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Research Report
Research Project T9903, Task 38
Zero Floodplain Rise

**AN ASSESSMENT OF THE ZERO-RISE
ORDINANCE IN KING COUNTY**

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EXECUTIVE SUMMARY

1. INTRODUCTION

Floodplain regulation strives to balance the benefits of reducing flood hazards to human life and property against the costs of limiting encroachment on areas that, under normal conditions, have appeal for many kinds of development. This balance has shifted and led to increasing floodplain regulation with a deepening understanding of the ecological importance of the floodplain and the added weight of resource protection.

The 1990 enactment of a zero-rise ordinance in King County tightened floodplain regulations enough that agencies responsible for maintaining safe bridges and roadways are now hampered by excessive design and construction costs. Balancing the costs of flood hazard reduction and ecosystem protection with the costs of maintaining transportation safety is not easy and was not given full consideration by King County policy makers in drafting the 1990 regulations. The result has been the creation of a highly restrictive regulatory environment in which bridge replacements and improvements are prohibitively expensive or impossible without variances from one or more regulations.

The general purpose of this report is to evaluate the implications of the zero-rise regulation for bridge builders in the King County Roads Division and the Washington State Department of Transportation (WSDOT). The report

- a) documents the development of the zero-rise regulation of the 1990 Sensitive Areas Ordinance (SAO)
- b) compares the King County floodplain regulation to other similarly restrictive regulations in other states and counties and to other "absolute zero"-type regulations
- c) assesses the costs of the ordinance for bridges designed since 1990

- d) evaluates the effectiveness of procedures for obtaining variances from the zero-rise criterion.

For the reader's convenience, a glossary of acronyms used in this document is provided after the report's references.

2. COMPARISON TO OTHER ZERO-RISE REGULATORY FRAMEWORKS

Although the zero-rise regulations in other states and locales legitimately require that a surface elevation increase be 0.01 foot or smaller, the extent of the application of this requirement varies, and in every case there are fewer conflicting requirements than in King County. These other zero-rise requirements fit into a scheme of resource protection without completely impeding public works agencies.

In King County, the zero-rise criterion compounds an already burdensome mass of requirements. In comparison to the other zero-rise regulations studied, the King County regulatory environment is extremely stringent. Important differences in other locales were found to include the following:

- freedom from substantial clearance requirements
- freedom from pier-in-channel prohibitions (unrelated to backwater considerations)
- exemption for replacement in-kind
- lenient permitting processes for rises where no damage is anticipated
- permission for flooding on approach roads.

In some locales, because of infrequent bridge work or local geologic and hydrologic characteristics, the zero-rise criterion has remained mostly untested since its adoption.

The regulation of the floodplain in King County is fragmented between King County local agencies and state agencies such as the Department of Fish and Wildlife and the Department of Ecology. In other states, many of these functions may be subsumed into

a common state agency department, allowing the development of a framework for regulation that is more internally consistent. This may be an important reason that the other cases studied revealed fewer conflicting regulations.

3. COSTS OF THE ZERO-RISE ORDINANCE

To estimate the impacts of the zero-rise criterion on bridge construction and design in King County, water crossings that were in any stage of development in the years 1989 to 1995 were examined. The overall goal of this portion of the project was to determine the average cost increase that would be incurred in meeting the zero-rise constraint in King County. Although the criterion affects every bridge uniquely, and the sample of bridges from which to draw conclusions is small, an averaging approach to defining impacts offers a general sense of zero-rise impacts on King County bridge projects. The following conclusions were drawn from the survey of these bridges.

1) Cost increases due to the zero-rise criterion alone were significant. For WSDOT and King County Public Works bridges together, the average cost increase associated with zero-rise was about 49 percent of the non-zero-rise project costs. For just the King County Public Works projects, the average cost increase was nearly 66 percent. For WSDOT bridges alone, the average cost increase was approximately 35 percent.

2) The additional funds spent on zero-rise designs could have been more effectively used on other bridge projects. For the King County Public Works bridges, a conservative estimate of the additional funds required to meet the zero-rise criterion to date is about \$7.6 million dollars. For WSDOT, the estimate of funds required is \$4.6 million dollars. Although the amount of damages avoided on the zero-rise projects was not definitively calculated in this or any other study, the conservative estimate of the additional funds spent on bridge design and construction is high enough to beg the question: was the flood damage reduction achieved worth the cost? In any case, the amounts spent on zero-rise in the past five years are large enough to have funded several additional bridge projects or retrofits in King County.

3) The implications of King County cost increases, if the ordinance were applied statewide, are considerable. King County has only 163 of the state's 3544 bridges (longer than 20 feet), or just under 5 percent. In contrast, King County's 1994 road funding budget was almost 23 percent of the state's budget (\$178 million of \$773 million) (CRAB, 1994). In contrast, the state's high priority bridge project budget is \$388 million for 1993 to 2003. If only a quarter of the budget covers bridges that cross water and are influenced by zero rise, and the same percentage cost increase as that found in King County applies, about \$48 million in cost increases will be incurred over the decade to meet zero rise. This amount is enough to support numerous additional bridge projects or needed repairs.

4. SUGGESTION FOR VARIANCE EVALUATION

The variance procedure outlined for King County does not differ greatly from the procedures of other states and counties. It is expensive and time-consuming and, as such, is not a viable option for bridge designers. Because of the case-specific nature of bridge design, a uniform standard such as the zero-rise criterion creates a well-intended but, at times, unsuitable constraint; therefore, the variance procedure is extremely important as a means to allow the designer to use professional judgment in adjusting the constraint.

At the very least, the variance procedure should be accessible. Actions already taken to reduce the risk of a public hearing (by requiring five rather than two objections) promises to save the bridge designer time and money. Perhaps another solution, although one that may decrease the accountability of the bridge designers and permitting agency, is to close the process and require review of variance application by a panel from local and state agencies that have jurisdiction—in this case the state Department of Ecology, the Department of Fish and Wildlife, the Department of Transportation, and King County's Public Works Department and Surface Water Management Division (SWM). This type of process has been employed by Wisconsin (Besadny and Jackson, 1983) and is used for variances to SWM's Surface Water Design Manual (SWDM) and Drainage Manual rules. Such an "in-house" review would decrease the time and expense of pursuing a variance.

In addition, understanding the potential outcome of an application would aid designers in recognizing when the pursuit of a variance might be worthwhile. For example, a list of conditions for successful application that clearly details the grounds on which a variance would be granted should be available. A set of specific requirements to be met would be helpful for estimating the costs and likelihood of obtaining a variance. This would allow the option of obtaining a variance to play a greater part in the design stages of bridge projects. Among the most important of the requirements should be demonstration that the costs of meeting the zero-rise requirement significantly outweigh the potential costs of a projected flood increase.

5. CONCLUSIONS AND RECOMMENDATIONS

The basic challenge in regulating public works in the floodplain lies in finding a level of regulation that balances the reduction of flooding risk with the reduction of other hazards, often the very purpose of the public works project. Complicating this task is the need to balance risk reduction economically, so that limited public works funding can be distributed effectively. This assessment of King County's zero-rise floodplain regulation evaluated King County's choice of the zero-rise bridge design constraint. The constraint was evaluated through a review of its enactment; through comparison to floodplain regulations of other states and counties and to broader zero-tolerance regulations; and through a tally of its cost for bridges designed since 1990. On the basis of this work, the following conclusions were drawn:

King County has more restrictive floodplain regulations than other locales in which a zero-rise water surface constraint has been adopted. Because additional Surface Water Design Manual constraints (such as the 6-foot clearance requirement) and Washington State Department of Fish and Wildlife regulations (such as those prohibiting piers in the channel) conflict with the zero-rise goal, it is particularly hard to achieve the goal of zero rise in King County. Other locales studied are free from at least one of these additional constraints. In some locales, major bridge work has not been undertaken since the inception of the zero-

rise regulation, and in others, geographic characteristics make the ordinance easier to achieve. Other states qualify the implementation of the zero-rise constraint by matching the stringency of the regulation to the risk of expensive damages.

Recommendation:

Resolve conflicts between the zero-rise regulation and SWDM constraints on the basis of the relative importance of each for preventing flood damages. Qualify the application of the zero-rise constraint so that it is dependent on the anticipated effects of the rise, without requiring recourse to a variance procedure.

The zero-rise ordinance has caused King County significant cost increases for bridge work, whereas the benefits of the ordinance have not been formally demonstrated.

Although the sample of bridges from which to draw conclusions is small, it is clear that the ordinance has cost King County millions of dollars since 1990 and caused substantial delays in project completions. At the same time, formal estimates of flood damage reductions gained by holding bridge designers to the 0.01-foot rise limit are not available. Even during the initial debate of the zero-rise constraint, a thorough cost and benefit assessment of the ordinance was not conducted. There is little evidence to suggest that 0.01 foot is an appropriate backwater constraint for bridge designers, from any standpoint.

Recommendation:

Perform a cost-benefit assessment of the 0.01-foot backwater constraint over a finite period by noting zero-rise bridge cost increases and studying expected incremental flood damages. Consider other rise limits, such as 0.1, 0.2, or 0.5 feet, which have been adopted around the country, as potentially more appropriate criteria.

The zero-risk paradigm has been found to be unworkable in well-tested examples of national environmental policy. In the past twenty years, regulations specifying zero risk tolerance have proven highly ineffective. Massive delays in implementation and a narrowed, unbalanced scope of application resulted from Congress' specification of zero risk, and as a result, fewer risks were addressed than intended. The zero-risk approach has

since been re-evaluated, and Congress is moving toward feasibility-based or technology-based standards that allow costs and benefits to be balanced.

Recommendation:

Consider the added costs, delays and reduced ability of bridge builders to address the transportation priorities of the region when policy makers adopt regulations for risk reduction. Revise the zero-rise approach to allow negligible increases in flood hazard while not excessively hampering risk reduction.

The intended balancing of flood mitigation against increased bridge expense has not occurred. The Sensitive Areas Ordinance of King County, like floodplain regulations of other locales, includes clauses that allow mitigation of an unavoidable rise through negotiations with property owners. This process has been avoided by the King County Roads Department and is viewed as practically or politically unrealistic. Previous efforts by King County engineers to negotiate with property owners regarding flooding damages have been unsuccessful. Nevertheless, WSDOT and bridge building agencies in other studied areas cite the mitigation procedure as a viable, if infrequently used, option that allows an economically justified deviation from the zero-rise constraint.

Recommendation:

An effort should be made to improve the workability of the mitigation or flooding easement option in King County so that a viable alternative exists when a zero-rise bridge is prohibitively expensive. This effort may involve public relations work and legal reassessment of damage estimations and property rights to create a more open atmosphere for negotiation.

1: INTRODUCTION

Floodplain regulation strives to balance the benefits of reducing flood hazard to human life and property against the costs of limiting encroachment on areas that under normal conditions have appeal for many kinds of development. This balance has shifted and led to increasing floodplain regulation with a deepening understanding of the ecological importance of the floodplain and the added weight of resource protection.

The 1990 enactment of a zero-rise ordinance in King County tightened floodplain regulations enough that agencies responsible for maintaining safe bridges and roadways are now hampered by excessive design and construction costs. Balancing the costs of flood hazard reduction and ecosystem protection with the costs of maintaining transportation safety is not easy and was not given full consideration by King County policy makers in drafting the 1990 regulations. The result has been the creation of a highly restrictive regulatory environment in which bridge replacements and improvements are prohibitively expensive or impossible without variances from one or more regulations.

This project evaluated the implications of the zero-rise regulation for bridge builders in the King County Roads Division and the Washington State Department of Transportation (WSDOT). This goal was accomplished by

- a) documenting the development of the zero-rise regulation of the 1990 Sensitive Areas Ordinance (SAO)
- b) comparing King County floodplain regulation to similarly restrictive regulations of other states and counties and to other "absolute zero"-type regulations
- c) assessing the costs of the ordinance for bridges designed since 1990
- d) evaluating the procedure for obtaining variances from the zero-rise criterion.

2: HISTORY OF THE ZERO RISE ORDINANCE

The trend in King County toward increasing protection of natural resources and preservation of sensitive areas dates back to at least the early 1970s. Floodplain management statutes have been in place since then, but more stringent floodplain management regulations have become features of the broader environmental policies of a King County administration interested in halting the impacts of rapid development. The following sections discuss the regional motivation for the Sensitive Areas Ordinance (SAO) and its floodplain provisions, as well as agency involvement in the legislative development of the zero-rise regulations.

2.1 REGIONAL MOTIVATION

King County initiated policies for preserving wetlands and open space with Ordinance 1838 in 1973. At that time, King County enrolled in the National Flood Insurance Program, adopting floodplain regulations in a Flood Hazard Ordinance that met the minimum national standards administered by the Federal Emergency Management Agency. By 1978, sensitive areas had been designated and published in the Sensitive Areas Map Folio, and in 1979 SAO 4365 was adopted, extending protection from development to “fish-bearing waters and land with coal mine, landslide, seismic and erosion hazards.” (Katsaros, 1992) These conservationist policies were broadened and detailed in the following five years, culminating in 1984 amendments to the SAO that added administrative guidelines for wetland management.

