the prediction equations. To exclude the truly anomalous data (the statistical outliers) and retain the characteristic variability, an objective outlier exclusion algorithm was applied (Rousseeuw 1998). The selected algorithm has the advantage that its performance is itself insensitive to the presence of the outliers, which overcomes a common problem encountered when attempting to exclude outliers.

The uncertainty analysis was performed using the database presented in Wahl (1998), with data on 108 case studies of actual embankment dam failures, collected from numerous sources in the literature. The majority of the available breach parameter and peak flow prediction equations were applied to this database of dam failures, and the predicted values were compared to the observed values. Computation of breach parameters or peak flows was straightforward in most cases. A notable exception was the peak flow prediction method of Walder and O'Connor (1997), which requires that the reservoir be classified as a large- or small-reservoir case. In addition, in the case of the small-reservoir situation, an average vertical erosion rate of the breach must be estimated. The Walder and O'Connor method was applied only to those dams that could be clearly identified as large-reservoir (where peak outflow is insensitive to the vertical erosion rate) or small-reservoir with an associated estimate of the vertical erosion rate obtained from observed breach heights and failure times. Two other facts should be noted:

1. No prediction equation could be applied to all 108 dam failure cases, due to the lack of required input data for the specific equation or the lack of an observed value of the parameter of interest. Most of the breach width equations could be tested against about 70 to 80 cases, the failure time equations against 30 to 40 cases, and the peak flow prediction equations against about 30 to 40 cases.
2. The testing made use of the same data used to originally develop many of the equations (since the 108-dam database was compiled from these and other sources), but each equation was also tested against additional cases, the number varying depending on the method. This should provide a fair indication of the ability of each equation to predict breach parameters for future dam failures. (It is difficult to say exactly how many additional cases were analyzed for each method, since the exact number of failures used to develop each method is not indicated clearly in literature for all methods, and some are based on a combination of statistical analysis of case studies and physically based theory.)

A step-by-step description of the uncertainty analysis method follows:

1. Plot predicted versus observed values on log–log scales.
2. Compute individual prediction errors in terms of the number of log cycles separating the predicted and observed value, $e_i = \log_{10}(\hat{x}) - \log_{10}(x) = \log_{10}(\hat{x}/x)$, where e_i is the prediction error, $\hat{x}$ is the predicted value, and x is the observed value.
3. Apply the outlier-exclusion algorithm to the series of prediction errors computed in Step 2. The algorithm is described by Rousseeuw (1998).
   - Determine T, the median of the e_i values. T is the estimator of location.
   - Compute the absolute values of the deviations from the median, and determine the median of these absolute deviations (MAD).
   - Compute an estimator of scale, $S_{MAD} = 1.483*(MAD)$. The 1.483 factor makes S_{MAD} comparable to the standard deviation, which is the usual scale parameter of a normal distribution.
   - Use S_{MAD} and T to compute a Z score for each observation, $Z_i = (e_i - T)/S_{MAD}$, where the e_i's are the observed prediction errors, expressed as a number of log cycles.
   - Reject any observations for which $|Z_i| > 2.5$.
   - If the samples are from a perfect normal distribution, this method rejects at the 98.7% probability level. Testing showed that application to normally distributed data would lead to an average 3.9% reduction of the standard deviation.
4. Compute the mean, $\bar{e}$, and the standard deviation, S_e, of the remaining prediction errors. If the mean value is negative, it indicates that the prediction equation underestimated the observed values, and if positive the equation overestimated the observed values. Significant over or underestimation should be expected, since many of the breach parameter prediction equations are intended to be conservative or provide envelope estimates, e.g., maximum reasonable breach width, fastest possible failure time, etc.
5. Using the values of $\bar{e}$ and S_e, one can express a confidence band around the predicted value of a parameter as $\{\hat{x} \cdot 10^{-\bar{e}-2S_e}, \hat{x} \cdot 10^{-\bar{e}+2S_e}\}$, where $\hat{x}$ is the predicted value. The use of $\pm 2S_e$ approximately yields a 95% confidence band.

Table 1 summarizes the results. The first two columns identify the method being analyzed, the next two columns show the number of case studies used to test the method, and the next two columns give the prediction error and the width of the uncertainty band. The last column shows the range of the prediction interval around a hypothetical predicted value of 1.0. The values in this column can be used as multipliers to obtain the prediction interval for a specific case.

Although the detailed data are not shown in Table 1, prediction errors and uncertainties also were determined prior to applying the outlier exclusion algorithm to determine its effect. Outlier exclusion reduced the values of S_e by at least 5% up to about 20% in most cases. Since this exceeds the 3.9% reduction one would expect when applying the algorithm to a normally distributed dataset, it suggests that true outliers were excluded rather than just occasional extreme values that one would expect in normally distributed data. The use of outlier exclusion did not materially change the results of the study (i.e., the same methods had the lowest uncertainty before and after outlier exclusion). One notable fact is that the outlier exclusion algorithm reduced S_e by 30 to 60% for two of the breach width equations (Bureau of Reclamation 1988; Von Thun and Gillette 1990) and four of the peak flow equations [Kirkpatrick 1977; SCS 1981; Bureau of Reclamation 1982; Singh and Snorrason 1984 (the first of the two equations shown in Table 1)]. All of these prediction equations are based solely on the dam height or water depth above the breach invert, suggesting that dam height by itself is a poor predictor for breach width or peak outflow.

Summary of Uncertainty Analysis Results

The four methods for predicting breach width (or volume of material eroded, from which breach width can be estimated) all had absolute mean prediction errors less than one-tenth of an order of magnitude, indicating that on average their predictions are on target. The uncertainty bands were similar (± 0.3 to ± 0.4 log cycles) for all of the equations except the MacDonald and Langridge-Monopolis equation, which had an uncertainty of ± 0.82 log cycles.

The five methods for predicting failure time all underpredict the failure time on average, by amounts ranging from about one-fifth to two-thirds of an order of magnitude. This is consistent with the previous observation that these equations are designed to conservatively predict fast breaches, which will cause large peak outflows. The uncertainty bands on all of the failure time equations are very large, ranging from about ± 0.6 to ± 1 order of magnitude, with the Froehlich (1995a) equation having the smallest uncertainty.

Most of the peak flow prediction equations tend to overpredict observed peak flows, with most of the "envelope" equations overpredicting by about two-thirds to three-quarters of an order of magnitude. The uncertainty bands on the peak flow prediction equations are about ± 0.5 to ± 1 order of magnitude, except the Froehlich (1995b) relation which has an uncertainty of ± 0.32 order of magnitude. In fact, the Froehlich equation has both the lowest prediction error and smallest uncertainty of all the peak flow prediction equations.

Application

To illustrate the application of the uncertainty analysis results, a case study is presented. In January 2001 the Bureau of Reclamation conducted a risk assessment study for a large embankment dam in North Dakota (Fig. 2). Two potential failure modes were considered: (1) Seepage erosion and piping through foundation materials, and (2) seepage erosion and piping through embankment materials. No distinction between the two failure modes was made in the breach parameter analysis, since most methods used to predict breach parameters lack the refinement needed to consider differences in breach morphology for such similar failure modes. Breach parameters were predicted using most of the methods discussed earlier in this paper, and also by modeling with the NWS-BREACH model.

The potential for failure and the downstream consequences from failure increase significantly at higher reservoir levels, although the likelihood of occurrence of high reservoir levels is low. The reservoir rarely exceeds its top-of-joint-use elevation (the water surface elevation corresponding to the maximum amount of storage allocated to joint use, i.e., flood control and

Table 1. Uncertainty Estimates for Breach Parameter and Peak Flow Prediction Equations

Reference	Equation	Number of case studies		Mean prediction error (log cycles)	Width of uncertainty band, $\pm 2S_e$ (log cycles)	Prediction interval around hypothetical predicted value of 1.0
		Before outlier exclusion	After outlier exclusion			
Breach width equations						
Bureau of Reclamation (1988)	$B_{avg}=3h_w$	80	70	−0.09	±0.43	0.45–3.3
MacDonald and Langridge-Monopolis (1984)	$V_{er}=0.0261(V_w h_w)^{0.769}$ earthfill $V_{er}=0.00348(V_w h_w)^{0.852}$ nonearthfills (e.g., rockfills)	60	58	−0.01	±0.82	0.15–6.8
Von Thun and Gillette (1990)	$B_{avg}=2.5h_w+C_b$	78	70	+0.09	±0.35	0.37–1.8
Froehlich (1995a)	$B_{avg}=0.1803K_o V_w^{0.32} h_b^{0.19}$	77	75	+0.01	±0.39	0.40–2.4
Failure time equations						
MacDonald and Langridge-Monopolis (1984)	$t_f=0.0179V_{er}^{0.364}$	37	35	−0.21	±0.83	0.24–11
Von Thun and Gillette (1990)	$t_f=0.015h_w$ highly erodible $t_f=0.020h_w+0.25$ erosion resistant	36	34	−0.64	±0.95	0.49–40
Von Thun and Gillette (1990)	$t_f=B_{avg}/(4h_w)$ erosion resistant $t_f=B_{avg}/(4h_w+61)$ highly erodible	36	35	−0.38	±0.84	0.35–17
Froehlich (1995a)	$t_f=0.00254(V_w)^{0.53}h_b^{-0.9}$	34	33	−0.22	±0.64	0.38–7.3
Bureau of Reclamation (1988)	$t_f=0.011(B_{avg})$	40	39	−0.40	±1.02	0.24–27
Peak flow equations						
Kirkpatrick (1977)	$Q_p=1.268(h_w+0.3)^{2.5}$	38	34	−0.14	±0.69	0.28–6.8
SCS (1981)	$Q_p=16.6(h_w)^{1.85}$	38	32	+0.13	±0.50	0.23–2.4
Hagen (1982)	$Q_p=0.54(S\cdot h_d)^{0.5}$	31	30	+0.43	±0.75	0.07–2.1
Bureau of Reclamation (1982)	$Q_p=19.1(h_w)^{1.85}$ envelope eq.	38	32	+0.19	±0.50	0.20–2.1
Singh and Snorrason (1984)	$Q_p=13.4(h_d)^{1.89}$	38	28	+0.19	±0.46	0.23–1.9
Singh and Snorrason (1984)	$Q_p=1.776(S)^{0.47}$	35	34	+0.17	±0.90	0.08–5.4
MacDonald and Langridge-Monopolis (1984)	$Q_p=1.154(V_w h_w)^{0.412}$	37	36	+0.13	±0.70	0.15–3.7
MacDonald and Langridge-Monopolis (1984)	$Q_p=3.85(V_w h_w)^{0.411}$ envelope eq.	37	36	+0.64	±0.70	0.05–1.1
Costa (1985)	$Q_p=1.122(S)^{0.57}$	35	35	+0.69	±1.02	0.02–2.1
Costa (1985)	$Q_p=0.981(S\cdot h_d)^{0.42}$	31	30	+0.05	±0.72	0.17–4.7
Costa (1985)	$Q_p=2.634(S\cdot h_d)^{0.44}$	31	30	+0.64	±0.72	0.04–1.22
Evans (1986)	$Q_p=0.72(V_w)^{0.53}$	39	39	+0.29	±0.93	0.06–4.4
Froehlich (1995b)	$Q_p=0.607(V_w^{0.295}h_w^{1.24})$	32	31	−0.04	±0.32	0.53–2.3
Walder and O'Connor (1997)	Q_p estimated by computational and graphical method using relative erodibility of dam and volume of reservoir	22	21	+0.13	±0.68	0.16–3.6

Note: All equations use metric units (m, m^3, m^3/s). Failure times are computed in hours. Where multiple equations are shown for application to different types of dams (e.g., earthfill versus rockfill), a single prediction uncertainty was determined, with the *set* of equations considered as a single algorithm.

conservation purposes), and has never exceeded an elevation of 440.7 m. Four potential reservoir water surface elevations at failure were considered in the study:

- Top-of-joint-use, elevation: 436.67 m, reservoir capacity of about 45.6×10^6 m^3,
- Elevation 438.91 m, reservoir capacity of about 105×10^6 m^3,
- Top-of-flood-space (the design maximum reservoir level reached during the temporary storage of flood runoff), elevation 443.18 m, reservoir capacity of about 273×10^6 m^3, and
- Maximum design water surface, elevation: 446.32 m, storage of about 469×10^6 m^3.

For illustration purposes, only the results from the top-of-joint-use and top-of-flood-space cases are presented here.

Dam Description

The case study dam is located a few kilometers upstream from a city with a population of about 15,000. It was constructed by the Bureau of Reclamation in the early 1950's. The dam is operated by Reclamation to provide flood control, municipal water supply, and recreational and wildlife benefits.

The dam is a zoned-earth fill with a height of 24.7 m above the original streambed. The crest length is 432 m at an elevation of 448.36 m and the crest width is 9.14 m. The design includes a central compacted zone 1 of impervious material, and upstream and downstream zone 2 of sand and gravel, shown in Fig. 3. The abutments are composed of Pierre Shale capped with glacial till. The main portion of the dam is founded on a thick section of

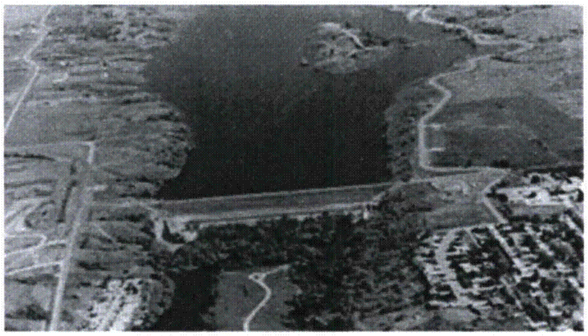

Fig. 2. Aerial photo of the dam and reservoir considered in the case study application

alluvial deposits. Beneath the dam, a cutoff trench was excavated to the shale on both abutments, but between the abutments, foundation excavation extended to a maximum depth of 7.6 m, and did not provide a positive cutoff of the thick alluvium. The alluvium beneath the dam is more than 37 m thick in the channel area.

There is a toe drain within the downstream embankment near the foundation level, and a wide embankment section to help control seepage beneath the dam, since a positive cutoff was not constructed. Based on observations of increasing pressures in the foundation during high reservoir elevations and significant boil activity downstream from the dam, eight relief wells were installed along the downstream toe in 1995 and 1996. To increase the seepage protection, a filter blanket was constructed in low areas downstream from the dam in 1998.

Results—Breach Parameter Estimates

Predictions were made for average breach width, volume of eroded material, and failure time. Side slope angles were not predicted because equations for predicting breach side slope angles are rare in literature; Froehlich (1987) offered an equation, but in his later paper (1995a), he suggested simply assuming side slopes of 0.9:1 (horizontal:vertical) for piping failures. Von Thun and Gillette (1990) suggested using side slopes of 1:1, except for cases of dams with very thick zones of cohesive materials where side slopes of 0.5:1 or 0.33:1 might be appropriate.

After computing breach parameters using the many available equations, the results were reviewed and judgment applied to develop a single predicted value and an uncertainty band to be provided to the risk assessment study team. These recommended values are shown at the bottom of each column in the tables that follow.

Breach Width

Predictions of average breach width are summarized in Table 2. Table 2 also lists the predictions of the volume of eroded embankment material made using the MacDonald and Langridge-Monopolis equation, and the corresponding estimate of average breach width.

The uncertainty analysis described earlier showed that the Reclamation equation tends to underestimate the observed breach width, so it is not surprising that it yielded the smallest values. The Von Thun and Gillette equation and the Froehlich equation produced comparable results for the top-of-joint-use scenario, in which reservoir storage is relatively small. For the top-of-flood-space scenario, the Froehlich equation predicts significantly larger breach widths. This is not surprising, since the Froehlich equation relates breach width to an exponential function of both the reservoir storage and reservoir depth. The Von Thun and Gillette equation accounts for reservoir storage only through the C_b offset parameter, but C_b is a constant for all reservoirs larger than $12.3\times 10^6\ m^3$, as was the case for both scenarios.

Using the MacDonald and Langridge-Monopolis equation, the estimate of eroded embankment volume and associated breach width for the top-of-joint-use scenario is also comparable to the other equations. However, for the top-of-flood-space scenario, the prediction is much larger than any of the other equations, and in fact is unreasonable because it exceeds the dimensions of the dam.

The prediction intervals developed through the uncertainty analysis are sobering for the analyst wishing to obtain a definitive result, as the ranges vary from small notches through the dam to a complete washout of the embankment. Even for the top-of-joint-use case, the upper bounds for the Froehlich equation and the Von Thun and Gillette equation are equivalent to about one-half of the length of the embankment.

Failure Time

Failure time predictions are summarized in Table 3. All of the equations indicate increasing failure times as the reservoir storage increases, except the second Von Thun and Gillette relation, which predicts a slight decrease in failure time for the top-of-flood-space scenario. For both Von Thun and Gillette relations, the dam was assumed to be in the erosion resistant category.

The predicted failure times exhibit wide variation, and the recommended values shown at the bottom of Table 3 are based on much judgment. The uncertainty analysis showed that all of the failure time equations tend to conservatively underestimate actual failure times, especially the Von Thun and Gillette and Reclamation equations. Thus, the recommended values are generally a compromise between the results obtained from the MacDonald

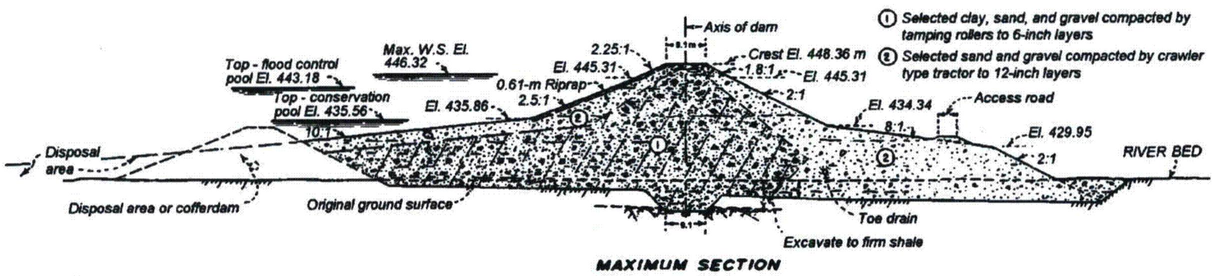

Fig. 3. Cross section through the case study dam

Table 2. Predictions of Average Breach Width

Equation	Top of joint use, elevation of 436.68 m		Top of flood space, elevation of 443.18 m	
	Predicted breach width (m)	95% prediction interval	Predicted breach width (m)	95% prediction interval
Bureau of Reclamation (1988)	39.0	17.7–129	58.5	26.2–193
Von Thun and Gillette (1990)	87.5	32.3–157	104	38.4–187
Froehlich (1995a)	93.6	37.5–225	166	66.4–398
MacDonald and Langridge-Monopolis (1984) Volume of erosion (m^3)	*146,000*	*22,200–991,000*	*787,000*	*118,000–5,350,000*
Equivalent breach width (m)	85.6	12.8–582[a]	462[a]	69.2–3140[a]
Recommended values (m)	90	35–180	165	60–400

[a]Exceeds actual embankment length.

and Langridge-Monopolis and Froehlich relations. Despite this fact, some very fast failures are documented in literature, and this possibility is reflected in the prediction intervals determined from the uncertainty analysis.

Results—Peak Outflow Estimates

Peak outflow estimates are shown in Table 4, sorted in order of increasing peak outflow for the top-of-joint-use scenario. The lowest peak flow predictions come from those equations that are based solely on dam height or depth of water in the reservoir. The highest peak flows are predicted by those equations that incorporate a significant dependence on reservoir storage. Some of the predicted peak flows and the upper bounds of the prediction limits would be the largest dam-break outflows ever recorded, exceeding the 65,000 m^3/s peak outflow from the Teton Dam failure. (Storage in Teton Dam at failure was 356×10^6 m^3). The length of the reservoir (about 48 km) may help to attenuate some of the large peak outflows predicted by the storage-sensitive equations, since there will be an appreciable routing effect in the reservoir itself that is probably not accounted for in the peak flow prediction equations.

The equation offered by Froehlich (1995b) clearly had the best prediction performance in the uncertainty analysis, and is thus highlighted in Table 4. This equation had the smallest mean prediction error and narrowest prediction interval by a significant margin.

The results for the Walder and O'Connor method are also highlighted. As discussed earlier, this is the only method that considers the differences between the so-called large-reservoir/fast-erosion and small-reservoir/slow-erosion cases. This dam proves to be a large-reservoir/fast-erosion case when analyzed by this method (regardless of the assumed vertical erosion rate of the breach—within reasonable limits), so the peak outflow will occur when the breach reaches its maximum size, before significant drawdown of the reservoir has occurred. Despite the refinement of considering large- versus small-reservoir behavior, the Walder and O'Connor method was found to have uncertainty similar to most of the other peak flow prediction methods (about ± 0.75 log cycles). However, among the 22 case studies to which the method could be applied, only four proved to be large-reservoir/fast-erosion cases. Of these, the method overpredicted the peak outflow in three cases, and dramatically underpredicted in one case (Goose Creek Dam, South Carolina, failed 1916 by overtopping). Closer examination showed some contradictions in the data reported in literature for this case. On balance, it appears that the Walder and O'Connor method may provide reasonable estimates of the upper limit on peak outflow for large-reservoir/fast-erosion cases.

For this application, results from the Froehlich method were considered to be the best estimate of peak breach outflow, and the results from the Walder and O'Connor method provided an upper bound estimate.

NWS-BREACH Simulations

Several simulations runs were made using the NWS-BREACH model (Fread 1988). The model requires input data related to reservoir bathymetry, dam geometry, the tailwater channel, embankment materials, and initial conditions for the simulated piping failure.

The results of the simulations are very sensitive to the elevation at which the piping failure is assumed to develop. In all cases analyzed, the maximum outflow occurred just prior to the crest of the dam collapsing into the pipe; after the collapse of the crest, a large volume of material partially blocks the breach and the outflow becomes weir controlled until the material can be removed. Thus, the largest peak outflows and largest breach sizes are ob-

Table 3. Failure Time Predictions

Equation	Top of joint use, elevation of 436.68 m		Top of flood space, elevation of 443.18 m	
	Predicted failure time (h)	95% prediction interval	Predicted failure time (h)	95% prediction interval
MacDonald and Langridge-Monopolis (1984)	1.36	0.33–14.9	2.45[a]	0.59–26.9
Von Thun and Gillette (1990), $t_f=f(h_w)$	0.51	0.25–20.4	0.64	0.31–25.6
Von Thun and Gillette (1990), $t_f=f(B,h_w)$	1.68	0.59–28.6	1.33	0.47–22.6
Froehlich (1995a)	1.63	0.62–11.9	4.19	1.59–30.6
Bureau of Reclamation (1988)	0.43	0.10–11.6	0.64	0.15–17.4
Recommended values	1.5	0.25–12	3.0	0.3–17

[a]Predicted erosion volume exceeded total embankment volume; total embankment volume was used in the failure time equation.

Table 4. Predictions of Peak Breach Outflow

Equation	Top of joint use, elevation of 436.68 m: Predicted peak outflow (m^3/s)	Top of joint use: 95% prediction interval	Top of flood space, elevation of 443.18 m: Predicted peak outflow (m^3/s)	Top of flood space: 95% prediction interval
Kirkpatrick (1977)	818	229–5,570	2,210	620–15,100
SCS (1981)	1,910	439–4,590	4,050	932–9,710
Bureau of Reclamation (1982) (envelope)	2,200	439–4,620	4,660	932–9,780
Froehlich (1995b)	**2,660**	**1,410–6,110**	**7,440**	**3,940–17,100**
MacDonald/Langridge-Monopolis (1984)	4,750	714–17,600	11,700	1,760–43,400
Singh/Snorrason (1984), $Q_p=f(h_d)$	5,740	1,320–10,900	5,740	1,320–10,900
Walder and O'Connor (1997)	**6,000**	**960–21,400**	**12,200**	**1,950–43,500**
Costa (1985), $Q_p=f(S^*h_d)$	6,220	1,060–29,200	13,200	2,240–61,900
Singh/Snorrason (1984), $Q_p=f(S)$	7,070	570–38,200	16,400	1,310–88,400
Evans (1986)	8,260	496–36,300	21,300	1,280–93,700
MacDonald/Langridge-Monopolis (1984) (envelope)	15,500	776–17,100	38,300	1,910–42,100
Hagen (1982)	18,100	1,270–38,100	44,300	3,100–93,000
Costa (1985), $Q_p=f(S^*h_d)$ (envelope)	25,300	1,010–30,900	55,600	2,220–67,800
Costa (1985), $Q_p=f(S)$	26,100	521–54,700	72,200	1,440–152,000

tained if the failure is initiated at the base of the dam, assumed to be at an elevation of 423.67 m. This produces the maximum amount of head on the developing pipe, and allows it to grow to the largest possible size before the collapse occurs. Table 5 shows summary results of the simulations. For each initial reservoir elevation, a simulation was run with the pipe initiating at an elevation of 423.7 m, and a second simulation was run with the pipe initiating about midway up the height of the dam.

There is a wide variation in the results depending on the assumed initial conditions for the elevation of the seepage failure. The peak outflows and breach widths tend toward the low end of the range of predictions made using the regression equations based on case study data. The predicted failure times are within the range of the previous predictions, and significantly longer than the very short (0.5 to 0.75 h) failure times predicted by the Bureau of Reclamation (1988) equation and the first Von Thun and Gillette equation.

Conclusions

This paper has presented a quantitative analysis of the uncertainty of various regression-based methods for predicting embankment dam breach parameters and peak breach outflows. The uncertainties of predictions of breach width, failure time, and peak outflow are large for all methods, and thus it may be worthwhile to incorporate uncertainty analysis results into future risk assessment studies when predicting breach parameters using these methods. Predictions of breach width generally have an uncertainty of about ±1/3 order of magnitude, predictions of failure time have uncertainties approaching ±1 order of magnitude, and predictions of peak flow have uncertainties of about ±0.5 to ±1 order of magnitude, except the Froehlich peak flow equation, which has an uncertainty of about ±1/3 order of magnitude.

The uncertainty analysis made use of a database of information on the failure of 108 dams compiled from numerous sources in literature (Wahl 1998). Those wishing to make use of this database may obtain it in electronic form (Lotus 1-2-3, Microsoft Excel, and Microsoft Access) on the Internet at http://www.usbr.gov/pmts/hydraulics_lab/twahl/

The case study presented here showed that significant engineering judgment must be exercised in the interpretation of predictions of breach parameters. The results from use of the physically based NWS-BREACH model were reassuring because they fell within the range of values obtained from the regression-based methods. However, at the same time, they also helped to show that even physically based methods can be highly sensitive to the assumptions of the analyst regarding breach morphology and the location of initial breach development. The NWS-BREACH simulations demonstrated the possibility for limiting failure mechanics that were not revealed by the regression-based methods.

Table 5. Results of National Weather Service-*BREACH* Simulations of Seepage-Erosion Failures

Initial water surface elevation (m)	Initial elevation of piping failure (m)	Peak outflow, (m^3/s)	Time-to-peak outflow, t_p (h)	Breach width at time t_p (m)
Top of joint use				
436.68	423.7	2,280	3.9	15.7
436.68	430.1	464	2.1	6.5
Top of flood space				
443.18	423.7	6,860	4.0	24.7
443.18	430.1	1,484	1.4	10.3

Notation

The following symbols are used in this paper:

B_{avg} = average breach width (m);
C_b = offset factor in the Von Thun and Gillette breach width equation, varies as a function of reservoir volume;
$\bar{e}$ = average prediction error;
e_i = individual prediction errors, log cycles;
h_b = height of breach (m);
h_d = height of dam (m);
h_w = depth of water above breach invert at time of failure (m);

K_o = overtopping multiplier: 1.4 for overtopping; 1.0 for piping;
MAD = median of absolute deviations from T;
Q_p = peak breach outflow (m^3/s);
S = reservoir storage (m^3);
S_e = standard deviation of the errors;
S_{MAD} = estimator of scale derived from the median of the absolute deviations, analogous to standard deviation;
T = median of the errors, an estimator of location;
t_f = failure time (h);
V_{er} = volume of embankment material eroded (m^3);
V_w = volume of water stored above breach invert at time of failure (m^3);
$\hat{x}$ = predicted value of parameter;
x = observed value of parameter; and
Z_i = standardized error.

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Von Thun, J. L., and Gillette, D. R. (1990). "Guidance on breach parameters." Internal Memorandum, U.S. Dept. of the Interior, Bureau of Reclamation, Denver, 17.

Wahl, T. L. (1998). "Prediction of embankment dam breach parameters—A literature review and needs assessment." *Dam Safety Rep. No. DSO-98-004*, U.S. Dept. of the Interior, Bureau of Reclamation, Denver.

Walder, J. S., and O'Connor, J. E. (1997). "Methods for predicting peak discharge of floods caused by failure of natural and constructed earth dams." *Water Resour. Res.*, 33(10), 12.

Table 1 from Text

Dam Name	Height of Breach (ft)	Top of Dam / Pool Elevation (ft)	Bottom of Breach[1] (ft)	Side Slope (--)	Average Breach Width (ft)	Bottom Width (ft)	Trigger Method	Breach Start Time[2]	Development Time[3] (hr)	Top of Dam Surface Area (acres)
Macinnes Marsh Dam	5	5	0	0.5	15	12.5	Specific Time	Jan 8 , 18:20	0.17	19
William Daly Marsh Dam	6	6	0	0.5	18	15		Jan 8, 19:10	0.17	5
Fruitland Mill Dam	10	10	0	0.5	30	25		Jan 8, 19:20	0.17	6

[1] Assumed reservoir bottom elevation at zero.

[2] Based on simulation beginning on January 1 at 00:00.

[3] Used development time of 0.5 hr for earthen dams.

Table 1 Formulas

	A	B	C	D	E	F	G	H	I	J	K
1											
2	Dam Name	Height of Breach (ft)	Top of Dam / Pool Elevation (ft)	Bottom of Breach[1] (ft)	Side Slope (--)	Average Breach Width (ft)	Bottom Width (ft)	Trigger Method	Breach Start Time[2]	Development Time[3] (hr)	Top of Dam Surface Area (acres)
3	Macinnes Marsh Dam	5	5	0	0.5	=3*B3	=F3-2*0.5*B3/2	Specific Time	Jan 8 , 18:20	0.17	19
4	William Daly Marsh Dam	6	6	0	0.5	=3*B4	=F4-2*0.5*B4/2		Jan 8, 19:10	0.17	5
5	Fruitland Mill Dam	10	10	0	0.5	=3*B5	=F5-2*0.5*B5/2		Jan 8, 19:20	0.17	6
6	[1] Assumed reservoir bottom elevation at zero.										
7	[2] Based on simulation beginning on January 1 at 00:00.										
8	[3] Used development time of 0.17 hr for earthen dams.										

APPENDIX D: REACH PARAMETER CALCULATIONS

SECTION 1.0

DEM METADATA


USGS
The National Map Viewer
Overlays
Selection
Cart
Content
Reorder Layers
Base Data Layers
Map Indices
Hydrography (NHD)
Land Cover
Elevation Availability
Best Available NED Resolution
arc-second (~meters)
1/9 arc-second (~3 meter)
1/3 arc-second (~10 meter)
1 arc-second (~30 meter)
2 arc-second (~60 meter)
Elevation Contours - Small Scale
Imagery
Scanned Topo Maps
Reference Polygons
Other Featured Data
User Added Content
Favorites
Search
Download Data
Clear | Hide Toolbox
Help
Standard
Advanced
Annotation
Active Tool: Zoom In Box
Topo
Imagery
Hydro-NHD
Hill Shade
Blank
Show
Cursor Position 44° 08' 16.079" N 79° 11' 22.635" W
Scale 1:36,978,595
FAQ | Accessibility | FOIA | Privacy | Policies and Notices
The National Map
100%

Digital Elevation Models (DEM) - New York State

Identification_Information:
Citation:
Citation_Information:
Originator: U.S. Geological Survey
Publication_Date: Unknown
Publication_Time: Unknown
Title: Digital Elevation Models (DEM) - New York State
Publication_Information:
Publication_Place: Reston, VA
Publisher: U.S. Geological Survey
Online_Linkage: http://cugir.mannlib.cornell.edu/datatheme.jsp?id=23
Description:
Abstract: A Digital Elevation Model (DEM) contains a series of elevations ordered from south to north with the order of the columns from west to east. The DEM is formatted as one ASCII header record (A-record), followed by a series of profile records (B-records) each of which include a short B-record header followed by a series of ASCII integer elevations per each profile. The last physical record of the DEM is an accuracy record (C-record). The 7.5-minute DEM (10- by 10-m data spacing, elevations in decimeters) is cast on the Universal Transverse Mercator (UTM) projection (the quads UTM zone can be found in the header record (Record A)) in the North American Datum of 1927. It provides coverage in 7.5- by 7.5-minute blocks. Each product provides the same coverage as a standard USGS 7.5-minute quadrangle, but overedges are published as separate DEM files. Coverage is available for all quads completely contained within New York State, plus some additional ones falling along the borders and containing significant area of the State's land.
Purpose: DEMs can be used as source data for digital orthophotos and as layers in geographic information systems for earth science analysis. DEMs can also serve as tools for volumetric analysis, for site location of towers, or for drainage basin delineation. These data are collected as part of the National Mapping Program.
Supplemental_Information: 7.5-minute DEMs have rows and columns which vary in length and are staggered. The UTM bounding coordinates form a quadrilateral (no two sides are parallel to each other), rather than a rectangle. The user will need to pad out the uneven rows and columns with blanks or flagged data values, if a rectangle is required for the user's application. Some software vendors have incorporated this function into their software for input of standard formatted USGS

DEMs.

Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: unknown
Currentness_Reference: ground condition
Status:
Progress: Complete
Maintenance_and_Update_Frequency: Irregular
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -79.77
East_Bounding_Coordinate: -71.85
North_Bounding_Coordinate: 45.02
South_Bounding_Coordinate: 40.49
Keywords:
Theme:
Theme_Keyword_Thesaurus: None
Theme_Keyword: digital elevation model
Theme_Keyword: digital terrain model
Theme_Keyword: hypsography
Theme_Keyword: altitude
Theme_Keyword: height
Theme_Keyword: landforms
Theme_Keyword: relief
Theme_Keyword: topography
Theme_Keyword: raster
Theme_Keyword: grid
Theme_Keyword: cell
Theme:
Theme_Keyword_Thesaurus: Library of Congress Subject Headings
Theme_Keyword: Hydrography
Theme_Keyword: Digital Mapping
Theme_Keyword: Digital mapping -- Automation
Theme_Keyword: Cartography -- Automation
Theme_Keyword: New York (State) -- Dept. of Environmental Conservation
Theme:
Theme_Keyword_Thesaurus: ISO 19115 Topic Category
Theme_Keyword: elevation
Theme_Keyword: 006
Place:
Place_Keyword_Thesaurus: Department of Commerce, 1987, Codes for the Identification of the States, The District of Columbia and the Outlying Areas of the U.S., and Associated Areas (Federal Information Processing Standard 5-2): Washington, Department of Commerce, National Institute of Standards and Technology (http://www.itl.nist.gov/fipspubs/fip5-2.htm)
Place_Keyword: New York
Place_Keyword: 36

Place_Keyword: NY
Place:
Place_Keyword_Thesaurus: Library of Congress Subject Headings
Place_Keyword: New York (State)
Place:
Place_Keyword_Thesaurus: Geographic Names Information System http://geonames.usgs.gov/pls/gnispublic
Place_Keyword: New York State
Access_Constraints: None
Use_Constraints: 1. The NYS DEC and the U.S. Geological Survey asks to be credited in derived products. 2. Secondary Distribution of the data is not allowed. 3. Any documentation provided is an integral part of the data set. Failure to use the documentation in conjunction with the digital data constitutes misuse of the data. 4. Although every effort has been made to ensure the accuracy of information, errors may be reflected in the data supplied. The user must be aware of data conditions and bear responsibility for the appropriate use of the information with respect to possible errors, original map scale, collection methodology, currency of data, and other conditions.
Point_of_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: New York State Department of Environmental Conservation. Division of Water
Contact_Position: Watershed Geographic Information Technologies Support Group, Chief
Contact_Address:
Address_Type: mailing and physical address
Address: 625 Broadway
Address: 4th floor
City: Albany
State_or_Province: New York
Postal_Code: 12233-3500
Contact_Voice_Telephone: 518-402-8259
Contact_Electronic_Mail_Address: watergis@gw.dec.state.ny.us
Contact_Instructions: All questions regarding metadata and/or data should go through the internal DEC contact.
Native_Data_Set_Environment: 24,000 scale hypsographic contour linework drawn by photogrametric, plane table or other methods by USGS, US Army Corp of Engineers, Tennessee Valley Authority or others. Linework copied onto stable-base mylar. Raster image of linework created by USGS, Reston, with Optronics drum scanner at an aperture of 20um, to give an equivalent resolution of 1024 DPI. Raster data converted to vector with line-center algorithm in LT4X v. 3.1, 11/11/93, by John Dabritz of Infotec Development Inc. Grid elevations calculated with 8-profile weighted linear interpolation, with cubic smoothing of slope at the contour line as per algorithm in above mentioned LT4X v. - export in DEM format, UTM meters, - grid height and width of 10 mt, - clipping (overedge) coordinate in UTM mt, - input coord feet or meters (depending on source material), output in meters/decimeters, - DEM grid points which are on a profile section longer than 80 mt are smoothed by passing the grid through a low pass-filter twice. The filter size (see below) is of 9 cell diameters (aprox 9 mt). The purpose here is to leave

well-contoured areas untouched while smoothing areas of less than 5-2.5% slope (to lessen streaking in flat areas typical of multiple-profile DEM derivation). - cubic smoothing of elevation profile across contours to 35% of the distance between adjacent contours. These profiles have a smaller, but still discontinuous change in slope at contour intersection than if not rounded. - 9 cell diameter for smoothing reach, - use all 8 directions (from grid point to N, S, E, W ,NE, NW, SE, SW) for each cell, - no line feeds. export dem <contour data name> 2 10.00 10.00 2 1 4 80 2 0.35 9 8 0

Cross_Reference:

Citation_Information:

Originator: US Geological Survey

Publication_Date: unknown

Title: Digital Elevation Model (DEM)

Online_Linkage: http://eros.usgs.gov/guides/dem.html

Data_Quality_Information:

Attribute_Accuracy:

Attribute_Accuracy_Report: 10 mt gridding cell spacing is the maximun that can be meaningfully extracted from hypsography contour lines. This allows very good hypsographic contour reproduction in all areas except very flat ones. Elevation_resolution_ is 1 decimeter (0.1 meter). Elevation accuracy is 24,000 contour data, i.e. plus/minus half the contour interval.

Logical_Consistency_Report: The fidelity of the relationships encoded in the data structure of the DEM are automatically verified using a USGS software program upon completion of the data production cycle. The test verifies full compliance to the DEM specification.

Completeness_Report: DEM visually inspected using Delta3D version 2.0, 1995 by John Dabritz and S. Phan of Infotec Development Inc. Checked for completness and drainage characteristics matching the USGS Hydrography Digital Line Graphs published at the same time as the model. Further validation for logical consistency performed previous to submission for archiving.

Positional_Accuracy:

Horizontal_Positional_Accuracy:

Horizontal_Positional_Accuracy_Report: The horizontal accuracy of the DEM is expressed as an estimated root mean square error (RMSE). The estimate of the RMSE is based upon horizontal accuracy tests of the DEM source materials with equal to or less than intended horizontal RMSE error of the DEM. The testing of horizontal accuracy of the source materials is accomplished by comparing the planimetric (X and Y) coordinates of well-defined ground points with the coordinates of the same points as determined from a source of higher accuracy.

Quantitative_Horizontal_Positional_Accuracy_Assessment:

Horizontal_Positional_Accuracy_Value: 3 meters (estimated)

Horizontal_Positional_Accuracy_Explanation: Digital elevation models meet horizontal National Map Accuracy Standards (NMAS) accuracy requirements.

Vertical_Positional_Accuracy:

Vertical_Positional_Accuracy_Report: A vertical RMSE of one-half of the contour interval of the source map is the maximum permitted. Systematic errors may not exceed the contour interval of the source graphic. Level 2 DEMs have been processed or smoothed for consistency and edited to remove identifiable systematic errors.

Quantitative_Vertical_Positional_Accuracy_Assessment:

Vertical_Positional_Accuracy_Value: 6 to 8 meters

Vertical_Positional_Accuracy_Explanation: DEMs meet vertical National Map Accuracy Standards (NMAS) accuracy requirements. Vertical Positional Accuracy Vaue varies with each quad.

Lineage:

Source_Information:

Source_Citation:

Citation_Information:

Originator: U.S. Geological Survey

Publication_Date: Unknown

Publication_Time: Unknown

Title: Albany

Publication_Information:

Publication_Place: EROS Data Center, SD

Publisher: U.S. Geological Survey

Type_of_Source_Media: mylar separate from original color separation plate

Source_Time_Period_of_Content:

Time_Period_Information:

Single_Date/Time:

Calendar_Date: unknown

Source_Currentness_Reference: ground condition

Source_Citation_Abbreviation: CONTOUR1

Source_Contribution: elevation values for interpolation

Source_Information:

Source_Citation:

Citation_Information:

Originator: U.S. Geological Survey or National Geodetic Survey (NGS) (ed.)

Publication_Date: Unknown

Publication_Time: Unknown

Title: project control

Publication_Information:

Publication_Place: EROS Data Center, SD

Publisher: U.S. Geological Survey

Type_of_Source_Media: field notes

Source_Time_Period_of_Content:

Time_Period_Information:

Single_Date/Time:

Calendar_Date: unknown

Source_Currentness_Reference: ground condition

Source_Citation_Abbreviation: CONTROL1

Source_Contribution: ground control points

Source_Information:

Source_Citation:

Citation_Information:

Originator: U.S. Geological Survey (ed.)
Publication_Date: Unknown
Publication_Time: Unknown
Title: photo ID number
Publication_Information:
Publication_Place: EROS Data Center, SD
Publisher: U.S. Geological Survey
Type_of_Source_Media: transparency
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: unknown
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: PHOTO1
Source_Contribution: elevation values from photogrametry
Process_Step:
Process_Description: The process can be seen as divided into several tasks, each with associated sub-processes. A. Original Data Source Preparation: 1. The United States Geological Service (USGS) office of Map Production (Mid Continent Mapping Center, Rolla, MO) selects the most recent original printing plates (1:24,000 or 1:25,000 scale) for each published quadrangle map. These plates are archived under controlled environmental conditions and are produced from the original map scripting materials onto dimensionally stable material (Mylar). A copy of the separate is made by contact methods onto photosensitive, opaque, dimensionally stable material. The separate plate copy is shipped to the USGS Mapping Applications Center (Reston, VA). 2. The MAC scans the separate plate with an Ektaprint (a.k.a. Optronics) drum scanner with an aperture of 24um (corresponding to a linear resolution of approx 1030 DPI) into a run-length encoded (RLE) formatted raster file. Contours lines have typically a thickness of 25 to 30 pixels. The file, typically between 10 and 20 Mb, would be checked for completeness and distortion. If satisfactory MAC forwards both the raster file, the plate separate and the corresponding published quadrangle to the digitization workshop at the New York State Department of Environmental Conservation Water GIS unit in Albany, NY. B. Raster file batch processing 1. The raster file was loaded into Line Tracer for X Windows (LT4X, Infotec Inc., Portland, Oregon) version 3.1. With it is georegistered and trimmed of any excess margin. 2. The file is put through an automated raster-to-vector batch process in which a vector following the center of the raster line is created, with a minimum vertex separation of 25 pixels. Once the vector has been calculated and the topology of the resultant data established, the resolution of the original raster was reduced to 500 DPI, to allow faster processing in the succeeding steps. C. Vector Contour Edit, Edge Matching and Labeling. 1. The vectorized contours are edited carefully to correct any line breaks, vector webbing (due to pen thickness or lack of resolution of the original's drafting process), labels and special line symbols (depressions, road fills, etc). 2. The contours are labeled with their corresponding elevations, as tagged in the original material. 3. The eight adjoining maps' vector contours are brought in and checked against those of

the map being edited. Vectors of matching labels are snapped together if the gap is less than 3 line-thicknesses. Otherwise they are tagged as "disagreement in the original" (see DLG standards for hypsography layer). For each border only one of the maps is edited. 4. An independent quality control check of contour edits and labeling is carried out. 5. The Digital Elevation Model is interpolated in a batch process (see "Native Dataset Environment" above). D. DEM Edit and Quality Control 1. The resultant DEM is loaded in Delta3D (Infotec Inc., Portland, OR) v. 2.1, together with the corresponding hydrography vectors. The DEM is checked for the presence of irregular patterns, in which case it is returned to the previous process; water body height (e.g. in large lakes) is set for all grid cells within the water body; and drainage along vector streams is enforced by lowering cells higher than the upstream one along the stream. Water retention areas (wetlands, marshes...) are not modified except for stream entrance and exit. - Edge matching with the adjoining eight DEMs. 2. From thirty to thirty-five height reference markers are collected from the corresponding cultural separate for the quadrangle. These are compared to heights as read from the DEM and an statistical RMS is calculated, this is recorded in the DEM's C record. 3. The quadrangle record A is filled and checked for consistency. 4. A final DEM-formatted elevation dataset for the quadrangle is recorded. E. Final Quality Control and Databasing 1. The DEM file is shipped to USGS's Rocky Mountain Mapping Center (Boulder, CO). There it undergoes a separate quality control process which essentially mimics D. 2. The corresponding quality control flags are established. The DEM is sub-sampled to 30 mt grid spacing and the resultant file is forwarded to USGS's EROS Data Center, were it is catalogued into the National Elevation database. The 10 mt grid spacing file is returned to NYS DEC, from where it is forwarded to Cornell University's Mann Library.
Process_Date: Unknown

Spatial_Reference_Information:
- *Horizontal_Coordinate_System_Definition:*
  - *Planar:*
    - *Grid_Coordinate_System:*
      - *Grid_Coordinate_System_Name:* Universal Transverse Mercator
      - *Universal_Transverse_Mercator:*
        - *UTM_Zone_Number:* 17 or 18 or 19
        - *Transverse_Mercator:*
          - *Scale_Factor_at_Central_Meridian:* .9996
          - *Longitude_of_Central_Meridian:* +075.000000
          - *Latitude_of_Projection_Origin:* +00.000000
          - *False_Easting:* 0
          - *False_Northing:* 0
    - *Planar_Coordinate_Information:*
      - *Planar_Coordinate_Encoding_Method:* row and column
      - *Coordinate_Representation:*
        - *Abscissa_Resolution:* 10

Ordinate_Resolution: 10
Planar_Distance_Units: Meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1927
Ellipsoid_Name: Clarke 1866
Semi-major_Axis: 6378206.4
Denominator_of_Flattening_Ratio: 294.9787
Vertical_Coordinate_System_Definition:
Altitude_System_Definition:
Altitude_Datum_Name: National Geodetic Vertical Datum of 1929
Altitude_Resolution: 1
Altitude_Distance_Units: decimeters
Altitude_Encoding_Method: Explicit elevation coordinate included with horizontal coordinates

---

Entity_and_Attribute_Information:
Overview_Description:
Entity_and_Attribute_Overview: The digital elevation model is composed of an elevation value linked to a grid cell location representing a gridded form of a topographic map hypsography overlay. Each grid cell entity contains an 8-character value between -32,767.0 and 32,768.0.
Entity_and_Attribute_Detail_Citation: U.S. department of the Interior, U.S. Geological Survey, 1992, Standards for digital elevation models: Reston, VA, a hypertext version of the Digital Elevation Model (DEM) is available at: http://eros.usgs.gov/guides/dem.html (see Cross Reference)

Distribution_Information:
Distributor:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Mann Library
Contact_Address:
Address_Type: mailing
Address: Cornell University
City: Ithaca
State_or_Province: NY
Postal_Code: 14853
Country: USA
Contact_Voice_Telephone: 607-255-5406
Contact_Electronic_Mail_Address: mann_ref@cornell.edu
Distribution_Liability: Although these data have been processed successfully on a computer system at the U.S. Geological Survey, no warranty expressed or implied is made regarding the accuracy or utility of the data on any other system or for general or

scientific purposes, nor shall the act of distribution constitute any such warranty. This disclaimer applies both to individual use of the data and aggregate use with other data. It is strongly recommended that careful attention be paid to the contents of the metadata file associated with these data. Neither the U.S. Geologial Survey nor the New York State Department of Environmental Conservation shall be held liable for improper or incorrect use of the data described and/or contained herein. Cornell University provides these geographic data "as is." Cornell University makes no guarantee or warranty concerning the accuracy of information contained in the geographic data. Cornell University further makes no warranty either expressed or implied, regarding the condition of the product or its fitness for any particular purpose. The burden for determining fitness for use lies entirely with the user. Although these files have been processed successfully on computers at Cornell University, no warranty is made by Cornell University regarding the use of these data on any other system, nor does the fact of distribution constitute or imply any such warranty.

Standard_Order_Process:
- *Digital_Form:*
  - *Digital_Transfer_Information:*
    - *Format_Name:* DEM
    - *File_Decompression_Technique:* zip
  - *Digital_Transfer_Option:*
    - *Online_Option:*
      - *Computer_Contact_Information:*
        - *Network_Address:*
          - *Network_Resource_Name:* http://cugir.mannlib.cornell.edu/datatheme.jsp?id=23
- *Fees:* None

Metadata_Reference_Information:
- *Metadata_Date:* 20080414
- *Metadata_Review_Date:* 20080414
- *Metadata_Contact:*
  - *Contact_Information:*
    - *Contact_Organization_Primary:*
      - *Contact_Organization:* New York State Department of Environmental Conservation
    - *Contact_Position:* Division of Information Services; GIS Unit
    - *Contact_Address:*
      - *Address_Type:* mailing and physical address
      - *Address:* 625 Broadway
      - *Address:* 3rd floor
      - *City:* Albany
      - *State_or_Province:* New York
      - *Postal_Code:* 12233-2750
    - *Contact_Voice_Telephone:* 518-402-9860
    - *Contact_Facsimile_Telephone:* 518-402-9031
    - *Contact_Electronic_Mail_Address:* enterpriseGIS@gw.dec.state.ny.us

Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998

SECTION 2.0

ORTHOIMAGERY REFERENCE

World Imagery

This map service presents satellite imagery for the world and high-resolution imagery for the United States and other areas around the world.

Map Service by esri

Last Modified: January 29, 2013

(29 ratings, 555,806 views)

Sign in to rate this item.

Facebook Twitter

Open

Description

This map was last updated December 2012. World Imagery provides one meter or better satellite and aerial imagery in many parts of the world and lower resolution satellite imagery worldwide. The map includes NASA Blue Marble: Next Generation 500m resolution imagery at small scales (above 1:1,000,000), i-cubed 15m eSAT imagery at medium-to-large scales (down to 1:70,000) for the world, and USGS 15m Landsat imagery for Antarctica. The map features 0.3m resolution imagery in the continental United States and 0.6m resolution imagery in parts of Western Europe from DigitalGlobe. In other parts of the world, 1 meter resolution imagery is available from GeoEye IKONOS, i-cubed Nationwide Prime, Getmapping, AeroGRID, IGN Spain, and IGP Portugal. Additionally, imagery at different resolutions has been contributed by the GIS User Community.

To view this map service now, along with useful reference overlays, click here to open the Imagery with Labels web map.

Tip: This service is one of the basemaps used in the **ArcGIS.com map viewer** and **ArcGIS Explorer Online**. Simply click one of those links to launch the interactive application of your choice, and then choose Imagery or Imagery with Labels from the Basemap control to start browsing the imagery. You'll also find this service in the Basemap gallery in ArcGIS Explorer Desktop and ArcGIS Desktop 10.

i-cubed Nationwide Prime is a seamless, color mosaic of various commercial and government imagery sources, including Aerials Express 0.3 to 0.6m resolution imagery for metropolitan areas and the best available United States Department of Agriculture Farm Services Agency (USDA FSA) National Agriculture Imagery Program (NAIP) imagery and enhanced versions of United States Geological Survey (USGS) Digital Ortho Quarter Quad (DOQQ) imagery for other areas.

The coverage for Europe includes AeroGRID 1m resolution imagery for Belgium, France (Region Nord-Pas-de-Calais only), Germany, Luxembourg, and The Netherlands and 2m resolution imagery for the Czech Republic, plus 1m resolution imagery for Portugal from the Instituto Geográfico Português.

For details on the coverage in this map service, view the list of Contributors for the World Imagery Map.

View the coverage maps below to learn more about the coverage for the high-resolution imagery:

- World coverage map: Areas with high-resolution imagery throughout the world.
- Imagery update maps for United States and Western Europe: Areas where imagery was updated in this release.

Metadata: This service is metadata-enabled. With the Identify tool in ArcMap or the ArcGIS Online Content Viewer, you can see the resolution, collection date, and source of the imagery at the location you click. The metadata applies only to the best available imagery at that location. You may need to zoom in to view the best available imagery.

To compare this service with the other imagery services available through ArcGIS Online, use the Imagery comparison app.

Reference overlays: The World Boundaries and Places service is designed to be drawn on top of this service as a reference overlay. This is what gets drawn on top of the imagery if you choose the Imagery With Labels basemap in any of the ArcGIS clients.

The World Transportation service is designed to be drawn on top of this service to provide street labels when you are zoomed in and streets and roads when you are zoomed out.

There are three ready to use web maps that use the World Imagery service as their basemap, Imagery, in which both reference layers are turned off, Imagery with Labels, which has World Boundaries and Places turned on but World Transportation turned off, and Imagery with Labels and Transportation, which has both reference layers turned on.

Feedback: Have you ever seen a problem in the Esri World Imagery Map that you wanted to see fixed? You can use the Imagery Map Feedback web map to provide feedback on issues or errors that you see. The feedback will be reviewed by the ArcGIS Online team and considered for one of our updates.

ArcGIS Desktop use: This service requires ArcGIS 9.3 or more recent. If you are using ArcGIS 9.2, use the Prime Imagery map service in your map to get the best free imagery available to you. Note that the Prime Imagery map service is in extended support and is no longer being updated.

The World Imagery map service is not available as a globe service. If you need a globe service containing imagery use the Prime Imagery (3D) globe service. However note that this is no longer being updated by Esri.

Tip: Here are some famous locations as they appear in this map service. The following URLs launch the Imagery With Labels and Transportation web map (which combines this map service with the two reference layers designed for it) and take you to specific locations on the map using location parameters included in the URL.

Grand Canyon, Arizona, USA

Golden Gate, California, USA

Taj Mahal, Agra, India

Vatican City

Bronze age white horse, Uffington, UK

Uluru (Ayres Rock), Australia

Machu Picchu, Cusco, Peru

Okavango Delta, Botswana

Scale Range: 1:591,657,528 down to 1:1,128

Coordinate System: Web Mercator Auxiliary Sphere (WKID 102100)

Tiling Scheme: Web Mercator Auxiliary Sphere

Map Service Name: World_Imagery

ArcGIS Desktop/Explorer URL: http://services.arcgisonline.com/arcgis/services

ArcGIS Desktop files: MXD LYR (These ready-to-use files contain this service and associated reference overlay services. ArcGIS 9.3 or more recent required).

ArcGIS Server Manager and Web ADF URL: http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer

REST URL for ArcGIS Web APIs: http://server.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer

SOAP API URL: http://services.arcgisonline.com/ArcGIS/services/World_Imagery/MapServer?wsdl

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Access and Use Constraints

Map Contents

World Imagery
http://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer

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Properties

Tags	world, imagery, basemap, satellite, aerial, community, community basemap, orthophotos, maps, AFA250_base
Credits	Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community
Size	1 KB
Extent	Left: -180 Right: 180 Top: 85 Bottom: -85

Comments (18)

lgreene2 (January 31, 2013)

I failed to mention that my post below was in response to the speed issues of having the online layer in an mxd.

---

lgreene2 (January 31, 2013)

If you turn off all your layers (except the aerial image), switch to data view, export to jpg making sure that you export a .wld file, you can then pull this in as a raster image. Define projection if you plan to use outside of that particular .mxd.

---

tosa.yasunari@gmail.com (January 22, 2013)

Please make sure that each resolution has the same time frame. We were looking at the Atlanta airport. The lower resolution image is the old image where one of the runways is missing the pavement ;-). The higher resolution image has the new runway clearly seen.

Dorothee (November 14, 2012)

The data was last updated on the 15.11.12 but that's misleading because although there is more detailed imagery available for regional Australia, in my particular area of interest (near Moranbah, QLD) the Imagery is from between 2004 and 2008. Most of the Mines in that area were developed later than that. Brisbane City Imagery is from 2003...

acoffin (November 7, 2012)

I want to use this base map (North America) in a printed map that will be published as a project fact sheet (noncommercial, quasi-academic publication). Can you tell me what the appropriate attribution should be for this product? Esri? i-cubed?

MissJesie (November 4, 2012)

what pherout said helps me now,thanks

tomstone1947 (September 4, 2012)

How do I find if there is archival imagery for a region? I am hoping to go back perhaps 10 years for a region in the upper great plains.

pherout (August 21, 2012)

Setting the data frame's extent to a clipped area of interest seems to help make working with these basemaps a lot more tolerable - Right click, data frame properties, data frame, clip options, clip to shape, specify shape, current visible extent. Took me a hot minute to figure that out. Hope it might help some others.

Emerge11 (May 24, 2012)

Use a higher spec computer, keep panning to a minimum, set bookmarks to avoid excessive panning, download an aerial instead

kphaneuf (May 10, 2012)

Why when I switch to layout view does the map get blurry?

mahabal (February 7, 2012)

just recently uploaded this layer to ArcGIS 9.3.1 but the image is just BLACK.

tmmoc (January 18, 2012)

If you do most of your editing in the layout view (if that's possible for your kind of work) it doesn't lag. Having these kinds of files open in the data view causes my computer to lag, so I do everything I can (editing attribute tables, drawing in property lines, etc.) from the layout view.

nice2835 (December 27, 2011)

I'd suggest that when you open it within arc-map 10. just zoom to one of your data layers, and it will load the images from there.

margaretannsclass (November 28, 2011)

And i just like pie

chino_is@hotmail.com (September 28, 2011)

I'm using an Intel Core 2 6700 at 2.66GHz with 2 G RAM ... it's not a very fast machine but I am on a university network in a university computer lab so I expect the problem is one of bandwidth. It lags but not so much that I can't keep productive momentum.

snelsonbanff (September 20, 2011)

That doesn't really make sense though - it's very fast when I use the same service in my FLEX viewer, but as soon as I drop the same service into ArcMap it's too slow to use.

tbwester (September 16, 2011)

They are interenet based, so you need a fast connection.

snelsonbanff (September 14, 2011)

Hmm, everytime I try to use these basemaps inside ArcMap 10 - it makes ArcMap so slow it's un-useable. Any suggestions as to why, or how to overcome this?

Sign in to add a comment.

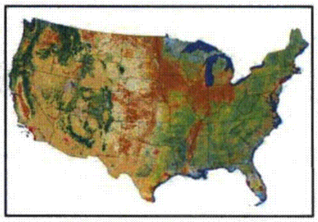
SECTION 3.0

NATIONAL LANDCOVER DATABASE METADATA

Multi-Resolution Land Characteristics Consortium (MRLC)

National Land Cover Database (NLCD)

National Land Cover Database 2006 (NLCD2006)



National Land Cover Database 2006 (NLCD2006) is a 16-class land cover classification scheme that has been applied consistently across the conterminous United States at a spatial resolution of 30 meters. NLCD2006 is based primarily on the unsupervised classification of Landsat Enhanced Thematic Mapper+ (ETM+) circa 2006 satellite data. NLCD2006 also quantifies land cover change between the years 2001 to 2006. The NLCD2006 land cover change product was generated by comparing spectral characteristics of Landsat imagery between 2001 and 2006, on an individual path/row basis, using protocols to identify and label change based on the trajectory from NLCD2001 products. It represents the first time this type of 30 meter resolution land cover change product has been produced for the conterminous United States. A formal accuracy assessment of the NLCD2006 land cover change product is planned for 2011.

Generation of NLCD2006 products helped to identify some issues in the NLCD2001 land cover and percent developed imperviousness products only (there were no changes to the NLCD2001 percent canopy). These issues were evaluated and corrected, necessitating a reissue of NLCD2001 products (NLCD2001 Version 2.0) as part of the NLCD2006 release. A majority of the NLCD2001 updates occurred in coastal mapping zones where NLCD2001 was published prior to the completion of the National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) 2001 land cover products. NOAA C-CAP 2001 land cover has now been seamlessly integrated with NLCD2001 land cover for all coastal zones. NLCD2001 percent developed imperviousness was also updated as part of this process.

Preferred NLCD2006 citation: Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, *PE&RS*, Vol. 77(9):858-864.

Other MRLC Program Publications for NLCD2006

Wickham, J.D., Stehman, S.V., Gass, L., Dewitz, J., Fry, J.A., and Wade, T.G. 2013. Accuracy assessment of NLCD 2006 land cover and impervious surface, *Remote Sensing of Environment*, Vol. 130, pp. 294-304.

Xian, G., Homer, C.G., Bunde, B., Danielson, P., Dewitz, J.A., Fry, J.A., and Pu, R., 2012, Quantifying urban land cover change between 2001 and 2006 in the Gulf of Mexico region: *Geocarto International*, v. 27, no. 6, p. 479-497.

Xian, G., Homer, C., Dewitz, J., Fry, J., Hossain, N., and Wickham, J., 2011. The change of impervious surface area between 2001 and 2006 in the conterminous United States.*Photogrammetric Engineering and Remote Sensing*, Vol. 77(8): 758-762.

Xian, G, Homer, C, and Fry, J. 2009. Updating the 2001 National Land Cover Database land cover classification to 2006 by using Landsat imagery change detection methods. *Remote Sensing of Environment*, Vol. 113, No. 6. pp. 1133-1147.

Identification_Information:
Citation:
Citation_Information:
Originator: U.S. Geological Survey
Publication_Date: 20110216
Title: NLCD 2006 Land Cover
Edition: 1.0
Geospatial_Data_Presentation_Form: remote-sensing image
Series_Information:
Series_Name: None
Issue_Identification: None
Publication_Information:
Publication_Place: Sioux Falls, SD
Publisher: U.S. Geological Survey
Other_Citation_Details:
References:

(1) Homer, C., Huang, C., Yang, L., Wylie, B., & Coan M., (2004). Development of a 2001 National Land Cover Database for the United States. Photogrammetric Engineering and Remote Sensing, 70, 829 - 840.

(2) Jin, S., Yang, L., Xian, G., Danielson, P., Fry, J., and Homer C., (2011). A multi-index integrated change detection method for updating the National Land Cover Database (In Preparation).

(3) Nowak, D. J., & Greenfield, E. J., (2010). Evaluating the National Land Cover Database tree canopy and impervious cover estimates across the conterminous United States: A comparison with photo-interpreted estimates. Environmental Management, 46, 378 - 390.

(4) Wickham, J. D., Stehman S. V., Fry, J. A., Smith, J. H., & Homer, C. G., (2010). Thematic accuracy of the NLCD 2001 land cover for the conterminous United States. Remote Sensing of Environment, 114, 1286 - 1296.

(5) Xian, G., Homer, C., and Fry, J., (2009). Updating the 2001 National Land Cover Database land cover classification to 2006 by using Landsat imagery change detection methods. Remote Sensing of Environment, 113, 1133-1147.

(6) Xian, G., and Homer C., (2010). Updating the 2001 National Land Cover Database impervious surface products to 2006 using Landsat imagery change detection methods. Remote Sensing of Environment, 114, 1676-1686.

The USGS acknowledges the support of USGS NLCD 2006 Land Cover Mapping Teams in development of data for this map.

Online_Linkage: http://www.mrlc.gov
Description:
Abstract:

The National Land Cover Database products are created through a cooperative project conducted by the Multi-Resolution Land Characteristics (MRLC) Consortium. The MRLC Consortium is a partnership of federal agencies (www.mrlc.gov), consisting of the U.S. Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Environmental Protection Agency (EPA), the U.S. Department of Agriculture (USDA), the U.S. Forest Service (USFS), the National Park Service (NPS), the U.S. Fish and Wildlife Service (FWS), the Bureau of Land Management (BLM) and the USDA Natural Resources Conservation Service (NRCS). Previously, NLCD consisted of three major data releases based on a 10-year cycle. These include a circa 1992 conterminous U.S. land cover dataset with one thematic layer (NLCD 1992), a circa 2001 50-state/Puerto Rico updated U.S. land cover database (NLCD 2001) with three layers including thematic land cover, percent imperviousness, and percent tree canopy, and a 1992/2001 Land Cover Change Retrofit Product. With these national data layers, there is often a 5-year time lag between the image capture date and product release. In some areas, the land cover can undergo significant change during production time, resulting in products that may be perpetually out of date. To address these issues, this circa 2006 NLCD land cover product (NLCD 2006) was conceived to meet user community needs for more frequent land cover monitoring (moving to a 5-year cycle) and to reduce the production time between image capture and product release. NLCD 2006 is designed to provide the user both updated land cover data and additional information that can be used to identify the pattern, nature, and magnitude of changes occurring between 2001 and 2006 for the conterminous United States at medium spatial resolution.

For NLCD 2006, there are 3 primary data products: 1) NLCD 2006 Land Cover map; 2) NLCD 2001/2006 Change Pixels labeled with the 2006 land cover class; and 3) NLCD 2006 Percent Developed Imperviousness. Four additional data products were developed to provide supporting documentation and to provide information for land cover change analysis tasks: 4) NLCD 2001/2006 Percent Developed Imperviousness Change; 5) NLCD 2001/2006 Maximum Potential Change derived from the raw spectral change analysis; 6) NLCD 2001/2006 From-To Change pixels; and 7) NLCD 2006 Path/Row Index vector file showing the footprint of Landsat scene pairs used to derive 2001/2006 spectral change with change pair acquisition dates and scene identification numbers included in the attribute table.

In addition to the 2006 data products listed in the paragraph above, two of the original release NLCD 2001 data products have been revised and reissued. Generation of NLCD 2006 data products helped to identify some update issues in the NLCD 2001 land cover and percent developed imperviousness data products. These issues were evaluated and corrected, necessitating a reissue of NLCD 2001 data products (NLCD 2001 Version 2.0) as part of the NLCD 2006 release. A majority of NLCD 2001 updates occur in coastal mapping zones where NLCD 2001 was published prior to the National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) 2001 land cover products. NOAA C-CAP 2001 land cover has now been seamlessly integrated with NLCD 2001 land cover for all coastal zones. NLCD 2001 percent developed imperviousness was also updated as part of this process.

