QUANTIFYING THE IMPACTS OF ROAD CONSTRUCTION ON WETLANDS LOSS: PRELIMINARY ANALYSIS

1. INTRODUCTION

Over the past decades, the role of federal programs in the generation of wetlands losses has received much attention. One of the federal programs most responsible for wetlands losses and degradation is believed to be the Federal Aid Highway Program. For example, a recent report by the U.S. Department of the Interior reported that, of the areas studied, the Federal Aid Highway Program was the most frequently identified federal program source of wetland loss after agricultural programs and multi-purpose water projects.[1]

The Federal Aid road system has led to wetland loss and degradation both directly and indirectly[2]. Road construction has led to losses of wetlands through the effects of filling, fragmentation, and alteration of hydrology. Road construction has also led to wetland losses by providing easy drainage outlets for agricultural wetlands conversions in the Upper Midwest and the Southeast. Constructed highways may also have indirectly led to wetland loss by enabling or inducing secondary development, although this effect is debatable[3].

While the available literature provides much anecdotal and qualitative evidence of the impacts of the Federal Aid Highway Program (FAHP) on wetlands loss and degradation, it appears to provide very little in the way of empirical data on these impacts. Review of the literature and consultations with wetlands experts conducted as part of this analysis did identify a few studies which relied on aerial photography to identify wetland losses linked to road construction in specific regions. However, no quantification of the extent of national wetland loss linked to the FAHP has been undertaken. This is not surprising given that a rigorous empirical analysis would likely require extensive analysis of historical Federal Aid road construction and wetland stock and loss trends at the state or regional level. Such an effort would require extensive data gathering and intensive analytical methods.

This paper makes a more modest and preliminary attempt to quantify the impacts of the FAHP

[1] U.S. Department of Interior. 1988 and 1994. *The Impact of Federal Programs on Wetlands. Volumes I and II.* Areas studied in the report include the Mississippi Delta region, the Prairie Pothole Region, southeastern Alaska, California's Central Valley, Florida's Everglades, Coastal Louisiana, Maryland's Eastern Shore, Coastal Michigan, Northern Michigan, the Pocosins in North Carolina, New Jersey, Puerto Rican Mangroves, the Texas Coast, and riparian areas in Idaho, Nevada, and New Mexico.

[2] As used in this report, the term "direct impacts" refers to impacts caused by the construction of roads themselves within a narrowly defined area around the road. This area can include either the roadway right-of-way or, more narrowly, the area that includes breakdown lanes, travel lanes, and medians only. The term "indirect impacts" refers to impacts of any other kind.

[3] To the extent that roads are built to accommodate the expected transportation needs of new land use development, road construction per se is not responsible for wetlands loss and degradation. To the extent that new development anticipates or relies on new transportation infrastructure, then road construction may in fact be responsible for wetlands losses attributable to land development. Whether and/or to what extent roads are responsible for land use development is an issue of considerable disagreement.

on wetlands loss. The analysis combines readily available data on the extent of Federal Aid road construction and wetland loss over the life of the program with certain assumptions to derive a rough national estimate of the *potential* magnitude of wetland loss resulting from the FAHP. It also uses the results of the few empirical studies identified in the literature to calculate rough estimates of FAHP-related wetland losses for specific regions which are used to augment and provide perspective for the evaluation of the national estimates.

This paper concludes that between about 310,000 and 570,000 acres of wetlands could potentially have been lost due to the construction of FAHP roads between 1955 and 1980, at a replacement cost of between $153 million and $6 billion. The wetland acreages represent rough estimates and the cost figures represent orders-of-magnitude estimates. The magnitudes of these numbers depend on the assumptions used in this analysis. Our assumptions are discussed explicitly throughout this report.

It should be noted again that this analysis addresses FAHP impacts on wetlands during the 1955-1980 time period only. This timeframe was selected to reflect the period in which the FAHP was active and the many environmental controls currently regulating road construction had not yet been established. As a result, the conclusions of this report should under no circumstance be construed to apply to highway construction impacts since 1980.

This paper is organized as follows. The quantitative analysis of the direct and indirect effects of Federal Aid roads on wetlands is described in Section 2. The results of this analysis are then summarized and evaluated in Section 3. Section 4 combines the results of the impact analysis with various estimates of per-acre wetland restoration costs to illustrate the potential costs of a program to replace wetlands impacted by the FAHP. Two appendices and several attached exhibits provide more detail on the roadway and wetland data used in the analysis.

