Johnson County flood warning/flood forecasting: Feasibility and implementation plan

Summary Report

Prepared for
Johnson County Public Works
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Flood risk in Johnson County and what can be done to reduce it

What is the flood risk?

Unlike other parts of the nation where the flood threat is highly seasonal, Johnson County, KS is subject to flooding every month of the year. For example, one of the worst floods in the history in the mid-continent region occurred in the winter—in December 1982. The weather pattern that caused this disastrous flood could cause similar flooding in Johnson County. This is due to a low level jet stream which brings very moist air north from the Gulf of Mexico, with moist storms tending to "anchor" over parts of the County. This tendency strengthens at night as temperatures drop. This may lead to storms with maximum rainfall intensity occurring between 1 AM and 4 AM, filling channels, overflowing streets, and creating a significant hazard in the dark of night for those who live in or travel through the County.

Johnson County, as shown in Figure 1, is divided into 3 major river basins: the Blue River, Kansas River, and Marais Des Cygnes River. Within these basins dozens of small, fast-rising streams drain urban and rural watersheds. The flooding risk has increased significantly over time, particularly in the northeastern portion of the County.

Flooding in and around Johnson County led to presidential disaster declarations in 1993 and 1998. The estimated cost of these disasters exceeded $50 million dollars. The severe thunderstorms on October 4, 1998 resulted in major flash flooding in the County and throughout the Kansas City metropolitan area. Reports indicate that 3 to 5 inches of rain fell on already saturated soil within a 3-hour period. More than 5 inches fell in Lenexa in little over an hour. Nearly 100 calls for water rescue were received, and numerous roads throughout the County—including individual sections of Interstate 35 and Interstate 435—were impassible. Two lives were lost, including a death in Lenexa near the intersection of West 93rd Street and Acuff Road and one in Overland Park on Connell Avenue near 103rd Street. Excessive property damage occurred as well. For example, some homes in the City of Merriam had over 11 feet of flood water and over 40 homes in Johnson County were ultimately purchased and demolished because of the extensive damage from the storm.

How can the risk be reduced?

Measures that will reduce flood risk

Flood risk—including both the risk of loss of life and the risk of property damage—can be reduced with one or some combination of measures shown in Table 1. Measures listed in col. 1 reduce risk by actually limiting the volume of water or its discharge rate. For example, a detention pond constructed as a component of new development within the County will hold back stormwater run off, releasing it at a rate that can reduce flooding potential downstream.

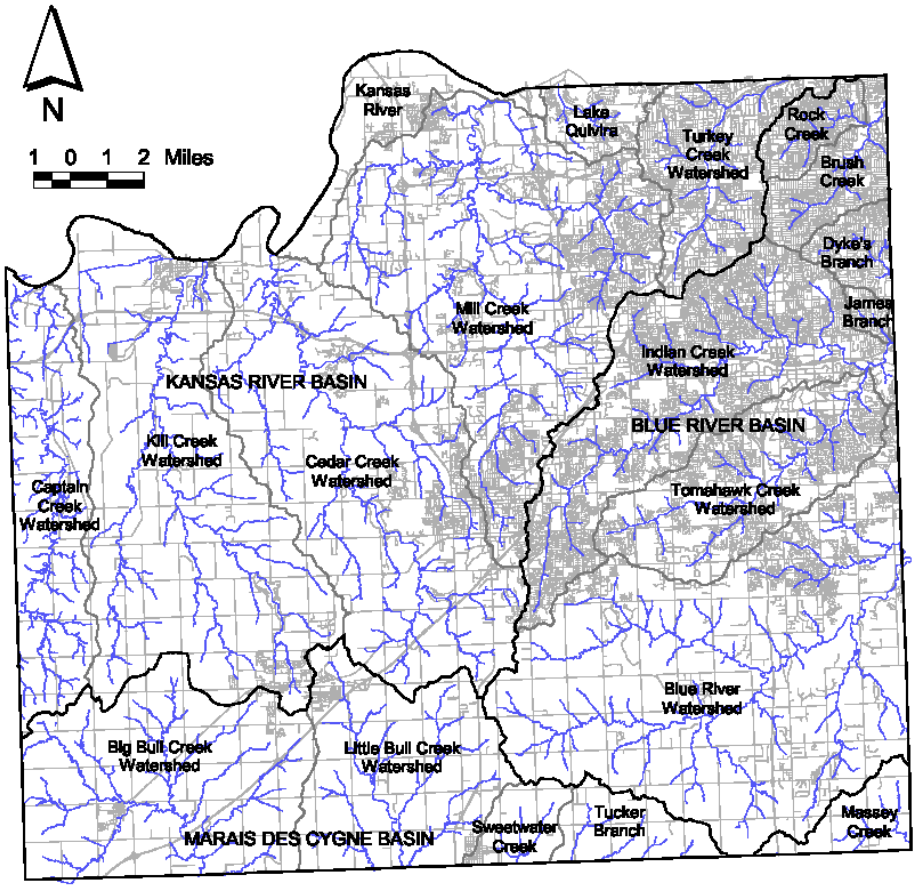

Figure 1. Johnson County watersheds and basins

Table 1. Flood damage reduction measures (from Corps of Engineers EM 1110-2-1419, 1995)

Measures that reduce damage by reducing discharge (1)	Measures that reduce damage by structural channel improvement (2)	Measures that reduce damage by reducing existing damage susceptibility (3)	Measures that reduce damage by reducing future damage susceptibility (4)
Reservoir, detention, or retention facility Diversion or bypass Watershed management	Channel improvement Levee or floodwall	Floodproofing property within floodplain Relocation of property to sites outside floodplain Flood warning, with preparedness planning	Land-use and construction regulation for new construction within floodplain

Measures listed in col. 2 do not reduce the volume or discharge rate, but they can reduce the water level (stage) in sections of a channel when floodwaters reach a given volume or discharge rate. For example, deepening or widening a channel will reduce the risk of overflow, and hence, the risk of property damage.

