APPENDIX C–AGRICULTURAL WATER USE

Methodology – Agricultural Irrigation Data Development

A listing of water withdrawal reports from the Maryland Department of the Environment (MDE) database (1980 – 2002) was sorted based on reported withdrawal by county and use codes. Entries with zero withdrawal or no reports were eliminated. . The reporting of agricultural water withdrawals was not required until 1995, therefore information from 1995 to 2002 was analyzed. Agricultural withdrawals include crops, horticulture, recreation, and livestock. For each year the withdrawal reports were summed for each group of use codes. Recreation was mostly landscape irrigation related to golf courses and a few parks. Water withdrawal for livestock use was a very small percentage, and projections for this category were made separately from the others based on knowledge of current trends.

A second database of water withdrawals, compiled by United States Geological Service (USGS), was analyzed for the following years: 1995, 1997, 2000, 2001. When the two data sets were compared the results were parallel but demonstrated unequal data points. Although the MDE water withdrawal database forms the basis of the USGS database, USGS also includes water use estimates of non-reporting permit holders. Golf courses were not separated from the broader category of irrigation until 2000, so the earlier year totals include them. Since the USGS estimates almost doubled agricultural withdrawal figures, permits in the original MDE withdrawal report database reporting zero were reexamined. USGS data assumed withdrawal even when none is reported. MDE confirmed that reporting is often incomplete. USGS data was used to project agricultural use trends through 2030.

Reported horticulture withdrawals varied from 6% to 9.7% of the State's total agricultural use. Five counties have no horticulture water use permits. The dollar value of the horticulture industry is increasing at a faster rate than the number of households in Maryland, but the quantity of water withdrawn does not exhibit an increasing trend. According to University of MD industry experts, efficiency of horticultural water use is improving due to new technology. Our analysis assumes that water withdrawals due to horticulture will not significantly increase over the time period. Marginal growth in horticultural use is assumed and is added to projections of cropland irrigation demand, separate from the process described here.

Data on acres of irrigated cropland by county were obtained from National Agriculture Statistics Service (NASS). The year 1997 was the only year for which MDE, USGS and NASS datasets were all available; 2002 NASS data is scheduled for release in June 2004. A regression analysis was performed using irrigated acres as the independent variable, holding the pumpage data set as the dependent variable. Each data point represents one county. Using all the counties there is good correlation (r^2= 0.97). When the same regression treatment is applied to smaller data sets, i.e.: using a smaller number of counties, correlation is lower. These regressions indicate the best regional correlation in the nine counties of the Eastern Shore (r^2= 0.94) and the differences between data sets are not significant. The three counties of the Monocacy watershed show greater correlation between water use and irrigated acres than the three southern Maryland counties. Similar land use (i.e. predominance of agricultural land among counties in a subset) appears to increase the degree of correlation.

Precipitation Excess

Five years (1999-2003) of growing season weather data (precipitation, winds, temperature, humidity, etc.) from Georgetown DE were used to generate estimates of annual precipitation excess (EX). This was the precipitation for the growing season minus the evapotranspiration demand. The EX had a mean of 1.324 and a standard deviation of 7.674. On average, there is a 1.34-inch surplus of precipitation during the growing season. However, distribution is uneven. High demand can occur if all the precipitation occurs at one period of the growing season. For example, the 2002 precipitation was fairly close to average, but during 2002 (the end of the drought), irrigation demand was high because all the precipitation fell in the fall.

We assumed that the EX was normally distributed because 5 observations were not sufficient to develop a probability density function. Hence, we assumed a normal distribution with a mean of 1.324 and a standard deviation of 7.674, which allowed us to generate EX values for the years up to 2030. The data are presented in the Table C-1.

Table C-1. Precipitation Excess for Five Years

Year	Precipitation	ET	EX
1999	23.40	20.97	-2.43
2000	22.21	24.94	2.73
2001	23.46	24.15	0.69
2002	25.50	16.62	-8.88
2003	18.05	32.56	14.51
Mean	22.524	23.848	1.324
Std. Dev.	2.474	5.248	7.674

Source: Data from Georgetown, DE
Note: negative numbers represent dry years.

Growth

Growth data were available for the irrigated acres in Maryland from the National Agricultural Statistics Service (NASS) for 1978,1982,1987,1992 and 1997. Certain irrigation factors were important. First, in any country, irrigated acres only rarely exceed 10% of the agricultural land. Second, irrigation improves profit, if well managed. These factors led to the assumption that because irrigation is a small part of agricultural lands and it is difficult to make a profit in agriculture, irrigation is attractive to people with appropriate land. It was further assumed that while there is a downward trend in overall agricultural land, this would not affect the trend in irrigated acres. In other words, the people under economic pressure (from growth or other factors) with appropriate land for irrigation will work very hard to incorporate irrigation into their production system. Therefore, the growth trend in irrigated land will not be depressed by the downward trend in the overall number of agricultural acres.