2. EFFECTS OF FEDERAL AID ROADS ON WETLANDS

2.1 DIRECT EFFECTS

2.1.1 National estimates

Four analytical steps, which relied on several key data sources and assumptions, were used to derive national estimates of FAHP-related wetlands loss. First, the time period over which FAHP spending was likely to have had the most significant impact on wetlands was identified. Second, the amount of land area absorbed by Federal Aid roadway and associated rights-of-way constructed during this period was calculated. Third, estimates for national wetland stock and net loss over the relevant time period were identified. Finally, the results of the first three steps were combined with certain assumptions about the probability that Federal Aid road construction would intersect with wetlands. The methods and results of these steps are discussed, in turn, below.

The FAHP has been in existence throughout most of this century. However, the bulk of FAHP spending began in the mid-1950's with the push to construct the interstate highway system. Thus, the year 1955 was chosen as the base year for analysis. The year 1980 was chosen as the end year under the assumption that, by that date, wetlands protection and compensatory mitigation requirements pursuant to NEPA, CWA Section 404 regulations, and state and local regulatory programs had substantially reduced net wetland losses associated with Federal Aid roads.

Estimating the total land area affected by the FAHP between 1955 and 1980 requires calculating: 1) the total land area affected by new road miles built with FAHP funds over the period, and 2) total land area affected by the widening of Federal Aid roads that were already in existence as of 1955. For the first part of this calculation, data on the stock of Federal Aid road mileage for years 1955 and 1980 were gathered and used to calculate the land area covered by Federal Aid roadway rights-of way (ROW) built over the period 1955-80.

It should be noted that the change in FAHP road miles over the period 1955-1980 may not exactly reflect new road construction during the study period. As a result, this analysis may overestimate somewhat the wetlands interception rate. This is because some fraction of roads added to the FAHP during the study period may simply have been pre-existing roads whose status was re-defined, as opposed to entirely new roads that generated wetland impacts. Data on the proportion of new FAHP roads that were constructed versus incorporated into the system are not easily available and, in our opinion, would not affect the order-of-magnitude of the impacts Apogee has estimated through this analysis.

This analysis also used certain "rules of thumb" for total ROW width for Federal Aid roadway in 1980.[4] However, these rules of thumb may not be realistic for Federal Aid roadway miles existing in the year 1955. Many of the Federal Aid roads in existence at that time were two-lane roads that were subsequently widened using Federal Aid funds. To the extent that this widening required increased ROW, then the total land area affected by Federal Aid road construction over the period would include: 1) land area affected by increased ROW for existing roads, and 2) land area affected by the construction of new road miles and ROW.

To account for this, estimates of the land area absorbed by Federal Aid road construction over the period 1955-80 were calculated for two scenarios. The first assumes that ROW width for 1955 roadway miles did not increase between 1955 and 1980; the second assumes that the area in ROWs for 1955 roads increased by one-third over the period. Under the first scenario, an estimated 3.184 million acres of land were covered by Federal Aid road construction between 1955 and 1980. Under the second scenario, an estimated 7.725 million acres were covered by Federal Aid road construction over the period. The derivation of these estimates is provided in Appendix 1.

Wetland stock and loss estimates for the period were then assembled (see Appendix 2). Only the wetland stock estimate for year 1955 was used in the analysis described below; the net loss estimates over the period are used in Section 3 to provide perspective for the estimates calculated for FAHP-related wetland loss.

Finally, to derive estimates of the direct wetland impacts of Federal Aid road construction from 1955 to 1980, the data generated in the steps described above were used together with one key assumption: that Federal Aid road construction over the period was randomly correlated with wetland locations. The derivation of estimates for the direct impacts associated with ROW Scenario 1 (no increase in ROW for Federal Aid road miles existing as of 1955) and ROW Scenario 2 (increase in ROW by one-third for 1955 roadway miles) are described below.

Under Scenario 1, an estimated 3.184 million land acres were absorbed by Federal Aid road construction between 1955 and 1980 (see Appendix 1). Assuming 3.184 million acres of roadway placed randomly within the 1,996.83 million acre land area of the continental U.S., the probability of any acre of land being covered by roadway would be 0.16 percent. Given an estimated 115.1 million acres of wetlands in the continental U.S. in 1955 (see Appendix 2), the probability of any of the 1,996.83 million land acres in the continental U.S. being a wetland is 5.76 percent. If road placement and wetland locations were independent, the probability of coincidence between a road and a wetland would be 0.00009216 (0.0016*0.0576). Scaling this probability to the continental U.S. land area yields an estimate of 184,027 total acres of wetlands directly impacted by road construction in the continental U.S. (0.000092*1,996.83 million).

[4] These were supplied by staff in the Federal Highway Administration's Office of Rights of Way.