Measures in col. 3 do not control flow rate or the water level at all. Instead, these measures reduce the damage or the risk incurred to current property and floodplain occupants if the flow rate or water level reaches a given magnitude. Notable among these measures is flood warning, which is intended to provide an opportunity to move or protect property that would otherwise get wet or people who would be threatened.

Finally, measures in col. 4 reduce risk in the future by acting to reduce the damage or life risk then. For example, floodplain management policies that require elevation of new construction above the 100-year water surface elevation will eliminate future damage due to events of that magnitude (or less).

Commonly, measures in col. 1 and 2 are referred to as structural measures, while those in col. 3 and 4 are referred to as nonstructural measures.

Current efforts within the County to reduce flood risk

Johnson County and cities within the County actively have sought to reduce flood risk by planning, designing, and constructing/implementing structural and nonstructural measures.

Structural measures implemented recently include channel improvement projects (including straightening, lining, widening, obstruction removal) and detention projects—both regional scale and on-site.

Nonstructural activities include:

- Home buyouts to remove/relocate homes to areas of lesser risk. For example, following the floods of 1998, 33 homes in Merriam were purchased for a total cost of $5.3 million and were subsequently demolished.
- Adoption of floodplain land use ordinances.
- Implementation of components of a flood warning system, including County-wide hydrometeorological observation, some computer-aided threat recognition, road barricading, and limited site-specific forecasting.

What can enhanced flood warning achieve in Johnson County?

This project focuses on the risk reduction achievable by enhancing flood warning in Johnson County.

What is a flood warning system?

A flood warning system (FWS) is an integrated package of equipment, plans, procedures, and human resources that permits its users to:

- Detect and recognize a flood hazard early in its existence, prior to the point at which lives and property are at imminent risk.
- Notify those whose lives and/or property are at risk.

- Make wise decisions and respond in a timely, efficient manner to the near-future flooding.
- Make wise decisions about how to recover from flooding, once the threat has passed.

How does flood warning reduce risk?

The risk reduction benefit of a FWS is derived through an increase in action or mitigation time—the time available to protect lives and property. Figure 2 is a time line that shows how time is spent responding to floods, thus illustrating this concept.

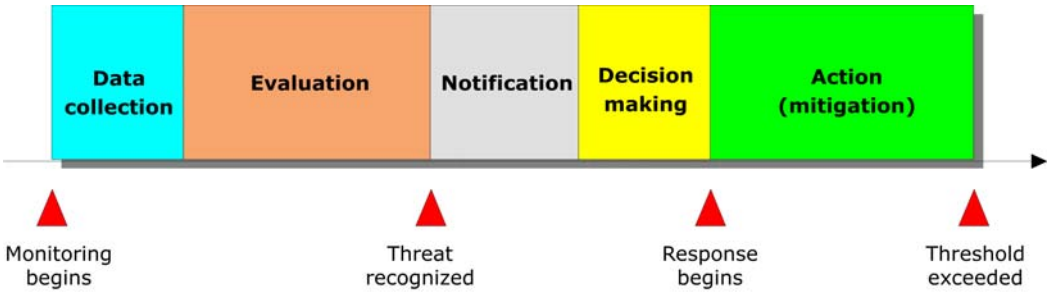

Figure 2. How time is spent responding to floods

The critical "block" of time in the figure above is the last block of time before a flood threshold is exceeded; this is labeled *Action (mitigation)* time. It is the time available between the initiation of response to an imminent flood threat and the actual occurrence of the flood. During this time, damageable property can be raised above the anticipated water level, vulnerable floodplain occupants can be evacuated, or, as is critical in Johnson County, risky road crossings can be barricaded and the motoring public warned to avoid driving through flood water. These actions reduce the risk.

Time prior to the action time is spent completing 4 tasks. First, time is spent detecting the flood event. This requires measuring environmental conditions, including rainfall depths and water levels in channels. The measurements are evaluated to determine if they indicate a current or likely-future threat. If they do, notification begins at the milestone labeled *Threat recognized* in Figure 2.

When a threat is recognized, additional time is required to provide information about the threat to emergency responders (labeled *Notification* time in the figure).

The responders will take some time to evaluate the information, to identify vulnerable people and property, and to make decisions about what to do. This period is labeled *Decision making* in Figure 2. Once a decision has been made, response begins, with actions taken before the water-level threshold is exceeded.

An effective flood warning system affects this process in a simple way: It reduces the time required for actions prior to the initiation of response to the flood threat. And because the time of threshold exceedence is fixed, this reduction in time for data collection, evaluation, notification, and decision making translates to more

time for action. More time for action means more property may be protected, more people evacuated, more low water crossing barricaded, and so on.

What is included in a flood warning system?

To achieve these goals, a complete flood warning system must include components that are illustrated conceptually in Figure 3.