Land cover maps, derivatives and all associated documents are considered "provisional" until a formal accuracy assessment can be conducted. The NLCD 2006 is created on a path/row basis and mosaicked to create a seamless national product. Questions about the NLCD 2006 land cover product can be directed to the NLCD

2006 land cover mapping team at the USGS/EROS, Sioux Falls, SD (605) 594-6151 or mrlc@usgs.gov.
Purpose: The goal of this project is to provide the Nation with complete, current and consistent public domain information on its land use and land cover.
Supplemental_Information:
Corner Coordinates (center of pixel, projection meters)
Upper Left Corner: -2493045 meters(X), 3310005 meters(Y)
Lower Right Corner: -177285 meters(X), 2342655 meters(Y)
Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 20050211
Ending_Date: 20071003
Currentness_Reference: ground condition
Status:
Progress: In work
Maintenance_and_Update_Frequency: Every 5 Years
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -130.232828
East_Bounding_Coordinate: -63.672192
North_Bounding_Coordinate: 52.877264
South_Bounding_Coordinate: 21.742308
Keywords:
Theme:
Theme_Keyword_Thesaurus: None
Theme_Keyword: Land Cover
Theme_Keyword: GIS
Theme_Keyword: U.S. Geological Survey
Theme_Keyword: USGS
Theme_Keyword: digital spatial data
Theme:
Theme_Keyword_Thesaurus: ISO 19115 Category
Theme_Keyword: imageryBaseMapsEarthCover
Theme_Keyword: 010
Place:
Place_Keyword_Thesaurus: U.S. Department of Commerce, 1995, Countries, dependencies, areas of special sovereignty, and their principal administrative divisions, Federal Information Processing Standard 10-4,): Washington, D.C., National Institute of Standards and Technology
Place_Keyword: United States
Place_Keyword: U.S.
Place_Keyword: US
Access_Constraints: None
Use_Constraints: None
Point_of_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: U.S. Geological Survey
Contact_Position: Customer Services Representative
Contact_Address:
Address_Type: mailing and physical address
Address: USGS/EROS
Address: 47914 252nd Street
City: Sioux Falls
State_or_Province: SD
Postal_Code: 57198-0001
Country: USA
Contact_Voice_Telephone: 605/594-6151
Contact_Facsimile_Telephone: 605/594-6589
Contact_Electronic_Mail_Address: custserv@usgs.gov
Hours_of_Service: 0800 - 1600 CT, M - F (-6h CST/-5h CDT GMT)
Contact_Instructions:
The USGS point of contact is for questions relating to the data display and download from this web site. For questions regarding data content and quality, refer to:
http://www.mrlc.gov/mrlc2k.asp or email: mrlc@usgs.gov
Data_Set_Credit: U.S. Geological Survey
Security_Information:
Security_Classification_System: None
Security_Classification: Unclassified
Security_Handling_Description: N/A
Native_Data_Set_Environment: Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 3; ESRI ArcCatalog 9.3.0.1770
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report: Data quality information for the NLCD 2001 re-issued base unchanged pixels is reported in the manuscript: Wickham, J., D., Stehman, S. V., Fry, J. A., Smith, J. H., & Homer, C. G., (2010), Thematic accuracy of the NLCD 2001 land cover for the conterminous United States, Remote Sensing of Environment, 114, 1286 - 1296. Accuracy for the NLCD 2006 changed pixels is currently being assessed.
Quantitative_Attribute_Accuracy_Assessment:
Attribute_Accuracy_Value: Unknown
Attribute_Accuracy_Explanation: This document and the described landcover map are considered "provisional" until a formal accuracy assessment is completed. The U.S. Geological Survey can make no guarantee as to the accuracy or completeness of this information, and it is provided with the understanding that it is not guaranteed to be correct or complete. Conclusions drawn from this information are the responsibility of the user.

Logical_Consistency_Report: The NLCD 2006 final seamless products include: 1) NLCD 2006 Land Cover map, 2) NLCD 2006 Percent Developed Imperviousness ; 3) NLCD 2001/2006 Change Pixels labeled with the 2006 land cover class; 4) NLCD 2001/2006 Percent Developed Imperviousness Change; 5) Maximum Potential Spectral Change; 6) NLCD 2001/2006 From - To Change pixels; 7) NLCD 2006 Path Row Index.
Completeness_Report: This NLCD product is the version dated February 14, 2011.
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report: N/A
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report: N/A
Lineage:
Process_Step:
Process_Description:
Landsat image selection and preprocessing. For the change analysis, a two-date pair of Landsat scenes was selected for each path/row restricting temporal range to reduce the impact of seasonal and phenological variation. A pre-processing step was performed to convert the digital number to top of atmosphere reflectance using procedures similar to those established for the NLCD 2001 mapping effort (Homer et al., 2004). Reflectance derivatives, including a tasseled-cap transformation and a 3-ratio index, were generated for each scene to use in the modeling process as independent variables. Where present, clouds and cloud shadows were digitized for masking.

NLCD 2006 Percent Developed Imperviousness (Final Product) and Percent Developed Imperviousness Change Analysis. Because the four NLCD developed classes are derived from a percent imperviousness mapping product, an overview of steps required to update the NLCD 2001 imperviousness to reflect urban growth captured in 2006 era Landsat imagery is provided here (Xian, et al., 2010). First, 2001 nighttime lights imagery from the NOAA Defense Meteorological Satellite Program (DMSP) was imposed on the NLCD 2001 impervious surface product to exclude low density imperviousness outside urban and suburban centers so that only imperviousness in urban core areas would be used in the training dataset. Two training datasets, one having a relatively larger urban extent and one having a smaller extent, were produced through imposing two different thresholds on city light imagery. Second, each of the two training datasets combined with 2001 Landsat imagery was separately applied using a regression tree (RT) algorithm to build up RT models. Two sets of RT models were then used to estimate percent imperviousness and to produce two 2001 synthetic impervious surfaces. Similarly, the same two training datasets were used with 2006 Landsat imagery to create two sets of RT models that produce two 2006 synthetic impervious surfaces. Third, the 2001 and 2006 synthetic impervious surface pairs were compared using both 2001 impervious surface products to retain 2001 impervious surface area (ISA) in the unchanged areas. The 2006 DMSP nighttime lights imagery was then employed to ensure that non-imperviousness areas were not included and that new impervious surfaces emerged in the city light extent. After this step, two 2006 intermediate impervious surfaces were produced. Finally, the two intermediate products and 2001 imperviousness were compared to remove false estimates in non-urban areas and generate a 2006 impervious surface estimate. Imperviousness threshold values used to derive the NLCD developed classes are: (1) developed open space (imperviousness < 20%), (2) low-intensity developed (imperviousness from 20 - 49%), (3) medium intensity developed (imperviousness from 50 -79%), and (4) high-intensity developed (imperviousness > 79%). During this process, inconsistencies in the NLCD 2001 Percent Developed Imperviousness product were corrected with the new product, NLCD 2001 Percent Developed Imperviousness Version 2.0, included as part of the NLCD 2006 product release.

Land Cover Change Analysis. For the NLCD 2006 Land Cover Update, a new change detection method, Multi-Index Integrated Change (MIIC), was developed to capture a full range of land cover disturbance and potential land cover change patterns for updating the National Land Cover Database (Jin, et al., In Preparation). Recognizing the potential complementary nature of multiple spectral indices in detection of different land cover changes, we integrated four indices into one model to more accurately detect true land cover changes between two time periods. Within the model, normalized burn ratio (NBR), change vector (CV, Xian, et al., 2009), relative change vector (RCV), and normalized difference vegetation index (NDVI) are calculated separately for the early date (circa 2001) and late date (circa 2006) scenes. The four pairs of indices for the two dates are differenced and then evaluated in a final model conditional statement that categorizes each pixel as either biomass increase, biomass decrease, or no change. Individual path/row raw results from this change analysis process are assembled into a seamless national product to form the NLCD 2001/2006 Maximum Potential Change map. The integrated change result is clumped and sieved to produce a refined change/no-change mask used below.

NLCD 2006 Land Cover Classification. Land cover mapping protocols used during NLCD 2006 processing are similar to those used to label the NLCD 2001 product (Homer, et al., 2004), but applied on a path/row basis instead of multiple path/row MRLC zones (Xian, et al., 2009). Classification was achieved using decision tree modeling that employed a combination of Landsat imagery, reflectance derivatives, and ancillary data (independent variables) with training data points (dependent variable) collected from a refined version of the NLCD 2001 land cover product. Training points were randomly sampled and limited to those areas that were determined to be unchanged between 2001 and 2006 during the MIIC spectral change analysis process. Training data for pixels changed to developed land cover were not collected since the four classes in urban and sub-urban areas were mapped separately using a regression tree modeling method (described in the Imperviousness Change Analysis process steps above). Post classification modeling and hand-editing were used to further refine the decision tree output. Following classification, the 2006 land cover was masked with the change/no-change result (captured during the MIIC change analysis modeling) to extract a label for spectrally changed pixels. Labeled change pixels were then compared to the NLCD 2001 land cover base to exclude those pixels identified as spectral change, but classified with the same label as the corresponding 2001 pixel. NLCD 2006 percent developed impervious pixels, identified as changed, were extracted to NLCD developed class codes using NLCD 2001 legend thresholds for developed classes and added to the change pixel map. This intermediate change pixel product was generalized using the NLCD Smart Eliminate tool with the following minimum mapping units (mmu) applied: 1 acre (approximately 5 ETM+ 30 m pixel patch) for developed classes (class codes 21, 22, 23, and 24); 7.12 acres (approximately 32 ETM+ pixel patch) for agricultural classes (class codes 81 and 82); and 2.67 acres (approximately 12 ETM+ pixel patch) for all other classes (class codes 11, 12, 31, 41, 42, 43, 52, 71, 90, and 95). The smart eliminate aggregation program subsumes pixels from the single pixel level to the mmu pixel patch using a queens algorithm at doubling intervals. The algorithm consults a weighting matrix to guide merging of cover types by similarity, resulting in a product that preserves land cover logic as much as possible. During the NLCD

2006 analysis and modeling process, inconsistencies in the NLCD 2001 Land cover product were corrected with the new product, NLCD 2001 Land Cover Version 2.0, included as part of the NLCD 2006 product release.

NLCD 2006 Land Cover (Final Product). Additional processing steps were designed to create the final NLCD 2006 land cover map. Individual path/row change pixel results were assembled to form an intermediate seamless national product. This seamless change pixel map was reviewed and edited to remove regional inconsistencies. Refined NLCD 2006 change pixels were then combined with the re-issued NLCD 2001 Land Cover Version 2.0, and the resulting image was smart-eliminated to a 5-pixel mmu. This final step eliminated single pixels and patches less than 5 pixels in extent that appeared as a result of combining the separate images.

NLCD 2006 Change Pixels (Final Product). A comparison of the NLCD 2001 re-issued base and the NLCD 2006 Land Cover was necessary to extract a final version of the NLCD 2006 Change Pixels. In a model, pixels that were labeled with the same land cover class code were removed and only those pixels that did not agree in the two classifications were retained as final NLCD 2006 Change Pixels.

NLCD 2001/2006 Percent Developed Imperviousness Change (Supplementary Raster Layer). The NLCD 2001 Percent Developed Imperviousness Version 2.0 and the NLCD 2006 Percent Developed Imperviousness were compared in a model to provide the user community with a layer that highlights imperviousness change between 2001 and 2006.

NLCD 2006 Maximum Potential Spectral Change (Supplementary Raster Layer). A raster layer containing all pixels identified in the raw change detection process and additional pixels identified as changed in NOAA C-CAP 2001-2006 change products. Raw change includes areas of biomass increase (value 1) and biomass decrease (value 2) with background (127) and clouds (value 250) identified separately. Only a portion of these pixels were ultimately selected as real change during our final protocols. This product was assembled from individual path/row MIIC raw change results.

NLCD 2006 From-To Change Pixels (Supplementary Raster Layer). Although similar to the NLCD 2006 change pixel map, the from-to change pixel image was derived from a direct comparison between the re-issued seamless NLCD 2001 Land Cover Version 2.0 Map and the seamless NLCD 2006 Land Cover Map. An index value for each possible change combination was assigned using a from-to change matrix with sequentially numbered cells (see matrix and index values in entity and attribute section). Pixels are labeled with an index value created from a matrix of every possible change combination (see entity and attribute information for details).

NLCD 2006 Path/Row Index (Supplementary Vector Layer). To create seamless national layers from individually processed path/rows required assembly of components. The path/row index identifies each Landsat scene pair footprint and includes a Landsat acquisition date attribute and scene identification number attribute for each scene pair used during the NLCD 2006 change analysis and land cover modeling process. The mosaic was made using a model to code each footprint with the appropriate path/row value using a <path>0<row> scheme. For example, all pixels in the footprint for path 29/row 30 would be value 29030 in the path/row index vector file.

Landsat data and ancillary data used for the land cover prediction -

For a list of Landsat scenes and scene dates by path/row used in this project, please see: appendix1_nlcd2006_scene_list_by_path_row.txt

Data Type of DEM composed of 1 band of Continuous Variable Type.

Data Type of Slope composed of 1 band of Continuous Variable Type.

Data Type of Aspect composed of 1 band of Categorical Variable Type.

Data type of Position Index composed of 1 band of Continuous Variable Type.

Data type of 3-ratio index composed of 3 bands of Continuous Variable Type.

Source_Used_Citation_Abbreviation: Landsat ETM, Landsat TM, DEM, USGS/EROS
Process_Date: Unknown
Source_Produced_Citation_Abbreviation: USGS NLCD
Process_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: U.S. Geological Survey
Contact_Position: Customer Service Representative
Contact_Address:
Address_Type: mailing and physical address
Address: USGS/EROS
Address: 47914 252nd Street
City: Sioux Falls
State_or_Province: SD
Postal_Code: 57198-0001
Country: USA
Contact_Voice_Telephone: 605/594-6151
Contact_Facsimile_Telephone: 605/594-6589
Contact_Electronic_Mail_Address: custserv@usgs.gov
Hours_of_Service: 0800 - 1600 CT, M - F (-6h CST/-5h CDT GMT)
Process_Step:
Process_Description: Metadata imported.
Source_Used_Citation_Abbreviation: C:\DOCUME~1\jfry\LOCALS~1\Temp\xml93.tmp
Process_Date: 20110211
Process_Time: 16103000

```
Spatial_Data_Organization_Information:
  Direct_Spatial_Reference_Method: Raster
  Raster_Object_Information:
    Raster_Object_Type: Pixel
    Row_Count: 104424
    Column_Count: 161190
    Vertical_Count: 1
Spatial_Reference_Information:
  Horizontal_Coordinate_System_Definition:
    Planar:
      Map_Projection:
        Map_Projection_Name: Albers Conical Equal Area
        Albers_Conical_Equal_Area:
          Standard_Parallel: 29.500000
          Standard_Parallel: 45.500000
          Longitude_of_Central_Meridian: -96.000000
          Latitude_of_Projection_Origin: 23.000000
          False_Easting: 0.000000
          False_Northing: 0.000000
      Planar_Coordinate_Information:
        Planar_Coordinate_Encoding_Method: row and column
        Coordinate_Representation:
          Abscissa_Resolution: 30.000000
          Ordinate_Resolution: 30.000000
        Planar_Distance_Units: meters
    Geodetic_Model:
      Horizontal_Datum_Name: North American Datum of 1983
      Ellipsoid_Name: Geodetic Reference System 80
      Semi-major_Axis: 6378137.000000
      Denominator_of_Flattening_Ratio: 298.257222
Entity_and_Attribute_Information:
  Detailed_Description:
    Entity_Type:
      Entity_Type_Label: Layer_1
      Entity_Type_Definition: NLDC Land Cover Layer
      Entity_Type_Definition_Source: National Land Cover Database
    Attribute:
      Attribute_Label: ObjectID
      Attribute_Definition: Internal feature number
      Attribute_Definition_Source: ESRI
      Attribute_Domain_Values:
        Unrepresentable_Domain: Sequential unique whole numbers that are automatically generated.
    Attribute:
      Attribute_Label: Count
      Attribute_Definition: A nominal integer value that designates the number of pixels that have each
value in the file; histogram column in ERDAS Imagine raster attributes table '
      Attribute_Definition_Source: ESRI
      Attribute_Domain_Values:
        Unrepresentable_Domain: Integer
    Attribute:
      Attribute_Label: Value
      Attribute_Definition: Land Cover Class Code Value.
      Attribute_Definition_Source: NLCD Legend Land Cover Class Descriptions
      Attribute_Domain_Values:
        Enumerated_Domain:
          Enumerated_Domain_Value: 11
          Enumerated_Domain_Value_Definition: Open Water - All areas of open water, generally with less than
25% cover or vegetation or soil
          Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
        Enumerated_Domain:
          Enumerated_Domain_Value: 12
          Enumerated_Domain_Value_Definition: Perennial Ice/Snow - All areas characterized by a perennial
cover of ice and/or snow,generally greater than 25% of total cover.
          Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
        Enumerated_Domain:
          Enumerated_Domain_Value: 21
          Enumerated_Domain_Value_Definition: Developed, Open Space - Includes areas with a mixture of some
constructed materials, but mostly vegetation in the form of lawn grasses.  Impervious surfaces account for
less than 20 percent of total cover.  These areas most commonly include large-lot single-family housing
units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or
aesthetic purposes.
          Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
        Enumerated_Domain:
          Enumerated_Domain_Value: 22
          Enumerated_Domain_Value_Definition: Developed, Low Intensity -Includes areas with a mixture of
constructed materials and vegetation.  Impervious surfaces account for 20-49 percent of total cover.  These
areas most commonly include single-family housing units.
          Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
        Enumerated_Domain:
          Enumerated_Domain_Value: 23
          Enumerated_Domain_Value_Definition: Developed, Medium Intensity - Includes areas with a mixture of
constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover.
These areas most commonly include single-family housing units.
          Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
```

Enumerated_Domain:
Enumerated_Domain_Value: 24
Enumerated_Domain_Value_Definition: Developed, High Intensity - Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
Enumerated_Domain:
Enumerated_Domain_Value: 31
Enumerated_Domain_Value_Definition: Barren Land (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
Enumerated_Domain:
Enumerated_Domain_Value: 41
Enumerated_Domain_Value_Definition: Deciduous Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
Enumerated_Domain:
Enumerated_Domain_Value: 42
Enumerated_Domain_Value_Definition: Evergreen Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
Enumerated_Domain:
Enumerated_Domain_Value: 43
Enumerated_Domain_Value_Definition: Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
Enumerated_Domain:
Enumerated_Domain_Value: 51
Enumerated_Domain_Value_Definition: Dwarf Scrub - Alaska only areas dominated by shrubs less than 20 centimeters tall with shrub canopy typically greater than 20% of total vegetation. This type is often co-associated with grasses, sedges, herbs, and non-vascular vegetation.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
Enumerated_Domain:
Enumerated_Domain_Value: 52
Enumerated_Domain_Value_Definition: Shrub/Scrub - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
Enumerated_Domain:
Enumerated_Domain_Value: 71
Enumerated_Domain_Value_Definition: Grassland/Herbaceous - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
Enumerated_Domain:
Enumerated_Domain_Value: 72
Enumerated_Domain_Value_Definition: Sedge/Herbaceous - Alaska only areas dominated by sedges and forbs, generally greater than 80% of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra, and sedge tussock tundra.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
Enumerated_Domain:
Enumerated_Domain_Value: 73
Enumerated_Domain_Value_Definition: Lichens - Alaska only areas dominated by fruticose or foliose lichens generally greater than 80% of total vegetation.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
Enumerated_Domain:
Enumerated_Domain_Value: 74
Enumerated_Domain_Value_Definition: Moss- Alaska only areas dominated by mosses, generally greater than 80% of total vegetation.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
Enumerated_Domain:
Enumerated_Domain_Value: 81
Enumerated_Domain_Value_Definition: Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
Enumerated_Domain:
Enumerated_Domain_Value: 82
Enumerated_Domain_Value_Definition: Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions
Enumerated_Domain:
Enumerated_Domain_Value: 90
Enumerated_Domain_Value_Definition: Woody Wetlands - Areas where forest or shrub land vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions

Enumerated_Domain:
Enumerated_Domain_Value: 95
Enumerated_Domain_Value_Definition: Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Enumerated_Domain_Value_Definition_Source: NLCD Legend Land Cover Class Descriptions

SECTION 4.0

MANNING'S COEFFICIENT REFERENCE

Manning's n Coefficients for Open Channel Flow

The fluid mechanics calculations website

Manning n values compiled from the references listed under Discussion and References as well as the references at the bottom of this page. Manning n has no units.

To: LMNO Engineering Home Page (more calculations)
Circular Culverts using Manning Equation Culvert Design using Inlet and Outlet Control
Trapezoidal Channels Rectangular Channels
Manning Equation Calculator Unit Conversions

Material	Manning n	Material	Manning n
Natural Streams		*Excavated Earth Channels*	
Clean and Straight	0.030	Clean	0.022
Major Rivers	0.035	Gravelly	0.025
Sluggish with Deep Pools	0.040	Weedy	0.030
		Stony, Cobbles	0.035
Metals		*Floodplains*	
Brass	0.011	Pasture, Farmland	0.035
Cast Iron	0.013	Light Brush	0.050
Smooth Steel	0.012	Heavy Brush	0.075
Corrugated Metal	0.022	Trees	0.15
Non-Metals			
Glass	0.010	Finished Concrete	0.012
Clay Tile	0.014	Unfinished Concrete	0.014
Brickwork	0.015	Gravel	0.029
Asphalt	0.016	Earth	0.025
Masonry	0.025	Planed Wood	0.012
		Unplaned Wood	0.013
Corrugated Polyethylene (PE) with smooth inner walls [a,b]			0.009-0.015
Corrugated Polyethylene (PE) with corrugated inner walls [c]			0.018-0.025
Polyvinyl Chloride (PVC) with smooth inner walls [d,e]			0.009-0.011

SECTION 5.0

SLOPE CALCULATION

Slope Claculation for Muskingum-Cunge Routing

	Macinnes Marsh Dam	Fruitland Mill Dam	William Daly Marsh Dam
Upstream Elevation (ft)	400	430	500
Downstream Elevation (ft)	280	270	270
Reach Distance Between Elevations (ft)	45400	30240	56690
Slope s (-)	0.0026	0.0053	0.0041

Slope Claculation Formulas

	A	B	C	D
1		Macinnes Marsh Dam	Fruitland Mill Dam	William Daly Marsh Dam
2	Upstream Elevation (ft)	400	430	500
3	Downstream Elevation (ft)	280	270	270
4	Reach Distance Between Elevations (ft)	45400	30240	56690
5	Slope s (-)	=(B2-B3)/B4	=(C2-C3)/C4	=(D2-D3)/D4

APPENDIX E: NCDC RAW DATA AND DOCUMENTATION

Note: Due to the size of the data in this appendix, the information has been archived in the AREVA file management system, ColdStor.

The path to the file is:

\cold\General-Access\32\32-9190280-000\official

APPENDIX F: 2 YEAR WIND SPEED CALCULATION

F.1 Wind Speed Calculation

Step 1: Maximum Wind Speeds from each year for the period of record (Station: GHCND USW00014768)

Year	Max (.1m/s)	Max (m/s)
1996	192	19.2
1997	264	26.4
1998	304	30.4
1999	232	23.2
2000	201	20.1
2001	259	25.9
2002	264	26.4
2003	228	22.8
2004	215	21.5
2005	192	19.2
2006	246	24.6
2007	197	19.7
2008	268	26.8
2009	197	19.7
2010	201	20.1
2011	228	22.8
2012	232	23.2

Step 2: Determine the 2 year return period wind speed using the Gumbel Distribution

Year	Peak Wind Speed (m/s)	Rank	Gringorten	Return Period (years)
1998	30.4	1	0.03	30.57
2008	26.8	2	0.09	10.97
1997	26.4	3	0.15	6.69
2002	26.4	4	0.21	4.81
2001	25.9	5	0.27	3.75
2006	24.6	6	0.32	3.08
1999	23.2	7	0.38	2.61
2012	23.2	8	0.44	2.26
2003	22.8	9	0.50	2.00
2011	22.8	10	0.56	1.79
2004	21.5	11	0.62	1.62
2000	20.1	12	0.68	1.48
2010	20.1	13	0.73	1.36
2007	19.7	14	0.79	1.26
2009	19.7	15	0.85	1.18
2005	19.2	16	0.91	1.10
1996	19.2	17	0.97	1.03

Period of Record (years)	17.00
Mean Peak Wind Speed (m/s)	23.06
Standard Deviation	3.29
α	2.56
ξ	21.58

$$\alpha = \frac{s\sqrt{6}}{\pi}$$

$$\xi = \bar{x} - 0.5772\alpha$$

$$x_p = \xi - \alpha \ln(-\ln(p))$$

Return Period (years)	Nonexceedance	Exceedance	Wind Speed

	Probability	Probability	(m/s)			
500	0.998	0.002	37.5			
200	0.995	0.005	35.2			
100	0.99	0.01	33.4			
50	0.98	0.02	31.6			
25	0.96	0.04	29.8			
10	0.9	0.1	27.4			
50	0.98	0.02	31.6			
2	0.5	0.5	22.5	=	73.86058	ft/sec

F.2 Wind Speed Calculation Formulas

	A	B	C	D	E	F	G
1	Step 1: Maximum Wind Speeds from each year for the period of record (Station: GHCND USW00014768)						
2	Year	Max (.1m/s)	Max (m/s)				
3	1996	=MAX('14768'!E2:E185)	=B3/10				
4	=A3+1	=MAX('14768'!E186:E548)	=B4/10				
5	=A4+1	=MAX('14768'!E549:E913)	=B5/10				
6	=A5+1	=MAX('14768'!E914:E1278)	=B6/10				
7	=A6+1	=MAX('14768'!E1279:E1644)	=B7/10				
8	=A7+1	=MAX('14768'!E1645:E2009)	=B8/10				
9	=A8+1	=MAX('14768'!E2010:E2374)	=B9/10				
10	=A9+1	=MAX('14768'!E2375:E2739)	=B10/10				
11	=A10+1	=MAX('14768'!E2740:E3105)	=B11/10				
12	=A11+1	=MAX('14768'!E3106:E3470)	=B12/10				
13	=A12+1	=MAX('14768'!E3471:E3835)	=B13/10				
14	=A13+1	=MAX('14768'!E3836:E4200)	=B14/10				
15	=A14+1	=MAX('14768'!E4201:E4566)	=B15/10				
16	=A15+1	=MAX('14768'!E4567:E4931)	=B16/10				
17	=A16+1	=MAX('14768'!E4932:E5296)	=B17/10				
18	=A17+1	=MAX('14768'!E5297:E5661)	=B18/10				
19	=A18+1	=MAX('14768'!E5662:E6024)	=B19/10				
20							
21	Step 2: Determine the 2 year return period wind speed using the Gumbel Distribution						
22	Year	Peak Wind Speed (m/s)	Rank	Gringorten	Return Period		
23	1998	30.4	1	=(C23-0.44)/($B$41+0.12)	=1/D23		
24	2008	26.8	2	=(C24-0.44)/($B$41+0.12)	=1/D24		
25	1997	26.4	3	=(C25-0.44)/($B$41+0.12)	=1/D25		
26	2002	26.4	4	=(C26-0.44)/($B$41+0.12)	=1/D26		
27	2001	25.9	5	=(C27-0.44)/($B$41+0.12)	=1/D27		
28	2006	24.6	6	=(C28-0.44)/($B$41+0.12)	=1/D28		
29	1999	23.2	7	=(C29-0.44)/($B$41+0.12)	=1/D29		
30	2012	23.2	8	=(C30-0.44)/($B$41+0.12)	=1/D30		
31	2003	22.8	9	=(C31-0.44)/($B$41+0.12)	=1/D31		
32	2011	22.8	10	=(C32-0.44)/($B$41+0.12)	=1/D32		
33	2004	21.5	11	=(C33-0.44)/($B$41+0.12)	=1/D33		
34	2000	20.1	12	=(C34-0.44)/($B$41+0.12)	=1/D34		
35	2010	20.1	13	=(C35-0.44)/($B$41+0.12)	=1/D35		
36	2007	19.7	14	=(C36-0.44)/($B$41+0.12)	=1/D36		
37	2009	19.7	15	=(C37-0.44)/($B$41+0.12)	=1/D37		
38	2005	19.2	16	=(C38-0.44)/($B$41+0.12)	=1/D38		
39	1996	19.2	17	=(C39-0.44)/($B$41+0.12)	=1/D39		
40							
41	Period of Record	=COUNT(A3:A19)					
42	Mean	=AVERAGE(B23:B39)					
43	Standard Deviation	=STDEV(B23:B39)					
44	α	=(B43*SQRT(6))/(PI())					
45	ξ	=B42-0.5772*B44					
46							
47	Return Period (years)	Nonexceedance Probability	Exceedance Probability	Wind Speed (m/s)			
48	500	=(-1/A48)+1	=1-B48	=$B$45-$B$44*LN(-LN(B48))			
49	200	=(-1/A49)+1	=1-B49	=$B$45-$B$44*LN(-LN(B49))			
50	100	=(-1/A50)+1	=1-B50	=$B$45-$B$44*LN(-LN(B50))			
51	50	=(-1/A51)+1	=1-B51	=$B$45-$B$44*LN(-LN(B51))			
52	25	=(-1/A52)+1	=1-B52	=$B$45-$B$44*LN(-LN(B52))			
53	10	=(-1/A53)+1	=1-B53	=$B$45-$B$44*LN(-LN(B53))			
54	50	=(-1/A54)+1	=1-B54	=$B$45-$B$44*LN(-LN(B54))			
55	2	=(-1/A55)+1	=1-B55	=$B$45-$B$44*LN(-LN(B55))		=D55*3.28	ft/sec

$$\alpha = \frac{s\sqrt{6}}{\pi} \qquad \xi = \bar{x} - 0.5772\alpha$$

$$x_p = \xi - \alpha \ln(-\ln(p))$$

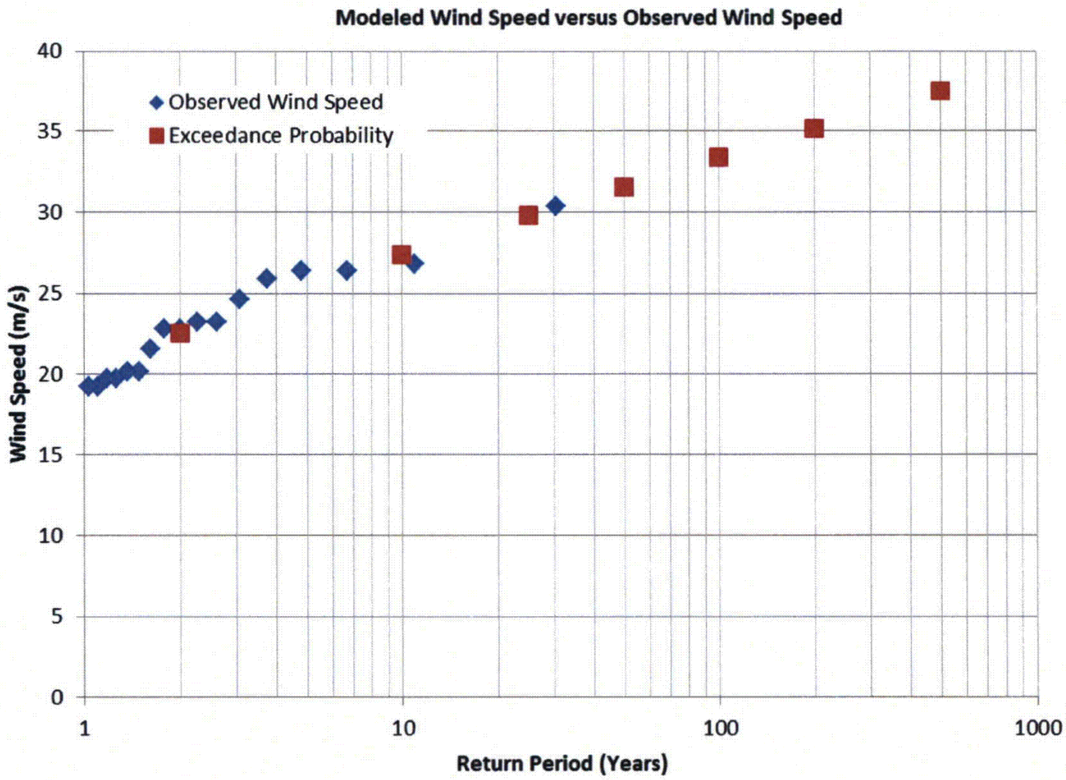


Figure C-1: Modeled Wind Speed versus Observed Wind Speed

APPENDIX G: HEC-HMS INPUTS AND OUTPUTS

```
Basin: Dam Failure
     Last Modified Date: 13 March 2013
     Last Modified Time: 13:28:34
     Version: 3.5
     Filepath Separator: \
     Unit System: English
     Missing Flow To Zero: No
     Enable Flow Ratio: No
     Allow Blending: No
     Compute Local Flow At Junctions: No

     Enable Sediment Routing: No

     Enable Quality Routing: No
End:

Subbasin: Mill Creek Watershed
     Canvas X: 309913.96877561207
     Canvas Y: 4785464.710326405
     Area: 10.82
     Downstream: Junction-2

     Canopy: None

     Surface: None

     LossRate: SCS
     Percent Impervious Area: 0.0
     Curve Number: 89.4

     Transform: User-Specified UH
     Unit Hydrograph Name: Adjusted Mill Creek

     Baseflow: None
End:

Reservoir: W. D. Marsh Dam
     Canvas X: 310391.9083864886
     Canvas Y: 4783335.486876718
     Downstream: Junction-2

     Route: Controlled Outflow
     Routing Curve: Elevation-Area
     Initial Elevation: 6
     Elevation-Area Table: William Daly Marsh Dam
     Adaptive Control: On
     Main Tailwater Condition: None
     Auxiliary Tailwater Condition: None

     Dam Breach: Overtop Breach
     Dam Breach Outlet: Main
     Breach Top Elevation: 6
     Breach Bottom Elevation: 0
     Breach Bottom Width: 15
     Left Side Slope: 0.5
     Right Side Slope: 0.5
     Trigger Type: Time
     Trigger Time: 8 January 2000, 19:10
     Development Time: 0.5
     Progression Type: Linear
     End Dam Breach:

     Evaporation Method: Zero Evaporation
     End Evaporation:
End:

Reservoir: F.M. Dam
     Canvas X: 309549.26459730905
     Canvas Y: 4788290.232357093
     Downstream: Junction-2

     Route: Controlled Outflow
     Routing Curve: Elevation-Area
     Initial Elevation: 10
     Elevation-Area Table: Fruitland Mill Dam
     Adaptive Control: On
     Main Tailwater Condition: None
     Auxiliary Tailwater Condition: None
```

```
     Dam Breach: Overtop Breach
     Dam Breach Outlet: Main
     Breach Top Elevation: 10
     Breach Bottom Elevation: 0
     Breach Bottom Width: 25
     Left Side Slope: 0.5
     Right Side Slope: 0.5
     Trigger Type: Time
     Trigger Time: 8 January 2000, 19:20
     Development Time: 0.5
     Progression Type: Linear
     End Dam Breach:

     Evaporation Method: Zero Evaporation
     End Evaporation:
End:

Junction: Junction-2
     Canvas X: 309751.4991067121
     Canvas Y: 4790009.2256870195
     Downstream: Junction-1
End:

Subbasin: Deer Creek Watershed
     Canvas X: 308267.7507324683
     Canvas Y: 4792259.101159017
     Area: 3.65
     Downstream: Junction-3

     Canopy: None

     Surface: None

     LossRate: SCS
     Percent Impervious Area: 0.0
     Curve Number: 90.4

     Transform: User-Specified UH
     Unit Hydrograph Name: Adjusted Deer Creek

     Baseflow: None
End:

Reservoir: M.M. Dam
     Canvas X: 307729.15401268116
     Canvas Y: 4793413.506595305
     Downstream: Junction-3

     Route: Controlled Outflow
     Routing Curve: Elevation-Area
     Initial Elevation: 5
     Elevation-Area Table: Macinnes Marsh Dam
     Adaptive Control: On
     Main Tailwater Condition: None
     Auxiliary Tailwater Condition: None

     Dam Breach: Overtop Breach
     Dam Breach Outlet: Main
     Breach Top Elevation: 5
     Breach Bottom Elevation: 0
     Breach Bottom Width: 12.5
     Left Side Slope: 0.5
     Right Side Slope: 0.5
     Trigger Type: Time
     Trigger Time: 8 January 2000, 18:20
     Development Time: 0.5
     Progression Type: Linear
     End Dam Breach:

     Evaporation Method: Zero Evaporation
     End Evaporation:
End:

Junction: Junction-3
     Canvas X: 309105.82537261426
     Canvas Y: 4793216.900747756
     Downstream: Junction-1
End:
```

