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FLOOD RISK MAPPING. A RISKY BUSINESS

S. MOLINO

Molino Stewart Pty Ltd, Parramatta, NSW
smolino@molinostewart.com.au

ABSTRACT

In the last decade there has been a tendency to delineate parts of the floodplain as having high, medium or low flood risk for town planning purposes. This has been picked up by the NSW Minister for Planning and specific directives have been given as to what are, and are not, appropriate controls in areas of high and low flood risk.

However, the term 'risk' has been used loosely and although there have been attempts within the floodplain management fraternity to more clearly define what is meant by the term, the risks which have been considered have been narrow in their scope.

This paper discusses the breadth and complexity of the risks which need to be considered in a true merits based approach to floodplain development and why 'risk mapping' is a useful but insufficient tool in the planning process.

A DEFINING MOMENT

In January 2007 the then NSW Planning Minister, Hon Frank Sartor, issued a Section 117 Directive under the Environmental Planning and Assessment Act which stipulated what development controls could and could not be imposed in areas which constituted a "low risk" area in respect of flooding.

The problem that this has created is that it has placed within the regulatory framework across the state a defined category "low risk" in relation to flooding but the way it has been defined means that when it is applied it is not necessarily delineating an area which is low risk. Essentially the directive defines any location with less than a 1% chance of flooding per year as having a low risk.

DEFINING RISK

The Australian and New Zealand Risk Management Standard AS/NZS 4360, defines risk as "the chance of something happening that will have an impact on objectives" while the new International Risk Standard ISO 31000 says it is "the effect of uncertainty on objectives". There are many other definitions of risk but generally they can be reduced to the commonly used simple formula

Risk = probability x consequence

This is the definition which I will use throughout this paper to explain the complexity of defining flood risks. Applying this definition means that estimating the risk at a location requires estimating the chance of the event occurring and forecasting what would happen if it does.

If we apply this definition of risk to the S117 directive it is saying that the consequence we are interested in is above ground flooding and if the probability of that occurring is less than 1% chance per year then the risk can be considered to be low.

However, the S117 directive then implicitly brings into consideration some other consequences of flooding and also introduces the concept of acceptability of risk.

By requiring that residential floor levels should be above the 1% flood level it is implicitly stating that a 1% chance (probability) of above floor flooding (the consequence) is the threshold of acceptability of this risk. It then states that critical infrastructure should not be built in low risk areas which implies that above ground flooding (the consequence) at critical infrastructure must have less than the probability of the PMF occurrence for it to be an acceptable risk.

This approach allows simple maps to be drawn up which divides the floodplain into zones of high/medium flood risk, low flood risk and no flood risk. This has been taken further in many local government areas by linking land use tables to these risk areas and defining what is permissible in each of these zones (See Table 1).

Implicit in this approach is the idea that particular consequences of flooding are acceptable at a given probability and others are not. For example, by specifying that building materials below the 1% flood level must be flood resistant implies that the risk of structural failure is not acceptable if it has more than a 1% chance of occurrence. The corollary is that less than a 1% chance of building failure is acceptable. This is more explicitly stated in the S117 directive which says that it is not permissible (other than in exceptional circumstances) to impose conditions on residential building materials above the 1% flood level.

This table also recognises the need for human safety to be managed as loss of life is another potential consequence of flooding.

While this approach takes the line on a map further, it too has its limitations.

UNDERSTANDING RISK

These limitations are best explained by considering the parts of the risk equation.

While risk = probability x consequence, consequence itself is a function of other factors.

For example, with regard to flooding the consequences of a flood will depend on what the floodwaters are doing and what they are interacting with. The consequences of fast flowing flood waters will be different to the consequences of slow moving floodwaters even if both have the same probability of occurring. The consequences of submerging a building will be different to the consequences of submerging a person even if the probability of each being submerged is the same. We use the concept of hazard to help describe the combination of flood characteristics which can have consequences. The flood hazard relates to how dangerous a site on a floodplain can be (HNFMSC, 2006). It depends on the behaviour of the flood at that location and changes with the probability of the event, generally the rarer the flood the greater the hazard. Hazard is independent of what is placed in the floodplain.

