Flood Risk Management Economics 101

Kurt Keilman – Economist
South Pacific Division

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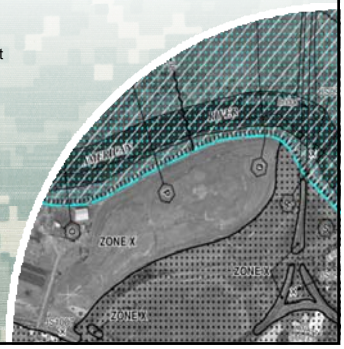

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Purpose

- Economic Analysis – Flood Risk Management
  - ▸ Address the Problems and Objectives of Group, Individual or Agency
  - ▸ Performed to level based on resources, resolution needed for plan selection, stakeholder concerns
  - ▸ Corps Perspective:
    a) Identify magnitude of the problem, benefits of alternatives
    b) Determine metrics to assist in establishing Federal Interest
    c) Provide information to help prioritize Federal Investment

Agenda

- Basic Economic Terms
- Corps Specifics
- Basic Flood Risk Concepts
- Computation of Consequence
- Integration of Engineering and Economics
- Tools of the Trade
- Direction for the Future

Economic Benefits and Costs

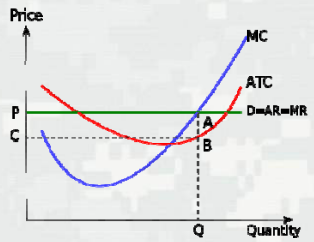
- Need to differentiate between Opportunity Costs and Financial Costs
- Opportunity costs: is the cost of any activity measured in terms of the best alternative forgone. It is the sacrifice related to the second best choice available to someone who has picked among several mutually exclusive choices.
  - What you give up – either explicit or implicit (example project related – you own land currently not being used – if it becomes a project use, therefore a project economic cost – even though no cash is required – implicit, another potential use is given up)

Nominal vs. Real Prices

- **Real value** adjusts nominal value to remove effects of price changes over time. For example, changes in the nominal value of some commodity bundle over time can happen because of a change in the quantities in the bundle *or* their associated prices, whereas changes in real values reflect *only* changes in quantities
- **Real Prices** – relative quantities over time expressed in prices of one year, called the *base year*

Marginal Analysis

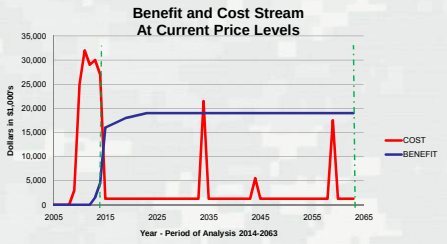
Basic Micro-econ > optimize > marginal revenue = marginal cost



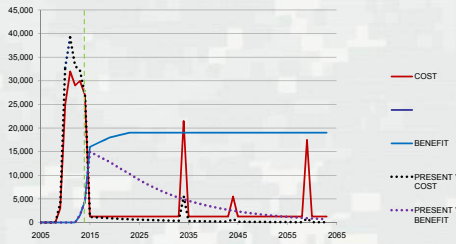
Time Value of Money

- Present value – future benefits and costs are discounted based on interest – higher the interest rate lower the present value
- Some life cycle costs include values prior to base year (By-1, By-2, By-3 the discount rate increases present value of costs)
- The adjustment represents what an investment/expenditure could return over time as different use

Time Value of Money – Period of Analysis



Present Value – Benefit Cost @ 7 Percent



Annualized Values

- Why do we use annualized values – to compare costs and benefits at an equal time – 'apples to apples'
- Period of analysis, interest rate, when expenditure or return occurs impacts annual value