Note that assuming a random wetlands interception rate for FAHP roads may yield an underestimate of the number of wetlands affected by FAHP road construction. This is because there are substantial portions of the continental U.S. that are sparsely inhabited and largely devoid of wetlands. These include large tracts of land in the Rockies and the Southwest. Subtracting these regions from the overall calculation could slightly reduce the numerators in our intercept rate calculation (the number of FAHP road miles and wetland acres) and would decrease considerably the size of the denominator (the amount of land in the lower 48 states considered for the analysis). Removing the road, wetland, and total land areas in these regions from our calculations could well yield a higher intercept rate for approximately the same national wetlands inventory, and thus a larger estimate of affected wetlands.

It is also important to note that additional research could potentially help to refine the random-interception assumption. It is possible, for example, that during the 1955-1980 timeframe highway engineers either preferentially selected or avoided wetland locations for highway construction. Reasons to select wetlands preferentially might relate to lower land acquisition costs and fewer eminent domain issues in wetland areas; reasons to avoid wetlands might relate to higher costs of construction in wetland areas.

Under scenario 2, an estimated 7.725 million land acres were absorbed by Federal Aid road construction between 1955 and 1980 (see Appendix 1). Assuming these roads were located randomly within the continental U.S., the probability of an acre of land being covered by roadway would be 0.39 percent. Given that in 1955 the probability of an acre being a wetland is 5.76 percent, the probability of coincidence between a road and a wetland would be 0.00022464 (0.0039*0.0576). Multiplying this probability by the land area in the lower 48 states yields an estimated 448,567 acres of wetlands directly impacted by road construction (0.00022464*1,996.83 million).

2.1.2 Regional Estimates

The U.S. Department of the Interior's (DOI) report on the effects of Federal programs on wetlands[5] discussed the results of a 1986 DOI study which attempted to empirically estimate the impacts of Federal Aid roadways on wetlands in the Prairie Pothole region.[6] That study used aerial surveys and analysis to sample 2,200 miles of Federal Aid roadways in the Prairie region. The study found that cumulatively, at least 49,000 wetland acres had been drained in conjunction with Federal Aid roadways in the sample survey area, and that 44 percent of these losses (21,560 acres) resulted from the direct effects of road construction. The DOI report further noted that "Preliminary analysis by the Service suggests that the total wetland loss in the Prairie Pothole Region associated with federally aided roadways is at least 4-5 times greater than the estimated loss in the sample region." Taking this estimate at face value, this suggests that approximately 100,000 acres (4.5 times 21,560) of wetlands were lost due to the direct impacts of Federal Aid

[5] U.S. Department of Interior (1988), supra note 1, page 91.

[6] David Nomsen, et al. undated. *Wetlands Drainage in Association with Federal Highway Projects in the Prairie Pothole Region*. As discussed in U.S. Department of Interior (1988), supra note 2. The prairie pothole region includes roughly the western half of Minnesota, the eastern half of South Dakota, all of North Dakota except the southeast corner, and the top third of Montana extending from North Dakota to the Rockies. The region includes approximately 38,400,000 acres (60,000 sq. mi.), or about 1.9 percent of the continental U.S. land mass.

road construction in the Prairie Pothole region.

Another study provides much more limited and less useful evidence on road building in regional wetlands during the period 1970-1980.[7] That study used a sub-sample of paired data points gathered from aerial photography in the Land Use/Cover Change Program of the U.S. Department of Agriculture (USDA) to analyze wetland changes in fast- and medium-growth (*i.e.*, urban growth) counties over the period. The wetlands analysis examined aerial photography of a total 133 paired random sample points from the USDA database, plus an additional 86 wetland non-change points for evidence of nearby wetland change. The final wetland change sample totaled 109 points in 14 states. Although the study included sample points throughout the U.S., 70 percent of the final wetland change points were in the Southeast. The study found that about 3 percent of the wetlands change points during the period resulted from wetland conversions to a class of land use labeled transportation/utility, which was defined to include roads and associated rights-of-way, other transportation infrastructure (e.g. airports), as well as corridors for communications and utility lines.

A number of problems seriously limit the usefulness of the study results for drawing conclusions about the effects of road building on wetlands. First, the very small number of sample points suggests that conclusions about wetland change trends, even in the Southeast region where most of the sample points were concentrated, would not be statistically reliable. Second, the study reports the percentage of wetland sample points that changed status over the period, but provides no indication of the amount of wetland land area converted. Third, the land use category for roads also includes other transportation infrastructure as well as utility corridors. Finally, this land use category covers all roadways, not just Federal Aid roads.

