

# Farnsworth House Flood Risk and Conceptual Mitigation Evaluation 14520 River Road Plano, Illinois

---



Flooding at Farnsworth House rising to near finished floor elevation, April 18, 2013  
*(Photograph from Deena Boatman of Farnsworth House site staff)*

Prepared for:  
NATIONAL TRUST FOR HISTORIC PRESERVATION  
1785 Massachusetts Avenue NW  
Washington, DC 20036

May 15, 2013

## Table of Contents

<b>Section I Flood Risk Assessment .....</b>	<b>1</b>
Executive Summary .....	2
1.0 Introduction.....	4
2.0 Background Information.....	5
2.1 FEMA Mapping and Documentation.....	8
2.2 Flooding History .....	11
2.3 Fox River Watershed .....	11
3.0 Spring 2013 Flooding .....	11
4.0 Hydrologic Analysis and Flood Risk Characterization .....	14
5.0 Hydraulic Analysis.....	17
5.1 Hydraulic Modeling Background & Approach.....	17
5.2 Hydraulic Modeling Results .....	19
5.3 Mies van der Rohe’s Basis of Design for Finished Floor Elevation.....	20
<b>Section II Evaluation of Mitigation Strategies for the Farnsworth House.....</b>	<b>22</b>
Executive Summary .....	23
1.0 Evaluation of Flood Risk Mitigation Alternatives.....	25
1.1 Do Nothing.....	25
1.2 Relocate House .....	26
1.3 Channel Improvements .....	26
1.4 Channel Maintenance.....	26
1.5 Floodwall and Levee Protection .....	27
1.6 Elevation .....	27
2.0 Regulatory Contacts.....	29
3.0 Potential Next Steps.....	29

## Tables

Table I-1.	Peak Flow Values for Fox River near Plano, Illinois .....	10
Table I-2.	Comparison of Estimated Flood Flows for Range of Frequencies and Periods of Record Analyzed .....	17
Table I-3.	Comparison of Key Elevations for Farnsworth House with FIS Flood Elevations & Flood Elevations from Statistical Analysis of 1980-2012 Period of Record.....	20
Table II-1.	Additional Elevation Needed to Provide One (1) Foot of Freeboard above Flood Water Surface Elevations based on 1980 – 2013 Gauge Analysis .....	28

## Figures

Figure I-1.	Effective FEMA Floodplain Mapping in Vicinity of Farnsworth House .....	6
Figure I-2.	Fox River Watershed .....	7
Figure I-3.	Water Surface Elevation Profiles from FEMA FIS .....	9
Figure I-4.	Spring 2013 Hydrograph for USGS Gauge at Dayton, IL Downstream of Farnsworth House .....	12
Figure I- 5.	Spring 2013 Hydrograph for USGS Gauge at Montgomery, IL Upstream of Farnsworth House.....	13
Figure I- 6.	Spring 2013 Hydrograph Estimated for Farnsworth House - Extrapolated from Upstream and Downstream Gauges .....	13
Figure I- 7.	Log Pearson III Statistical Distribution of Peak Flow Data for the Fox River at the Farnsworth House (1915 – 2012) .....	15
Figure I- 8.	Log Pearson III Statistical Distribution of Peak Flow Data for the Fox River at the Farnsworth House - Comparison of 1915 – 1979 with 1980 – 2012.....	16

# **Section I**

## **Flood Risk Assessment**

## Executive Summary

This report presents results of an assessment of hydrology, flooding risk and conceptual mitigation strategies for the Farnsworth House and grounds located at 14520 River Road in Plano, Illinois. Wright Water Engineers, Inc. (WWE) has prepared this report for the National Trust for Historic Preservation (NTHP). While the Farnsworth House has a history of flooding dating back to 1954, the frequency and severity of flooding have intensified over the past decade or more as urbanization has occurred in the 1,900-square mile Fox River watershed upstream of the house. Ludwig Mies van der Rohe intentionally designed the Farnsworth House to “float” with freeboard above the floodwater surface during the design event (and lesser events) that he chose. As discussed in this report, analysis of hydrologic data indicates that the magnitude of the peak discharges that are considered severe, as well as more frequent (e.g. 10-year) flood events, has increased over the years.

This report is presented in two sections. Section I summarizes the hydrologic and hydraulic analyses of the Fox River reach relevant to the Farnsworth House and documents spring 2013 flooding of the site. Section II identifies and evaluates conceptual alternatives for mitigating future flood risk.

Major findings of this Section I include the following:

1. Statistical analyses of stream gauge data for different periods of record indicate that the flood risk for the property has increased over time, most notably from urbanization since the 1950s in the 1,900- square-mile watershed<sup>1</sup>. Based on statistical analysis of a period of record from 1980 through 2012, floods with water surface elevations high enough to exceed the finished floor elevation of the Farnsworth House would be expected to occur with an annual exceedance probability of 5%, meaning that flooding of this severity would be expected to occur, on average, once every 20 years (based on ideal site conditions, which would not account for build-up of debris and other items during a flood event). Historical records since the house was constructed demonstrate that flood waters have reached above the finished floor elevation at least once every 15 years on average.
2. Based on statistical analysis of the 1980 through 2012 portion of the gauge record, the 100-year event would have a discharge of approximately 34,100 cubic feet per second (cfs). In the 100-year event, the depth of water above the finished floor elevation would be expected to be approximately 2 feet. The published 100-year flood discharge in the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for this location is approximately 27,000 cfs.

---

<sup>1</sup> Because there is significant variability in the 95-year record in terms of annual peak flows, confidence limits are broad, and from a purely statistical standpoint, it cannot be concluded with statistical confidence at a high level (i.e. 95% confidence) that the more recent flows are from a different statistical distribution than the historic flows. This is a conclusion more related to the high variability of peak flows rather than the lack of a shift, which is supported by increased imperviousness in the watershed and the actual record of flooding at the house since it was constructed.

3. The area around the Farnsworth House floods when flows in the Fox River exceed the banks. Based on statistical analysis, this would be expected to happen more or less on an annual basis and may actually occur multiple times in any given year as the river rises and falls periodically in the spring in response to snowmelt and rainfall events. In some years, this results in minor inundation of pockets of low-lying areas surrounding the house. In other years, the flooding is more substantial surrounding the house with shallow flooding.

# Farnsworth House Flood Risk Assessment

---

## 1.0 Introduction

This report presents results of an assessment of hydrology, flooding risk and conceptual mitigation strategies at the Farnsworth House and grounds located at 14520 River Road, Plano, Illinois. Section I of this report presents the flood risk assessment. Wright Water Engineers, Inc. (WWE) has prepared this report for the National Trust for Historic Preservation (NTHP)<sup>2</sup>. Figure I-1 is an aerial photograph showing the current Federal Emergency Management Agency (FEMA) floodplain mapping for the site and vicinity. As the mapping shows, the Farnsworth House lies within FEMA's Special Flood Hazard Area (SFHA), also known as the 100-year floodplain<sup>3</sup>. While the Farnsworth House has a history of flooding dating back to 1954, the frequency and severity of flooding have intensified over the past decade or more as urbanization has occurred in the 1,900-square-mile Fox River watershed (Figure I-2) upstream of the house. Mies van der Rohe intentionally designed the Farnsworth House to "float" with freeboard above the floodwater surface during the design event (and lesser events) that he chose. As discussed in this report, analysis of hydrologic data indicates that the magnitude of the peak discharges considered severe, as well as more frequent (e.g. 10-year) flood events, has increased over the years.

WWE engineers visited the site on April 1, 2013, and met with site staff and NTHP Architect, Ashley Wilson, AIA, ASID. We gained valuable information from seeing the site and reviewing documentation kept in the Visitor Center related to past flooding and the history of the Farnsworth House and property. WWE has also consulted with state floodplain regulators at the Illinois Department of Natural Resources (IDNR) and other experts on the National Flood Insurance Program (NFIP).

This report presents background information on the site and the history of flooding analysis of flood event hydrology, hydraulic analysis and assessment of risk of flooding of the house for different flood events. Documentation of the spring 2013 flooding of the site is provided including photographs of shallow out-of-bank flooding in late March and flooding almost to

---

<sup>2</sup> This report has been prepared by T. Andrew Earles, Ph.D., P.E., D.WRE and Eliot Wong, CFM with peer review from Kenneth Wright, P.E., D.WRE and Bill DeGroot, P.E., CFM, an adjunct flood risk management expert to WWE. These engineers have gained experience addressing water engineering at sensitive cultural and archaeological sites through consulting and engineering assignments at locations including Machu Picchu, Tipon, Moray, Sacsaywaman and Ollantaytambo, Peru; Mesa Verde National Park, Colorado, USA; Olympia, Greece; and UNESCO World Heritage sites including Phnom Bakheng at the Angkor Archaeological Park in Cambodia; Wat Chaiwatthanaram in Ayutthaya, Thailand; and the Nanyue Palace Archaeological Site and Museum in Guangzhou, China. Appendix A provides a summary listing of experience at such sites.

<sup>3</sup> This refers to the area that would be expected to flood with an annual exceedance probability (AEP) of 0.01 or 1%.

the finished floor elevation of the house on April 18. Section II of the report presents and evaluates conceptual alternatives to reduce flood risk.

WWE would like to thank the NTHP and the knowledgeable staff at the site who provided many useful documents, photographs of the site during flooding, and insight into the history of the Farnsworth House and property.

## 2.0 Background Information

The Farnsworth House is a historic residential structure designed by architect Ludwig Mies van der Rohe that was constructed between 1949 and 1951 in Plano, Illinois along the north bank of the Fox River, just upstream of the confluence with Big Rock Creek. The house was originally constructed on a 9-acre lot; however, Dr. Edith Farnsworth purchased an adjacent 55 acres to the east in 1961. A portion of this land was taken by the county via eminent domain in 1967 to accommodate construction of a bridge across the Fox River, just downstream of Ms. Farnsworth's property. As the site currently stands, the overall property encompasses approximately 62 acres.

The Historic American Building Survey (HABS) for the Farnsworth House prepared by the National Park Service (HABS No. IL – 1105) provides a good characterization of flooding issues for the structure and property:

*...regional development and climatic changes have significantly impacted the house by altering its relationship with its site. In addition to visually isolating the house as an object, Mies' decision to raise the building placed it more than a foot above the highest known flood level (established in consultation with local officials and long-term residents). Since that time, however, development in the Fox River valley has increased the impermeable surfaces of the region. A larger amount of water runs directly into waterways without soaking into the ground first, increasing the rainfall runoff throughout the valley. This, in conjunction with recent extreme weather events, means that the river now rises higher, faster and more frequently than it did historically, and it is this flooding that has had the greatest impact on the history of the Farnsworth House, and poses the most intractable preservation problem.*

Based on the information WWE reviewed, the house itself has flooded on at least four occasions since it was constructed, dating back to a 1954 flood that reportedly resulted in approximately two feet of water inside the house. More recent floods affecting the structure were documented in 1996, 1997 and 2008.