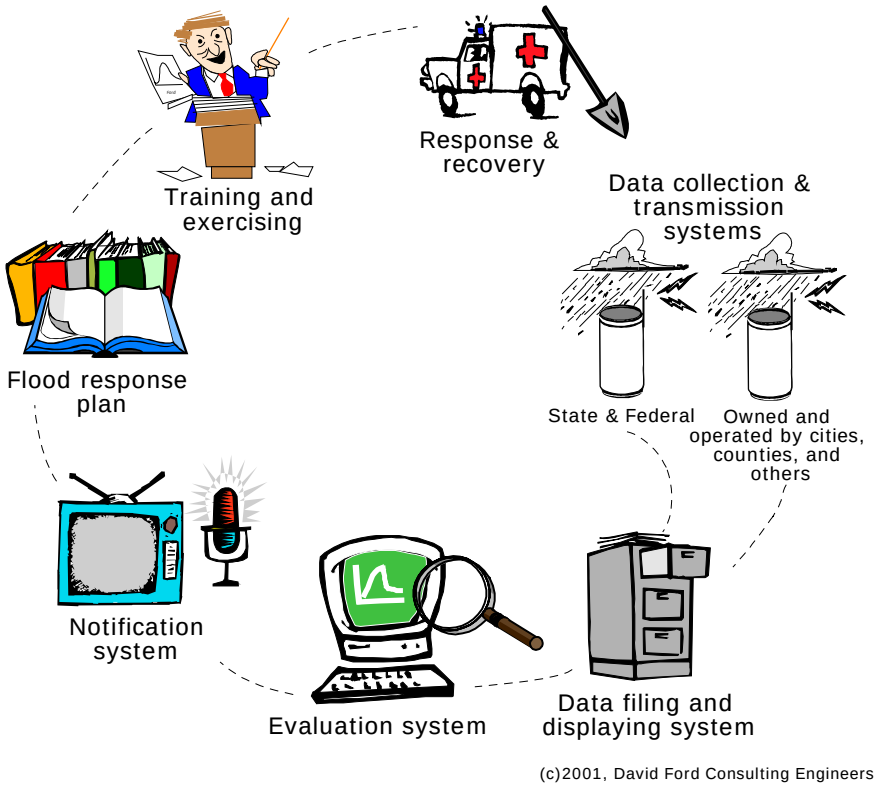

Figure 3 Components of a flood warning system

Flood warning starts with data collection and transmission. Sensors measure current rainfall depths and water levels and other indices of watershed conditions. [Measurement can be manual or automated, but discussions herein focus on automated systems. Only these will reliably provide the timely data required for fast-responding watersheds in Johnson County.]

These measurements of environmental conditions are used to recognize flood threats in advance of their occurrence. This recognition relies on comparison of the observed condition with pre-determined triggers or thresholds. For example, measured water level in a channel can be compared with known elevations of overflow. Simple comparisons can be made by "intelligent" sensors at the measurement site, or the data may be transmitted to a central site for more detailed evaluation.

In the latter case, radios, telephones, or other communications equipment relays the measurements to the central site—a flood warning center—for evaluation. At the flood warning center, the rainfall, stage, and other environmental data are received, managed, and analyzed. Database-management software stores data

for subsequent analysis, and reporting/visualization software expedites examination of the data for threat detection.

The goal of the evaluation is to identify *when* a hazard exists, either by recognition of a current threatening condition or by forecast of a future threatening condition. To provide maximum mitigation time, this evaluation must be fast, so it commonly is automated and computerized to some extent.

The evaluation system, at a minimum, includes a threat recognition plan that includes specific numerical standards with which flood threats can be identified, and a threat recognition procedure with which the threat recognition plan is implemented. This may be computerized, or at least computer-aided.

Other components of an evaluation system may include flood forecasting, weather forecasting (for use of a quantified precipitation forecast), and real-time inundation mapping. Each provides enhanced information for recognition and decision making.

As threats are recognized, appropriate information must be disseminated to emergency managers, to public agencies, and to citizens. That is the goal of the notification component of the FWS. The information may be communicated via telephone, fax, radio, e-mail, or other media.

Once threats are recognized and warnings are issued, actions begin in earnest to protect lives and property. For efficiency, these actions should follow procedures spelled out in a flood response plan, which will address evacuation and mass care, temporary protection of people and property, maintenance of vital services, provision of information to the public, and post-flood recovery.

Finally, training and exercising ensure that all emergency managers, responders, and the public know how to use the flood warning system components to save lives and reduce property damage.

Project tasks, actions, and key findings

Task

The objective of the work reported herein is to identify enhancements to the flood warning system in Johnson County—enhancements that will yield increased mitigation time. This includes identifying the requirements for, assessing the feasibility of, and developing a plan to implement an effective flood warning and forecasting system for the County and the cities within the County.

Actions

To meet the objectives, the project consulting team, at the direction of the steering committee, completed the following seven fundamental steps:

1. The team consulted stakeholders in the County and cities in the County to determine what they required from a flood warning system. The results of these investigations are described in the appendices of this report. [For convenience, Table 2 identifies the appendices and the objectives of the investigation included in each. It also summarizes the principle findings of each.]
2. The team inventoried the existing flood warning system to assess its ability to satisfy those requirements. The results of this inventory are described in the appendices of this report.
3. The team identified measures that could be added to the existing flood warning system to satisfy unmet needs. The measures proposed are identified in the technical appendices (appendix 2).
4. The team, County staff, and steering committee filtered the initially identified measures to eliminate the inferior and ineffective alternatives, then categorized the remainder, forming plans. This is described in detail in the next chapter.
5. The team identified a preferred plan for implementation - this is referred to through the report as the "*backbone* plan".
6. The team identified specific goods and services that are required to implement and to operate the backbone plan over a proposed project life, contacted appropriate vendors and service providers to estimate costs for these goods and services, and estimated the total cost for the proposed backbone system.
7. The team proposed an implementation schedule for the backbone plan.