Despite these serious problems, the study results are used below to derive a very rough estimate of wetland loss in the Southeast during the 1970's due to Federal Aid road construction. This calculation requires several assumptions. First, the study assumes that 3 percent of the wetland sample points that changed status to the transportation/utility land use category during the 1970's was due to conversions to roadways. Second, it assumes that, since Federal Aid roadways comprise only about 25 percent of all roadways, only 0.75 percent (0.03*0.25) of the change in wetland status in the Southeast over the period can be attributed to Federal Aid road construction. This estimate is then combined with data from the Fish and Wildlife Service (FWS) on wetland loss in the Southeast from 1974-1983, the closest comparable time period for which data are available.[8] That source reports that net wetland loss in the Southeast during this period was 2.331 million acres (89 percent of the national total). Multiplying this estimate by 0.75 percent yields an estimate of 17,482 wetland acres lost in the Southeast as a result of Federal Aid road construction during the 1970's.

[7] Earth Satellite Corporation. 1988. *Wetlands Loss in Rapid Growth Counties: Analysis of Remote Sensing Data*. Report prepared for the U.S. Environmental Protection Agency, Office of Policy Analysis, Water Economics Branch. (September).

[8] J.M. Hefner et al. 1994. *Southeast Wetlands; Status and Trends, Mid-1970's to Mid-1980's*. U.S. Department of Interior, Fish and Wildlife Service.

2.2 INDIRECT EFFECTS OF ROADS

2.2.1 Induced Agricultural Drainage

The U.S. Department of the Interior's (DOI) analysis of the effect of federal programs on wetlands noted that the roadside ditches associated with Federal Aid roadway rights-of-way provide a ready outlet for draining nearby wetlands for agriculture, particularly in the Prairie Pothole region.[9] The 1986 aerial survey and analysis of the impacts of Federal Aid roads on wetlands in the Prairie Pothole region described in the previous section[10] concluded that, of the estimated 49,000 acres of wetland loss linked to Federal Aid roadways, 56 percent of this loss (27,440 acres) resulted from agricultural drainage facilitated by ready access to roadway ditches. Again, taking at face value DOI's conclusion that the total wetland loss in the Prairie Pothole region associated with Federal Aid roadways was at least 4-5 times greater than the estimated loss in the sample region, this suggests that approximately 123,000 acres of wetland loss in the Prairie Pothole region resulted from agricultural wetland drainage into Federal Aid roadway rights-of-way.

2.2.2 Other Indirect Impacts

In addition to induced wetland drainage for agriculture, Federal Aid roadways have led to wetland loss and degradation in other indirect ways. For example, when a highway bisects or even abuts a wetland area, significant adverse effects can result from altered hydrology and loss of contiguity. Federal Aid road construction can also indirectly impact wetlands by inducing or enabling secondary development. The construction of additional road capacity, by increasing travel opportunities and reducing travel cost, could spur additional residential and commercial development or cause development to be more dispersed (i.e. development sprawl), thus covering more total land acreage, including wetlands. While these types of effects are no doubt real, we did not locate any data that would support even a rough quantitative estimate of their possible magnitude.

3. SUMMARY AND DISCUSSION OF RESULTS

The key results of the preceding analysis are summarized in Table 3.1. The table includes the estimates derived for direct wetland loss associated with the two ROW scenarios as well as the estimate of indirect wetland loss derived for the Prairie Pothole region. The estimates of direct wetland loss for the Prairie and Southeast regions are not included in the table. The latter is excluded because it is unreliable. The former, while not included in the table, is used below to lend perspective for evaluating the national estimates of direct wetland loss.

In the table, each of the ROW scenario estimates of direct wetland loss for the nation are summed with the estimate of indirect wetland loss for the Prairie Pothole region to produce an estimated range for total wetland losses attributable to Federal Aid road construction over the period 1955-80. Since the direct loss estimates comprise the bulk of the total loss estimates, these are reviewed and evaluated further below.

[9] U.S. Department of Interior (1988), supra note 3.
[10] Nomsen, et al (undated), supra note 4.

TABLE 3.1 WETLAND LOSSES POTENTIALLY ATTRIBUTABLE TO FEDERAL AID ROADS SINCE 1955

TYPE OF IMPACT	WETLAND ACRES LOST	BASIS FOR ESTIMATE
Direct: road construction	184,027 acres 448,567 acres	Random correlation national estimate: ROW scenario 1 Random correlation national estimate: ROW scenario 2
Indirect: induced drainage for agriculture	123,000 acres	Prairie region only
Induced agricultural drainage in other regions and other indirect effects	NA	No basis for quantitative estimate
Total (direct + indirect)	307,027 to 571,567 acres	Direct (ROW scenario 1) plus indirect -- Direct (ROW scenario 2) plus indirect

The two estimates of direct wetland loss for the nation (184,027 and 448,567 acres, respectively) differ only because of the different assumptions used in their calculation regarding the widening of the stock of Federal Aid roads and associated rights-of-way over the period 1955-1980. Both national estimates are based on the random correlation assumption which likely understates the actual impact of Federal Aid roadways on wetlands given that a large share of federal Aid roadways were built in the Eastern U.S., where the bulk of historical and current U.S. wetlands are located. Application of the random correlation assumption for individual regions would probably produce, when aggregated to the national level, a higher estimate of Federal Aid road impacts on wetlands than that produced by applying the random correlation assumption to the nation as a whole.

