POTOMAC RIVER BASIN LAND USE DATA: EVALUATION AND METHODOLOGY TO DETERMINE BASIN LAND USE FROM NON-DIGITIZED COUNTY LAND USE DATA

Prepared by

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NOTATION

Counties:

Carr	:	Carroll
Char	:	Charles
Garr	:	Garrett
Mont	:	Montgomery
PrGe	:	Prince Georges
StMa	:	St. Marys
Adam	:	Adams
Bedf	:	Bedford
Fran	:	Franklin
Fult	:	Fulton
Some	:	Somerset
Augu	:	Augusta
Fauq	:	Fauquier
High	:	Highland
KiGe	:	King George
Nort	:	Northumberland
Staf	:	Staford
West	:	Westmoreland

INTRODUCTION

Land use is one of the most important input data required in watershed models. Accurate estimation of basin land uses for input data in the Chesapeake Bay Watershed Model can have a major impact in the estimation of the contribution of runoff and associated nutrients from the different sub-basins of the watershed. However, there are uncertainties associated with the estimation of basin land uses. These uncertainties are mainly due to land use data base estimation procedures, and the use of different sources of land use data from the jurisdictions sharing a common drainage area. The potential model input errors due to uncertainties in basin land use estimations can be reflected in the total model errors when the model is verified with observed data. However, in addition to land use estimation errors, the total model errors may be due to errors in other input data; errors in the model representation of the different physical, chemical and biological processes; and errors in the observed data with which the calibrated model predictions are verified. Evaluation of model errors due to uncertainty in input data is difficult if these uncertainties are unknown. Therefore, evaluation of the uncertainty in basin land use estimation procedures used in the watershed model, will help understand the model errors when evaluating the model results.

Recently, CBLO (1989) reported a compilation of 1985 land use for the Chesapeake Bay counties for use in the watershed model. County land use data was used to estimate the land uses in each of the watershed segments in the model. Due to the unavailability of digitized 1985 land uses within the Chesapeake Bay counties, a county wide uniform land use distribution was assumed to obtain the land use in each watershed segment for use in the watershed model.

The main objective of this report is to evaluate the county wide uniform distribution assumption to determine basin land use from non-digitized county data. Then, an alternative methodology is proposed to estimate basin land use from non-digitized county data using the digitized USGS 1973 land use data. In order to accomplish this objective, the county uniform land use distribution assumption is evaluated for the digitized 1973 land use data where the true land use spatial distribution is known. The 1973 land use Geographical Information System (GIS) data base has recently become available for the Potomac river basin. This data base is the only one available in digitized form for the entire Potomac river basin. Therefore, a Potomac river basin data base has been created for use in this evaluation. Land use, political and hydrologic boundary geographic data bases were obtained from the Chesapeake Bay Program GIS data base. The GIS data were processed using the ARC/INFO software installed at the Chesapeake Bay Program (CBP) computer system.

DATA BASES

A Potomac river basin GIS data base has been created for the evaluation of the county wide uniform land use distribution. The GIS data base is also used in the proposed methodology for the estimation of basin land uses from non-digitized county data. Land use, political and hydrologic boundary maps were used. The land use/land cover, political and hydrologic units maps have been incorporated into the Geographic Information Retrieval and Analysis System (GIRAS) (Mitchell et al., 1977). The digital form of these systems can be converted into ARC/INFO format (Environmental Systems Research Institute, ESRI 1986) for manipulation and analysis. In this section the software and the digitized data bases used in this report are briefly described.

ARC/INFO System

The geographical information system in ARC/INFO format consists of two basic types of data: 1) cartographic coordinates which identify the points, lines, and polygons defining a coverage, and 2) data attributes which describe the characteristics of these features. The software can perform sophisticated manipulation and geographical analysis including map overlays, buffer generation, boundary dissolution, tabular and network analysis with numerous applications in hydrologic studies (Lee and Camacho, 1986, 1987). The ARC/INFO software developed by the ESRI was installed in November 1987 at the CBP computer system.

Land Use/Land Cover

The source of the land use/land cover maps are the data from the NASA high-altitude U-2/RB-57 aerial photographs. The base maps used, for compilation and reproduction, are the standard topographic maps at the scale which the maps are digitized: 1:250,000 (U.S. Geological Survey, 1986). These maps cover a quadrangle unit of 1 degree of latitude times 2 degrees of longitude based on the UTM (Universal Transverse Mercator) projection. Table 1 shows the level II land use/land cover classification adopted by the U.S. Geological Survey in the development of these maps (Anderson, et al., 1972, 1976).

Political Unit Map

Sources of these maps are the 1:250,000 or 1:100,000 scale maps (unpublished) of the 1970 Bureau of Census. Another source is the 1980 County Subdivision Maps (U.S. Bureau of the Census, 1983).

Hydrologic Unit Map

These maps are obtained from the Hydrologic Unit Maps published by the U.S. Geological Survey office of Water and Data Coordination and the list of "Boundary Descriptions and Name of Region, Sub-region, Accounting Units, and Cataloging Unit" or USGS Circular 878-A (USGS, 1982).

Table 1.--U.S. Geological Survey Land Use and Land Cover Classification System for Use with Remote Sensor Data

	LEVEL I		LEVEL II
1	Urban or Built-up Land	11	Residential
		12	Commercial and Services
		13	Industrial
		14	Transportation, Communications and Utilities
		15	Industrial and Commercial Complexes
		16	Mixed Urban or Built-up Land
		17	Other Urban or Built-up Land
2	Agricultural Land	21	Cropland and Pasture
		22	Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
		23	Confined Feeding Operations
		24	Other Agricultural Land
3	Rangeland	31	Herbaceous Rangeland
		32	Shrub and Brush Rangeland
		33	Mixed Rangeland
4	Forest Land	41	Deciduous Forest Land
		42	Evergreen Forest Land
		43	Mixed Forest Land
5	Water	51	Streams and Canals
		52	Lakes
		53	Reservoirs
		54	Bays and Estuaries
6	Wetland	61	Forested Wetland
		62	Nonforested Wetland
7	Barren Land	71	Dry Salt Flats
		72	Beaches
		73	Sandy Areas Other than Beaches
		74	Bare Exposed Rock
		75	Strip Mines, Quarries, and Gravel Pits
		76	Transitional Areas
		77	Mixed Barren Land
8	Tundra	81	Shrub and Brush Tundra
		82	Herbaceous Tundra
		83	Bare Ground
		84	Wet Tundra
		85	Mixed Tundra
9	Perennial Snow or Ice	91	Perennial Snowfields
		92	Glaciers

PROCEDURES

The data bases described in the previous section were manipulated using the ARC/INFO software. ARC/INFO commands were used to obtain, for each hydrologic unit and county, the 1973 geographical location of the different land use areas in the Potomac river basin. These procedures are summarized in the following sub-sections.

Potomac River Basin Coverages

Eight 1X2 degree (UTM) quadrangles cover the entire Potomac river basin (Figure 1). For each type of map (land use/land cover, political and hydrologic unit maps) ARC/INFO coverages are available for the quadrangles of Pittsburgh, Harrisburg, Baltimore, Cumberland, Charlottesville, Washington, Richmond and Roanoke. Using the ARC intersect command, the land use/land cover, political boundaries and hydrologic boundary coverages were overlaid for the eight quadrangles. The intersection of these polygon coverages generated a polygon coverage for each quadrangle. Each polygon in the resulting intersected coverage is described by an attribute data set of 1973 level II land use, county and state name, and hydrologic unit number. Table 2 shows, for each quadrangle, the number of polygons in each of the resulting intersected coverages.

Table 2. Land Use/Land Cover, Hydrologic and Political Boundary Intersected Coverages

Quadrangle name	Number of polygons
Pittsburgh	7756
Harrisburg	5898
Baltimore	11999
Cumberland	7342
Charlottesville	7616
Washington	14649
Roanoke	10704
Richmond	14145