Annual Values – Dependent on Interest Rate and Time

	@ 0 %	@ 4 1/8%	@ 7 %
Total Project Cost	$ 146,000	$ 146,000	$ 146,000
O&MRRR	$ 2,070	$ 1,860	$ 1,730
Annual Costs	$ 4,990	$ 9,420	$ 13,930
Annual Benefits	$ 18,890	$ 18,800	$ 18,760
Net Benefits	$ 13,900	$ 9,420	$ 4,830
Benefit Cost Ratio	3.79	2.00	1.35

Corps Specifics

- Code of Accounts – Principals & Standards 1971, Principals & Guidelines 1983
- Flood Risk Management focus: National Economic Development (NED)
- Measure of Risk
- Criteria – plan formulation base
- Economic Optimization Criteria

Keeping Track of Output- Four Accounts

- National Economic Development (NED) – monetary, changes in value of the national output of goods and services
- Regional Economic Development (RED) – monetary, specific effects based on boundary definition
- Other Social Effects (OSE) – non-monetary effects of social well-being - Includes urban/community impacts – life, health, safety, community resiliency and connectedness
  - * Loss of Life – starting to be estimated and used as both authorization and Federal investment criteria
- Environmental Quality (EQ) – non-monetary effects on significant natural or cultural resources – usually not a direct output for Flood Risk Management, UNLESS project is multi-purpose

National Economic Development

- Contributions to national economic development (NED) are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the nation. (P&G 1983)
- Beneficial effects in the NED account are increases in the economic value of the national output of goods and services from a plan. Adverse effects in the NED account are the opportunity costs of resources used in implementing a plan.
- But what does this really mean?

NED (cont.)

- Differentiate between opportunity costs and financial costs
- Address local, regional effects vs. national
- Account for transfers, net changes
- Bottom line: what is the Net Gain or Loss in Stuff to the Nation as a whole

RED Effects

- ***Direct effects:*** the initial change of the new expenditure stream on industries in direct support of the new project. These 'direct' industries will require support.
- ***Indirect effects:*** changes in inter-industry transactions as supplying industries respond to new demands placed on them by 'direct' industries.
- ***Induced effects:*** changes in consumer spending patterns caused by increases in employment and income as 'direct' and 'indirect' industries increase their employment.

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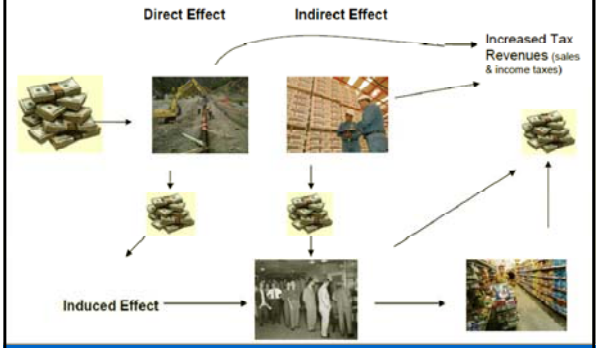
RED – Direct Construction leads Indirect and Induced Effects



Other Social Effects (OSE)

As defined by the P & G:

"The Other Social Effects account registers plan effects from perspectives that are relevant to the planning process but are not reflected in the other three accounts. OSE reflects a highly complex set of relationships and interactions between inputs and outputs of a plan and the social and cultural setting in which these are received and acted upon"

So every thing not in the other three boxes?

Bottom line: While NED/RED represent dollars

OSE is People

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OSE Handbook

- Social Effects" Defined
  - Health and Safety
  - Economic Vitality
  - Social Connectedness
  - Identity
  - Social Vulnerability and Resiliency
  - Participation
  - Leisure and Recreation
  - Loss of Life as an OSE Issue
  - Environmental Justice

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Each alternative plan, strategy or action is to be formulated to consider the following four criteria

- Completeness - extent to which plans account for all actions to ensure realization of objectives
- Effectiveness – extent plans contribute to achieving the objectives
- Efficiency – extent to which plan is the most cost effective means of achieving objectives
- Acceptability – extent plans meet applicable laws, regulations and public policies.