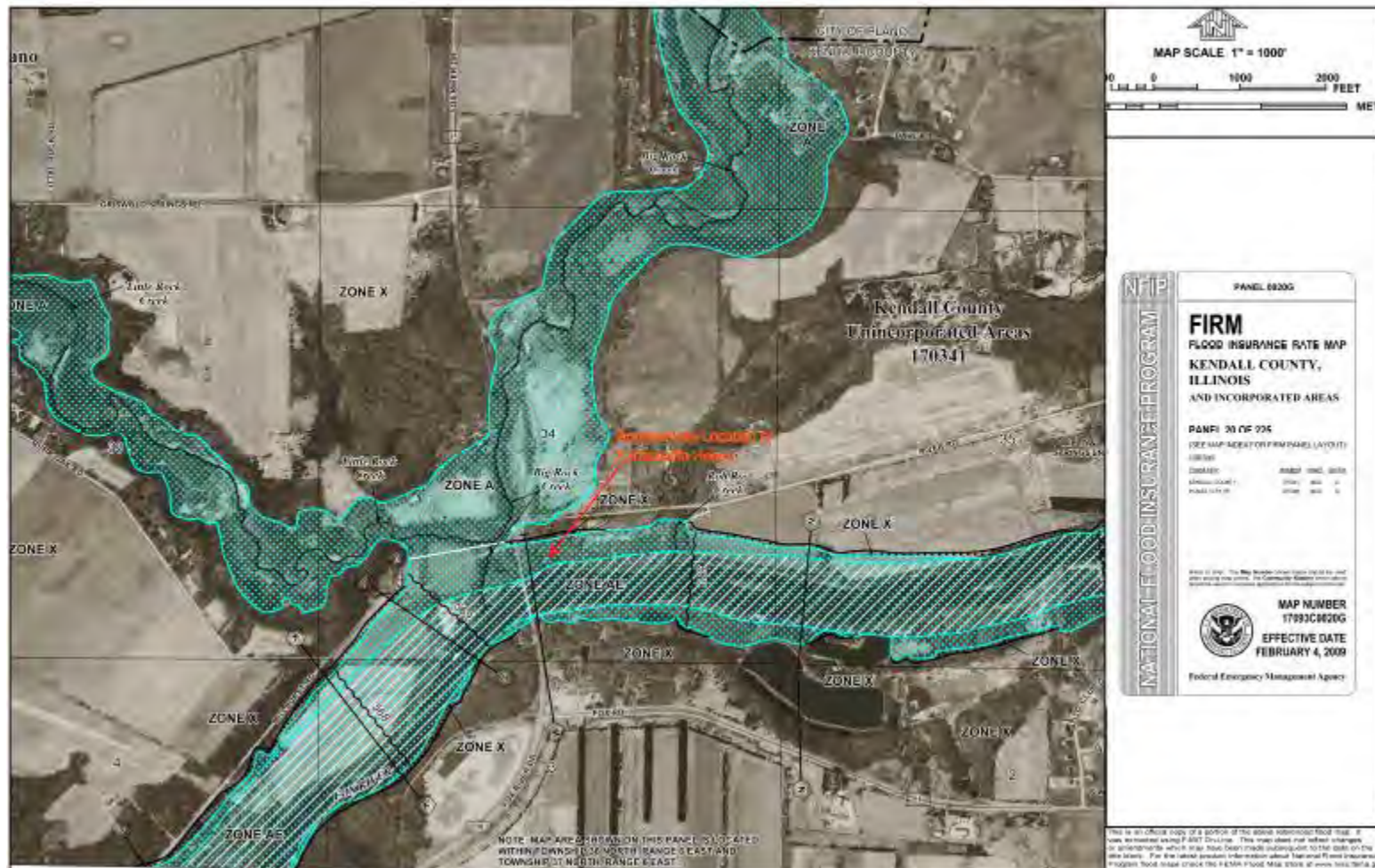
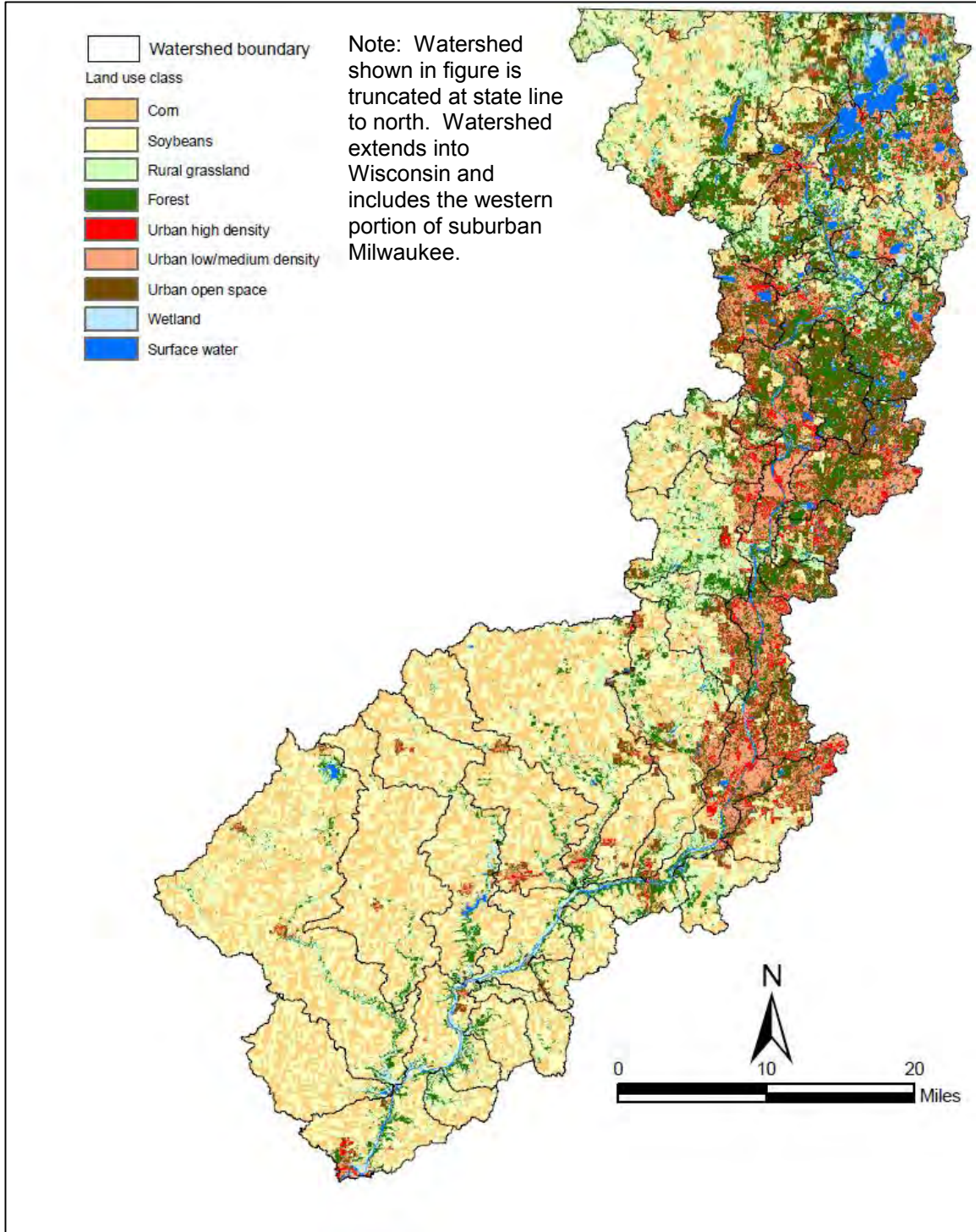


Figure I-1. Effective FEMA Floodplain Mapping in Vicinity of Farnsworth House



**Figure I-2. Fox River Watershed**

*Source: Illinois State Water Survey, Fox River Watershed Investigation Stratton Dam to the Illinois River Phase II, April 2011*

The terrace and meadow surrounding the house flood frequently and, as of March 2013, these areas were already experiencing rising floodwaters due to the spring thaw and ongoing rainfall. The boathouse on the property reportedly floods “several times a year,” and log-jams routinely build up on the west side of the structure. Additionally, the channel between the boathouse and the river is choked with silt several feet thick. A perimeter fence on the property has also suffered damage from flooding, with the last fence post near the river experiencing undermining. Log-jams have collapsed sections of the fence. Beavers are also a nuisance in this riparian region.

Over the history of the house, it appears that there have been few physical modifications to the Fox River floodplain relative to the Farnsworth House. (The floodplain mapping has been essentially unchanged since the early 1980s). A notable exception is the Fox River Drive Bridge, which was constructed just downstream of the Farnsworth House in 1967, after a prolonged legal battle. Based on the water surface profile in the FEMA Flood Insurance Study (FIS), it appears that this bridge has a relatively small backwater effect, on the order of 0.5 to 1.0 feet. Siltation in the river over many years upstream of the bridge also may explain part of this effect. The finished floor of the house is more or less at the same elevation as the 100-year water surface elevation reported in the FIS.

## **2.1 FEMA Mapping and Documentation**

The Farnsworth House lies entirely within the SFHA. The SFHA defines the limits of flooding for an event with an annual exceedance probability of 1%, or a one-in-one-hundred year likelihood of occurrence. Figure I-1 (above) is mapping excerpted from the effective FEMA Flood Insurance Rate Map (FIRM), and Figure I-3 shows the longitudinal water surface profile from the FEMA FIS in the vicinity of the property. Table I-1 summarizes applicable peak flow values from the FIS.

The flood zone designation for the property is Zone AE, which is FEMA’s designation for a stream that has been studied using detailed methods (i.e. hydraulic modeling). A floodway has been established for this reach, which defines an area of restricted activity to provide safe conveyance for the 100-year flood event. The house itself actually appears to sit right on the boundary between the floodway and the “flood fringe<sup>4</sup>.” Based on the FEMA mapping, the regulatory 100-year water surface elevation is approximately 569.5 to 570.0 feet in the vicinity of the Farnsworth property. The finished floor elevation for the Farnsworth House is at elevation 570.0 feet. Therefore, there is little if any freeboard available between the finished floor elevation of the house and the regulatory 100-year water surface elevation. As discussed later in this report, WWE’s analysis of more recent flow data suggests that the current regulatory 100-year water surface elevation at the house is underestimated.

---

<sup>4</sup> The “flood fringe” refers to the portion of the 100-year floodplain (or SFHA) that is not designated as floodway. Generally, there is much more flexibility to make modifications to the flood fringe area than for the floodway.