In state law, the Planning Enabling Act (RCW 36.70) established a general planning and zoning model that was followed by home rule jurisdictions, such as King County. In 1985, the King County Comprehensive Plan was published, adopting policy guidelines for land use and development, some of which included floodplain regulation. The 1990 Growth Management Act (RCW 36.70A) required the development of SAO-type

regulations for counties with sensitive areas, and in many regards, the 1990 King County SAO was designed to anticipate the trend in Washington State policy.

At the county level, the public increasingly supported environmental protection. In the 1980s, King County experienced unprecedented growth, and in 1988, it was the 14th fastest growing county in the nation, facing an expected addition of 300,000 people (one third of the existing population) in the 1990s. As in 1988, when 80 percent of 4100 new lots were created in unincorporated areas, the projected population growth was expected to have the greatest impact in these areas. Alarmed by county growth rates, the public increasingly supported growth management and resource protection. In response, in 1988 King County prioritized a rewrite of the 1979 SAO to incorporate growth management regulation.

A common criticism of the 1979 SAO was that it failed to provide a consistent set of standards by which developers of sensitive area lands could guide their planning. County officials, on the other hand, felt that there were no consistent protective mechanisms to guarantee the preservation of sensitive areas (Katsaros, 1992). The new version of the 1979 SAO set more uniform standards and lessened the need for case-by-case judgments by permitting divisions. The zero-rise floodplain regulation criterion is one example of such a uniform standard.

The proposed revisions to the SAO were highly controversial, although little of the controversy centered around the new floodway regulations. The amendments concerning wetlands, stream buffer zones, grading and clearing regulations, and steep slopes were condemned by land developers, realtors, homeowners, farmers, and forestry concerns throughout the county. Environmental groups and the Muckleshoot and Tulalip Indian Nations supported the ordinance. Law firms responded to the still-contested issue of public condemnation or "taking" of private land--the power of eminent domain--largely with the view that the amendments were unconstitutional. The Town of Snoqualmie voiced reservations that the SAO would put a virtual halt on all development within its borders. At

the public hearing that preceded Council action on the SAO, over 200 speakers gave testimony.

2.2 AGENCY INVOLVEMENT

Riley Atkins of the King County Parks, Planning and Resources Department (PPRD) originally drafted the proposed amendments for the SAO, with later involvement by the King County Surface Water Management Division (SWM), particularly concerning the floodplain regulations. The King County Prosecuting Attorney's office was consulted throughout the process on the legality of the amendments. The King County Public Works Roads Division raised objections to the floodplain regulations, but subsequent negotiations resulted in support of the SAO by the King County Public Works Department (Bean, 1995).

As the amendments were developed, SWM evaluated the zero-rise regulation. After a ten-day assessment of future impacts of floodplain development and the zoning changes resulting from the zero-rise floodway change, SWM recommended zero-rise over the existing regulations. Included in this recommendation, however, was the suggestion that "the potential impact on roads from the revised floodway standard is significant enough to warrant special conditions and/or exemptions for some road improvements" (Kramer, 1988), which specifically included "bridge replacements." Perhaps because of the controversial nature of the amendments, the Council did not, in the end, opt to allow this public project exemption. In general, assessments of the impacts of the zero-rise regulation focused on potential residential and commercial development, rather than on transportation in the floodplain.

King County Executive Tim Hill vigorously supported the tighter environmental regulations and suggested only small changes to the draft before formally proposing the SAO to the King County Council in January 1989. In April, criticism of the draft at the first public hearings from property rights activists prompted committee review of the ordinance (Katsaros, 1992). The King County Council Growth Management, Planning,

and Environment Committee (GMPEC) studied issues associated with the proposed 1990 SAO, but the floodplain regulations from SWM and the PPRD went through the evaluation largely unchallenged. Of the 110 changes to the SAO amendments proposed before the Council vote, fewer than ten (seeking minor changes in phrasing) pertained to the floodplain regulations. In August of 1990, the SAO was adopted by a nearly unanimous Council vote.

A review of the development and review process reveals conspicuously limited commentary from groups involved in public works, such as major utilities, water and sewer districts, road builders such as the WSDOT and the Federal Highway Administration, and public works contractors. A token few raised the issues of exceptions for public works and reliance on a "Best Management Practice" approach to regulation, which allows for case-by-case judgment. The Master Builders' Association noted "significant problems with floodway restrictions on development" and that "all of these costs [of existing transportation services and other public service] are increased with this ordinance" (MBA, 1989). Also noted was the apparent inconsistency between the environment-related cost increases of public works under the SAO and the 1985 Comprehensive Plan guidelines supporting capital improvements and regional economic stability. One law firm observed that the SAO, in general, "fails to balance our need to protect sensitive areas with the enormous economic impact these regulations will have" (Ferguson and Burdell, 1988). With these exceptions, however, the SAO amendments appear to have been developed largely by resource management groups, with little input from those who would actually implement the ordinance.

The 1993 and 1994 sessions of the state legislature introduced legislation which, if passed, would have required the model floodplain ordinance, administered by the Washington State Department of Ecology (DOE), to specify a zero-rise policy for all flood-prone counties. In both years, this legislation passed the House Committee on Environmental Affairs but failed in the Senate Natural Resources Committee (Johnson,

1995). Currently, legislation that requires merely consistency between state and county regulations, but defers to the more stringent of the two, is under review by the House and Senate committees. This legislation does not specifically mention zero-rise restrictions.

Also on the state level, in 1994 the Department of Fisheries Hydraulic Code moved away from a zero-rise design criterion for bridges, amending the code governing bridge design from prohibiting “any appreciable increase in backwater elevation” to disallowing “any appreciable increase (not to exceed 0.2 feet) in backwater elevation” between the Ordinary High Water Marks of the channel (WAC 220-110-060).

A chronology of important events in the development of floodplain regulations in King County is given in Appendix A.

3: BRIDGE PROJECTS IN KING COUNTY

3.1 THE ZERO RISE CRITERION

Before 1990, King County floodplains were regulated to the minimum standards required for membership in the National Flood Insurance Program (NFIP), which is administered by Federal Emergency Management Association (FEMA). Parties involved in the construction or maintenance of bridges and roadways in King County were particularly concerned with the SAO inclusion of a "zero-rise" floodway, delineated to encompass the entire floodplain, and policies that prohibit development that causes a rise of 0.01 foot or greater in the 100-year flood elevation upstream or downstream of the development. The difficulties experienced by bridge engineers in King County since the 1990 SAO stem from a number of requirements imposed either by the SAO or by the other regulatory codes.

The most significant change in regulations is the zero-rise requirement and the associated widening of the regulatory floodway. Formerly, King County's NFIP-based standard, common to most states in the U.S., defined a "floodway" in the central portion of the channel and a "flood fringe" encompassing the remainder of the floodplain landward of the floodway boundaries. Floodway boundaries are delineated at the point where complete fill of the margins of the floodplain causes a rise of some specified increment in the 100-year flood elevation. The NFIP increment is 1.0 foot; 0.01 foot is the increment allowed under King County's zero-rise policy. The floodway and flood fringe areas are shown on FEMA maps created for the major streams of a state or locality that enrolls in the NFIP (450 of 3,000 river miles in King County are mapped in this way). Because King County does not possess maps showing the 0.01-foot rise floodway, the entire floodplain is currently used as the regulatory floodway. The delineation of these areas under the NFIP and King County policies is displayed in Figure 1a. Figure 1b shows the NFIP floodway and the flood fringe in which abutments or piers formerly were allowable. Figure 1c shows

the reduction of the flood fringe area under the zero-rise ordinance, once the zero-rise floodplain has been modeled and mapped.

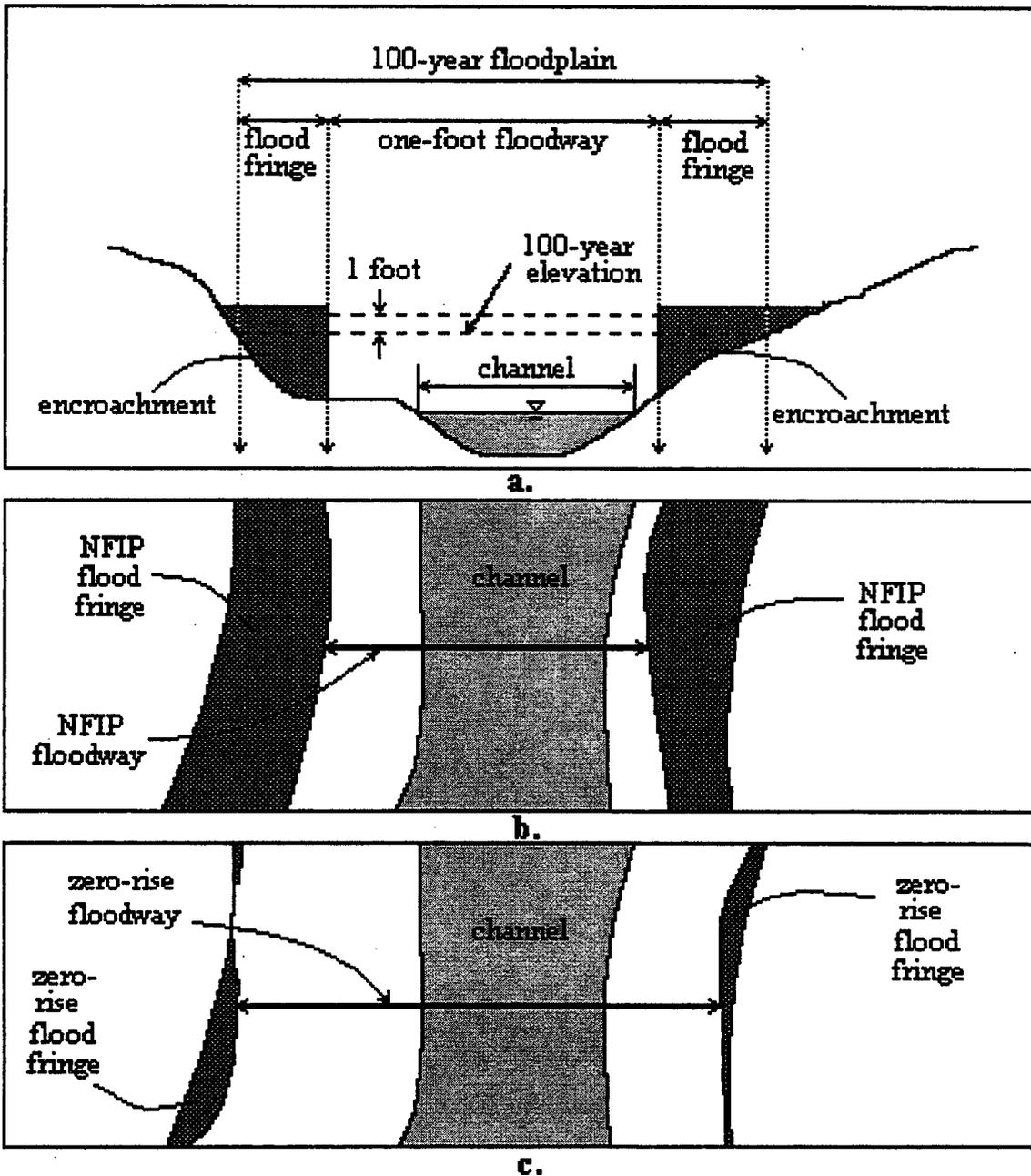


Figure 1 Comparison of NFIP and zero-rise floodplain regulations: a) profile of channel and floodplain; b) plan view of the NFIP 1-foot floodway; and c) plan view of the zero-rise floodway

Like the former King County NFIP regulations, the zero-rise policy does not allow construction or development in the floodway that obstructs flow and causes a rise in flood elevation; thus the significant difference in the present policy is the widening of the floodway over which this restriction applies.

Exceptions to the zero-rise elevation rule are clauses in the ordinance that allow the permitting of non-zero-rise designs. The SAO allows an exception under the following conditions:

1. amendments to the Flood Insurance Rate Map (FIRM) have been adopted by FEMA in accordance with 44 CFR 70 to incorporate the increase in base flood elevations
2. appropriate legal documents are prepared in which all property owners affected by the increased flood elevations consent to the impacts on their property. (KCC 21.54C, 1993)

The first condition applies only to rises caused by development within the FEMA floodway because the FEMA maps assume that the FEMA flood fringe has been filled in. FEMA does not amend the FIRM for a rise caused by development outside of the FEMA floodway. In the second condition, the legal means for obtaining consent of property owners is not explicitly stated. Common legal preparations range from freely obtained consent to condemnation and compensation under the rights of eminent domain, which often carries the risk of a lawsuit. Between these extremes lie the options of purchasing flowage easements on a property, paying for floodproofing on the property, and relocation of the owners. All of these options involve negotiation with property owners unless King County owns the property. The provisions are intended to encourage cost-effective designs that balance zero-rise bridge costs with property impact mitigation or acquisition costs.

A second feature of the King County ordinance is the specification that there can be no net loss of flood storage as a result of development in the floodplain. If a loss occurs,

compensatory storage must be provided “on the site, or off-site if legal arrangements can be made to assure that the volume will be preserved over time” (KCC 21.54.82). Loss of flood storage can occur because of fill placed to support an approach road for a bridge or modification of the bridge abutments. A section of the SAO relating specifically to floodway dependent structures, such as bridge piers and abutments, states that their location in the floodway is not exempted from the zero-rise criteria and is subject to the regulations of the other agencies that have jurisdiction.