Dam_Failure

```
Junction: Junction-1
     Description: Combination of Deer Creek and Mill Creek Flows
     Canvas X: 312413.7098393652
     Canvas Y: 4794305.967682988
End:

Basin Schematic Properties:
     Last View N: 4795132.499925232
     Last View S: 4779897.500216865
     Last View W: 305301.5002035737
     Last View E: 313628.50023320835
     Maximum View N: 4795132.499925232
     Maximum View S: 4779897.500216865
     Maximum View W: 305301.5002035737
     Maximum View E: 313628.50023320835
     Extent Method: Elements Maps
     Buffer: 10
     Draw Icons: Yes
     Draw Icon Labels: Yes
     Draw Map Objects: No
     Draw Gridlines: No
     Draw Flow Direction: No
     Fix Element Locations: No
     Fix Hydrologic Order: No
     Map: hec.map.aishape.AiShapeMap
     Map File Name: J:\170,000-179,999\171356\171356-00.DML\Work Files\GIS\Data\Watersheds\Deer Creek
Watershed\GlobalWatershedNY.shp
     Minimum Scale: -2147483648
     Maximum Scale: 2147483647
     Map Shown: Yes
     Map: hec.map.aishape.AiShapeMap
     Map File Name: J:\170,000-179,999\171356\171356-00.DML\Work Files\GIS\Data\Watersheds\Mill Creek
Watershed2.shp
     Minimum Scale: -2147483648
     Maximum Scale: 2147483647
     Map Shown: Yes
End:
```

Fruitland Mill Dam Elevation-Area Function

Paired Data | Table | Graph

Name: Fruitland Mill Dam

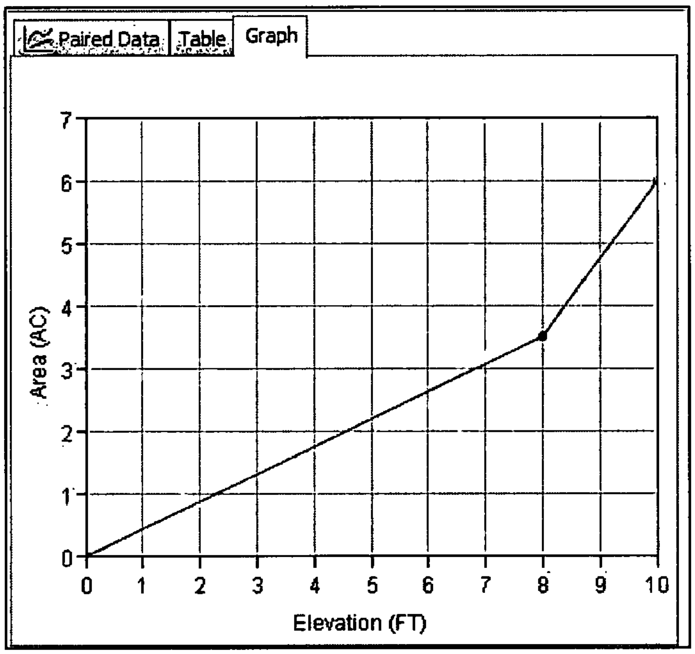
Description:

Data Source: Manual Entry

Units: FT : AC

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
0.0	0.0
8.0	3.5
10.0	6.0



Macinnes Marsh Dam Elevation-Area Function

Paired Data | Table | Graph

Name: Macinnes Marsh Dam

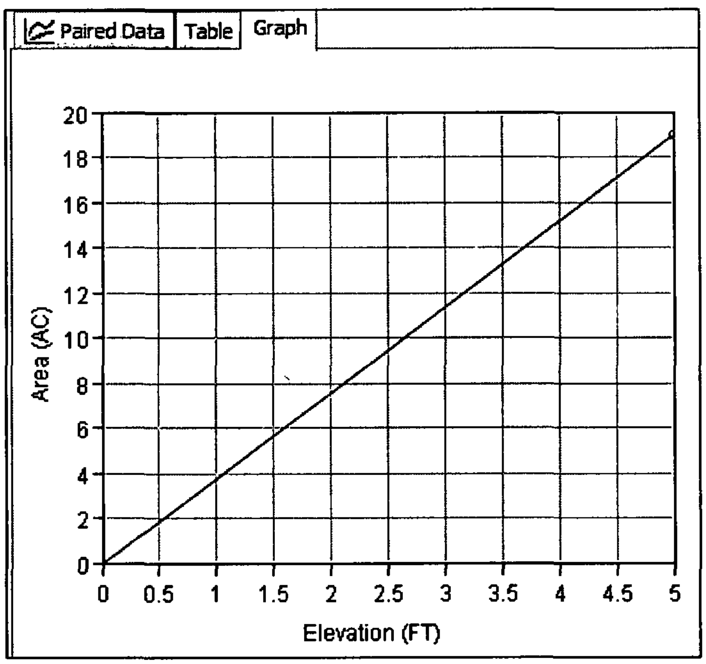
Description:

Data Source: Manual Entry

Units: FT : AC

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
0.0	0.0
5.0	19.0



William Daly Marsh Dam Elevation-Area Function

Paired Data | Table | Graph

Name: William Daly Marsh Dam

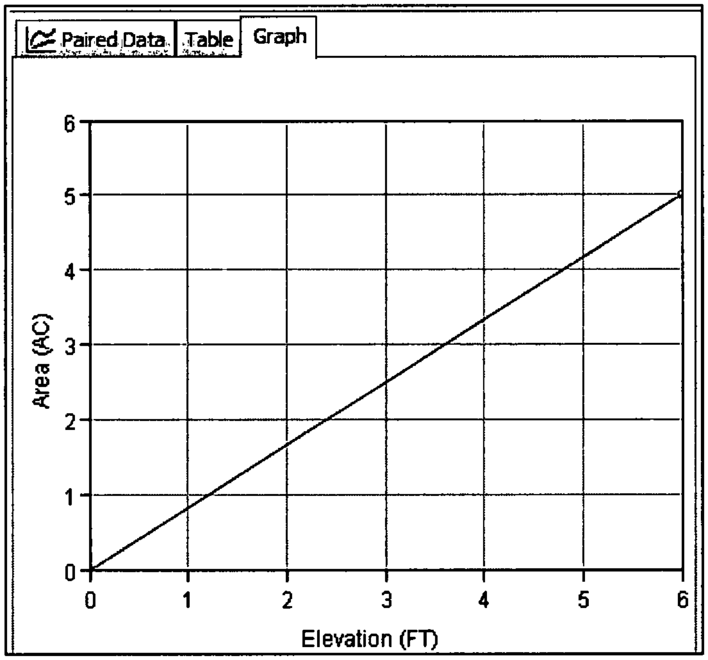
Description:

Data Source: Manual Entry

Units: FT : AC

Paired Data | Table | Graph

Elevation (FT)	Area (AC)
0.0	0.0
6.0	5.0



Global Summary Results for Run "PMF Dam Breach"

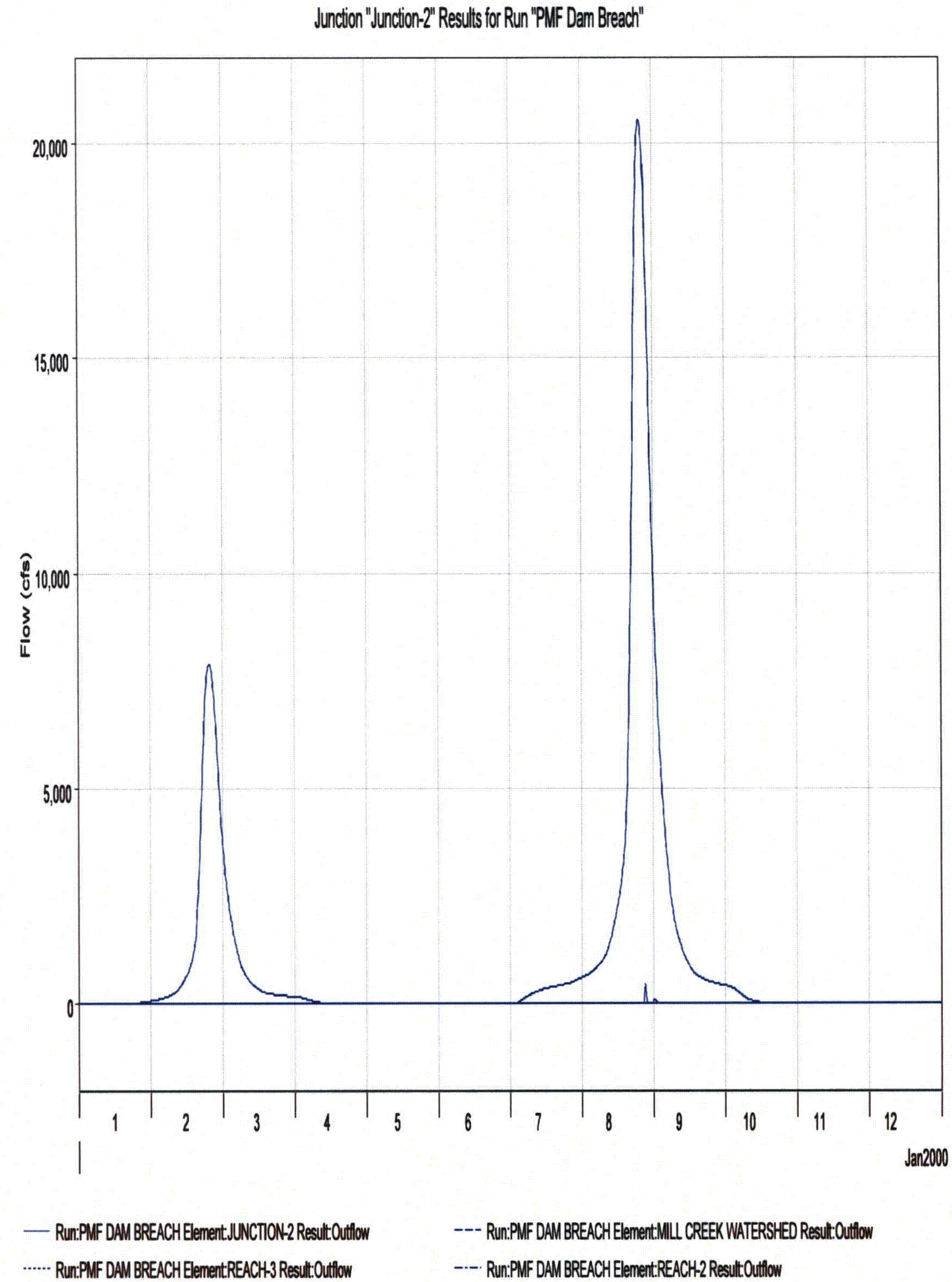
Project: GINNA PMF Simulation Run: PMF Dam Breach

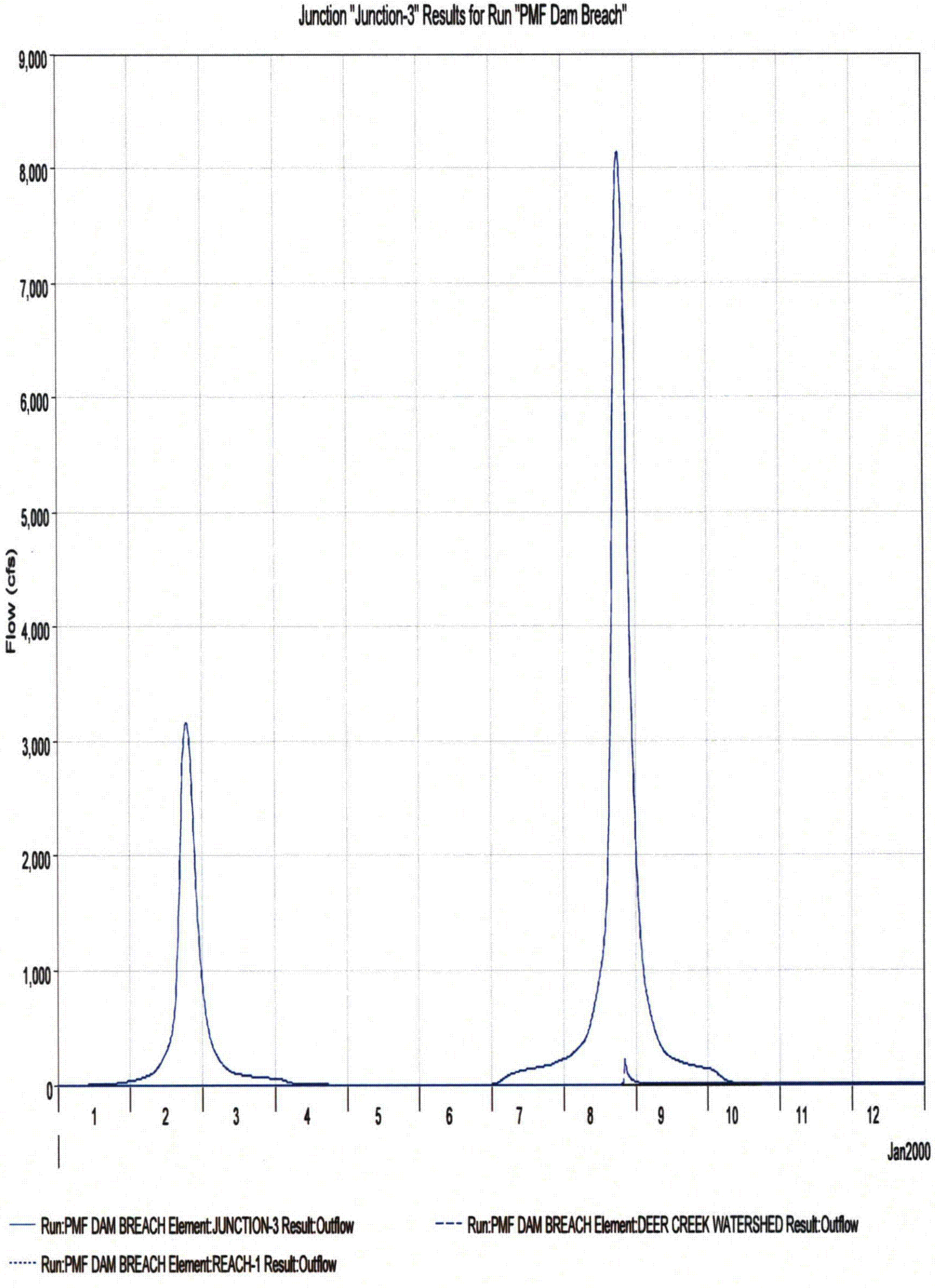
Start of Run: 01Jan2000, 00:00
End of Run: 13Jan2000, 00:00
Compute Time: 26Mar2013, 11:43:54

Basin Model: Dam Failure
Meteorologic Model: 72hr_PMP
Control Specifications: 12-day

Show Elements: All Elements Volume Units: IN AC-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Mill Creek Watershed	10.82	20528.7	08Jan2000, 19:40	41.36
W. D. Marsh Dam	0.00	483.3	08Jan2000, 19:50	
Reach-3	0.00	101.4	09Jan2000, 00:10	
F.M. Dam	0.00	1910.4	08Jan2000, 19:50	
Reach-2	0.00	490.8	08Jan2000, 21:00	
Junction-2	10.82	20528.7	08Jan2000, 19:40	41.41
Deer Creek Watershed	3.65	8138.2	08Jan2000, 18:50	41.48
M.M. Dam	0.00	425.1	08Jan2000, 19:00	
Reach-1	0.00	216.2	08Jan2000, 20:20	
Junction-3	3.65	8138.2	08Jan2000, 18:50	41.64
Junction-1	14.47	28460.4	08Jan2000, 19:20	41.47


Junction "Junction-2" Results for Run "PMF Dam Breach"
Flow (cfs)
20,000
15,000
10,000
5,000
0
1
2
3
4
5
6
7
8
9
10
11
12
Jan2000
Run:PMF DAM BREACH Element:JUNCTION-2 Result:Outflow
Run:PMF DAM BREACH Element:MILL CREEK WATERSHED Result:Outflow
Run:PMF DAM BREACH Element:REACH-3 Result:Outflow
Run:PMF DAM BREACH Element:REACH-2 Result:Outflow


Junction "Junction-3" Results for Run "PMF Dam Breach"
Flow (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1
2
3
4
5
6
7
8
9
10
11
12
Jan2000
Run:PMF DAM BREACH Element:JUNCTION-3 Result:Outflow
Run:PMF DAM BREACH Element:DEER CREEK WATERSHED Result:Outflow
Run:PMF DAM BREACH Element:REACH-1 Result:Outflow

1/2 PMF & 25 Year Flood Basin File

Basin_1_ArcIII_NLA.basin

```
Basin: Basin 1-ArcIII_NLA
     Last Modified Date: 13 September 2012
     Last Modified Time: 13:07:38
     Version: 3.5
     Filepath Separator: \
     Unit System: English
     Missing Flow To Zero: No
     Enable Flow Ratio: No
     Allow Blending: No
     Compute Local Flow At Junctions: No

     Enable Sediment Routing: No

     Enable Quality Routing: No
End:

Subbasin: Mill Creek Watershed
     Canvas X: 309397.98409064166
     Canvas Y: 4788810.645207537
     Area: 10.82
     Downstream: Junction-1

     Canopy: None

     Surface: None

     LossRate: SCS
     Percent Impervious Area: 0.0
     Curve Number: 89.4

     Transform: User-Specified UH
     Unit Hydrograph Name: Adjusted Mill Creek

     Baseflow: None
End:

Subbasin: Deer Creek Watershed
     Canvas X: 308370.4034651506
     Canvas Y: 4792943.30641875
     Area: 3.65
     Downstream: Junction-1

     Canopy: None

     Surface: None

     LossRate: SCS
     Percent Impervious Area: 0.0
     Curve Number: 90.4

     Transform: User-Specified UH
     Unit Hydrograph Name: Adjusted Deer Creek

     Baseflow: None
End:

Junction: Junction-1
     Description: Combination of Deer Creek and Mill Creek Flows
     Canvas X: 312413.7098393652
     Canvas Y: 4794305.967682988
End:

Basin Schematic Properties:
```

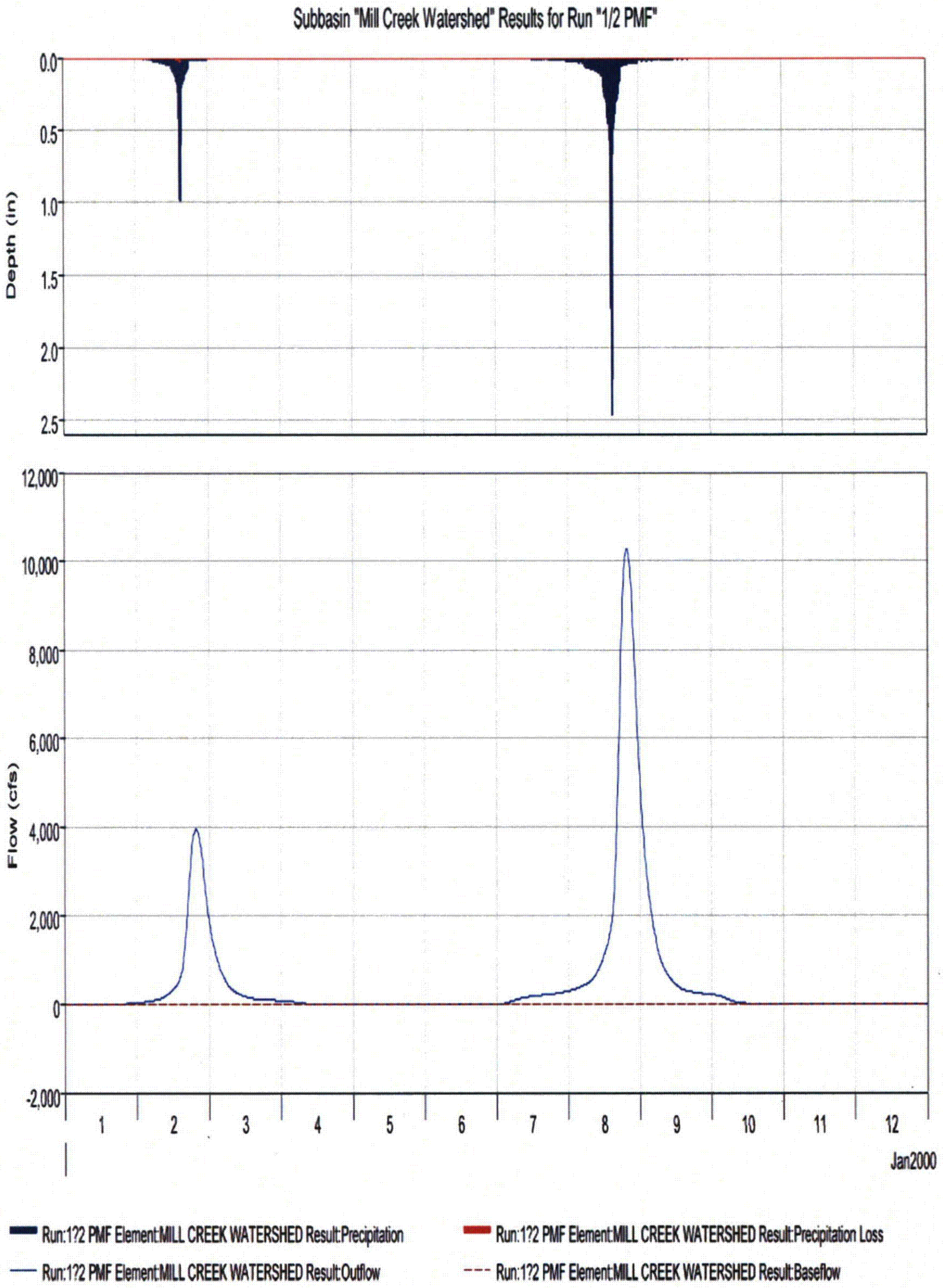
1/2 PMF & 25 Year Flood Basin File

```
                                   Basin_1_ArcIII_NLA.basin
     Last View N: 4795132.499925232
     Last View S: 4779897.500216865
     Last View W: 305301.5002035737
     Last View E: 313628.50023320835
     Maximum View N: 4795132.499925232
     Maximum View S: 4779897.500216865
     Maximum View W: 305301.5002035737
     Maximum View E: 313628.50023320835
     Extent Method: Elements Maps
     Buffer: 10
     Draw Icons: Yes
     Draw Icon Labels: Yes
     Draw Map Objects: No
     Draw Gridlines: No
     Draw Flow Direction: No
     Fix Element Locations: No
     Fix Hydrologic Order: No
     Map: hec.map.aishape.AiShapeMap
     Map File Name: J:\170,000-179,999\171356\171356-00.DML\Work
Files\GIS\Data\Watersheds\Deer Creek Watershed\GlobalWatershedNY.shp
     Minimum Scale: -2147483648
     Maximum Scale: 2147483647
     Map Shown: Yes
     Map: hec.map.aishape.AiShapeMap
     Map File Name: J:\170,000-179,999\171356\171356-00.DML\Work
Files\GIS\Data\Watersheds\Mill Creek Watershed2.shp
     Minimum Scale: -2147483648
     Maximum Scale: 2147483647
     Map Shown: Yes
End:
```

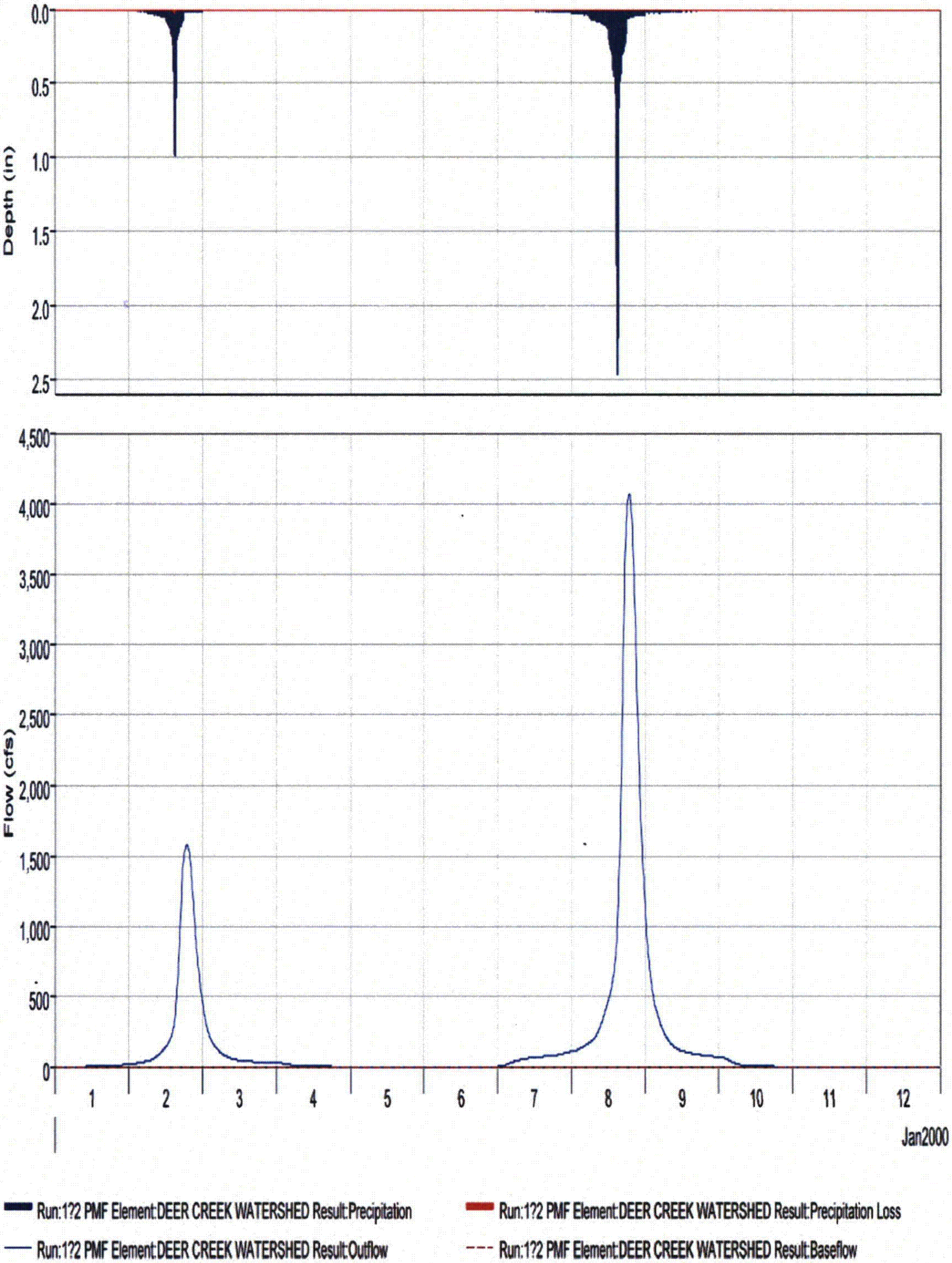
Project: GINNA PMF Simulation Run: 1/2 PMF

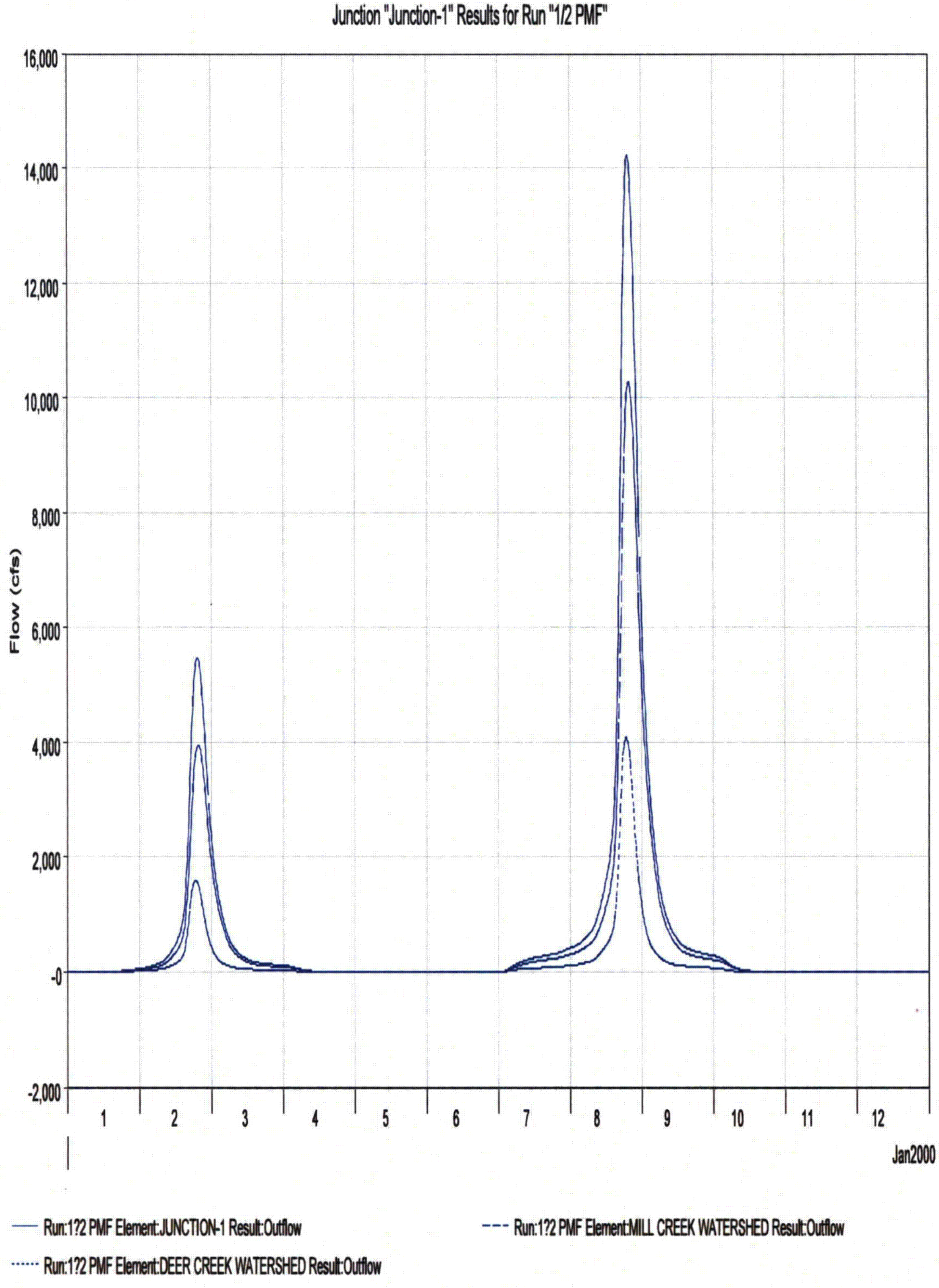
Start of Run: 01Jan2000, 00:00 Basin Model: Basin 1-ArcIII_NLA
End of Run: 13Jan2000, 00:00 Meteorologic Model: 72hr_PMP
Compute Time: 28Mar2013, 11:34:06 Control Specifications: 12-day

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Mill Creek Watershed	10.82	10264.3	08Jan2000, 19:40	20.68
Deer Creek Watershed	3.65	4069.1	08Jan2000, 18:50	20.74
Junction-1	14.47	14230.2	08Jan2000, 19:20	20.69


Subbasin "Mill Creek Watershed" Results for Run "1/2 PMF"
Depth (in)
0.0
0.5
1.0
1.5
2.0
2.5
Flow (cfs)
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
1
2
3
4
5
6
7
8
9
10
11
12
Jan2000
Run:1?2 PMF Element:MILL CREEK WATERSHED Result:Precipitation
Run:1?2 PMF Element:MILL CREEK WATERSHED Result:Precipitation Loss
Run:1?2 PMF Element:MILL CREEK WATERSHED Result:Outflow
Run:1?2 PMF Element:MILL CREEK WATERSHED Result:Baseflow

Subbasin "Deer Creek Watershed" Results for Run "1/2 PMF"



