Flood Easements

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Paper presented at the Western Agricultural Economics Association Annual Meetings, Vancouver, British Columbia, June 29-July 1, 2000.

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FLOOD EASEMENTS
ABSTRACT

We examine the efficiency of current flood risk allocation and the use of flood easements as a means of reallocating flood risk and reducing total flood damages in large river floodplains. Changes in agricultural floodplain land use and levels of crop insurance coverage as the risk of flooding changes are simulated using mathematical programming. The net benefits of flood easements to a portion of the Lagrange Reach of the Illinois River region are then simulated. Our results indicate that flood easements may provide positive net benefits. This positive result stems primarily from the decreased risk of flooding for non-inundated agricultural levee districts, rather than from reduced municipal flood damages. Our results are robust to changes in the estimated dollar damages, yet extremely sensitive to changes in hydrological estimates.

Background

Levees and other flood protection devices provide protection to both agriculture and municipal developments in the floodplain. Individual levee districts have an economic incentive to construct levees up to the point where the district's marginal benefit from increasing levee height equals the district's marginal cost of levee construction. However, an increase in an individual levee's height increases the probability that other nearby levees will be topped or breached. Since individual levee districts fail to account for this affect, a negative externality exists. So, from a social perspective, the current allocation of flood risk may be inefficient.

In Illinois, levee construction was not regulated until 1921 and numerous levee construction projects for agricultural purposes were undertaken prior to regulation. Landowners in these districts took advantage of the reduced probability of flooding to their land, but paid little attention to the externalities the levees imposed on the river and other residents. The Division of Waterways of the State of Illinois stated in a 1937 report that ". . . the districts in their eagerness to reclaim every possible acre from the floodway of the Illinois River, set up a series of levee systems which have encroached unduly on this floodway and raised the flood heights of the river to the detriment of the success of many of these districts" (State of Illinois, Department of Conservation p 26).

As flood waters exceed a river's capabilities to convey water, it may be more efficient to intentionally inundate low-capital areas in order to protect other areas, particularly those with high amounts of capital investment. We investigate the use of flood easements as a tool for reducing flood risk and expected damages to capital-intensive levee districts (*i.e.,* municipalities and high-value agricultural districts). Under flood easements, landowners retain property rights and continue to optimally operate the land given the increased probability of flooding. We examine the impact of alternative intentional flooding of agricultural levee districts on the conditional probabilities of flooding other levee districts, both agricultural and municipal. The changes in landowner welfare are used to estimate the costs of implementing flood easements. The results of this land-use model are then incorporated into the flood easement model to determine the expected benefits and costs of instituting the easements. The model accounts for both the changes in expected damages to municipalities and agricultural levee districts in the region.

Previous Work

The idea of using agricultural levees to provide flood storage is not novel and can be traced back to 1915 (refer to the State of Illinois River and Lake Commission). However, previous empirical work (U.S. House Document 1931 and 1942) examines the outright purchase of agricultural land in levee districts and wholesale conversion to flood storage and wildlife habitat. Studies on the procedures for estimating agricultural flood damage include work by Singh (1976) and Eidman and Lacewell (1974).

In the 1950's, Gilbert White (Moore and Moore) examined the impact of flood control structures and their relation to flood damages. He concluded that for each six dollar reduction in flood damages from new structural measures came at least an additional five dollars in potential new flood damages.

In 1970, Brown outlined the theoretical rationale for increased private capital investment when the risk of flooding is reduced. He concludes that with a reduction in the risk of flooding, the most profitable land use leads to increased capital intensity. Thus, while billions have been invested in flood control, flood damages continue to rise. However, he contends that this does not condemn the government projects nor imply irrationality of the landowner since the landowner's goal is to maximize net returns less damages. Unfortunately, floodplain landowners have been allowed to retain the benefits of flood control projects while the government has largely born the cost of the flood control project as well as flood damages, resulting in greater development of floodplains (Stavins and Jaffe). This point was previously made by Kurtilla (1966) when he suggested that flood insurance should be compulsory.

Following the 1993 midwest floods, several studies were undertaken by the federal government. Most prominent of these studies is the Interagency Floodplain Management Review Committee report *Sharing the Challenge: Floodplain Management into the 21st Century* (Interagency Floodplain Management Review Committee 1994a), commonly called the Galloway report after the executive director Brigadier General Gerald E. Galloway. The Galloway report examines the policies in place at the time of the 1993 flood and outlines alternatives to improve floodplain policy. The accompanying report *Science for Floodplain Management into the 21st Century* (Interagency Floodplain Management Review Committee 1994b) provides a scientific assessment of the 1993 floods and outlines how science can help improve floodplain policies and decisions.