Although the two clauses above offer legal means of economically selecting bridge project designs, the non-zero rise bridge coupled with negotiated flooding mitigation is generally not a politically viable option. As will be seen from the codes of the two other states that have zero-rise regulations, more lenient coding of the non-zero-rise option makes zero-rise less of an absolute constraint and hence allows economically and politically feasible alternatives.

3.2 BRIDGE DESIGN IMPLICATIONS

The effect of the zero-rise ordinance on bridge design varies, depending on the design problem. In the case of a new river crossing, any encroachment into the floodplain that is required for a bridge abutment or pier will cause a backwater (an upstream rise), as well as a loss of flood storage. Changes made in the channel cross-section at the bridge to increase the conveyance of the constriction and counteract this backwater effect may potentially cause a downstream rise or higher velocity flows downstream. In floodplains that have wide, flat cross-sections, the potential to cause a rise is slightly lower than for narrow, steep floodplains because 0.01 foot of water surface elevation represents a greater volume of storage in the flat floodplains. In flat floodplains, however, the width of the regulatory floodway requires a long bridge with widespread abutments, a situation exacerbated by the zero-rise floodway delineation.

Bridge refurbishments and replacements are also complicated by the zero-rise criterion. These projects almost always involve widening the roadway for improvements in

traffic safety and can change the substructure of the bridge or the hydraulic characteristics of the crossing, thereby requiring added fill or pilings to support a wider or higher approach road. For structural reasons, new piers to support a widening are usually located in the floodplain adjacent to existing piers (placed before implementation of the new floodplain regulations). These alterations have potential to cause a rise, remove storage from the floodplain, or both.

Although the SAO includes the provision that storage losses can be compensated, the identification and acquisition of compensatory storage areas in urban, suburban, and even rural areas of King County are often problematic and expensive. The situation in which a zero-rise design bridge is prohibitively expensive, perhaps because of increased length, is equally serious. Despite the aforementioned provision to allow non-zero rise designs with the consent of the affected property owners and a map amendment by FEMA, King County Public Works views the pursuit of flooding easements, either negotiated or through condemnation, as politically untenable in nearly all situations (O'Brien, 1995; O'Neill, 1995).

Condemnation, in particular, may be viewed as public taking of private property and has been avoided for bridge projects in King County. According to an SWM engineer, obtaining the consent of property owners to increase flooding on their property, with or without fair compensation, is "next to impossible." Past attempts have had little success (O'Neill, 1995). In general, the option to purchase easements is occasionally viable in rural areas where property values are low, or where land is undeveloped, but it is difficult to pursue in urban or suburban areas.

The FEMA map amendment process has also been described as a major obstacle to negotiating a non-zero rise bridge by the engineers involved in permitting (Haglen, 1995; O'Neill, 1995). The agency with jurisdiction over the bridge permitting must initiate the application for a map amendment from FEMA, and therefore the support of the agency manager for the non-zero-rise project must be strong. Obtaining this approval may be as

difficult as obtaining an outright variance (Haglen, 1995; O'Neill, 1995). This difficulty may be less of a factor for the King County Public Works Department than for WSDOT. Applying for a Letter of Map Revision (LOMR) incurs the engineering expenses of determining the new floodway area and delays of at least 3 to 5 months in the project permitting process (FEMA, 1990). The application fees alone can be several thousand dollars, but they are negligible in comparison to the engineering expenses (Steele, 1995). In addition, the FIRM amendment requires certification that "no structures are located in areas which would be impacted by the increased base flood elevation" (44 CFR 65.12). This clause disallows non-zero rise bridges in developed areas. The bridge designer's only recourse is to buy these properties at market value.

3.3 ADDITIONAL REGULATIONS THAT AFFECT BRIDGE DESIGN

Additional policies in King County currently complicate road and bridge design, some directly prohibiting bridges designed to comply with the zero-rise regulations. Besides the regulations listed below, federal and SAO wetland protection regulations are a major source of cost increases on roadway and bridge projects. Because wetlands concerns tend to complement—rather than conflict with—zero-rise concerns, they were not studied in detail for this report.

3.3.1 State Department of Fish and Wildlife Regulations

The Washington State Department of Fish and Wildlife (WSDFW) "discourages" the placement of piers within the Ordinary High Water (OHW) marks of a stream, as delineated by the transition from riparian to upland vegetation or soil type (Deusen, 1995). The OHW marks generally straddle a central portion of the channel, but their width is dependent on the channel topography. This requirement is expressed in both the laws and administrative codes of Washington. The first give the WSDFW the right to deny a hydraulic permit approval for work within the OHW, but they note that "protection of fish life shall be the only ground upon which approval may be denied or conditioned" (RCW 75-20-100). The second, the Hydraulic Code, has required since 1994 that bridge piers

within the OHW marks must not cause greater than a 0.2-foot backwater (WAC 220-110-060). The Hydraulic Code, however, vests in the Department of Fisheries the authority to review the projects on a case-by-case basis and to apply technical criteria as warranted to protect fish life (WAC 220-110-032). The general interpretation of these criteria has been to prohibit piers in the OHW channel, although on occasion exceptions have been made (O'Brien, 1995). Note that the backwater criterion of the Hydraulic Code is more lenient than the zero-rise code. In 1990, however, the WSDFW supported the adoption of the zero-rise policy (Deusen, 1995).

In the expanded zero-rise floodplain, bridge abutments must be set back from the channel. This sometimes requires spans that exceed structural length limits on bridge span types (about 130 feet for prestressed concrete girders and 260 feet for steel plate girders). The long spans then require the addition of intermediate piers in the channel. As they have been interpreted, Fish and Wildlife criteria preclude multispan bridges with supporting piers as a design option for large bridges, unless the piers can be kept toward the margins of the floodplain.

3.3.2 Surface Water Design Manual Clearance Rule

A more troublesome criterion is the 6-foot clearance rule of the King County SWDM. Under the clearance rule, bridges in King County must clear the 100-year flood elevation by 6 feet. This regulation is intended to prevent the accumulation of debris against bridges during floods. In comparison, the less stringent NFIP standard requires that structures in the floodplain not obstruct the flow of the river beneath the 100-year flood elevation and that their lowest floor be elevated to the level of the 100-year flood; essentially, no clearance is required. The origin of the 6-foot clearance magnitude is unknown (O'Brien, 1995).

This requirement comes into direct conflict with the zero-rise criterion because the raised bridges necessitate raised approach roads supported on more fill or bridge structure. The placement of the fill almost inevitably causes a backwater rise, and in any case the

storage loss must be compensated by the provision of new storage. In part, the regulation has the effect of limiting development adjacent to the river channel and near the bridge because the raised approaches cause an increased rise on these areas. Mitigation for at least one of these effects is inevitable, with the result that easements on properties near the bridge and adjacent to the stream channel must be purchased by the county. Variances from the clearance requirement have been provided in several cases after an in-house determination by SWM that the exemption was justified. For example, the Raging River #234A bridge near the town of Snoqualmie was granted a 3-foot clearance requirement, since the severity of the flooding in the town during a 100-year flood event trivializes the importance of maintaining 6 feet of clearance for the bridge crossing.

3.3.3 FEMA

FEMA's regulations regarding the floodplain are generally more permissive than those of the King County zoning code. The FEMA floodway is used by the SAO (KCC 21.54.320.B.4) to define a zone from which piers must be excluded. This requirement may be more restrictive than the similar Hydraulic Code requirement for the OHW channel, depending on the relative locations of these boundaries.

3.3.4 Route Classifications

King County identifies roads that shall not flood during the 100-year event, a classification that depends on whether the roadway provides access to a critical facility, such as a hospital. Any road that must be raised to the elevation of the 100-year flood is normally supported on fill (potentially violating the zero-rise criterion and the storage provisions of the SAO) or on an expensive bridge structure.

3.4 DISCUSSION

In the different and sometimes conflicting requirements of the agencies that have jurisdiction over floodplains in King County, the bridge designer faces a morass of poorly coordinated legislation. In some cases, even the exact replacement of existing bridges is impossible without administrative relief from at least one of the requirements detailed

above. The negotiations involved in gaining variances or exemptions and the added iterations of the bridge design process are presently a waste of engineering resources and funding. As may be seen from a comparison with other zero-rise locales, freedom from some of these additional requirements would allow a more flexible and economical design environment, making the zero-rise policy a more viable regulation.

The next chapter discusses floodplain regulations in other states and counties that are more stringent than the NFIP standards. Although it was not possible within the scope of this report to obtain data describing the costs of these regulations, the structure of the regulations is described for comparison, and suggestions are offered regarding the reasons the zero-rise approach has been sustainable elsewhere.

4: COMPARISON OF FLOODPLAIN REGULATIONS

Although the enactment of the zero-rise ordinance in King County is recent, similar policies have been in effect for at least a decade in other parts of the country. Nine states, most in the Great Lakes region, have floodplain regulations that are more stringent than the minimum suggested standards of the NFIP regulations. A 0.1-foot rise regulation was adopted by Michigan in 1968 and by Illinois in 1975, and Wisconsin adopted a zero-rise policy in 1986. On the East Coast, New Jersey uses a 0.2-foot rise regulation, and Maryland adopted a zero-rise policy in 1981. Arizona very recently adopted a zero-rise policy (ASFPM, 1992). In the Northwest, Wyoming adopted a statewide 0.1-foot rise policy in 1989, Montana has had a 0.5-foot rise policy for over two decades, and Oregon and Idaho currently abide by a 1.0-foot policy. Various counties within these states have zero-rise ordinances to which the state minimum standards defer.

The backwater limitations used here to label floodplain management policies do not include the additional regulatory constraints, discussed previously, that affect bridge design issues. To evaluate the impact of the rise constraint properly, not only the state code specification of the rise limit but also other constraints must be examined. The following discussion details regulations of Wisconsin and Maryland (two “zero-rise states”), as well as those of other states, and their effects on the implementation of the zero-rise policy. Table 1 summarizes features of the regulations for comparison.

4.1 WISCONSIN FLOODPLAIN REGULATIONS

Wisconsin adopted a statewide zero-rise policy in 1976. The objectives of the floodplain ordinance included minimizing the occurrence of flood blight areas and public spending on flood control projects, protecting life and property, and preventing increased flooding and flood damages that might be cause for litigation between landowners. Implicit within these goals is the restriction of development within the floodplain, as can be seen from the coding of the ordinance.

Table 1. Comparison of several “no-rise” ordinances.

code feature	State or Locale		
	King County	Maryland	Wisconsin
rise criterion	0.01' over existing	0.01' over existing	0.01' over existing
clearance requirement	6 feet	0 feet	0 feet
downstream rise regulated?	yes	yes	yes
prohibited pier in floodway or channel?	yes	yes	no
in-kind replacement exception?	no	yes	no
negotiated alternatives	easements	easements and notification	easements and notification
constraint depends on effect?	no	yes	yes

4.1.1 Similarities to King County Regulations

The key elements of Wisconsin’s regulation of the floodplain are similar to those of King County. The zero-rise regulatory floodway is specified through the definition of “hydraulic floodway lines,” which enclose the portions of the channel required to convey the 100-year flood with no increase in elevation. The flood fringe is the portion of the floodplain outside of the floodway and is generally associated with standing water during the regional flood. Also defined are “shallow depth flooding areas,” which are sections of the floodplain in which depths do not exceed 1.0 foot and flooding does not last more than 6 hours. With the exception of shallow depth flooding areas, these definitions are essentially the same as those in King County.

The zero-rise policy is stated to mean no increase in 100-year flood height equal to or greater than 0.01 foot “resulting from a comparison of existing conditions and proposed conditions which is directly attributable to development in the floodplain but not attributable to manipulation of mathematical variables such as roughness factors, expansion and

contraction coefficients and discharges.” With the inclusion of this clause, Wisconsin explicitly recognizes the vulnerability of model results to inconsistent parameterization.

The Wisconsin zoning code directs modelers to use expected future flow conditions (based on a synthetic hydrograph or a mathematical model) in rapidly urbanizing watersheds, watersheds in which 20 percent of the land area of the watershed is developed, or where projected growth rates are 10 percent or more for the next ten years. This feature of the code was considered by SWM and, although not included in the SAO, has been adopted in the SWM Flood Hazard Reduction Plan. However, the effect of using estimated future runoff conditions on the determination of rise is unclear, since flow is only one of many variables that affect water surface elevation and that are held constant in the sensitivity analysis. This is true when any model is used, although the U.S. Army Corps of Engineers Hydrologic Engineering Center’s HEC-2 model is most commonly used. The added effort and costs of developing estimates of future runoff conditions can be significant.

Standards for hydraulic analysis specify the use of HEC-2. The contractor can be required to submit justification for cross-sectional spacing, differences in energy grade, methods for analyzing the hydraulics of structures such as bridges and culverts, lack of flow continuity, use of gradually varied flow models in addition to HEC-2, Manning’s n values, and calibration of the hydraulic model.

In the flood fringe, development cannot affect the conveyance capacity of the stream by causing an obstruction to the flow or by decreasing the storage capacity of the floodplain. This is evaluated by estimating whether the regional flood height or discharge would be increased. This essentially means the entire floodplain is regulated as a floodway. Roads must be at base flood elevation and floodproofed if their failure would result in danger to public health or safety.