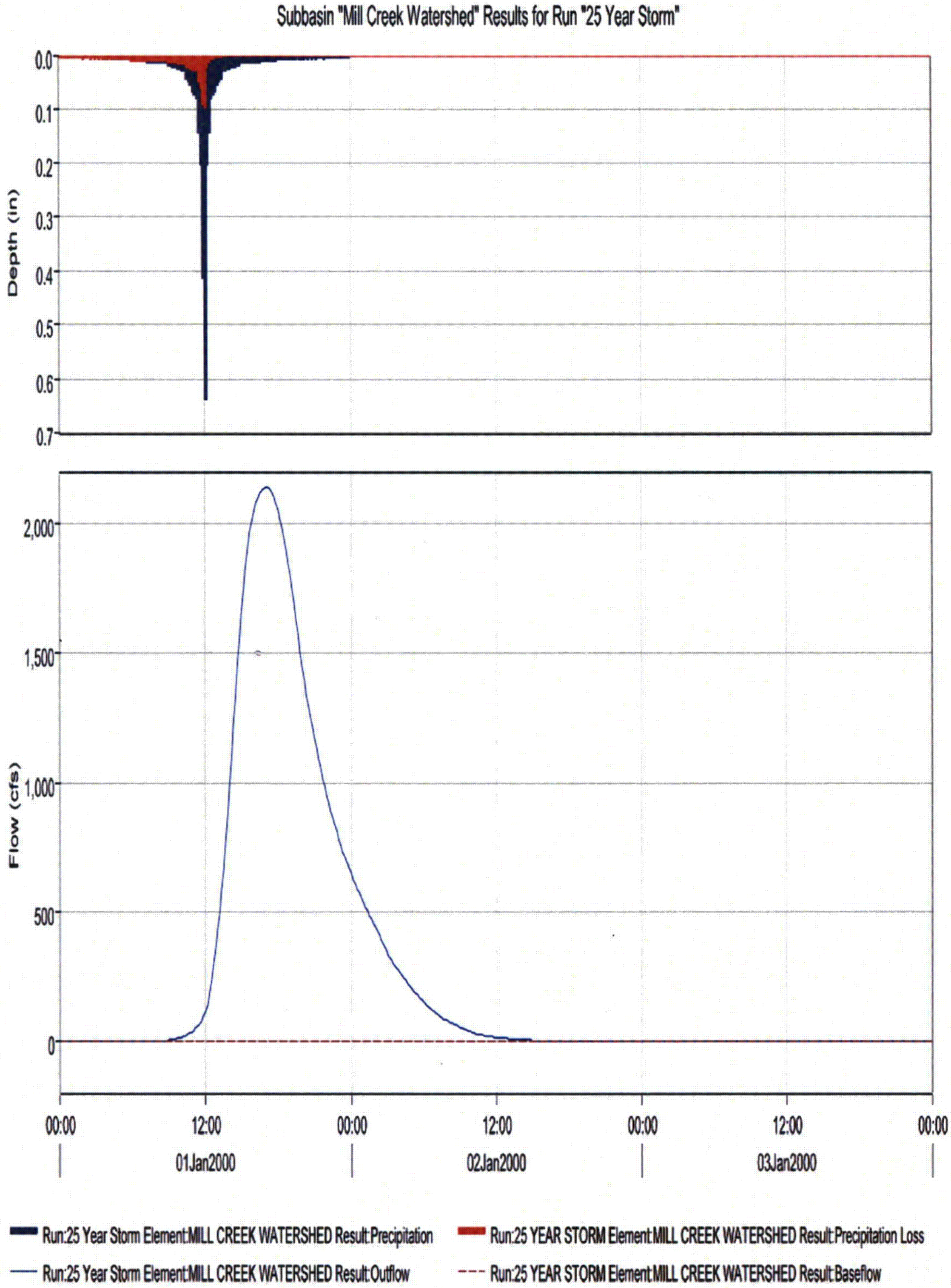


Junction "Junction-1" Results for Run "1/2 PMF"
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-0
-2,000
Flow (cfs)
1
2
3
4
5
6
7
8
9
10
11
12
Jan2000
Run:1?2 PMF Element:JUNCTION-1 Result:Outflow
Run:1?2 PMF Element:MILL CREEK WATERSHED Result:Outflow
Run:1?2 PMF Element:DEER CREEK WATERSHED Result:Outflow

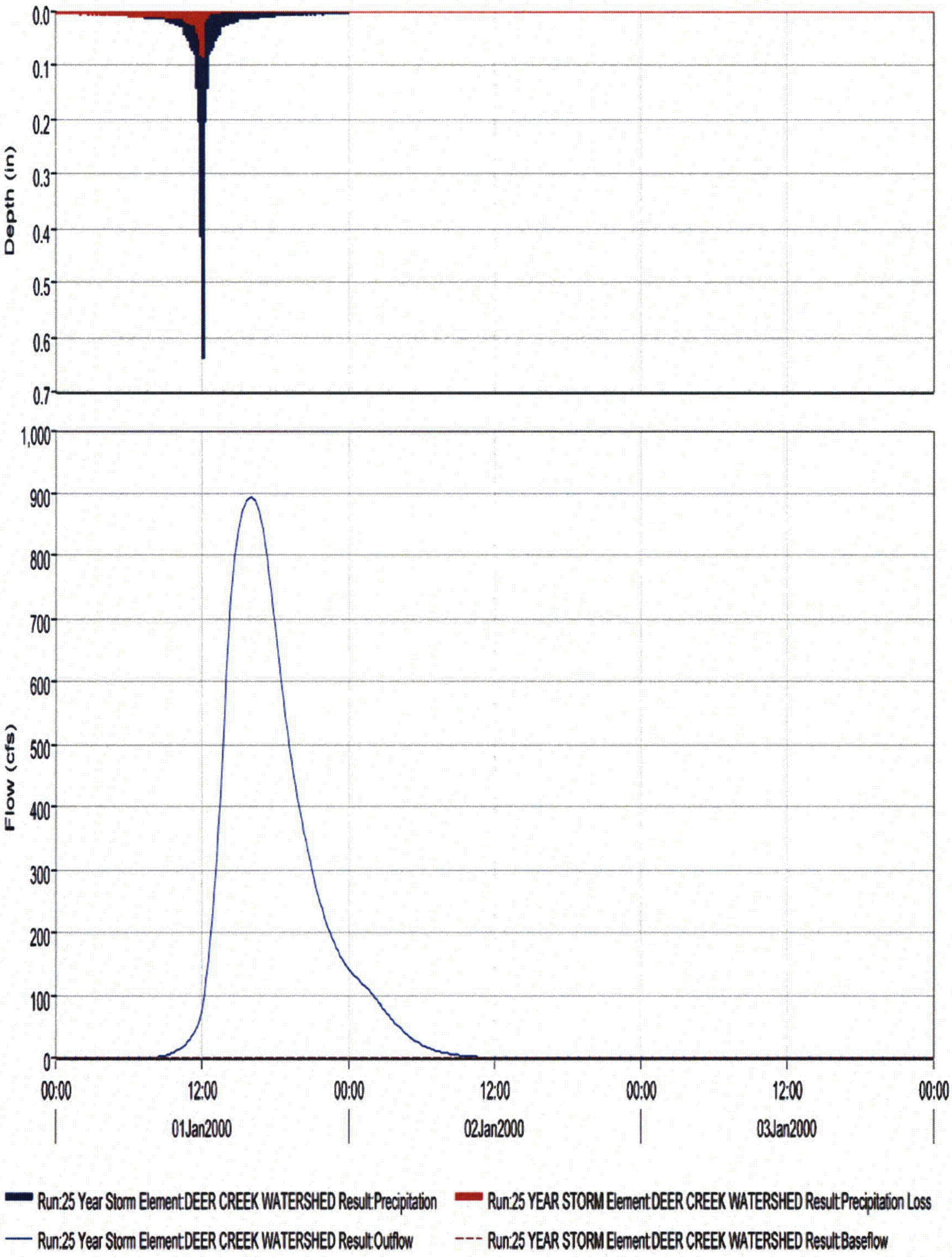
Project: GINNA PMF Simulation Run: 25 Year Storm

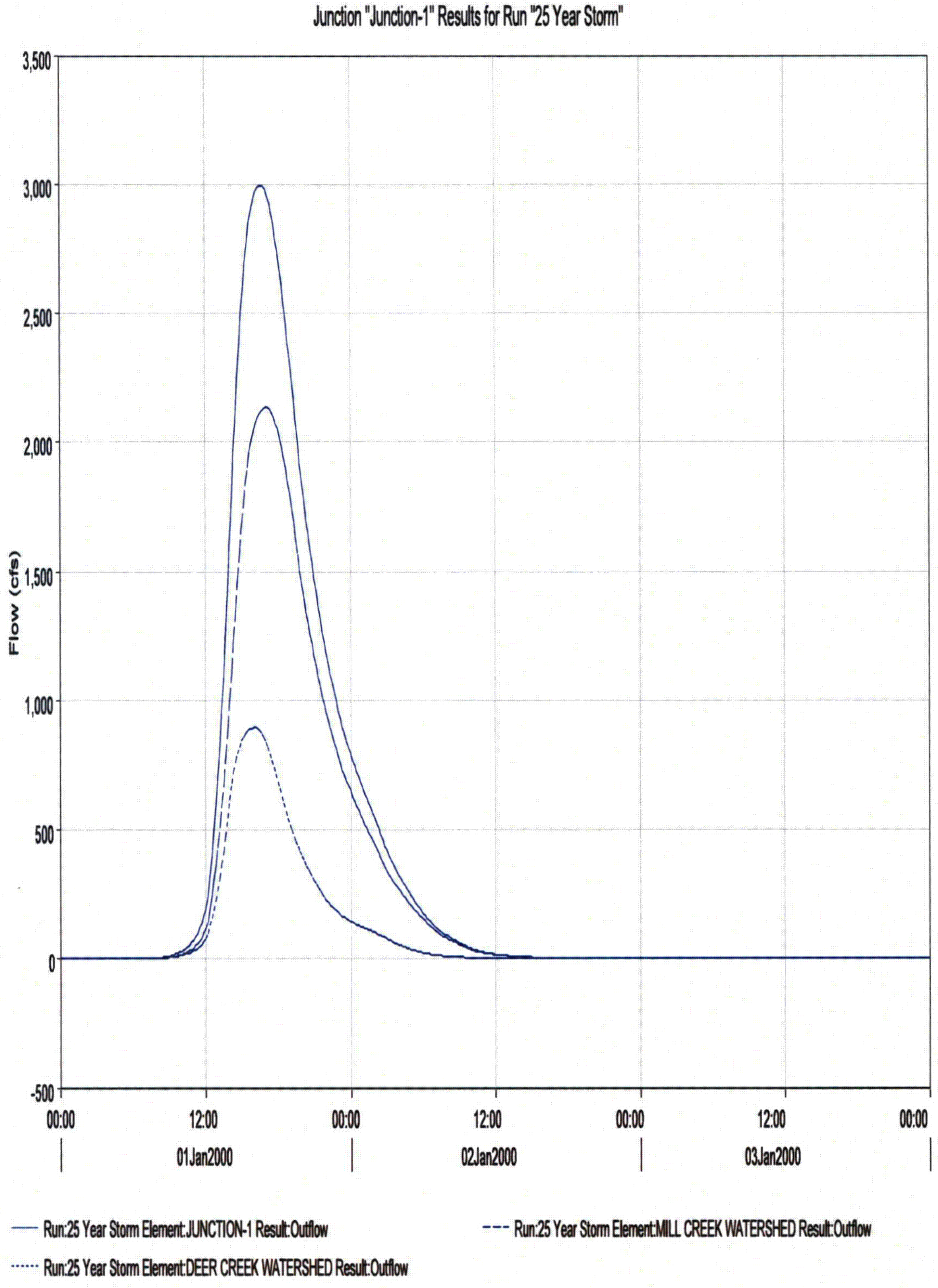
Start of Run: 01Jan2000, 00:00 Basin Model: Basin 1-ArcIII_NLA
End of Run: 04Jan2000, 00:00 Meteorologic Model: 25-YR
Compute Time: 01Apr2013, 16:41:52 Control Specifications: 3-day

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Mill Creek Watershed	10.82	2137.2	01Jan2000, 17:00	2.66
Deer Creek Watershed	3.65	894.6	01Jan2000, 16:00	2.76
Junction-1	14.47	2995.0	01Jan2000, 16:30	2.69


Subbasin "Mill Creek Watershed" Results for Run "25 Year Storm"
Depth (in)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Flow (cfs)
2,000
1,500
1,000
500
0
00:00
12:00
00:00
12:00
00:00
12:00
00:00
01Jan2000
02Jan2000
03Jan2000
Run:25 Year Storm Element:MILL CREEK WATERSHED Result:Precipitation
Run:25 YEAR STORM Element:MILL CREEK WATERSHED Result:Precipitation Loss
Run:25 Year Storm Element:MILL CREEK WATERSHED Result:Outflow
Run:25 YEAR STORM Element:MILL CREEK WATERSHED Result:Baseflow

Subbasin "Deer Creek Watershed" Results for Run "25 Year Storm"




Junction "Junction-1" Results for Run "25 Year Storm"
Flow (cfs)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
-500
00:00
12:00
00:00
12:00
00:00
12:00
00:00
01Jan2000
02Jan2000
03Jan2000
Run:25 Year Storm Element:JUNCTION-1 Result:Outflow
Run:25 Year Storm Element:MILL CREEK WATERSHED Result:Outflow
Run:25 Year Storm Element:DEER CREEK WATERSHED Result:Outflow

APPENDIX H: FLO-2D INPUTS/OUTPUTS AND ADDITIONAL FLO-2D RESULTS FOR BOUNDING ALTERNATIVE

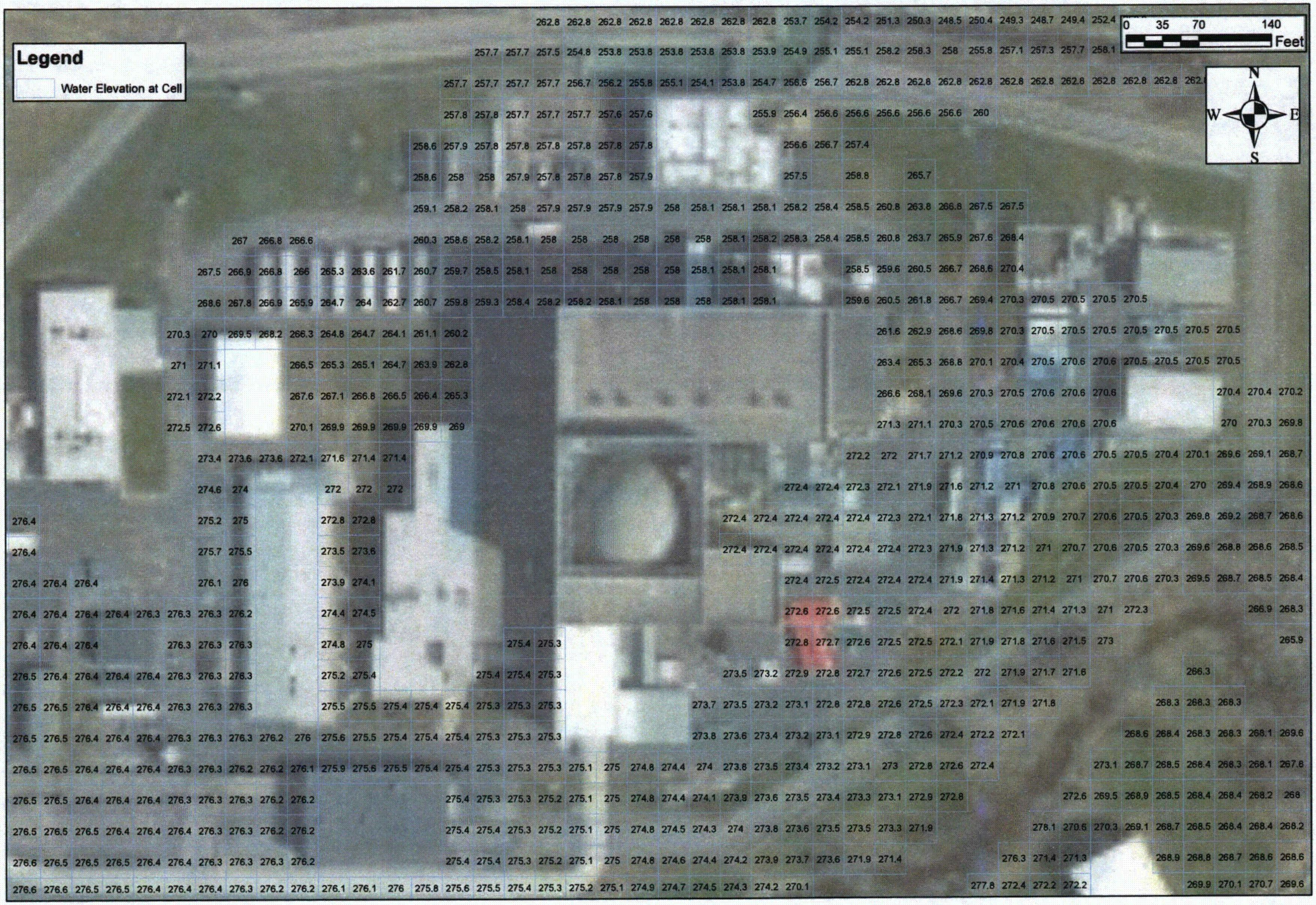
FLO-2D INPUTS AND OUTPUTS

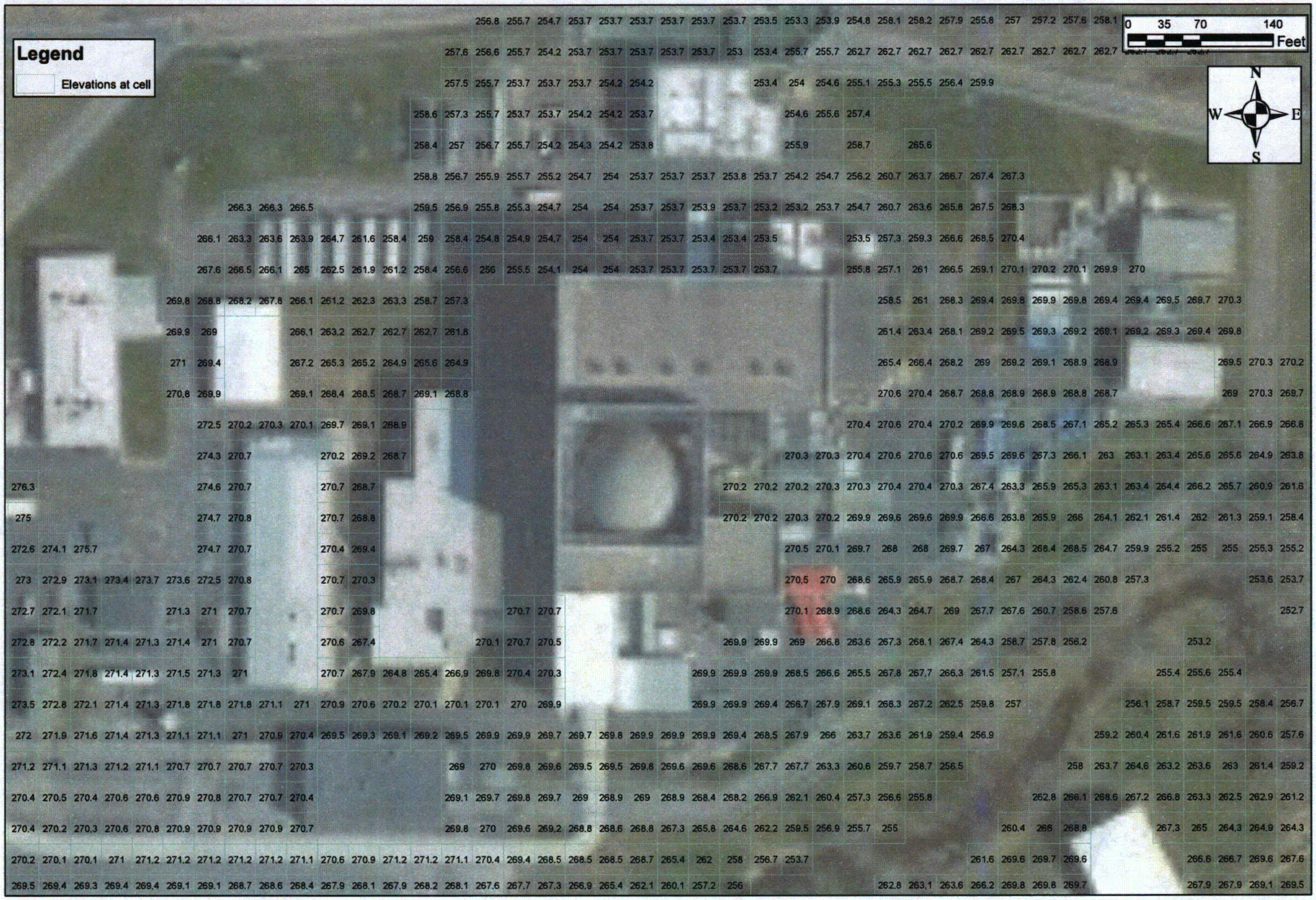
Note: Due to the size of the data in this appendix, the information has been archived in the AREVA file management system, ColdStor.

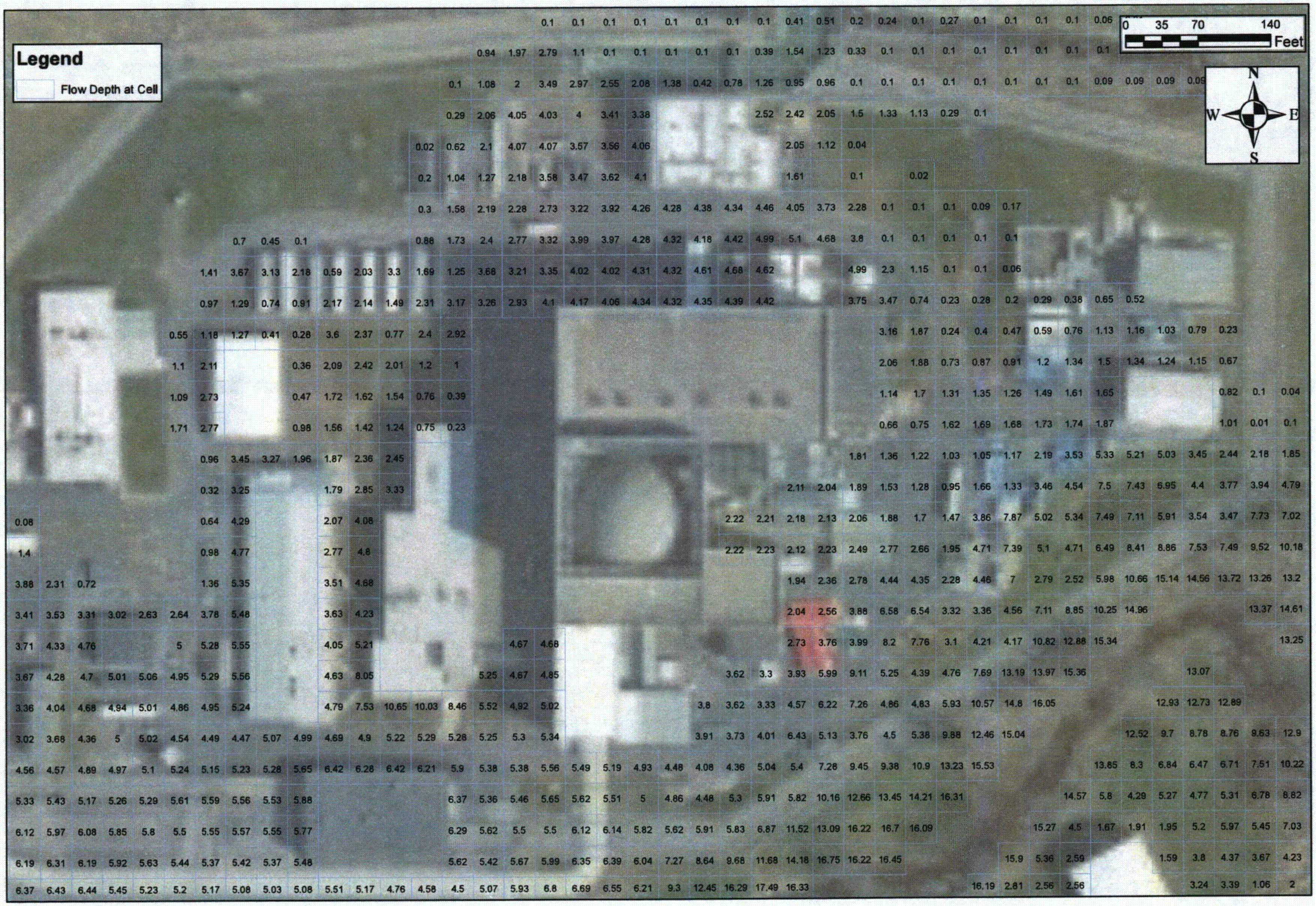
The path to the file is:

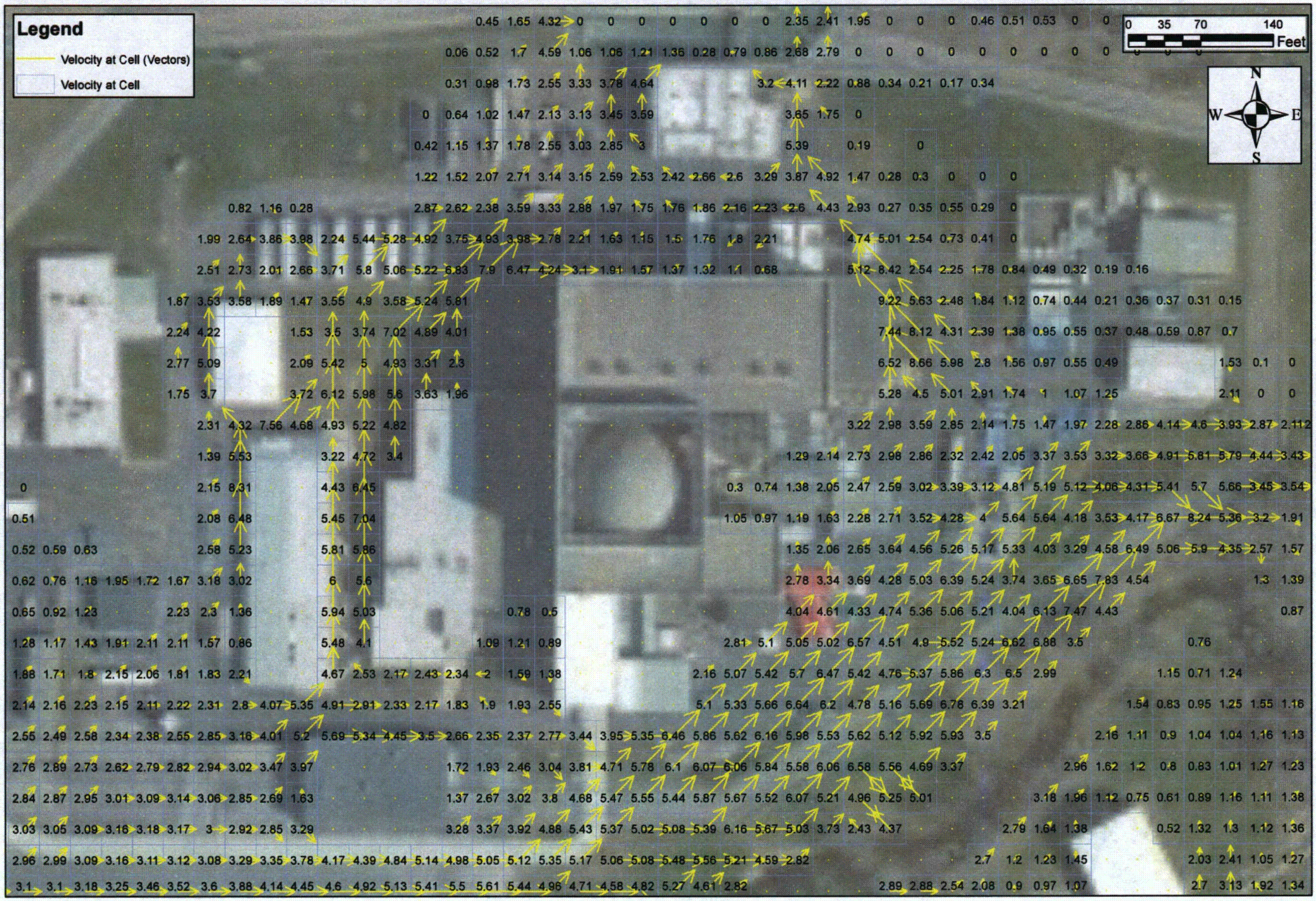
\cold\General-Access\32\32-9190280-000\official