The United States Army Corps of Engineers (1995) estimates the hydrologic conditions and economic impacts of alternative floodplain management policies had they been in place during the 1993 flood. Alternative actions examined by the Corps on agricultural levees include: limiting flood fighting and removing, lowering (to the 25-year height), and raising (to confine the 1993 floods) the levees. (Flooding risk and levee protection are often referred to as "x-years," meaning that the probability of flooding is 1 in x. So, a 25-year levee height or flood risk implies that the district will flood, on average, once in every 25 years.) These results are reported at the Corps district level and do not account for any changes in land use under the new policies.

The United States General Accounting Office points out that four of the nine states involved in the 1993 flood have no specific regulatory programs for nonfederal levees. (Illinois is one of the four.) They conclude that levees did increase the height of water during the 1993 floods, but that many other factors also contributed to river stages.

Several other studies have emerged from the aftermath of the 1993 Midwestern floods. Cassidy and Althaus examine the impact of not repairing 355 ‘inactive’ levees in Missouri and conclude it would expose approximately 478,000 crop land acres that have an estimated annual crop production value of $200 per acre. If this land was not in production, there would be a decrease in economic activity of $208 million and have a potential job loss of 3,200 jobs in Missouri. Taylor, Penson and Alt examine placing 7.8 million acres in a “noncropped” floodway reserve. Landowners would be paid an average of $125 per acre per year. This would cost the federal government almost one billion dollars annually. However, the authors estimate that the increase in feed and livestock prices would reduce other government subsidies and lower the programs costs to 700 million dollars in 1994. Furthermore, they estimate that the cost would approach zero by the end of 1999, presumably by replacing government farm subsidies.

This issue has recently resurfaced. In October 1999, FEMA and USDA proposed a pilot program to use agricultural land to store flood water (Springer). The proposed program is in response to widespread flooding in North Dakota and Minnesota in 1997 and the 1999 catastrophic flooding in North Carolina caused by Hurricane Floyd. The proposed program would be funded under the 2001 farm bill. The research reported here is similar to the FEMA/USDA proposal.

Study Area

The selected study area is along the Illinois River in the Lagrange reach. This segment of the floodplain has a diverse mix of agriculture and municipal levee districts and has experienced floods that equal or have exceeded the designated flood stage annually since 1978 (Kingston and Taylor). According to the State of Illinois Department of Conservation, levees are largely responsible for increasing flood heights by 10 feet at Beardstown.

The United States Army Corps of Engineers has estimated the storage capacity of selected levee districts along the Illinois River and the crest reduction that would be obtained by flooding the districts during a “superflood” (computed to be an elevation of 452.2 at Beardstown) assuming a 10-day filling period. The crest reduction values range from 0.07 feet to 0.85 feet at Beardstown, IL; 0.02 feet to 0.23 feet at St. Louis, MO; and 0.02 feet to 0.18 feet at Cairo, IL (U.S. House Document 692-77-2, 1942). Using the 1992 UNET model calculations, a “superflood” is approximately a 200-year flood. The crest reduction benefits are limited only to those districts in the study area; however, it is recognized that additional benefits exist to other districts both down and upstream.

Singh (1996) reports that the reduction in flood peaks from having the levees removed is not as great as it would be with flood peak storage in an agricultural levee district if the district is flooded near the river’s crest. Since under levee removal, the area would already be inundated prior to the river’s crest, reducing the capability to reduce the flood’s crest. Using the UNET model, Singh shows a crest reduction of 2.34 feet could be reached by inundating a district of 10,000 acres. The district would be able to be farmed since flooding would occur only once every 10 to 20 years.

Analytics of Levee Externalities

We address the problem from the perspective of a social planner maximizing social welfare and compare the resulting solution to that of each individual levee districts maximizing the expected return of that district. The first-order conditions derived identify an excess investment in levees due to the unaccounted negative externality that levee construction in one district imposes on other districts. This result stems from the assumption that as the height of one levee district is increased, the other districts' welfare decrease due to an increase in the probability of flooding. Since the individual levee district considers only their private marginal cost, the negative impact on other districts is not internalized, leading to an over-investment in levees.

First, we derive sufficient conditions for inefficient allocation of flood risk to exist by comparing the socially optimal levee heights to individual levee heights. Then we test the hypothesis that current flood risk is inefficiently allocated by investigating the impact of intentionally inundating various combinations of agricultural levee districts during high-water events. We compare the resulting social welfare with the existing social welfare. If one or more of the intentional flooding strategies results in higher social welfare, we conclude that the current allocation is inefficient.