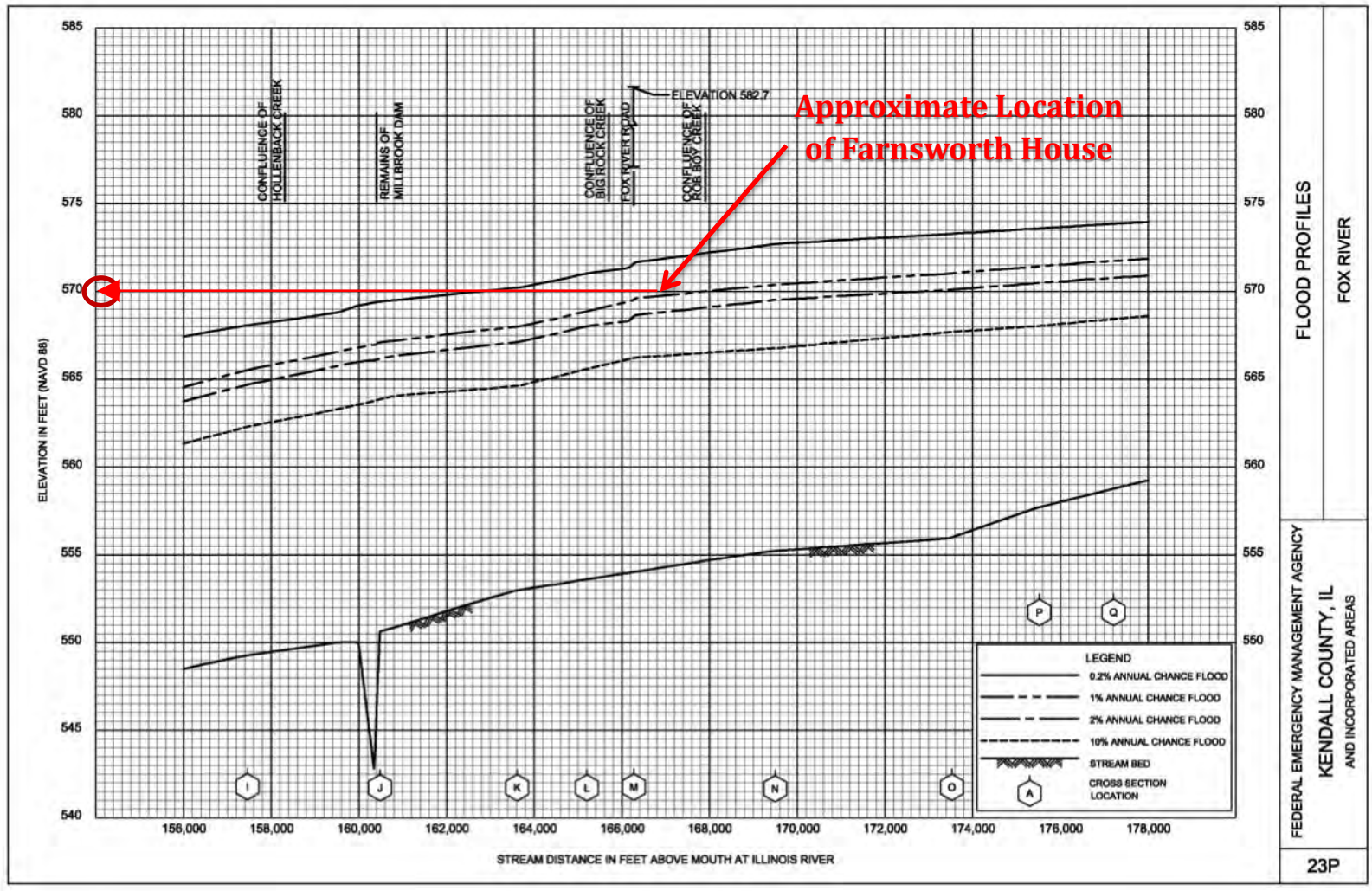


Figure 1-3. Water Surface Elevation Profiles from FEMA FIS

**Table I-1. Peak Flow Values for Fox River near Plano, Illinois**

<b>Location</b>	<b>Drainage Area (mi<sup>2</sup>)</b>	<b>10-Percent Annual Chance/ 10-yr Event</b>	<b>2-Percent Annual Chance/ 50-yr Event</b>	<b>1-Percent Annual Chance/ 100-yr Event</b>	<b>0.2-Percent Annual Chance/ 500-yr Event</b>
Fox River 900 feet upstream of Bridge Street, Millington	2,138	15,327	23,899	27,412	36,894
Fox River at Bridge Street, Yorkville	1,804	10,580	15,221	17,697	22,615

\*The Farnsworth House lies approximately 5 miles downstream from the Yorkville station and approximately 6 miles upstream from the Millington station, just upstream of confluence with Big Rock Creek.

The FIS and FIRM both have effective dates of February 2009. Based on review of historic mapping; however, the floodplain mapping essentially has been unchanged since at least the early 1980s. WWE requested documentation for hydraulic models from FEMA. The floodplain hydraulic models were available on microfiche (copies of printed model input and output) and were in an old model format that is no longer widely used. It appears that the hydraulic modeling for this reach of the Fox River has not been reevaluated for some time. WWE updated the model format to the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center—River Analysis System (HEC-RAS) model. The model was used with flood flows published in the FIS to duplicate the results upon which the regulatory mapping is based. The duplicated model prepared by WWE produced 100-year water surface elevations to within 0.10 foot along the reach in the vicinity of the Farnsworth House.

The underlying hydrology used to define the regulatory flows presented in Table I-1 likely has not been updated recently. Typically, FEMA bases hydrology on existing conditions at the time the study is conducted. Since the floodplain delineation does not appear to have changed significantly since the early 1980s, it is reasonable to conclude that the hydrology has similarly remained unchanged. In reality, it is likely that urbanization in the watershed over the past 60 years has changed the hydrology of the stream, increasing the magnitude and frequency of high flows with the potential to cause flooding. According to the FIS, these discharge rates were determined (at least in part) through analysis of stream gauge data. At the time, the Dayton gauge had a period of record of 65 years. This gauge now has a period of record of nearly 100 years.

## 2.2 Flooding History

Since its construction in 1949-1951, the Farnsworth House has been beset by problems related to flooding. The first major flood to damage the house occurred in 1954, damaging the interior curtains with water raising about 2 feet inside of the house. Between 1954 and 1971 there were a few other minor floods, and there is anecdotal evidence that neighboring farmers would even routinely boat down the Fox River to check on Ms. Farnsworth during floods. In 1996, at least several feet of water flooded the house, only to be followed the next year by another flood that inundated the house with a few inches of water. In 2008, the house was again flooded with about 1.5 feet of water. More recently, on March 11, 2013, flooding again encroached on the property, flooding portions of the terraces, and on April 18, 2013, as the Fox River reached its crest following heavy rainfall in the watershed, the water surface elevation came within inches of the finished floor elevation. Appendix B is a Photographic Log of WWE's April 1, 2013 site visit, and Appendix C provides photographs of the spring 2013 flooding from NTHP site staff. Appendix D provides photos of historical flooding from records provided by the NTHP Farnsworth House site staff. Appendix F provides HEC-RAS model files in an electronic format.

## 2.3 Fox River Watershed

The Fox River watershed drains an area of approximately 1,900 square miles upstream of the Farnsworth property. The headwaters of the watershed lie in Wisconsin, where western portions of Milwaukee feed the upper reaches. While many portions of the watershed remain agricultural in nature, significant urban and suburban growth has occurred over the past 60 years and continues. Although the watershed comprises only approximately 3% of the total land area in Illinois, it is home to approximately 450,000 people, approximately 11 percent of the state total. This is projected to increase by more than 30% over the next 20 years ([www.foxriverstudygroup.org](http://www.foxriverstudygroup.org)). Figure I-2 depicts the Fox River watershed and land uses within the watershed.

## 3.0 Spring 2013 Flooding

As documented in Appendix C, the Farnsworth House flooded within inches of its finished floor elevation on April 18, 2013. In late March, the river came out of its banks and inundated portions of the site. Initial shallow flooding usually begins as the drainage ditch to the east of the house backs up from the river. This drainage ditch is shown in Photographs 13 and 14 in Appendix B. When this ditch overtops, and the water flows around the north side of the house and pools in a shallow depression. At higher flows (typically those exceeding about 7,000 cfs), the banks start to overtop along the entire river frontage and flood waters can rise inundating the floodplain with 5 feet of water or more in extreme events (flows of 26,000 cfs or greater).

Figures I-4, I-5, and I-6 show hydrographs at the USGS gauge at Dayton (downstream of Farnsworth), the USGS gauge at Montgomery (upstream of Farnsworth), and the

estimated hydrograph at the Farnsworth property. The Farnsworth estimated hydrograph was developed using an area-weighted approach. The drainage area for the Dayton gauge is 2,642 square miles and the area draining to the Farnsworth property is 1,905 square miles. The flows recorded at the Dayton gauge were multiplied by an area ration of 0.72 (2,642 divided by 1,905) to get an estimate of the flows at the Farnsworth property.

Based on the area-weighted method, the peak flow at the Farnsworth house during the April 18-19, 2013 flood event was approximately 28,100 cfs. This flow rate would be characterized as a 100-year flow when comparing to the published flows in the FIS. Compared to statistical analysis of data from 1980 to 2012, this flow rate would correspond to an annual exceedance probability of slightly less than 4% or greater than a 25-year event.