Growth in irrigated acres was assumed to be directly proportional to growth in pumping. In any given year, farmers will apply roughly the appropriate amount of water to supply moisture necessary for growth without applying excess water, which would create runoff. Therefore, the major controlling factor in pumping should be the area irrigated.

Linear relationships between year and irrigated acres were developed for the five regions in Maryland (Figure C-1).

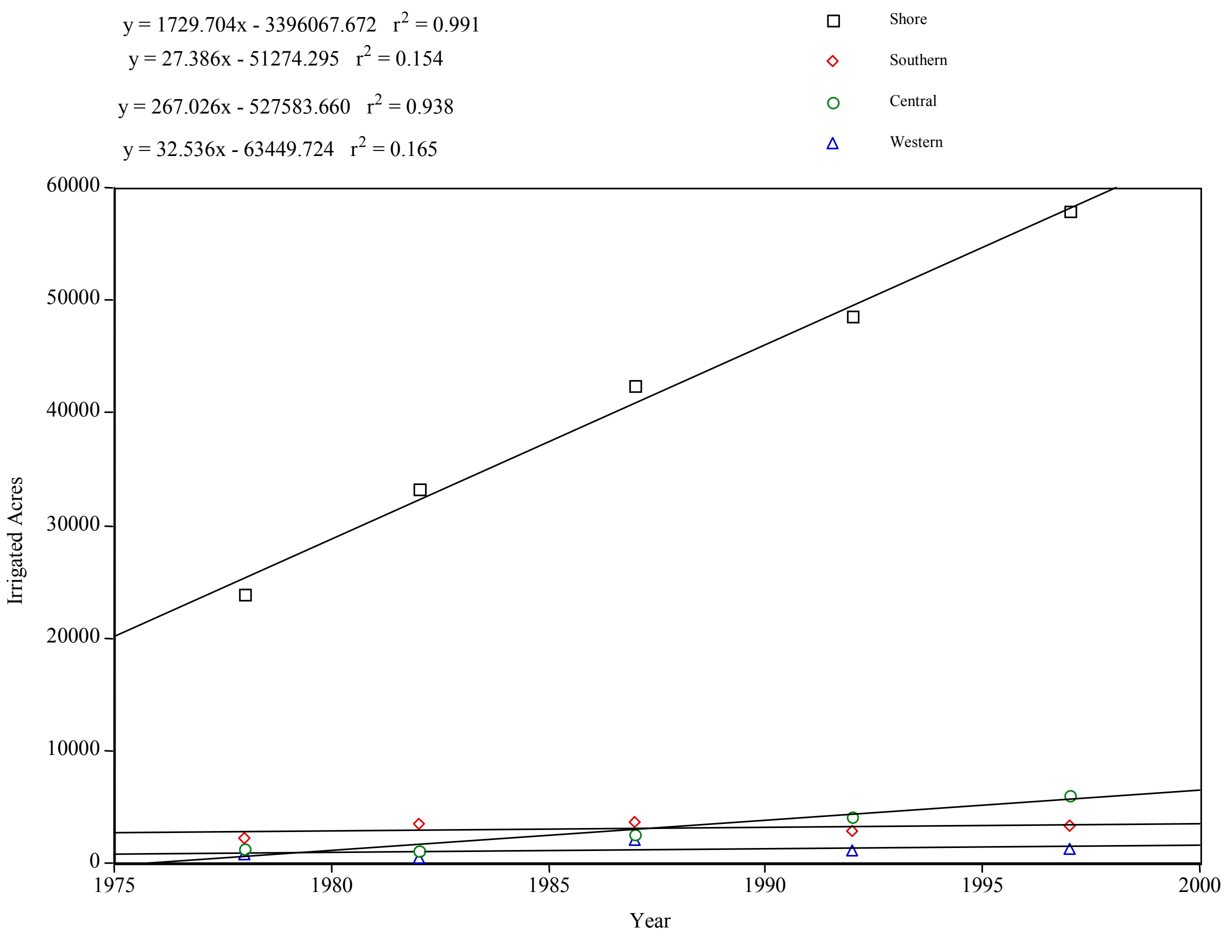

Figure C-1. Change in the Number of Irrigated Acres in Maryland Regions

Examination of the r^2 values indicates that the southern and western regions have poor correlation between year and acreage. A plot of these two data sets is shown in Figure C-2. The data from 1982 and 1987 are highly variable compared to the other data. It is not clear why irrigated acres dropped in the western region while it increased in the southern region (1982) or why it rose so dramatically in the western region in 1987. However, the long-term trend developed from these regression lines does not seem inaccurate. Hence, these predictions were used even though the