Table 1 - Floodplain Development Control Matrix (PCC, 2006)

FLOODPLAIN MATRIX

Planning & Development Controls

Planning Consideration	Flood Risk Precincts (FRP's): Low Flood Risk									Medium Flood Risk									High Flood Risk								
	Sensitive Uses & Facilities	Critical Uses & Facilities	Subdivision	Filling	Residential *	Commercial & Industrial	Tourist Related Development	Open Space & Non-Urban	Concessional Development	Sensitive Uses & Facilities	Critical Uses & Facilities	Subdivision	Filling	Residential *	Commercial & Industrial	Tourist Related Development	Open Space & Non-Urban	Concessional Development	Sensitive Uses & Facilities	Critical Uses & Facilities	Subdivision	Filling	Residential *	Commercial & Industrial	Tourist Related Development	Open Space & Non-Urban	Concessional Development
Floor Level		3			2, 5	2, 5	2, 5							2, 5	2, 5	2, 5	1, 5	4, 5								1, 5	4, 5
Building Components		2												1	1	1	1	1								1	1
Structural Soundness		2												1	1	1	1	1								1	1
Flood Affectation		2	2	1	2	2	2					1		1	1	1	2	1								1	1
Car Parking & Driveway Access		1, 3, 5, 6			1, 3, 5, 6	1, 3, 5, 6	1, 3, 5, 6	2, 4, 6, 7						1, 3, 5, 6, 7	1, 3, 5, 6, 7	1, 3, 5, 6, 7	2, 4, 6,7	1, 5								2, 4, 6,7	1, 5
Evacuation		2, 4, 6	5		3, 4	4	4					5, 3, 4		3, 4, 6	3, 4, 6	3, 4, 6	1, 4	3, 6								1, 4	3, 4, 6
Management & Design		2, 3, 4	1									1		2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4								2, 3, 4	2, 3, 4

Not Relevant | Unsuitable Land Use | * For redevelopment of an existing dwelling refer also to 'Concessional Development' provisions

Floor Level

1. All floor levels to be equal to or greater than the 20 year *ARI flood level* plus *freeboard*.
2. Habitable floor levels to be equal to or greater than the 100 year *ARI flood level* plus *freeboard*.
3. All floor levels to be equal to or greater than the *PMF* level plus *freeboard*.
4. Floor levels to be equal to or greater than the *100 year ARI flood level plus freeboard*. Where this is not practical due to compatibility with the height of adjacent buildings, or compatibility with the floor level of existing buildings, or the need for access for persons with disabilities, a lower floor level may be considered. In these circumstances, the floor level is to be as high as practical, and, when undertaking alterations or additions, no lower than the existing floor level.
5. A restriction is to be placed on the title of the land, pursuant to S.88B of the Conveyancing Act, where the lowest *habitable floor area* is elevated more than 1.5m above finished ground level, confirming that the subfloor space is not to be enclosed.

Building Components & Method

1. All structures to have *flood compatible building components* below the 100 year ARI *flood level* plus *freeboard*.
2. All structures to have *flood compatible building components* below the *PMF*.

Structural Soundness

1. Engineers report to certify that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a 100 year ARI *flood* plus *freeboard*.
2. Engineers report to certify that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a PMF level.

Flood Affectation

1. Engineers report required to certify that the development will not increase *flood affectation* elsewhere, having regard to: (i) loss of flood storage; (ii) changes in flood levels, flows and velocities caused by alterations to flood flows; and (iii) the cumulative impact of multiple potential developments in the vicinity.
2. The impact of the development on flooding elsewhere to be considered having regard to the three factors listed in consideration 1 above.

Car Parking and Driveway Access

1. The minimum surface level of open spaces or carports shall be as high as practical, but no lower than 0.1m below the 100 year ARI flood level. In the case of garages, the minimum surface level shall be as high as practical, but no lower than the 100 year ARI flood level.
2. The minimum surface level of open parking spaces or carports shall be as high as practical, but no lower than 0.3m above the 20 year ARI flood level.
3. Garages capable of accommodating more than 3 motor vehicles on land zones for urban purposes, or enclosed car parking, must be protected from inundation by floods equal to or greater than the 100 year ARI flood. Ramp levels to be no lower than 0.5m above the 100 year ARI flood level.
4. The driveway providing access between the road and parking spaces shall be as high as practical and generally rising in the egress direction.
5. The level of the driveway providing access between the road and parking spaces shall be no lower than 0.2m below the 100 year ARI flood level.
6. Enclosed car parking and car parking areas accommodating more than 3 vehicles, with a floor below the 100 year ARI flood level, shall have adequate warning systems, signage, exits and evacuation routes.
7. Restraints or vehicle barriers to be provided to prevent floating vehicles leaving a site during a 100 year ARI flood.