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Optimization for Federal Interest for Flood Risk Management

- Net Benefits = Annual NED Benefits – Annual NED Costs
- NED is still King, NED PLAN reasonably maximizes net benefits (efficiency)
- NED Determines Federal vs. Non-Federal Sponsor cost share for any selected plan
- Also is used in the Federal Investment priority process

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Still Need to Know Effectiveness

- For Flood Risk Management – reduction in risk:
  - ▸ Most effective could be measured in percent reduction in expected annual damages
  - ▸ Probability of catastrophic flood
  - ▸ Reduction in the probability of loss of life (may help us in justification)
- Other effectiveness measures and ways to show project accomplishments (best for last)

Criteria Requiring Economic Analysis

- Effectiveness : In general, the most effective alternative has greatest output, largest reduction to the problem – measurable
- Efficiency : alternative with greatest net benefits.

	Average Annual Damages	Benefits	Costs	Net Benefits
Without	150,000			
Alt1	75,000	75,000	60,000	15,000
Alt 2	50,000	100,000	70,000	30,000
Alt 3	10,000	140,000	150,000	-10,000

Basic Flood Risk Concepts

- Problem:
  - ▸ People, places and things get wet - can lead to losses in: dollars, lives, critical activities
  - ▸ How Bad? Economist measures the potential consequences
  - ▸ How Often? What is the chance, the probability that losses occur
  - ▸ Defined - Risk of Flooding

What is Risk ?

- Basic Definition : concerns the expected value of one or more results of one or more future events. Technically, the value of those results may be positive or negative. However, general usage tends focus only on potential harm that may arise from a future event, which may accrue either from incurring a cost ("downside risk") or by failing to attain some benefit ("upside risk “)

Risk as a Function

Simplest Terms:

RISK = PROBABILITY X CONSEQUENCE

The Probability that something ‘bad’ may occur

Consequence is ‘how’ bad - often measured in dollars

Calculation Example

- Risk of my car stolen over the next year = 1 %
- Chance of getting it back in one piece if stolen = 1 %
- Value of my car = $ 2,000
- Expected Value of Loss = $ 19.80

- Premium to cover theft = $ 100 per year
- Acceptable Risk to not insure my car against theft

Risk =Loss of Life Example

- Russian Roulette – six shooter with one round = Probability = 16.7% Consequence = Death
  - Two variations of the 'game' :

    A) spin the cylinder between each round, same probability for each 'player'

    B) if the round does not go off, the next 'player' gets in effect one less empty chamber. Probability for next player= 20%, 3rd = 25%, 4th = 33%, 5th = 50% 6th = 100%
- Risk for a rational person is probably not acceptable even with one round and one-hundred chambers

Traditional Corps Analysis

- The Corps has always been estimating RISK even pre 1990 guidance – we just didn't call it risk
- The perspective that we are looking at risk management vs. flood control
- The tools we are now using have changed
- And there are reasons why we needed to change

Estimation Of Consequences

- Need to know where the UNWANTED water is likely to be: Flood plains at various probabilities
- Need to know what might get wet – buildings, infrastructure, agriculture
- Need to know value of the 'stuff' that might get wet
- And what percent loss of function or damage based on depth (and possibly velocity, duration, sediment, other)

Flooding

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And More Flooding

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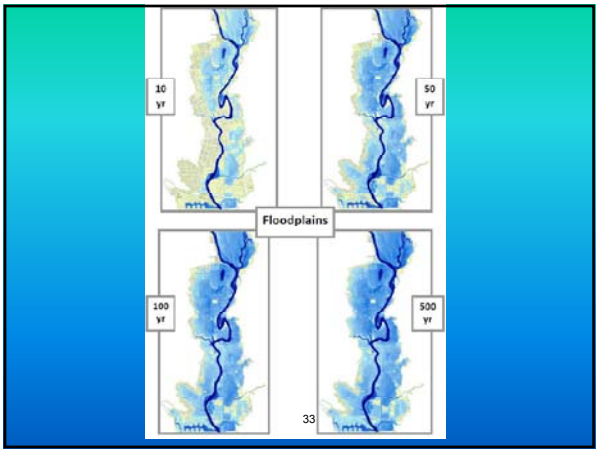