Compensatory storage requirements in Wisconsin apply to flood storage areas, in which compensation may be effected by any means other than excavation below the water

table. Flood storage areas are defined as areas not associated with central flood flow, but where floodwaters are quiescent. A compensatory storage requirement for these areas is more appropriate than for the main channel flow area. The obstruction of flood flow (and thus the creation of a backwater) in the main flood flow channel caused by the addition of fill is generally more problematic than the loss of storage associated with that fill. In some cases the storage in these areas, such as overbank storage, merely delays the flood peak with little or no attenuation. The King County code is not sensitive to this distinction and is more restrictive in prohibiting a loss of storage anywhere in the floodplain.

Issuance of a variance by the Wisconsin Department of Natural Resources (WIDNR) requires a public hearing, and a variance is not granted for economic gain or loss, self-created hardship, to permit a lower degree of flood protection than the current flood protection elevation, and unless it is shown to be in the public interest. Variances are limited to dimensional breaches of the zoning code and are prohibited if they change the nature of an ordinance.

4.1.2 Important Differences from King County's Regulations

Wisconsin law does not generally prohibit the placement of piers within the regulatory floodway, although the backwater criterion may limit pier placement, and there may be specific streams where piers are not allowed. The issue of protecting spawning beds is probably less political in Wisconsin than in King County. As noted earlier, the ability to place a pier in the center of a channel allows the use of a multi-section bridge to span wide channels, where the flow may be slow enough that the piers do not cause a discernible backwater.

The King County 6-foot clearance requirement has no counterpart in the Wisconsin regulations, where bridges must be designed to pass the 100-year flood, meaning that they must be elevated to the base flood elevation. Without the 6-foot clearance requirement, the backwater and compensatory storage problem associated with raising approach roads to meet the requirements is not an issue.

These two differences alone frame the zero-rise regulation differently than that of King County. In Wisconsin, moving to a zero-rise design more often means simply lengthening the bridge, perhaps by adding a pier, to keep the abutments out of the floodplain, without the difficulties faced in King County of completely spanning the floodplain, selecting a much deeper substructure or completely different bridge type, or raising the approach roads and creating a backwater. Replacement bridges in King County may improve the channel cross-section, but the design still fails when the approaches and bridge deck are raised, causing a flood level rise over existing conditions (cf. Raging River #234A). In Wisconsin, replacement bridges do not pose as much of a problem.

In addition, although the Wisconsin Department of Transportation (WIDOT) projects are not exempt from the requirements governing the floodplain, the agreement between the WIDOT and WIDNR, described in the following subsection, allows a cooperative design process by which unreasonable adherence to the technical specification of the 0.01-foot criterion is often avoided.

4.1.3 Cooperation Between WIDOT and WIDNR

A cooperative agreement between WIDOT and WIDNR acknowledged the conflict between the duties of the WIDOT and WIDNR (Besadny and Jackson, 1983).

The Wisconsin DOT and DNR recognize that the WI Legislature has charged DNR with the responsibility for protecting the State's land, water, fish and wildlife resources; and has charged DOT with furnishing the citizens of Wisconsin with an adequate, safe and economical transportation system. The DOT and DNR further recognize that the construction, reconstruction, maintenance and repair of transportation facilities, including highways and bridges, may have potentially adverse effects on the environment.

Proceeding from this problem statement, the agreement establishes a procedure whereby the two agencies consult and assist one another in reaching economical and environmentally sound project completions. Notable features of this procedure include the following:

- WIDOT notification to WIDNR of proposed projects
- WIDNR review and recommendations on projects that “recognize that it is the policy of the state to provide a safe and economic transportation system with a minimal environmental impact”
- a provision that “if DOT feels that it is not practicable to comply with DNR recommendations, appropriate department staffs will meet and resolve any differences....[keeping in mind] the total needs of the public as well as the specific needs that each is mandated to administer”
- agreement that before special land-use restrictions are implemented, WIDNR will advise WIDOT so that “measures to provide for needed transportation corridors can be taken”
- agreement that WIDOT will abide by NR 116 floodplain regulations [(zero rise)] and aid local governments in complying.

Aside from the apparent climate of cooperation between WIDOT and WIDNR, note that the final point does not waive the zero-rise regulations for WIDOT.

Provisions for appropriate legal arrangements and easements are also included in the cooperative agreements:

- For streams for which no zoning ordinance is in effect, or for which no adverse effects associated with a base flood rise are anticipated, notification of property owners is sufficient.
- Otherwise, notification and just compensation for future damages (purchase of flowage easements and possible condemnation) are required.

The first option allows the bridge designer to raise the backwater to NFIP limits (1 foot) with no cost if no devaluation of property occurs, such as in steep-banked channels; the second simply enables the use of easements to mitigate potential damages of flooding, a provision also available in King County. In the “no adverse effects” clause for WIDOT, the application of the zero rise regulation is limited to cases where it matters.

4.1.4 Floodplain Management under Wisconsin Law

Bridge engineers from the FHWA and WIDOT indicated that, on the whole, bridge operations in Wisconsin are slightly hampered by the regulatory climate. Data were not available that would allow a direct comparison of bridge costs incurred under zero-rise regulations to the baseline costs under NFIP regulations. According to the WIDOT Bridge office, an estimated 10 to 15 percent of bridge projects are affected by the zero-rise criterion. Easements are purchased in about 10 percent of these cases (about 1 percent of the total number of bridge projects) but are pursued primarily in rural areas (Woods, 1995). The remainder of the affected projects end up with costlier zero-rise designs, particularly in urban or suburban areas where real estate costs are greater and the economically justified solution is to build a longer bridge. The zero-rise regulations have been estimated to cost the State of Wisconsin millions of dollars per year (Alleva, 1995). Most of these cost increases are thought to be incurred on small bridge projects. According to WIDNR, the procedure for obtaining a variance is costly and labor intensive, and not many, if any, variances have been granted (Stigen, 1995).

The payment of flood mitigation costs in the form of easements is an important component of the floodplain regulations. By allowing the state designer recourse to a method of land acquisition, the regulations guide bridge design to the most economically efficient solution. These right-of-way acquisitions and other negotiations usually occur before the project design and are not included in the costs of the project. Estimates of the frequency with which these options are used were unavailable.

In conclusion, although the Wisconsin zero-rise regulation is essentially the same as the King County regulation, two important differences lessen the consequences. First, it is easier for the bridge builder to build a zero-rise bridge that causes no adverse impacts in Wisconsin because of the exception granted when it can be shown that the rise is not harmful. Unlike in King County, the Wisconsin code clause focuses the regulation on bridge cases in which the zero-rise design may be economically justified. Second, no

substantial clearance rule or fisheries-based pier prohibition conflicts with zero-rise clause. The state floodplain regulations are consistent with the FEMA regulations in this regard, making it easier to replace bridges without significantly altering the hydraulic design of the approaches. The state of Wisconsin is still required to lengthen some bridges and pay property acquisition costs in other cases and is apparently reconciled to the idea that such a use of state funds is justified.

4.2 MARYLAND FLOODPLAIN REGULATIONS

Maryland adopted a zero-rise policy 20 years ago under Title 08 Annotated Code of Maryland (COMAR) (MDDNR, 1989). The policy requires permits for any obstruction that changes “the course, current, or cross-section of a stream or body of water...including the 100-year frequency floodplain...” (COMAR 08.05.03.01). The laws further state that

[proposed] projects which increase the risk of flooding to other property owners are prohibited, unless that area subject to additional risk of flooding is purchased, placed in designated flood easement, or addressed by other means acceptable to the Administration (COMAR 08.05.03.11).

The stated objectives of the regulations are much the same as in Wisconsin, namely to permit only those waterway constructions that are “in the best public interests and...provide for the greatest feasible utilization of the waters of the State, adequately preserve the public safety, and promote the general public welfare” (COMAR 08.05.03.01).

The language of the law does not specify an allowable increment, but 0.01 foot is the smallest criterion, used where no surface increase is to be allowed (Kosicki, 1995). The actual application of the policy is not written in law but in the practices of the Maryland Department of Natural Resources (MDDNR), which is the permitting agency for waterway construction. MDDNR reviews permit applications case by case and renders decisions on the basis of the impact of the rise. Any rise on improved properties must be compensated through the purchase of flooding easements, floodproofing, or relocation; however, for non-improved (undeveloped) properties, MDDNR requirements are the following:

<u>Backwater</u>	<u>Acceptable Action</u>
less than 4 inches	notify property owner
4-12 inches	obtain signed consent of owner
greater than 12 inches	require purchase of flooding easement

The implementation of the Maryland zero-rise policy is qualified, as are the Wisconsin regulations, to focus on situations in which a rise can be related to significant monetary damages (Quinn, 1995).

4.2.1 Similarities to King County Regulations

In most regards, the regulations in Maryland are at least as strict and comprehensive as those in King County. Piers are prohibited in the base-flow channel because of concerns about anadromous fish habitat, just as the WSDFW prohibits piers between the OHW marks. Backwater evaluations are based on flows for the ultimate forecasted watershed development, as best estimated from existing conditions. In Maryland, however, designers must evaluate 2-, 10-, and 100-year events, rather than the 100-year event alone, as required by the King County SAO. The downstream rise is regulated to the same tolerance as the upstream rise, and a number of flow requirements (limiting velocities, Froude numbers, change in tractive force) are also established for downstream flows. Maryland bridges “which have a width from top-of-bank of 80 feet or less, measured along the centerline of the proposed roadway” are required to completely span the stream channel.

As in King County, a legal process exists through which flooding easements and negotiation or mitigation of potential flood damages may be pursued as an alternative to building a zero-rise bridge. This process applies in both rural and urban areas.

Variations can be granted by the Administration (MDDNR) following a letter of justification, without requiring a public hearing process. The criteria established in the laws are guidelines for the bridge permit applicant, but the Administration will grant a variance if the regulation is not in the public’s interest. The Administration determines whether the proposed project or the letter of the law best promotes the general public

welfare. Unlike in King County, MDDNR reviews all permit requirements in what is termed a "joint permitting process," and extended and contested negotiations between the road builder and multiple resource agencies arise infrequently.

4.2.2 Important Differences from King County Regulations

Particularly for urban, developed areas, the Maryland laws are similar to those of King County. The impact of the zero-rise criterion, however, is alleviated by a number of significant differences.

- Maryland requires bridges only to clear the 100-year flood elevation. As discussed above for Wisconsin, freedom from a 6-foot clearance requirement avoids many of the difficulties associated with placing fill under raised approaches.
- Maryland allows an exemption from a new permit if the bridge is replaced "in kind," which includes widening projects or reconstructions in which the hydraulic parameters of the cross-section do not change by more than 10 percent (Kosicki, 1995). Because bridge replacements make up the majority of bridge projects, bridge designers often do not contend directly with the zero-rise criterion.
- The regulations for unimproved property are clearly more lenient than those in King County, where the zero-rise criterion governs all property types.

The Maryland laws, taken together, do not create quite the restrictive environment that has developed in King County. Their sustainability over the years is undoubtedly a direct result of the extent to which they are not blanket criteria but depend upon the potential effects of a rise.

4.2.3 Floodplain Management in Maryland State

As noted above, the body of floodplain management regulations in Maryland has largely been in place for over 20 years. Although a few of the engineers interviewed in MDDOT remember a period of comment (Pollicelli, 1995; Kosicki, 1995) in which

MDDOT challenges made challenges to the MDDNR floodplain regulations, no documentation of that effort was available. In addition to the differences noted above that lessen the impact of the zero-rise criterion, the MDDOT-property owner negotiation process appears more accessible than the negotiation process in King County. Although the application of easements, floodproofing, or property acquisition is infrequent in urban areas, the use of these alternatives seems more frequent in Maryland than in King County. In one case, cited by both MDDNR and MDDOT personnel, over \$1 million was paid for a dozen homes to avoid zero-rise costs (Kral, 1995; Quinn, 1995). Although some media-driven negative publicity arose from this project, the property owners were amenable (Kral, 1995). In most cases, however, easement costs are smaller and occur in rural areas, and urban bridges conform to the zero-rise criterion. In Baltimore, for example, no new bridges have been built since the regulations were enacted, but on the most recent replacement, a 20 percent to 40 percent cost increase was incurred in lengthening the bridge span over the existing length (Baltimore PW, 1995). Variances to the zero-rise criterion have been sought rarely (MDDOT, 1995).

4.3 INTERESTING FEATURES OF OTHER STATE'S REGULATIONS

In addition to regulations in Wisconsin and Maryland, regulations in Michigan and Illinois were evaluated. The regulations of the latter states were found to be less stringent than those of Wisconsin and Maryland and therefore will not be discussed at length. However, several interesting alternative approaches to some aspects of floodplain regulation were found.

- In Illinois, the downstream rise is regulated relative to original rather than existing conditions. The underlying premise is that with the constriction of an existing bridge, the downstream property owners have been afforded an incidental benefit of flood protection. If the Illinois DOT then opens up an existing bridge constriction to avoid backwater effects and causes a downstream rise, the new flood risk downstream may still be lower than

before existence of the initial bridge. The downstream rise in this case is not prohibited. The upstream rise is still compared to existing conditions, however (Hoskins, 1995).