We represent the social planner by summing the welfare across levee districts. The planner must determine the mix of land use activities in each district and the optimal levee height of each district, given the endowment of capital in each district. Some of the activities considered have multi-year cash flows (*e.g.*, forests, pastures, and forage crops). To allow for this, the stream of returns associated with each activity is converted to an annualized equivalent return. The returns for district *j* are represented as $R_j(a_j, \bar{z}_j, L)$ where $a_j = (a_{1j}, a_{2j}, \ldots, a_{Aj})$ is a vector of the number of acres devoted to activities1 through *A* in district *j*, $\bar{z}_j$ is the fixed value of capital located in district *j*, $L = (l_1, l_2, \ldots, l_D)$ is the vector of heights of the levee districts, and D is the number of districts.

Further, we allow these returns to vary. We vary crop yields by using county averages for 15 years. Also, yields for crops and timber production are allowed to vary due to flooding. Prices are varied using historical data (15 years) and assumed to be independent of yields.

The planner's problem then is to maximize the sum of expected annualized returns across districts (*SW*) or

$$\max_{a,L} SW = \sum_{j=1}^{D} E[R_j(a_j, \bar{z}_j, L)] \ . \qquad \textbf{(1)}$$

If capital and levee heights are fixed, the optimal combination of activities is the same for both the social planner and the individual levee districts. But, we explicitly assume that as the levee height in district *k* (not equal *j*) increases, the risk of flooding in district *j* increases consequently, decreasing the expected returns from district *j*. So,

$$\frac{\partial E[R_j(\cdot)]}{\partial l_k} < 0 \quad \forall \quad l_k \neq l_j. \qquad \textbf{(2)}$$

The social planner's first-order conditions require

$$\frac{\partial SW}{\partial a_{ij}} = \frac{\partial E[R_j(\cdot)]}{\partial a_{ij}} = 0 \ \forall \ i, j \qquad \textbf{(3a)}$$

and

$$\frac{\partial SW}{\partial l_k} = \frac{\sum_{j=1}^{D} \partial E[R_j(\cdot)]}{\partial l_k} = 0 \ \forall \ k \ . \qquad \textbf{(3b)}$$

At the optimum, the marginal benefit from increasing the height of levee district *k* equals both the additional cost of installing and maintaining the levee and the additional cost imposed on the other levee districts (*i.e.,* increased flood risk).

We model the objective of each individual levee district as the maximization of the district's expected returns or:

$$\underset{a_i,\, l_j}{Max} \ E[R_j(a_j, \bar{z}_j, L)]. \qquad \textbf{(4)}$$

The first-order conditions require:

$$\frac{\partial E[R_j(\cdot)]}{\partial a_{ij}} = 0 \qquad \textbf{(5a)}$$

and

$$\frac{\partial E[R_j(\cdot)]}{\partial l_j} = 0. \qquad \textbf{(5b)}$$

The individual levee district's expected return is maximized where the marginal benefit of increasing the levee height equals the marginal private cost of constructing and maintaining the levee. This result differs from the theoretical optimum of the social planner since the negative externality of increasing the levee height on other districts is not considered. This argues that levees are higher than is socially optimal. It is this hypothesis that we test.

Overview of Hypothesis Testing

To test our hypothesis, we first derive estimates of the crest reduction provided by intentionally inundating a given levee district. (We refer to this distict as “A” and subsequent districts that are intentionally flooded are called “B”, “C”, ...) From these crest reduction estimates, we derive the conditional probabilities that other levee districts will be flooded if district A is intentionally flooded. We similarly derive conditional probabilities that other districts will be topped for any given flooding sequence (*i.e*., any sequence including districts A, B, C, D, and/or E).

Given the conditional probability that a district will be flooded, we then determine the optimal land use and maximum expected annualized returns. By varying the conditional probabilities (through an intentional flooding sequence) and observing the change in expected returns, we can determine the gains or losses to each of the levee districts (including municipal levee districts) of a given flooding sequence. Then summing the gains and losses gives us the net benefit of any flooding sequences. If one or more sequences result in a positive net benefit, a potential Pareto improvement exists and we conclude that current flood risk is inefficiently allocated.

Conditional Probabilities of Flooding

Estimating the conditional probabilities of a district flooding, with other districts being inundated, is critical in estimating the willingness-to-accept payment and the reduction in flood damages to protected districts using flood easements. Employing the 1942 U.S. Army Corps of Engineers estimates (U.S. House Document 1942), we estimate this probability as described below.