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Inventory of Structures within 500year (0.2%) Floodplain/Study Area

- Databases linked by floodplain and location of structures represented by point in GIS

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Valuation of Inventory

- Corps uses the concept of Depreciated Replacement Value
- Flood damages DO NOT equal total market value of structure and its contents – damages are some percent function of loss times depreciated replacement value (which does not include land value)

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Damage Calculation – Single Family Home One-Story

- Example : **Depreciated Replacement Value** -> Square footage X price per square foot (quality, type, stuff) X remaining value (100% - depreciated value – determined by observation – effective age – restoration cycle) $1500_{sq\ ft}$ X \$ $95_{per/sf}$ X $80\%_{remaining}$ **= $114,000**
- Flood conditions: for single event – say 3 feet above the first floor (short duration, fresh water)
- Percent loss (from Corps standard curves EGM 04-01) at 3 feet = Structure 40 % Content 22 % of ($114,000) depreciated replacement value = **$ 75,240**

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And So On…

- Do the same for another event same structure (say 7 feet above first floor, 63% and 34 % = $ 110,580)
- Now select the rest of the single family houses…
- Commercial, Industrial, Public…
- And aggregate damages by event/stage/flow

Total Damages by Event and Category

Table 12 – Without Project Probability-Stage-Damage Functions - EIA 4R
Damages in $1,000's, October 2009 Prices

EIA 4R	Stage	Damage Category				
		AUTO	COM	IND	PUB	RES
STRUCTURE DAMAGE ($1,000s) AT:						
0.1 Probability	10.99	0	475	1,396	10	13
0.02 Probability	14.16	3,403	5,322	4,805	143	13,957
0.01 Probability	15.11	5,569	8,056	5,652	149	20,607
0.002 Probability	15.74	7,099	9,813	5,937	294	25,802
CONTENT DAMAGE ($1,000s) AT:						
0.1 Probability	10.99	0	793	5,135	0	9
0.02 Probability	14.16	0	12,351	27,400	268	7,975
0.01 Probability	15.11	0	19,312	34,184	269	11,683
0.002 Probability	15.74	0	22,350	34,553	269	14,584
TOTAL DAMAGE ($1,000s) AT:						
0.1 Probability	10.99	0	1,268	6,531	10	22
0.02 Probability	14.16	3,403	17,672	32,205	411	21,932
0.01 Probability	15.11	5,569	27,368	39,836	418	32,290
0.002 Probability	15.74	7,099	32,163	40,490	563	40,386

Other NED Consequences

- Agriculture – primarily measured in loss in yield or increase in production costs – damages more of a function of time of year and duration than depth
- Infrastructure: roads, bridges, public utilities – very difficult to use general relationships – usually only data is site specific
- Emergency response – difficult to assign $$$

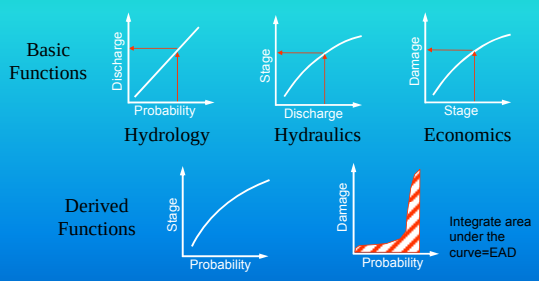
Non NED Consequences

- Loss of Life
- Community Cohesion
- Environmental Justice
- Local or Regional Income Effects
- Other OSE and RED

Integration of Engineering and Economics

- Hydrology – discharge vs. probability
- Hydraulics – discharge vs. stage in the channel
- Geo-tech - existing levees - failure probabilities
- Economics – stage vs. aggregated damage