- The Illinois policy was intended to be a zero-rise policy but was codified as a 0.1-foot rise criterion because this increment is recognized by regulators to be the accuracy limitation of the water surface profile models used by engineers (Juhl, 1995).
- Michigan follows a policy that prohibits any “harmful interference” of increased flooding on adjacent properties to the project and defines harmful interference as being detectable at a 0.1-foot rise limit. This type of regulation, like the Maryland and Wisconsin regulations, strives to base the regulation of a project on the potential effects, rather than to apply a uniform standard.

Although it is unclear whether the Illinois downstream provision would withstand intense legal scrutiny, these variations in method demonstrate that the zero tolerance statutes now in effect in King County are not the only approach to more tightly regulating the floodplain.

4.4 NORTHWEST STATES AND COUNTIES

Idaho, Wyoming, and Oregon use the default NFIP minimum standards, although in some areas, such as near Corvallis, Ore., tighter regulations of 0.2 feet have been adopted. In Sheridan, Wyo., a zero-rise policy has been followed. In this primarily rural environment, where the floodplains in the city of Sheridan are 150 feet at the widest points and the channels and banks are relatively steep, bridge designs have not been greatly impacted (Evans, 1995). The most recent bridge project, a replacement, was completed in the 1960s and involved a clear span.

For about 20 years, the statewide backwater criterion of Montana, at 0.5 foot, has been more stringent than the NFIP standard. This criterion applies wherever the floodplain

is defined, such as in flood hazard areas, and the default NFIP standard is used elsewhere. The Montana Department of Natural Resources circulated a model flood ordinance to counties that suggested the implementation of this criterion and other floodplain regulations, including a 2-foot clearance criterion on bridges. The town of Sun River, however, adopted a zero-rise design approach for crossings of the Sun River. The reason for adopting this approach is the severity of flooding in Sun River, where flows of as low as a 5-year mean return interval overtop the main channel (Goodman, 1995).

Currently, a bridge reconstruction project is under way in Sun River, but the zero-rise criterion does not greatly affect the replacement of the bridge, a three-span steel truss bridge with two piers in the main channel. The new bridge also is allowed piers in the channel. Because of the flooding hazard severity, the approach roads to the bridge are required to be at grade and are milled. Therefore, by simply maintaining the conveyance of the old bridge in the main channel, the new configuration does not heighten the 100-year flood backwater. The stipulation that the approach roads may flood contrasts with the King County clearance requirements and normal route classification limitations on the flooding of roads, which, as discussed above, conflict with the zero-rise criterion. Although the Sun River case shows a situation in which the zero-rise criterion does not affect bridge design significantly, the regulatory environment is importantly different from that of King County.

Similar high flooding risks in the City of Snoqualmie, Wash., motivate an essentially zero-rise policy. The Snoqualmie Flood Hazard Ordinance prohibits the placement of fill in the floodplain unless compensatory storage is provided and, in addition, disallows modifications of the floodplain that would adversely affect adjacent properties, where adverse effect is meant any rise of floodwaters on the property. Any state or federally constructed bridge is subject to this requirement (Gmazel, 1995). Although the town has had no new bridges for the past 60 years, two projects currently under way may be affected: the Meadowbrook reconstruction (a federal replacement project) and the SR 202 Intersection, in which a bridge over the Kimball Slough is being replaced with a pipe

arch crossing with approach roads on pilings. Because of the subcritical flows in the slough and the reduced constriction of the replacement crossing, no rise was estimated (Hassan, 1995).

Although the town of Snoqualmie has worked within the ordinance since its adoption, opportunities for conflict with public works/public safety projects have not arisen until now. The Meadowbrook Bridge reconstruction is only in the preliminary design report phase, but the compound effects of the zero-rise ordinance, the clearance rule, and the compensatory storage requirements are apparent. The floodway is sufficiently wide that most of the town of Snoqualmie lies within it and would be inundated by the 100-year flood. The present bridge has a 300-foot span and would need at least a 420-foot span to clear the floodway (O'Brien, 1995). In addition, the approach roads, which presently act as weirs during flooding events, must be raised so that the bridge will meet the clearance requirements. A design that accommodates both requirements must have a lengthened span and approach roads on pilings and, as a result, will be substantially more costly.

4.5 DISCUSSION

In comparison to the other zero-rise regulations studied, the King County regulatory environment is the most stringent. Although the zero-rise regulations in some other states and locales legitimately require a 0.01-foot or smaller surface elevation increase, the extent of the application of this requirement varies, and in every case there are fewer conflicting requirements. The result is that in other locales the zero-rise requirement fits into a scheme of resource protection without impeding public works agencies. In King County, the zero-rise criterion compounds an already burdensome mass of requirements.

In other locales, the important differences from the King County regulations include the following:

- freedom from substantial clearance requirements
- freedom from pier-in-channel prohibitions (unrelated to backwater considerations)

- exemption for replacement in-kind
- lenient permitting processes for rises where no damage is anticipated
- permission for approach roads to flood.

In some locales, infrequent bridge work or local geologic and hydrologic characteristics have allowed the zero-rise criterion to remain mostly untested since its adoption.

The regulation of the floodplain in King County is fragmented among local King County agencies and state agencies such as WSDFW and WSDOE. In other states, many of these functions are subsumed into a common state agency, allowing the development of a framework for regulation that is more internally consistent. This may be an important reason that there are fewer conflicting regulations in the other cases studied.

5: ASSESSMENT OF KING COUNTY VARIANCES

Variations are procedures through which a law may be applied more leniently than its literal interpretation allows. Variations exist as a legal means of avoiding the strict application of a law in extreme cases where the result is no longer in the public interest or is infeasible. Recourse to the variance process should occur seldom if at all; frequent applications for variations may indicate a poor fit between the written law and its practical implementation.

5.1 PROCEDURES FOR OBTAINING A VARIANCE

Until 1990, no variance process was defined for exceptions to the floodplain regulations of the SAO (Oakes, 1995). The 1990 SAO outlined a process for obtaining a variance that required a public hearing. At present, this stipulation has been relaxed so that a public hearing is only required if five or more dissenting comments are received during the public comment period.

To obtain a variance to the zero-rise ordinance, two requirements (of the three stated in the King County Code) are relevant to bridge design. The following must be demonstrated by the applicant:

- "The granting of the variance will not be materially detrimental to the public welfare or injurious to the property or improvements in the vicinity and zone in which subject property is situated, or contrary to the goals and purposes of the sensitive areas code...."
- "In the case of sensitive areas... the variance granted shall be the minimum necessary to accommodate the permitted uses" (KCC 21.58.020).

In addition, detailed notice of the variance application must be posted, as well as mailed to the nearest twenty different property owners or to all of the property owners within 300 feet of the boundaries of the subject property, whichever includes more owners.

Additional forms of public notice may be required by the building and land development

division. The comment period is fifteen days. At this point, the SWM manager may either render a decision or, if necessary, require a public hearing before the zoning adjuster. Public hearings are required if the manager deems it necessary to address issues of "public significance" or of "vague, conflicting or inadequate information, or when at least five adverse comments are received during the comment period" (KCC 21.58.052, 1993; O'Neill, 1995). Variance decisions are final unless appealed to the zoning and subdivision examiner. A provision allows the combination of variance review processes if variances in permits from more than one agency are required, although the strictest review process is chosen. Engineers from SWM, Roads, and the WSDOT all stated that the determination of need for a variance to zero-rise is difficult to obtain.

5.2 PAST AND FUTURE USE

At least one Washington hydraulics engineer has commented that "variances will be required for every new bridge" (Witecki, 1995). Fortunately, King County's recent bridge projects have been bridge replacements, so there has been as yet no evidence to support or contradict this conclusion. In the five years since the implementation of the SAO and the establishment of the variance process, no application for a variance to the zero-rise criterion has been made (Oakes, 1995). As a result, meaningful estimation of the future use of the variance procedure is not possible.

Only once since 1990 has the zero-rise criterion been waived--in the case of the SR 169 Cedar River Crossing in Maple Valley. In this instance, under the threat of lawsuit by WSDOT for costly delays in the permitting process, King County DDES granted an executive "public safety exemption" to allow a rise of less than 0.2 tenths of a foot behind the bridge. It had been determined that no damages would result from the rise, and the bridge had entered the design phase before the 1990 SAO. With this exemption, however, DDES issued a letter to WSDOT stating that no further exemptions of this type would be granted (Witecki, 1995; Hagglund, 1995; O'Brien, 1995).

King County's variance experience is similar to that of the two other zero-rise states, Wisconsin and Maryland. DOT and FHWA bridge engineers in those states commented that few if any variances have been granted in those states since the enactment of floodplain regulation standards more stringent than NFIP standards (Woods, 1995; Kosicki, 1995). Clearly the variance process for zero floodplain rise is not designed to be a frequent recourse for the bridge designer.

At present, variances are more often obtained for WSDFW permits (from the WAC regulations) and for specifications of the King County SWDM. In particular, variances to the 6-foot clearance requirement have been negotiated frequently, and the requirement is currently under review by the King County Public Works Department (O'Brien, 1995).

5.3 ESTIMATED COSTS OF OBTAINING A VARIANCE

As the lack of application for variance to the SAO requirements indicates, obtaining a variance is a costly and arduous process. Delays of 9 to 12 months are likely to occur while engineering analysis and review of the variance application are conducted. As a necessary part of the review procedure, numerical modeling may cost from \$60,000 to \$120,000, depending on the quality of the flow records at the project site (Oakes, 1995). Administrative fees related to the variance process are small in comparison.

5.4 SUGGESTED FRAMEWORK FOR VARIANCE EVALUATION

The variance procedure outlined for King County does not differ greatly from the procedures of other states and counties. It is often prohibitively expensive and time-consuming and, as such, is not a viable option for bridge designers. Because of the case-specific nature of bridge design, a uniform standard such as the zero-rise criterion creates a well-intended but, at times, unsuitable constraint; therefore, the variance procedure is extremely important as a means to allow the designer to use professional judgment in adjusting the constraint.

At the very least, the variance procedure should be accessible. The step already taken to reduce the risk of a public hearing (by requiring five rather than two objections) promises to save the bridge designer time and money. Perhaps another solution, although one that may decrease the accountability of the bridge designers and permitting agency, is to close the process and require review of variance application by a panel from local and state agencies that have jurisdiction—in this case the state DOE, DFW, DOT, and King County's Public Works Department and SWM Division. This type of process has been used by Wisconsin (Besadny and Jackson, 1983) and is used for variances to SWM's SWDM and Drainage Manual rules. Such an "in-house" review would decrease the time and expense of pursuing a variance.

In addition, understanding the potential outcome of an application would aid designers in recognizing when the pursuit of a variance might be worthwhile. For example, a list of conditions for successful application that clearly details the grounds on which a variance would be granted should be available. A set of specific requirements to be met would be helpful for estimating the costs and likelihood of obtaining a variance. This would allow the option of obtaining a variance to play a greater part in the design stages of bridge projects. Among the most important of the requirements should be demonstration that the costs of meeting the zero-rise requirement outweigh the potential costs of a slight flood increase.

6: COSTS OF THE ZERO-RISE CRITERION

The effect of the zero-rise criterion on bridge project costs has been debated since the evaluation of the proposed SAO amendments in 1990. King County Capital Improvement Plan (CIP) Resource Books, published annually, estimate county revenues and expenditures for a 6-year period (beginning with the previous year). The CIP budgets money toward transportation projects that are prioritized in the annual Transportation Needs Report (TNR). In 1993, the TNR identified 452 high priority projects, estimated to cost \$1.41 billion, and 573 projects of medium or low priority, costing \$1.61 billion, for the coming decade (TNR, 1993). Only about 10 percent of these projects are bridges; they account for \$388 million of the total transportation budget, of which King County's anticipated share is \$91.8 million. On average, fewer than 50 percent of these bridges cross water, and the design of only a smaller number of these will be affected by the backwater criteria. It is perhaps obvious that an increase in the cost of completing bridge projects will affect King County's ability to afford all of the projects anticipated in the CIP. It is unclear, however, how significant an impact the zero-rise criterion will have in raising bridge costs. The following analysis is an attempt to estimate this impact.

6.1 PROJECT FUNDING ISSUES

The issue of federal funding for bridge projects is a major concern for the county CIP. A 1986 FHWA memorandum noted the following:

Application of these more restrictive standards can also result in larger, more costly highway structures and/or right of way costs than would have been required under the NFIP standards. These increased costs to meet standards more restrictive than NFIP standards are the responsibility of the State. Therefore, Federal-aid highway funds should not be used either (1) for payments to property owners or (2) for more costly highway facilities if, in either case, the costs are incurred to meet State standards that require less than a 1-foot rise in water surface elevation for the 100-year flood (FHWA, 1986).

In 1992, the FHWA rescinded the guidelines that accompanied the 1986 memorandum for all roadway projects with the exception of Interstate projects, stating that “[for] all other projects, State highway agencies may use backwater criterion determined in accordance with their respective laws” (FHWA, 1992). Within the state, however, additional funding is not necessarily available for bridge projects made more costly by a more restrictive backwater criterion.

The FHWA distributes funds for bridge and roadway projects to states in proportion to the number of highway miles driven in each state (Markus, 1995). The state then allocates funding to counties on the basis of a statewide prioritization of bridge projects. Additional funding for counties depends on property taxes, gas taxes, state and countywide road levees, and more recently on the Mitigation Payment System, which accounts for 5 to 10 percent of the County Road Fund revenues. Thus a state has a relatively fixed amount of funding for roadway projects, regardless of the expense of those projects. Within the state, counties also have a fixed amount of outside funding available for local projects from the state or the regional FHWA office.