correlation coefficients for the regression equations were low. It is possible that the remaining years' data might have been used (1978, 1992, 1997) but the overall prediction would not have been dramatically different and the statewide irrigation demand is dominated by the eastern shore, so the overall estimates would not change dramatically.

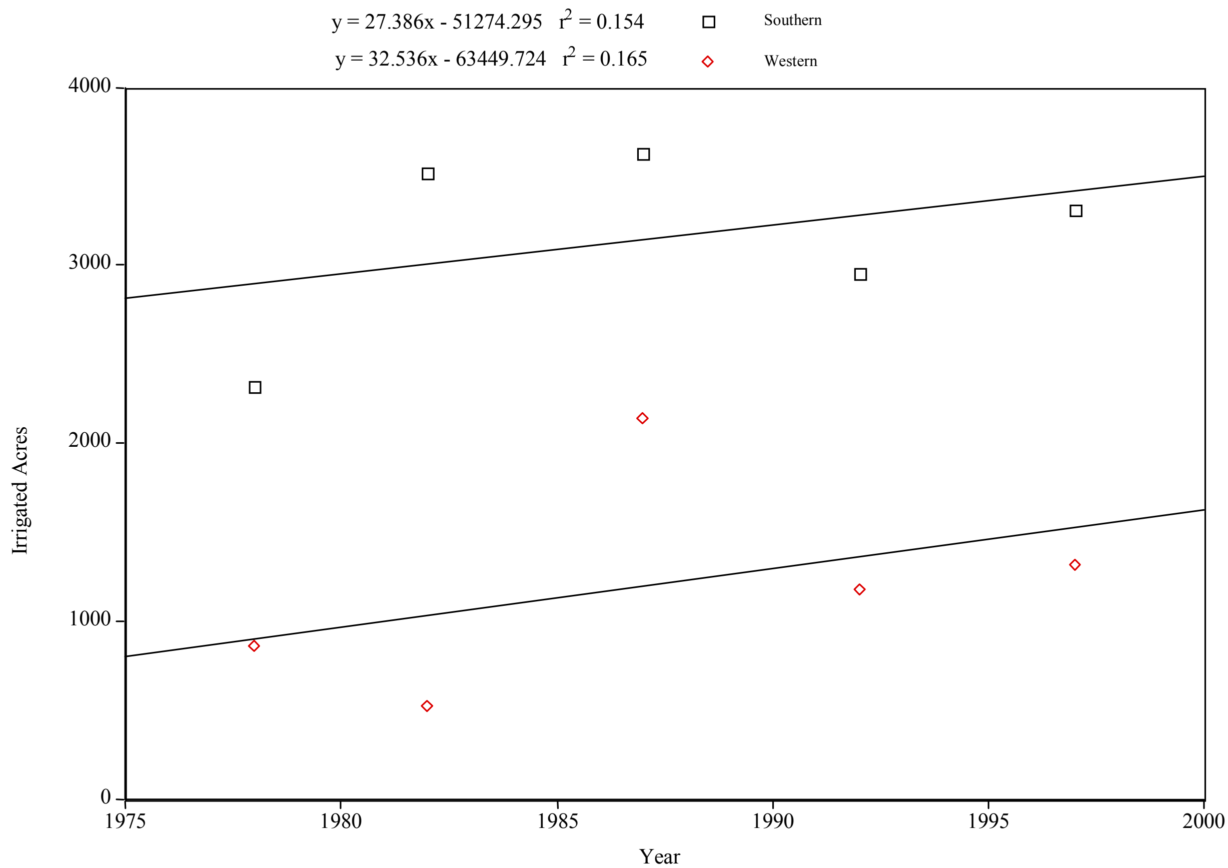

Figure C-2. Change in the number of irrigated acres for the southern and western regions in Maryland

Pumping

The USGS estimates of agricultural withdrawal were used for the years 2000 and 2001. Individual county estimates were collected into regional values so that the regions corresponded to other regional data being used (irrigated acres). The Lower Shore comprised Dorchester, Somerset, Wicomico, and Worcester Counties; Upper Shore comprised Queen Anne's, Kent, Talbot, Caroline Counties; Southern Maryland comprised Anne Arundel, St. Mary's, Calvert, Charles, and P.G. Counties; Central Maryland comprised Cecil, Harford, Baltimore, Carroll, Montgomery, and Howard Counties; and the Western Region comprised Frederick, Washington, Allegany, and Garrett Counties.