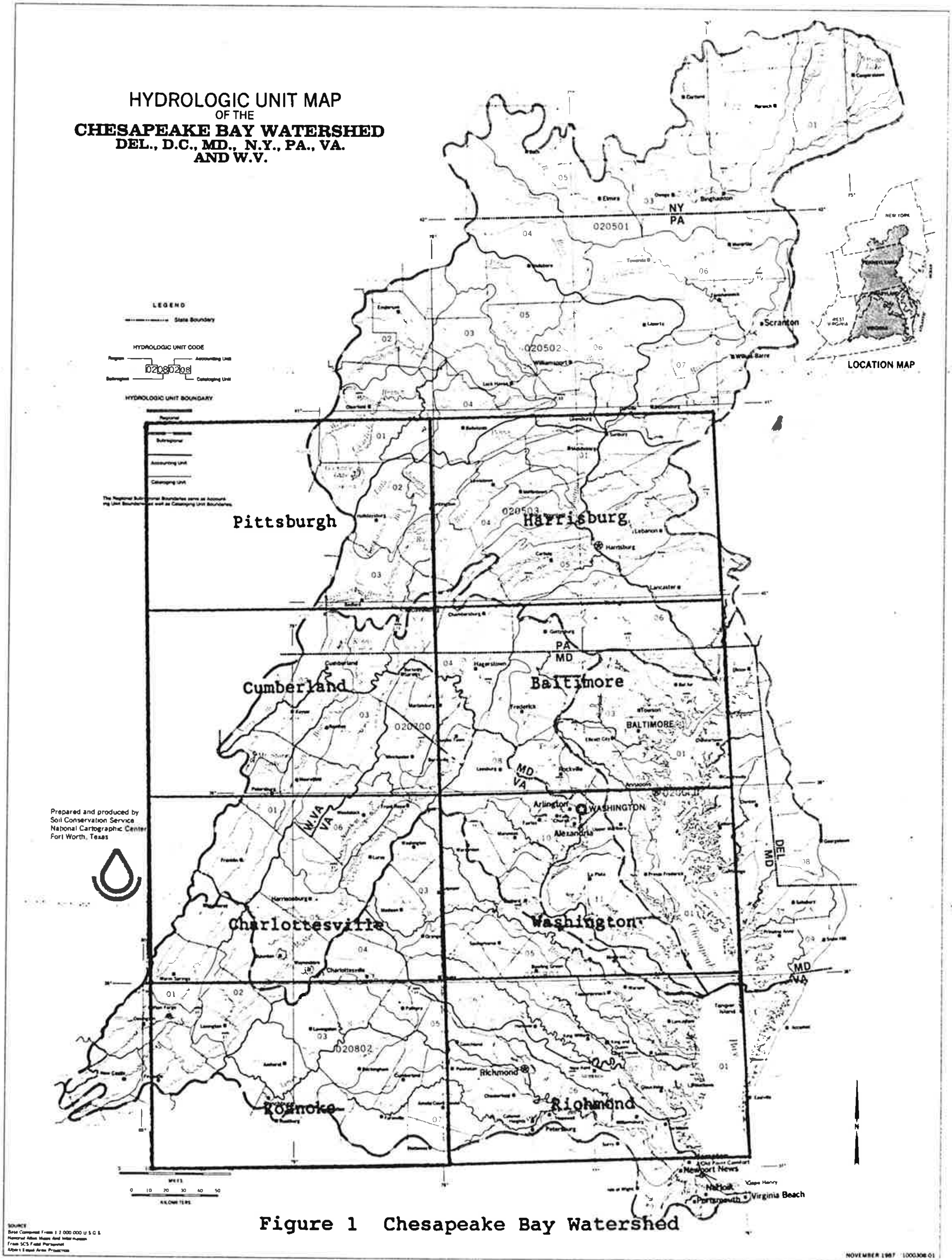


Figure 1 Chesapeake Bay Watershed

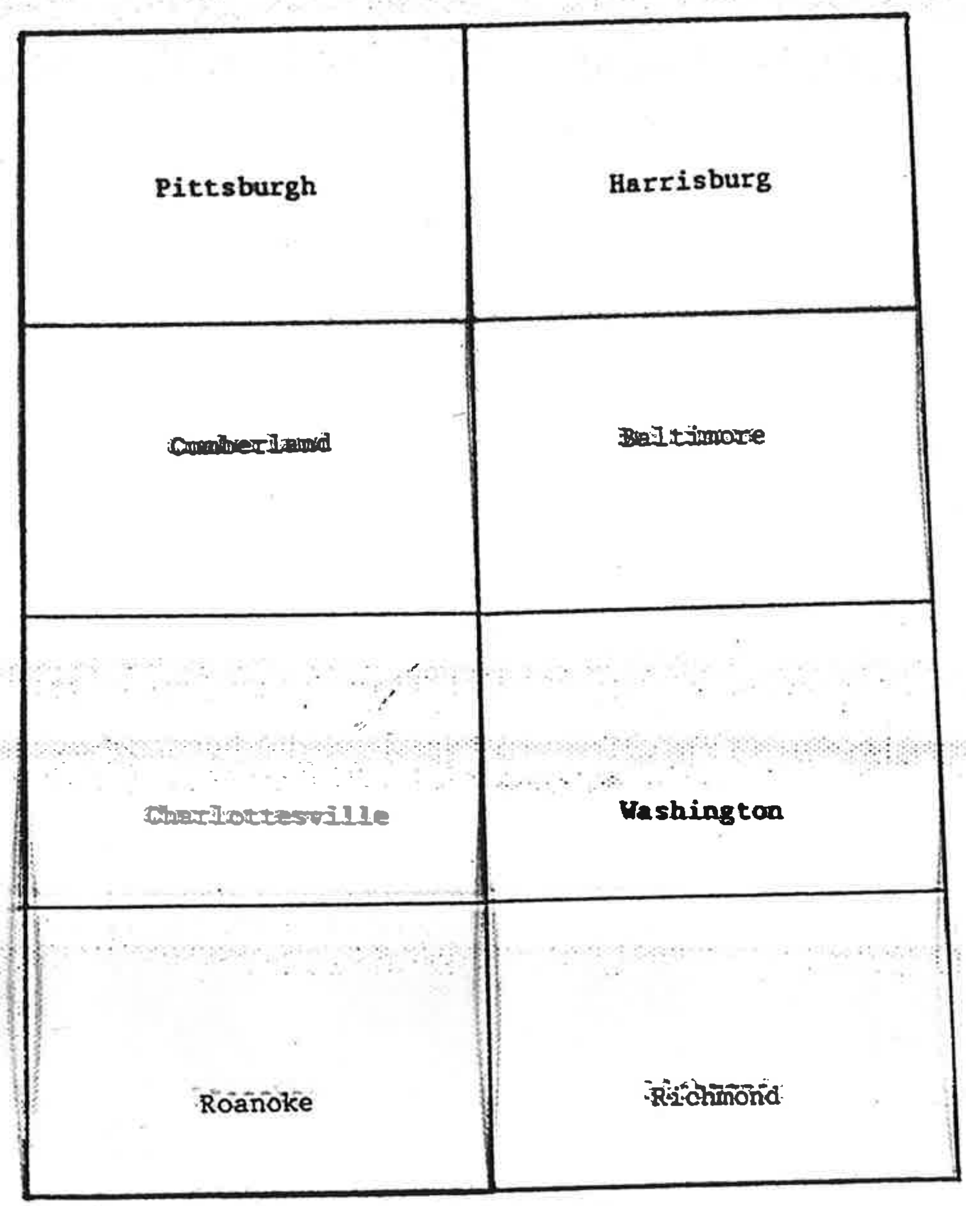
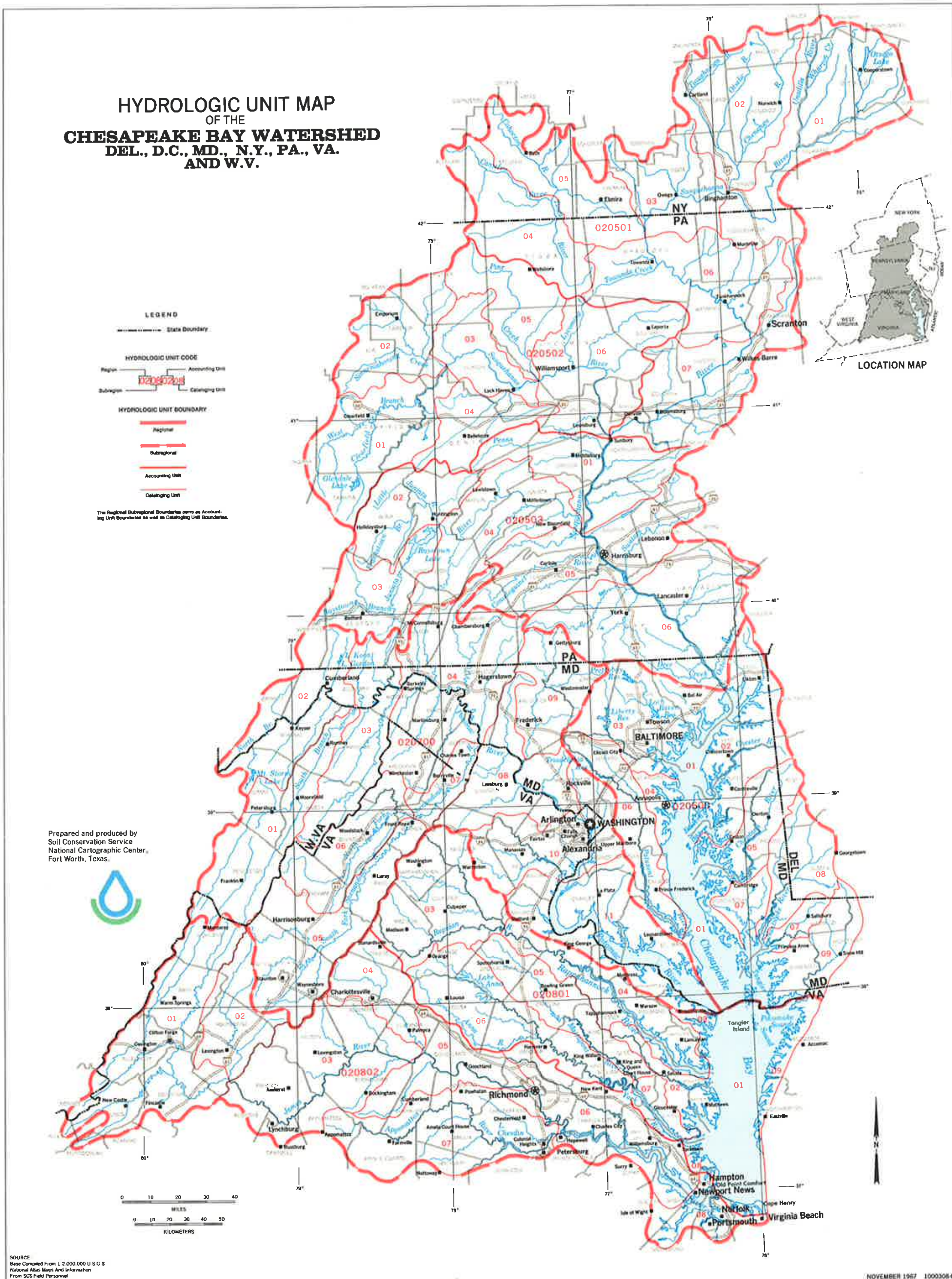


Figure 1 Chesapeake Bay Watershed



USDA-SCS-NATIONAL CARTOGRAPHIC CENTER, FT. WORTH, TX 1989

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Land Uses by County and Hydrologic Unit within the Potomac River Basin

Land uses for each county and hydrologic unit within the Potomac river basin were obtained. The land uses were computed from attribute data files of the intersected coverages. Using INFO commands, polygons were selected by county name along with the hydrologic unit number and area. The files were transferred to ICPRB's computers where a computer program was written to obtain the land use for each county and hydrologic unit within the Potomac river basin.

The Appendices A and B, show, for each county and hydrologic unit, the 1973 proportion of each county land use category that lies within the Potomac river basin and the different hydrologic units.

EVALUATION OF THE UNIFORM LAND USE DISTRIBUTION ASSUMPTION

Proper determination of basin land uses is important for the achievement of a reliable watershed model. Contributions of runoff, sediment, and nutrient loads from basins and studies of basin delivery ratios of constituents to the bay are dependent on the estimated basin land uses. Therefore accurate knowledge of the basin land uses can have a significant impact on the reliability of the model for use as a management tool when modeling different scenarios. In addition, understanding of some of the uncertainties in the estimation of land use input data may help in the evaluation of total model errors.

This section shows an evaluation of the basin land use estimation approach used in the Chesapeake Bay Watershed Model. To address this issue, the evaluation is performed using the USGS 1973 land use spatial data developed for the Potomac river basin.

1985 Basin Land Use Estimation Methodology for the Chesapeake Bay Watershed Model

CBLO (1989) reported the 1985 county land uses compiled from many sources for the Chesapeake Bay Watershed. The data mainly consist of cropland, pasture, woodland (forest) and urban for each county. Manure acres were also given for each county to address the effects of animal waste on the nutrient loads. Water acres were reported directly for the watershed segments, and were obtained from the 1973 USGS GIRAS data base. The county data were revised by each state which used their own methods to develop their data sets (CBLO, 1989).

For the Chesapeake Bay Watershed model, the basin land use data were estimated from the non-digitized county land use data assuming a uniform distribution of land uses within the county. This approach was adopted because of the unavailability of a digitized 1985 land use data base for the entire Chesapeake Bay Watershed. Using this uniform land use distribution approach, the county acreages for each land use category are multiplied by the percentage of county area within a basin. The resulting county acres within the basin, for each land use category, is proportional to the portion of the county intersected by that basin. For instance, if a given county has 20,000 acres of urban land and 10% of its land area is within a basin, the amount of urban acres corresponding to the portion of the basin intersected by the county is 2,000. To obtain the basin land uses for the watershed model, the urban, cropland, pasture, woodland (forest) and manure acres county data were assigned to basins using this approach.

Evaluation of the Uniform Land Use Distribution Assumption for Counties Split by the Potomac River Basin Boundary

Using 1973 USGS GIRAS land use data, the relative errors of assuming uniform land use distribution for these data and this year are examined. Although these relative errors are only valid for the 1973 land use data, they may be used as a guide to evaluate the uncertainties of the county uniform land use distribution assumption for other years. Again, the 1973 land use data for the Potomac river basin is the only one available in digitized form. The evaluation is performed for the urban, agriculture and forest land uses. Potomac basin counties split by the basin boundary are selected for the analysis.