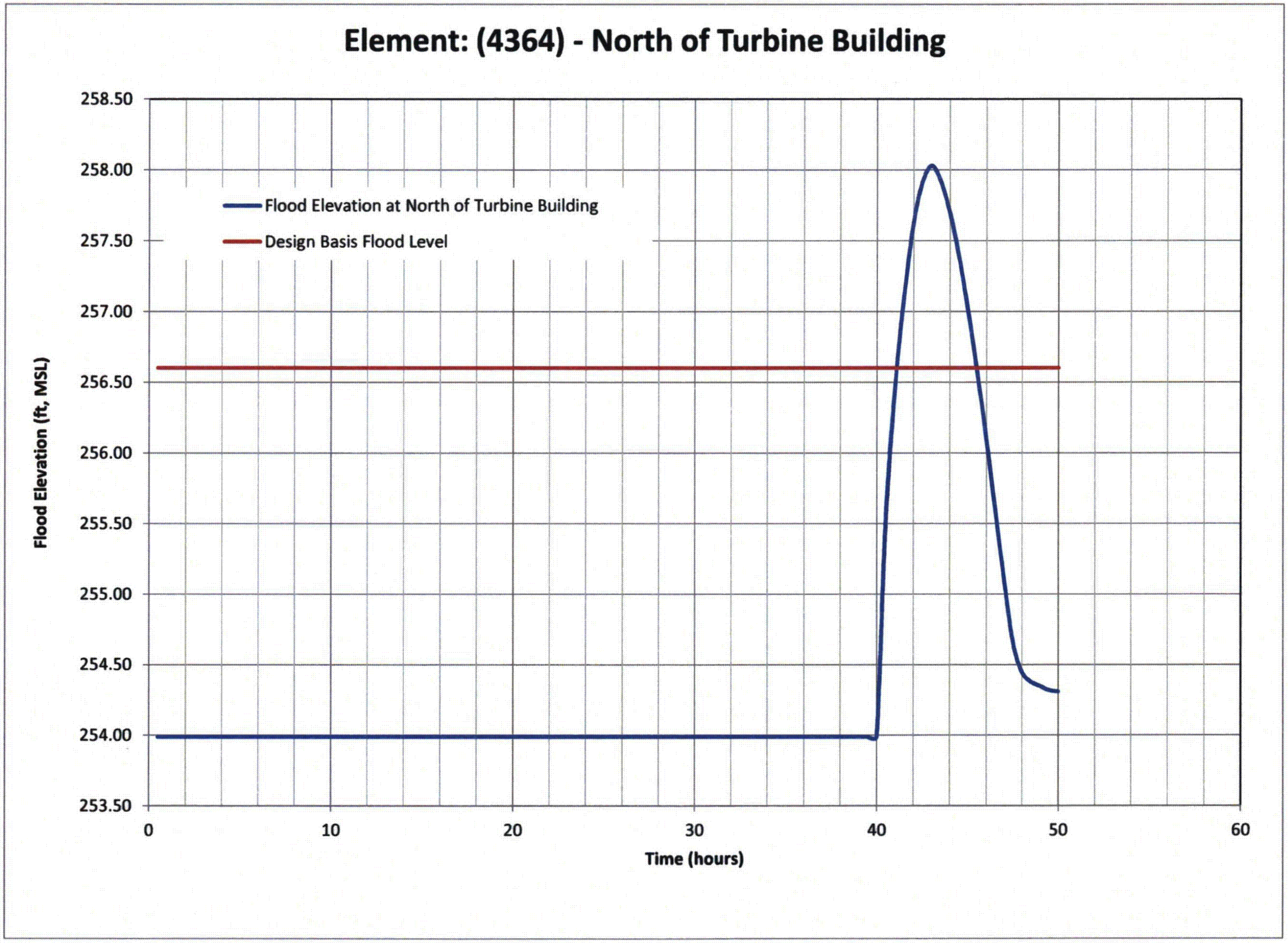
ADDITIONAL FLO-2D RESULTS

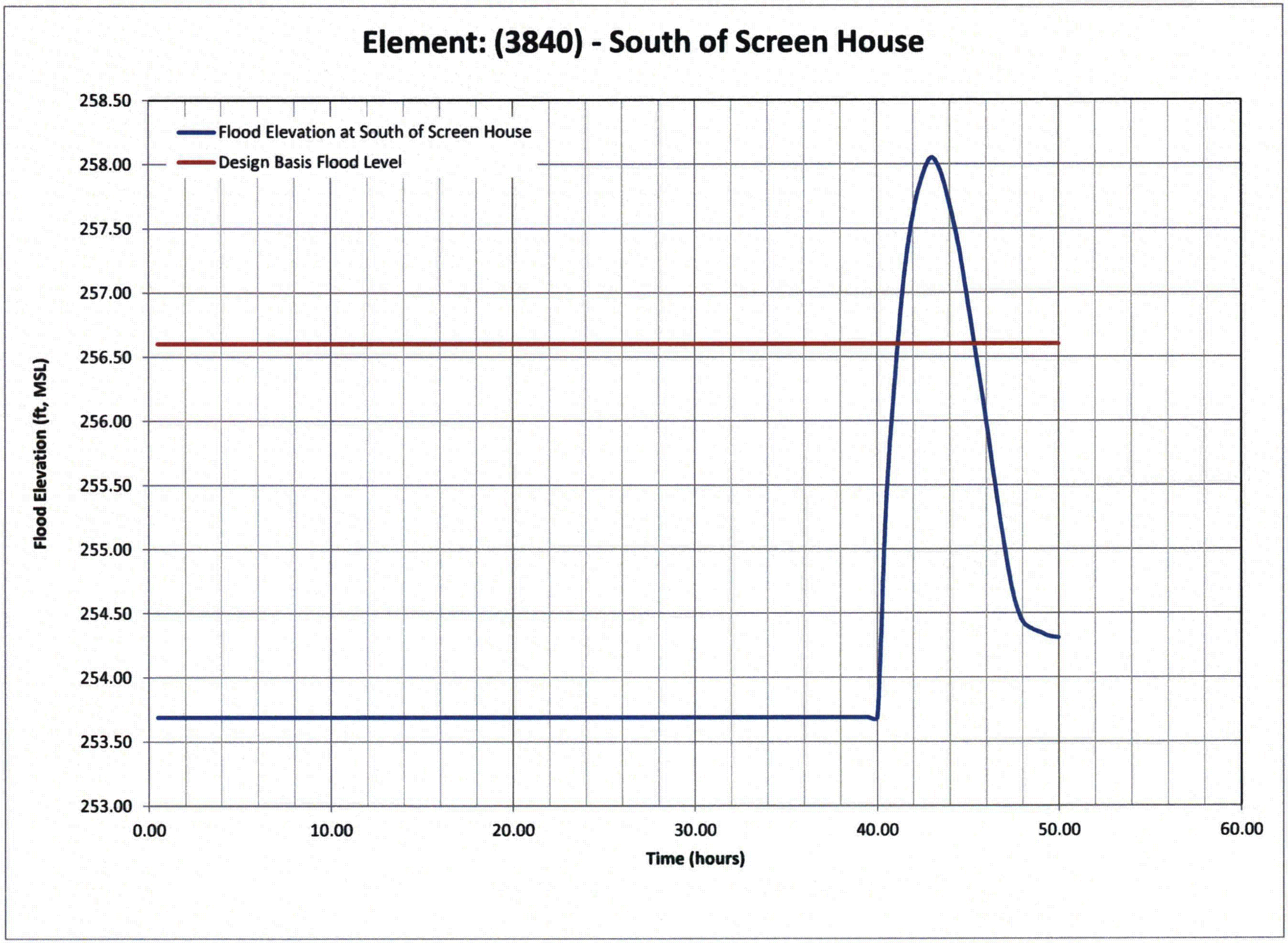

Legend
Water Elevation at Cell
0 35 70 140
Feet
N
S
E
W

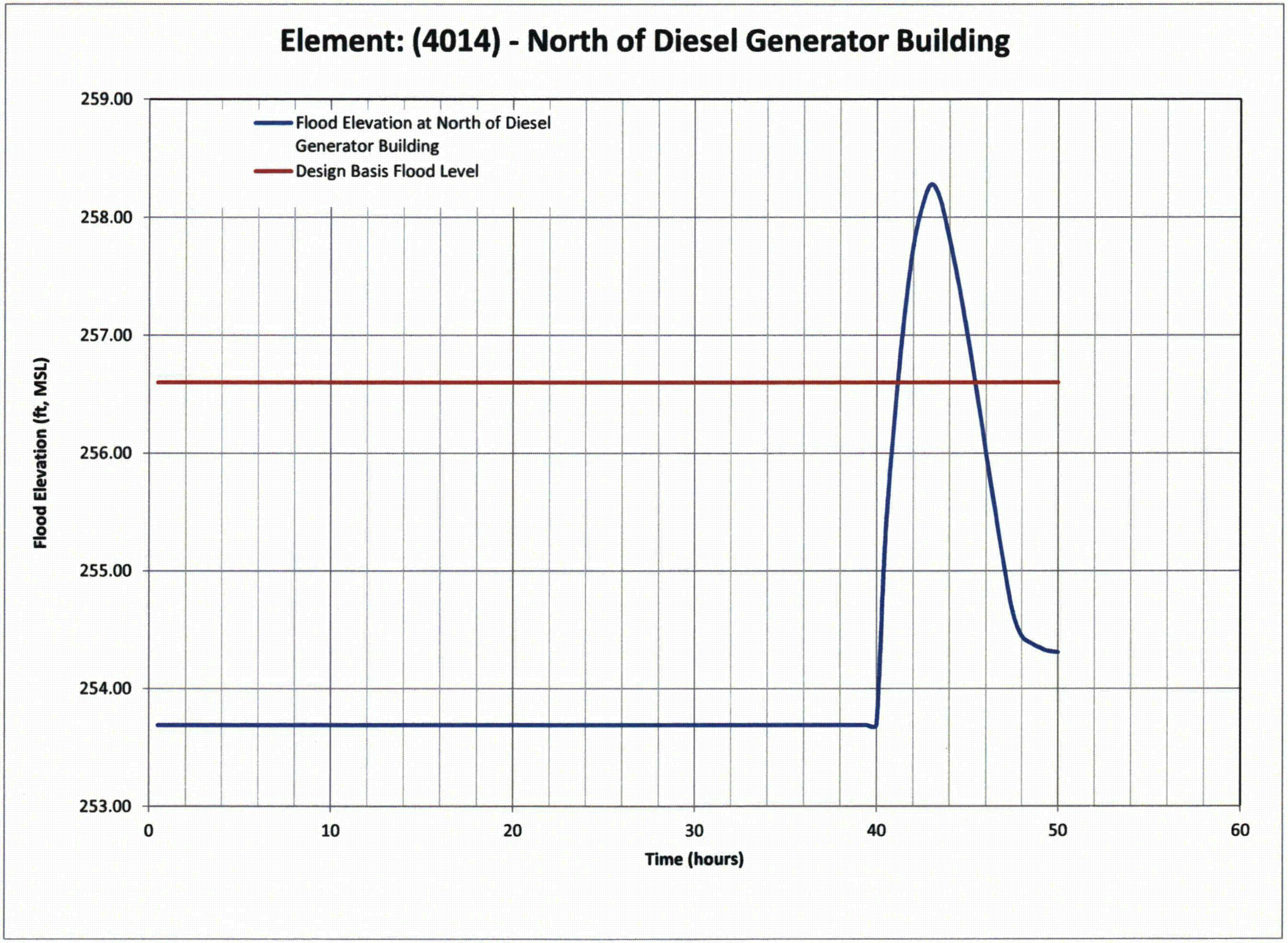

Legend
Elevations at cell
0 35 70 140
Feet
N
S
E
W

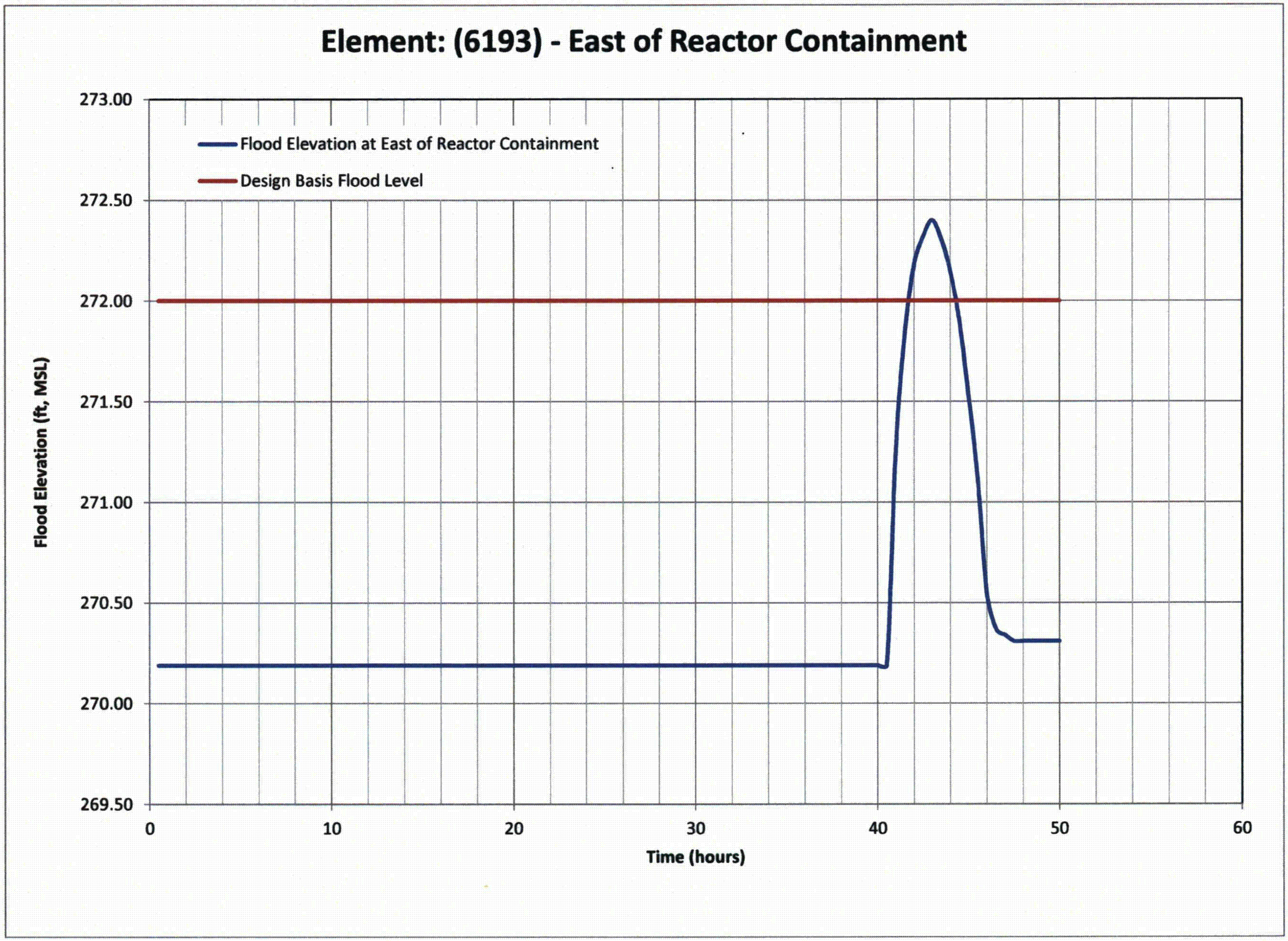

Legend
Flow Depth at Cell
0 35 70 140
Feet
N
W
E
S

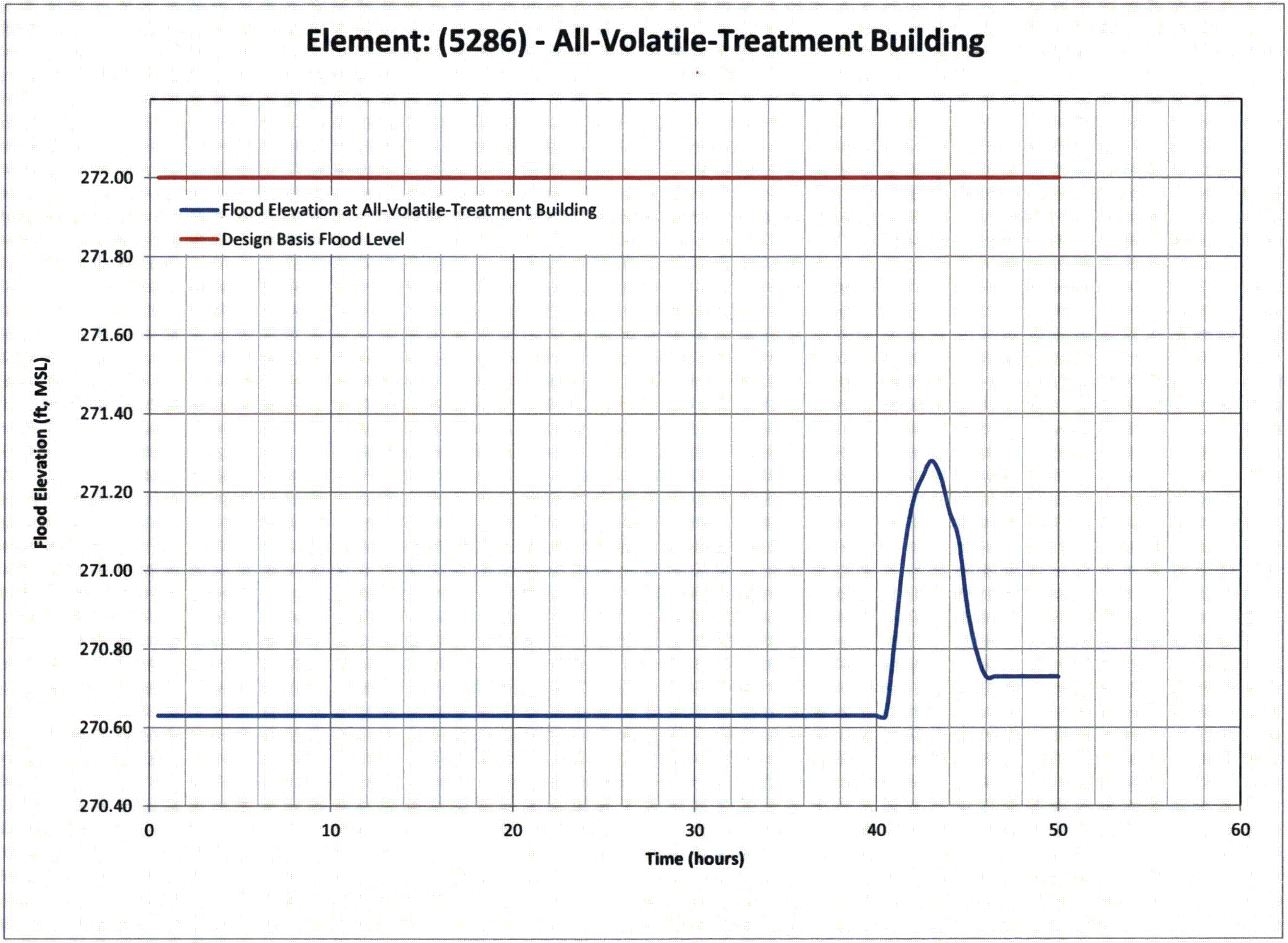

Legend
Velocity at Cell (Vectors)
Velocity at Cell
0 35 70 140
Feet
N
W
E
S

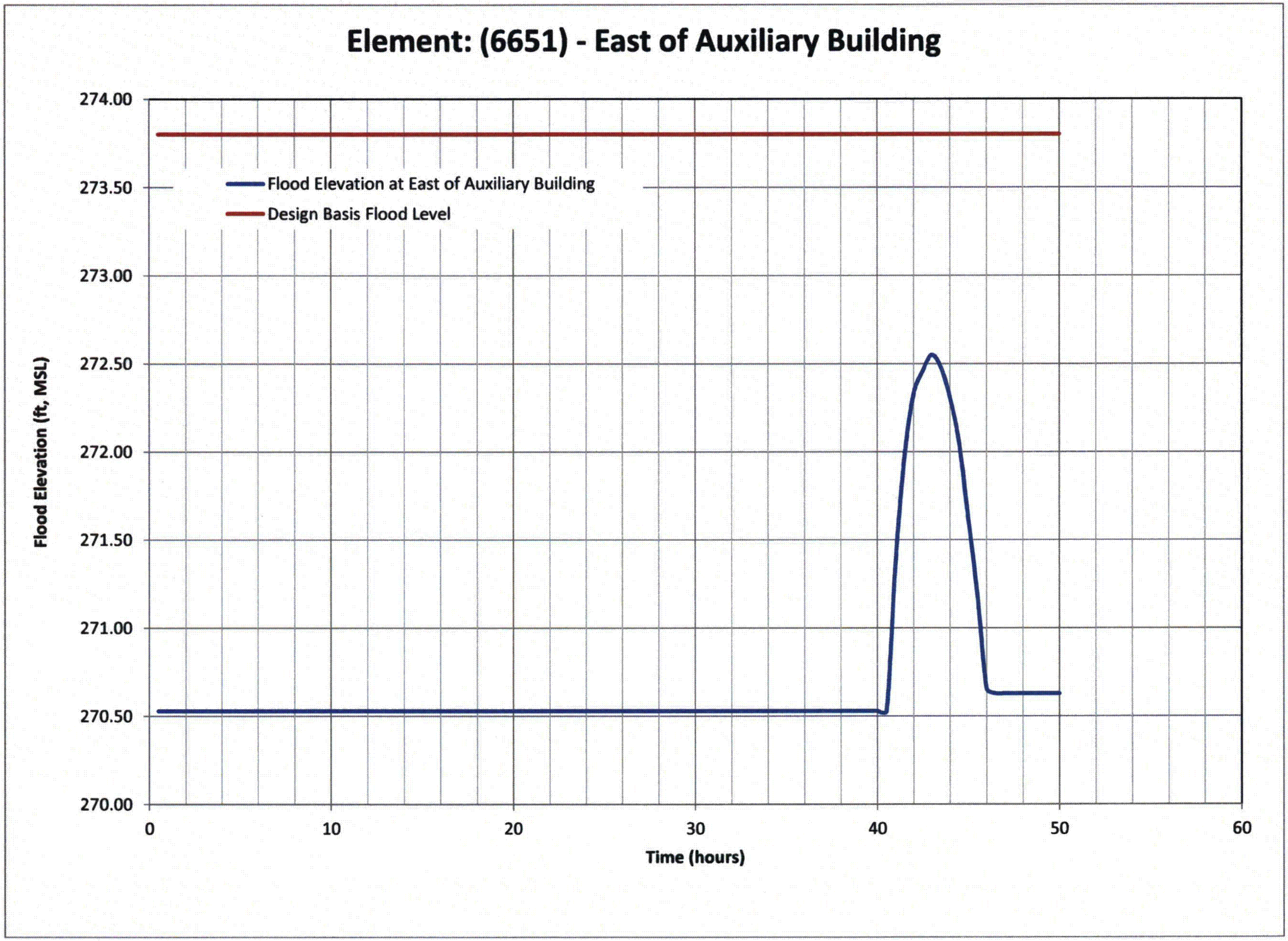

Element: (4364) - North of Turbine Building
Flood Elevation at North of Turbine Building
Design Basis Flood Level
Flood Elevation (ft, MSL)
258.50
258.00
257.50
257.00
256.50
256.00
255.50
255.00
254.50
254.00
253.50
0
10
20
30
40
50
60
Time (hours)

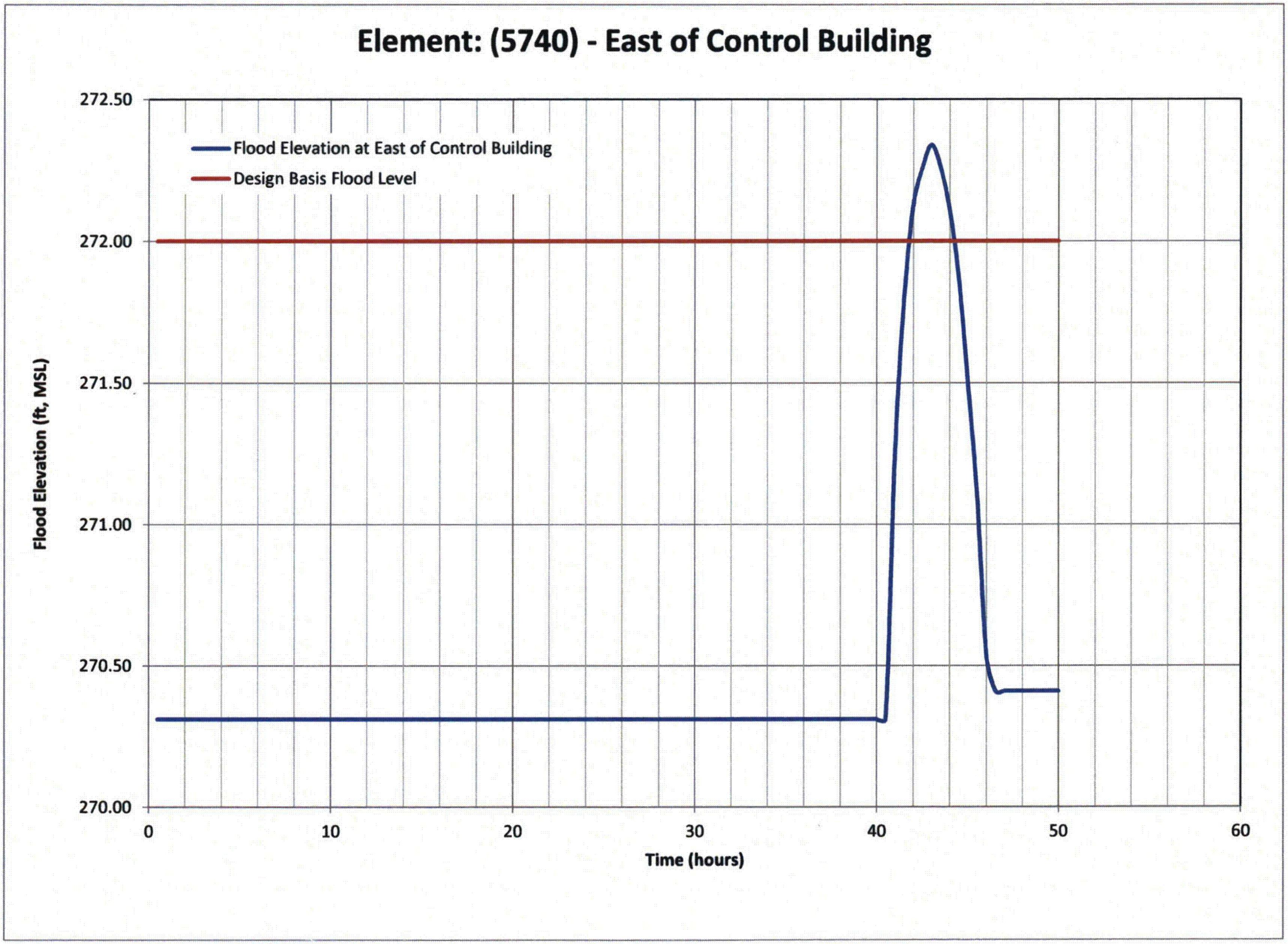

Element: (3840) - South of Screen House
Flood Elevation at South of Screen House
Design Basis Flood Level
258.50
258.00
257.50
257.00
256.50
256.00
255.50
255.00
254.50
254.00
253.50
253.00
Flood Elevation (ft, MSL)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
Time (hours)

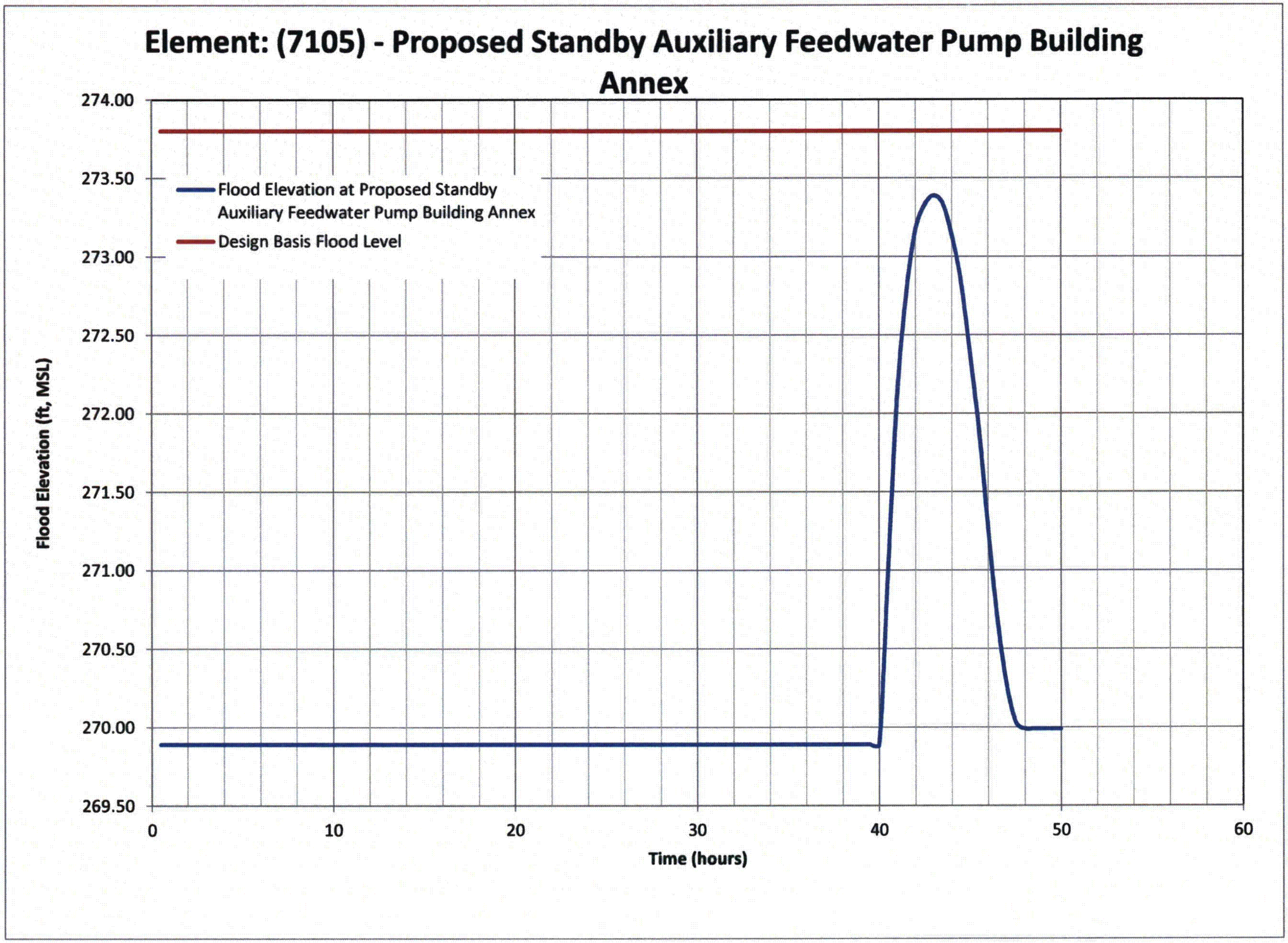

Element: (4014) - North of Diesel Generator Building
Flood Elevation at North of Diesel Generator Building
Design Basis Flood Level
259.00
258.00
257.00
256.00
255.00
254.00
253.00
Flood Elevation (ft, MSL)
0
10
20
30
40
50
60
Time (hours)

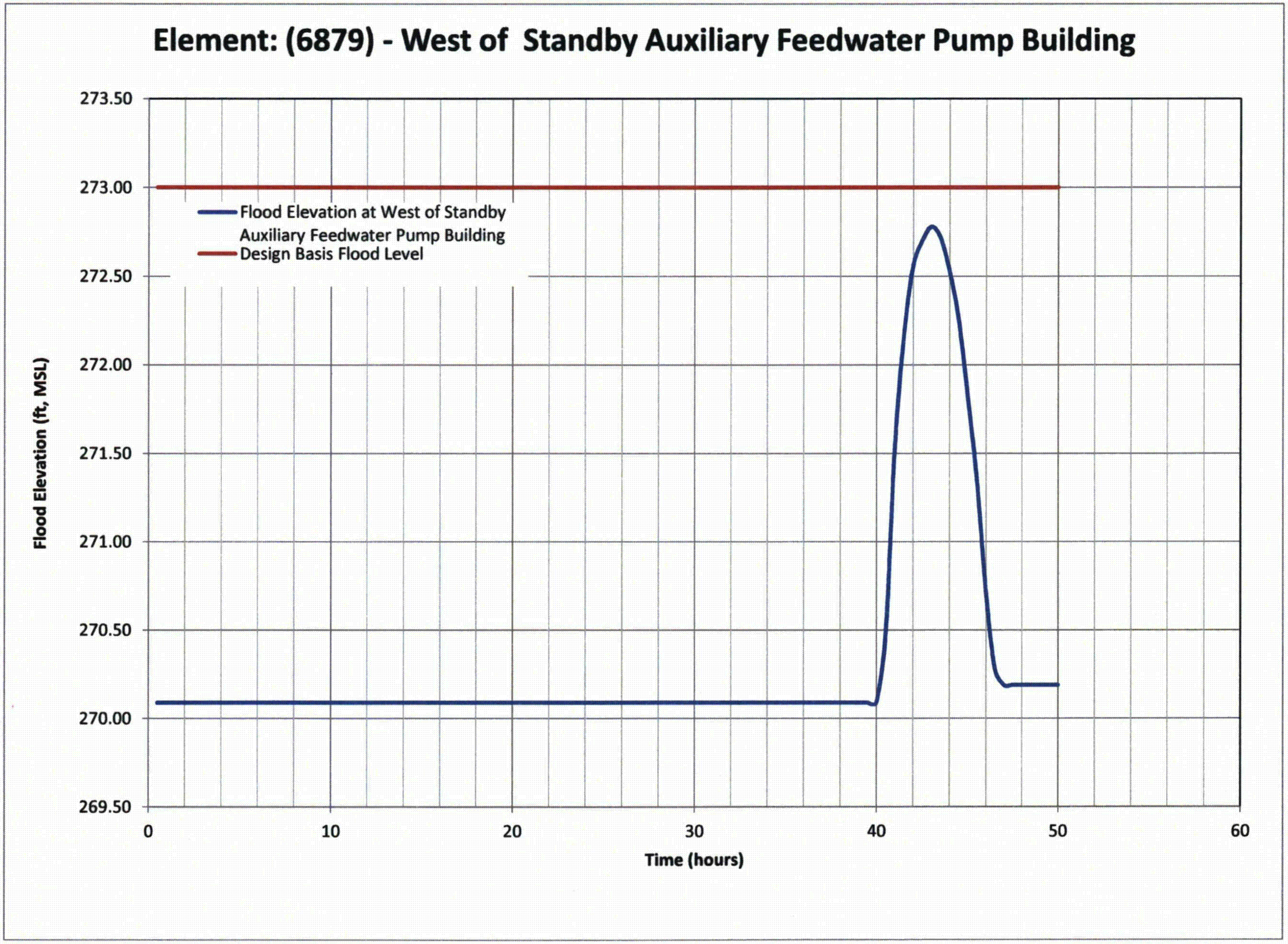

Element: (6193) - East of Reactor Containment
Flood Elevation at East of Reactor Containment
Design Basis Flood Level
Flood Elevation (ft, MSL)
273.00
272.50
272.00
271.50
271.00
270.50
270.00
269.50
0
10
20
30
40
50
60
Time (hours)


Element: (5286) - All-Volatile-Treatment Building
Flood Elevation at All-Volatile-Treatment Building
Design Basis Flood Level
Flood Elevation (ft, MSL)
272.00
271.80
271.60
271.40
271.20
271.00
270.80
270.60
270.40
0
10
20
30
40
50
60
Time (hours)


Element: (6651) - East of Auxiliary Building
Flood Elevation at East of Auxiliary Building
Design Basis Flood Level
Flood Elevation (ft, MSL)
274.00
273.50
273.00
272.50
272.00
271.50
271.00
270.50
270.00
0
10
20
30
40
50
60
Time (hours)


Element: (5740) - East of Control Building
Flood Elevation at East of Control Building
Design Basis Flood Level
Flood Elevation (ft, MSL)
272.50
272.00
271.50
271.00
270.50
270.00
0
10
20
30
40
50
60
Time (hours)


Element: (7105) - Proposed Standby Auxiliary Feedwater Pump Building Annex
Flood Elevation at Proposed Standby Auxiliary Feedwater Pump Building Annex
Design Basis Flood Level
Flood Elevation (ft, MSL)
274.00
273.50
273.00
272.50
272.00
271.50
271.00
270.50
270.00
269.50
0
10
20
30
40
50
60
Time (hours)


Element: (6879) - West of Standby Auxiliary Feedwater Pump Building
Flood Elevation at West of Standby Auxiliary Feedwater Pump Building
Design Basis Flood Level
Flood Elevation (ft, MSL)
273.50
273.00
272.50
272.00
271.50
271.00
270.50
270.00
269.50
0
10
20
30
40
50
60
Time (hours)

APPENDIX I: CEDAS OUTPUTS

I.1 Wind Wave Prediction

Project: Ginna Wind Wave Run Up
Group: Ginna Run Up Calculation

Case: Wave Prediction Deer Creek - south

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	32.81	feet
Observed Wind Speed (Uobs)	73.86	fps
Air Sea Temp. Diff. (dT)	-27.00	deg F
Dur of Observed Wind (DurO)	2.00	min
Dur of Final Wind (DurF)	120.00	min
Lat. of Observation (LAT)	43.25	deg
Results		
Wind Fetch Length (F)	870.00	FEET
Eq Neutral Wind Speed (Ue)	62.75	fps
Adjusted Wind Speed (Ua)	89.44	fps
Wave Height (Hmo)	0.74	feet
Wave Period (Tp)	1.21	sec

Wind Obs Type	Wind Fetch Options
Inland	Deep openwater

Wave Growth: Deep

I.2 Wave Runup Prediction

Project: Ginna Wind Wave Run Up
Group: Ginna Run Up Calculation

Case: Wave Runup Deer Creek - south

Wave Runup and Overtopping on Impermeable Structures

Wave type: Irregular — Slope type: Smooth
Rate estimate: Runup

Breaking criteria:	0.780					
Incident wave ht (Hi):	0.740	ft	Wave Runup (R):	0.861	ft
Peak wave period (T):	1.210		Onshore wind velocity (U):	73.860	ft/sec
COTAN of nearshore slope (cot phi):	40.000		Deepwater wave (Ho):	0.740	ft
Water depth at structure toe (ds):	5.200	ft	Relative height (ds/Ho):	7.027	
COTAN of structure slope (cot theta):	0.000		Wave steepness (Ho/gT²):	0.016	
Structure height above toe (hs):	100.000	ft	Overtopping coef(alpha):	0.000	
			Overtopping coef(Q*o):	0.000	
			Overtopping rate (Q):	0.000	ft³/s-ft

APPENDIX J: SOFTWARE VERIFICATION

SECTION 1.0 SOFTWARE CERTIFICATION

SECTION 2.0 POST CALCULATION VALIDATION RESULTS

SECTION 1.0: SOFTWARE CERTIFICATION

CEDAS VERSION 4.03

Program Capability / Intended Use

The CEDAS v.4.03 computer program was originally developed by the Army Corp of Engineers to accompany the Coastal Engineering Manual. CEDAS v.4.03 is a comprehensive collection of coastal engineering software. Veri-Tech, Inc. purchased the software suite and enhanced the existing models with windows-based interface with graphics. The module of CEDAS used for the calculations of wave prediction, setup, and runup at Ginna is ACES.