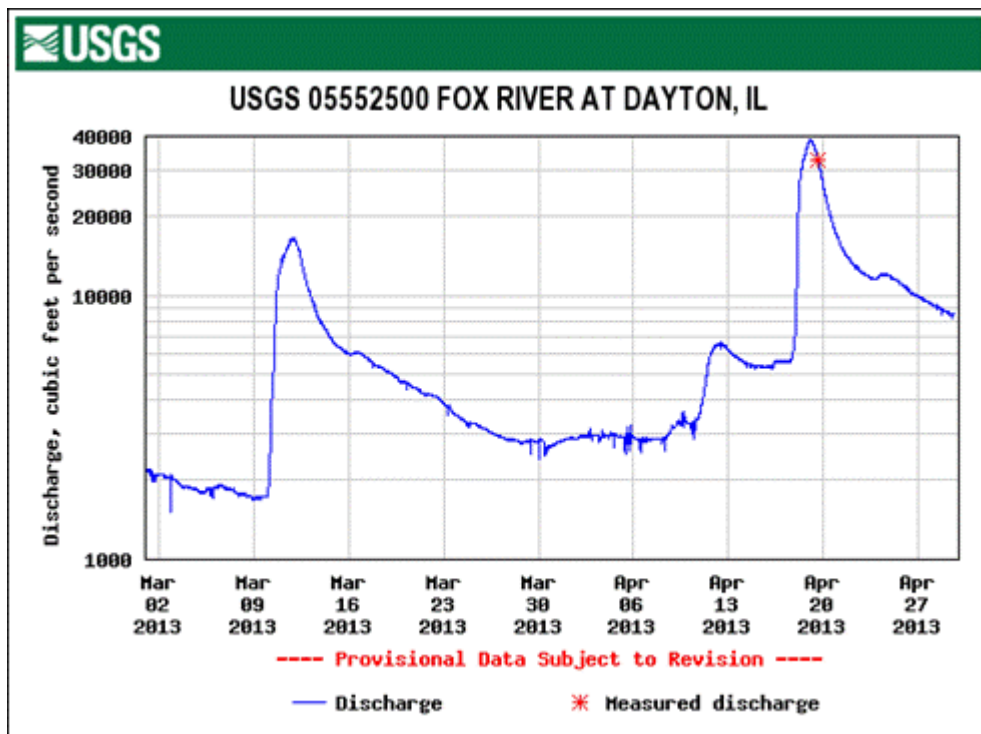
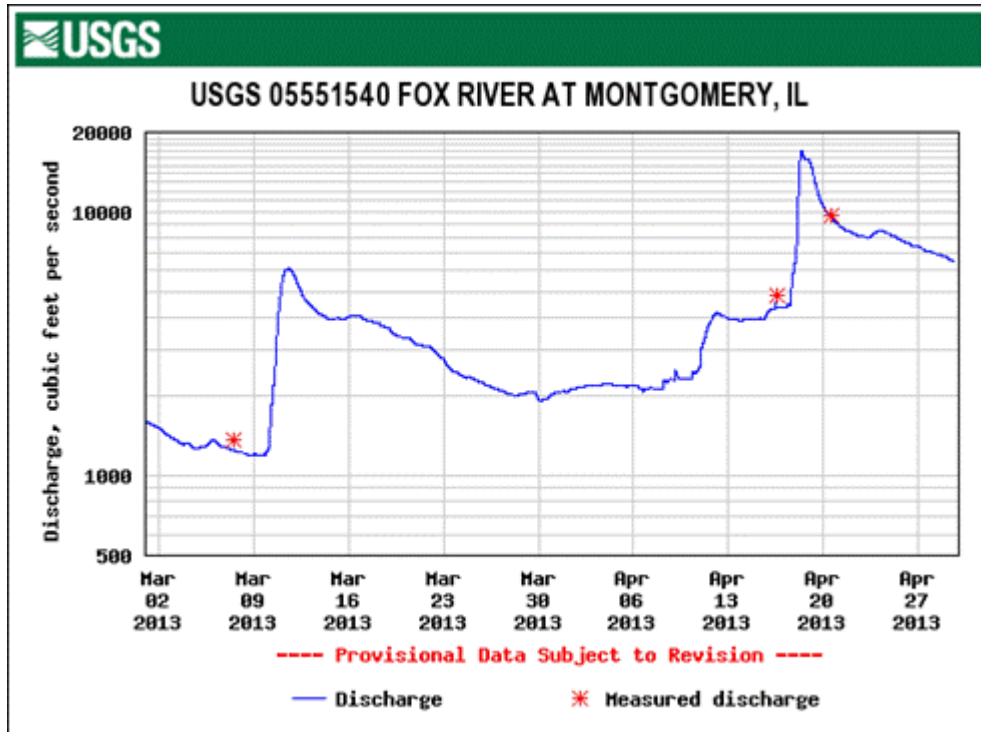
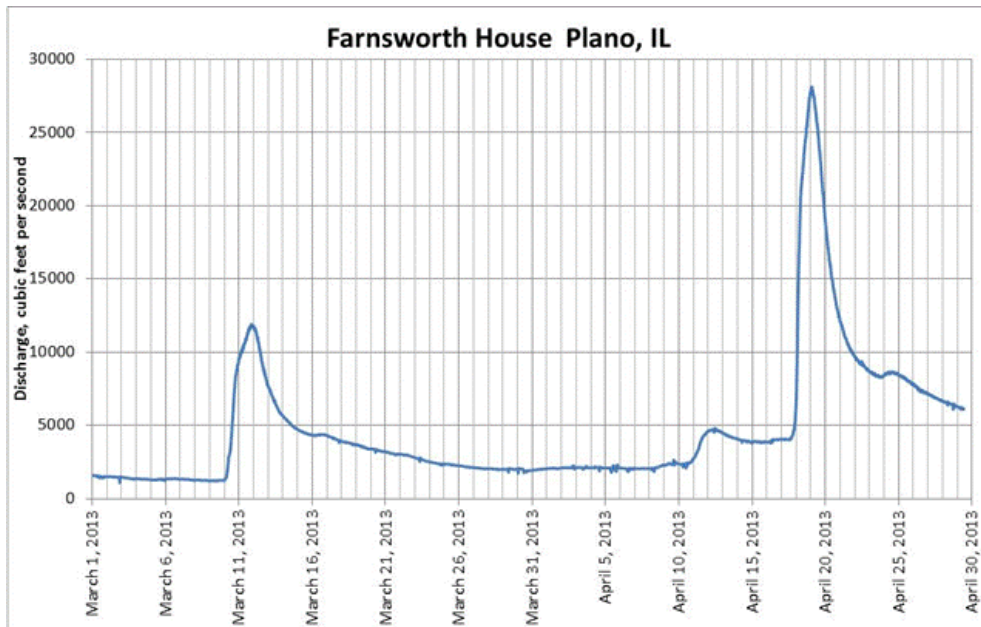


Figure I-4. Spring 2013 Hydrograph for USGS Gauge at Dayton, IL Downstream of Farnsworth House



**Figure I- 5. Spring 2013 Hydrograph for USGS Gauge at Montgomery, IL Upstream of Farnsworth House**



**Figure I- 6. Spring 2013 Hydrograph Estimated for Farnsworth House - Extrapolated from Upstream and Downstream Gauges**



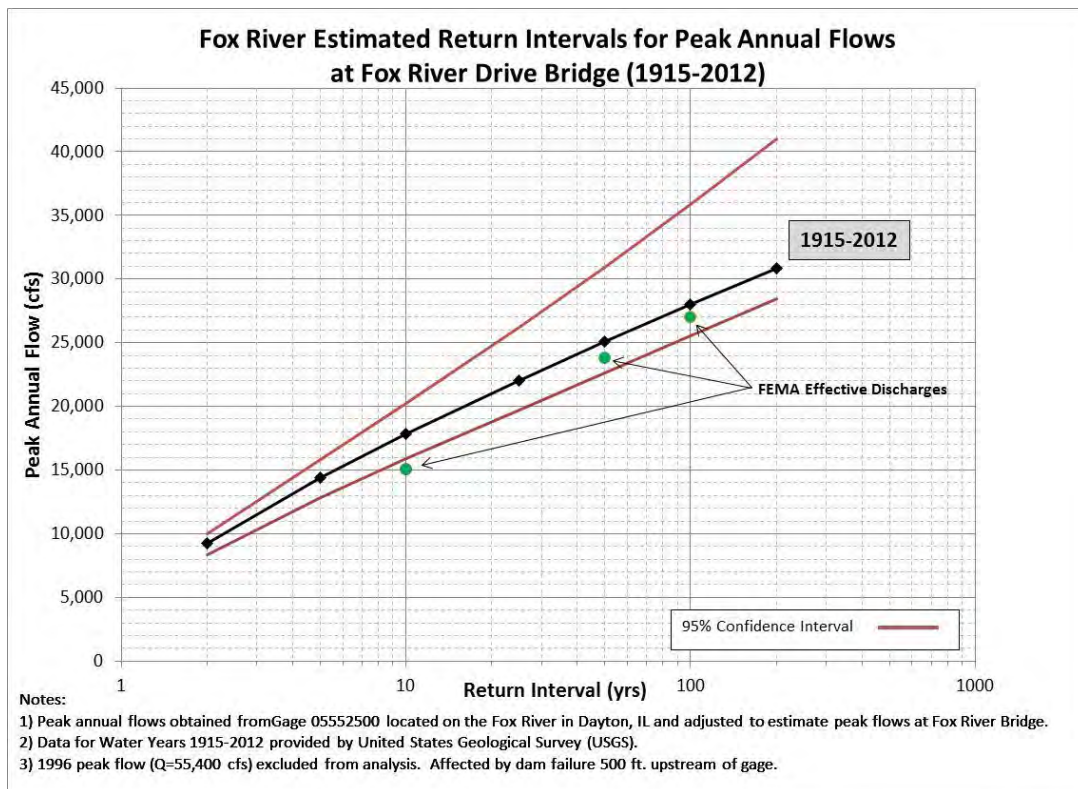
## 4.0 Hydrologic Analysis and Flood Risk Characterization

As a part of our research, WWE investigated stream gauges on the Fox River to determine data availability. There are more than a half-dozen stream gauges listed by the United States Geological Survey (USGS) within 40 miles upstream and downstream of the Farnsworth House. Unfortunately, many of these gauges have only recently been established or have periods of record that are too short to be useful in terms of statistical analysis. The most notable exception is the USGS Fox River gauge at Dayton, Illinois (Gauge No. 05552500). This gauge, which is located approximately 26 miles downstream of the Farnsworth House, has a period of record of nearly 100 years (1915 to present). WWE used the data from this gauge, adjusted for the Farnsworth House location to approximate flows near the Farnsworth House, and statistical analysis methods were used to analyze the long period of record of annual peak flows to evaluate changes in hydrology in time and to characterize current flood risk.

The Dayton gauge has a period of record of nearly 100 years, the longest period of record of all of the USGS gauges on the Fox River relevant to this study, thus the flows it has recorded are the most useful when determining flood flows for different recurrence intervals, i.e. flood event frequencies. There are several methods that can be implemented to determine the frequencies of flood events. One of the most widely used statistical methods is the Log Pearson Type III Method (Log Pearson Method) published in the USGS “Bulletin 17B of the Hydrology Subcommittee – Guidelines for Determining Flood Flow Frequency.” WWE applied the Log Pearson Method to Dayton gauge flow data for the entire period of record, 1915 to 2012. The three flood frequencies proved reasonable when compared to the published FEMA FIS flows. Because the Dayton gauge is approximately 26 miles downstream of the Farnsworth House, the flows obtained at the Dayton gauge would have to be adjusted to obtain flows for different events at the Farnsworth House. In order to accomplish this, an area adjustment was considered, wherein the ratio of the area draining to the Farnsworth House to the area draining to the Dayton gauge would be applied to the Dayton gauge flows. This method was first checked for reasonableness by applying the area adjustment method to the flood frequencies obtained from data recorded by USGS Gauge 05551540 on Fox River at Montgomery, which is approximately 15 miles upstream of the Farnsworth House, and comparing them to the Dayton gauge. When the drainage area ratio was applied to the flood frequencies estimated at the Montgomery gauge, the area-adjusted flows fell within 10 percent for each flood event at the Dayton gauge.

The flood frequencies calculated at the Dayton gauge were then adjusted to obtain flood frequencies at the Farnsworth House. The areas draining to the Dayton gauge and the Farnsworth House are approximately 2,640 square miles and 1,900 square miles, respectively, for an area adjustment of 0.72.

