Contract Report 584

Determination of 100-Year Ground-Water Flood Danger Zones for the Havana and Bath Areas, Mason County, Illinois

by Adrian P. Visocky
Office of Ground-Water Resources Evaluation and Management

Prepared for the
Illinois Emergency Management Agency

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Illinois State Water Survey
Hydrology Division
Champaign, Illinois

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by

Adrian P. Visocky, Senior Hydrologist

INTRODUCTION

Severe ground-water flooding occurred in portions of Mason County during Fall 1993, commencing on Labor Day weekend and continuing for several months. Noticeable areas of ponding, primarily in rural areas, remained even in early Spring 1994. Record-setting precipitation in much of the state during 1993, coupled with high stages in the Illinois River, contributed to a nearly continuous rise in ground-water levels, eventually peaking in September. Many topographic depressions intersecting the water table filled, often beyond capacity, and the water eventually spilled over onto roadways and into ditches. In other cases, when the rising water table intersected sloping ground, ground-water seepage surfaces appeared, and ground water ran overland to lower elevations. Numerous basements in the Havana and Bath areas were reported to have filled as the water table rose above the levels of basement floors and sump systems were unable to keep up. Severe structural damage occurred in houses where sump systems were operating and creating inward hydraulic gradients outside basement walls and floors.

In response to the flood damage, the Federal Emergency Management Agency (FEMA) negotiated for buyouts of some of the flooded homes in which basement foundations were damaged by the hydraulic pressure of the rising water table. In order to make sound judgments in addressing damage claims related to the flooding of 1993 and in formulating flood management plans for the future at Havana and Bath, FEMA and its state counterpart, the Illinois Emergency Management Agency (IEMA), sought information from the Illinois State Water Survey concerning the frequencies of ground-water flooding and the locations of ground-water flood-prone areas. Specifically, they requested maps that indicated areas subject to ground-water flooding at a frequency of 1 percent, that is, a 100-year event.

ACKNOWLEDGMENTS

Many individuals contributed to the production of the map products that are the focus of this report. The author used information from potentiometric surface maps prepared by Ellis W. Sanderson and Andrew G. Buck in their concurrent study of irrigation effects for the Imperial Valley Water Authority and the Illinois Department of Transportation-Division of Water Resources (IDOT-DWR). Mark A. Anliker, Andrew G. Buck, Curtis R. Benson, Scott C. Meyer, and Robert D. Olson conducted the mass measurements of water levels that made the potentiometric surface maps for that project possible. Without the information gathered during that study, especially the data collected during the flood period, the present study would have been virtually impossible.

The author is indebted to Stephen L. Burch for planning and leading the surveying portion of the study, which used Global Positioning System (GPS) equipment to determine measuring point elevations of selected observation wells. Mr. Burch also trained the author to use the GPS equipment so he could assist in the surveying. Kenneth J. Hlinka also assisted with the surveying. After the measuring point elevations were thus determined, Mr. Buck incorporated these corrected data points in the database and mapping model for his own study, so he could revise the potentiometric surface maps he had previously prepared.

Precision of the map products for this study was also contingent upon the availability of detailed, high-quality orthophoto maps of the Havana and Bath areas. Aero-Metric Engineering of Sheboygan, Wisconsin, provided outstanding services and delivered excellent quality orthophoto maps for use in the study. The author is grateful not only for the quality of their work, but also for the promptness with which they delivered the maps.

James R. Angel provided precipitation data for use in the statistical analysis of the study area. H. Vernon Knapp combined the precipitation, Illinois River, and ground-water-level data and performed predictive model and frequency analyses to generate vital 100-year ground-water stage information, the basis for the map products.

The Geographical Information System (GIS) map products were completed under the supervision of Robert A. Sinclair to whom the author is indebted for his many helpful suggestions. Kingsley M. Allan, Scott D. Maddux, and Mark A. Varner generated the preliminary maps. Sean V. Sinclair contributed significantly to the maps by digitizing the flood-danger zones, optically scanning the aerial photos to provide GIS coverages for the physical features, and completing the final version of the maps.

Pamela S. Lovett provided word processing for the camera-ready copy of this report. Linda J. Hascall and David L. Cox prepared the graphics, and Eva C. Kingston edited the report.