A selected district will be flooded for crest reduction purposes when the river exceeds a specified height. Thus, when districts are flooded sequentially the probability of the river exceeding a specified level is reduced due to the crest reduction provided by the other flooded districts. For example, consider an intentional flooding sequence A, B, C. If the river reaches a predetermined stage, district A is intentionally flooded. If the river then reaches the next threshold stage, B is flooded. Similarly for C. Given A is flooded first, the probability that the river will reach the next threshold is diminished. So, the probability that a given district will be intentionally flooded is conditional on the districts to be flooded earlier in the sequence. Also, the probability that other levee districts will be topped or breached is conditional on the districts previously flooded. It is this added flood protection that potentially justifies inundating low-capital districts.

We need to estimate 1) the annual probability of flooding and 2) given that a flood occurs, when within the year the flood occurs. Estimates of flood frequencies are obtained using mathematical models, such as the UNET model, to simulate flows. UNET is a one-dimensional, unsteady flow model developed by Dr. Robert Barkau and used by the U.S. Army Corps of Engineers. The model accounts the timing of inflows, as well as the backwater effects, and is capable of estimating the crest reduction under scenarios such as levees breaching or overtopping. The model uses U.S. Geological Survey (USGS) 7.5 minute quad sheets to characterize the geometry cross sections. Data from the USGS gauged stations and estimated inflows from ungauged drainage areas provided inflow information (U.S. Army Corps of Engineers 1995). This study uses the U.S. Army Corps of Engineers 1992 flood frequency estimates for the Illinois River as an estimate of the annual probability that a given levee district will be flooded. (Note, not all levee districts within the study area have the same height. So, some districts flood more frequently than others.) The annual flood frequency for each of the levee districts is reported in Table 1.

To determine the flood frequencies within a year, it is assumed that the probability of flooding occurring in any particular time period (monthly or bi-monthly) is equal to the number of days above flood stage in that period divided by the total number of days above flood stage. Using daily flood stages at both the Havana (1960-1996) and Beardstown (1955-1996) gaging stations, the monthly and bi-monthly probabilities of flooding are estimated. During the spring and fall months, bi-monthly estimates are employed to more accurately reflect the economic costs, particularly to agriculture, of flooding. The monthly flood frequencies, given that flooding occurs within a levee district, are reported in Table 2.

Optimal Land Use Activity

Both the social planner and individual levee district owner seek the optimal land use activity considering the flood frequency of the district. Using GAMS (Brooke, Kendrick and Meeraus), the optimal land use activities at each level of flood risk are simulated.

Producer Returns

The producer's objective is to maximize the net returns to the land. Net returns include the returns from commodity sales, crop insurance payments, and the leasing of hunting rights given a probability of flooding. A land payment is not charged in the model, thus returns are to land, capital, management, and unpaid labor. (Recall we are comparing returns under the current flood risks to returns under an intentional flooding sequence. So, we assume that opportunity costs of land are unchanged.) Revenues and costs of crops such as timber, forage, and pasture which have production cycles greater than one year are converted to an annualized equivalent return for comparison with the other annual crop alternatives. We incorporate the risks associated with flooding and all other risks are represented by deviations in county average production. We assume that flood risks can be partially offset by purchasing crop insurance. Since other individual risk factors such as wind, hail, and fire are not specifically modeled, our model does not allow producers to insure against these risks.

The model selects the optimal land use given the various costs of each crop insurance program and the crop insurance program yielding the greatest expected net return. It is assumed that levee heights are fixed at the current level. (Later, we model intentionally breeching levees, *i.e.*, reducing their heights to examine the impact of alternative levee heights.) The expected profit maximization model for district j is written as:

(6)

$$\begin{aligned}\underset{a_{b,m},\ CIP_b}{Max}\ E[R_j(\cdot)] = {} & [(1-p)\sum_{b,m} NR^{nf}_{b,m}\ a_{b,m}] + [p\sum_{b,m} NR^{f}_{b,m} PB_m a_{b,m}] \\ & - I(CIP)\, a_{b,m} + \sum_{s,b,m} HNT_s^{*}\, HSI_{s,b,m} a_{b,m}\end{aligned}$$

subject to

(7)

$$\sum_{b,m} a_{b,m} \ \le\ \bar{a}_j$$

and

(8)

$$\sum_{b}\ a_{b,m} \ \le\ PP_{b,m}\,\bar{a}_j \quad \forall\, m$$

where,

b	index of crop activity
m	index of time period within a year (bimonthly)
s	index of species
p	annual probability of flooding
NR^{nf}	expected net returns in non-flood years (revenues less costs)/acre
NR^{f}	expected net returns in flood years (revenues plus crop insurance payment less costs and damages to fields)/acre
PB_m	conditional probability of flooding in time period m
I	crop insurance premium which is a function of the crop insurance program (CIP)
HNT_s^*	maximum lease value of hunting rights for species, s
$HSI_{s,b}$	Habitat Suitability Index for species s, in land use b at time period m
$a_{b,m}$	land use in each crop activity planted in time m (endogenous variable)/acre
$\bar{a}_j$	total land available in district *j* (acres)
$PP_{b,m}$	percent of crop plantable based on work day probabilities.