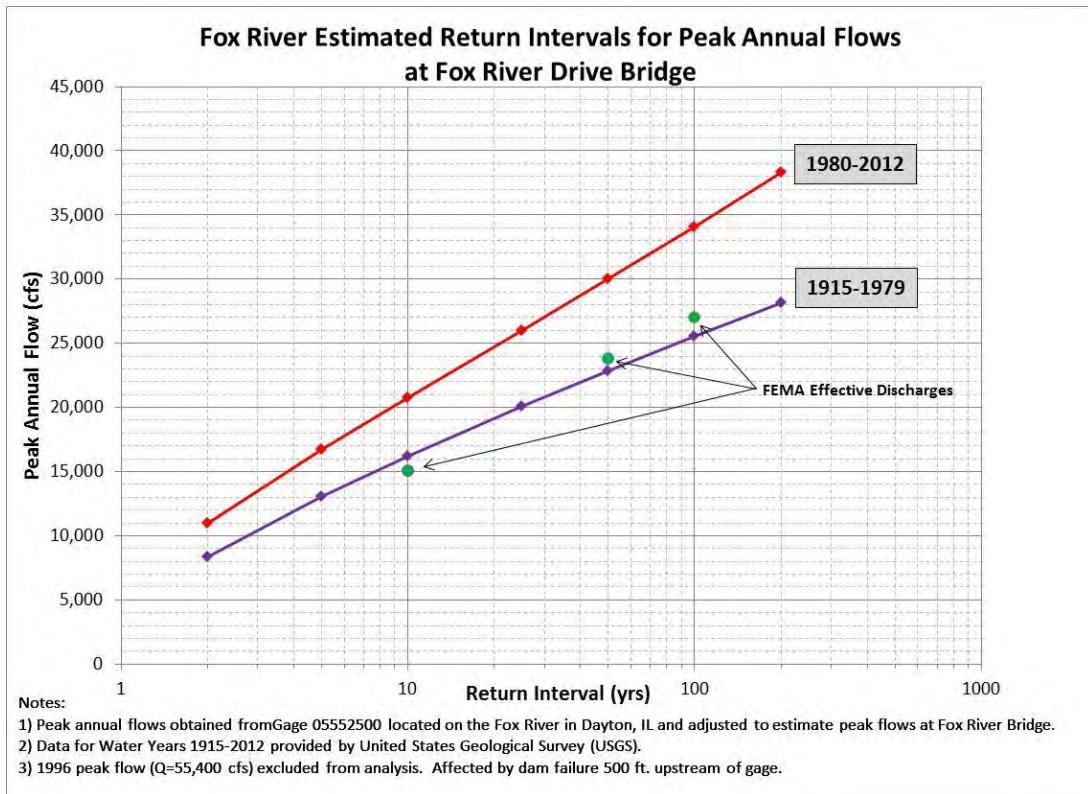
The area-adjustment method was applied to different periods of record within the entire 1915-2012 period of record for the Dayton gauge. Table I-2 shows flood frequency flows for five different time intervals. The period from 1915-1979 appears to most closely represent the flows one would expect to see published in the FEMA FIS. The period from 1980-2012 appear to more closely represent the observed flood flows at the Farnsworth House over the past few decades. The increase in urbanization in the watershed over the past thirty years supports higher flows seen in the 1980-2012 period of record. It is for this reason that these flows were used for the hydraulic analysis described in the next section.



**Figure I- 7. Log Pearson III Statistical Distribution of Peak Flow Data for the Fox River at the Farnsworth House (1915 – 2012)**

Figure I-7 shows the peak flows estimated for different flood events for the entire period of record with 95 percent confidence intervals. This graph demonstrates that flood flows at the Farnsworth House are greater than the flood flows estimated from the FEMA FIS. Although the flows for the entire period of record are greater than those estimated using the current FIS, an evaluation of flows for 1915-1979 and 1980-2012 was also conducted. The results of this analysis are shown in Figure I-8, which demonstrates an increase in flood flows for different recurrence intervals when comparing flood events that occurred prior to a spike in urbanization in the contributing watershed with those that occurred after upstream urbanization had occurred. There is also a marked increase flood flows

when comparing the entire period of record to 1980-2012. As is discussed in the Hydraulics Section (below), the more recent flood elevations observed at the Farnsworth House more closely compare with the flood flows estimated for 1980-2012 than any other period of record that was evaluated. Increased urbanization and observed flood flows and depths are the basis for using the flood frequencies estimated for 1980-2012 in this study, rather than using flows estimated from FEMA’s FIS.



**Figure I- 8. Log Pearson III Statistical Distribution of Peak Flow Data for the Fox River at the Farnsworth House - Comparison of 1915 – 1979 with 1980 – 2012**

**Table I-2. Comparison of Estimated Flood Flows for Range of Frequencies and Periods of Record Analyzed**

Flow at Fox River Drive Bridge (cfs)					
Return Interval (yrs)	1915-2012	1915-1949	1950-2012	1915-1979	1980-2012
2	9300	8100	10000	8400	11000
5	14400	12100	15700	13100	16700
10	17800	14300	19600	16200	20700
25	22000	16700	24800	20100	26000
50	25100	18200	28700	22800	30000
100	28000	19600	32600	25500	34100
200	30800	20700	36600	28100	38300
Max yearly peak flow (cfs)	34000	20900	34000	34000	31900

This hydrologic analysis shows that flow frequency has shifted to higher magnitude discharges over the past 30 or so years relative to those that were used to establish flood discharges in the FIS. The flood flows estimated for the years 1915 through 1979 most closely represent the flows published in the FIS. The changes in flows between those published in the FIS and the estimated flows calculated using the most recent 30-year period of record, show increases of 5,600 cubic feet per second (cfs) for the 10-year event, 6,200 cfs for the 50-year event and 7,100 cfs for the 100-year event. These changes are even more pronounced when compared to the period that Mies van der Rohe had available at the time he determined the finished floor elevation for the house. In fact, the maximum recorded flow between 1915 and 1949 is estimated at 20,900 cfs, a flow that would put the water surface elevation approximately 1 foot below the finished floor elevation of the Farnsworth House (assuming that the old Fox River Road Bridge and the new bridge would have had similar conveyance capacities). As a result of increased peak flows, the flood risk of the Farnsworth House and property has increased over time, and, as recent experiences have demonstrated, the property floods with greater frequency than it did historically.

## 5.0 Hydraulic Analysis

### 5.1 Hydraulic Modeling Background & Approach

To determine the effects of increased flood flows at the Farnsworth House and property, and understand the future level of protection that different mitigation alternatives will provide, a hydraulic analysis was conducted. The hydraulic analysis comprised of the following steps:

- Obtaining models from FEMA – The hydraulic models that support the flood flows and frequencies published in the FIS were requested from FEMA. The current floodplain hydraulic data were determined using the U.S. Army Corps of Engineers (USACE) Hydraulic Engineering Center Water Surface Profile Program (HEC-2). WWE received input and output printouts from the HEC-2 model that was used to determine water surface elevations for different flood events. The original HEC-2 model was not available. Receiving HEC-2 printouts from FEMA (rather than an updated model such as the USACE’s Hydraulic Engineering Center River Analysis System (HEC-RAS), which is now currently used instead of HEC-2) was evidence that a more current model has not been implemented to determine flood depths along the reach of the Fox River relevant to the Farnsworth House.
- Converting HEC-2 models to HEC-RAS models – WWE converted the data on the HEC-2 printouts to create cross sections in HEC-RAS. Flood flows, the Fox River Drive Bridge, bank stations, roughness coefficients, and other data used in the original HEC-2 model were input into the HEC-RAS model.
- Creating a Duplicate Effective Model – The HEC-RAS model prepared with the HEC-2 model data was adjusted so that 100-year water surface elevations were within at least six inches of the flood profile published in the FIS. The Duplicate Effective Model produced 100-year flood elevations to within 0.1 foot of the published water surface elevations. With differences in water surface elevations of 0.1 foot, the model could then be adjusted to reflect current conditions. This analysis would feed directly into future floodplain permitting if the NTHP decides to pursue mitigation alternatives identified below requiring floodplain permitting.
- Creating a Current Effective Model – The Duplicate Effective Model was adjusted to reflect current conditions at the site. The newly estimated peak flows (estimated from the 1980-2012 period of record) were input to the model. Flood elevations for the 2-year, 5-year, 25-year, 50-year, and 100-year flood events were determined. These flood elevations were compared to observed water surface elevations for past known events for reasonableness.
- Evaluating Newly Determined Flood Elevations – Current flood elevations (based on current conditions at the site and newly determined flood flows) were compared to key elevations at the Farnsworth House and with different flood mitigation alternatives to determine level of risk and potential levels of protection against future flooding.

The reach of the Fox River floodplain relevant to the Farnsworth House is an area that can be characterized with a Manning’s  $n$  (hydraulic roughness parameter) between 0.07 and 0.08, which is indicative of medium to dense brush with some trees in the winter and light brush and trees in the summer. The Manning’s  $n$  for the Fox River is about 0.035, which is described as a clean, straight river with no rifts or deep pools, but with some

stones and weeds. WWE did not modify the Manning's n values used in the FEMA study.

The Farnsworth House is located approximately 85 feet to the north of the top of the Fox River overbank. It is approximately 250 feet west of the Fox River Drive Bridge and 400 feet south of River Road, both of which are at significantly higher elevations than the Farnsworth House. Flood waters that encroach on the overbanks and surround the house are essentially "trapped" until they can be effectively discharged downstream beneath the Fox River Drive Bridge. These floodwaters are "trapped" because there is a lack of a direct flow path downstream, causing an "ineffective flow" condition on the overbanks upstream of the Fox River Bridge abutments. Additionally, The Fox River Drive Bridge acts as a constriction to flow due to its large abutments on each side of the river. This constriction to flow causes backwater to build up upstream of the bridge, eventually finding its way onto the property. In addition to the Fox River Drive Bridge, piers from the old bridge still remain in the floodway. These old piers do cause some backwater due to their approximate 10-foot width, but their overall effect is inconsequential.

## **5.2 Hydraulic Modeling Results**

Table I-3 presents key elevations of the Farnsworth property and flood elevations associated with different recurrence intervals, or flood events. The table shows how the key elevations at the Farnsworth House compare to the flood frequencies reported in the FIS and the flood frequencies determined with this study.

Based on WWE's analysis of the 1980 – 2012 gauge record, the Farnsworth House would be expected to be inundated with flood waters to a depth exceeding the finished floor elevation during the 20-year event or greater, or have a 5 percent chance of occurring in any given year. Although one might expect it to flood once every 20 years, it is important to note that even with an exceedance probability of 5 percent, flooding of the same magnitude might still occur two years in a row or even twice or more in the same year.

During the 25-year event, the depth of water in the house is estimated to be approximately 0.4 foot. During the 50-year, 100-year and 500-year events, the depths of water in the house will be approximately 1.3 feet, 2.2 feet, and just under 4.0 feet, respectively. With increased urbanization in the watershed, these depths may continue to increase, resulting in floodwaters entering the house more frequently and at greater depths.