STUDY APPROACH

The study approach focused on five activities:

1. Determining the well-head elevations at approximately 75 selected observation wells, and revising existing potentiometric surface maps in primary study areas around Havana and Bath.

2. Performing statistical analyses to determine the recurrence interval for the 1993 ground-water flood event for the Havana and Bath areas and determining the 100-year potentiometric surface configuration.

3. Developing detailed, high-quality orthophoto maps (at a scale of 1 inch = 200 feet and a contour interval of 2 feet) and digitizing aerial photos.

4. Mapping 100-year surface flood-danger zones and 100-year basement flood-danger zones in the primary study areas.

5. Generating final map products from various GIS coverages.

While ground-water flooding occurred throughout much of western Mason County during Fall 1993, the primary study areas of interest to the sponsor were centered on the flooded region in the immediate vicinity of Havana (14.5 square miles or sq mi) and Bath (1.8 sq mi), as outlined on the U.S. Geological Survey (USGS) topographic maps shown in figure 1 and figure 2.

A summary of the five activities outlined above is presented in the following sections: Observation Well Network, Statistical Analysis, Orthophoto Maps, 100-Year Flood-Danger Zone Mapping, and GIS Map Products.

OBSERVATION WELL NETWORK

The Illinois State Water Survey has recently concluded a study of ground-water levels in the Havana lowlands region (Sanderson and Buck, 1995) that was in progress at the time of the Fall 1993 flooding. Sponsored by the Imperial Valley Water Authority and IDOT-DWR, the study focused on two mass measurements of ground-water levels in a network of 290 wells that had been established in the irrigated area of Mason and southern Tazewell Counties. Mass measurements had been conducted in Fall 1992 and Spring 1993 to indicate the impact of seasonal irrigation pumpage and recovery of ground-water levels. Potentiometric surface maps were then constructed from the two sets of water-level data. Because of the much-above-normal rainfall during 1993 and the onset of ground-water flooding over the Labor Day weekend, an additional mass measurement was conducted in late September 1993 to document this historical event for future use in resource and land use planning. The decision to conduct that measurement ultimately proved to be critical for the present study.

Water-level information collected during the three mass measurements for the Imperial Valley Water Authority and IDOT-DWR consisted of depth-to-water readings from some defined measuring point such as a mark on a pump base. Depth readings were converted to approximate water-level elevations by subtracting the water levels from the estimated elevations of the measuring points. Measuring point elevations, in turn, were determined from USGS topographic maps at a scale of 1:24,000 and contour intervals of 5 to 10 feet.

Weil-Head Elevations

Inasmuch as the present mapping study used the data sets collected during the three mass measurements, the need for maximizing the precision of this information in the primary