Evacuation

1. Reliable access for pedestrians required during a 20 year *ARI peak flood*.
2. Reliable access for pedestrians and vehicles required to a publicly accessible location during the *PMF peak flood*.
3. Reliable access for pedestrians and vehicles is required from the site to an area of refuge above the PMF level, either on site (eg. second storey) or off site.
4. Applicant to demonstrate the development is consistent with any relevant *flood evacuation strategy* or similar plan.
5. Applicant to demonstrate that evacuation in accordance with the requirements of this DCP is available for the potential development resulting from the subdivision.
6. Adequate flood warning is available to allow safe and orderly evacuation without increased reliance upon SES or other authorised emergency services personnel.

Management and Design

1. Applicant to demonstrate that potential development as a consequence of a subdivision proposal can be undertaken in accordance with this the relevant FRMS and FRMP
2. Site Emergency Response Flood plan required where the site is affected by the 100 year ARI flood level, (except for single dwelling-houses).
3. Applicant to demonstrate that area is available to store goods above the 100 year *flood* level plus *freeboard*.
4. No storage of materials below the 100 year *ARI flood level*.

Notes

i. *Freeboard* equals an additional height of 500mm.

ii. The relevant environmental planning instruments (generally the Local Environmental Plan) identify development permissible with consent in various zones in the LGA. Notwithstanding, constraints specific to individual sites may preclude Council granting consent for certain forms of development on all or part of a site. The above matrix identifies where flood risks are likely to determine where certain development types will be considered "unsuitable" due to flood related risks.

iii. Filling of the site, where acceptable to Council, may change the FRP considered to determine the controls applied in the circumstances of individual applications.

iv. Any fencing that forms part of a proposed development is subject to the relevant Flood Effects and Structural Soundness planning considerations of the applicable land use category.

v. Development within the floodplain may be subject to the Foreshore Building Line objectives of the LEP and REP

vi. Terms in italics are defined in the glossary of this policy. Development types are specified in each land use category. These development types are generally as defined within Environmental Planning Instruments applying to the local government area.

It is recognised that there are thresholds of hazard which have different consequences for different things placed in the floodplain. An accepted practice has been to develop hazard category tables, and though there are variants on where the thresholds are drawn, they all work on the idea that a certain combination of depth and velocity will have certain consequences for different things exposed to that flood hazard.

In the diagram below the H1 category is defined as that which would have minimal consequence for people, vehicles or buildings. In category H2 vehicles begin to float, in category H3 able bodied adults cannot safely walk, in Category H4 light frames buildings fail and in Category H5 all buildings can fail. This discussion demonstrates that different things have different vulnerabilities to flooding. People are more vulnerable than buildings and cars have a different vulnerability again.