The Prairie region study discussed in Section 2.1.2 provides the only reliable estimate of direct wetland loss associated with Federal Aid roads identified for this study. Accordingly, the study estimate of 100,000 wetland acres lost in that region due to the direct effects of Federal Aid road construction lends valuable perspective for evaluating the national estimates of direct wetland loss derived in this paper. The Prairie Pothole region, which includes parts of Montana, North Dakota, South Dakota, Iowa and Minnesota accounts for only two percent of the total land area in the continental U.S.. The region once contained about nine percent, and now accounts for about seven percent, of the current wetland stock of the continental U.S.. Comparison of the 100,000 acre estimate of direct wetland loss for that one region with the direct loss estimates for the nation suggests that the national estimates are well within the realm of reason.

Further perspective is provided by comparing the direct loss estimates with estimates for total wetland loss over the period 1955-1983 (see Appendix 2). For this comparison, only the sum of wetland losses attributable to urban and other development are applicable. The urban category includes wetland loss due to wetland conversion in heavily urbanized areas, while the “other”

category includes all wetland loss not attributable to urban or agricultural development.[11] Using these wetland loss estimates, the national estimates of direct wetland loss associated with Federal Aid roadway provided in the table represent 6.3 percent (ROW scenario 1) and 15.0 percent (ROW scenario 2) of total wetland loss over the period not accounted for by agricultural conversions. Again, these percentages suggest that the estimates of direct wetland loss for the nation attributable to Federal Aid roads may not be unreasonable.

4. ESTIMATES OF WETLAND REPLACEMENT COSTS

This section takes the estimates of wetland loss attributable to Federal Aid roads developed in Section 1, and combines them with different wetland restoration scenarios and their associated unit costs as developed below. This provides estimates of the potential cost of a hypothetical wetlands restoration program intended to compensate for wetland losses resulting from Federal Aid roads. Again, these estimates are based on hypothetical restoration programs and do not necessarily represent the type of wetlands that will actually be restored or an opinion of what types of wetlands restoration programs should seek to restore.

This analysis relies on the median per acre estimates of wetland restoration costs for the wetland types presented in Exhibit 1. Median rather than average cost estimates are used since the average cost estimates provided by Exhibit 3 are skewed upwards by sample points reflecting extremely high per acre restoration costs for each wetland type listed. It should also be noted that the cost data are based on small sample sizes, and are thus uncertain.

4.1 UNIT RESTORATION COST ESTIMATES

A number of possible per acre replacement cost estimates can be calculated based on a variety of assumptions about the types of wetlands which might be the focus of a wetland replacement program. Four different replacement scenarios and their associated per acre costs are developed below.

It should be noted that the following replacement scenarios are meant to illustrate the potential range of costs associated with the replacement of wetlands lost due to federal aid highway projects. The breadth of the range estimated reflects the fact that replacement costs vary greatly depending on the type of wetland to be replaced. These costs can range from a low of $100 per acre for restoring agricultural wetlands to as much as $50,000 to $80,000 per acre for mitigation projects in more urban contexts. An accurate assessment of replacement costs would require much more detailed information on the nature of the wetlands impacts.

Scenario 1. Replacement program focus: 100% prior converted croplands

This scenario assumes that a wetlands replacement program for Federal Aid road impacts would focus exclusively on restoring former wetlands that had been converted to agricultural uses. As shown in Exhibit 1, the median cost for restoring such prior converted croplands is $500 per acre.

[11] Personal communication with Thomas Dahl of the U.S. Fish and Wildlife Service.

Scenario 2. Replacement program focus: 80% prior converted croplands; 20% freshwater mixed wetlands

Given the median restoration cost estimates for these two types of wetland restorations shown in Exhibit 1, the weighted average per acre restoration cost for this scenario is $5,080 [(0.80*$500)+(0.20*$23,400)].

Scenario 3. Replacement program focus: 70% prior converted croplands; 30% freshwater mixed wetlands

Given the median restoration cost estimates for these two types of wetland restoration shown in Exhibit 1, the weighted average per acre restoration cost for this scenario is $7,370 [(0.70*$500)+(0.30*$23,400)].