Figure 2 shows the actual land use proportions in the Potomac basin for counties bisected by the basin boundary. For each county, the first bar (legend Land) is the percentage of total county land area within the Potomac river basin. Bars 2-4 show, for each land use category (urban, agriculture, and forest), the percentage of that land use's county wide acreage that lies within the Potomac basin. Values for bars 2-4 are taken from the Appendix A for each of the land use categories. Cropland and pasture percentages were found to be nearly equal to the percentages for the total agriculture land use. The main reason for this result is that cropland and pasture are the major type of land use in the agriculture land use category (level I). Using the county uniform land use distribution assumption, the first bar (i.e. percentage of land use area within the county) is used to determine the land uses in the basin. As explained before, this percentage is multiplied by the total area of each land use category in the county to obtain the corresponding one within the basin. Therefore, differences between the height of the first bar and any of bars 2-4 indicate errors in estimating land use acreages by assuming uniform county wide land use distributions for the 1973 data. These differences are expressed as relative errors in Figure 3. The relative error is computed as $[(L-X)/X]$, where L is the computed percentage of county area within the basin, and X is the actual land use category percentage within the basin for urban, agriculture and forest land. Positive error means overestimation, and negative error underestimation.

Figures 4 to 6 show the relative errors obtained in Figure 3 for each land use category. The relative errors in these figures are shown as a function of the percentage of each county land area that lies within the Potomac basin. From the results shown is these figures, it can be concluded that the relative error in estimating land uses with the uniform distribution assumption tends to increase as the portion of county areas within the basin decrease. The main reason for this result is that the likelihood of finding each land use equally proportioned in a section of a county diminishes as the proportion of county acres intersecting the basin decreases.

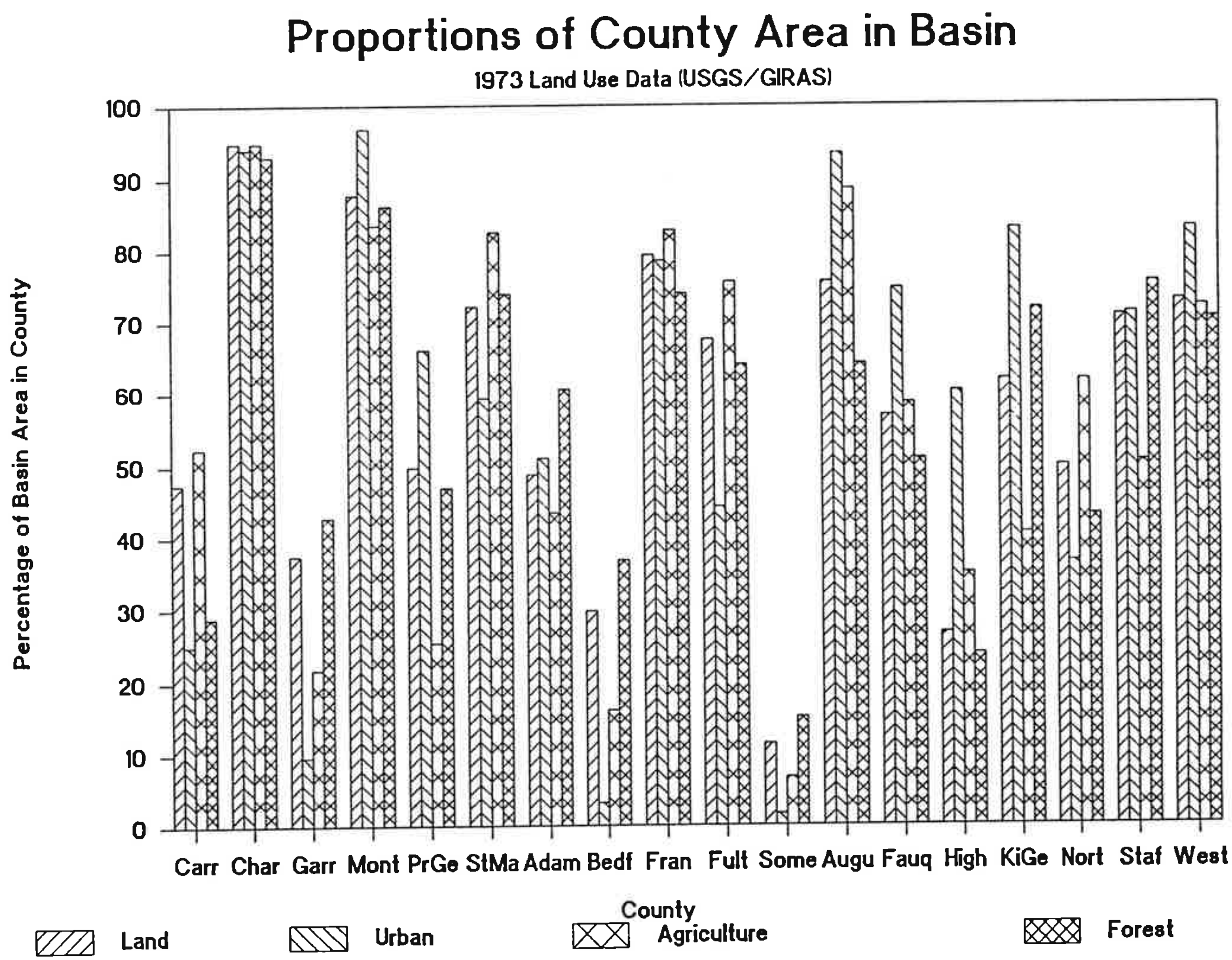

Proportions of County Area in Basin
1973 Land Use Data (USGS/GIRAS)
Percentage of Basin Area in County
100
90
80
70
60
50
40
30
20
10
0
Carr
Char
Garr
Mont
PrGe
StMa
Adam
Bedf
Fran
Fult
Some
Augu
Fauq
High
KiGe
Nort
Staf
West
County
Land
Urban
Agriculture
Forest

Figure 2

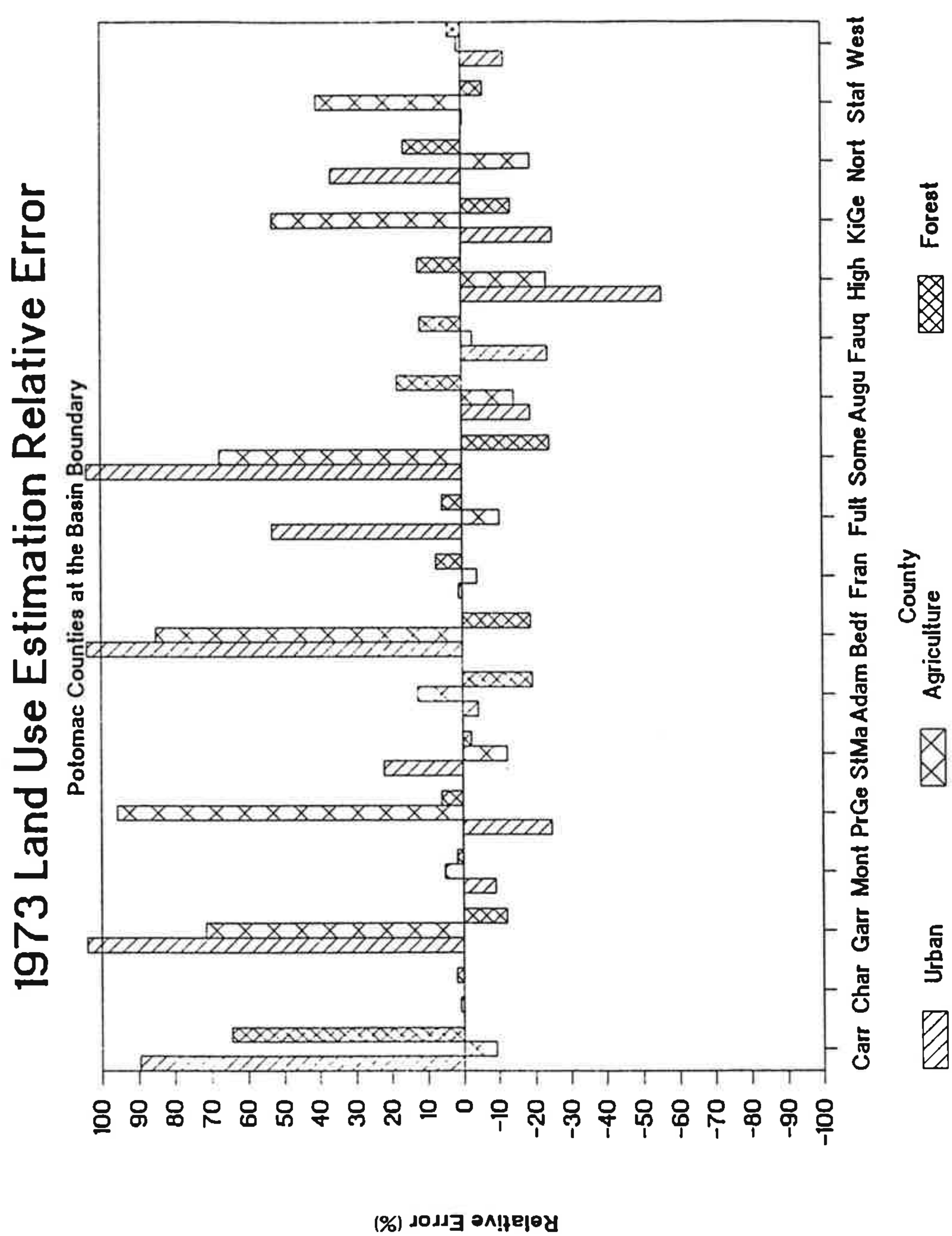

1973 Land Use Estimation Relative Error
Potomac Counties at the Basin Boundary
Relative Error (%)
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Carr Char Garr Mont PrGe StMa Adam Bedf Fran Fult Some Augu Fauq High KiGe Nort Staf West
County
Urban
Agriculture
Forest