The 10-year flood has a water surface elevation of 569.0 feet, just one foot below the finished floor elevation of the Farnsworth House. It is important to note that if, during a flood event, a tree or two along the northern bank of the Fox River were to be dislodged and trapped along the house, the boathouse or the property fence, along with the collection of debris and/or other items, the resulting effect could be higher water surface elevations at the Farnsworth House during a more frequent event. In other words, it is

possible that during a 10-year flood event, flood waters could rise above the finished floor elevation if this scenario were to occur.

As has been observed within the past decade, flood events occurring more frequently than the 2-year event will inundate the property surrounding the Farnsworth House. In fact, this study shows that one can expect the property itself (not the house) to experience flooding on at least an annual basis. The 2-year event results in a water surface elevation of approximately 566.0 feet, a flood depth of up to 2 feet above existing grade on the property, which is about a foot below the Farnsworth House patio. One could expect flood waters to rise above the patio once every five years on average, which is a twenty percent chance of occurring in any given year.

**Table I-3. Comparison of Key Elevations for Farnsworth House with FIS Flood Elevations & Flood Elevations from Statistical Analysis of 1980-2012 Period of Record**

Description	Site Elevations (feet)	FIS Flood Elevations (feet)	Flood Elevations from 1980-2012 Gauge Analysis (feet)
Typical River Elevation	558.0	--	--
Fox River North Bank	564.0	--	--
2-year Flood		--	566.0
Patio Elevation	567.0	--	--
5-Year Flood		--	567.9
10-year Flood		566.3	569.0
Finished Floor Elevation	570.0	--	--
25-year Flood		--	570.4
50-year Flood		568.7	571.3
100-year Flood		569.7	572.2

### 5.3 Mies van der Rohe’s Basis of Design for Finished Floor Elevation

In many ways, Mies van der Rohe was visionary in his recognition and planning for the inevitable flooding of the property. He recognized the flood risk and used the best available data at the time (anecdotal reports and high water marks) and added freeboard above the design flood elevation he used:

*Mies requested information from the Illinois State Water Survey concerning the highest flood stages of the Fox River. Informed that such records were not kept, he was advised to “interview old settlers in the vicinity.” He decided to set the top of the finished floor five feet above grade, two feet higher than the highest stage reported by old-timers.*

--Excerpt from *Mies van der Rohe: A Critical Biography*, New and Revised Edition, By Franz Schulze and Edward Windhorst, University of Chicago Press, 2012.

Other documentation reviewed during the site visit, including transcripts of oral history, indicated freeboard on the order of one foot.

Based on review of the hydrologic record, WWE believes that the event that Mies van der Rohe would have been told about by “old-timers” would have been the peak flow in 1948 estimated to be approximately 20,900 cfs by extrapolation from the Dayton gauge. Based on the hydrologic modeling, this would correspond to a water surface elevation of 568.8 feet, approximately 1 foot beneath the finished floor elevation of the house.

As experiences on the site and the hydrologic analysis above show, even the freeboard designed by Mies van der Rohe was inadequate to account for extreme events beyond what had been reported by “old-timers” and for increases resulting from urbanization in the watershed.



## **Section II**

# **Evaluation of Mitigation Strategies for the Farnsworth House**

## Executive Summary

Over the years, many alternatives have been suggested for reducing the flood risk of the Farnsworth House and property ranging from relocation of the house to construction of flood proofing measures to accepting a known flood risk and responding during flooding to minimize damage to the house and contents. With more frequent flooding in recent years and increases in flooding levels over the past several decades due to urbanization in the watershed, mitigating this flood risk is important for preservation of the Farnsworth House. Section II of this report summarizes WWE's evaluation of conceptual alternatives for decreasing flood risks to the Farnsworth House and grounds located at 14520 River Road in Plano, Illinois. The evaluation of alternatives is based on the hydrologic and hydraulic analyses and findings presented in Section I of this report (above).

Major findings of Section II include the following:

1. The report evaluates a range of alternatives, the more viable ones in greater depth than others. Many traditional flood proofing practices such as levees, flood walls and other barriers are not suitable for the Farnsworth House due to the need to preserve site and house aesthetics to the maximum extent practical and the fact that flood water elevations are more than 8 feet above the ground surface in the 100-year event, presenting structural challenges and the need for a very sturdy structural wall.
2. Of the alternatives evaluated, WWE believes that site practices, including clearing of debris and trees nearing collapse along the banks and tying the chain link fence along Fox River Road into the boat house rather than extending it to the river edge (as it currently is), will help with the potential for localized effects of debris collection during flooding, but the flooding of the house will not be alleviated in a meaningful way without more substantial work.
3. Channel dredging, modifications to the Fox River Road bridge abutments to reduce the constriction, and/or removal of the old abutments would lead to decreases in flood water surface elevations, but such improvements would likely reduce the 100-year water surface elevations by less than a foot and would be very costly, as well as difficult and expensive to obtain permits to conduct the work. Further, periodic future channel dredging would be required to maintain the channel slope as sediment naturally deposits. For these reasons, this is not a recommended alternative.
4. The alternative of raising the house, along with the ground surrounding the house within the flood fringe, i.e. outside of the regulatory floodway, but inside the 100-year floodplain, (to maintain perspective) is worth further consideration. Based on the 1980 – 2012 portion of the gauge record, the house would need to be elevated by 1.0, 2.0, or 3.0 feet to raise the finished floor elevation *one foot above* the flood elevations for the 25-year, 50-year and 100-year events, respectively.

5. There are contractors in Illinois who have experience performing work to elevate flood prone structures. A list provided by IDNR is provided in Appendix E. While raising the house may be expensive, it would be far more affordable and would achieve greater benefits than the other alternatives evaluated. Based on initial discussions and observations on the site, the floodplain permitting for such work should be fairly straightforward as long as no fill is placed in the floodway.

# Evaluation of Mitigation Strategies for the Farnsworth House

---

## 1.0 Evaluation of Flood Risk Mitigation Alternatives

Over the years, many alternatives have been suggested for reducing the flood risk of the Farnsworth House and property ranging from relocation of the house to construction of flood proofing measures to accepting a known flood risk and responding during flooding to minimize damage to the house and contents<sup>5</sup>. With more frequent flooding in recent years and increases in flooding levels over the past several decades due to urbanization in the watershed, mitigating this flood risk is important for preservation of the Farnsworth House. The following sections describe alternatives that have been considered for flood risk mitigation for the site. Some alternatives are quickly dismissed on the basis of aesthetics and/or costs. The most viable alternatives are discussed in greater detail. The evaluation of alternatives is based on the hydrologic and hydraulic analyses and findings presented in Section I of this report (above).

### 1.1 Do Nothing

This alternative involves living with the existing flood risk at the Farnsworth House. The area surrounding the house would be expected to be flooded to a point that would limit access on an annual basis, as has recently been experienced. Flooding to the finished floor elevation or above would be expected to occur with an annual exceedance probability of 5%, corresponding to a 20-year return frequency. As noted above, flood insurance premiums will escalate, and the amount of coverage may be limited for ongoing repetitive losses. The flooding is of particular concern when it reaches the finished floor elevation because the cost of flood damages and clean up escalates dramatically. If a “do nothing” alternative were adopted, this would be expected to occur on average roughly once every 20 years (but could happen twice in one year or two years in a row). As urbanization continues in the watershed, it is likely that peak flood flows will increase in frequency. Repeated flooding causes the need for repair/restoration and additional maintenance and is costly. A 100-year flood of 34,100 cfs would be projected to have a water surface depth of approximately 2 feet above the finished floor elevation under existing conditions. Future urbanization would increase this value.

---

<sup>5</sup> Landmarks Illinois, Flood Mitigation to limit future flood damage at the Farnsworth House, undated flyer from review of files at Farnsworth House. From review of documents, it appears the Landmarks Illinois and the operators of the Farnsworth House were at some time in the 2000s considering a “design competition” to evaluate potential flood risk reduction strategies. We were unable to determine if such an event was ever actually held.

## **1.2 Relocate House**

Based on review of documents provided by the site staff during our visit and background research, we understand that relocating the house to a new location outside of the floodplain (in some scenarios off of the property entirely) has been considered at a preliminary planning level by local floodplain regulators<sup>6</sup>. A significant disadvantage of this alternative is that it would remove the house from the landscape for which it was designed and would not preserve the relationship between the house and its surroundings and other architectural intentions.

## **1.3 Channel Improvements**

The Fox River Road Bridge was constructed just downstream of the Farnsworth House in 1967, after a prolonged legal battle. The construction of the bridge and abutments predates the NFIP. Based on the water surface profile in the FEMA Flood Insurance Study (FIS), it appears that this bridge has a relatively small backwater effect, on the order of 0.5 to 1.0 feet. Piers from the old bridge still remain downstream of the new bridge and are accounted for in the regulatory hydraulic model. Siltation in the river over many years upstream of the bridge also has likely reduced channel discharge capacity. Conceptual modeling indicates that water surface elevations in the 100-year flood event could be brought down by approximately 0.5 to 1.0 foot if the channel were dredged to increase the slope of the channel over a several thousand-foot distance, old abutments were removed and existing bridge abutments were modified to reduce the constriction effect. Currently abutments slope down to the water surface. Cross sectional area could be increased if abutments were cut back to vertical; however, this would likely require major structural improvements to provide the support required for the bridge. These improvements would likely cost millions of dollars and would require extensive regulatory coordination and permitting. The Cost-Benefit ratio of channel improvements as a flood risk reduction measure is too high for this to be considered as a viable alternative.

## **1.4 Channel Maintenance**

From the April 1, 2013 site visit, it is clear that the grounds are well maintained. For a forested riparian corridor, the amount of debris in the understory with the potential to create obstructions to back up water in localized areas is not excessive. It appears that the forest is well managed. During the site visit, WWE noted that bank erosion is occurring along the north bank of the Fox River along the reach upstream of the property. Undercutting of banks has caused some trees to lean. Removing these trees by flush cutting the stump to the ground and leaving the roots in place to help stabilize the bank would be helpful in decreasing hazards during flooding. If these trees were to fall into the flow during a flood event they could become lodged on the property or at the bridge,

---

<sup>6</sup> Kendal County Multi-Hazard Mitigation Plan, January 26, 2011. Prepared by Department of Geology, Southern Illinois University and the Polis Center for Kendall County Sheriff's Office.

contributing to backwater. Additional bank stabilization measures could be considered if it appears that the banks are migrating toward the house over time.

Realigning the fence that runs along the west boundary of the property between the boathouse and Fox River Road would also help to decrease hazards during flooding. If the fence were turned to the east and connected to the north end of the boathouse, it would still serve the purpose of restricting access from that side of the property; however, the potential for the fence to trap debris and cause water to back up would be reduced.