Damage-Probability Derivation
(Traditional Method –Best Estimates)



Expected Annual Damages (EAD) the economic metric used to describe Risk

Risk vs. Uncertainty In Terms of Corps Flood Analysis

- **Risk** is the probability an area will be flooded, resulting in undesirable consequences.
- **Uncertainty** is a measure of imprecision of knowledge of parameters and functions used to describe the hydraulic, hydrologic, geotechnical, and economic aspects of a project plan.
- **Risk Analysis** is an approach to evaluation and decision making that explicitly, and to the extent practical, analytically, incorporates considerations of risk and uncertainty in a flood damage reduction study.

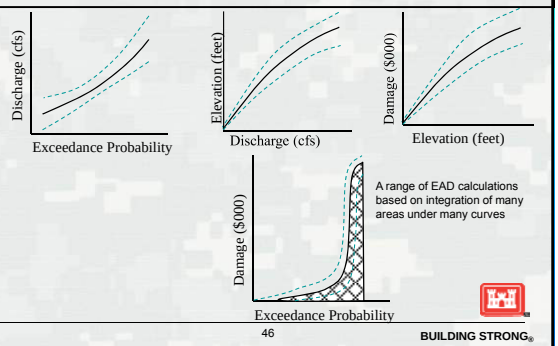
Why Change to include Uncertainty

- Because we were told to…
- The original traditional methods never included any uncertainty in 'best estimates'
- In fact, standard practice was to apply conservative judgment – example freeboard – and to apply the same regardless of conditions
- To include UNCERTAINTY regarding key inputs and assumptions directly into models and the decision making process.

Uncertainties

- Hydrology – period of record – small sample size
- Hydraulics – roughness of channel – capacity unknown
- Economics – values, first floor elevations, percent damages
- Geo-technical – levee failure mechanisms, conditions

Same Flood Risk Relationships but With Uncertainty



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Levee Break

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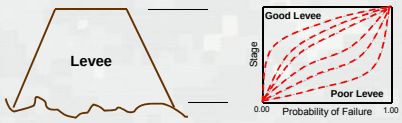
Levee Failure Probability vs. Stage



- Past performance is to be considered.
- Engineering/geotechnical evaluations required.
- Failure elevations/probabilities to be assigned.
- Locate critical section, be practical, perform analysis.

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Levee Probability and Damage in Flood Risk Models

- Flood plains based on some chance levee can fail below top of levee
- Damages for a given event as expected value based on levee failure curve – best way Monte Carlo simulation (more later) but here is deterministic example

STAGE IN FEET	PROB OF FAILURE	DAMAGE	EXPECTED VALUE
10	0%	1,000	0
12	25%	2,100	525
14	50%	2,500	1250
16	75%	2,700	2025
18 = TOP	100%	3,000	3000