Scenario 4. Replacement program focus: 70% prior converted croplands; 10% freshwater mixed wetlands; 10% freshwater emergent wetlands; 10% freshwater forested wetlands

Given the median restoration cost estimates for these four types of wetland restoration shown in Exhibit 1, the weighted average per acre restoration cost for this restoration scenario is $10,480 [(0.70*$500)+(0.10*$23,400)+(0.10*$35,200)+(0.10*$42,700)].

4.2 SUMMARY: WETLAND REPLACEMENT PROGRAM COSTS

The unit cost estimates derived above can be coupled with the estimates of wetland loss attributable to Federal Aid roads (summarized in Table 3.1) to derive estimates for the cost of a hypothetical wetland replacement program. These estimates of replacement costs for the four program scenarios are provided in Table 4.1 below.

Table 4.1 Possible Wetland Replacement Program Costs

FAHP Wetland Impacts*	Unit Replacement Cost	Total Replacement Cost
307,027 to 571,567 acres	$500 per acre	$153 to $285 million
307,027 to 571,567 acres	$5,080 per acre	$1,559 to $2,903 million
307,027 to 571,567 acres	$7,370 per acre	$2,262 to $4,212 million
307,027 to 571,567 acres	$10,480 per acre	$3,217 to $5,990 million

* Estimates taken from Table 3.1

Appendix 1

FEDERAL AID ROAD MILEAGE AND LAND AREA

The analysis outlined below was used to estimate the total acreage directly impacted by Federal Aid road construction during the period in which Federal Aid spending likely had the greatest impact on wetlands loss. The analysis includes three steps. First, the cumulative acreage affected by Federal Aid roads as of year 1980 was calculated. The 1980 cutoff date is used under the assumption that, by that year, wetland protections had eliminated net wetland impacts associated with Federal Aid road construction. Second, the total land area affected by Federal Aid roads as of the year 1955 was calculated for two different scenarios for assumed rights-of-way (ROW): 1) Federal Aid road miles as of 1955 had ROW area of 150 feet, 2) Federal Aid road miles in 1955 had ROW area of 100 feet. Third, the estimated land area for Federal Aid roads existing as of 1955 under the two different ROW scenarios were subtracted from the land area estimate for year 1980 to isolate the effect of Federal Aid road construction between 1955 and 1980. These analytical steps are described in detail below.

Step 1. Estimate total land area covered by Federal Aid roads as of year 1980

1. Total U.S. public road and street mileage broken down by rural, urban, and functional system was reported for 1980.[12]

2. Total road mileage for Alaska and Hawaii was subtracted out.

3. Rural interstate, rural non-interstate, urban interstate, urban non-interstate and total Federal Aid highway road mileage was computed for the continental U.S. (lower 48 states). Rural Federal Aid highways include: interstates, principal arterials, minor arterials, and major collectors. Federal Aid highway funding may not be used for rural minor collectors and local roads. Urban Federal Aid highways include: interstates, freeways and expressways, principal arterials, minor arterials, and collectors. Federal Aid highway funding may not be used for urban local roads.

4. Right-of-way width varies significantly based on functional system classification as well as on less predictable factors such as cost and availability of land. However, rule of thumb estimates provided by FHWA's Office of Right-of-Way were used in these calculations. This analysis assumed a 300 foot right-of-way for rural interstates, and a 150 foot right-of-way for urban interstates as well as both rural and urban non-interstate Federal Aid roads.

5. For each functional system classification, highway mileage was multiplied by 5280 (representing the number of feet in a mile) to estimate total length in feet. This estimate was then multiplied by right-of-way area (300 or 150 feet) to estimate total area in square feet. Finally, this estimate was divided by 43,560, the number of square feet in an acre (see table below).

[12] United States Department of Transportation, FHWA, Highway Statistics 1980, page 114.

1980 Continental U.S. Federal Aid Rural/Urban Mileage	Highway Mileage	Estimated Right of Way (Feet)	Acreage Lost as of 1980
Rural Interstate Federal Aid Mileage	31,997	300	1,163,527
Rural Non-Interstate Federal Aid Mileage	662,918	150	12,109,727
Urban Interstate Federal Aid Mileage	9,184	150	166,982
Urban Federal Non-Interstate Aid Mileage	185,087	150	3,365,218
Total Rural and Urban Federal Aid Mileage	892,303	-	16,805,455

Step 2. Estimate land area covered by Federal Aid roads existing as of 1955

1. Total U.S. Federal Aid road mileage of 749,166 was reported for 1955.[13] (Note: data on road miles broken down by state, urban and rural, and functional system are not available for this year).

2. For the 150 foot ROW scenario, the estimate of total Federal Aid road mileage for 1955 was multiplied by 5280 (the number of feet in a mile) to calculate total road length in feet. This estimate was then multiplied by an assumed 150 foot ROW to calculate total area in square feet. This estimate was then divided by 43,560 (the number of square feet in an acre) to estimate a total land area in acres of 13,621,200 million.