ACES is an interactive computer based design and analysis system in the field of coastal engineering containing six functional areas. These functional areas include wave prediction, wave theory, wave transformation, structural design, wave runup, and littoral processes.

Purpose

The purpose of this Computer Program Certification is to document that CEDAS v.4.03 is an acceptable computer software program for its intended use in calculating wave prediction, setup, and runup for Flood Hazard Re-evaluation Project sites, in accordance with AREVA's Controlled Document No.0402-01 (Rev.43, dated September 2012). The certification methodology, documentation and results of CEDAS v.4.03 are presented below.

Methodology

To perform the certification of wave prediction and runup, a computer analysis was performed using CEDAS v.4.03 for benchmark calculations presented in the Automated Coastal Engineering System User's Guide (Reference 1). The output wave predictions and wave runup of the CEDAS v.4.03 computer analysis are then compared to the results of the benchmark CEDAS v.4.03 calculations run on a GZA workstation. For wave setup, CEDAS v.4.03 results were compared to those results from an example calculation as part of the USACE Coastal Engineering Manual Chapter 4, Part II (Reference 3). This certification methodology is consistent with AREVA Controlled Document Nos.0402-01 (Rev.43, dated September 2012) and 0902-30 (Rev.6, dated September 2012).

Upon achieving a good agreement between the calculated results and the benchmark calculation, the accuracy of the software is verified and validated.

Inputs

The example calculation selected for the software certification is consistent with the intended use for Flood Hazard Re-evaluation Projects. Inputs to CEDAS v.4.03 for calculating wave prediction are as follows:

Parameter Description	GZA	ACES User's Guide
Elevation of observed wind speed	60 ft	60 ft
Observed Wind Speed	30 knots	30 knots
Air-sea temperature difference	-9 deg F (equivalent)	-5 deg C
Duration of observed wind speed	1 hr	1 hr
Duration of final wind speed	3 hr	3 hr
Latitude of wind observation	45 deg	45 deg
Wind Observation type	Overwater (ship)	Overwater (ship)
Wind Fetch Option	Open Water	Open Water
Open water wave growth equation	Deep	Deep
Length of wind fetch	60 mi	60 mi

The example calculation selected for the software certification is consistent with the intended use for Flood Hazard Re-evaluation Projects. Inputs to CEDAS v.4.03 for calculating wave runup are as follows:

Parameter Description	GZA	ACES User's Guide
Incident wave height	7.5 feet	7.5 feet
Wave period	10 seconds	10 seconds
Cotan of nearshore slope	100	100
Water depth at structure toe	12.5 feet	12.5 feet
Cotan of structure slope	3	3
Structure height above toe	20 feet	20 feet
Empirical coefficient (alpha)	0.076463	0.076463
Empirical coefficient (Q_0^*)	0.025	0.025
Onshore wind velocity	59.073 ft/sec (equivalent)	35 knots

The example calculation selected for the software certification is consistent with the intended use for Flood Hazard Re-evaluation Projects. Inputs to CEDAS v.4.03 for calculating wave setup are as follows:

Parameter Description	GZA	USACE CEM Chapter 4 Part II
Beach slope	0.01	0.01
Deep water wave height	2 feet	2 feet
Period	10 seconds	10 seconds

Results

Results by CEDAS-ACES

The inputs and outputs to CEDAS ACES v.4.03 are shown in Figures 1 and 2. The calculated predicted wave height and period are 4.74 feet and 4.65 seconds. The calculated wave runup is 21.366 feet, respectively.

Figure 1: Wave Prediction Calculator Screen

Project: Grand Gulf Wind Wave Run Up
Group: Verification and Validation

Case: Wave Prediction Verification

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	60.00	feet
Observed Wind Speed (Uobs)	30.00	knots
Air Sea Temp. Diff. (dT)	-9.00	deg F
Dur of Observed Wind (DurO)	1.00	hours
Dur of Final Wind (DurF)	3.00	hours
Lat. of Observation (LAT)	45.00	deg
Results		
Wind Fetch Length (F)	60.00	MILES
Eq Neutral Wind Speed (Ue)	27.71	knots
Adjusted Wind Speed (Ua)	36.18	knots
Wave Height (Hmo)	4.74	feet
Wave Period (Tp)	4.65	sec

Wind Obs Type	Wind Fetch Options
Overwater (ship)	Deep openwater

Wave Growth: Deep

Figure 2: Wave Runup Calculator Screen

Project: Grand Gulf Wind Wave Run Up
Group: Verification & Validation

Case: Smooth Slope Runup

Wave Runup and Overtopping on Impermeable Structures

Wave type: Irregular Slope type: Smooth

Rate estimate: Runup and Overtopping

Breaking criteria:	0.780				
Incident significant wave ht (Hi):	7.500	ft	Runup for significant waves (R):	21.366	ft
Peak wave period (T):	10.000		Onshore wind velocity (U):	59.073	ft/sec
COTAN of nearshore slope (cot phi):	100.000		Deepwater significant wave (Ho):	6.386	ft
Water depth at structure toe (ds):	12.500	ft	Relative height (ds/Ho):	1.957	
COTAN of structure slope (cot theta):	3.000		Wave steepness (Ho/gT^2):	0.002	
Structure height above toe (hs):	20.000	ft	Overtopping coef(alpha):	0.076	
			Overtopping coef(Q*o):	0.025	
			Overtopping rate (Q):	2.728	ft^3/s-ft

Figure 3: Setup Calculator Screen

Project: Grand Gulf Wind Wave Run Up
Group: Verification & Validation

Case: Setup Verification

Wave Setup Across Surf Zone

Acceleration of gravity (g):	9.806000	m/sec²	H_o	2.000000	m
T	10.000000	sec	m	0.010000	
K_R	1.000000				
H (unrefracted)	2	m	L_o	156.067	m
Ω_b	1.33858		H_b	2.67716	m
a	7.57919		b	0.85581	
γ_b	0.835118		d_b	3.20573	m
Setup gradient	0.00207314		Width of surf zone	320.573	m
$\overline{\eta}_b$ (setdown)	-0.139734	m	$\overline{\eta}_s$ (shoreline)	0.524857	m
η_{max}	0.662125	m	Shoreward displacement	66.2125	m

Gradient in the Wave Setup

Surf Zone Width, x (m)	Still Water Depth, h (m)	Setup (m)
320.573	3.20573	-0.139734
280	2.8	-0.055621
240	2.4	0.0273045
200	2	0.11023
160	1.6	0.193155
120	1.2	0.276081
80	0.8	0.359006
40	0.4	0.441932
0	0	0.524857
-66.2125	-0.662125	0.662125

Results from the ACES User's Guide

Tables 1 and 2 show the example inputs and outputs to the CEDAS v.4.03 for wave prediction and wave runup.

Table 1: Wave Prediction inputs/outputs example from Reference 1

ACES User's Guide — Wave Prediction

Example 2 - Shipboard Wind Observation - Open-Water Fetch - Deepwater Wave Equations

Input

Main Input Screen

Item	Symbol	Value	Units
Elevation of observed wind	Z_{obs}	60	ft
Observed wind speed	U_{obs}	30	knots
Air-sea temperature difference	ΔT	-5	deg C
Duration of observed wind	DUR	1	hr
Duration of final wind	DUR	3	hr
Latitude of wind observation	LAT	45	deg

Wind Observation Type -> Overwater (ship)

Wind Fetch Option -> Open Water

Open-Water Wave Growth Equations Requestor

Open-Water Wave Growth Equation -> Deep

Item	Symbol	Value	Units
Length of wind fetch	F	60	mi

Output

Item	Symbol	Value	Units
Equivalent neutral wind speed	U_e	27.71	knots
Adjusted wind speed	U_a	36.18	knots
Wave height	H_{mo}	4.74	ft
Peak wave period	T_p	4.65	sec

Wave Growth: Deepwater Duration-limited

1-1-18 — Windspeed Adjustment and Wave Growth

Table 2: Wave Runup inputs/outputs example from Reference 1

Example 8 - Irregular Wave - Smooth Slope Runup and Overtopping

Input

Item	Symbol	Value	Units
Incident wave height	H_s	7.50	ft
Wave period	T	10.00	sec
Cotan of nearshore slope	$cot\ \Phi$	100.00	
Water depth at structure toe	d_s	12.50	ft
Cotan of structure slope	$cot\ \Theta$	3.00	
Structure height above toe	h_s	20.00	ft
Overtopping item			
Empirical coefficient (computed)	α	0.076463	
Empirical coefficient	Q^*_0	0.025	
Onshore wind velocity	U	35.000	kn

Output

Item	Symbol	Value	Units
Deep water			
Wave height	H_{s0}	6.386	ft
Relative height	d_s/H_0	1.957	
Wave steepness	H_{s0}/gT^2	0.001985	
Runup	R_s	21.366	ft
Overtopping rate	Q	2.728	ft^3/s-ft

Results from the USACE Coastal Engineering Manual

Figure 4: Results from the USACE Coastal Engineering Manual EM-1110-2-1100 Part II

(Change 1) 31 July 2003

EXAMPLE PROBLEM II-4-2

FIND:

Setup across the surf zone.

GIVEN:

A plane beach having a 1 on 100 slope, and normally incident waves with deepwater height of 2 m and period of 10 sec (see Example Problem II-4-1).

SOLUTION:

The incipient breaker height and depth were determined in Example Problem II-4-1 as 2.7 m and 3.2 m, respectively. The breaker index is 0.84, based on Equation II-4-5.

Setdown at the breaker point is determined from Equation II-4-21. At breaking, Equation II-4-21 simplifies to $\bar{\eta}_b = -1/16\, \gamma_b^2\, d_b$, (sinh $2\pi d/L = 2\pi d/L$, and $H_b = \gamma_b d_b$), thus

$$\bar{\eta}_b = -1/16\,(0.84)^2\,(3.2) = -0.14 \text{ m}$$

Setup at the still-water shoreline is determined from Equation II-4-24

$$\bar{\eta}_s = -0.14 + (3.2 + 0.14) + 1/(1 + 8/(3\,(.84)^2)) = 0.56 \text{ m}$$

The gradient in the setup is determined from Equation II-4-23 as

$$d\bar{\eta}/dx = 1/(1 + 8/(3\,(0.84)^2))(1/100) = 0.0021$$

and from Equation II-4-25, $\Delta x = (0.56)/(1/100 - 0.0021) = 70.9$ m, and

$$\bar{\eta}_{max} = 0.56 + 0.0021(64.6) = 0.65 \text{ m}$$

For the simplified case of a plane beach with the assumption of linear wave height decay, the gradient in the setup is constant through the surf zone. Setup may be calculated anywhere in the surf zone from the relation $\bar{\eta} = \bar{\eta}_b + (d\bar{\eta}/dx)(x_b - x)$, where x_b is the surf zone width and $x = 0$ at the shoreline (x is positive offshore).

x, m	h, m	$\bar{\eta}$, m
334	3.3	-0.14
167	1.7	0.21
0	0.0	0.56
-71	-0.7	0.71

Setdown at breaking is - 0.14 m, net setup at the still-water shoreline is 0.56 m, the gradient in the setup is 0.0021 m/m, the mean shoreline is located 71 m shoreward of the still-water shoreline, and maximum setup is 0.71 m (Figure II-4-10).

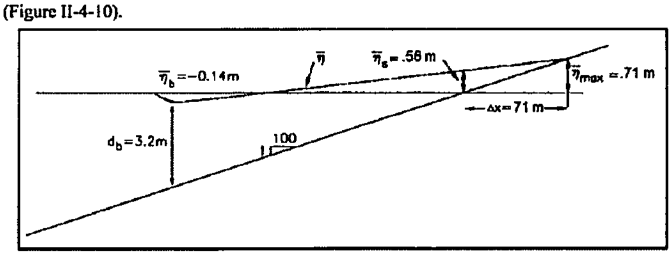


Figure II-4-10. Example problem II-4-2

Comparison of Results

The comparison between CEDAS-ACES v.4.03 and benchmark calculations from Reference 1 are presented in Table 3 below.

Table 3: Summary of Calculated Results

Calculation	Output	CEDAS v.4.03	USACE CEM Ch.4 Part II	ACES User's Manual benchmark	Percent Difference
Wave Prediction	Wave Height	4.74 ft	–	4.74 ft	0.0%
	Wave Period	4.65 sec	–	4.65 sec	0.0%
Wave Runup	Runup	21.366 ft	–	21.366 ft	0.0%
Wave Setup	Max setup	.66 m	.65 m	–	1.5%

The results indicate no difference of the computed runup and wave prediction by CEDAS-ACES from the benchmark calculation results in Reference 1. Results for wave setup indicated a minor (less than 2%) error compared to the example calculation provided in Reference 3.

The percent difference is insignificant and believed to be a result of:

1. More input parameters were used by the software than the hand calculation using Reference 3.
2. Inherent variability in the hand calculation (i.e. rounding error).

Therefore, CEDAS v.4.03 is determined to be acceptably accurate for its intended use for wave prediction, setup, and runup at GGNS.

CEDAS-ACES User's Manual / Documentation

The CEDAS-ACES User's Guide is filed with the project records. The source code is proprietary and not readily available or distributed by the software vendor.

Known Deficiencies

All known deficiencies of the software have been reviewed and have no effect on the accuracy of the data created by this software. By monitoring the software provider's website, notifications of errors (bugs) and updates are evaluated for significance and resolved.

Program Access/Security

This example calculation, selected for the software certification, is consistent with the intended software application Flood Hazard Re-evaluation projects. The computer software certification analysis was performed on the GZA workstation used for the calculation:

- System Name: Microsoft Windows 07
- Version: 2002, Service Pack 3
- Computer Name: 01-BONAV
- Processor Intel® Core™2 Duo CPU
- Memory: 2.96 GB of RAM

The software is maintained on designated computers as an executable file to prevent unauthorized editing. Access to each computer is password protected to restrict access and deletion. Passwords are selected by the employee. The GZA headquarters in Norwood, Massachusetts maintains the computer software on the following designated computers.

Computer Name	Program Name
01-wangbin	CEDAS v.4.03

REFERENCES

1. "Automated Coastal Engineering System User's Guide", Coastal Engineering Research Center, Leenknecht, David; Szuwalski, Andre, Version 1.07, September 1992.
2. "Automated Coastal Engineering System Technical Reference", Coastal Engineering Research Center, Leenknecht, David; Szuwalski, Andre, Version 1.07, September 1992.
3. U.S. Army Corp of Engineers (USACE). Coastal Engineering Manual, Report Number EM 1110-2-1100 Part II Chapter 4 Surf Zone Hydrodynamics, U.S. ACE Coastal and Hydraulics Laboratory – Engineer Research and Development Center, Waterways Experiment Station – Vicksburg, Mississippi, August 2008.

USACE HEC-HMS VERSION 3.5 AND FLO-D2 VERSION 2012.02

Note: Due to the size of the data in this appendix, the information has been archived in the AREVA file management system, ColdStor.

The path to the file is:

\cold\General-Access\32\32-9190280-000\official

SECTION 2.0: POST-CALCULATION VALIDATION RESULTS

HEC-HMS v3.5 was tested on the computer used for this document by Kenneth Hunu on March 25, 2013. The inputs for the installation test were the same as those used in the software verification reports (Reference 25). The results of the installation test were acceptable.

Project: Post-Project-Verification
Simulation Run: Run 1 Subbasin: Subbasin-1

Start of Run:	24Jan2012, 00:00	Basin Model:	Basin 1
End of Run:	25Jan2012, 00:00	Meteorologic Model:	Met 1
Compute Time:	25Jan2013, 09:00:11	Control Specifications:	Control 1

Volume Units: IN

Computed Results

Peak Discharge :	2317.5 (CFS)	Date/Time of Peak Discharge :	24Jan2012, 06:20
Total Precipitation :	5.00 (IN)	Total Direct Runoff :	3.37 (IN)
Total Loss :	1.63 (IN)	Total Baseflow :	0.00 (IN)
Total Excess :	3.37 (IN)	Discharge :	3.37 (IN)

FLO-2D Pro Version 2012.02 was tested on the computer used for this document by Kenneth Hunu on April 4, 2013. The inputs for the installation test were the same as those used in the software verification reports (Reference 24). The results of the installation test were acceptable.

BASE

INFLOW HYDROGRAPH AT NODE 1

HOUR	CFS
0.00	0.
0.50	2000.
2.00	2000.

INFLOW HYDROGRAPH AT NODE 2

HOUR	CFS
0.00	0.
0.50	2000.
2.00	2000.

INFLOW HYDROGRAPH AT NODE 3

HOUR	CFS
0.00	0.
0.50	2000.
2.00	2000.

INFLOW HYDROGRAPH AT NODE 4

HOUR	CFS
0.00	0.
0.50	2000.
2.00	2000.

THIS OUTPUT FILE WAS CREATED ON: 4/ 4/2013 AT: 15: 6:25
Pro Model - Build No. 12.09.01

==

MODEL TIME = 0.10 HOURS TOTAL TIMESTEP NUMBER = 536.

NODE BED ELEV. DEPTH Q-OUT MAX. VEL. AVE. VEL.

**** NO DISCHARGE AT THE SPECIFIED CROSS SECTIONS *
***
AT THIS TIMESTEP

CROSS SECTION # 1

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.
77	6.00	0.00	0.00	0.00	0.00
78	6.00	0.00	0.00	0.00	0.00
79	6.00	0.00	0.00	0.00	0.00
80	6.00	0.00	0.00	0.00	0.00

CROSS SECTION # 1 * NO DISCHARGE *

CROSS SECTION DISCHARGE = 0.00 CFS
AVERAGE CROSS SECTION VELOCITY = 0.00 FPS
CROSS SECTION FLOW WIDTH = 0.00 FT
AVERAGE CROSS SECTION DEPTH = 0.00 FT

CROSS SECTION # 2

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.
157	3.00	0.00	0.00	0.00	0.00
158	3.00	0.00	0.00	0.00	0.00
159	3.00	0.00	0.00	0.00	0.00
160	3.00	0.00	0.00	0.00	0.00

CROSS SECTION # 2 * NO DISCHARGE *

CROSS SECTION DISCHARGE = 0.00 CFS
AVERAGE CROSS SECTION VELOCITY = 0.00 FPS
CROSS SECTION FLOW WIDTH = 0.00 FT
AVERAGE CROSS SECTION DEPTH = 0.00 FT

CROSS SECTION # 3

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.
233	0.15	0.00	0.00	0.00	0.00
234	0.15	0.00	0.00	0.00	0.00
235	0.15	0.00	0.00	0.00	0.00
236	0.15	0.00	0.00	0.00	0.00

CROSS SECTION # 3 * NO DISCHARGE *

CROSS SECTION DISCHARGE = 0.00 CFS
AVERAGE CROSS SECTION VELOCITY = 0.00 FPS
CROSS SECTION FLOW WIDTH = 0.00 FT
AVERAGE CROSS SECTION DEPTH = 0.00 FT

MIN. TIMESTEP(SEC.) = 0.36 MAX. TIMESTEP(SEC.) = 30.00 MEAN TIMESTEP(SEC.) = 0.67

==

MODEL TIME = 0.20 HOURS TOTAL TIMESTEP NUMBER = 1383.

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.
CROSS SECTION # 1					
77	6.00	3.22	-626.86	3.91	-3.34
78	6.00	3.22	-626.89	3.92	-3.15
79	6.00	3.22	-625.84	3.91	-3.14
80	6.00	3.22	-625.19	3.92	-3.33

CROSS SECTION DISCHARGE = 2504.79 CFS
AVERAGE CROSS SECTION VELOCITY = 3.89 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 3.22 FT

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.
CROSS SECTION # 2					
157	3.00	0.00	0.00	0.00	0.00
158	3.00	0.00	0.00	0.00	0.00
159	3.00	0.00	0.00	0.00	0.00
160	3.00	0.00	0.00	0.00	0.00

CROSS SECTION # 2 * NO DISCHARGE *

CROSS SECTION DISCHARGE = 0.00 CFS
AVERAGE CROSS SECTION VELOCITY = 0.00 FPS
CROSS SECTION FLOW WIDTH = 0.00 FT
AVERAGE CROSS SECTION DEPTH = 0.00 FT

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.
CROSS SECTION # 3					
233	0.15	0.00	0.00	0.00	0.00
234	0.15	0.00	0.00	0.00	0.00
235	0.15	0.00	0.00	0.00	0.00
236	0.15	0.00	0.00	0.00	0.00

CROSS SECTION # 3 * NO DISCHARGE *

CROSS SECTION DISCHARGE = 0.00 CFS
AVERAGE CROSS SECTION VELOCITY = 0.00 FPS
CROSS SECTION FLOW WIDTH = 0.00 FT
AVERAGE CROSS SECTION DEPTH = 0.00 FT

MIN. TIMESTEP(SEC.) = 0.35 MAX. TIMESTEP(SEC.) = 0.51 MEAN TIMESTEP(SEC.) = 0.43

==

MODEL TIME = 0.30 HOURS TOTAL TIMESTEP NUMBER = 2542.

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.
CROSS SECTION # 1					
77	6.00	4.47	-1051.95	4.72	-4.03
78	6.00	4.47	-1052.07	4.72	-3.80
79	6.00	4.47	-1051.42	4.73	-3.80
80	6.00	4.47	-1047.25	4.72	-4.00

CROSS SECTION DISCHARGE = 4202.68 CFS
AVERAGE CROSS SECTION VELOCITY = 4.70 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 4.47 FT

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.
CROSS SECTION # 2					
157	3.00	3.95	-877.72	4.46	-3.81
158	3.00	3.95	-877.73	4.46	-3.59

				BASE	
159	3.00	3.95	-877.39	4.47	-3.59
160	3.00	3.95	-875.65	4.47	-3.80

CROSS SECTION DISCHARGE = 3508.49 CFS
AVERAGE CROSS SECTION VELOCITY = 4.44 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 3.95 FT

CROSS SECTION # 3

233	0.15	3.34	-603.73	3.62	-3.09
234	0.15	3.34	-603.58	3.62	-2.91
235	0.15	3.34	-602.47	3.61	-2.91
236	0.15	3.34	-604.40	3.63	-3.09

CROSS SECTION DISCHARGE = 2414.17 CFS
AVERAGE CROSS SECTION VELOCITY = 3.62 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 3.34 FT

MIN. TIMESTEP(SEC.) = 0.05 MAX. TIMESTEP(SEC.) = 0.42 MEAN TIMESTEP(SEC.) = 0.31

===

MODEL TIME = 0.40 HOURS TOTAL TIMESTEP NUMBER = 3068.

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.

CROSS SECTION # 1

77	6.00	5.52	-1471.17	5.34	-4.56
78	6.00	5.52	-1471.06	5.34	-4.30
79	6.00	5.52	-1471.01	5.34	-4.29
80	6.00	5.52	-1470.83	5.34	-4.56

CROSS SECTION DISCHARGE = 5884.06 CFS
AVERAGE CROSS SECTION VELOCITY = 5.33 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 5.52 FT

CROSS SECTION # 2

157	3.00	5.19	-1328.75	5.13	-4.38
158	3.00	5.19	-1328.25	5.13	-4.13
159	3.00	5.19	-1328.11	5.13	-4.13
160	3.00	5.19	-1328.07	5.13	-4.38

CROSS SECTION DISCHARGE = 5313.18 CFS
AVERAGE CROSS SECTION VELOCITY = 5.12 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 5.19 FT

CROSS SECTION # 3

233	0.15	4.97	-1173.76	4.73	-4.04
234	0.15	4.97	-1174.87	4.73	-3.81
235	0.15	4.97	-1173.07	4.72	-3.80
236	0.15	4.97	-1174.78	4.73	-4.04

CROSS SECTION DISCHARGE = 4696.48 CFS
AVERAGE CROSS SECTION VELOCITY = 4.73 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 4.97 FT

MIN. TIMESTEP(SEC.) = 0.42 MAX. TIMESTEP(SEC.) = 0.95 MEAN TIMESTEP(SEC.) = 0.69

===

MODEL TIME = 0.50 HOURS TOTAL TIMESTEP NUMBER = 3438.

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.

CROSS SECTION # 1

77	6.00	6.44	-1882.63	5.86	-5.00
78	6.00	6.44	-1882.63	5.86	-4.71
79	6.00	6.44	-1882.63	5.86	-4.71

				BASE	
80	6.00	6.44	-1882.63	5.86	-5.00

CROSS SECTION DISCHARGE = 7530.53 CFS
AVERAGE CROSS SECTION VELOCITY = 5.85 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 6.44 FT

CROSS SECTION # 2

157	3.00	6.19	-1757.61	5.68	-4.85
158	3.00	6.19	-1757.61	5.68	-4.57
159	3.00	6.19	-1757.61	5.68	-4.57
160	3.00	6.19	-1757.61	5.68	-4.85

CROSS SECTION DISCHARGE = 7030.43 CFS
AVERAGE CROSS SECTION VELOCITY = 5.68 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 6.19 FT

CROSS SECTION # 3

233	0.15	6.05	-1630.78	5.40	-4.61
234	0.15	6.05	-1630.78	5.40	-4.34
235	0.15	6.05	-1630.78	5.40	-4.34
236	0.15	6.05	-1630.78	5.40	-4.61

CROSS SECTION DISCHARGE = 6523.11 CFS
AVERAGE CROSS SECTION VELOCITY = 5.39 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 6.05 FT

MIN. TIMESTEP(SEC.) = 0.92 MAX. TIMESTEP(SEC.) = 1.03 MEAN TIMESTEP(SEC.) = 0.97

==

MODEL TIME = 0.60 HOURS TOTAL TIMESTEP NUMBER = 3846.

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.

CROSS SECTION # 1

77	6.00	6.79	-1992.48	5.87	-5.01
78	6.00	6.79	-1992.48	5.87	-4.73
79	6.00	6.79	-1992.48	5.87	-4.73
80	6.00	6.79	-1992.48	5.87	-5.01

CROSS SECTION DISCHARGE = 7969.91 CFS
AVERAGE CROSS SECTION VELOCITY = 5.87 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 6.79 FT

CROSS SECTION # 2

157	3.00	6.74	-1974.05	5.86	-5.00
158	3.00	6.74	-1974.05	5.86	-4.71
159	3.00	6.74	-1974.05	5.86	-4.71
160	3.00	6.74	-1974.05	5.86	-5.00

CROSS SECTION DISCHARGE = 7896.20 CFS
AVERAGE CROSS SECTION VELOCITY = 5.86 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 6.74 FT

CROSS SECTION # 3

233	0.15	6.71	-1944.82	5.79	-4.95
234	0.15	6.71	-1944.82	5.79	-4.66
235	0.15	6.71	-1944.82	5.79	-4.66
236	0.15	6.71	-1944.82	5.79	-4.95

CROSS SECTION DISCHARGE = 7779.29 CFS
AVERAGE CROSS SECTION VELOCITY = 5.79 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 6.71 FT

MIN. TIMESTEP(SEC.) = 0.85 MAX. TIMESTEP(SEC.) = 0.92 MEAN TIMESTEP(SEC.) = 0.88

==

BASE

MODEL TIME = 0.70 HOURS TOTAL TIMESTEP NUMBER = 4269.

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.
CROSS SECTION # 1					
77	6.00	6.82	-1999.13	5.86	-5.00
78	6.00	6.82	-1999.13	5.86	-4.72
79	6.00	6.82	-1999.13	5.86	-4.72
80	6.00	6.82	-1999.13	5.86	-5.00

CROSS SECTION DISCHARGE = 7996.52 CFS
AVERAGE CROSS SECTION VELOCITY = 5.86 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 6.82 FT

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.
CROSS SECTION # 2					
157	3.00	6.82	-1997.04	5.86	-5.00
158	3.00	6.82	-1997.04	5.86	-4.72
159	3.00	6.82	-1997.04	5.86	-4.72
160	3.00	6.82	-1997.04	5.86	-5.00

CROSS SECTION DISCHARGE = 7988.16 CFS
AVERAGE CROSS SECTION VELOCITY = 5.86 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 6.82 FT

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.
CROSS SECTION # 3					
233	0.15	6.81	-1993.78	5.85	-5.00
234	0.15	6.81	-1993.78	5.85	-4.71
235	0.15	6.81	-1993.78	5.85	-4.71
236	0.15	6.81	-1993.78	5.85	-5.00

CROSS SECTION DISCHARGE = 7975.11 CFS
AVERAGE CROSS SECTION VELOCITY = 5.85 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 6.81 FT

MIN. TIMESTEP(SEC.) = 0.85 MAX. TIMESTEP(SEC.) = 0.86 MEAN TIMESTEP(SEC.) = 0.85

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MODEL TIME = 0.80 HOURS TOTAL TIMESTEP NUMBER = 4692.

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.
CROSS SECTION # 1					
77	6.00	6.82	-1999.90	5.86	-5.00
78	6.00	6.82	-1999.90	5.86	-4.72
79	6.00	6.82	-1999.90	5.86	-4.72
80	6.00	6.82	-1999.90	5.86	-5.00

CROSS SECTION DISCHARGE = 7999.60 CFS
AVERAGE CROSS SECTION VELOCITY = 5.86 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 6.82 FT

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.
CROSS SECTION # 2					
157	3.00	6.82	-1999.66	5.86	-5.00
158	3.00	6.82	-1999.66	5.86	-4.72
159	3.00	6.82	-1999.66	5.86	-4.72
160	3.00	6.82	-1999.66	5.86	-5.00

CROSS SECTION DISCHARGE = 7998.63 CFS
AVERAGE CROSS SECTION VELOCITY = 5.86 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 6.82 FT

NODE	BED ELEV.	DEPTH	Q-OUT	MAX. VEL.	AVE. VEL.
CROSS SECTION # 3					
233	0.15	6.82	-1999.28	5.86	-5.00
234	0.15	6.82	-1999.28	5.86	-4.72
235	0.15	6.82	-1999.28	5.86	-4.72
236	0.15	6.82	-1999.28	5.86	-5.00

CROSS SECTION DISCHARGE = 7997.14 CFS
AVERAGE CROSS SECTION VELOCITY = 5.86 FPS
CROSS SECTION FLOW WIDTH = 200.00 FT
AVERAGE CROSS SECTION DEPTH = 6.82 FT

MIN. TIMESTEP(SEC.) = 0.84 MAX. TIMESTEP(SEC.) = 0.85 MEAN TIMESTEP(SEC.) = 0.85

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MAXIMUM WATER SURFACE VALUES FOR FLOODPLAIN

NODE	1	2	3	4	5	6	7	8	9	10
ELEVATION	15.67	15.67	15.67	15.67	15.52	15.52	15.52	15.52	15.37	15.37
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.99	5.99	5.99	5.99	5.98	5.98	5.98	5.98	5.98	5.98
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.99	5.99	5.99	5.99	5.98	5.98	5.98	5.98	5.98	5.98
DEPTH	6.67	6.67	6.67	6.67	6.66	6.66	6.66	6.66	6.66	6.66
TIME	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

NODE	11	12	13	14	15	16	17	18	19	20
ELEVATION	15.37	15.37	15.22	15.22	15.22	15.22	15.07	15.07	15.07	15.07
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.98	5.98	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.98	5.98	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97
DEPTH	6.66	6.66	6.65	6.65	6.65	6.65	6.64	6.64	6.64	6.64
TIME	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

NODE	21	22	23	24	25	26	27	28	29	30
ELEVATION	14.92	14.92	14.92	14.92	14.77	14.77	14.77	14.77	14.62	14.62
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.95	5.95
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.95	5.95
DEPTH	6.63	6.63	6.63	6.63	6.62	6.62	6.62	6.62	6.62	6.62
TIME	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

NODE	31	32	33	34	35	36	37	38	39	40
ELEVATION	14.62	14.62	14.47	14.47	14.47	14.47	14.32	14.32	14.32	14.32
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95
DEPTH	6.62	6.62	6.61	6.61	6.61	6.61	6.60	6.60	6.60	6.60
TIME	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

NODE	41	42	43	44	45	46	47	48	49	50
ELEVATION	14.17	14.17	14.17	14.17	14.02	14.02	14.02	14.02	13.87	13.87
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	

										6.82
VELOCITY	5.94	5.94	5.94	5.94	5.94	5.94	5.94	5.94	5.93	5.93
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.94	5.94	5.94	5.94	5.94	5.94	5.94	5.94	5.93	5.93
DEPTH	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60
TIME	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
NODE	51	52	53	54	55	56	57	58	59	60
ELEVATION	13.87	13.87	13.72	13.72	13.72	13.72	13.57	13.57	13.57	13.57
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.93	5.93	5.93	5.93	5.93	5.93	5.93	5.93	5.93	5.93
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.93	5.93	5.93	5.93	5.93	5.93	5.93	5.93	5.93	5.93
DEPTH	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60
TIME	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
NODE	61	62	63	64	65	66	67	68	69	70
ELEVATION	13.42	13.42	13.42	13.42	13.27	13.27	13.27	13.27	13.12	13.12
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92	5.92
DEPTH	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60
TIME	0.51	0.51	0.51	0.51	0.52	0.52	0.52	0.52	0.52	0.52
NODE	71	72	73	74	75	76	77	78	79	80
ELEVATION	13.12	13.12	12.97	12.97	12.97	12.97	12.82	12.82	12.82	12.82
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.92	5.92	5.91	5.91	5.91	5.91	5.91	5.91	5.91	5.91
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.92	5.92	5.91	5.91	5.91	5.91	5.91	5.91	5.91	5.91
DEPTH	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60
TIME	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
NODE	81	82	83	84	85	86	87	88	89	90
ELEVATION	12.67	12.67	12.67	12.67	12.52	12.52	12.52	12.52	12.37	12.37
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.91	5.91	5.91	5.91	5.90	5.90	5.90	5.90	5.90	5.90
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.91	5.91	5.91	5.91	5.90	5.90	5.90	5.90	5.90	5.90
DEPTH	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60	6.60
TIME	0.52	0.52	0.52	0.52	0.53	0.53	0.53	0.53	0.53	0.53
NODE	91	92	93	94	95	96	97	98	99	100
ELEVATION	12.37	12.37	12.22	12.22	12.22	12.22	12.07	12.07	12.07	12.07
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.90	5.90	5.90	5.90	5.90	5.90	5.89	5.89	5.89	5.89
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80