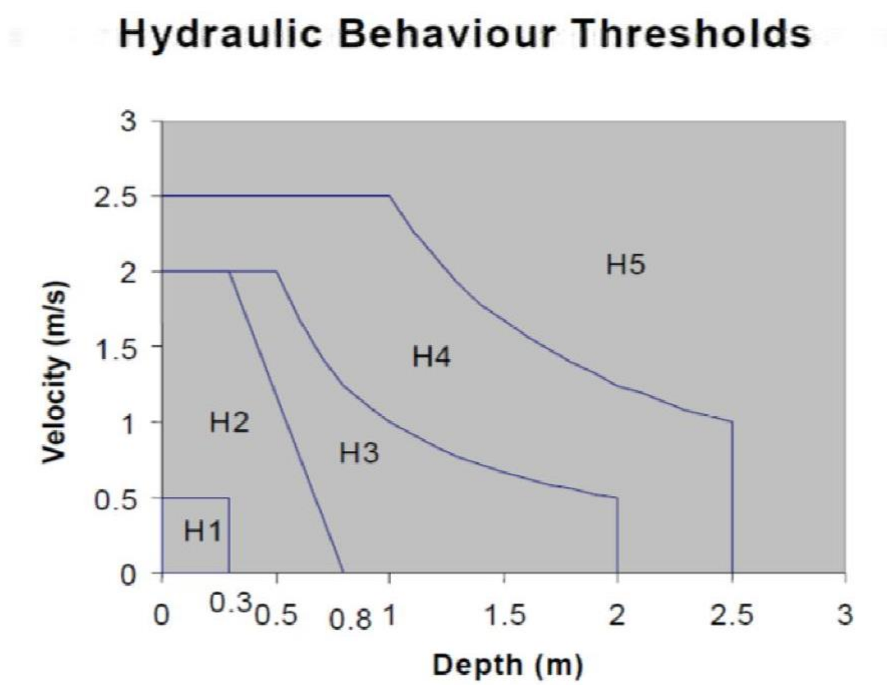

Figure 1 - Hydraulic Behaviour Thresholds for Newcastle LGA (BMT WBM, 2008)

This diagram however suggests that hazard is purely a function of water depth and velocity but there are other flood parameters which contribute to the consequences of flooding and can be considered to be part of the flood hazard. For example the rate of flood rise may be relevant to the hazard posed to people, cars and building contents because even if the peak depth and velocity combination may be detrimental to them, the rate of rise may be so slow that there is ample opportunity for people to move themselves and their possessions out of the way of the floodwaters.

The preceding discussion shows that it is not appropriate or even possible to assign a single risk value to a location based on probability of above ground flooding alone. Different risk profiles need to be assigned to different land uses which take into account not only the flood probability but the various aspects of the flood hazard and the consequences they have for the various things associated with that land use.

DECC has suggested a table of risk profiling for buildings based on the probability of the flood and the damage it may cause. This takes into account the fact that in different locations the flood hazard and therefore consequence will vary for the same flood probability.

Table 2 - Risk Analysis to residential development in floodplains (HNFMSC, 2006)

Risk analysis for structural damage to residential development in floodplains
based on a traditional single storey, brick veneer, slab on ground house

Floor level range	Likelihood of above floor flooding	Chance of experiencing in a life time	Structural damage consequences				
			Insignificant < $1,000	Minor d < 0.1m $1,000 - $5,000	Moderate d > 0.1 & < 0.5m $5,000 - $25,000	Major d > 0.5 &< 1.0m $25,000 - $50,000	Catastrophic loss of house $150,000 plus
1:10,000 AEP to PMF	Improbable	0.7% - 0.07%	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
1:1,000 to 1:10,000 AEP	Rare	7% - 0.7%	Low Risk	Low Risk	Low Risk	Low Risk	Medium Risk
Flood of record to 1:1,000 AEP	Unlikely	30% - 7%	Low Risk	Low Risk	Low Risk	Medium Risk	High Risk
1:100 AEP to flood of record	Possible	50% - 30%	Low Risk	Low Risk	Medium Risk	High Risk	Extreme Risk
1:50 to 1:100 AEP	Likely	75% - 50%	Low Risk	Medium Risk	High Risk	Extreme Risk	Extreme Risk
Below 1:50 AEP	Almost Certain	100% - 75%	Medium Risk	High Risk	Extreme Risk	Extreme Risk	Extreme Risk

Such risk categorisation helps account for some of the differences in residential land use risks between diverse floodplains and allows a different approach to residential land use planning depending on the risk. It recognises that houses in each of the floodplains in the following diagram actually have different risk profiles even though they have the same chance of overground or overfloor flooding and according to the S117 directive would be categorised as “low risk”.