Modeling constraints include acres planted can not exceed the number of acres available (7), and the percent of crop planted in each time period can not exceed the average percent of crop planted by bi-monthly time period, based on historical data for Illinois (8). The rational for this constraint stems from the fact that while farmers would like to plant their entire crop in early spring, labor and machinery limitations and weather prevent them from consistently getting into their fields at that given time period.

We assume constant returns to size and fixed input prices. Given the assumption of constant returns to size, the optimal combination of activities on one acre of land in the district is optimal for all acres in the district at the given level of capital endowment and flood protection. Constant returns to size allows for the modeling to be completed on a single unit, such as an acre, and the results linearly transformed for larger farm sizes. The enterprise budgets are based on operations of approximately 500 acres. Budgets also vary by planting date.

The model also allows landowners to receive income from the leasing of hunting rights. Land along the Illinois River provides habitat for numerous species ranging from whitetail deer to migrant waterfowl, such as Canadian geese[1]. Land, regardless of its use, provides some form of habitat for wildlife. This joint product can be partially captured by landowners through the leasing of hunting rights. The price land owners are able to command for hunting leases depends on the quality of habitat the land provides. To estimate the variation in habitat quality and resulting rental price, a Habitat Suitability Index (HSI) is adapted from three studies, Heitmeyer; Allen; and Short. The HSI is used to measure the habitat quality of each alternative land use. The rental rates associated with land uses and the corresponding HSI's are given in Table 3.

Results of Land Use Model

For various levels of flood protection, we determine the optimal activities within each district. We assume that the maximum level of protection for an agricultural district is a 200-year flood frequency equivalent. The marginal cost of increasing the level of protection beyond 200 years would certainly not be offset by the additional agricultural returns. Districts in the study area with levels of flood protection higher than 200 years are also protecting non-farm residents.

The profit-maximizing land use for all flood frequency levels except for the two-year flood is a combination of corn and soybeans; however, the optimal crop insurance level varies. At the two-year level of flood protection, enrolling the land in a CRP/WRP program becomes the optimal land use. The results concur with the findings in the main report of *Floodplain Management Assessment of the Upper Mississippi River and Lower Missouri Rivers and Tributaries* by the United States Army Corps of Engineers which observes that corn and soybean production occurs up to the two-year flood zone (U.S. Army Corps of Engineers 1995).

When the risk of flooding is relatively low (less than two percent annually), not purchasing crop insurance is the optimal choice, and only marginally more profitable than purchasing Minimum Catastrophic Risk Protection (CAT). This result likely stems from the fact that flooding is the main focus of the study and other than the deviations in annual yields, other risk factors facing producers such as drought and hail are excluded from consideration. As the risk of flooding increases, the optimal crop insurance yield coverage level increases from zero insurance to 50 percent yield coverage for the 25-year level of protection and 65 percent yield coverage at the ten-year level of protection. The 65 percent yield coverage level has the highest subsidization rate. At the five-year level of flood protection, land is considered a high-risk investment and is given the AAA-risk rating. At this higher insurance premium, it becomes optimal to purchase crop insurance with only 50 percent yield coverage, since the premiums for greater levels of yield coverage outweigh the benefits of purchasing the additional protection. At two-year level of flood protection, the land is entered in CRP/WRP. There is a difference in expected returns based on the selected level of crop insurance. Most notable is the five-year level of flood protection, a 50 percent yield coverage has an expected return of $94.13, while the 70 and 75 percent yield coverage levels have an expected return of only $82.34, a difference of $11.79.

Given the optimal crop insurance yield coverage, the maximum expected net returns and optimal land use are shown in Table 4. Note that the percent of crops planted in each bi-monthly time period remains constant over all levels of flood protection except the two-year level of protection. The optimal land use remains constant for all other levels of flood protection.

The binding constraints for flood protection levels of five years and greater are the land available constraint, the amount of corn that can be planted in late April, and the amount of soybeans that can be planted in early May. The corn and soybean rotation yields the highest expected net returns for all levels of flood protection except the 2-year level of flood protection.