Key Findings – make changes from executive summary

The following represents a summary of the key findings resulting from interviews with local, state and federal agencies within the study area.

1. Based on the significant interest by Johnson County communities combined with the extent and capabilities of the existing rain and stream gage network in the County, a flood warning/flood forecasting system is feasible for Johnson County.

2. Based on the interest by communities in the Kansas City Metropolitan area, combined with the extent and capabilities of the existing rain and stream gage network in the region, a regional flood warning/flood forecasting system should be considered.
3. Numerous communities expressed interest in participating in a regional system that could decrease the number of multiple, redundant activities performed by individual communities.
4. Multiple local, regional, state and federal agencies expressed an interest in being involved in and supporting a regional flood warning/flood forecasting system.
5. Multiple Johnson County communities recognize flood warning/flood forecasting as a practical and cost-effective alternative to structural improvements.
6. An implementation plan can be developed for Johnson County to initiate development of a flood warning/flood forecasting system without compromising the development of a regional flood warning/flood forecasting system.
7. Johnson County should continue to enhance and fund the flood warning system "backbone". The backbone consists of the basic rain and stream gage data collection network, and the data transmission and management system necessary for the basic operation of the system. However, the steering team felt it was important to identify this cost now.
8. Each city will be responsible for the desired flood warning system/components needed – these systems/components include the locating, design, construction, maintenance and operation of specific flood warning activities including flashing lights, automated gates and other features necessary to warn the public of flooding conditions.
9. Johnson County should evaluate the potential for watershed-based and/or countywide 24x7 flood forecasting services/support. At this time it appears that outsourcing is the most cost-effective method for providing this service/support.
10. The inventory of the existing rain and stream gage network showed that the system requires an additional eight rain and stream gages to function at a service level capable of supporting the ultimate countywide flood warning system.
11. The critical flood warning system requirements identified by the cities include location specific forecasting, basic transmission network infrastructure, and a system that provides opportunity for future automation.

Table 2. Summary of Actions and Findings

Appendix (1)	Title (2)	Objectives of investigation (3)	Summary of findings (4)
1	Evaluation of the current rain and stream gage system	Evaluate the current stream and rain gage system and identify improvements/enhancements.	The team recommends: • Upgrading to dual frequency store and forward repeaters. • Keeping all transmitters on the frequency of 169.425 MHz. • Install separate input/output antennae on both repeaters.
2	Evaluation of ten flood warning systems	Identify and evaluate ten flood warning systems throughout the nation to take advantage of lessons learned by owners/operators of those systems.	At least half of flood warning system owners and operators do the following: • Automate data collection, data transmission, data management, threat recognition, and notification of key personnel. • Transmit data using ALERT protocol with line-of-sight radio transmission to at least two or three base stations. • Share data with other agencies and the public via the Internet. • Forecast flood threats in-house. • Notify the public of flood threats.
3	Industry trends in flood warning	Identify current and likely future trends in data collection and transmission, data management, threat recognition, flood forecasting, and notification so that the County can develop a system that is state-of-the-art and usable in the future.	The following technologies will improve and will be more widely used: • ALERT transmission. • Satellite telemetry. • Radar rainfall. • Expert systems. • Site-specific forecasting. • Flood inundation mapping.
4	Regional, state, and federal agency input	Coordinate with regional, state, and federal agencies to 1) ensure they are aware of Johnson County's current efforts; 2) learn about ongoing or planned projects that may provide opportunities for coordination; and 3) learn what role, if any, these agencies might play in the design of a countywide flood warning system.	The team recommends the County do the following: • Keep agencies up-to-date on project development. • Provide National Weather Forecast Office (WFO) in Pleasant Hill with a list of watersheds with unit hydrographs and channel locations for which ratings are available (or could be developed with available models). • Investigate efficient communication paths between the County and WFO so that flood forecasts can be sent to the WFO as quickly as possible. • Strengthen vulnerability assessments and response plans for communities in the County.

Appendix (1)	Title (2)	Objectives of investigation (3)	Summary of findings (4)
5	Cities and County needs and desires for flood warning/flood forecasting	Interview 15 County agencies and cities within the County to identify their needs and expectations for a flood warning system.	County agencies and cities within the County are willing to participate in the funding of a system. They expect at least the following: • Site-specific forecasting. • Increased lead-time. • Participation in a shared system between cities and the County.
6	Flood warning seminars	Prepare and present flood warning seminar to County and city personnel to ensure that they have a firm understanding of what is involved in flood warning.	"Flood warning 101" was presented on November 20, 2003.
7	Coordination with Kansas City, MO	Coordinate with Kansas City, MO (KCMO)on project efforts to identify opportunities for future flood warning coordination and to learn from city experiences.	The team recommends the County: • Provide Kansas City, MO with information about the hydrologic and hydraulic models available and the parameters of each. • Keep Kansas City, MO informed of what flood warning measures will be implemented in the County. • Periodically check in with Kansas City, MO to determine how the Time-Warner camera system is working.
8	Flood forecasting alternatives	Evaluate small-stream, flood-forecasting alternatives to identify the best option for Johnson County and the cities within the County.	The team recommends the County: • Select and use a conceptual forecasting model. • Use an off-the-shelf forecasting tool that can utilize the County's currently available HEC-1 models.
9	Hydrologic and hydraulic model integration	Identify existing hydrologic and hydraulic models and evaluate whether these can be integrated successfully within the recommended flood warning system.	The team identified watershed model studies that exist or are being developed. Fifty-five of the 67 identified flood problem areas are covered by one of these studies. The team recommends adding eight stage gages.
10	Legal issues pertaining to flood warning systems	Identify County's questions and concerns about owning and operating a flood warning system, research Kansas law and national legal cases to answer the questions and respond to concerns.	The amount of liability a Kansas county could incur by installing a flood warning system is minimal. A county could incur liability for diverting flood waters onto the property of another.