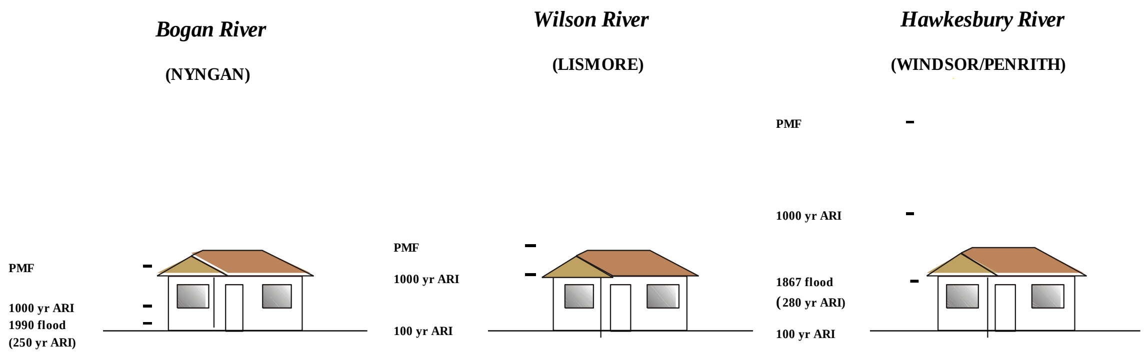

Figure 2 - Comparative Flood Risks for Properties with Floor at 1 in 100 level (HNFMAC, 1997)

Of course building damage is only one of the consequences of flooding for residential land use. There are risks of contents damage, risk to life and risk of social disruption. Table 3 suggests a broader range of factors which need to be considered to when assigning risk profiles to land uses but as discussed later in this paper, even these may not be sufficient.

TOLERATING RISK

The whole purpose of identifying risks in a floodplain is to determine how those risks should be managed. Where the risk is unacceptable, a change is made to the flood behaviour (levee, detention basin etc) or the land use (building modifications, development controls etc) until the risk is tolerable. Yet even here one size does not necessarily fit all. What is the tolerable probability for one consequence of flooding may not be for another.

The S117 directive suggests that above floor flooding is the key risk for urban planning and having floor levels 0.5m above the 1% flood level is a tolerable risk for most urban land uses. This results in residential planning as shown diagrammatically in Figure 2. But if Table 2 is considered and only a medium risk of structural damage is tolerable then in some locations it would be the dominant risk and Figure 3 may be representative of the planning decisions made using this threshold.

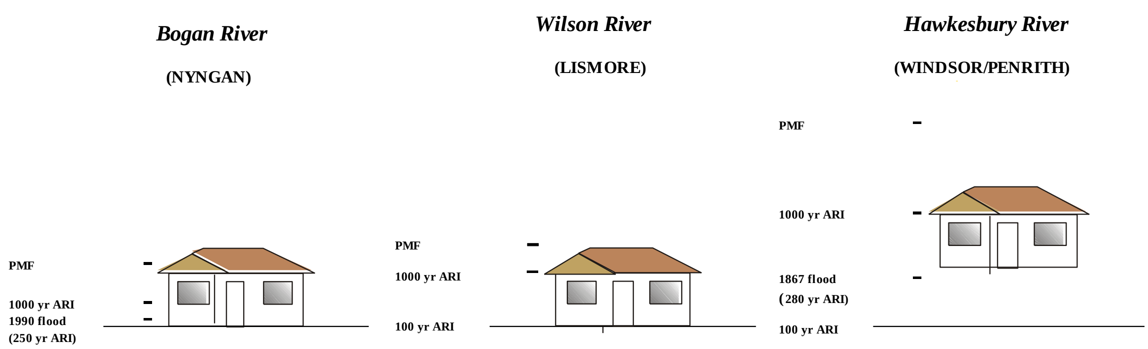

Figure 3 - Comparative Flood Risks for Properties with ceiling at 1 in 1000 level (Molino, 2004).

Table 3 – Minimum Considerations for a Merits Based Assessment (Molino, 2004)

CRITICAL THRESHOLDS	FACTORS AFFECTING FLOOD RISK - LIKLIHOOD OR CONSEQUENCE			POTENTIAL FACTORS INFLUENCING RISK TOLERANCE
	Flood factors	**Development parameters**	**Human factors**	
Above floor flooding	Flood peaks and durations and their probability	Floor level, Number of buildings	Unapproved modifications	Social & economic effects of flooding Number of properties affected Financial ability of occupants to recover Benefits of development Cost of mitigation
Substantial but repairable property damage	Flood durations, depths, velocities and critical combinations and their probability	Location of buildings, Building design, Number of buildings	Unapproved modifications Actions in response to flood warning	Social & economic effects of damage Number of properties affected Financial ability of owners to recover Benefits of development Cost of mitigation
Irreparable structural damage	Flood durations, depths, velocities and critical combinations and their probability	Location of buildings, Building design, Number of buildings	Unapproved modifications	Social & economic effects of building failure Number of properties affected Financial ability of owners to recover Benefits of development Cost of mitigation
Failure of Co-ordinated evacuation strategy	Peak flood height. Rate of rise of floodwaters, Probability	Location of buildings, Number of buildings, Road network design	Ability of emergency Services to resource & manage; Action of public in response to flood warning	Number of evacuees affected Availability of alternative means of evacuation (self-rescue) Impact on regional evacuation Benefits of development Cost of mitigation Cost of rescue by emergency services
Failure of self-rescue	Peak Flood height Rate of rise of floodwaters, Probability	Location of buildings, Building and urban design Topography	Willingness and ability to walk from building	Number of lives lost Benefits of development Cost of mitigation Cost of rescue by emergency services