Flood Damage and Mitigation

The easement model maximizes the net benefit of implementing flood easements on selected agricultural levee districts to test the inefficiency hypothesis. The model accounts for the expected damages that would occur if the district were flooded and the change in net returns as the optimal land use changes due to an increase in the probability of flooding. Structural capital in districts selling easements would be purchased to eliminate further damages when flooded. The model accounts for the changes in expected annual damages when flood risk is reallocated by changing the probability of flood risk facing each district.

Using the given flood frequency levels and levee heights, the current level of flood protection is estimated for each district. The current expected flood damages of each district are estimated using the flood frequencies and amount of capital in each district. The estimated reduction in flood peaks determined in the U.S. Army Corps of Engineers study are used to examine the changes in flood damages when the heights of selected levees are reduced.

Municipalities incur damages differently depending on the presence of levees. If no levee is present, municipalities suffer marginal damages as the water rises. On the other hand, municipal and industrial districts with levee protection suffer minimal damages from surface water prior to the levee topping. However, since most buildings are located well below the levee top, incremental damages are extremely large when the levee is overtopped and the district is inundated. While it is recognized that ground water flooding, piping, and seepage are present prior to overtopping, these damages are not modeled since levee height does not change the damages they cause (United States General Accounting Office). The model does not account for multiple flood occurrences within a given year.

With ten districts in the study area, we consider 2,560 combinations with up to five of these districts being flooded sequentially. The expected annual net benefit of a given sequence is computed as:

(16)
$$NB(k) = \sum_{j=1}^{10} \text{Ä}E_j[R(\cdot)\,|k] - C(k)$$

where

k	flooding sequence = 1,2, . . . ,2560;
NB(k)	net benefit of flooding sequence k;
C(k)	annualized structural capital payments with sale of easement;
$\text{Ä}E_j[R(\cdot)\,\|k]$	change in expected annual returns given the probability of flooding.

For agricultural districts flooded, $\text{Ä}E_j[R(\cdot)\,|k]$, the change in expected returns is negative; for other agricultural districts and municipal levee districts it is greater than zero. For municipal levee districts, $\text{Ä}E_j[R(\cdot)\,|k]$ is measured by the reduction in expected flood damages. In the case of agricultural districts, farmers are assumed to act optimally given the conditional probabilities of flooding (as determined by the land use model).

The damages to municipalities are computed using estimates from the Army Corps of Engineers. The damages consist of the structural and content damages to residential and commercial structures. Commercial damages also consist of the lost revenue that occurs due to the days out of business when flooding occurs. Damages to public facilities consist of damaged water supplies, sewers, and other public areas such as city parks and recreation facilities. The last measure is the cost of disrupted water and electrical services to residents of the city when lost during a flood. These factors make up the total damages to a municipality. The total city damages when flooded are $4,821,202 for Liverpool, $5,234,754 for Browning, and $138,214,600 for Beardstown. Damages to those villages and municipalities without levees are determined by using the stage-damage data for split-level homes (U.S. Army Corps of Engineers 1992) and an estimate of the portion of the town at each flood frequency level.

To test the hypothesis that the current allocation of flood risk is inefficient, the easement model combines the given crest reduction capabilities of each levee district and the expected annual flood damages currently and under sequential flooding of up to five districts, with the results from the land use model. In other words, the model simulates the changes in expected damages and returns from the districts and municipalities to determine if there is a net benefit to reallocating the flood risk through intentionally flooding agricultural levee districts. The study looks at the net benefits of exercising the easements at the ten-year flood. Assuming that up to five levee districts may be flooded, a Fortran program is used to determine the different combinations of flooding one to five of the ten levee districts. A district that is flooded second in the sequence benefits from the crest reduction of the first levee district. Likewise the third, fourth, and fifth districts flooded in each combination benefit from previous crest reduction provided by the other districts.

The crest reduction provided by each combination is computed, and the changes in the level of flood protection for both municipalities and districts are determined. These values are used to determine the expected annual damages under each combination. It is assumed that if a district is included in the combination, all capital structures, both farmsteads and residencies, are bought out. Thus, districts selling easements have no more expected annual damages for farm structures and residencies. However, pump and road damage still exist in districts selling easements. These costs of purchasing these structures are converted to an annualized value over a 30-year time frame at a nine percent discount rate, the assumed private cost of capital. Sensitivity analysis shows the impact of reducing the discount rate.