Continued diligent maintenance of debris, fallen trees, etc. in the floodplain is recommended as well as clearing of leaning trees along the bank to help with the potential for localized effects of debris during flooding. Realignment of the fence would be a low cost improvement; however, the effects of these maintenance practices would generally be small relative to the flood depths affecting the house.

## **1.5 Floodwall and Levee Protection**

The goals of preserving the Farnsworth House for its architectural, historical and cultural values on the property where Mies van der Rohe intended for it to stand are contrary to erecting a floodwall or levee to separate the house from the surrounding environment. Even if the house were not a significant historical structure, this strategy would not be recommended for many reasons including difficulty of permitting, costs and necessary height of the floodwall relative to the finished floor elevation and ground elevation 6 feet below.

In some applications, “hidden” flood walls can be installed that can be raised manually and/or mechanically/pneumatically. These systems are expensive. While these systems sound good in theory, in a large flood event, there are many things that can go wrong, and only one malfunctioning segment of a floodwall is needed for the whole system to be ineffective. These systems require maintenance and often require manual labor to fully set the barriers up. Given that there is only a handful of NTHP staff at the Farnsworth House, this is not a practical alternative.

## **1.6 Elevation**

Elevating the Farnsworth House is an alternative that has been considered in the past. One of the shortcomings of simply raising the structure and patio by several feet is that the perspective of the house relative to the ground would shift. This would alter the view from within the house, and would also require an additional step or ramp on the exterior. Raising the house also would expose more of the “umbilical” cord of utilities that runs into the house. With the current perspective between the ground and the bottom of the house, this utility trunk line is concealed and can be mistaken for a tree trunk when looking toward the house from the top of the river bank. For these reasons, simply elevating the house is not an ideal solution.

As an alternative, the house and the surrounding ground (outside of the floodway) could both be raised by equivalent amounts. Table II-1 provides elevations that would be required to achieve one foot of freeboard above model water surface elevations for various return frequencies. This would present some challenges relative to the utility trunk line, which would have to be extended and reconnected. Fill would be placed in the flood fringe area to raise the ground, which can legally be accomplished with proper floodplain and other permitting (county grading permits and stormwater permits would likely be required in addition to a floodplain permit). Floodplain permitting through FEMA and IDNR may be required; however, if the floodway can be avoided, permitting may only be required through the county. This is not an “active” conveyance portion of the floodplain, so the placement of fill within the flood fringe would not have a measurable effect on neighboring properties. While this would help maintain the external perspective with the immediate surroundings, the perspective from the interior looking out would be shifted. Additionally, elevating the house above the effective 100-year water surface elevation would bring a reduction in insurance premiums compared to the costs associated with being a repetitive loss structure at the current elevation.

**Table II-1. Additional Elevation Needed to Provide One (1) Foot of Freeboard above Flood Water Surface Elevations based on 1980 – 2013 Gauge Analysis**

Flood Recurrence Interval	Flood Water Surface Elevation (1980 -2013 gauge analysis) (feet)	Depth of Flooding Relative to Existing Finished Floor Elevation (FFE)	Additional elevation needed to provide 1-foot of freeboard for design event (feet)
10-year (AEP = 10%)	569.0	1.0 foot below	0.0
25-year (AEP = 4%)	570.4	0.4 foot above	1.4
50-year (AEP = 2%)	571.3	1.3 feet above	2.3
100-year (AEP = 1%)	572.2	2.2 feet above	3.2
500-year (AEP = 0.2%)	573.9	3.9 feet above	4.9

Major cost components for this alternative would be the elevation of the historic structure, fill to elevate the surrounding ground surface, utility reconnection, revegetation and landscaping. The costs would tend to be higher for greater elevation/greater risk reduction.

If fill were extended to the east of the house to the bank of the drainage ditch between the house and access road, it could be graded to provide a mild slope from the house toward the drainage ditch to eliminate nuisance ponding on the north side of the house. NTHP

could also consider elevating the access road and providing a culvert beneath draining from the east to the west to improve access during shallow flooding events and to address nuisance ponding of water to the east of the access road (see Photograph 13 in Appendix B). It is likely that this could all be encompassed in the same floodplain permit application.

## 2.0 Regulatory Contacts

As a part of WWE's analysis, we contacted Mr. Brian Eber of the Statewide Floodplain Programs/National Flood Insurance Program of the Illinois Department of Natural Resources, Office of Water Resources. Brian is a long-term contact of WWE and is a Certified Floodplain Manager (CFM). Brian was well aware of the floodplain issues at the Farnsworth House, and provided valuable information on potential mitigation strategies and floodplain permitting that may be required. To the extent that modifications associated with mitigation avoid the floodway and are confined only to the flood fringe area, floodplain permitting may be simplified and may be handled at the county level, which would decrease permitting time and costs. Mr. Eber also indicated that there are some special conditions that may apply to historic structures that also may provide greater flexibility with floodplain permitting to the extent it is needed for mitigation.

WWE also consulted with adjunct NFIP expert Bill DeGroot, P.E.<sup>7</sup>. Based on the documentation provided by the NTHP staff, the Farnsworth House is considered a repetitive loss property by FEMA. The NTHP has a flood insurance policy for the site, and in past flooding events, there have been claims from flood damage that has occurred. Congress has recently taken action to more closely align flood insurance premiums with actuarial costs. For many years, flood insurance rates have been subsidized. As a repetitive loss property, the Farnsworth House falls into the category that will see the most immediate increases in premiums, starting October 1, 2013, with 25% annual increases in premiums until rates are aligned with actuarial insurance costs. This provides additional motivation to reduce the flood risk for the Farnsworth House and property.

## 3.0 Potential Next Steps

WWE looks forward to feedback from the NTHP on the analyses described in this report, and we would enjoy the opportunity to further discuss and brainstorm strengths and weaknesses of the various flood risk mitigation strategies discussed above. There are a number of actions, including management of fallen trees along the banks and in the floodplain and modifications to the chain link fence between the boathouse and Fox

---

<sup>7</sup> Mr. DeGroot has been Manager, Floodplain Management Program for the Urban Drainage and Flood Control District (UDFCD) in Denver for approximately 39 years and manages the FEMA floodplain map revision program throughout the metropolitan Denver area. He has been involved in national floodplain policy for most of his career.



River Road that will reduce the potential for debris to cause blockage and localized increases in flood elevations. These mitigation strategies are prudent but generally will have relatively small benefits in terms of lowering flood risk. Based on review of more substantial alternatives, including bridge modifications, channel dredging and site modifications, it seems that the alternative of raising the house (and ground surrounding the house to maintain perspective) is likely the most cost effective alternative with potential to significantly reduce flood risk for the house. We believe that floodplain permitting for this alternative, including fill in the flood fringe, is feasible and would likely be straightforward.

Ideally, it would be desirable to preserve the Farnsworth House “as is” without modifying the finished floor elevation or other elevations on the property; however, there are substantial flood risks if a “do nothing” alternative is selected. Considering that the 500-year flood is estimated to have a magnitude of approximately 44,000 cfs, with a water surface elevation about 4 feet above the existing finished floor, and the fact that the Fox River Watershed will likely continue to urbanize for the foreseeable future (it is in no way “built out”), adopting the “do nothing” alternative could lead to eventual devastation of the house in a large flood to the point it would need to be substantially reconstructed.

A critical decision relative to the elevation alternative for the NTHP to consider is how much additional elevation to provide. Obviously, the more the structure is elevated, the more flood risk will be reduced. However, the need to preserve the architectural and landscape context of the house would limit the extent to which elevation would be acceptable from an aesthetic standpoint. Working with the NTHP and/or a landscape architecture firm, it would be possible to prepare renderings simulating the appearance of the house and surroundings for different elevations that may be considered. We could also work with the list of contractors provided by IDNR to develop cost estimates for different elevation scenarios.

WWE looks forward to feedback from the NTHP and further discussions and refinement of mitigation strategies that are best suited for the site.

**Appendix A. Summary of Project Team Water Engineering Experience at Cultural and Archaeological Sites & Resumes of Selected Team Members**

## **Summary of Project Team Water Engineering Experience at Cultural and Archaeological Sites**

1. Machu Picchu Paleohydrology and Water Engineering—Kenneth Wright, P.E. and colleagues at WWE have been studying water engineering at Machu Picchu for more than 20 years. Studies at Machu Picchu have included identification and documentation of the water supply source and infrastructure including stone-lined canals and sculpted fountains, evaluation of terrace engineering and stability, documentation of construction methods and unfinished construction, mapping and assessment of trails and other related work. Building on the success of the work at Machu Picchu, WWE and the Wright Paleohydrological Institute (WPI) have evaluated additional Inca sites in the Sacred Valley including Tipon, Moray, Sachsaywaman and most recently Ollantaytambo.
2. Mesa Verde Paleohydrology and Post-Fire Runoff Assessment and Management- - Since the 1990s, WWE and WPI have conducted Paleohydrological research at Mesa Verde National Park, working with the National Park Service to study and document four ancient water supply reservoirs and a cistern constructed by the ancestral Puebloans through surveying, sediment stratigraphy, palynology, hydrologic and hydraulic analysis and other methods. In addition to this paleohydrology work, WWE performed work for the National Park Service following the 2000 Bircher Wildfire, including assessment of elevated runoff potential due to the fire and recommendations for mitigation of adverse effects to archaeological sites in the burn area.
3. Phnom Bakheng Drainage and Erosion Control, Angkor Archaeological Park, Cambodia—Since 2011 WWE has worked as a consultant to the World Monuments Fund (WMF) evaluating drainage and erosion issues at Phnom Bakheng, one of the earliest sites within the Angkor Archaeological Park. Phnom Bakheng is a UNESCO World Heritage Site. WMF is working closely with Authority for Protection and Management of Angkor and the Region of Siem Reap (APSARA) on a project to restore the temple at Phnom Bakheng, which has deteriorated over the centuries. WWE has supported WMF with analysis of drainage, drainage planning/engineering and evaluation of erosion.
4. Wat Chaiwatthanaram, Ayutthaya, Thailand—WWE is currently working as a consultant to WMF on flood protection issues for Wat Chaiwatthanaram, a 17<sup>th</sup> Century Buddhist Temple in Ayutthaya, Thailand, an historic city which was the second capital of Siam. WMF is working closely with the Thai Department of Fine Arts and the United States Embassy in Thailand on this project, which officially started in 2012. The site was severely flooded in 2011, when a record monsoon caused extensive flooding on the Chao Phraya River. Currently WWE is assisting with engineering of a floodwall to improve flood protection for this UNESCO World Heritage Site.
5. Nanyue Palace Water Management, Guangzhou, China—In 2011, WWE and WPI assisted WMF with a consultation on water management issues at this 2000-year old site in the heart of the metropolis of Guangzhou, China. The archaeological site, rediscovered near the city center in the 1970's includes what is believed to be the

earliest discovered Chinese water garden as well as palace ruins. WVE provided consultation on groundwater and surface water management issues on the site.