Figure 3

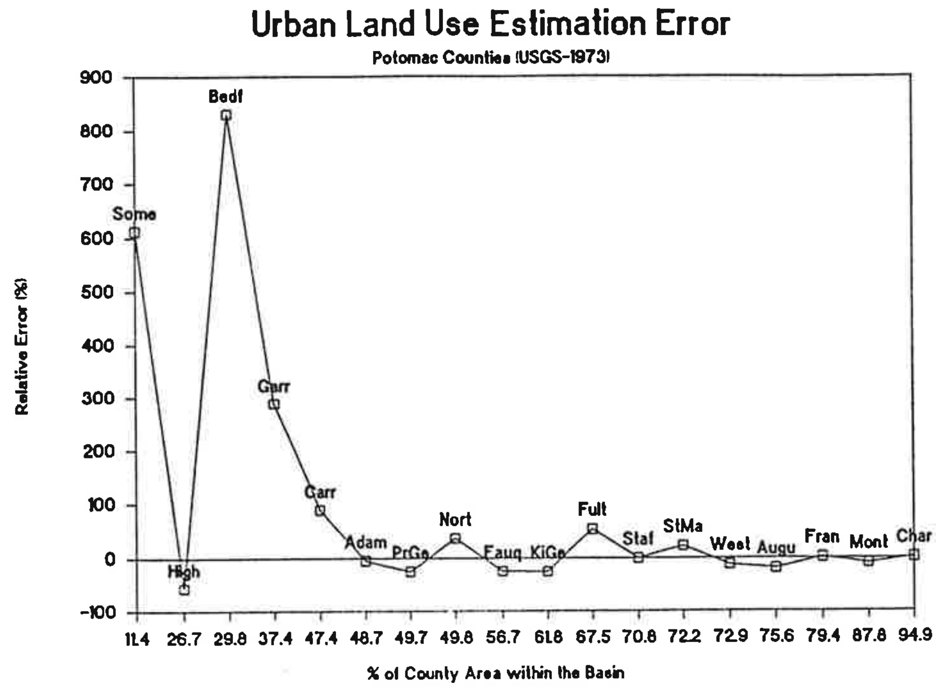


Figure 4

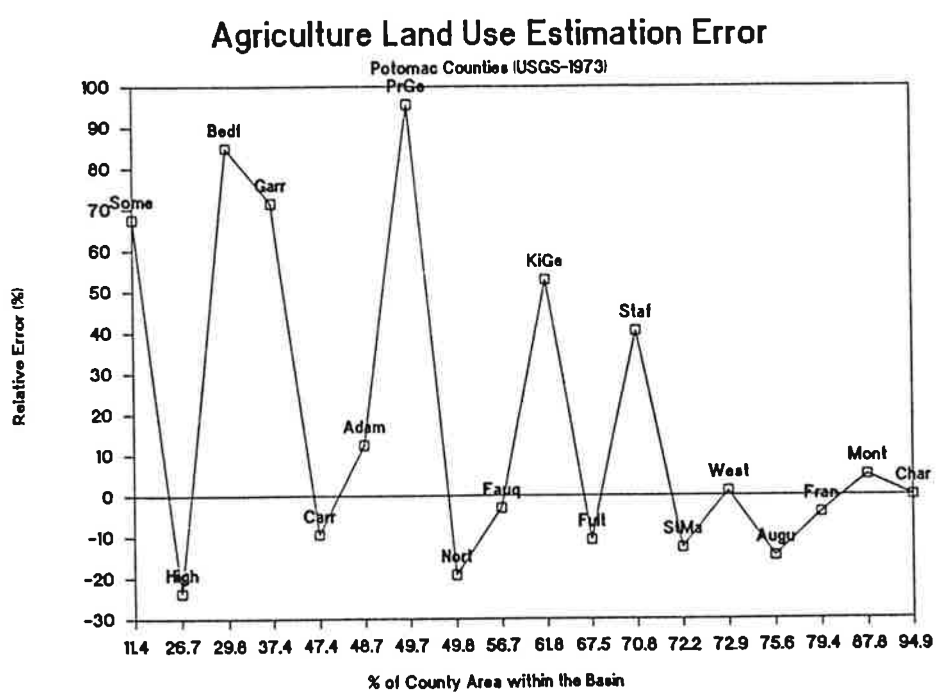
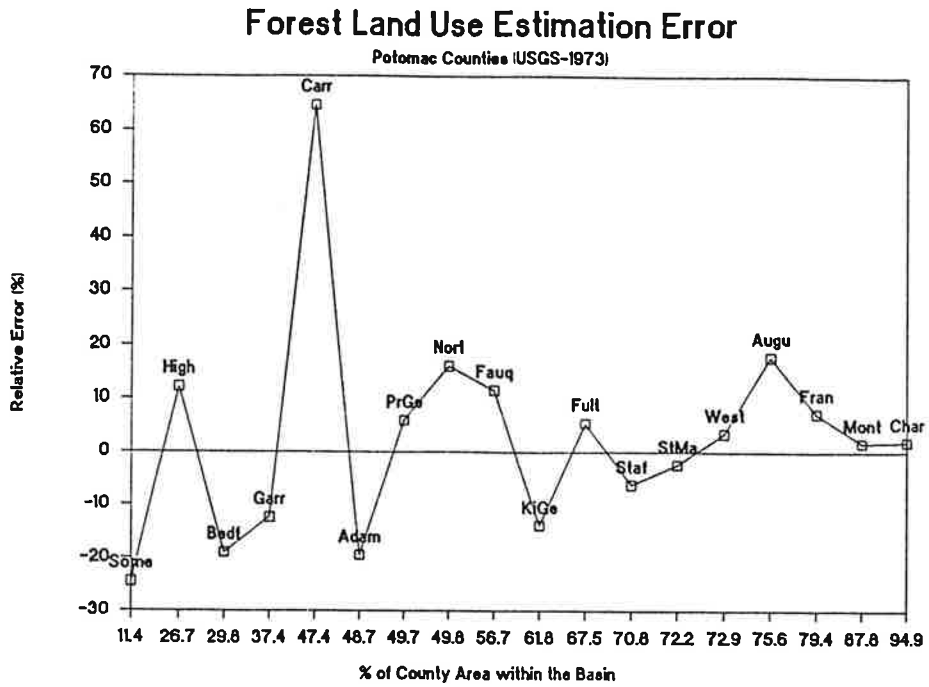


Figure 5



Forest Land Use Estimation Error
Potomac Counties (USGS-1973)
Relative Error (%)
70
60
50
40
30
20
10
0
-10
-20
-30
Carr
High
Norl
Fauq
PrGe
Full
Augu
Fran
West
Mont
Char
StMa
Staf
KiGe
Garr
Bedf
Adam
Some
11.4
26.7
29.8
37.4
47.4
48.7
49.7
49.8
56.7
61.8
67.5
70.8
72.2
72.9
75.6
79.4
87.8
94.9
% of County Area within the Basin

Figure 6

The magnitude of the error may also depend on the amount of acreages of each land use category within the county. For instance, it is observed in Figure 4 that errors in urban areas can be large, because urban areas are generally a small proportion of the total county land area and they are concentrated. This is a departure from the assumption of uniform distribution. On the other hand, errors in forest land use estimation tend to be smaller since they are generally the major land use in each county.

The potential errors can be large for small basins. However, as the basins increase in size relative to the county size, these errors tend to decrease. Also for a basin bisecting many counties, underestimation errors in one county may be balanced with overestimation errors in another county when computing the total error for the basin. Therefore, the evaluation of the errors at a basin level of similar scale to the watershed segments of the Chesapeake Bay is of interest. This evaluation is addressed in the next section.

Evaluation of the Uniform Land Use Distribution Assumption for Hydrologic Units in the Potomac River Basin

To address the issue of uncertainty of land use estimation for the size of the sub-basins used in the Chesapeake Bay Watershed Model, the preceding analysis is extended to hydrologic units within the Potomac basin. The hydrologic units are comparable (although not equal) in size and location to the watershed model segments in the Potomac river basin. The relative errors of assuming the uniform land use distribution to assign county land use data to sub-basins were computed for each hydrologic unit and land use category (urban, agriculture and forest). Again, the relative errors are computed for the year of 1973 using the digitized land use data bases.

Figures 7 to 9 show the relative error for the different land use categories and hydrologic units within the Potomac river basin. For comparisons of the magnitude of the relative errors among the different land use categories, Figure 10 shows a summary of Figures 7 to 9. The hydrologic numbers shown in these figures represent the USGS hydrologic code numbers depicted in Figure 1 (i.e. 01 for 02070001, 02 for 02070002 etc..). As expected, the errors for urban areas are larger than the ones of agriculture and forest. Particularly, for the hydrologic unit 3 the relative error is very high (+246%). The main reason for this is that the towns of Cumberland, Bedford, Romney and Berkeley Springs are out of this hydrologic unit. These towns belong to counties intersected by this hydrologic unit. Therefore, proportions of this urban land area are assigned to the hydrologic unit according to the percentage of county land area within the hydrologic unit. Consequently the urban land use within this hydrologic unit is overestimated. Similar situations are found for the other hydrologic units. The errors in agriculture are relatively smaller than the ones for urban areas. However for the hydrologic units 2,3 and 10, the errors are higher than 20%. Figure 9 shows that the errors in forest land use estimation using the uniform distribution assumptions are small compared to the ones in agriculture and urban land use. This result is due mainly to the fact that forest land is the major single land use in a county and therefore errors using the uniform distribution approach are small.