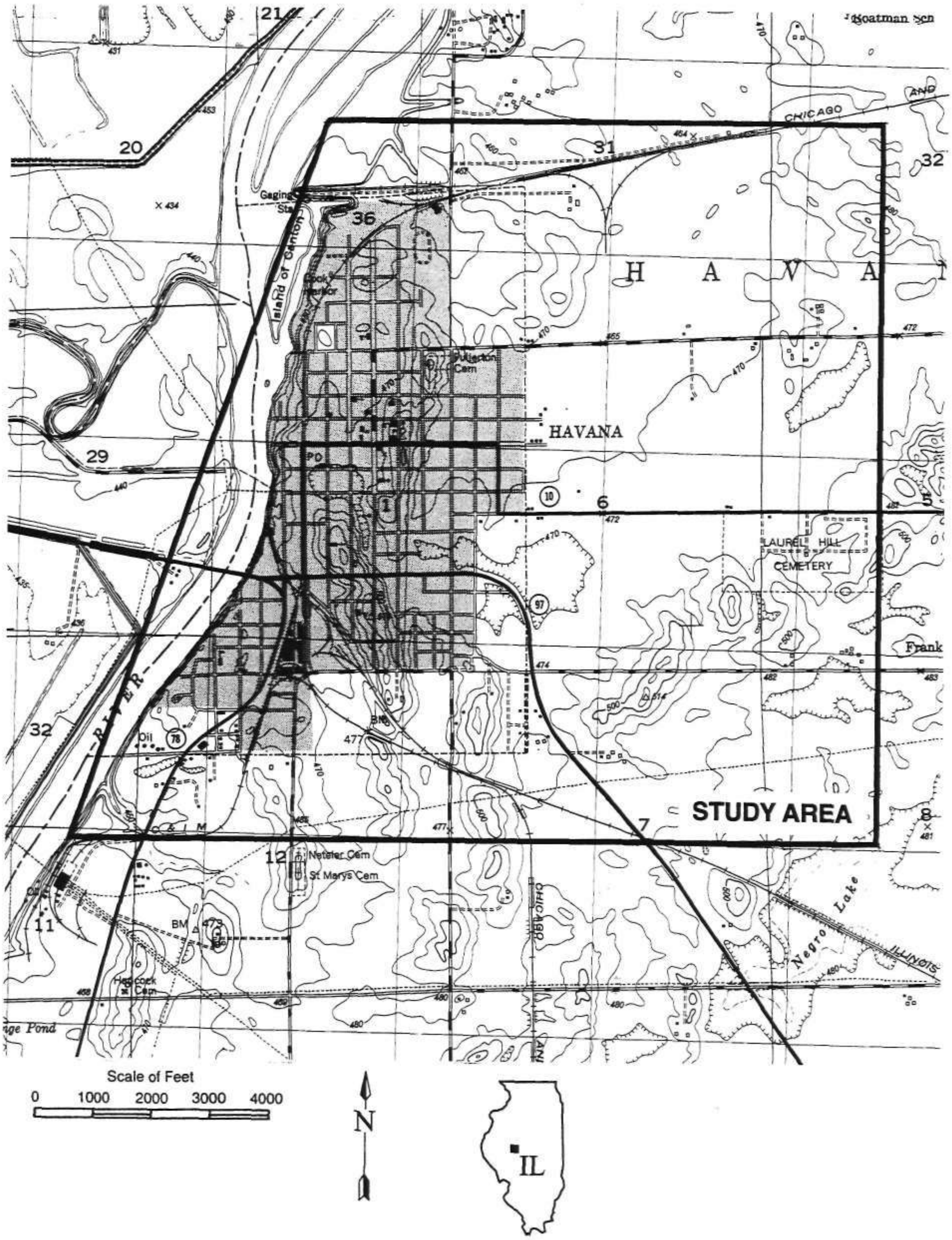

Figure 1. Study area at Havana

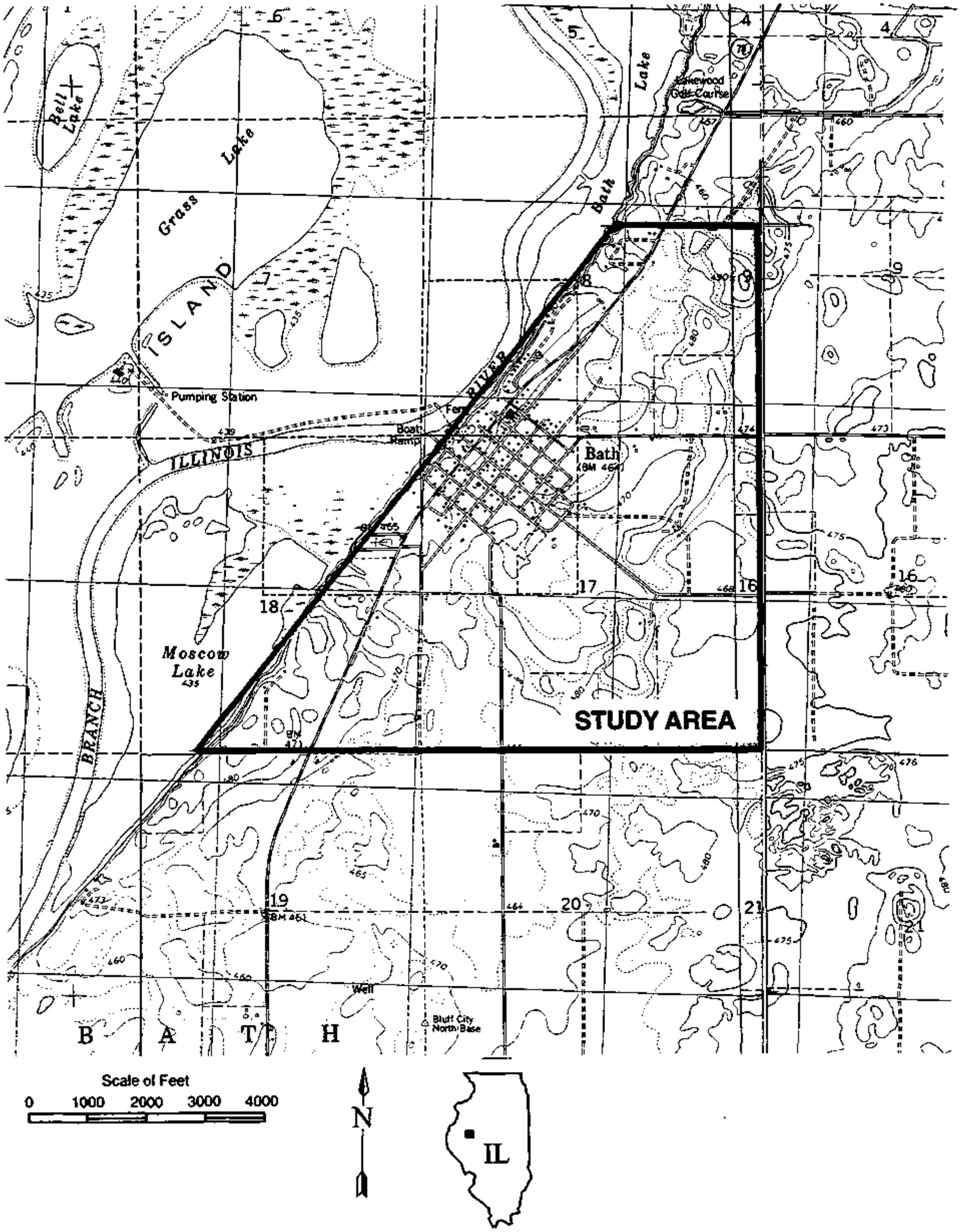

Figure 2. Study area at Bath

study areas dictated that the measuring-point elevations be determined for the observation wells within and adjacent to the study areas. Approximately 75 observation wells were targeted for surveying.

Surveying was conducted during Summer 1994, using state-of-the-art GPS surveying equipment. GPS surveying compares observations at a known reference point (e.g., a National Geodetic Survey or USGS benchmark) with those at points for which location information is needed. Sensitive receivers at the known benchmark (reference station) and at unknown positions ("rover" stations) simultaneously record signals from four or more orbiting satellites. Because the coordinates of the satellites and the reference station are known, it is possible to compute the relative latitude, longitude, and vertical height of the rover receivers by comparing differences in the timing of satellite signal reception. Locations and elevations can be pinpointed to within 5 millimeters (less than ¼ inch).

Six benchmarks were located within practical distance of the wells to be surveyed. The locations of these benchmarks have been included in the final GIS map products, as requested by the sponsor. The most important of these was the first-order benchmark known as "Havana" and located on a high, sandy ridge in the city of Havana near the now abandoned Oak Grove School. First-order benchmarks are critical because their position is known both vertically and horizontally.