If county, rather than state, requirements drive bridge costs up, federal and state funds may cover only the portion of bridge costs that is consistent with state requirements. As was noted in the SWM presentation to the King County Council in 1990,

The federal government will pay 80% of allowable costs on a bridge project. Cost increases caused by the SAO may be considered self-inflicted and may not be funded by the Federal government (KCC Staff, 1990).

The ultimate impact of zero-rise design costs falls upon King County as either the number of bridges it is able to replace or construct declines or the total county funding of bridge or roadway projects is forced to rise. Indeed, CIP reports since 1990 have observed that

[for] many of these projects, costs have increased due to regulatory changes. These changes include Building and Land Development regulations stemming from the Sensitive Areas Ordinance, drainage regulations from the Surface Water Management Division, and Federal wetlands regulations (KC, 1992; 1993).

The 1993 CIP reflected a decline in project completions because

available revenues were first assigned to cover these cost increases on existing projects; therefore, few revenues were available for new projects. In order to balance the budget, a number of projects previously funded for construction in the 1992-1997 period have been deferred (KC, 1993).

In the 1994 CIP report, 25 of a total of 207 road projects were abandoned or were “deferred [to future years] due to funding constraints.” This represents a 12 percent decline in the number of projects King County was able to afford. Clearly, environmental costs have had an impact, although the portion of those costs that arise solely from the zero-rise ordinance is unclear.

6.2 THE ELLIOTT BRIDGE: A CASE STUDY

One example of a project that has been in design or construction since the enactment of the 1990 SAO illustrates some of the issues raised by the zero-rise criterion. In 1990, the SWM reviewed the Elliott Bridge Replacement Project (the 149th Avenue SE crossing of the Cedar River) as an example of the type of cost increases that would be faced by bridge engineers because of the SAO. One alignment option was estimated to cost \$2.4 million, in addition to the original \$3.0 million, the cost for a 1-foot backwater bridge. Because of the fortunate existence of a “naturally elevated area” in the floodplain by which one end of the bridge span could be supported, an alternative bridge alignment option (“Alternative 3”) supposedly allowed modifications of the bridge in a manner that would not cause a rise in the base flood elevation or in the costs of the zero-rise bridge (KCC Staff, 1989). The review concluded that the zero-rise criterion could cause, at most, an 85 percent increase in the cost of the Elliott Bridge Replacement project.

By 1993, King County had not completed the design of a major roadway CIP project since the enactment of the SAO, but cost increases due to zero-rise were beginning to be apparent at the Elliott bridge, the very project that the SWM used as an argument for the zero-rise criterion. The bridge project was still incomplete, and a SWM engineer cited costs slightly exceeding those of the initial high estimate:

Analysis of surface water profiles and development of structural options to comply with the ordinance has delayed the project two years in the SEPA process alone. Project costs have escalated from 2 million dollars to between 4.2 and 5.9 million dollars depending on [the bridge] alignment. The greatest part of the cost increase is directly attributable to zero-rise compliance (O'Neill, 1995).

By 1994, the cost estimate for the Elliott Bridge was \$10.1 million (KC, 1994).

More recently, however, a cost analysis of the zero-rise impact showed that compared with the Washington State DFW's new 0.2-foot backwater rules, the zero-rise ordinance may incur cost increases of between only 5 and 10 percent of the bridge structure cost. This seemingly small impact of the zero-rise ordinance is due both to a more restrictive baseline for comparison (0.2-foot backwater) and to new hydraulic information found during the preparation of the final environmental impact statement (Vlcek, 1995).

Ultimately, the Roads Division sought an extension on the deadline for the bridge project from the federal and state funding agencies, without which King County would have faced the loss of an estimated \$6 million in federal funding for the project (Markus, 1995). The project was listed in the 1994 CIP as in the environmental phase, with "construction deferred to 1996 due to funding constraints."

6.3 A BROADER ASSESSMENT

To estimate the impacts of the zero-rise criterion on bridge construction and design in King County, water crossings that were in any stage of development in the years 1989 to 1995 were examined. This period covers the plausible range of bridges for which there are data and that could have been affected by the 1990 SAO. The overall goal of this portion of the research was to determine the average cost increase that would be incurred in meeting the zero rise constraint in King County. While it must be acknowledged that the criterion affects every bridge uniquely, and the sample of bridges from which to draw conclusions was still small, an averaging approach to defining impacts offered at least a general sense of zero-rise impacts on King County bridge projects.

WSDOT bridges were identified from preliminary plan records on file in the WSDOT Bridges and Structures office, where a list was compiled of all bridges that crossed streams or rivers and that were dated 1990 or later. From these, the bridges for which the placement of abutments or piers appeared to be affected by the elevation of the 100-year flood were noted, and interviews were conducted with the preliminary plan engineers, primary design engineers, hydraulic engineers, and others with relevant involvement in these projects. The goal of these interviews was to assess the extent to which a bridge design was affected by the zero-rise constraint and the estimated cost of meeting the zero-rise constraint. In cases where the constraint was not met, the rationale for this decision was investigated.

King County Public Works Department bridges were identified from the 6-year CIP reports for the years 1989 to 1994 (1995 was not yet available). All bridges for which the work included replacement, widening, new construction, or significant structural/hydraulic modification were noted. From these, the projects for which the cost estimates in the CIP increased substantially were isolated, and interviews were conducted with the project managers to determine the extent to which the cost increases and/or designs had been affected by the zero-rise criterion. Note that the CIP costs reflect the best estimate of the design at the time it was prepared, and the accuracy of the predicted design varies; thus CIP costs for some bridges rose simply because the designs on which they were based had advanced.

Table 2 shows the bridge projects from this time period. A "Yes" in the "Zero rise-compliant design constructed?" column indicates that the final design actually meets the zero-rise criterion (whether intentionally or not). In a number of cases, the final design was not required to be zero-rise compliant because of the timing of the design work or other factors. The second column shows the lowest possible cost of the bridge, estimated by assuming the NFIP default backwater criterion and freedom from environmental constraints. The final column shows the fractional cost increases resulting from meeting

the zero-rise constraint, as estimated by WSDOT bridge engineer Karl Kirker (Kirker, 1996). This cost increase was calculated by comparing the lowest cost bridge for the site to a lowest cost bridge for the site that would meet the zero rise constraint.

Appendix B offers greater detail about the bridges described in Table 2. One of the main conclusions that may be drawn from the survey of projects is that every bridge design project is uniquely constrained by physical, regulatory, and financial requirements, and the resulting designs are influenced also by the agency response to the recommendations of the design engineers. In many cases, for example, had the SWDM clearance rule not been relaxed after preliminary engineering analysis, the zero-rise design criterion would have been achieved with even greater difficulty, or not achieved at all.

Table 2. Bridges under design or construction since the 1990 SAO affected by the zero-rise ordinance

KC Public Works Dept. Bridges	Zero rise-compliant design constructed?	Least-cost bridge cost (\$ M.)	Percentage cost increase due to the ordinance
Avondale Road	Yes	0.6	15
Elliott Bridge	Yes	5.4	85
Flaming Geyser	Yes	1.5	170
Green River w/ Approaches	Yes	1.3	20
Raging River #234A	Yes	1.5	5
Rock Creek	Yes	0.7	0
NE 124th Street (Sammamish River)	Yes	0.6	10
DOT Bridges in King County	Zero rise compliant design constructed?	Least-cost bridge cost	Percentage cost increase due to the ordinance
SR 405: BR. 405/18 E&W Replacement	Yes	8.4	15
SR 520 W. Lake Sammamish Pkwy. to SR 202	Yes	1.9	5
SR 169 196th Ave. SE/Jones Rd. to Maplewood	No	0.9	280
SR 18 Issaq./Hobart Rd Raging R. no 18/34	Yes	0.6	0
SR 18 Auburn Black Diamond Road (Green R.)	No	1.4	50

6.4 DISCUSSION

Although five years worth of bridge projects is a small sample from which to assess the impacts of a change in design requirements, several conclusions may be drawn from the survey of bridges presented above.

Cost increases due to the zero-rise criterion alone were significant. For WSDOT and King County Public Works bridges together, the average cost increase associated with zero-rise was about 49 percent of the non-zero rise bridge costs. For just the King County Public Works projects, the average cost increase was around 66 percent. For WSDOT bridges alone, the average cost increase was about 35 percent.

The additional funds required for zero-rise designs are substantial enough to have funded several additional bridge projects. For the King County Public Works bridges, a conservative estimate of the additional funds required to meet the zero-rise criterion is about \$7.6 million dollars. For WSDOT, the estimate of funds required is also around \$4.6 million dollars. (Note that because of various exemptions from the ordinance, \$3.2 million of this amount will not be spent.) Although the amount of damages avoided on the zero-rise projects was not calculated in this study, the conservative estimate of the additional funds spent on bridge design and construction is high enough to beg the question: is the flood damage reduction achieved worth the cost? In any case, the amounts spent on zero-rise in the past five years are large enough to have funded several additional bridge projects in King County.

The implications of King County cost increases, if the ordinance were applied statewide, are considerable. King County has only 163 of the state's 3544 bridges (longer than 20 feet), or just under 5 percent. However, its road funding budget was almost 23 percent of the state's budget (\$178 million of \$773 million) (CRAB, 1994). As noted previously, the state's high priority bridge project budget was \$388 million for the 1993-2003. If only a quarter of the budget covers bridges that cross water and are influenced by zero rise, and the same percentage cost increase as that found in King County applies,

about \$48 million in cost increases will be incurred over the decade to meet the zero-rise criterion. This amount is enough to support numerous additional bridge projects or needed repairs, if it is not spent meeting the zero rise criterion.

7: THE EFFECTIVENESS OF ZERO IMPACT REGULATIONS

Examples of other federal "absolute zero" regulations offer a caveat regarding the fate of "absolute" floodplain management regulations. Environmental regulations have been derived from human health considerations ("risk-based standards"), from practical issues of implementation ("technology-based standards"), and from economic considerations ("cost-based standards"). Although most federal human health and environmental regulations balance risks with the costs of risk reduction, usually through provisions that allow professional judgment to be exercised on a case-by-case basis, some regulations contain no such flexibility. The eventual implementation of these statutes demonstrates the problems that arise from rigid rule making. The hazardous air pollution section of the 1970 Federal Clean Air Act (CAA) and the infamous Delaney Clause of the 1958 Food Additives Amendment to the Federal Food Drug and Cosmetic Act (FDCA) both reflect Congress' intent that the regulating agency consider health and safety without regard to cost.

7.1 EPA IMPLEMENTATION OF THE 1972 CLEAN AIR ACT

7.1.1 Hazardous Pollutants: Section 112

Section 112 of the CAA intended stringent and uniform control of all pollutants found to pose serious health risks at low concentrations. The phrasing of the section directs the administrator of the regulation (the Environmental Protection Agency) (EPA) to set a National Emission Standard for Hazardous Air Pollutants (NESHAP) that "provides an ample margin of safety to protect the public health...." The concept of an "ample margin of safety" essentially invokes a zero-risk standard. No provisions are included that either explicitly or implicitly direct the EPA to consider the social or economic costs of its regulation. The only flexibility in the standard is expressed through the availability of waivers to allow temporary (up to 2-year) non-compliance with the standard in the case of extreme hardship or while appropriate technologies are implemented.

Carcinogens are substances for which no safe exposure levels have yet been identified. With regard to carcinogens, therefore, a literal reading of the statute requires the EPA to eliminate all emissions of carcinogens to achieve "an ample margin of safety." For an industry in which the technology necessary to achieve elimination of emissions does not exist, the promulgation of a standard consistent with the wording of Section 112 is tantamount to industry shutdown, regardless of the importance of the industry to the national economy. In addition, animal studies have determined that over 2,000 chemical substances, many of which are used commercially, can be classified as "potential human carcinogens;" a smaller number have been classified as "known human carcinogens." Under the wording of the CAA, emissions of any of these chemicals that are volatile must be banned outright by the EPA. Instead, public health standards are commonly set using the criterion that permissible levels of the chemical in the environment should not increase a sensitive subject's risk of cancer by greater than one chance in a million (Doniger, 1978).

Where the regulation of carcinogens is concerned, hazardous air pollutant regulation under Section 112 is widely regarded as a failure. In the 18 years that passed before the Clean Air Act was significantly amended to change this approach, the EPA managed to promulgate emissions regulations for only a handful of carcinogens, few of which conformed to the stated requirement of Section 112.

7.1.2 Actual Implementation

Much of the following discussion of the implementation of Section 112 has been taken from Cross (1989), except where other citations are given.

The first standard setting by the EPA was for asbestos, in 1973, in which the EPA selected five asbestos emissions sources for control. The EPA rejected a proposed complete ban for economic reasons, notwithstanding the dubious legality of this approach. Clearly, the "ample margin of safety" was not followed literally.