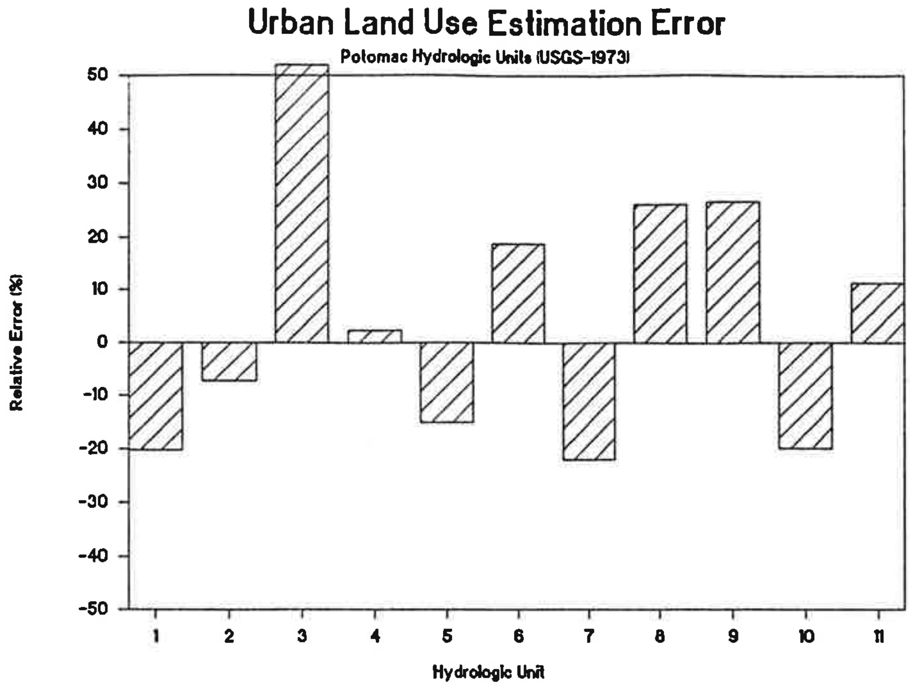


Figure 7

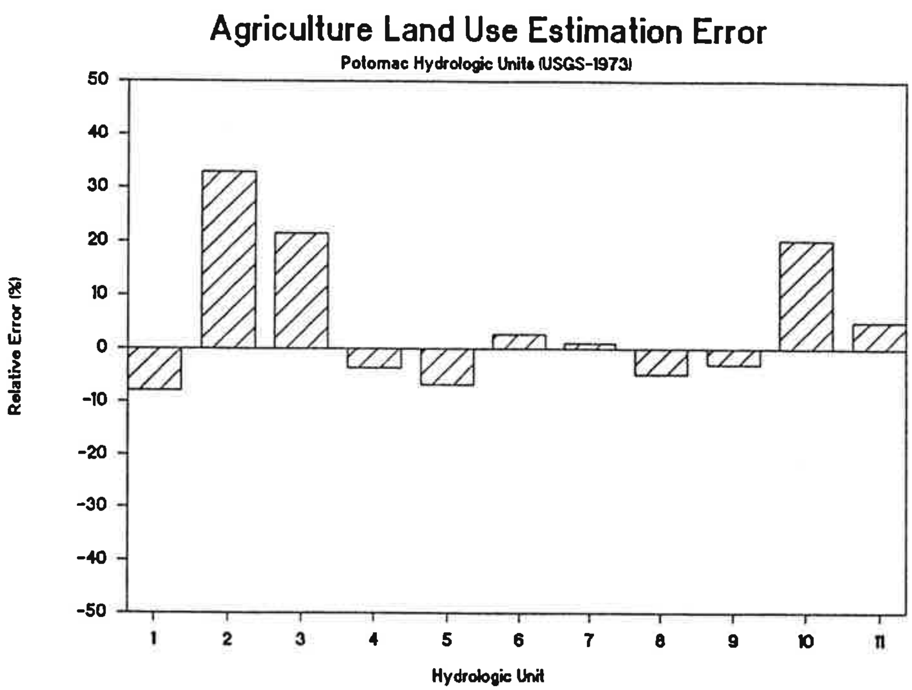


Figure 8

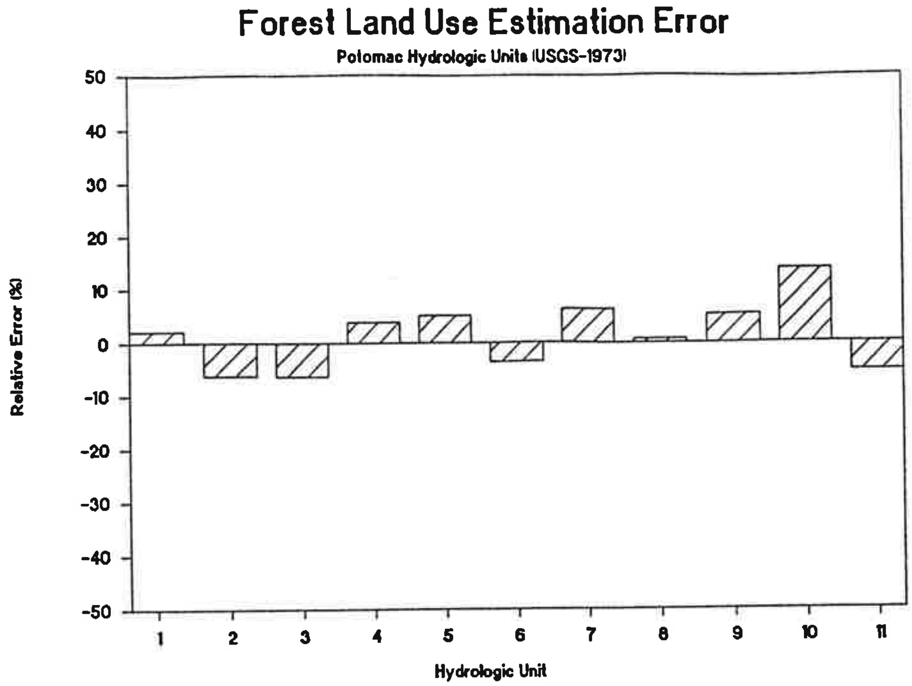


Figure 9

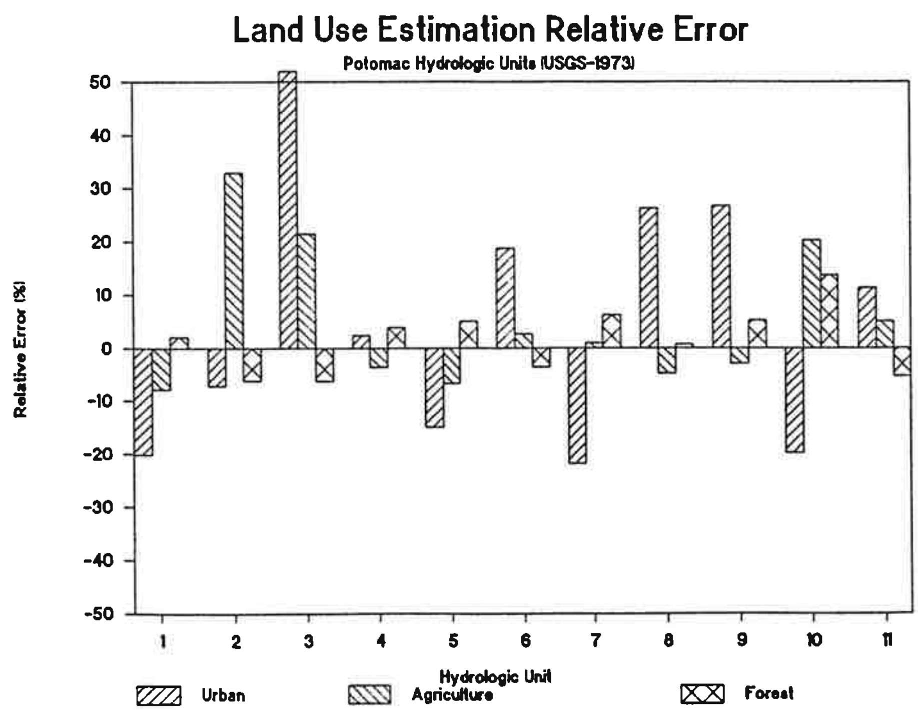


Figure 10

METHODOLOGY

As an alternative to the uniform distribution approach, a method is developed here which assigns 1985 land use compiled by county to hydrologic basins based on the distribution of land uses in 1973. ARC/INFO was used to determine 1973 land use areas by county and hydrologic basin. From these results, for each county, the fraction of total area for each land use lying within the Potomac river basin was computed. 1985 land use areas for the Potomac river basin were then computed by multiplying these (1973) land use percentages by the 1985 county land use areas. This method implicitly assumes that changes in land use areas from 1973 to 1985 occurred uniformly throughout each county. However, when using constant percentages (1973) over time (applied to the 1985 county land use) the amount of total county acres inside the basin may increase (overestimation) or decrease (underestimation). This amount must remain unchanged since the drainage boundaries of the basin are assumed to remain constant over time. The amount of underestimation or overestimation can be corrected using the procedure shown in Table 3. This table shows a method with which 1973 land use distributions are applied to 1985 county land uses, and any underestimation or overestimation is corrected. This procedure is applied to counties bisected by the Potomac river basin boundary. Explanation of the different steps in Table 3 are explained in the following section.

Example Methodology

Consider Garrett county in Maryland where 37.4% of the total area lies within the Potomac river basin. The lines in Table 3 are explained as follows:

- Line 1 shows the county wide acreages of each land use category according to the 1985 data compiled by CBLO.

- Line 2 shows the percentages of each land use category within the Potomac basin assuming uniform land use distribution throughout the county.

- Line 3 shows the number of acres in the Potomac river basin after multiplying line 1 by line 2.

- Line 4 shows the 1973 percentages of each land use within the Potomac river basin. The percentages are obtained, for each land use category, as the ratio of the amount of acres in the basin and the total acres in the county corresponding to each

Table 3. Land Use Estimation within the Potomac River Basin for Garrett County

		A Cropland	B Pasture	C Woodland	D Urban	E Total
1-	CBLO 1985 County Wide Land Use (acres)	45,100	30,992	305,779	38,500	420,371
2-	1985 % of County Wide Acres in the Potomac (uniform land use distribution)	37.4	37.4	37.4	37.4	---
3-	1985 Potomac Basin Land Use (acres) (uniform land use distribution)	16,867.4	11,591.0	114,361.4	14,399.0	157,218.8
4-	1973 % of County Wide Acres in the Potomac (USGS, ARC/INFO)	21.8	21.8	42.7	9.6	---
5-	1985 Potomac Basin Land Use (acres), 1st. Approx. (based on 1973 %)	9,831.8	6,756.3	130,567.6	3,696.0	150,851.7
6-	Correction Factor for 1st. Approx. (% of land use in county)	10.7	7.4	72.7	9.2	100.0
7-	1985 Potomac Basin Land Use (acres) (row 5 + row 6 x 6,367.1 /100)	10,513.1	7,227.4	135,196.5	4,281.8	157,218.8
8-	% of 1985 County Wide Acres in the Potomac (estimated from 1973 distributions)	23.3	23.3	44.2	11.1	---

land use category. For instance, in the example shown in the table, 42.7% of the total county woodland acres lie in the Potomac basin. Again, these percentages were obtained using the USGS 1973 data sets processed in ARC/INFO at the CBP computer center. For cropland and pasture, the percentage of the sum of cropland and pasture is assumed since the 1973 data do not differentiate between them. However, is it to be noted that the uniform distribution approach also assigns an equal percentage to cropland and pasture.

- Line 5 shows the number of acres in the Potomac river basin after multiplying line 1 by line 4. This is a first approximation which underestimates (overestimation is possible in other situations) the county area within the basin. As shown in column E, when applying these percentages to line 1, the sum of the land use acres within the basin was underestimated by about 4% (it should be 157,218.8 acres since 37.4% of the total county area is within the Potomac basin).

- Line 6 shows the percentages of total area (420,371) for each land use category in line 1. This percentage is used to correct the areas obtained in the first approximation. In effect, the amount of correction is proportional to the area of each land use within the county.

- Line 7 shows the adjusted acres for each land use category within the Potomac river basin. The sum of the acres obtained in line 5 (150,851.7) must be equal the total acres of Garrett county within the Potomac river basin (157,218.8). The underestimation is due to the use of the 1973 percentages constant over time. However, this underestimation may be corrected by adding, for each land use category, a portion of the amount of underestimation (for this case 157,218.8 - 150,851.7 = 6,367.1) weighted by the percentage of each land use category computed in line 6.

- Line 8 shows the estimated portion of 1985 county wide acres that are in the Potomac river basin. The difference between this line and line 2 indicates the magnitude of the differences in assigning land use areas to watersheds using the two methods. Comparing this line with line 4 shows that this new method assigns land use acres using the known 1973 land use distributions.

Estimated 1985 Land Uses for the Potomac River Basin

Table 4 shows the estimated 1985 land use data for the Potomac river basin. To obtain this table, 1985 Chesapeake Bay land use data (CBLO, 1989) for the Potomac river basin counties

Table 4. Estimated 1985 County Land Use Data within the Potomac River Basin

County	Cropland	Pasture	Forest	Urban	Water
	acres				
DC	0	0	3100	34660	4398
Allegany	20000	45000	181186	23100	3499
Carroll	77117	24478	28177	7341	46
Charles	36572	4812	180394	52493	76128
Frederick	163000	54000	135140	72000	2828
Garrett	10515	7226	135199	4279	243
Montgomery	57233	19623	82840	118701	6170
Prince Georges	6872	838	49183	98015	5837
St. Marys	37788	6161	97175	31019	18378
Washington	105200	48100	96680	41200	6112
Other Estuary					180381
Maryland Total	514297	210237	985974	448148	299621
Adams	74536	17673	59675	10442	472
Bedford	24127	9746	159412	604	354
Franklin	154514	49434	156863	32281	59
Fulton	46948	13560	124908	3592	172
Somerset	9066	4644	64202	400	0
Pennsylvania Total	309191	95056	565060	47320	1056
Arlington	0	0	0	16614	86
Augusta	125751	117725	214492	28212	84
Clarke	30036	40048	38046	6007	1428
Fairfax	9020	7015	91202	159353	7474
Fauquier	67991	59641	98704	9858	357
Frederick	60118	53103	149293	9018	508
Highland	5307	14859	50282	605	0
King George	8500	3863	53978	4880	2069
Loudoun	102845	91861	108836	29955	728
Northumberland	23033	1885	31647	2252	7967
Page	31397	28407	131570	8971	1762
Prince William	34270	16880	104842	62502	5558
Rockingham	86054	127081	332212	12008	219
Shenandoah	40578	64072	213572	9611	147
Stafford	10415	5351	96733	10346	4765
Warren	9270	39141	83431	7210	2861
Westmoreland	32153	2193	64672	6723	11875
Virginia Total	676738	673125	1863512	384124	47885
Berkeley	27403	23187	97664	57480	448
Grant	20984	54961	222342	9105	1643
Hampshire	5302	63627	318134	25391	2351
Hardy	21246	50585	290358	11955	94
Jefferson	38458	20895	25937	48674	1764
Mineral	12393	23940	164957	9494	589
Morgan	11602	4834	116018	14502	545
Pendleton	21859	69770	348451	5791	90
West Virgina Total	159247	311799	1583861	182392	7523
Potomac Total	1659473	1290217	5001508	1096643	360483

were used. Land uses of Potomac river basin counties that are split by the boundary basin were computed using the methodology shown in the previous section. Similarly, Table 5 shows the estimated 1985 land uses for the Potomac river basin hydrologic units. Figures A1 to A12 in the Appendix A, show the distribution of land uses for the Potomac basin hydrologic units. The water acres were estimated with the digitized 1973 GIS data. In Table 3 the water acres marked as "Other Estuary" were obtained from the GIS data base. This estuary area was not assigned to any county in the GIS data base; however this area belongs to Maryland, and it is adjacent to the counties of Charles and St Marys. The sum of the total acres in either Table 3 or 4 results in approximately 14,700 square miles (9,408,000 acres). This area is 30 square miles more than the Potomac river basin area estimated by the USGS (14,670). However, this difference of 0.2% is insignificant considering the fact that the county areas reported in the compilation made by CBLO are not obtained from the GIS data base. Therefore, when adding the water acres with the 1973 GIS data base, the resulting areas do not exactly match because of the use of two different land use data sources. Also, it is observed that the totals in Tables 4 and 5, for each land use category, are not exactly the same. This discrepancy is mainly due to round off error when using land uses percentages to assign land use county acres to a basin. However, for each land use category, the relative difference between the totals of these two tables is about 0.01% which is considerably insignificant.