Using the Havana benchmark as the main control point, a control network was established among the rest of the benchmarks with GPS equipment prior to surveying individual observation wells. To verify consistency within the control network, three GPS receivers were set up on June 15, 1994, at each benchmark and run simultaneously. Surveying involved operating a GPS receiver (as base station) at one of the control points while two "rovers" moved from well to well. The base station remained fixed, while the rovers occupied each of their points for approximately 15 minutes. Surveying of observation wells began in July and continued intermittently until completion in September.

Revised Potentiometric Surface Maps

The surveyed elevations of measuring points for the selected observation wells were incorporated into the data sets from the three mass measurements conducted in Fall 1992, Spring 1993, and Fall 1993. Depths to water in each well were subtracted from the surveyed measuring point elevations, to calculate more precisely the corresponding water-level elevations at those wells. This updated information was then processed by SURFER® contouring software (Golden Software, Inc.), using a kriging gridding algorithm, to construct revised potentiometric surface maps for Fall 1992, Spring 1993, and Fall 1993. Information contained in the revised potentiometric surface maps was crucial to the subsequent determination of the 100-year potentiometric surface map, as will be discussed in the section on Statistical Analysis.

STATISTICAL ANALYSIS

Precipitation, Illinois River, and Snicarte Ground-Water Data

Daily climatic information (temperature and mean temperature) has been available for Havana since 1901, while the period of record for Illinois River stages is from 1940 to the present.