## **Appendix B. Photographic Log of April 1, 2013 Site Visit**

## Farnsworth House Field Visit Conducted by WWE – April 1, 2013



Photo 1. Farnsworth House facing north. Photo taken from top of Fox River bank.



Photo 2. Farnsworth House facing west.



Photo 3. Farnsworth House facing east.



Photo 4. Fox River facing south. Photo taken from patio.



## Farnsworth House Field Visit Conducted by WWE – April 1, 2013



Photo 5. Fox River Drive Bridge facing west and Fox River overbanks in front of Farnsworth House.



Photo 6. Fox River Drive Bridge right abutment.



Photo 7. Fox River Drive Bridge left abutment.



Photo 8. Fox River Drive Bridge with a view of one of two abutments remaining from the old bridge.



## Farnsworth House Field Visit Conducted by WWE – April 1, 2013



Photo 9. Farnsworth House elevated several feet above existing grade. Photo taken facing north.



Photo 10. Close-up photo of Farnsworth House elevated several feet above existing grade.



Photo 11. Photo of one of several steel I-beams that “suspend” Farnsworth House above ground.



Photo 12. Evidence of water damage to underside of Farnsworth House.



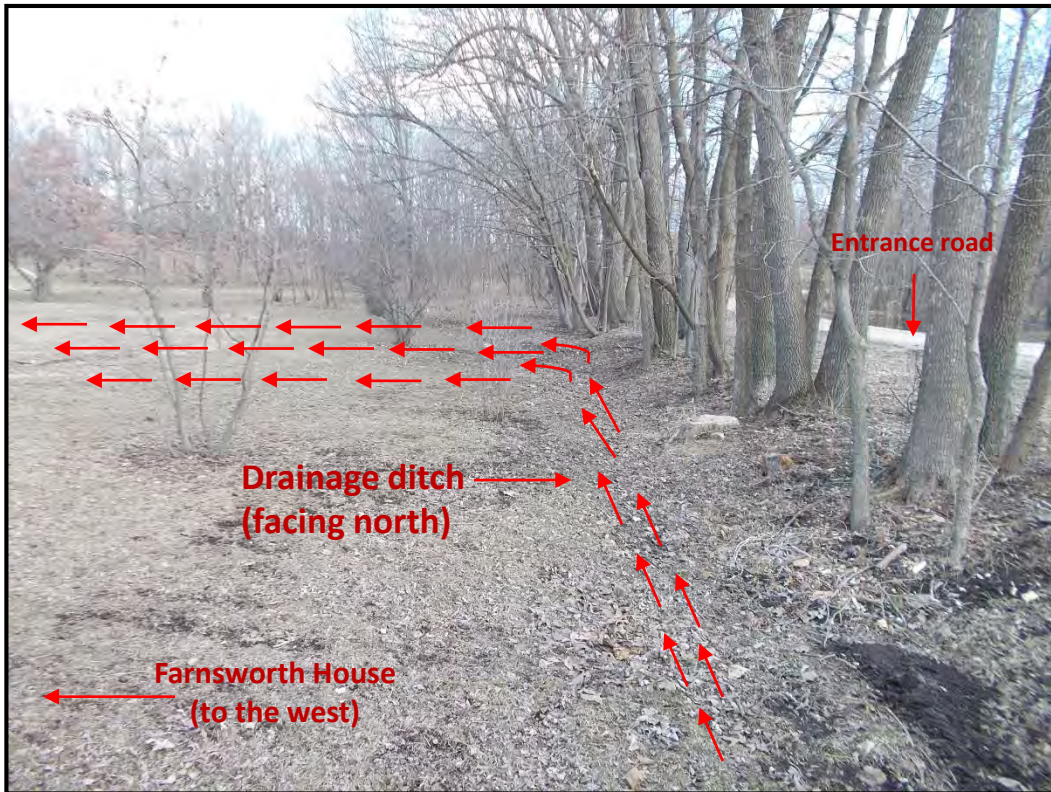


Photo 13. Looking north at drainage ditch that serves as a conveyance path for floodwaters as Fox River rises.



Photo 14. Looking east at drainage ditch on east side of Farnsworth lawn that serves as a conveyance path for flood waters as Fox River rises.

**Appendix C. Photographic Log of Spring 2013 Flooding (provided by NTHP  
Farnsworth House staff)**



# Appendix B. Photographic Log of Spring 2013 Flooding (provided by NTHP Farnsworth House site staff)



Photo 1. March 11, 2013.



Photo 2. March 11, 2013.



Photo 3. March 11, 2013.



Photo 4. March 12, 2013.



# Appendix B. Photographic Log of Spring 2013 Flooding (provided by NTHP Farnsworth House site staff)



Photo 5. March 12, 2013.



Photo 6. March 12, 2013.



Photo 7. March 12, 2013.



Photo 8. April 18, 2013.

# Appendix B. Photographic Log of Spring 2013 Flooding (provided by NTHP Farnsworth House site staff)



Photo 9. April 18, 2013.



Photo 10. April 18, 2013.



Photo 11. April 18, 2013.



Photo 12. April 18, 2013.



Appendix B. Photographic Log of Spring 2013 Flooding  
(provided by NTHP Farnsworth House site staff)



Photo 13. April 18, 2013.



Photo 14. April 18, 2013.



Photo 15. April 18, 2013.



Photo 16. April 18, 2013.

**Appendix D. Photographic Log of Historical Flooding (provided by NTHP  
Farnsworth House staff)**

# Appendix C. Photographic Log of Historical Flooding (provided by NTHP Farnsworth House site staff)



Photo 1. 1949.



Photo 2. 1970.



Photo 3. 1970.



Photo 4. 1970.



# Appendix C. Photographic Log of Historical Flooding (provided by NTHP Farnsworth House site staff)



Photo 5. 1996.



Photo 6. 2004.



Photo 7. 2004.



Photo 8. 2004.

## Appendix C. Photographic Log of Historical Flooding (provided by NTHP Farnsworth House site staff)



Photo 9. 2004.



Photo 10. 2004.



Photo 11. 2004.



Photo 12. 2004.



## Appendix C. Photographic Log of Historical Flooding (provided by NTHP Farnsworth House site staff)



Photo 13. 2004.



Photo14. 2004.



Photo 15. 2004.



Photo 16. 2004.

# Appendix C. Photographic Log of Historical Flooding (provided by NTHP Farnsworth House site staff)



Photo 17. 2004.



Photo 18. June 13, 2004.



Photo 19. June 13, 2004.



Photo 20. June 13, 2004.



## Appendix C. Photographic Log of Historical Flooding (provided by NTHP Farnsworth House site staff)



Photo 21. September 26, 2004.



Photo 22. September 26, 2004.



Photo 23. September 26, 2004.



Photo 24. August 25, 2007.

## Appendix C. Photographic Log of Historical Flooding (provided by NTHP Farnsworth House site staff)



Photo 25. August 25, 2007.



Photo 26. August 25, 2007.

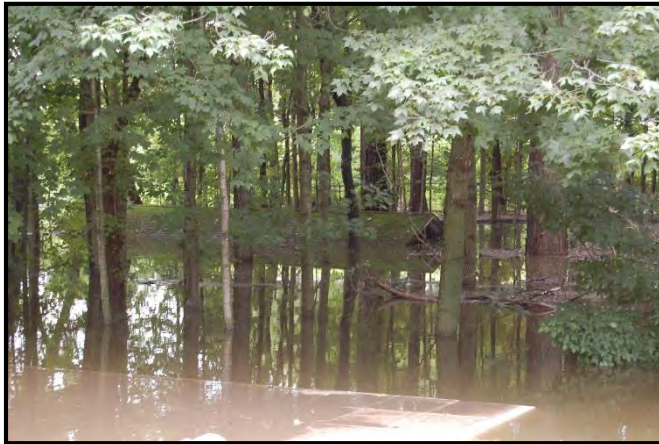


Photo 27. August 25, 2007.



Photo 28. August 25, 2007.



## Appendix C. Photographic Log of Historical Flooding (provided by NTHP Farnsworth House site staff)



Photo 29. August 25, 2007.



Photo 30. August 25, 2007.



Photo 31. August 25, 2007.



Photo 32. August 25, 2007.



## Appendix C. Photographic Log of Historical Flooding (provided by NTHP Farnsworth House site staff)



Photo 33. August 26, 2007.



Photo 34. August 26, 2007.



Photo 35. August 26, 2007.



Photo 36. August 26, 2007.



## Appendix C. Photographic Log of Historical Flooding (provided by NTHP Farnsworth House site staff)



Photo 37. August 27, 2007.



Photo 38. August 27, 2007.



Photo 39. August 27, 2007.



Photo 40. August 27, 2007.



## Appendix C. Photographic Log of Historical Flooding (provided by NTHP Farnsworth House site staff)



Photo 41. August 2007.



Photo 42. August 2007.



Photo 43. August 2007.



Photo 44. August 2007.

## Appendix C. Photographic Log of Historical Flooding (provided by NTHP Farnsworth House site staff)



Photo 45. February 22, 2008.



Photo 46. February 22, 2008.



Photo 47. September 14, 2008.



Photo 48. September 14, 2008.



## Appendix C. Photographic Log of Historical Flooding (provided by NTHP Farnsworth House site staff)



Photo 49. March 8, 2009.



Photo 50. March 8, 2009.



Photo 51. September 14, 2008.



Photo 52. September 14, 2008.



# Appendix C. Photographic Log of Historical Flooding (provided by NTHP Farnsworth House site staff)



Photo 53. July 25, 2010.



Photo 54. July 25, 2010.



Photo 55. July 25, 2010.



Photo 56. July 25, 2010.

**Appendix E. Home Moving and Excavation Contractors (List of contractors  
with past experience provided by IDNR)**



# Home Moving and Elevation Contractors

**1 Peters House  
& Building Movers**

R.R. #1 Box 114  
Farmer City, IL 61842  
(309) 928-2532

**2. MCE Home Movers**

1637 East 800 North Rd.  
Loda, IL 60948  
[mcemoving@yahoo.com](mailto:mcemoving@yahoo.com)  
217-379-2955 – office  
217- 519-0244 – cell

**3. Lyle Hyatt and Company  
House Movers**

612 Green Street  
Sandwich, IL  
815-786-6591

**4. Balagna House Moving, Inc.**

21529 E. Illinois Highway 116  
Farmington, IL 61531  
(309) 245-4486

**5. Greene County Steel**

Eldred, IL 62027  
(618) 576-9730

**6. Louvier's Construction Inc.**

1038 Urna Drive  
St. Louis, MO 63301  
(636) 250-3189  
\*elevation only

**7. Expert House Movers**

7144 Pershing Avenue  
St. Louis, MO 63130  
(314) 727-2722  
Or  
(800) 305-8939



□ *This list includes contractors who have done ICC elevation projects in the past. It is not a complete list and does not imply an endorsement by the State of Illinois. Consult your phonebook for local contractors.*

**Appendix F. CD-ROM with Hydraulic Model Files and Documentation  
(included with hard copy report only)**