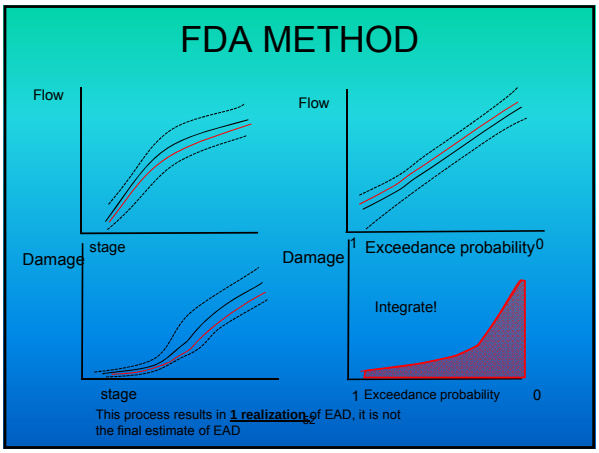
Tools and Why we Use Them

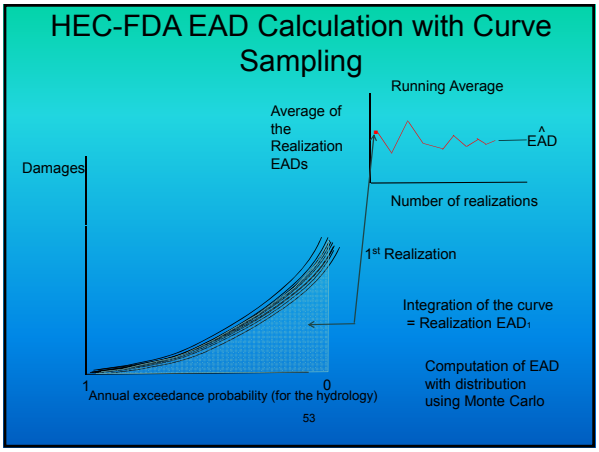
- Old days – everything on paper – fine with simple relationships
- Volume of information, consistency, complexity – Need Models
- Corps current Corporate Flood Risk Management Model : HEC-FDA 1.2.5

http://www.hec.usace.army.mil/software/hec-fda/downloads.html

Current Model HEC-FDA

- Corps certified planning tool for National use
- Integrates these three basic relationships
- Also has module of levee considerations
- And reservoir operations
- Uses Monte Carlo Simulation to generate consequences by event (with uncertainty)
- Also uses Monte Carlo to sample each relationship to provide a probabilistic EAD





Hazus (FEMA)

- Models for estimating losses from earthquakes, floods and hurricanes
- Uses existing engineering and topographic data, basic inventory and **GIS** to identify high-risk areas
- Estimates:
  - Physical damages (structures and contents)
  - Economic loss (jobs, business interruptions)
  - Social Impacts (displaced households)

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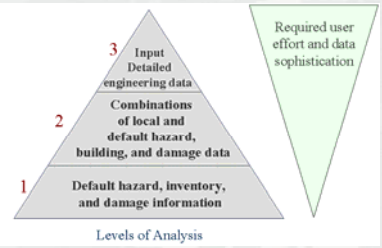
Hazus – Flood Risk Management Uses

- Preparedness and Response
- Mitigation and Recovery
- Initial Plan Formulation Screening when you have limited data
- Identifying priority problem areas among many

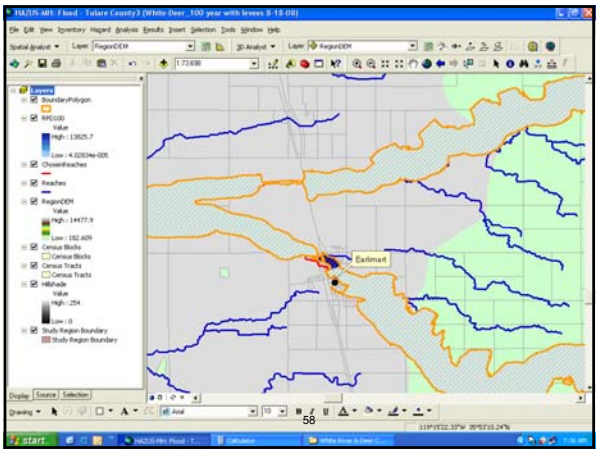
Hazus - Limitations



The farther you move up the pyramid, the less Hazus adapts to developed modeling and formatted datasets

Hazus Pros and Cons

- Analysis at Census Block Level – analysis has to assume certain density homogeneity
- Free accessible data for almost anywhere
- Generates H&H conditions with existing data and topography in simple terms
- Does not have the internal capability for complex analysis – doesn't account for **uncertainty**



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Determining Accomplishments- Using HEC-FDA