Appendix (1)	Title (2)	Objectives of investigation (3)	Summary of findings (4)
11	Coordination, ownership, and responsibility of the flood warning system	Investigate options for responsibility, ownership, and coordination of the flood warning system.	The team recommends the Steering Committee coordinate the flood warning system. Four options for the ownership and responsibility of data collection system, evaluation system, and notification systems met the team's criteria. Three options for ownership and responsibility of the response system met the criteria.
12	Changes to existing gage sites to support effective flood warning	Analyze the effectiveness and limitations of the existing gage system and identified opportunities for enhancement.	The team recommends implementation of gage-adjusted radar and removal of select existing gages (in order to save on maintenance fees).
13	Staffing options for Johnson County flood control	Identify options for round-the-clock staffing and support.	The team recommends the County outsource monitoring of the flood warning system to a commercial company.
14	Costs of the flood warning system	Identify goods and services required for acquisition and implementation of the recommended system and estimate the probable costs.	The team provided costs for acquisition, operation, maintenance, and replacement of the "backbone" flood warning system. For comparisons, all costs are amortized and summed, thus providing a total first cost and the equivalent annual cost of the system.
15	Review and evaluate notification alternatives	Review alternatives for notification of flood and identify options which would be most effective for Johnson County.	The team recommends: • Using at least one active and one or more passive notification systems for notification. • Using a commercial company contractor for notification of key personnel.
16	Benefits of implementing a flood warning system	Quantify and describe the overall benefits gained from implementing a flood warning system in Johnson County.	The team estimated the annual inundation-reduction benefits for: • Rock Creek watershed, $12,000. • Mill Creek watershed, $12,000. • County's portion of Upper Turkey Creek watershed, $73,000. The primary life safety benefits are increased time available to: • Deploy road crews to low water crossings and for emergency service providers to plan alternative routes. • Notify the public that crossings and roadways are closed. • Deploy emergency response crews to carry out rescue and to notify and assist with evacuation of vulnerable facilities. • Notify residents near creeks so they can evacuate.

Recommended system enhancements

Measures considered

During the investigations reported in the appendices, technical specialists from the project team, working with County staff, identified specific measures that will enhance the performance of existing flood warning system components. These include modifications to the data collection system to improve coverage, improvements to the evaluation system to include forecasts of future water levels, and so on.

In many cases, the measures identified include alternative configurations or options for the same goods or services. For example, the appendix that reports on flood forecasting identifies three options for forecasting: 1) relying on the National Weather Service for forecasts; 2) hiring a contractor to provide flood forecasts; or 3) allowing each city and the County to develop forecasts independently.

Approximately 35 measures are identified; all are described in detail in the appendices to this report.

Measure screening and plan formulation strategy

The project team identified the recommendations from the technical investigations, then reviewed this set with cooperation and input County staff and the steering committee. In that review, measures that were not complete, effective, efficient, or technically/politically/financially acceptable in the judgment of the team, staff, or committee were eliminated.

The remaining measures were categorized to identify those for which:

1. Most cities and the County indicated a requirement, for which a clear and compelling need exists, and for which an obvious economy of scale exists for implementation on a county-wide basis, rather than on a city-by-city basis.
2. Other measures that would yield increased mitigation time, but that were not widely identified as necessary by cities in Johnson County or that could be implemented on a city-by-city basis in an efficient manner.

Measures in the first category form what is referred to herein as the "*backbone plan"* for Johnson County. As this plan is implemented, it will provide the fundamental goods and services that are required for effective and efficient flood warning.

The measures in the second category are gathered and identified herein as *add-on measures*. Cities within the County may elect to implement these measures on their own, with funding provided by the City.

System backbone plan

The backbone plan—which includes measures that offer broad benefit throughout the county—provides fundamental goods and services that are required for effective and efficient flood warning.

The following enhancements to the data collection, transmission, and management system are recommended in the backbone plan:

- Add gage-adjusted radar with alarms. This will improve estimation of watershed average rainfall for forecasting, and it will provide better data for quantitative precipitation forecasting.
- Add stream gages at eight locations. Data from these additional gages will provide an opportunity to improve threat recognition within the floodplain when observed water levels are used as the triggers. The data will also provide an opportunity to improved forecasting models, as it will permit verification of those models.
- Upgrade ALERT radio transmission system to dual frequency store-and-forward repeaters. This will strengthen the data transmission system, which provides water level and rainfall depth necessary for threat detection county-wide.

The following enhancements to the evaluation system are recommended for the backbone plan:

- Provide automated threat recognition system tool. The County should select and make available for use by a city that desires to do so, a computer-aided threat recognition and notification software package. Including this within the backbone system will avoid duplication of effort and will ensure that a critical mass of expertise and experience can be built amongst users within the County.
- Provide site-specific water level forecasting services. The ability to forecast water levels at specific locations on streams was identified by many beneficiaries of flood warning as a critical need. However, streams within the County cross political boundaries, so developing the capabilities within one city and not the adjacent is inefficient. Accordingly, the backbone plan should include capability to provide such forecasts at multiple location. However, the County should select and provide the service and tools, with funding for application from individual cities.