3. For the 100 foot ROW scenario, the estimate of total Federal Aid road mileage for 1955 was multiplied by 5280 to calculate total road length in feet. This estimate was then multiplied by an assumed 100 foot ROW to calculate total area in square feet. This estimate was then divided by 43,560 to estimate total land area in acres of 9,080,080 million.

Step 3. Isolate Federal Aid land area covered between 1955 and 1980

1. The estimate of land area covered by Federal Aid road in 1955 for the 150 foot ROW scenario (13.621 million acres) was subtracted from the estimate of land area for Federal Aid road in 1980 (16.805 million acres), resulting in an estimated 3.184 million acres covered by Federal Aid roads and rights-of-way between 1955 and 1980.

2. The estimate of land area covered by Federal Aid road in 1955 for the 100 foot ROW scenario (9.080 million acres) was subtracted from the estimate of land area for Federal Aid road in 1980 (16.805 million acres), resulting in an estimated 7.725 million acres covered by Federal Aid roads and rights-of-way between 1955 and 1980.

[13] U.S. Department of Transportation, FHWA. Highway Statistics Summary to 1985.

Appendix 2

WETLAND STOCK AND NET LOSS ESTIMATES FOR THE CONTERMINOUS U.S.
(In millions of acres)

YEAR/ TIME PERIOD	WETLAND STOCK	TOTAL NET LOSS	NET LOSS FROM AGR. DEV.	NET LOSS FROM URBAN DEV.	NET LOSS FROM OTHER DEV.
1955	115.1				
1955-1974		9.15	6.91	1.09	0.69
1974	105.9				
1974-1983		2.61	1.38	0.12	1.03
1983	103.3				
1983-1992		0.79	0.16	NA	0.45
TOTALS		12.55	8.45	1.21	2.17

Sources:

1. The U.S. FWS 1982 National Wetlands Inventory (1982 NWI). As reported by: W.E. Frayer, et al. 1983. *Wetlands and Deepwater Habitats in the Conterminous United States, 1950's to 1970's.* U.S. Department of the Interior, U.S. Fish and Wildlife Service. (April).

2. The USFWS 1991 National Wetlands Inventory (1991 NWI). As reported by: Thomas Dahl, et al. 1991. *Wetlands Status and Trends in the Conterminous United States Mid-1970's to Mid-1980's. First Update of the National Wetlands Status Report*. U.S. Department of the Interior, U.S. Fish and Wildlife Service.

3. The USDA 1992 National Resources Inventory (1992 NRI). As reported by: Ralph Heimlich. 1995. "Wetlands Lost, Wetlands Gained". *National Wetlands Newsletter*. Vol. 17, No. 3. (May-June)

Explanation of Data:

- The loss estimates provided by the table represent *net* losses which reflect the amount of wetlands converted to development uses less the amount of land that was classified as developed land at the beginning of the period but reclassified as wetlands at the end of the period. In any period, the sum of net losses attributed to agriculture, urban, and other development is slightly lower than the total net loss for the period because some of the total is accounted for by the conversion of wetlands to open water.

- The 1955 inventory estimate was derived from the revised estimate of wetland stock in 1974 as reported by the 1991 NWI, less the estimate of total net wetland loss over the period 1955-1974 as reported by the 1982 NWI.

- The estimates of net losses for the period 1955-1974 were reported by the 1982 NWI. Note:

this source reports *gross wetland losses* resulting from agriculture, urban, and other development, but only reports one aggregate estimate of the amount of developed land which was *reclassified as wetlands* during the period. For the table, it was assumed that formerly agricultural lands accounted for the total reported amount of developed land that was reclassified as wetlands during the period.

- The 1974 and 1983 stock estimates, as well as the net loss estimates for the period 1974-1983, were reported by the 1991 NWI.

- The estimates of net losses for the period 1983-1992 were reported by the 1992 NRI. These represent conservative estimates since the NRI covers primarily rural wetlands located on non-federal lands. Note: the NRI does not report separate loss estimates for urban and other development as does the NWI; the estimate attributed to other development in the table includes all development loss that is not attributed to agriculture or similar uses (e.g. rangeland, silviculture).

Exhibit 1

WETLAND RESTORATION COSTS

The table below provides estimates of restoration costs (which exclude land costs) for different wetland types. The estimates were constructed based on detailed engineering and cost accounting profiles for over 500 different wetland restoration projects. Note: the sample sizes may limit the certainty of these estimates for nationwide use.