Continuous ground-water level data have been collected since 1958 at an observation well located in Section 11, T. 19N., R. 10W., about 15 miles southwest of Havana and two miles from the unincorporated community of Snicarte. An automatic water-level recording device at the well monitors ground-water stages on paper charts changed monthly by State Water Survey staff. Manual measurements are taken at each visit to assure accuracy.

Comparison of Snicarte Ground-Water Levels and Illinois River Flooding

The first comparison of data was made between Snicarte ground-water levels and Illinois River flooding events. The river stage at Snicarte was interpolated between observed values at the Beardstown and Havana gages using a straight line (uniform slope) relationship. Available data indicated that for much of 1993, the river stage was at an elevation higher than the ground-water stages at Snicarte (located about two miles from the river flooding). Simulations by Clark (1995), using the MODFLOW ground-water model, indicated that high river stages in 1993 might have affected ground-water levels three to four miles from the river by as much as a foot. To examine the potential impact of river flooding on the Snicarte ground-water levels, a water-budget study was made to determine the relative impact of other contributing factors, most notably precipitation.

Water Budget at the Snicarte Well

The most direct factors influencing temporal variations in ground-water levels at Snicarte are recharge from precipitation, evapotranspiration, changes in ground-water storage, and pumpage from irrigation wells.

The first two factors, precipitation and evapotranspiration, were examined by the use of the Precipitation Augmentation for Crops Experiment (PACE) soil moisture model (Durgunoglu et al., 1987) to estimate ground-water recharge. A description of the application of the PACE model to different soil types was described by Knapp et al. (1991). Climatic inputs used in the water budget modeling were daily precipitation and mean daily temperature at Havana from 1901 to 1994, and the duration of daylight (sunrise to sunset). The PACE model computes the seepage from the soil to shallow ground-water and surface runoff. The model also estimates the losses to evapotranspiration, which during dry summers can affect shallow ground-water levels by as much as two feet. Use of the PACE model for estimating recharge was previously evaluated by Clark (1995), who found the model highly suitable for water-budget calculations of highly permeable soils such as those in the vicinity of Havana and Bath.

The effects of irrigation and changes in ground-water storage were assessed by use of a simple ground-water recession equation:

$$STORAGE(t) = k\,STORAGE(t-1) + RECHARGE - WITHDRAWALS$$

where k is the recession constant and t represents time in days. Storage, recharge, and withdrawals were estimated in feet of depth. Irrigation withdrawals were estimated by assuming one inch of water whenever the net evapotranspiration (evapotranspiration minus precipitation) over a period of seven consecutive days exceeded one inch. Ground-water stage was computed from storage using the following equation:

$$STAGE(t) = STORAGE(t)/Y + BE$$

where Y is the specific yield of the aquifer and BE is the base elevation for estimating the storage. Both stage and base elevation were estimated in feet. Values of k, Y, and BE were calibrated using observed Snicarte ground-water levels. Values of k and Y were determined as 0.996 and 0.14, respectively, while BE was estimated to be 430.5 feet NGVD, or 42.5 feet below the ground surface at Snicarte.

Simulations were performed for the period 1958-1993, using several alternatives:

1) Recharge was estimated using ground-water seepage from the PACE model, and irrigation withdrawals were simulated.

2) Recharge was estimated using ground-water seepage from the PACE model, and irrigation withdrawals were ignored.

3) Recharge was estimated as the addition of ground-water seepage and surface runoff from the PACE model, and irrigation withdrawals were simulated.

4) Recharge was estimated as the addition of ground-water seepage and surface runoff from the PACE model, and irrigation withdrawals were ignored.

Of these simulations, the second alternative produced the best fit between estimated and observed ground-water levels at Snicarte and were, therefore, used for the remainder of the analysis.

Regression Analysis of Maximum Ground-Water Levels

A multiple regression analysis was conducted to examine the relationship between the annual maximum ground-water level at the Snicarte observation well and the following independent parameters:

- Cumulative precipitation (over various durations)
- Annual peak stage on the Illinois River

- Total number of days for which the Illinois River was above flood stage
- Annual peak discharge on the Illinois River
- 91-day high flows on the Illinois River
- Annual maximum ground-water level as estimated by the budget simulations

Correlation coefficients, r, are presented from the regression analysis below. The results indicate that the Snicarte levels are most highly correlated to the ground-water budget simulations, precipitation, and the number of days above flood stage. The magnitude of the annual peak on the Illinois River also correlates with the maximum observed values at the Snicarte well, but to a lesser extent. The 1993 ground-water levels at Snicarte, for example, were by far the highest on record, yet the peak river stage at Havana was only the fourth highest during the period 1958-1993.