Recommended enhancements to the backbone notification system include:

- Promote use of NOAA weather radio. This system provides an opportunity for wide-spread notification. A public education program, promoting use, should be mounted by the County.
- Continue funding for Web site for sharing information with public. The currently-funded Web site (*www.stormwatch.com*) is widely used as a source of real-time flood information. This is supported by the County, and as it is useful for all cities, such support should continue.

Enhancements recommended for the preparedness and response system include the following:

- Provide a template for flood response plans for cities within Johnson County and others in the Kansas City Region if applicable. The study team's investigation found that flood response plans for cities within the County are not in a uniform state of readiness. Thus, even if other components of the flood warning system are deployed and operating optimally, the system may

fail to deliver the expected benefits because decisions regarding evacuation, mass care, and so on will not be made efficiently. Accordingly, the backbone includes this activity in which a template for an efficient flood response plan will be developed and provided to the cities. It may be most effective for the County to select a contractor to complete this task. Individual cities can contract with the same or another contractor to take the template and complete their plans.

Add-on measures

Measures in this category were identified through the investigations conducted by the study team and are described in detail in the appendices. These measures are intended as add-ons or supplements to the backbone plan that is described above. The measures may be selected and provided by individual cites, depending upon the needs and requirements for those cities.

Add-on measures include:

- Use of real-time video to capture and record flood events.
- Production and dissemination of real-time inundation maps for threat evaluation.
- Acquisition, installation, and use of an auto-dial (i.e. Reverse 911™) system for public notification.
- Acquisition, installation, and use of outdoor sirens for public notification.
- Acquisition, installation, and use of automated flash flood warning signs at low water crossings.
- Configuration and use of e-mail for emergency notification.
- Acquisition and use of portable notification devices.
- Train, test, and update flood response plans.
- Assess vulnerability of people and property within city to improve response.

Measures in this category, if implemented alone, will not form the basis for a flood warning system - without the backbone plan these measures will be ineffective or only marginally effective in terms of providing increased mitigation time. However, when coupled with the backbone system, these measures permit each city to tailor the system to meet needs of citizens.

Funding for backbone and add-ons

To maximize coordination, efficiency and effectiveness, it may make the most sense for the backbone system within Johnson County to be the County. As noted, this primary system includes the goods and services necessary to meet basic needs for flood warning, as well as the maintenance of the facilities to ensure availability 24 hour per day, seven days per week.

Cities may select and implement the add-ons, with their own funding. Exceptions to this funding standard will be when part or all of the enhancements are a portion of an approved Stormwater Management Program-eligible/funded project.

Probable cost of recommended plan

Appendix 14 describes steps taken to develop a cost estimate for the backbone system. These steps include:

- Identifying broad categories of costs associated with implementation of the backbone plan.
- Developing a list of goods and services required for measures included in the backbone plan.
- Contacting appropriate vendors and service providers to obtain cost estimates for those goods and services.
- Using those vendor and service-provider estimates to develop the overall cost estimate.

The total estimated acquisition cost for the system proposed is approximately $800,000. The annual recurring costs (which includes operation, maintenance, changing out smaller parts, training, exercising the system, and outsourcing operation of threat recognition and water level forecasting) is approximately $160,000.

Costs to replace equipment that has reached the end of its useful life prior to the end of the expected project life cycle is estimated at approximately $130,000. This includes replacement of ALERT gage equipment at 15-year intervals and replacement of computer equipment at five-year intervals throughout an assumed 50-year project life. [This life was selected to be consistent with Corps of Engineers benefit and cost analysis procedures.]

With a 50-year project life and an annual interest rate of 5-5/8%, the present value total cost of the system is estimated to be approximately $3,600,000. The uniform annual cost is estimated to be approximately $220,000.

Table 3. Probable acquisition cost of components of backbone system, in-house operation

Component (1)	Goods or services (2)	Quantity (3)	Unit (4)	Unit cost (5)	Extension (6)
1. Add gage-adjusted radar with alarms	Acquire and configure system and services	1	LS	$5,000	$5,000
	Train users	1	LS	$1,500	$1,500
	Implement data feed to Web site	1	LS	$12,000	$12,000
	Sub Total				**$18,500**
2. Add stream gages at 8 locations	Design, engineer sites	8	each	$1,000	$8,000
	Site acquisition and utility locate	8	each	$6,400	$51,200
	Acquire and install gages	8	each	$9,500	$76,000
	Sub Total				**$135,200**
3. Upgrade ALERT radio transmission system to dual frequency store-and-forward repeaters	Acquire new frequency	1	LS	$5,500	$5,500
	Acquire and install repeaters and add second antenna and receiver to both base stations	2	each	$14,000	$28,000
	Train on dual-frequency repeater operation	1	LS	$1,100	$1,100
	Sub Total				**$34,600**
4. Provide automated threat recognition system tool	Design, specify, select system	1	LS	$5,000	$5,000
	Acquire hardware and software	1	LS	$100,000	$100,000
	Deploy and configure at 24X7 site	1	LS	$150,000	$150,000
	Train users	1	LS	$10,000	$10,000
	Test, confirm system prior to activation	1	LS	$10,000	$10,000
	Sub Total				**$275,000**
5. Provide site-specific water level forecasting services	Design, specify, select system	1	LS	$5,000	$5,000
	Acquire hardware and software	1	LS	$50,000	$50,000
	Deploy and configure at 24X7 site	1	LS	$50,000	$50,000
	Prepare watershed and channel models	7	watershed	$50,000	$350,000
		4	watershed	$30,000	$120,000
	Integrate models into system	11	watershed	$3,000	$33,000
	Train users	1	LS	$10,000	$10,000
	Test, confirm system prior to activation	1	LS	$10,000	$10,000
	Sub Total				**$628,000**
6. Promote use of NOAA weather radio and other NOAA public education campaigns	Design public education campaign	1	LS	$10,000	$10,000
7. Continue funding for Web site for sharing information with public	Acquire additional Web server hardware	1	LS	$24,000	$24,000
8. Provide a template for flood response plans for cities within Johnson County	Establish requirements, develop template, distribute	1	LS	$15,000	$15,000
Total					$1,140,300

Notes:
1. Costs do not include Johnson County or city staff costs.
2. Gage installation cost presumes all contract labor.
3. New repeaters would replace those at the Johnson County Public Works and Overland Park Public Works buildings.