Wetland Restoration Cost Estimates and Cost Allocation by Task and Input Category (excludes land cost)

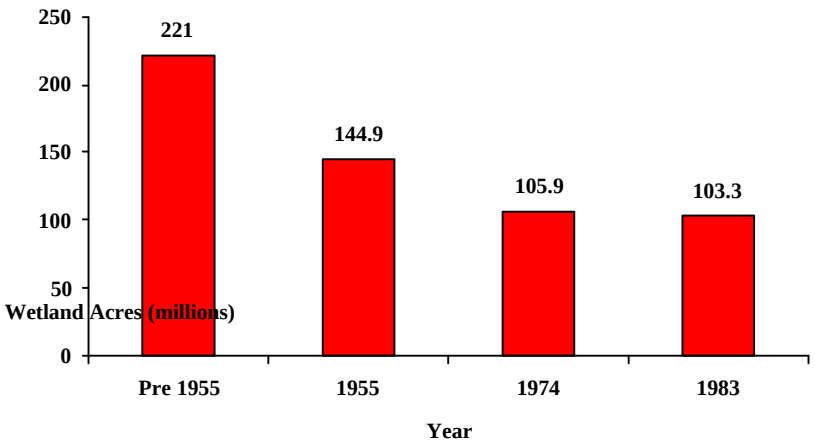
	Project Type								
	Aquatic Bed	Complex	Fresh-water mixed	Fresh-water Forest*	Fresh-water Emerg.	Fresh-water Tidal	Salt Marsh	Man-grove	Agric. Conv**
Project Cost (thousands of dollars)									
Average	$19.5	$56.7	$25.3	$77.9	$48.7	$42.0	$18.1	$18.0	$1.0
Minimum	18.3	4.3	1.4	0.9	1.7	0.6	1.0	2.1	0.005
Maximum	21.7	258.8	65.8	248.4	170.6	92.6	43.6	42.8	20.8
Median	18.6	24.8	23.4	42.7	35.2	32.9	10.2	13.6	0.5
Sample Size	3	8	10	19	28	3	9	4	494
Cost Breakdown by Tasks (% of total cost):									
Preconstruction	17%	10%	5%	9%	13%	9%	16%	13%	0%
Construction	63	74	78	74	58	87	73	66	100
Postconstruction	20	16	17	18	28	4	11	21	0
Cost Breakdown by Input Category (% of total cost):									
Labor	58%	50%	74%	51%	63%	31%	52%	51%	45%
Materials	8	23	10	30	26	54	27	21	0
Equipment	34	14	16	18	9	14	20	28	55
Other	0	14	0	2	1	1	2	0	0

* High end of range involves researching and restoring hydrology and planting; low end involves restoring hydrology only.

** Cost breakdowns for agricultural conversions are based on a project consisting of hydrologic modification without planting or formal plan development.

Source: Dennis King and Curtis Bohlen. 1994. *Making Sense of Wetland Restoration Costs*. University of Maryland, Center for Environmental and Estuarine Studies. Unpublished paper. (January).

Exhibit 2. Wetland Stock (millions of acres)

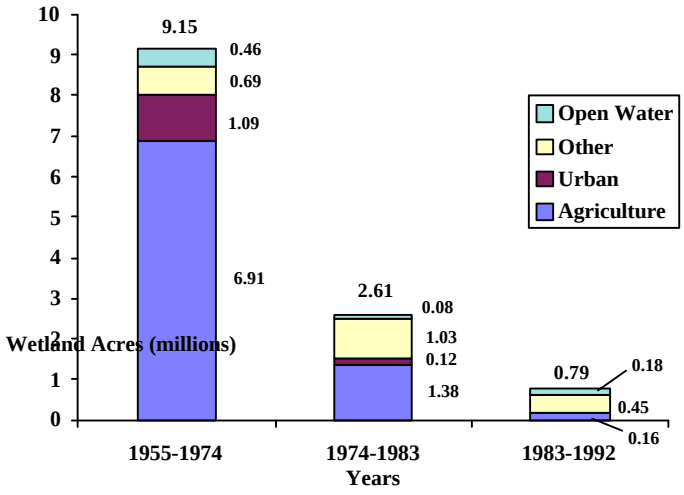


Explanation of graph:

- Appendix 4 graphically depicts the aggregate wetland stock from the time of settlement[14] through 1983.

[14] Dahl, Thomas E. "Wetlands Losses in the United States 1780's to 1980's," U.S. Department of Interior, U.S. Fish and Wildlife Service, 1990.

Exhibit 3. Net Loss Estimates for the Conterminous U.S.
(millions of acres)



Explanation of graph:

- Appendix 5 graphically depicts net wetland losses during the periods 1955-1974, 1974-1983, and 1983-1992.

- Total net losses have been disaggregated into the following groups: agriculture, urban, other, and open water.