The changes in expected annual net returns from crop production in each levee district are determined by subtracting the optimal land use net returns under the new level of flood protection from the current expected net returns from the optimal land use. These values include the cost of clean-up and restoring soil tilth. It is assumed that there is no additional costs in levee repairs for districts that are flooded. When districts are flooded, the pressure on both sides of the levee are equalized preventing “blow-outs.”

Easement Model Results

The model assumes that the easements will be exercised at the level of the ten-year flood. The model calculates the current expected annual damages to municipalities and districts in the study area. Of the 2,560 different combinations of district flooding, 20 have a net positive benefit. In Table 5, those flooded sequences with the ten highest net benefits are reported. By far, the largest benefit is from intentional flooding of the Thompson Lake levee district when a ten-year or greater flood is realized. The net benefit of this action, $697,937, is more than double the next closest flooding sequence. The second highest net benefit, $313,778, comes from flooding Thompson Lake and then Kelly Lake levee districts. These results support the hypothesis that current flood risk allocation is inefficient.

Combinations that are extremely negative include flooding the Sid Simpson project which consists of numerous residential homes and currently has a flood protection level of 380 years. While the district provides the greatest amount of crest reduction, the cost of buying out capital and the large difference in agricultural returns produces an extremely negative net benefit.

Sensitivity Analysis

To examine the robustness of the results, selected variables are varied and the results examined. The results are based on the purchase of an easement from the Thompson Lake levee district. If the discount rate is reduced from nine percent to five percent, the net benefit of the easements policy increases $802,056. A lower discount rate reduces the annualized cost of purchasing capital in the area and the installation of flood gates. If the loss of stored grain is reduced to zero by transporting the grain out of the floodplain, the net benefit is reduced by $28,539, since the added flood protection to other districts does not reduce the loss of stored grain. If the city damages are reduced by half, the net benefits decrease only $175,320; however if agricultural district damages are reduced by half, net benefits decrease by $606,332.

The results are relatively robust to variations in the dollar amount of damages. However, when the required freeboard is varied, the results vary greatly. When the two-foot required freeboard for districts and three-foot required for municipalities with levees is reduced by one-half of one foot, the net benefit of flood easements becomes a net loss of $168,626 annually. The change from a net positive benefit to a net loss stems from the changes in levels of flood protection to each district and municipality with levees. The Thompson Lake district present level of flood protection increases to a 15.63 year level of flood protection up from the previous 12.5 year level of flood protection. (With only a six-inch decrease in required freeboard, the agricultural districts’ levels of protection increase to 15.63 to 480 years of flood protection from 12.5 to 380 years of flood protection.) Thus to compensate for lost production, the easement payment is higher. In addition, the other districts and municipalities with levees have greater levels of flood protection. Consequently, the change in expected agricultural returns decreases to -$541,848 down from positive $54,450. The per acre payment to Thompson Lake for changes in expected agricultural returns increases to $8.96 from $3.98. Since all agricultural and municipal districts have higher levels of protection, the expected reduction in flood damages are reduced. The annualized cost of buying the capital in the district selling an easement and the cost of installing a gate for easements to function remain the same. If the freeboard requirement is cut in half, the expected annual benefit of implementing flood easements decreases to -$574,409. This emphasizes the importance of reliable hydrological estimates in determining the net benefits of flood easements.

Conclusions

Floodplain managers face a complex balancing act as economic activity in the floodplain often competes with the forces of nature that built the floodplain. Following the 1993 floods, the need to evaluate current floodplain policy and assess alternatives was recognized. We investigate flood easements as a possible alternative and find that the current allocation of flood risk is inefficient.

We employ flood frequency information to determine the current levels of flood protection in each district and the frequency at which flooding is expected to occur. This information is used in the agricultural model with enterprise budgets of selected land use alternatives in the floodplain to determine the optimal land use at each level of flood protection. The model is solved for a profit-maximizing producer. The results of the agricultural land use model find that a corn-soybean rotation is the optimal land use for most levels of flood protection. When the level of flood protection decreases to 2 years, the optimal land use switches to entering the land into the government sponsored Conservation Reserve Program or Wetland Reserve Program (CRP/WRP). These programs provide a constant annual payment to retire land into approved land uses.