Independent parameter	Correlation coefficient (r)
Precipitation (previous 24 months)	0.778
Precipitation (previous 18 months)	0.700
Precipitation (previous 12 months)	0.751
Precipitation (previous 6 months)	0.530
Precipitation (previous 3 months)	0.503
Peak stage on the Illinois River	0.599
Total number of days above flood stage	0.741
Peak discharge on the Illinois River	0.598
91-day high flow on the Illinois River	0.584
Simulated maximum ground-water stage	0.886

A stepwise regression identified variables with the greatest significance for use in predicting maximum ground-water levels. The successive impact of adding independent variables into the multiple regression analysis is shown below. When using only one independent parameter, the simulated maximum level, the standard error of estimate is 0.951 feet. When a second variable, the 12-month cumulative precipitation, was added, the predictive ability improved and the standard error of estimate dropped to 0.871. However, addition of a third variable, 91-day high flow, did little to improve the correlation and actually increased the standard error of estimate. Therefore, the best regression equation used two parameters, the simulated maximum ground-water stage and 12-month precipitation.

Step.	Independent variable(s)	Multiple correlation coefficient (r)	Standard error of estimate (ft)
1	Simulated maximum ground-water stage	0.886	0.951
2	Simulated maximum ground-water stage Precipitation for previous 12 months	0.900	0.871
3	Simulated maximum ground-water stage Precipitation for previous 12 monthes 91-day high flow	0.901	0.888

Frequency Estimates of Ground-Water Levels at Snicarte

Simulation of the water budget and ground-water levels at the Snicarte well were performed for the maximum period for which daily climatic data were available, 1901-1993. Annual maximum ground-water levels were identified for each year of simulation. A frequency analysis was conducted using the simulated annual maximum ground-water levels at Snicarte using the period, 1901-1993. A log-Pearson 3 frequency distribution was applied using the sample skew. Maximum ground-water levels at the Snicarte well for selected frequencies are shown below. The 1993 event had a ground-water level of 442.97 feet, roughly equal to a 250-year event, while the 100-year level was determined to be 442.27 feet.

Recurrence	Depth from surface (ft)	Elevation (ft)
1993 event	30.50	442.97
100-year	-31.20	442.27
50-year	31.75	441.72
25-year	32.35	441.12
10-year	33.20	440.27

Snicarte Data and Observation Well Data

Once the 100-year ground-water stage at the Snicarte long-term observation well had been determined, it was necessary to find a method of translating this information to the other observation wells in the well network in order to construct the 100-year potentiometric surface map. Ideally, the solution would be to find whether a linear correlation existed between water levels at Snicarte and corresponding water levels at the wells in the observation well network. If a direct correlation could be found, then the 100-year stage at each observation well could be calculated and the 100-year potentiometric surface map constructed.

Since water levels were available at all wells from the three mass measurements, water levels at various observation wells were plotted versus corresponding water levels at the Snicarte long-term observation well. Eight scattered sites in the Havana area and four sites in the Bath area were tested, and each of the 12 plots exhibited a linear (straight-line) relationship, which suggested a direct correlation between water-level changes throughout the study area.

100-Year Potentiometric Surface Map

The difference between the 100-year stage and the Fall 1992 stage at Snicarte was observed to be 5.79 feet, and the difference between the Fall 1993 stage and the Fall 1992 stage was 6.67 feet. The ratio between these two relationships is 0.867. Since a linear relationship was demonstrated between water levels in the observation wells, it is not unreasonable to assume that this ratio applies for each well in the network. Therefore, in order to calculate the 100-year stage elevation at each observation well, the following formula was employed:

100-year datum = (Fall 1993 - Fall 1992) x 0.868 + (Fall 1992)

The calculated 100-year stages at the observation wells were processed by SURFER® contouring software to generate the 100-year potentiometric surface map. The map was printed at a scale of 1 inch = 200 feet for compatibility with the orthophoto maps discussed in the following section.