Table 4. Probable acquisition cost of components of backbone system if outsourcing

Component (1)	Goods or services (2)	Quantity (3)	Unit (4)	Unit cost (5)	Extension (6)
1. Add gage-adjusted radar with alarms	Acquire and configure system and services	1	LS	$5,000	$5,000
	Train users	1	LS	$1,500	$1,500
	Implement data feed to Web site	1	LS	$12,000	$12,000
	Sub Total				**$18,500**
2. Add stream gages at 8 locations	Design, engineer sites	8	each	$1,000	$8,000
	Site acquisition and utility locate	8	each	$6,400	$51,200
	Acquire and install gages	8	each	$9,500	$76,000
	Sub Total				**$135,200**
3. Upgrade ALERT radio transmission system to dual frequency store-and-forward repeaters	Acquire new frequency	1	LS	$5,500	$5,500
	Acquire and install repeaters and add second antenna and receiver to both base stations	2	each	$14,000	$28,000
	Train on dual-frequency repeater operation	1	LS	$1,100	$1,100
	Sub Total				**$34,600**
4. Provide automated threat recognition system tool	Initiation of 24X7 service	1	LS	$9,000	$9,000
	Initial rule development	1	LS	$50,000	$50,000
	Sub Total				**$59,000**
5. Provide site-specific water level forecasting services	Initiation of 24X7 service	1	LS	$0	
	Prepare watershed and channel models	7	watershed	$50,000	$350,000
	Prepare watershed and channel models	4	watershed	$30,000	$120,000
	Integrate models into system	11	watershed	$3,000	$33,000
	Sub Total				**$503,000**
6. Promote use of NOAA weather radio and other NOAA public education campaigns	Design public education campaign	1	LS	$10,000	$10,000
7. Continue funding for Web site for sharing information with public	Acquire additional Web server hardware	1	LS	$24,000	$24,000
8. Provide a template for flood response plans for cities within Johnson County	Establish requirements, develop template, distribute	1	LS	$15,000	$15,000
Total					$799,300

Notes:
1. Costs do not include Johnson County or city staff costs.
2. Gage installation cost presumes all contract labor.
3. New repeaters would replace those at the Johnson County Public Works and Overland Park Public Works buildings.

Table 5. Probable annual recurring cost of components of backbone system, in-house operation

Component (1)	Goods or services (2)	Quantity (3)	Unit (4)	Unit cost (5)	Extension (6)
1. Add gage-adjusted radar with alarms (see attachment 1)	Real-time data	1	LS	$21,000	$21,000
	End of month analysis	1	LS	$36,000	$36,000
	Sub Total				**$57,000**
2. Add stream gages at 8 locations	Maintenance and repair	8	LS	$1,200	$9,600
3. Upgrade ALERT radio transmission system to dual frequency store-and-forward repeaters	System performance oversight	1	LS	$9,500	$9,500
4. Provide automated threat recognition system tool	Annual operation at 24X7 center	1	LS	$72,000	$72,000
	Annual training	1	LS	$10,000	$10,000
	Annual testing, confirming, fine-tuning	1	LS	$10,000	$10,000
	Sub Total				**$92,000**
5. Provide site-specific water level forecasting services	Annual operation at 24X7 center	1	LS	$72,000	$72,000
	Annual training	1	LS	$10,000	$10,000
	Annual testing, confirming, fine-tuning	1	LS	$10,000	$10,000
	Sub Total				**$92,000**
6. Promote use of NOAA weather radio and other NOAA public education campaigns	Annual public information "blitz"	1	LS	$15,000	$15,000
7. Continue funding for Web site for sharing information with public (labor)	Annual operation	1	LS	$10,000	$10,000
8. Provide a template for flood response plans for cities within Johnson County	No annual cost to County	0	–	$0	$0
Total					**$285,100**

Notes:
1. Costs do not include Johnson County or city staff costs.

Table 6. Probable annual recurring cost of components of backbone system if outsourcing

Component (1)	Goods or services (2)	Quantity (3)	Unit (4)	Unit cost (5)	Extension (6)
1. Add gage-adjusted radar with alarms (see attachment 1)	Real-time data	1	LS	$21,000	$21,000
	End of month analysis	1	LS	$36,000	$36,000
	Sub Total				**$57,000**
2. Add stream gages at 8 locations	Maintenance and repair	8	LS	$1,200	$9,600
3. Upgrade ALERT radio transmission system to dual frequency store-and-forward repeaters	System performance oversight	1	LS	$9,500	$9,500
4. Provide automated threat recognition system tool	Annual operation at 24X7 center	1	LS	$19,000	$19,000
5. Provide site-specific water level forecasting services	Annual operation at 24X7 center	1	LS	$40,000	$40,000
6. Promote use of NOAA weather radio and other NOAA public education campaigns	Annual public information "blitz"	1	LS	$15,000	$15,000
7. Continue funding for Web site for sharing information with public (labor)	Annual operation	1	LS	$10,000	$10,000
8. Provide a template for flood response plans for cities within Johnson County	No annual cost to County	0	–	$0	$0
Total					**$160,100**

Notes:
1. Costs do not include Johnson County or city staff costs.