Table 5. Estimated 1985 Land Use Data for the Potomac River Basin Hydrologic Units

Hydrologic Unit	Cropland	Pasture	Forest	Urban	Water
	acres				
02070001	52416	158633	709831	28493	2365
02070002	64126	90022	660973	41586	4995
02070003	38656	96048	612199	24128	1852
02070004	413953	197589	668697	169310	7469
02070005	210727	236004	573231	49240	3809
02070006	89499	133453	423748	14437	414
02070007	46406	61129	76806	41389	3945
02070008	226737	150278	270901	140511	9682
02070009	277357	83870	179300	76600	634
02070010	88938	58324	258119	392989	37533
02070011	150881	24985	567138	117893	287785
Potomac Total	1659696	1290334	5000944	1096576	360483

CONCLUSIONS

This report has primarily addressed some of the uncertainties on basin land use estimation for the Chesapeake Bay Watershed Model. The uniform land use distribution has been evaluated using the 1973 USGS GIRAS data. A methodology for assigning 1985 county wide land uses to basins using the 1973 land use distributions has been proposed.

With the 1973 USGS GIRAS data, evaluation of the uniform land use distribution shows that the potential for error in estimating basin land uses increases as the portions of watershed segments inside a county become smaller. For the hydrologic units in the Potomac river basin, relative errors were found to be high for urban land use areas, and low for forest areas. For agriculture, errors were relatively significant for three out of eleven hydrologic units in the Potomac river basin. The relative errors computed in this report are errors due to the use of the uniform land use distribution assumption (with the 1973 data) obtained by relative comparison with the true land use distribution in 1973 using the USGS GIRAS data. The magnitude of the errors for 1973 using the uniform distribution assumption may be used as a guide for the evaluation of the uncertainty in the 1985 land use estimation for the Potomac river sub-basins used in the watershed model. These errors may also be used for the evaluation of the watershed model sources of errors when the calibrated model is verified with observed data. Evaluation of the magnitude of the true 1985 basin land use estimation relative errors for the watershed segments used in the model, will require digitized 1985 land use data for the entire Chesapeake bay basin. However, due to the lack of digitized 1985 land use data or even more recent land use data than 1973, the 1973 digitized land use data is used for the evaluation and the proposed methodology.

The alternative methodology proposed in this report for the estimation of basin land use data from the computed distribution of land uses in 1973, can help improve the accuracy of basin land use estimation for counties lying within multiple hydrologic basins. The accuracy of the proposed method of distributing 1985 county based land uses using the 1973 land use distributions as a guide is not tested in this report. Again, such a test is not possible since no 1985 digitized land use data are available at this moment for the entire Potomac river basin. However, the method is presented because it is based on the knowledge of the 1973 land use distributions, which are the only ones available for the entire Potomac river basin. Therefore, the proposed method is thought to be a reasonable alternative to the uniform land use distribution approach. However, it is pointed out that the proposed method can not be consistently applied to the entire Chesapeake Bay Watershed because the 1973 data GIS data base is not yet available for the entire basin.

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APPENDICES

APPENDIX A
1973 Percentages of Total County Land Use Category within the Potomac River Basin

1973 Percentages of Total County Land Use Category within the Potomac River Basin

County	Cropland & Pasture	Forest	Urban
DC	100	100	100
Allegany	100	100	100
Carroll	52.3	28.8	25
Charles	94.9	93.1	94.1
Frederick	100	100	100
Garrett	21.8	42.7	9.6
Montgomery	83.6	86.3	96.8
Prince Georges	25.4	46.9	66.1
St Marys	82.6	74	59.2
Washington	100	100	100
Adams	43.3	60.5	51
Bedford	16.1	36.8	3.2
Franklin	82.8	74	78.6
Fulton	75.6	64	44.1
Somerset	6.8	15.1	1.6
Arlington	100	100	100
Augusta	88.6	64.1	93.4
Clarke	100	100	100
Fairfax	100	100	100
Fauquier	58.5	50.8	74.7
Frederick	100	100	100
Highland	35	23.8	60.1
King George	40.4	71.8	83
Loudoun	100	100	100
Northumberland	61.7	42.9	36.5
Page	100	100	100
Prince William	100	100	100
Rockingham	100	100	100
Shenandoah	100	100	100
Stafford	50.4	75.5	71.1
Warren	100	100	100
Westmoreland	72.1	70.4	83.1
Berkeley	100	100	100
Grant	100	100	100
Hampshire	100	100	100
Hardy	100	100	100
Jefferson	100	100	100
Mineral	100	100	100
Morgan	100	100	100
Pendleton	99.9	99.8	100

APPENDIX B
1973 Percentages of Total County Land Use Category within Potomac Hydrologic Units

1973 Percentages of Total County Land Use Category within Potomac Hydrologic Units

Potomac River Basin Hydrologic Unit: 02070001

County	Cropland & Pasture	Forest	Urban
Grant	64.2	48.6	70.1
Hampshire	21.5	28.5	39.5
Highland	35	23.7	60.1
Hardy	52.2	40.8	50.1
Pendleton	99.9	99.6	100
Rockingham	0.006	0.18	0

Potomac River Basin Hydrologic Unit: 02070002

County	Cropland & Pasture	Forest	Urban
Allegany	61.7	57.6	94.9
Bedford	8	15.9	3.2
Garrett	21.8	42.7	9.6
Grant	35.8	51.3	29.9
Hampshire	2.6	2.6	9.5
Hardy	0.008	0.04	0
Mineral	99.9	99.9	100
Somerset	6.8	15.1	1.6

Potomac River Basin Hydrologic Unit: 02070003

County	Cropland & Pasture	Forest	Urban
Allegany	38.3	42.8	5.1
Bedford	8.1	20.8	0
Frederick	0	0.091	0
Fulton	4.6	3.2	0
Hampshire	75.3	68.6	50.9
Hardy	46	55.9	48
Morgan	12.5	36.6	24.7
Shenandoah	0	0.243	0
Washington	0.55	10.4	0.7

1973 Percentages of Total County Land Use Category within Potomac Hydrologic Units

Potomac River Basin Hydrologic Unit: 02070004

County	Cropland & Pasture	Forest	Urban
Adams	0.018	18.1	0
Berkeley	100	100	100
Clarke	22.2	12.2	3.3
Franklin	82.8	73.4	77.3
Frederick	71	71.4	88.2
Fulton	71.1	60.8	44.1
Hampshire	0.55	0.22	0
Jefferson	58	35.1	24.4
Morgan	87.5	63.4	75.3
Washington	97	83.7	98.6

Potomac River Basin Hydrologic Unit: 02070005

County	Cropland & Pasture	Forest	Urban
Augusta	88.6	64	93.4
Page	100	94.6	100
Rockingham	56.9	53.8	68.5
Warren	43.2	63.8	52.4

Potomac River Basin Hydrologic Unit: 02070006

County	Cropland & Pasture	Forest	Urban
Frederick	18	24.6	3.4
Hardy	1.9	3.3	1.8
Page	0	5.4	0
Rockingham	43.1	45.9	31.5
Shenandoah	100	99.7	100
Warren	13	8.7	8.8

Potomac River Basin Hydrologic Unit: 02070007

County	Cropland & Pasture	Forest	Urban
Clarke	77.8	86.7	95.6
Frederick	11	3.9	8.4
Jefferson	42	64.2	75.6
Loudoun	0	0.195	0
Warren	43.8	27.3	38.7

1973 Percentages of Total County Land Use Category within Potomac Hydrologic Units

Potomac River Basin Hydrologic Unit: 02070008

County	Cropland & Pasture	Forest	Urban
Clarke	0	1.1	1.1
Fairfax	47.3	29.6	21.6
Fauquier	27.3	19	17.2
Frederick	26.3	24.3	21.5
Loudoun	95.5	93.1	90.6
Montgomery	61.7	63	42.6
DC	0	3	4
Warren	0.012	0.089	0.092
Washington	2.4	5.6	0.543

Potomac River Basin Hydrologic Unit: 02070009

County	Cropland & Pasture	Forest	Urban
Adams	43.3	42.4	51
Carroll	52.3	28.8	25
Franklin	0.0022	0.7	1.3
Frederick	73.6	75.5	78.4
Montgomery	9.2	6	0.8

Potomac River Basin Hydrologic Unit: 02070010

County	Cropland & Pasture	Forest	Urban
Charles	1	3.3	3.8
Arlington	0	100	100
DC	100	97	96
Farifax	52.7	70.4	78.4
Fauquier	31.1	30.4	56.6
Loudoun	4.5	6.7	9.4
Montgomery	12.6	17.3	53.5
Prince Georges	17.9	35.2	63.8
Prince William	98.5	66.6	86

1973 Percentages of Total County Land Use Category within Potomac Hydrologic Units

Potomac River Basin Hydrologic Unit: 02070011

County	Cropland & Pasture	Forest	Urban
Charles	93.8	89.8	90.2
Fauquier	0.105	1.3	0.7
King George	40.4	71.8	83
Northumberland	61.7	42.9	36.5
Prince Georges	7.5	11.8	2.3
Prince William	1.5	33.3	14
Stafford	50.4	75.4	71.1
St Marys	82.6	74	59.2
Westmoreland	72.1	70.4	83.1