ORTHOPHOTO MAPS

Subcontract to Aero-Metric Engineering

As noted in the acknowledgments, the precision of the 100-year flood-danger zone maps was contingent upon the availability of high-quality topographic maps at a suitable scale. It was determined that a working scale of 1:2400 (1 inch = 200 feet), with a contour interval of 2 feet, would be preferable. It was also necessary to have a way of locating roadways, railways, and building footprints on the flood maps. The only maps available were USGS topographic maps at a scale of 1:24,000 (1 inch = 2000 feet), with contour intervals of 5 feet or 10 feet. Consequently, it was decided to employ an aerial photo service to generate high-quality orthophoto maps.

An orthophoto map is a black-and-white photo image prepared from aerial photographs that have been rectified to eliminate image displacement due to terrain relief. Superposed on the orthophoto are certain cartographic treatments, including contours, lettering, and some symbols.

A subcontract was let to Aero-Metric Engineering, Sheboygan, Wisconsin, which took the aerial photographs on April 14, 1994, and prepared the orthophoto maps at the desired scale of 1:2400. Cartographic treatments included on the maps were topographic elevation contours at 2-foot intervals, numerous spot elevations derived photogrammetrically from the stereo model, and a grid of horizontal location markings based on the Illinois State Plane Coordinate system. The finished product was on 36 inch by 36 inch reproducible mylar. A set of 9 inch by 9 inch black-and-white contact prints prepared from the aerial photography was also delivered by Aero-Metric.

Digitized Orthophotos

The black-and-white orthophotographs provided an unexpected direct method to circumvent the cumbersome necessity of digitizing streets, highways, railways, and building footprints. Prints of the Havana area, at a scale of 1 inch = 1640 feet, and of the Bath area, at a scale of 1 inch = 1000 feet, were scanned by the State Water Survey Graphics Office, using a Hewlett-Packard (HP) legal-size DeskScan color scanner connected to a Windows environment Personal Computer. Each orthophoto was scanned at a resolution of 100 dots per inch. Photo images were captured with the HP DeskScan II software and transferred to the State Water Survey GIS Technology Group's network of Sun workstations, where spatial registration and analysis were done. Subsequently, additional GIS features were built and integrated with the orthophotography.

The combination of scanning resolution and photo resolution translated to a pixel size of 17 square feet for Havana and 10 square feet for Bath. In other words, when the computer image is gready magnified, an object smaller than the pixel size is represented in the image as a square block on the screen of a single shade of gray and is indistinguishable.

Large mylar sheets of the orthophotos were provided by Aero-Metric Engineering at a scale of 1 inch = 200 feet: eight sheets for Havana and four sheets for Bath. Each mylar sheet came premarked with reference marks every 1000 feet in the State Plane West Coordinate System. This set of reference marks was then converted into Lambert Conformal coordinates. Features from the mylar sheets could then be digitized directly into Lambert Conformal coordinates.

Unlike the mylar sheets, the orthophotos did not have premarked coordinates, so, in order to register the orthophotos to Lambert Conformal coordinates, significant features such as road intersections or field corners were digitized from the mylars, and those same features were identified in the orthophotos. These corresponding features on the orthophotos and mylars were then aligned and linked electronically, creating registration marks for the orthophotos. Approximately 20 features for each orthophoto were selected in this manner.

The registered orthophotos were converted from the scanner pixel format, Tag Image File Format (TIFF), to a raster GIS format usable in Arc/Info (Environmental Systems Research Institute) 6.1.1 program module GRID. This conversion process permanently applied to the raster GIS format images the alignment parameters determined registration. Four scanned orthophotos for Havana and four for Bath were registered and converted. Using a number of GRID program commands, the overlapping areas between the four images of each city were eliminated, and a single image was created for each city.

100-YEAR FLOOD-DANGER ZONE MAPPING

Surface Flooding Areas

Areas prone to surface flooding by ground water at a frequency of once in 100 years were determined by subtracting 100-year potentiometric surface map elevations from the land surface elevations on the orthophoto maps. Since the orthophoto maps were produced on mylar, the mylar maps were superposed over the potentiometric surface maps and the subtractions performed manually. Areas in which the land surface was higher than the potentiometric surface generated a positive number when the subtraction was performed. Areas in which the land surface was lower than the potentiometric surface (i.e., areas in which the water table would rise above the ground and cause surface flooding) generated a negative number. Flood-danger zones were, therefore, areas with negative numbers, and the bounding value which delineated those areas was zero (the point at which the water table intersects the land surface).