Yet even this approach is somewhat simplistic because it does not recognise vulnerability as part of the planning decision. Granted, the S117 directive makes it clear that particular land uses should not be built in the floodplain either because the occupants are particularly vulnerable (aged care facilities) or the community as a whole is particularly vulnerable to the loss of the asset (hospitals, major substations). But there are other aspects of vulnerability which need to be considered.

In the current risk framework which is applied to flooding there is the implicit assumption that the more people and properties we expose to flooding, the same our ability to cope yet this is fallacious.

If one home is flooded during a major storm event, the consequences are different at a societal level than if 1,000 buildings are flooded even if the chance of them being flooded are the same. If the 1,000 flooded buildings are scattered along the NSW coast the consequences at the local level are likely to be tolerable because by and large local communities and facilities would continue to function and with some external resources would be able to help those affected recover. If however the flooded buildings were all at the one location resources would be more stretched. If they were at the fringes of a major city the consequences may be more tolerable than if they are part of a small town of only a few thousand dwellings. If they are in the main commercial district of a town or city the consequences may be less tolerable.

It is this cumulative and strategic aspect of flood risk that has been recognised by the Dutch such that rural areas have levees which protect them from floods with about a 1 in 1,450 chance per year while the major cities of Rotterdam and Amsterdam have protection from a 1 in 10,000 year event.

What is tolerable is also an important consideration in regard to risk to life. Where development exists or is proposed in areas which could experience flood hazards which pose a danger to people the conventional wisdom is that they should have a means of escape to a flood free location. While evacuation out of the floodplain is the preference of the SES, it is not possible in all locations and the question has to be asked whether sheltering in place is a tolerable alternative. This decision may be influenced by the rate of rise of flood waters, the depth and velocities in the building, the duration of flooding and the strength of the building. But it might also be influenced by the type of building, with most people inclined to flee a commercial building but shelter in their home without due consideration of the flood hazard.

From a life safety point of view alone there are therefore several risks that need to be considered. The first is the risk to life if they stay put in a flood. The second is the risk of orderly evacuation failure. The probability of this happening is not only dependent on the probability of the flooding but a whole lot of other factors such as the probability of roads remaining open, the probability of orderly evacuation, the probability that people will be willing and able to evacuate.

Should they stay put then until the floodwaters arrive then they may try and leave the building or they may try to shelter in a higher part of the building. The probabilities of them doing either of these will depend on the nature of the flooding, the type of building they are in, the terrain surrounding the building, the distance to flood free shelter and their own beliefs and attitudes.

The consequences of choosing one or the other will depend on the nature of the flooding (depth, velocity, rate of rise and duration) and their personal vulnerability. All of these will vary from location to location and flood to flood. It is therefore almost impossible to reduce life safety risk to a single number.

CONCLUSION

In summary then:

Risk = probability x consequence

Probability = probability of the flood x probabilities of each possible consequence for the risk being considered

Consequence = a function of hazard, direct flood impacts, indirect flood impacts, cumulative impacts and vulnerability

Hazard = a function of velocity, depth, rate of rise, duration etc

Vulnerability = a function of individual and communal ability to respond and recover

In making floodplain management decisions for any particular location we need to consider above floor flooding risk, structural damage risk, loss of life risk, isolation risk, community dysfunction risks and other risks. While mapping flood probabilities and flood hazards are useful tools, the idea of being able to reduce flood risk to a line on a map is fallacious and is inconsistent with a merits based approach to floodplain development.

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