The EPA regulated vinyl chloride in 1975. This second non-zero NESHAP continued the EPA's approach of allowing a feasibility-based standard that takes into

account the economic consequences of regulation. In the case of vinyl chloride, the EPA decided not to apply the section strictly to a "non-threshold pollutant" by speculating that Congress never explicitly considered the consequences of regulating such pollutants under section 112. Like asbestos, vinyl chloride, the raw material from which PVC plastic is made, is widely used in modern society; thus the economic consequences of regulation were potentially severe. Following a lawsuit by the Environmental Defense Fund, the EPA finally agreed to require a phasing out of vinyl chloride emissions, but the experience led the EPA to re-evaluate the standard setting procedure for carcinogens.

In 1977, the EPA attempted to shift from the feasibility-based interpretation of Section 112 to a "significant" risk-based approach that applied risk-assessment techniques to identify an emissions level with an extremely low probability of cancer (10^{-5} or 10^{-6} additional risk). The zero-risk paradigm was still considered to be impractical for "non-threshold pollutants," although it was the only approach with any real basis in law.

In 1979, the EPA turned to radionuclides, but after a risk assessment and a narrowing of the regulatory focus to "significant public exposures" only, it stalled in the preparation of a NESHAP because of concern over the legality of the "significant risk approach." A 1982 court order to proceed led to emissions-limiting regulation of some sources, for which the EPA was "bombarded" with criticism.

The significant-risk approach (adopting an arbitrary "safe threshold" of emissions) was again followed in proposing NESHAPs for arsenic and benzene. The arsenic emissions standards applied to four sources only, took six years to develop, and again failed to satisfy the letter of the law. The benzene standard similarly circumvented the stringent requirements of Section 112 and regulated only four sources of benzene. Later attempts by the EPA to withdraw three of these standards prompted a lawsuit by the Natural Resources Defense Council.

After a bruising legal evaluation of the EPA's approach, a court ruled in 1987 that "a section 112 NESHAP need not eliminate all risk" but could allow a level of "acceptable"

risk. Although the determination of risk could not be based on economic considerations, the proposed NESHAP could at least account for costs and technical feasibility. Thus the significant-risk approach for carcinogens was upheld by the courts, even though it represented a meaningful relaxation of the initial Clean Air Act. In retrospect,

[the] approach of the pre-1990 [Clean Air] Act was universally regarded as a failure, as EPA designated only eight [hazardous air pollutants] and proposed only seven NESHAPs during the 20-year life of the law. (Robertson, 1992).

Much of the cause of this failure was directly attributable to the rigidity of the section 112 zero-risk requirements. Not surprisingly, this approach was abandoned in the 1990 amendments to the Clean Air Act.

7.1.3 The Fate of the Section 112

In 1990, a major rewrite of the Clean Air Act was undertaken by Congress, and section 301 of Title III superseded and qualitatively altered the approach of section 112. The new approach for standard setting involves first the control of emissions by requiring either the use of the Maximum Achievable Control Technologies (MACTs) or, if the MACT is infeasible, the use of Generally Available Control Technologies (GACTs). Following this step, a risk assessment will identify failures of the approach to adequately reduce risks, and further measures may be required to achieve an acceptable level of residual risk. Most importantly, section 301 explicitly sets the acceptable level of residual risk for carcinogens at a 10^{-6} additional risk level (Robertson, 1992).

Extensive debate during the legislative process about how to define an acceptable level of "residual risk" resulted in a compromise...EPA's latest approach for defining acceptable risks for carcinogens and other nonthreshold pollutants is specifically incorporated...thereby bringing to a merciful end decades of abstruse litigation over...determining "how safe is safe" for regulating air toxics (Campbell-Mohn, 1993).

The EPA finally shifted from a purely health-based standard to a technology and health-based standard, and in doing so rejected the zero-risk approach as not implementable.

7.2 FDA EXECUTION OF THE FEDERAL FOOD DRUG AND COSMETIC ACT

7.2.1 The Delaney Clause

The Food, Drug, and Cosmetic Act of 1970 codified the regulation of foods and substances added to foods, placing the burden of proof of "safety" on the proponent of a substance's use. In contrast to the Clean Air Act, Section 409 of the FDCA explicitly addresses carcinogenic substances with a provision called the Delaney Clause. The Delaney Clause states that a substance may not be considered safe "if it is found to induce cancer when ingested by man or animal, or if it is found, after tests which are appropriate for the evaluation of safety of food additives, to induce cancer in man or animal." Thus the Delaney Clause explicitly prohibits the addition of known carcinogens to food, allowing also that addition can occur through migration from food packaging.

Sections 402 and 406 of the FDCA were also available to the FDA as avenues for regulation and were somewhat more forgiving. Covering the addition of "poisonous or deleterious" substances to foods, the sections allow the FDA to determine the extent of regulations "necessary for the protection of public health." The presence of more lenient statutes has allowed the FDA to circumvent the rigidity of the Delaney Clause in many cases, and at times the courts have upheld this less stringent rule-making.

7.2.2 Actual Implementation

In 1968 the FDA was faced with regulating oil of calamus, a flavoring additive known to be carcinogenic. Rather than use the Delaney Clause and set a precedent, the FDA banned oil of calamus using other sections of the Act. Similarly, in setting standards for selenium in animal feed, the FDA skirted the opportunity to employ the Delaney Clause, instead using section 406.

Examples of this sort abound in the history of the Delaney Clause. For acrylonitrile in beverage containers, the FDA actually attempted a ban based on the Delaney Clause, but a suit by manufacturers resulted in the determination by the courts that a literal interpretation of section 409 was not necessary. In 1965, the FDA regulated aflatoxin, a carcinogenic

mold found in peanuts and corn, by setting a non-zero standard based on cost-benefit assessment. Ten years later the standard was reduced by 50 percent, but remained above zero (Cross, 1989). This cost-benefit approach also characterized the FDA's standard setting for PCBs in fish. Faced with estimated costs of PCB regulation of \$127 million for a 1 ppm standard and \$65 million for a 2 ppm standard, the FDA chose the cheaper approach. Although no risk assessment was performed before regulating PCBs, the promulgation of the standard took 45 months. When regulating vinyl chloride (VC) in 1974, despite its known carcinogenic potential, the FDA used section 406 rather than the Delaney Clause in banning a number of uses of VC related to food packaging (Doniger, 1978). In the mid-1970s the FDA also banned ten minor food additives as carcinogenic, still without using section 409. Even when the FDA sought the complete ban that would be directed by section 409, the use of 409 was avoided.

In 1980, Congress established the level of "acceptable" cancer risk at one additional chance in one million. The FDA used the relaxation to allow lead acetate to remain in cosmetics and in doing so shifted toward a "significant risk" paradigm in regulating carcinogens. The Delaney Clause continued to be a purely symbolic environmental regulation, and by the end of the Carter administration, the FDA had used it to regulate only two very minor food additives (Cross, 1989).

7.2.3 The Fate of the Delaney Clause

During the deregulation of the Reagan administration, the FDA attempted to formally shift the requirements of the Delaney Clause to permit minimal (less than 10^{-6}) risks for food additives. This approach had been accepted, first for non-carcinogenic substances and then for carcinogenic impurities in additives, through several FDA ruling made in the early 1980s. When the FDA attempted to extend this approach formally to carcinogenic additives, public interest groups sued the FDA, and the courts rejected the approach. The zero-risk approach was maintained for direct carcinogenic additives (Cross, 1989). In the final analysis, however,

[the] FDA's carcinogen control policy must be considered a failure....Review of the record reveals considerable administrative effort to evade the strictures of the Delaney Clause's rigid prohibition of carcinogenic additives....[which] inevitably detracted from FDA's ability to attend to more serious carcinogenic risks in food products (Cross, 1989).

7.3 DISCUSSION

The review of two absolute "zero-risk" regulations demonstrates the difficulties that arise for the agencies responsible for implementing them. Attempting to avoid excessively costly regulations, the EPA and the FDA drew back from applying the laws with the required stringency, but their efforts to strike a balance between economic or feasibility considerations and health or safety considerations drew lawsuits from environmental groups and industry representatives alike. Political and economic concerns, such as the need to avoid the expense and deadlock of litigation, in the end determined the practical interpretation of the federal zero-risk statutes, and in no case could the interpretations be as rigid as intended by the legislators.

Recently, on a national scale, reform of risk regulation has become a priority, and many environmental regulations passed in the 1970s are now under review. An oft-repeated conclusion of the reviews is that regulations that failed to allow for cost-benefit considerations. A recent policy study at the Harvard School of Public Health noted that

...Congress has passed several laws that overtly prohibit regulators from achieving a reasonable relationship between the costs of their actions and the benefits....When agencies are forced to regulate some risks too stringently, they are induced to neglect a larger array of risks that could be reduced significantly at modest cost to the public. Laws that mandate zero risk or that preclude benefit-cost balancing become highly dysfunctional in practice (HSPH, 1995).

Important lessons may be drawn from federal experiences with zero-tolerance regulation. First, the zero-risk directive severely inhibited the standard-setting agencies and undermined the breadth and permanence of improvements or new regulations that were finally implemented. It is already apparent in King County that just as "[overly] stringent control regimes chill the promulgation of regulations" (Cross, 1989) by the EPA and FDA,

overly stringent control of the floodplain has stalled or delayed the replacement, maintenance, and construction of bridges by public works agencies. Second, part of the difficulty experienced by the EPA and FDA arose from the need to regulate to a zero tolerance based on poorly understood or quantified evidence of human health risks. Similarly, although King County regulates the bridge designer to a zero tolerance for water surface rise, the methods used by the designer (numerical analysis) to calculate the rise are widely regarded as neither accurate nor precise enough to quantify a rise of 0.01 foot and should not be used to justify excessive costs in meeting the rise criterion. Third, the EPA and FDA clearly struggled with the question of whether their regulations struck a sensible balance between costs and benefits, whether they were legally empowered to do so or not. In King County, disallowing any rise in the floodplain (that is not negotiated, as discussed in Section 3.1) does not allow for balancing flood hazard reduction benefits with bridge costs.

8: CONCLUSIONS AND RECOMMENDATIONS

The basic challenge in regulating public works in the floodplain lies in finding a level of regulation that balances the reduction of flooding risk with the reduction of other hazards, often the very purpose of the public works project. Complicating this task is the need to balance risk reduction economically, so that limited public works funding can be distributed effectively. The foregoing assessment of King County's zero-rise floodplain regulation evaluated King County's choice of the zero-rise bridge design constraint. The constraint was evaluated through a review of its enactment; through comparison to floodplain regulations of other states and counties and to broader zero-tolerance regulations; and through tally of its cost for bridges designed since 1990. On the basis of this work, a number of conclusions may be drawn.

- King County has more restrictive floodplain regulations than other locales in which a zero-rise water surface constraint has been adopted. Because additional SWDM constraints (such as the 6-foot clearance requirement) and Washington State DFW regulations (such as those prohibiting piers in the channel) conflict with the zero-rise goal, it is particularly difficult to achieve this goal in King County. Other locales studied are free from at least one of these additional constraints. In some locales, major bridge work has not been undertaken since the inception of the zero-rise regulation, and in others, geographic characteristics make the ordinance easier to achieve. Other states qualify the implementation of the zero-rise constraint so as to match the stringency of the regulation to the risk of expensive damages.

Recommendation:

Resolve conflicts between the zero-rise regulation and SWDM constraints on the basis of the relative importance of each for preventing flood damages. Qualify the application of the zero-rise constraint so that it is dependent on the anticipated effects of the rise, without requiring recourse to a variance procedure.

- The zero-rise ordinance has caused King County significant cost increases for bridge work, whereas the benefits of the ordinance have not been formally demonstrated. Although the sample of bridges from which to draw conclusions is still small, it is clear that the ordinance has cost King County millions of dollars since 1990 and caused substantial delays in project completions. At the same time, formal estimates of flood damage reductions gained by holding bridge designers to the 0.01-foot rise limit are not available. Even during the initial debate of the zero-rise constraint, a thorough cost and benefit assessment of the ordinance was not conducted. There is little evidence to suggest that 0.01 foot is an appropriate backwater constraint for bridge designers, from any standpoint.

Recommendation:

Perform a cost-benefit assessment of the 0.01 foot backwater constraint over a finite period by noting zero-rise bridge cost increases and studying expected incremental flood damages. Consider other rise limits, such as 0.1, 0.2, or 0.5 feet, which have been adopted around the country, as potentially more appropriate criteria.

- The zero-risk paradigm has been found to be unworkable in well-tested examples of national environmental policy. In the past twenty years, regulations specifying zero risk tolerance have proven highly ineffective. Massive delays in implementation and a narrowed, unbalanced scope of application resulted from Congress' specification of zero risk, and as a result, fewer risks were addressed than intended. The zero-risk approach has since been re-evaluated, and Congress is moving toward feasibility-based or technology-based standards that allow costs and benefits to be balanced.

Recommendation:

Consider the added costs, delays and generally reduced ability of bridge builders to address the transportation priorities of the region when policy makers adopt

regulations for risk reduction. Revise the zero-rise approach to allow negligible increases in flood hazard while not excessively hampering risk reduction.

- The intended balancing of paid flooding mitigation with increased bridge expense has not occurred. The SAO, like floodplain regulations of other locales, includes clauses that allow mitigation of an unavoidable rise through negotiations with property owners. This process has been avoided by the King County Roads Department and is viewed as practically or politically unrealistic. Previous efforts by King County engineers to negotiate with property owners regarding flooding damages have been unsuccessful. Nevertheless, WSDOT and bridge building agencies in other studied areas cite the mitigation procedure as a viable, if infrequently used, option that allows an economically justified deviation from the zero-rise constraint.