Tracing paper was overlaid as a work map on the mylar and potentiometric surface maps and placed on a light table. Flood-danger zones for surface flooding were outlined on the work maps by red lines, which were later digitized and incorporated into GIS coverages. Surface-flooding danger zones are shown in red on the final GIS maps.

Basement Flooding Areas

The depth to basement floors was arbitrarily assumed to be six feet below the land surface. In order to perform subtractions, as above, six feet of elevation could be subtracted from the land surface or added to the potentiometric surface. Since it was more readily accomplished with the water-level database and computer mapping software on hand, six feet was added to the potentiometric surface and an adjusted potentiometric surface map was generated that was six feet higher at every point than the 100-year potentiometric surface map.

Areas prone to basement flooding by ground water at a frequency of once in 100 years were determined by subtracting the adjusted (+6 feet) 100-year potentiometric surface map elevations from the land surface elevations on the orthophoto maps, as was done for the surface flooding maps. Areas in which the land surface was higher than the adjusted potentiometric surface generated a positive number when the subtraction was performed. Areas in which the land surface was lower than the adjusted potentiometric surface (i.e., areas in which the water table would rise above the basement floor and cause basement flooding) generated a negative number. The basement flood-danger zones were, therefore, areas with negative numbers, and the bounding value that delineated those areas was zero (the point at which the water table intersects the land surface).

Tracing paper was overlaid as a work map on the mylar and potentiometric surface maps and placed on a light table. Flood-danger zones for basements were outlined on the work maps by red lines which were later digitized and incorporated into GIS coverages. Basement-flooding danger zones are shown in green on the final GIS maps.

100-Year Special Flood Hazard Areas

Flood insurance studies for Havana and Bath, performed by the Federal Emergency Management Agency (FEMA, 1983), determined that the 100-year flood elevation on the Illinois River at those communities is at an elevation of 453 feet and 452 feet, respectively. At the request of the sponsor, following their review of the draft GIS maps, the 453-foot contour at Havana and the 452-foot contour at Bath were digitized from the orthophoto maps and a GIS coverage was generated. The area between the digitized contour and the Illinois River is shown on the final GIS maps in fuchsia and labeled "100-Year Special Flood Hazard Area."

GIS MAP PRODUCTS

Large maps of 100-year surface flooding and basement flooding areas for Havana and Bath were created using Arc/Info software and produced on an electrostatic plotter. The map products include 1 inch = 500 feet scale color maps of each city, showing the locations of 100-year surface flooding in red and 100-year basement flooding in green, superimposed on the orthophotos of each city. Key streets and the Illinois River are labeled by name. These maps also include basic map elements, including title, north arrow, legend, scale, logo, neat lines, and credit. Because the scale of the map for each city is the same, the map sizes are different: the map for Bath is approximately 2 feet by 3 feet, and the map for Havana is approximately 3 feet by 4 feet.

After initial review by the sponsor, additional features were added to the maps:

1. Seepage elevations of surface flood zones were identified in a table.

2. A 100-year "Special Flood Hazard Area," showing the area at Havana and at Bath that would be flooded by a 100-year event on the Illinois River, was mapped in fuchsia.

3. The study area location was identified in an index map.

4. Municipal boundaries were identified.

5. The date was added to each map, and the title revised to include Mason County.

6. A paragraph of text was added describing the differences between the 100-year flood determinations on the maps and the 250-year flood event that occurred in September 1993.

7. An alphanumeric grid system was placed on the border of each map to facilitate the identification of site-specific locations.

8. A special mapped area on the Havana map identified a zone of potential basement flooding requiring site-specific information. The zone was shown in lighter green with hatchures at right angles to the hatchures of the darker green areas.

Letter-size versions of these maps were created in a similar manner, and were initially printed on a color laser printer, using the map production module of Arc/Info, ArcView2. At the request of the sponsor, black-and-white versions were then produced to facilitate the production of photocopies for interested parties. Since the black-and-white versions relied on various shades of gray, the gray orthophoto background was deleted and streets were added from an existing 1:100,000 scale GIS coverage. Copies of the page-sized black-and-white maps are available from EEMA.

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