The flood frequency and agricultural land use model results are then incorporated into the easement model. The easement model tests the inefficiency hypothesis by estimating the net benefits of implementing flood easements. The model results indicate that other agricultural levee districts gain the greatest benefit from the implementation of flood easements followed by municipalities. The results however are sensitive to changes in the hydrological assumptions, stressing the importance of further hydrological research. Based on the results, we conclude that the current allocation of flooding risk is inefficient, since there is a net positive benefit in implementing flood easements and a potential Pareto improvement exists. This suggests the need for policies to alleviate this inefficiency. Current policies of subsidized insurance and levee construction and maintenance further the problem

Table 1. Current Flood Protection Levels for Agricultural Districts in Years

District		Flood Protection Level[*]
Number	Name	
1	East Liverpool	50
2	Liverpool	50
3	Thompson Lake	12.5
4	Lacey, West Matanza, Kerton Valley	63.4
5	Seahorn	18.75
6	Big Lake	21.74
7	Kelly Lake	183.33
8	Coal Creek	175
9	Crain Creek	25
10	Sid Simpson	380

[*] Flood protection is given in years. For example, a flood protection level of 50 years implies that a district will flood one out of fifty years.

Table 2. Conditional Probability of Flooding by Month and Bi-Month

Month	Conditional Flood Probability[*]		
	Monthly	Bi-monthly early	Bi-monthly late
Jan.	6.95%	NA[**]	NA
Feb.	NA	3.962%	3.929%
Mar.	NA	5.709%	7.287%
Apr.	NA	8.093%	10.242%
May	NA	10.813%	9.234%
June	NA	6.347%	5.306%
July	6.31%	NA	NA
Aug.	2.71%	NA	NA
Sept.	NA	0.571%	0.940%
Oct.	NA	2.082%	1.444%
Nov.	NA	0.537%	1.545%
Dec.	5.84%	NA	NA

[*] Derived from daily river stage data at Havana, IL (1960-1996) and Beardstown, IL (1955-1996).
[**] Not applicable.

Table 3. Habitat Suitability Index (HSI) and Hunting Lease Rates ($/acre)

	Deer		Waterfowl	
Crop	HSI	$/acre[*]	HSI [**]	$/acre
corn	0.6	9.00	0.80	24.00
soybeans	0.4	4.50	0.06	1.80
forages	0.4	4.50	0.00	0.00
pasture	0.6	9.00	0.00	0.00
trees	0.6	9.00	0.07	2.10
CRP/WRP	0.6	9.00	0.90	27.00

[*] Hunting lease rates are based on a maximum (*i.e.*, HSI equal 1) lease rate of $15 per acre and $30 per acre for deer and waterfowl, respectively.

[**] Adapted from Heitmeyer; Allen; and Short.

Table 4. Expected Net Returns and Optimal Land Use as a Percentage of Acreage

Protection Level	Crop Insurance Yield Coverage	Expected Net Returns	Late April Corn	Early May Corn	Early May Soybeans	Late May Soybeans	CRP/ WRP
200	0%	$194.24	27.75%	22.25%	31.5%	18.5%	0%
100	0%	$191.57	27.75%	22.25%	31.5%	18.5%	0%
50	0%	$186.04	27.75%	22.25%	31.5%	18.5%	0%
25	50%	$176.42	27.75%	22.25%	31.5%	18.5%	0%
10	65%	$152.52	27.75%	22.25%	31.5%	18.5%	0%
5	50%	$94.13	27.75%	22.25%	31.5%	18.5%	0%
2	N/A[*]	$67.34	0%	0%	0%	0%	100%

[*] Crop Insurance is not applicable for CRP/WRP.

Table 5. Crest Reduction for Flooding Sequence of Districts with the Highest Net Benefits

		Sequence of Districts Flooded	
Crest Reduction	Net Benefit	First District	Second District
0.52	$697,937	Thompson Lake	N/A
0.59	$313,778	Thompson Lake	Kelly Lake
0.59	$278,456	Kelly Lake	Thompson Lake
0.79	$150,918	Thompson Lake	Big Lake
0.79	$148,168	Big Lake	Thompson Lake
0.27	$147,188	Big Lake	N/A
0.38	$103,689	Crane Creek	N/A
0.51	$90,435	Big Lake	Liverpool
1.29	$89,933	Lacey, Langellier, West Matanza, Kerton Valley	Thompson Lake
0.51	$86,534	Liverpool	Big Lake

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Footnotes

1.According to Jim Raspis of the Illinois Department of Natural Resources, the leasing of hunting rights for white-tail deer is driving much of the market in west-central Illinois with hunting rights selling for $3 to $17 per acre for white-tail deer. Waterfowl hunting leases along the major rivers in Illinois are also at a premium. According to Andy French, former Manager of Illinois River Wildlife Refuges, there are over 350 duck clubs along the Illinois River. Raspis reports an example of a 1,000 acre tract located along the Mississippi River which rents for $37.50 per acre annually.