Table 7. Probable replacement cost of components of backbone system

Component (1)	Goods or services (2)	Quantity (3)	Unit (4)	Unit cost (5)	Extension (6)	Replacement year (7)	Present value of replacement cost (8)
1. Add gage-adjusted radar with alarms	No replacement costs	0	–	$0	$0	–	$0
2. Add stream gages at 8 locations	Acquire and install gages	8	each	$9,500	$76,000	15	$33,440
	Acquire and install gages	8	each	$9,500	$76,000	30	$14,714
	Acquire and install gages	8	each	$9,500	$76,000	45	$6,475
	Sub Total						**$54,629**
3. Upgrade ALERT radio transmission system to dual frequency store-and-forward repeaters	Replace repeaters	2	each	$5,000	$10,000	15	$4,400
	Replace repeaters	2	each	$5,000	$10,000	30	$1,936
	Replace repeaters	2	each	$5,000	$10,000	45	$852
	Sub Total						**$7,188**
4. Provide automated threat recognition system tool	No replacement costs	0	–	$0	$0	–	$0
5. Provide site-specific water level forecasting services	No replacement costs	0	–	$0	$0	–	$0
6. Promote use of NOAA weather radio and other NOAA public education campaigns	No replacement costs	0	–	$0	$0	–	$0
7. Continue funding for Web site for sharing information with public	Replace server	1	each	$24,000	$24,000	5	$18,242
	Replace server	1	each	$24,000	$24,000	10	$13,884
	Replace server	1	each	$24,000	$24,000	15	$10,560
	Replace server	1	each	$24,000	$24,000	20	$8,033
	Replace server	1	each	$24,000	$24,000	25	$6,110
	Replace server	1	each	$24,000	$24,000	30	$4,646
	Replace server	1	each	$24,000	$24,000	35	$3,535
	Replace server	1	each	$24,000	$24,000	40	$2,688
	Replace server	1	each	$24,000	$24,000	45	$2,045
	Sub Total						**$69,743**
8. Provide a template for flood response plans for cities within Johnson County	No replacement costs	0	–	$0	$0	–	$0
Total							**$131,560**

Notes:
1. Costs do not include Johnson County or city staff costs.

Implementation plan

Required actions

It is recommended that implementation of the flood warning system be completed in two phases. The phases are as follows:

Phase 1: Acquisition and implementation of components. During phase 1, implementation of gage-adjusted radar and the addition of stream gages will be completed. Promotion of NOAA weather radio and adding a server for public information web site will be completed. The flood response template to be shared with communities within the County will be completed. Implementation of the threat recognition system will be completed in this phase, but tested in phase 2. Site-specific water level forecasting components will begin in phase 1, but will be completed in phase 2.

Phase 2: Testing of components and completion of model integration. During phase 2, both the threat recognition system and the water level forecasting components will be tested and confirmed by the service provider. Preparation of watershed and channel models, which begins in phase 1, will be completed and the models will be integrated into the water level forecasting system.

Schedule

If staff, funding and other required resources are available, it is recommended that each phase be completed within 1 year (4 quarters). The 8 quarters are shown in Figure 4 along with the associated tasks. Each quarter is discussed below. It is recognized that the actual implementation schedule may vary based on resource availability.

Quarter 1: The following actions should be taken in quarter 1:

- Acquire and configure system and services for gage-adjusted radar.
- Design and engineer sites for stream gages; begin acquisition of sites and utility locate.
- Acquire new radio frequency.
- Design, specify, and select automated threat recognition service and design, specify, select site-specific water level forecasting service.
- Begin work on public education materials.
- Begin to acquire additional web server hardware.
- Begin work on flood response plan template.

Quarter 2: The following actions should be taken in quarter 2:

- Train users on gage-adjusted radar; implement gage-adjusted radar data feed to Web site.
- Complete acquisition and utility locate for stream gage sites; begin acquisition and installation of gages.

- Acquire repeaters and add second antenna to both base stations; train users on the use of dual-frequency repeater operation.
- Complete preparation of public education materials
- Complete acquisition of Web server hardware.
- Continue work on response plan template.

Quarter 3: Following are actions that should be taken in quarter 3:

- Complete installation of stream gages.
- Begin to deploy threat recognition system at 24X7 site.
- Deploy site-specific water level forecasting at 24X7 site and begin to prepare watershed and channel models for forecasting.
- Continue work on flood response template.

Quarter 4: Following are actions that should be taken in quarter 4:

- Complete configuration of threat recognition system at 24X7 site.
- Continue to prepare watershed and channel models.
- Complete and distribute flood response plan template.

Quarter 5: Following are actions that should be taken in quarter 5:

- Continue with watershed and channel model preparation.
- Begin to integrate models into forecasting system.
- Begin testing of automated threat recognition system and of water level forecast system by service provider.

Quarter 6: Following are actions that should be taken in quarter 6:

- Complete watershed and channel model preparation and complete integration of models into forecasting system.
- Continue testing of automated threat recognition system and of water level forecast system by service provider.

Quarter 7: The following actions should be taken in quarter 7:

- Continue testing of automated threat recognition system and of water level forecast system by service provider.

Quarter 8: The following actions should be taken in quarter 8:

- Complete testing of automated threat recognition system and of water level forecast system by service provider.

Figure 4. Implementation plan