- Annual Average Benefits
- Reduction in damages, structures at risk
- Project Performance:
  - AEP – Annual Exceedance Probability – chance of getting damages in any given year
  - Long term risk – chance of getting one or more damaging events over a fixed period of time (10-yr, 30-yr, 50-yr)
  - CNP – Conditional Non-Exceedance Probability – chance of no damages from a specific 'size' event

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Compare Average Annual Equivalent (AAE) Damages and Project Performance With and Without Project

Condition	AAE – Without Project	AAE – With Project	Annual Benefits	AEP	CNP of 1% Event
Without	$ 100,000	$ 100,000	0	1 in 20	2 %
Levee	$100,000	$50,000	$ 50,000	1 in 100	53 %
Big Levee	$100,000	$ 25,000	$ 75,000	1 in 150	85 %
Channel Improvement	$ 100,000	$ 50,000	$ 50,000	1 in 75	47 %
Little Levee + Channel	$ 100,000	$ 10,000	$ 90,000	1 in 200	95 %

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Compare Annual Benefits With Annual Costs

CONDITION	ANNUAL BENEFITS	ANNUAL COSTS	NET BENEFITS
Levee	$ 50,000	$ 60,000	- $ 10,000
Big Levee	$ 75,000	$ 100,000	- $ 25,000
Channel Improvement	$ 50,000	$30,000	$ 20,000
Little Levee + Channel	$ 90,000	$ 75,000	$ 15,000

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Compare Annual Benefits in a Probabilistic Manner

Condition	AAE – Without Project	AAE – With Project	Annual Benefits	75% Prob. Benefits Exceed	50% Prob. Benefits Exceed	25% Prob. Benefits Exceed
Without	$ 100,000	$ 100,000	0	0	0	0
Levee	$100.000	$50,000	$ 50,000	$ 12,750	$39,100	$68,650
Channel Improvement	$ 100,000	$ 50,000	$ 50,000	$ 13,900	$ 44,000	$62,500
Little Levee + Channel	$ 100,000	$ 10,000	$ 90,000	$ 29,700	$ 72,500	$ 103,000

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Goal to show probability B/C >1

Table A-3: Expected Value and Probabilistic Values of Benefit/Cost Ratios

Plan	Expected Benefit/Cost Ratio		Probability B/C > 1	B/C Ratio Value that is Exceeded with Specified Probability		
	Mean	Standard Deviation		0.75	0.50	0.25
20 foot levee	1.21	0.26	0.80	1.03	1.19	1.35
25 foot levee	1.28	0.24	0.88	1.11	1.26	1.43
30 foot levee	1.05	0.22	0.55	0.89	1.03	1.17
channel	1.26	0.27	0.83	1.06	1.24	1.41
detention basin	1.19	0.35	0.70	0.94	1.18	1.42
relocation	1.44	0.27	0.97	1.25	1.40	1.60

From ER 1105-2-101, Table A-3

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Limitations of HEC-FDA

- Loss of Life
- Rebuilding
- Agricultural Damages
- Coincident Flooding
- Systems Analysis

The model can't internally handle any of these issues

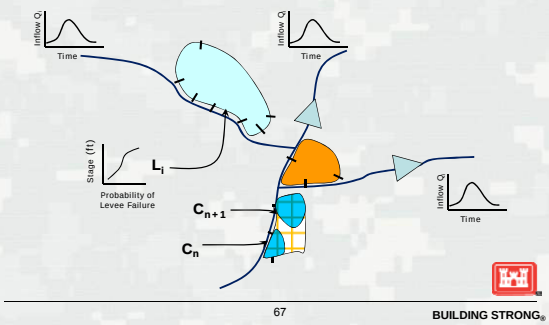
Next Generation – HEC-FRM

- Will be fully integrated GIS program using linked reservoir operations, hydrology, in channel hydraulics, flood plain hydraulics, geo-tech, economics and cost estimating models
- Will be able to run systems analysis evaluating upstream uncertainties on downstream impacts.
- Will perform true life-cycle benefits and costs over period of analysis vs. current frequency approach
- Estimate Loss of Life and Agriculture within the model