BASE

MAX VEL	5.90	5.90	5.90	5.90	5.90	5.90	5.89	5.89	5.89	5.89
DEPTH	6.60	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61
TIME	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
NODE	101	102	103	104	105	106	107	108	109	110
ELEVATION	11.92	11.92	11.92	11.92	11.77	11.77	11.77	11.77	11.62	11.62
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89
DEPTH	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.62	6.62	6.62
TIME	0.53	0.53	0.53	0.53	0.54	0.54	0.54	0.54	0.54	0.54
NODE	111	112	113	114	115	116	117	118	119	120
ELEVATION	11.62	11.62	11.47	11.47	11.47	11.47	11.32	11.32	11.32	11.32
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.89	5.89	5.88	5.88	5.88	5.88	5.88	5.88	5.88	5.88
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.89	5.89	5.88	5.88	5.88	5.88	5.88	5.88	5.88	5.88
DEPTH	6.62	6.62	6.62	6.62	6.62	6.62	6.63	6.62	6.63	6.62
TIME	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
NODE	121	122	123	124	125	126	127	128	129	130
ELEVATION	11.17	11.17	11.17	11.17	11.02	11.02	11.02	11.02	10.87	10.87
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.88	5.88	5.88	5.88	5.87	5.87	5.87	5.87	5.87	5.87
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.88	5.88	5.88	5.88	5.87	5.87	5.87	5.87	5.87	5.87
DEPTH	6.63	6.63	6.63	6.63	6.64	6.64	6.64	6.64	6.65	6.64
TIME	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
NODE	131	132	133	134	135	136	137	138	139	140
ELEVATION	10.87	10.87	10.72	10.72	10.72	10.72	10.57	10.57	10.57	10.57
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.87	5.87	5.87	5.87	5.87	5.87	5.87	5.87	5.87	5.87
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.87	5.87	5.87	5.87	5.87	5.87	5.87	5.87	5.87	5.87
DEPTH	6.64	6.64	6.65	6.66	6.65	6.66	6.67	6.67	6.67	6.67
TIME	0.55	0.55	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
NODE	141	142	143	144	145	146	147	148	149	150
ELEVATION	10.42	10.42	10.42	10.42	10.27	10.27	10.27	10.27	10.12	10.12
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
DEPTH	6.69	6.69	6.69	6.68	6.72	6.72	6.72	6.72	6.82	6.82
TIME	0.57	0.57	0.57	0.57	0.58	0.58	0.58	0.58	0.80	

0.80

NODE	151	152	153	154	155	156	157	158	159	160
ELEVATION	10.12	10.12	9.97	9.97	9.97	9.97	9.82	9.82	9.82	9.82
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80

NODE	161	162	163	164	165	166	167	168	169	170
ELEVATION	9.67	9.67	9.67	9.67	9.52	9.52	9.52	9.52	9.37	9.37
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80

NODE	171	172	173	174	175	176	177	178	179	180
ELEVATION	9.37	9.37	9.22	9.22	9.22	9.22	9.07	9.07	9.07	9.07
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80

NODE	181	182	183	184	185	186	187	188	189	190
ELEVATION	8.92	8.92	8.92	8.92	8.77	8.77	8.77	8.77	8.62	8.62
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80

NODE	191	192	193	194	195	196	197	198	199	200
ELEVATION	8.62	8.62	8.47	8.47	8.47	8.47	8.32	8.32	8.32	8.32
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80

NODE	201	202	203	204	205	206	207	208	209	210
ELEVATION	8.17	8.17	8.17	8.17	8.02	8.02	8.02	8.02	7.87	

BASE

7.87

MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80

NODE	211	212	213	214	215	216	217	218	219	220
ELEVATION	7.87	7.87	7.72	7.72	7.72	7.72	7.57	7.57	7.57	7.57
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80

NODE	221	222	223	224	225	226	227	228	229	230
ELEVATION	7.42	7.42	7.42	7.42	7.27	7.27	7.27	7.27	7.12	7.12
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80

NODE	231	232	233	234	235	236	237	238	239	240
ELEVATION	7.12	7.12	6.97	6.97	6.97	6.97	6.82	6.82	6.82	6.82
MAX DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82	6.82
VELOCITY	5.86	5.86	5.86	5.86	5.86	5.86	0.00	0.00	0.00	0.00
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
MAX VEL	5.86	5.86	5.86	5.86	5.86	5.86	0.00	0.00	0.00	0.00
DEPTH	6.82	6.82	6.82	6.82	6.82	6.82	0.00	0.00	0.00	0.00
TIME	0.80	0.80	0.80	0.80	0.80	0.80	0.00	0.00	0.00	0.00

MASS BALANCE INFLOW - OUTFLOW VOLUME

*** INFLOW (ACRE-FEET) ***

	WATER
INFLOW HYDROGRAPH	363.84

*** OUTFLOW (ACRE-FT) ***

OVERLAND FLOW	WATER
FLOODPLAIN STORAGE	92.43

	BASE
FLOODPLAIN OUTFLOW HYDROGRAPH	271.41

FLOODPLAIN OUTFLOW AND STORAGE	363.84

==

*** TOTALS ***

TOTAL OUTFLOW FROM GRID SYSTEM	271.41
TOTAL VOLUME OF OUTFLOW AND STORAGE	363.84

SURFACE AREA OF INUNDATION REGARDLESS OF THE TIME OF OCCURRENCE:
(FOR FLOW DEPTHS GREATER THAN THE "TOL" VALUE TYPICALLY 0.1 FT OR 0.03 M)

THE MAXIMUM INUNDATED AREA IS: 13.77 ACRES

==

COMPUTER RUN TIME IS : 0.00049 HRS

THIS OUTPUT FILE WAS TERMINATED ON: 4/ 4/2013 AT: 15: 6:27

CEDAS-ACES 4.03 was tested on the computer used for this document by Bin Wang on March 25, 2013. The inputs for the installation test were the same as those used in the software verification reports (Reference 9). The results of the installation test were acceptable.

Project: Ginna Wind Wave Run Up
Group: Post Verification

Case: Smooth Slop Runup 3/25/2013

Wave Runup and Overtopping on Impermeable Structures

Wave type: Irregular Slope type: Smooth
Rate estimate: Runup and Overtopping

Breaking criteria:	0.780				
Incident significant wave ht (Hi):	7.500	ft	Runup for significant waves (R):	21.366	ft
Peak wave period (T):	10.000		Onshore wind velocity (U):	59.073	ft/sec
COTAN of nearshore slope (cot phi):	100.000		Deepwater significant wave (Ho):	6.386	ft
Water depth at structure toe (ds):	12.500	ft	Relative height (ds/Ho):	1.957	
COTAN of structure slope (cot theta):	3.000		Wave steepness (Ho/gT^2):	0.002	
Structure height above toe (hs):	20.000	ft	Overtopping coef(alpha):	0.076	
			Overtopping coef(Q*o):	0.025	
			Overtopping rate (Q):	2.728	ft^3/s-ft

Project: Ginna Wind Wave Run Up
Group: Post Verification

Case: Wave Prediction Verification 3/25/2013

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	60.00	feet
Observed Wind Speed (Uobs)	30.00	knots
Air Sea Temp. Diff. (dT)	-9.00	deg F
Dur of Observed Wind (DurO)	1.00	hours
Dur of Final Wind (DurF)	3.00	hours
Lat. of Observation (LAT)	45.00	deg
Results		
Wind Fetch Length (F)	60.00	MILES
Eq Neutral Wind Speed (Ue)	27.71	knots
Adjusted Wind Speed (Ua)	36.18	knots
Wave Height (Hmo)	4.74	feet
Wave Period (Tp)	4.65	sec

Wind Obs Type	Wind Fetch Options
Overwater (ship)	Deep openwater

Wave Growth: Deep

APPENDIX K: 1 HOUR WATER LEVEL DATA

Note: Due to the size of the data in this appendix, the information has been archived in the AREVA file management system, ColdStor.

The path to the file is:

\cold\General-Access\32\32-9190280-000\official

APPENDIX L: 25 YEAR SURGE CALCULATION

Table L-1: Rochester, NY Yearly Maximums and Logarithmic Transformations

Year	Surge (m)	Log(Surge)
1989	0.3962	-0.402
1996	0.3146	-0.502
1964	0.3003	-0.522
1986	0.2476	-0.606
2001	0.2462	-0.609
1974	0.236	-0.627
2006	0.2268	-0.644
1992	0.2229	-0.652
2000	0.2218	-0.654
1973	0.2202	-0.657
1988	0.2048	-0.689
1999	0.2047	-0.689
2008	0.2026	-0.693
1993	0.1995	-0.700
1984	0.1954	-0.709
1972	0.184	-0.735
2011	0.1787	-0.748
1994	0.1763	-0.754
2003	0.1744	-0.758
1966	0.1721	-0.764
1977	0.1676	-0.776
1985	0.1664	-0.779
1981	0.1661	-0.780
2007	0.1661	-0.780
1998	0.163	-0.788
2010	0.1595	-0.797
1968	0.1589	-0.799
1983	0.1587	-0.799
1965	0.1523	-0.817
2009	0.1446	-0.840
1991	0.1398	-0.854
1980	0.139	-0.857
1990	0.1384	-0.859
1967	0.1356	-0.868
1969	0.1328	-0.877
1982	0.1327	-0.877
1971	0.1316	-0.881
1975	0.131	-0.883
2002	0.1305	-0.884
1979	0.1302	-0.885
1963	0.1297	-0.887
2005	0.1296	-0.887
1995	0.1289	-0.890
1997	0.1251	-0.903
1978	0.1245	-0.905
1962	0.122	-0.914
1976	0.1206	-0.919
1987	0.1158	-0.936
1970	0.1084	-0.965
2004	0.0991	-1.004

	A	B	C	H
1	**Table L-1: Rochester, NY Yearly Maximums and Logarithmic Transformations**			
2	**Year**	**Surge (m)**	**Log(Surge)**	
3	1989	0.3962	=LOG(B3)	
4	1996	0.3146	=LOG(B4)	
5	1964	0.3003	=LOG(B5)	
6	1986	0.2476	=LOG(B6)	
7	2001	0.2462	=LOG(B7)	
8	1974	0.236	=LOG(B8)	
9	2006	0.2268	=LOG(B9)	
10	1992	0.2229	=LOG(B10)	
11	2000	0.2218	=LOG(B11)	
12	1973	0.2202	=LOG(B12)	
13	1988	0.2048	=LOG(B13)	
14	1999	0.2047	=LOG(B14)	
15	2008	0.2026	=LOG(B15)	
16	1993	0.1995	=LOG(B16)	
17	1984	0.1954	=LOG(B17)	
18	1972	0.184	=LOG(B18)	
19	2011	0.1787	=LOG(B19)	
20	1994	0.1763	=LOG(B20)	
21	2003	0.1744	=LOG(B21)	
22	1966	0.1721	=LOG(B22)	
23	1977	0.1676	=LOG(B23)	
24	1985	0.1664	=LOG(B24)	
25	1981	0.1661	=LOG(B25)	
26	2007	0.1661	=LOG(B26)	
27	1998	0.163	=LOG(B27)	
28	2010	0.1595	=LOG(B28)	
29	1968	0.1589	=LOG(B29)	
30	1983	0.1587	=LOG(B30)	
31	1965	0.1523	=LOG(B31)	
32	2009	0.1446	=LOG(B32)	
33	1991	0.1398	=LOG(B33)	
34	1980	0.139	=LOG(B34)	
35	1990	0.1384	=LOG(B35)	
36	1967	0.1356	=LOG(B36)	
37	1969	0.1328	=LOG(B37)	
38	1982	0.1327	=LOG(B38)	
39	1971	0.1316	=LOG(B39)	
40	1975	0.131	=LOG(B40)	
41	2002	0.1305	=LOG(B41)	
42	1979	0.1302	=LOG(B42)	
43	1963	0.1297	=LOG(B43)	
44	2005	0.1296	=LOG(B44)	
45	1995	0.1289	=LOG(B45)	
46	1997	0.1251	=LOG(B46)	
47	1978	0.1245	=LOG(B47)	
48	1962	0.122	=LOG(B48)	
49	1976	0.1206	=LOG(B49)	
50	1987	0.1158	=LOG(B50)	
51	1970	0.1084	=LOG(B51)	
52	2004	0.0991	=LOG(B52)	

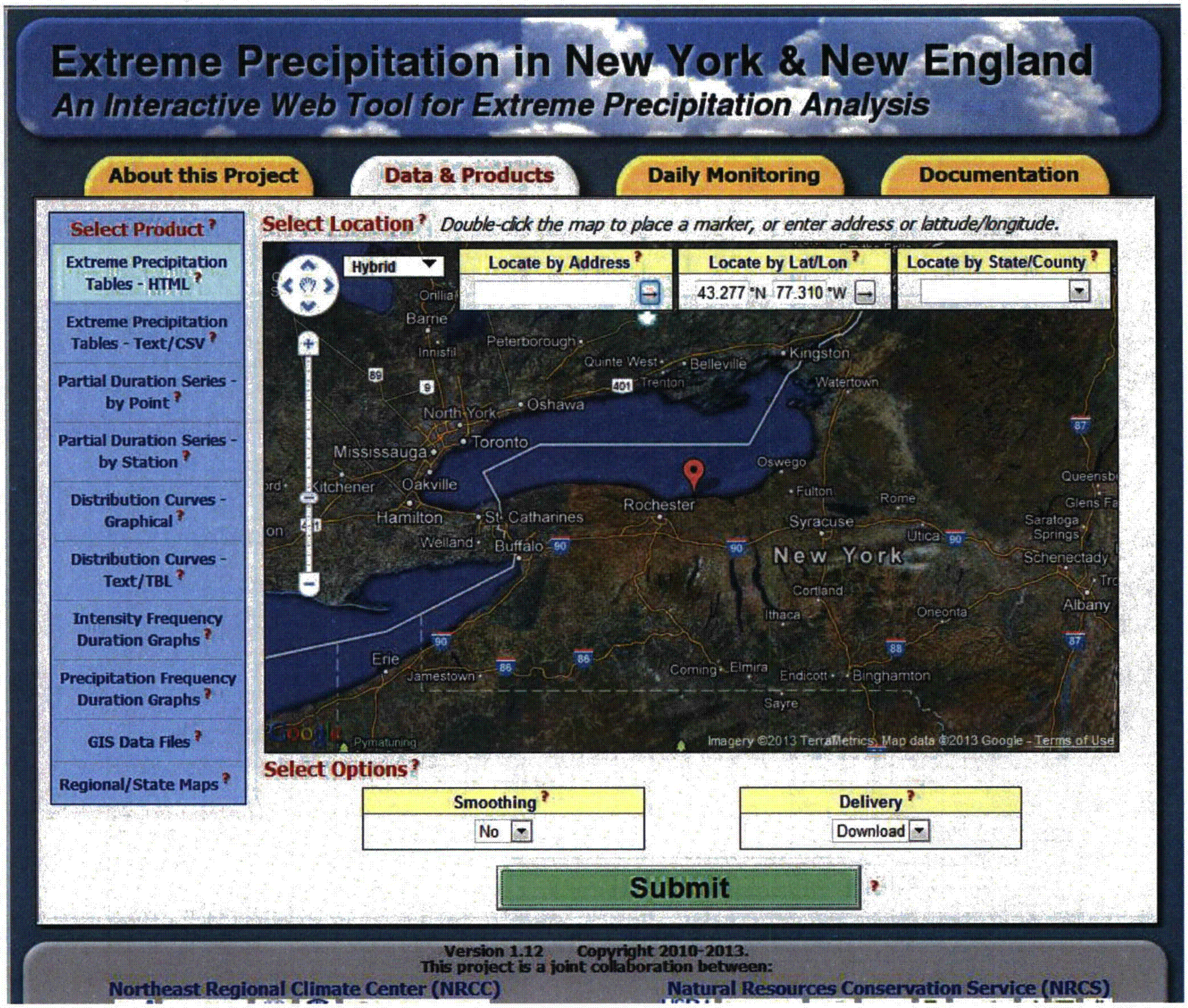
Table L-2: Statistical Analysis of Maximum Hourly Surge Water Level Data at Rochester, NY

No. Years in Record	50
Average Surge Water Level (SWL) (m)	0.173
Average Log of SWL	-0.78
Variance Log of SWL (m)	0.01591
Stdev Log of SWL (m)	0.12613
Skew (Sy)	0.80

		Skew = 0.80			
Return Period	**Exceedance Probability**	**K**	**Log SWL (m)**	**SWL (m)**	**SWL (ft)**
2	0.5	-0.132	-0.797	0.160	0.51
5	0.2	0.780	-0.682	0.208	0.67
10	0.1	1.336	-0.612	0.245	0.78
25	0.04	1.993	-0.529	**0.296**	**0.95**
50	0.02	2.453	-0.471	0.338	1.09

	A	B	C	D	E	F
1	**Table L-2: Statistical Analysis of Maximum Hourly Surge Water Level Data at Rochester, NY**					
2	**No. Years in Record**	=COUNT('Table L-1'!A3:A52)				
3	**Average Surge Water Level (SWL) (m)**	=AVERAGE('Table L-1'!B3:B52)				
4	**Average Log of SWL**	=AVERAGE('Table L-1'!C3:C52)				
5	**Variance Log of SWL (m)**	=VAR('Table L-1'!C3:C52)				
6	**Stdev Log of SWL (m)**	=STDEV('Table L-1'!C3:C52)				
7	**Skew (Sy)**	=SKEW('Table L-1'!C3:C52)				
8						
9						
10			**Skew =**	**=B7**		
11	**Return Period**	**Exceedance Probability**	**K**	**Log SWL (m)**	**SWL (m)**	**SWL (ft)**
12	2	=1/A12	-0.13199	=$B$4+(C12*$B$6)	=10^D12	=E12*3.2084
13	5	=1/A13	0.77986	=$B$4+(C13*$B$6)	=10^D13	=E13*3.2084
14	10	=1/A14	1.3364	=$B$4+(C14*$B$6)	=10^D14	=E14*3.2084
15	**25**	=1/A15	1.99311	=$B$4+(C15*$B$6)	**=10^D15**	**=E15*3.2084**
16	50	=1/A16	2.45298	=$B$4+(C16*$B$6)	=10^D16	=E16*3.2084

APPENDIX M: 25 YEAR PRECIPITATION DATA


Extreme Precipitation in New York & New England
An Interactive Web Tool for Extreme Precipitation Analysis
About this Project
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Extreme Precipitation Tables - HTML
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Partial Duration Series - by Point
Partial Duration Series - by Station
Distribution Curves - Graphical
Distribution Curves - Text/TBL
Intensity Frequency Duration Graphs
Precipitation Frequency Duration Graphs
GIS Data Files
Regional/State Maps
Select Location Double-click the map to place a marker, or enter address or latitude/longitude.
Hybrid
Locate by Address
Locate by Lat/Lon
43.277 °N 77.310 °W
Locate by State/County
Toronto
Rochester
New York
Imagery ©2013 TerraMetrics, Map data ©2013 Google - Terms of Use
Select Options
Smoothing
No
Delivery
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This project is a joint collaboration between:
Northeast Regional Climate Center (NRCC)
Natural Resources Conservation Service (NRCS)

Extreme Precipitation Tables

Northeast Regional Climate Center

Data represents point estimates calculated from partial duration series. All precipitation amounts are displayed in inches.

Smoothing	No
State	New York
Location	near 1487 Lake Road, Ontario, NY 14519, USA
Longitude	77.310 degrees West
Latitude	43.277 degrees North
Elevation	270 feet
Date/Time	Thu, 28 Mar 2013 10:52:45 -0400

Extreme Precipitation Estimates

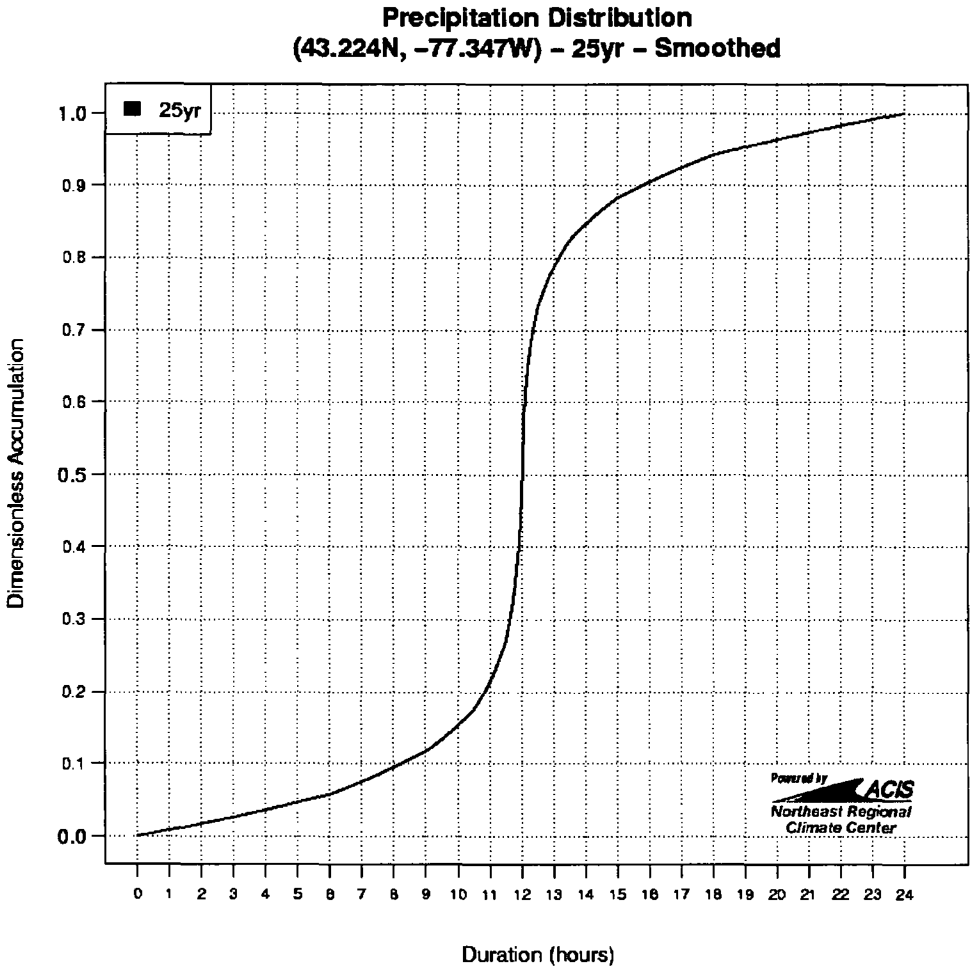
	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.26	0.40	0.49	0.66	0.81	0.92	**1yr**	0.70	0.90	1.03	1.27	1.53	1.85	2.07	**1yr**	1.64	1.99	2.39	2.87	3.30	**1yr**
2yr	0.30	0.47	0.57	0.78	0.96	1.09	**2yr**	0.83	1.06	1.19	1.47	1.77	2.17	2.43	**2yr**	1.92	2.34	2.75	3.26	3.73	**2yr**
5yr	0.35	0.55	0.68	0.93	1.18	1.35	**5yr**	1.02	1.32	1.49	1.80	2.18	2.66	2.99	**5yr**	2.35	2.88	3.35	3.92	4.48	**5yr**
10yr	0.41	0.62	0.77	1.08	1.39	1.59	**10yr**	1.20	1.55	1.76	2.11	2.55	3.10	3.51	**10yr**	2.74	3.37	3.90	4.51	5.15	**10yr**
25yr	0.49	0.74	0.92	1.32	1.73	1.97	**25yr**	1.49	1.93	2.20	2.60	3.15	3.79	4.32	**25yr**	3.36	4.16	4.76	5.44	6.20	**25yr**
50yr	0.56	0.85	1.06	1.52	2.04	2.33	**50yr**	1.76	2.28	2.60	3.05	3.70	4.42	5.07	**50yr**	3.91	4.87	5.54	6.26	7.14	**50yr**
100yr	0.64	0.97	1.22	1.76	2.41	2.75	**100yr**	2.08	2.69	3.09	3.58	4.36	5.16	5.94	**100yr**	4.56	5.71	6.45	7.21	8.21	**100yr**
200yr	0.74	1.12	1.41	2.05	2.85	3.26	**200yr**	2.46	3.18	3.68	4.21	5.12	6.01	6.97	**200yr**	5.32	6.71	7.51	8.30	9.46	**200yr**
500yr	0.90	1.34	1.73	2.51	3.57	4.07	**500yr**	3.08	3.98	4.63	5.22	6.37	7.38	8.62	**500yr**	6.53	8.29	9.18	10.01	11.40	**500yr**

Lower Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.21	0.33	0.40	0.54	0.66	0.74	**1yr**	0.57	0.72	0.83	1.07	1.41	1.71	1.81	**1yr**	1.51	1.74	2.20	2.55	2.98	**1yr**
2yr	0.29	0.45	0.55	0.75	0.92	1.03	**2yr**	0.80	1.01	1.15	1.41	1.71	2.12	2.38	**2yr**	1.87	2.28	2.69	3.18	3.65	**2yr**
5yr	0.33	0.50	0.62	0.86	1.09	1.23	**5yr**	0.94	1.20	1.35	1.65	2.01	2.50	2.82	**5yr**	2.21	2.71	3.14	3.69	4.23	**5yr**
10yr	0.36	0.55	0.68	0.95	1.22	1.38	**10yr**	1.06	1.35	1.51	1.85	2.24	2.81	3.19	**10yr**	2.49	3.07	3.50	4.10	4.68	**10yr**
25yr	0.40	0.61	0.76	1.09	1.43	1.61	**25yr**	1.24	1.57	1.75	2.14	2.58	3.25	3.77	**25yr**	2.88	3.63	4.03	4.71	5.37	**25yr**
50yr	0.44	0.67	0.84	1.20	1.62	1.80	**50yr**	1.40	1.76	1.95	2.40	2.86	3.64	4.27	**50yr**	3.22	4.11	4.49	5.23	5.94	**50yr**
100yr	0.49	0.73	0.92	1.33	1.82	2.01	**100yr**	1.57	1.97	2.15	2.67	3.17	4.06	4.84	**100yr**	3.59	4.65	5.01	5.80	6.57	**100yr**
200yr	0.53	0.80	1.01	1.47	2.05	2.26	**200yr**	1.77	2.21	2.38	2.98	3.49	4.53	5.48	**200yr**	4.01	5.27	5.55	6.42	7.25	**200yr**
500yr	0.60	0.90	1.15	1.67	2.38	2.62	**500yr**	2.05	2.56	2.72	3.44	3.97	5.21	6.48	**500yr**	4.61	6.23	6.34	7.34	8.26	**500yr**

Upper Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.29	0.45	0.55	0.74	0.91	1.02	**1yr**	0.78	1.00	1.14	1.40	1.72	1.99	2.26	**1yr**	1.76	2.17	2.57	3.05	3.54	**1yr**
2yr	0.31	0.49	0.60	0.81	1.00	1.13	**2yr**	0.86	1.11	1.25	1.52	1.85	2.26	2.50	**2yr**	2.00	2.40	2.85	3.34	3.85	**2yr**
5yr	0.38	0.59	0.74	1.01	1.28	1.48	**5yr**	1.11	1.44	1.63	1.95	2.34	2.85	3.19	**5yr**	2.52	3.07	3.56	4.14	4.75	**5yr**
10yr	0.45	0.70	0.87	1.21	1.56	1.81	**10yr**	1.35	1.77	2.00	2.38	2.83	3.42	3.84	**10yr**	3.03	3.70	4.24	4.88	5.60	**10yr**
25yr	0.58	0.88	1.09	1.56	2.05	2.40	**25yr**	1.77	2.35	2.64	3.09	3.65	4.38	4.93	**25yr**	3.87	4.74	5.36	6.08	6.96	**25yr**
50yr	0.68	1.04	1.30	1.86	2.51	2.96	**50yr**	2.16	2.89	3.27	3.78	4.42	5.26	5.95	**50yr**	4.65	5.72	6.40	7.19	8.23	**50yr**
100yr	0.82	1.24	1.55	2.24	3.07	3.65	**100yr**	2.65	3.57	4.04	4.60	5.38	6.36	7.18	**100yr**	5.63	6.91	7.66	8.49	9.72	**100yr**
200yr	0.98	1.47	1.86	2.70	3.76	4.51	**200yr**	3.25	4.41	5.02	5.62	6.53	7.67	8.66	**200yr**	6.79	8.33	9.16	10.03	11.49	**200yr**
500yr	1.25	1.85	2.38	3.46	4.93	5.98	**500yr**	4.25	5.84	6.69	7.35	8.47	9.84	11.13	**500yr**	8.71	10.70	11.62	12.53	14.35	**500yr**



Time (hours)	25yr Accumulation (dimensionless)
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0.1	0.0008
0.2	0.0016
0.3	0.0024
0.4	0.0032
0.5	0.0040
0.6	0.0049
0.7	0.0057
0.8	0.0065
0.9	0.0074
1.0	0.0082
1.1	0.0091
1.2	0.0099
1.3	0.0108
1.4	0.0117
1.5	0.0126

1.6	0.0134
1.7	0.0143
1.8	0.0152
1.9	0.0161
2.0	0.0170
2.1	0.0180
2.2	0.0189
2.3	0.0198
2.4	0.0207
2.5	0.0217
2.6	0.0226
2.7	0.0236
2.8	0.0245
2.9	0.0255
3.0	0.0264
3.1	0.0274
3.2	0.0284
3.3	0.0293
3.4	0.0303
3.5	0.0313
3.6	0.0323
3.7	0.0333
3.8	0.0343
3.9	0.0353
4.0	0.0363
4.1	0.0374
4.2	0.0384
4.3	0.0394
4.4	0.0405
4.5	0.0415
4.6	0.0426
4.7	0.0436
4.8	0.0447
4.9	0.0458
5.0	0.0468
5.1	0.0479
5.2	0.0490
5.3	0.0501
5.4	0.0512
5.5	0.0523
5.6	0.0534
5.7	0.0545
5.8	0.0556
5.9	0.0568
6.0	0.0579
6.1	0.0595
6.2	0.0612
6.3	0.0629
6.4	0.0646
6.5	0.0663
6.6	0.0681
6.7	0.0699
6.8	0.0717
6.9	0.0735
7.0	0.0754
7.1	0.0773
7.2	0.0792
7.3	0.0811
7.4	0.0830
7.5	0.0850

7.6	0.0870
7.7	0.0890
7.8	0.0910
7.9	0.0930
8.0	0.0951
8.1	0.0972
8.2	0.0993
8.3	0.1015
8.4	0.1036
8.5	0.1058
8.6	0.1080
8.7	0.1103
8.8	0.1125
8.9	0.1148
9.0	0.1171
9.1	0.1202
9.2	0.1233
9.3	0.1266
9.4	0.1300
9.5	0.1335
9.6	0.1371
9.7	0.1409
9.8	0.1447
9.9	0.1487
10.0	0.1528
10.1	0.1570
10.2	0.1613
10.3	0.1658
10.4	0.1703
10.5	0.1750
10.6	0.1819
10.7	0.1891
10.8	0.1967
10.9	0.2048
11.0	0.2132
11.1	0.2233
11.2	0.2341
11.3	0.2454
11.4	0.2573
11.5	0.2697
11.6	0.2917
11.7	0.3149
11.8	0.3466
11.9	0.3908
12.0	0.4708
12.1	0.6092
12.2	0.6534
12.3	0.6851
12.4	0.7083
12.5	0.7303
12.6	0.7427
12.7	0.7546
12.8	0.7659
12.9	0.7767
13.0	0.7868
13.1	0.7952
13.2	0.8033
13.3	0.8109
13.4	0.8181
13.5	0.8250

13.6	0.8297
13.7	0.8342
13.8	0.8387
13.9	0.8430
14.0	0.8472
14.1	0.8513
14.2	0.8553
14.3	0.8591
14.4	0.8629
14.5	0.8665
14.6	0.8700
14.7	0.8734
14.8	0.8767
14.9	0.8798
15.0	0.8829
15.1	0.8852
15.2	0.8875
15.3	0.8897
15.4	0.8920
15.5	0.8942
15.6	0.8964
15.7	0.8985
15.8	0.9007
15.9	0.9028
16.0	0.9049
16.1	0.9070
16.2	0.9090
16.3	0.9110
16.4	0.9130
16.5	0.9150
16.6	0.9170
16.7	0.9189
16.8	0.9208
16.9	0.9227
17.0	0.9246
17.1	0.9265
17.2	0.9283
17.3	0.9301
17.4	0.9319
17.5	0.9337
17.6	0.9354
17.7	0.9371
17.8	0.9388
17.9	0.9405
18.0	0.9421
18.1	0.9432
18.2	0.9444
18.3	0.9455
18.4	0.9466
18.5	0.9477
18.6	0.9488
18.7	0.9499
18.8	0.9510
18.9	0.9521
19.0	0.9532
19.1	0.9542
19.2	0.9553
19.3	0.9564
19.4	0.9574
19.5	0.9585

19.6	0.9595
19.7	0.9606
19.8	0.9616
19.9	0.9626
20.0	0.9637
20.1	0.9647
20.2	0.9657
20.3	0.9667
20.4	0.9677
20.5	0.9687
20.6	0.9697
20.7	0.9707
20.8	0.9716
20.9	0.9726
21.0	0.9736
21.1	0.9745
21.2	0.9755
21.3	0.9764
21.4	0.9774
21.5	0.9783
21.6	0.9793
21.7	0.9802
21.8	0.9811
21.9	0.9820
22.0	0.9830
22.1	0.9839
22.2	0.9848
22.3	0.9857
22.4	0.9866
22.5	0.9874
22.6	0.9883
22.7	0.9892
22.8	0.9901
22.9	0.9909
23.0	0.9918
23.1	0.9926
23.2	0.9935
23.3	0.9943
23.4	0.9951
23.5	0.9960
23.6	0.9968
23.7	0.9976
23.8	0.9984
23.9	0.9992
24.0	1.0000