APPENDIX C
Estimated 1985 Land Use Distributions for the Potomac River Basin

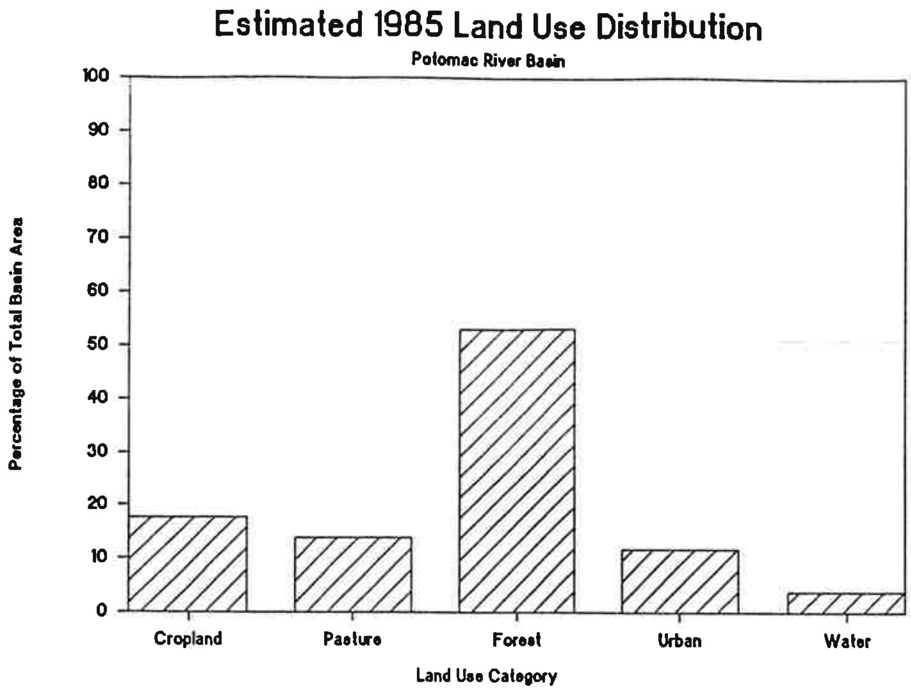


Figure C1

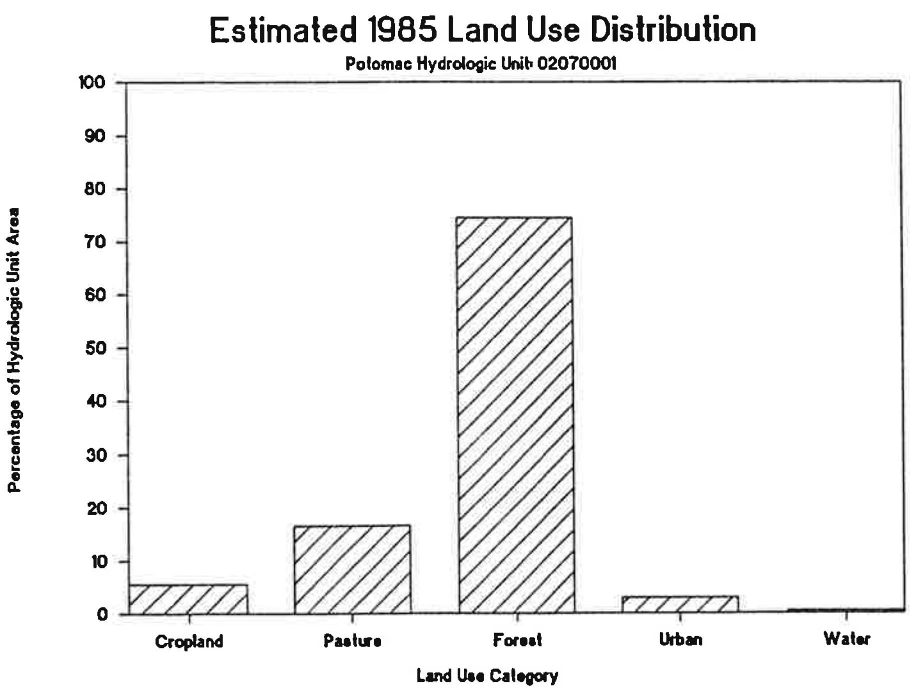
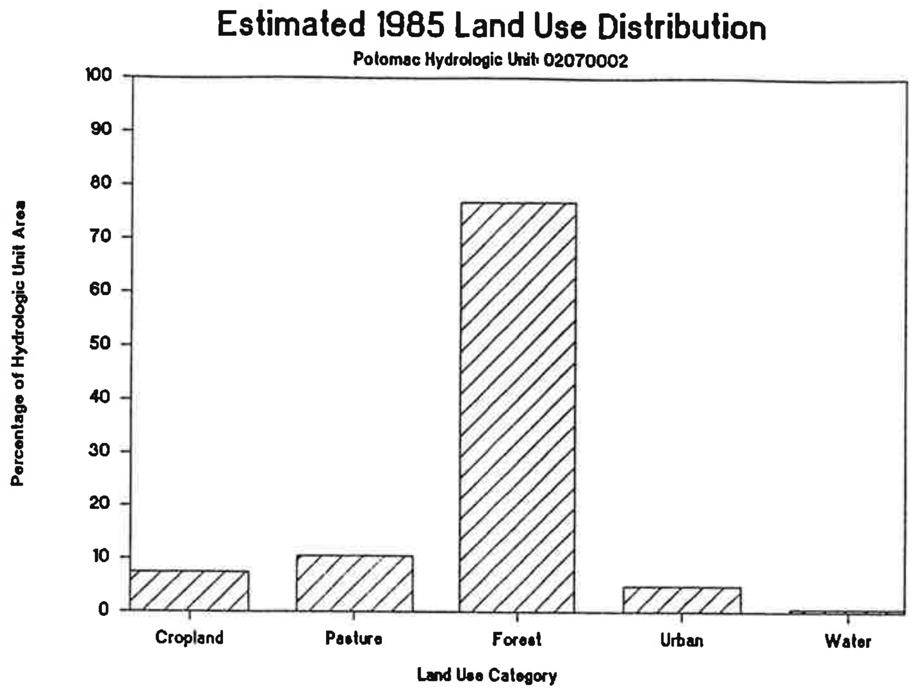


Figure C2



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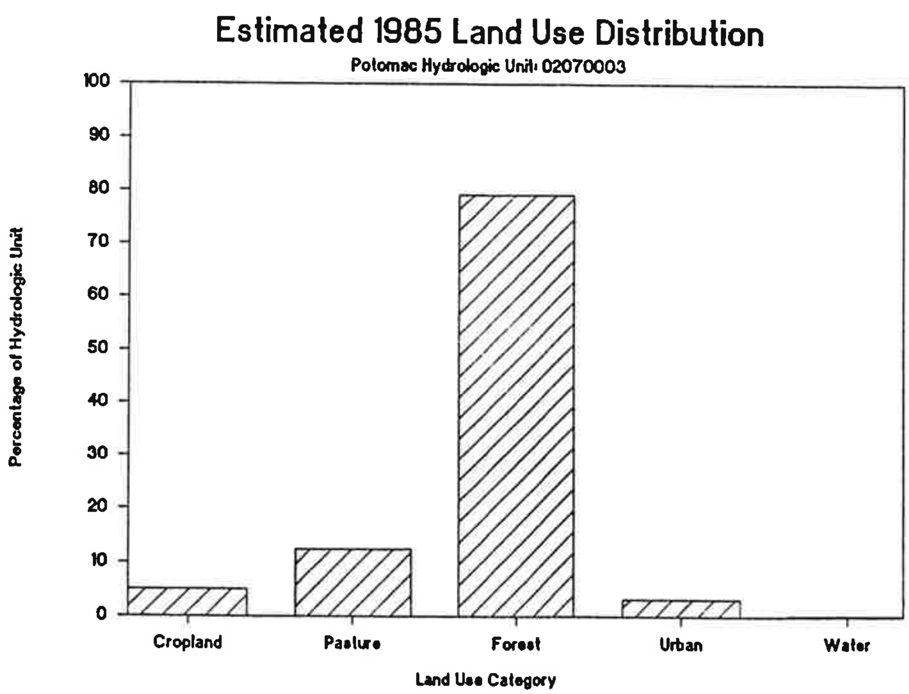

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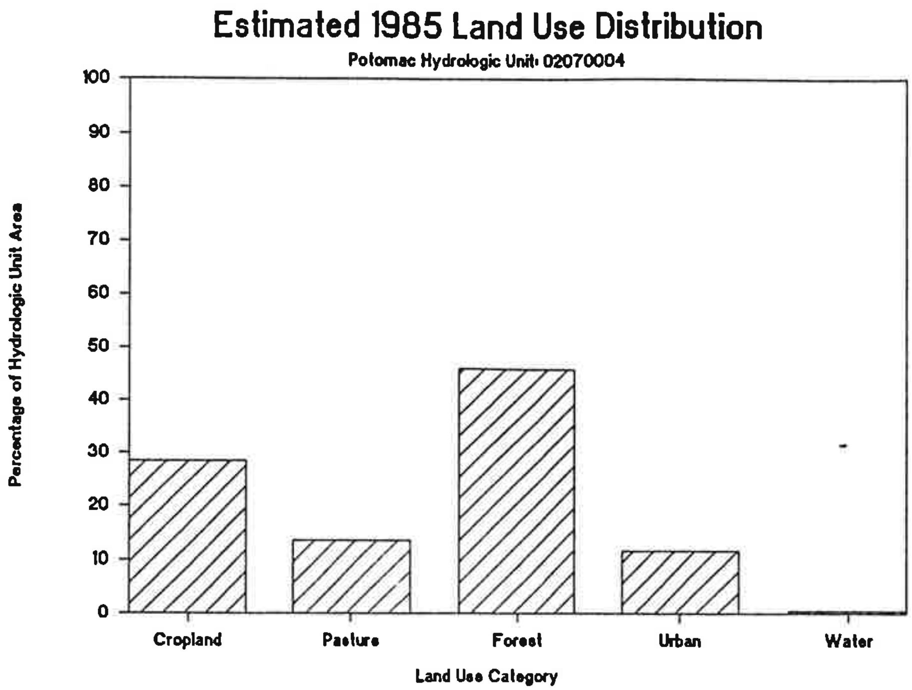

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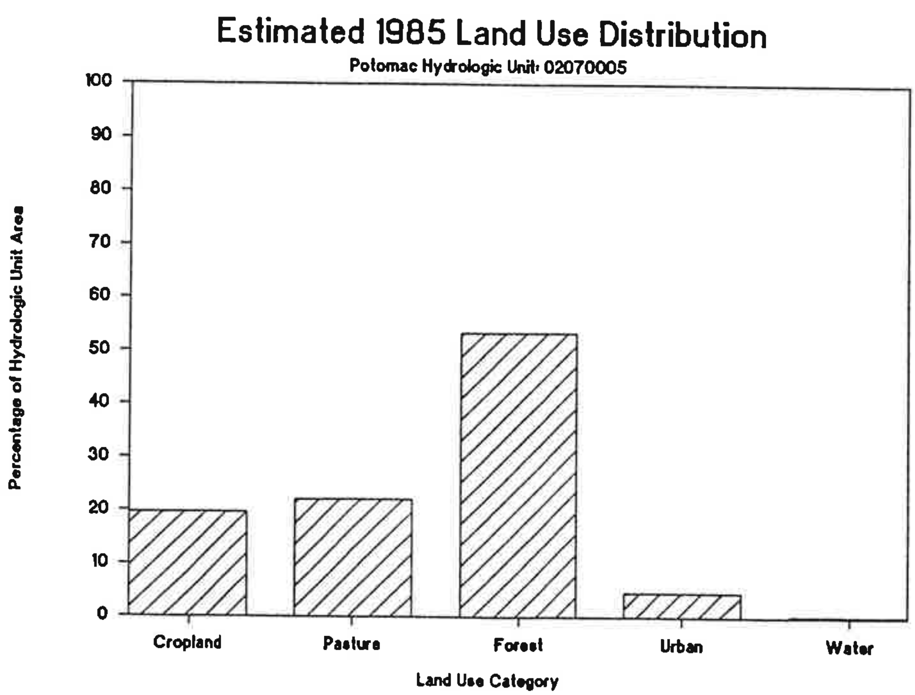