FRM Sampling Sequence

- For each project alternative, a single scenario of the project life cycle (e.g., 50 years) is simulated by sampling annual maximum flood events for the duration of the life cycle.
- Sample Frequency and Hydrograph Set
- Route Hydrograph Set
- Check System-Wide Levee Fragility Functions
- Determine if Consequence Area (CA) system Spills/Fails and where
- Compute Damage/Loss-of-Life
- Repeat

Inflow Spreading and Consequences



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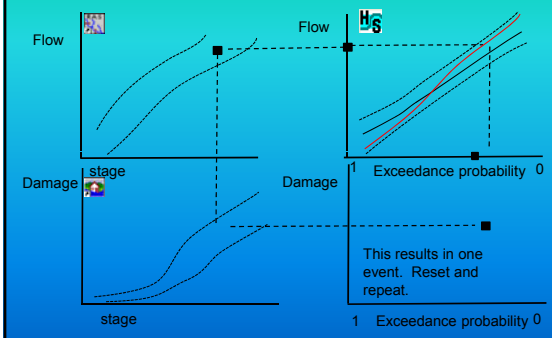
Concept behind event sampling



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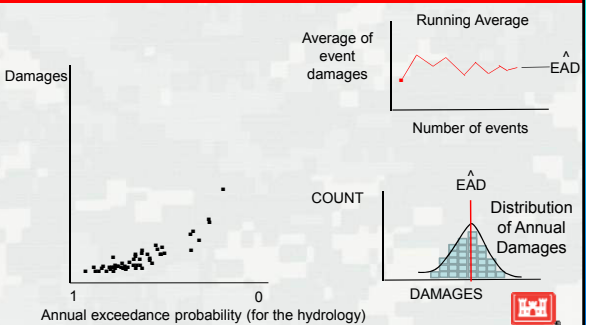
EVENT SAMPLING



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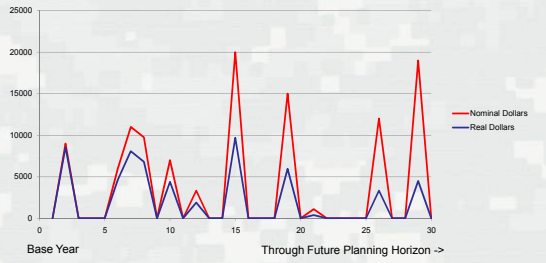
Lifecycle in FRM



Base Year

Through Future Planning Horizon ->

Sum all real (discounted) **event** damage estimates and divide by the number of years. The result is equivalent annual damages over the period of analysis(for a single realization).

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Planning and Opportunities beyond Textbook NED Flood Risk Management

Alternative	Average Annual Damages	Annual Benefits	Annual Costs	Net Benefits	AEP	CNP for 1% Event
Without	200,000	0	0	0	1 in 10	1 %
Alt 1 – Raise 50 Homes	180,000	20,000	10,000	10,000	Still 1 in 10	1 %
Alt 2 – Levee Complete	20,000	180,000	200,000	-20,000	1 in 200	90 %
Alt 3 Levee Left Bank Only	50,000	150,000	110,000	40,000	1 in 200 left bank	90 %
Alt 4 Little Levee Complete	35,000	165,000	115,000	40,000	1 in 100	55 %
Alt 5 Multi-Purpose Ecosystem/FRM	20,000	180,000	250,000 (?)	-70,000 (?)	1 in 200	90 %

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Other Considerations

- By strict guidance, Alt 3 should be NED – highest net benefits – least cost
- But Alt 4 has same net benefits – provided reduction for more people, possible OSE, Loss of Life considerations
- But as a multi-purpose plan, Alt 5 may have best total outputs (NED, OSE and EQ) and a potential cost distribution between both ecosystem restoration and flood risk management

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Any Questions?