Recommendation:

An effort should be made to improve the workability of the mitigation or flooding easement option in King County so that a practical and workable alternative exists when a zero-rise bridge is prohibitively expensive. This effort may involve public relations work and legal reassessment of damage estimations and property rights to create a more open atmosphere for negotiation.

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GLOSSARY OF ACRONYMS

CAA	Clean Air Act
CFR	Code of Federal Regulations
COMAR	Code of Maryland
DNR	Department of Natural Resources
EPA	Federal Environmental Protection Agency
FDA	Federal Food and Drug Administration
FDCA	Food, Drug and Cosmetic Act
FEMA	Federal Emergency Management Association
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
GMA	Growth Management Act
GMPEC	Growth Management, Planning, and Environment Committee (King County Council)
KCC	King County Code
NESHAP	National Emission Standard for Hazardous Air Pollutants
NFIP	National Flood Insurance Program
PPRD	Parks, Planning and Resources Department (King County)
RCW	Revised Code of Washington
SAO	Sensitive Areas Ordinance (King County)
SWDM	Surface Water Design Manual
SWM	Surface Water Management Division (King County)
WAC	Washington Administrative Code
WSDFW	Washington State Department of Fish and Wildlife
WSDOE	Washington State Department of Ecology
WSDOT	Washington State Department of Transportation

APPENDIX A

A Chronology of

the Development of King County's Floodplain Regulations

- 1968 National Flood Insurance Policy was established by the federal government, administered by FEMA. This legislation set minimum regulations for communities that enroll for flood insurance.
- 1973 King County adopted a flood hazard ordinance, intending to comply with federal flood insurance requirements under NFIP (rise policy: one foot in the FEMA floodway)
- 1979 King County enacted a Sensitive Areas Ordinance (SAO) that restricted development in areas containing special natural and manmade features--including wetlands and 100-year floodplains.
- 1985 The King County Comprehensive Plan urged use of non-structural flood prevention methods and prohibited commercial and residential development in the FEMA floodway. This zoning was more restrictive than the NFIP requirements, but complied with requirements adopted by Washington State (which otherwise mirror NFIP requirements). The Comprehensive Plan guidelines set the stage for revisions to the SAO that stringently limited development in the floodplain.
- 1988 Planners from the King County Department of Parks, Planning and Resources (PPRD) developed amendments to the SAO zero-rise ordinance. King County Surface Water Management (SWM), the County Prosecuting Attorney's (PA) Office, and technical staff from the Building and Land Development Division (BALD) consulted on the new law, coordinating the SAO revisions with the SWM proposed Drainage Manual and amendments to the Flood Hazard Ordinance. Eventually, the King County Department of Public Works also supported it, after resolving objections from their Roads Division.
- A limited cost/benefit analysis of at least one case (Elliott Bridge) was made by SWM, as well as a cursory hydraulic and land-use impact assessment.
- 1989 County Executive Tim Hill submitted the new SAO to the King County Council, where the Growth Management, Planning and Environment Committee began a year-long review in which over 150 public meetings were held throughout King County. The County Executive continued to be involved, submitting amendments up until the final public hearing and Council vote on the ordinance in August, 1990.
- 1990 Washington State Legislature passed ESHB 2929 and the Growth Management Bill (1990 Wash. Laws 17) mandate that counties address the growth management issue and adopt development regulations for critical areas, including "frequently flooded areas".
- The revised SAO, including the zero-rise ordinance, passed the Council vote. Additional flood hazard reduction provisions specified that on-site compensatory storage be provided to mitigate downstream effects of eliminated flood storage capacity, and that building floor elevations be at least one foot above the 100-year flood elevation.
- 1991 In the Washington State Legislatures, following flooding on the Skagit River, the Flood Damage Reduction Bill was passed, becoming Chapter 322 of the Washington Laws.
- 1992 SAO was revised but no appreciable changes to the zero-rise ordinance were made.
- 1993 King County Comprehensive Plan was revised to include the King County Flood Hazard Reduction Plan, which also specifies zero-rise criteria, in its guidelines for development.

House Bill 441, the "Zero-Rise" bill, was proposed in the Washington State Legislature requiring zero-rise zoning ordinances in flood-prone counties of Washington. The legislative session ended before the bill could be evaluated.

- 1994 The Zero-Rise bill was reintroduced with substantive changes (as Substitute House Bill 441), including the removal of zero-rise phrasing of floodplain zoning ordinances. As before, the bill died in the committees.
- 1994 Bridge design criteria in the State Hydraulic Code were amended from a zero-rise to a 0.2 foot allowable rise requirement between the OHW marks (WAC 220-110-060)
- 1995 Proposed amendments (relating to flood damage reduction) that alter permitting procedures in the floodplain are being examined in the House Environmental Affairs Committee (Subst. HB 1597) and in the Senate Natural Resources Committee (Subst. SB 563). Existing floodplain regulations in the State administrative codes would be required to be consistent with County regulations, but zero-rise was not mentioned.

APPENDIX B

Description of Bridge Projects Chosen for the Cost Analysis of Chapter 6

B.1 KING COUNTY PUBLIC WORKS PROJECTS

The following summary provides details of bridge projects designed or undertaken by the KC Public Works Department in the period from 1989-1994.

Avondale Road Bridges over Bear Creek

The Avondale Road project involved the replacement of two bridges over Bear Creek. To meet the zero-rise criterion and Hydraulic Code requirements (WAC 220-110-030 with 220-110-060), one bridge was increased from 55 to 65 feet, which was not considered to increase costs significantly. The second bridge was lengthened from a 45-foot span to a 125-foot span (on piles), most of which was necessary to clear the OHW channel. A secondary channel that expands the boundaries of the floodplain may potentially be present during the 100-year event. Wetland mitigation on this project required by the SAO and the SWDM accounted for the majority of cost increases. A small volume of compensatory storage was also required. Variance to the SWM clearance rule was obtained, relaxing the clearance requirement to 3 feet (McClung, 1995; Kerber, 1995).

An estimated 10 to 20 percent of the cost of the bridge portion of the Avondale Road project arose from meeting the zero-rise criterion. The bridge portion accounted for approximately \$600,000, so \$60,000 to \$120,000 could be attributed to zero-rise, representing 1 to 2 percent of the total project costs. There were enough regulatory constraints on this project that few of the "environment-related" costs were derived from the zero-rise constraint (Kerber, 1995).

Elliott Bridge #3166 over the Cedar River

As discussed in detail in Section 6.2, the cost increases due to the zero-rise criterion were at most 10 percent of the original structure costs.

Flaming Geyser Bridge

The Flaming Geyser Bridge was in the design phase before the zero-rise criterion was in effect; therefore, zero-rise was not an issue in the design of the new bridge. The proposed least cost bridge for the site, however, is a three-span pre-stressed girder bridge costing roughly \$1.5 million. In comparison, the least cost bridge that would meet the zero-rise constraint is \$4 million, representing an increase of 170 percent.

Green River Bridge with Approaches

The Green River bridge was not affected because of both the timing of the design (before the ordinance) and the existence of levees at the bridge that are spanned by the present design (Gillespie, 1995). A proposed least cost bridge for the site is a two-span, pre-stressed girder with an abutment at the location of pier two of the present bridge. A least cost zero-rise bridge would cost \$1.6 million.

Raging River Bridge #234A

The existing Raging River Bridge, with four piers in the main channel, was so poor a design in terms of conveyance and backwater that significant improvements were possible for the replacement bridge. Nonetheless, the zero rise criterion created difficulties for the designers. The current project cost is estimated at about \$4 million, of which at least \$250,000 can be attributed to meeting the zero-rise requirement. The new design in this replacement crossing reduced the number of piers in the main channel from four to one and increased the conveyance of the crossing. To meet a clearance requirement of 3 feet (another variance to the SWDM requirement), the roadway at the right bank was raised, which meant that if the existing levees were overtopped during a flood, a rise (with respect to existing conditions) would occur. Because of the improved hydraulics of the crossing, the risk of overtopping was actually decreased, but to avoid entirely the possibility of a rise under the 100-year flood, Roads Division funds were spent to raise the levee.

The 6 to 7 percent cost increase noted above is conservative because the additional costs of the 8-month delay incurred in resolving the design difficulties presented by the various regulations are not included (Jaramelo, 1995).

Rock Creek Bridge

No floodplain had been determined for this small (80 foot span) replacement bridge, so SWM modeled and estimated the floodplain. Backwater concerns were minimal because of the steepness of the channel, which lay in a forested area. CIP cost estimates increased from \$300,000 in 1993 to \$700,000 in 1994, mostly for meeting FHWA concerns related to the approaches. Without zero-rise, the abutments would have been located at the Ordinary High Water mark, the bridge might have used 20 percent less concrete, and the skew angle of the bridge might have been smaller. Because structural costs were at most 50 percent of the project costs, a generous estimate of the cost of meeting the zero-rise criterion is about 10 percent of the project costs, or \$70,000 (Shuler, 1995). For summary purposes, a conservative estimate of 0 percent is used in Table 2.

NE 124th Street over the Sammamish River

CIP-reported costs for this project changed from \$6.6 million to \$10.7 million. The 1990 SAO compensatory storage regulation was estimated to result in \$2 million—about 20 percent—of the construction budget, and flood hazard issues delayed the project by between 6 months and a year (O'Neill, 1993).

Zero-rise concerns and the clearance rule also hindered bridge design, leading to the use of a single-span bridge rather than a least cost three-span bridge. A cost analysis of the different design alternatives noted that "the cost to keep the piers outside of the 100-year floodway is prohibitive." As a result, "all alternatives have some bridge feature in the 100-year floodway" (KC DPW, 1995). A cost comparison of a zero-rise design with a non-zero-rise design was not available. Taken together, the delays and additional cost of attempting to meet the zero-rise and other environmental requirements constitute a significant impact.

B.2 WSDOT PROJECTS IN KING COUNTY

A smaller number of WSDOT bridges than King County Public Works bridges have been affected by the ordinance, but this conclusion may be premature. From the five WSDOT bridges in King County that might have been affected by the ordinance, two designs resulted that met the zero-rise criterion. The designs of the other bridges did not appear to be influenced by the zero-rise ordinance for a variety of reasons, the foremost being timing and jurisdiction.

SR 405: BR. 405/18 E&W Replacement over the Cedar River

The Cedar River crossing in South Renton has been constructed so that the piers on both the east and west sections are either outside of the floodplain or very nearly outside. The piers are tapered and would cause negligible backwater effects during the 100-year flood. The major project constraints were specified by the city of Renton to protect an aquifer over which the bridge is built, as stated in a Memorandum of Agreement signed by the city and WSDOT. The nearly zero-rise design does not differ greatly from a design that might have been used in the absence of backwater-related concerns; thus the most that can be said of this bridge is that costs may have been increased by about 15 percent because of the zero-rise ordinance. No backwater analysis was conducted (Bushnak, 1995).

SR 520 West Lake Sammamish Parkway to SR 202 over Sammamish River

Although this bridge widening project involves placing additional piers in the floodway, they were aligned with the existing piers in the direction of flow, and no backwater analysis was performed (Braxmeyer, 1995). Here the resulting design is considered to be zero-rise compliant, and only a small cost increase of 5 percent was noted.

SR 169 196th Ave SE / Jones Road to Maplewood over the Cedar River

This is one of the few bridges for which a zero-rise design has been compared directly to the non-zero rise design that was "grandfathered" by the timing of the design work. The existing design was budgeted at about \$900,000 and would cause a slight

modeled rise of about 0.1 foot upstream of the bridge. The hydraulic engineer recommended that the rise be allowed because there appeared to be no major impacts of this rise. Continuing the evaluation, WSDOT engineers assessed the cost of a zero-rise design that spanned the floodplain and did not use fills. To meet zero-rise, a four-span, prestressed concrete-girder bridge, in which a 160-foot section spans the floodplain, was suggested at a partial cost of \$2.65 million, instead of the existing two-span bridge with one pier in the floodplain (Walley and Lwin, 1991). If included, the added costs of sales tax, engineering, contingencies and inflation would drive this cost increase to 280 percent over the cost of the non-zero rise design.

The bridge was permitted through an "executive exemption," which was granted by DDES on the basis of the length of time the bridge had been in design. The county was slow enough to render a decision on the bridge that the state threatened to sue, and the permit was granted by the manager of DDES. With the permit, however, the DDES issued a statement that no further permits of this sort would be granted without a proper variance procedure (Haglen, 1995; O'Brien, 1995).

SR 18 Issaquah/Hobart Road over Raging River (no 18/34)

As with many widening projects, a second set of piers are placed in the floodway adjacent to existing piers. No backwater analysis was conducted for this project (Braxmeyer, 1995).

SR 18 Auburn Black Diamond Road to SE 312th over the Green River

Another bridge for which documented cost comparisons exist, the non-zero-rise version incorporated a 171-foot composite steel plate girder span over the Green River, whereas for the zero-rise version a cast-in-place concrete segmental bridge with a central span of 220 feet was necessary. The cost would have increased from \$1.4 million up to at least \$2.1 in adopting a zero-rise design (Lwin and Schaeffer, 1993), so a non-zero rise design was approved for the bridge structure after it became apparent that the minimal rise could be mitigated through channel modifications (McKee, 1995).

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