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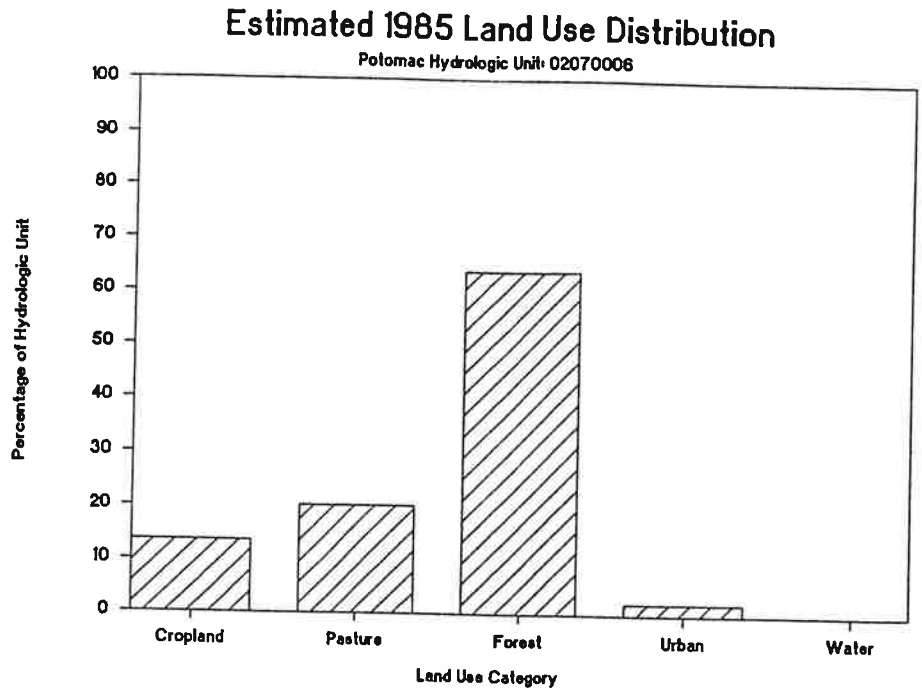

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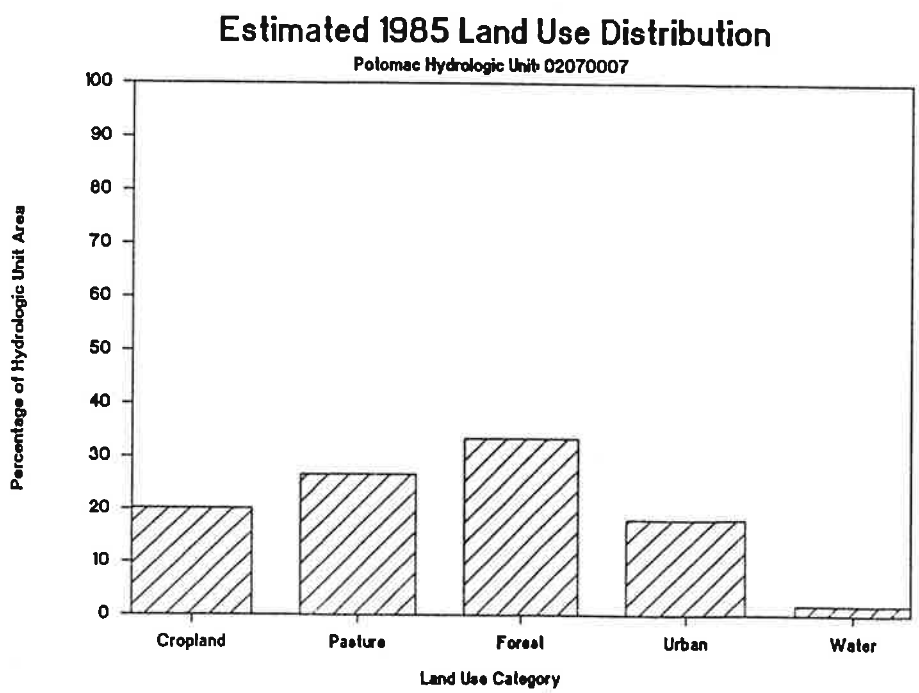

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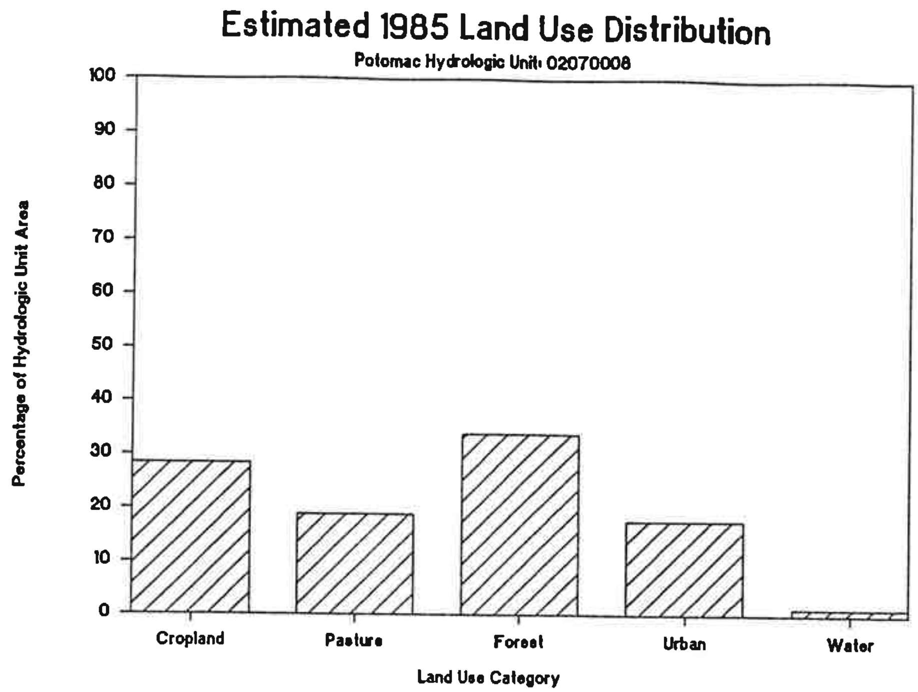

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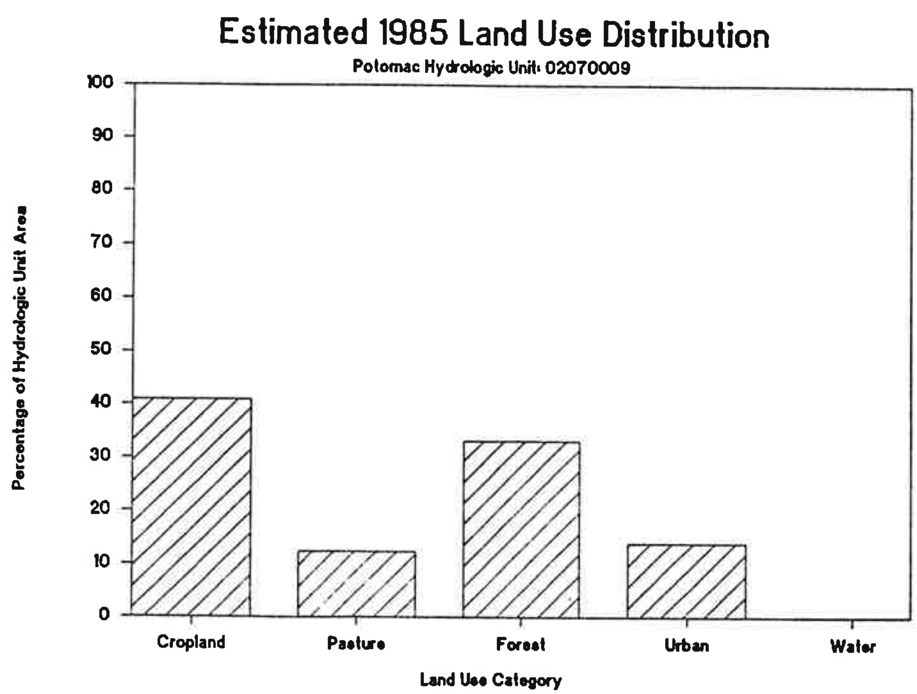

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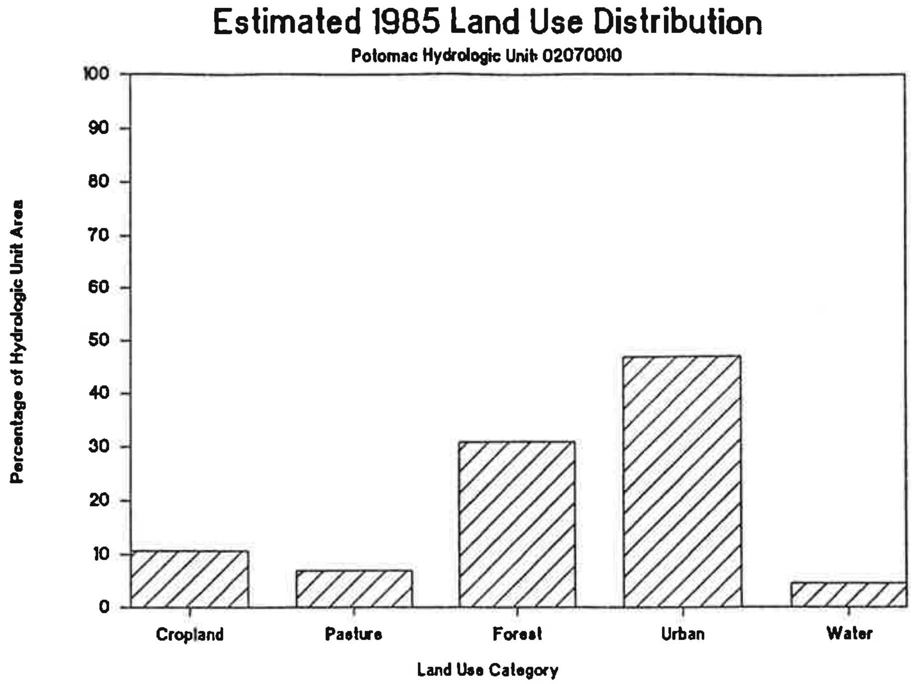

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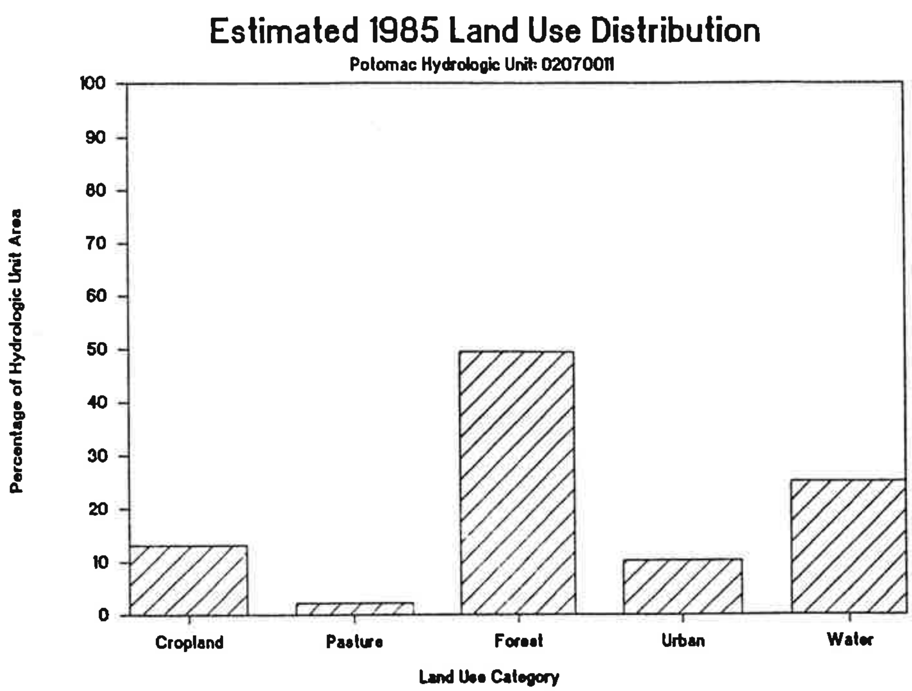

Figure C12