Data for both annual agricultural pumpage and moisture deficit were only available for two years (2000 and 2001). A linear regression of the data was possible, but no statements could be made about the quality of the regression. The relationships were developed for each of the five regions in Maryland (Figure C-3).

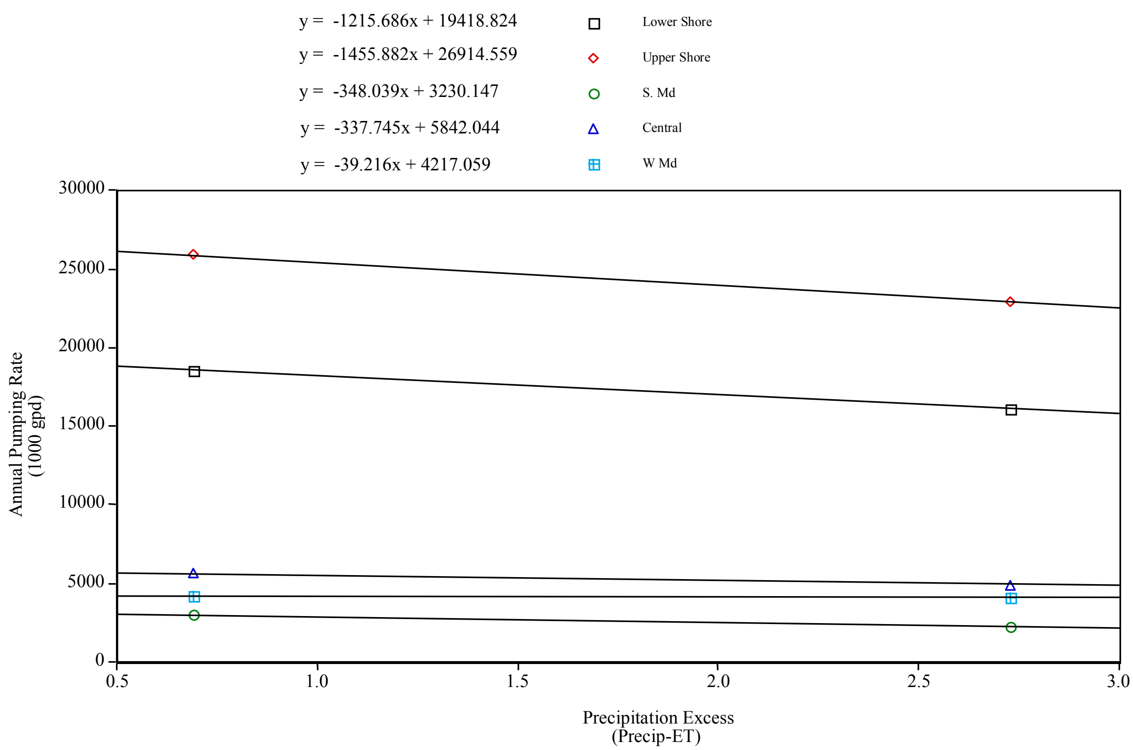

Figure C-3. Relationships between precipitation excess (Precip.-ET) and the annual pumping rate for each region in Maryland

The data presented above were combined to develop a simulation of irrigation demand for Maryland up to 2030. The steps of the procedure are outlined below.

Steps

1) A random number generator was used to develop EX values for each year.

2) The EX value was then used to generate Annual Pumping Rates on a regional basis from the regression equations in Figure C-3.

3) A growth factor was generated for each year up to 2030. The reference year was 1997, the last year for which there is NASS irrigated acres data. The growth factor was the number of irrigated acres generated by the regression equations in Figure C-1 divided by the number of irrigated acres for 1997.

4) The pumping generated in step 2 was multiplied by the growth factor. This provided the estimate of pumping for each region for each year. Regional values were summed to get the state value for each year up to 2030, which is plotted in Figure C-3.

Random simulations are presented in Figure C-4. Ten simulations were run to develop this range of possible demand figures. Several more simulations (perhaps about 25), would be needed to provide some statistical analysis representative of the possibilities. The results would be a range of possible withdrawal scenarios, but it is important to understand that any one data point only represents a simulation not a prediction for that year.

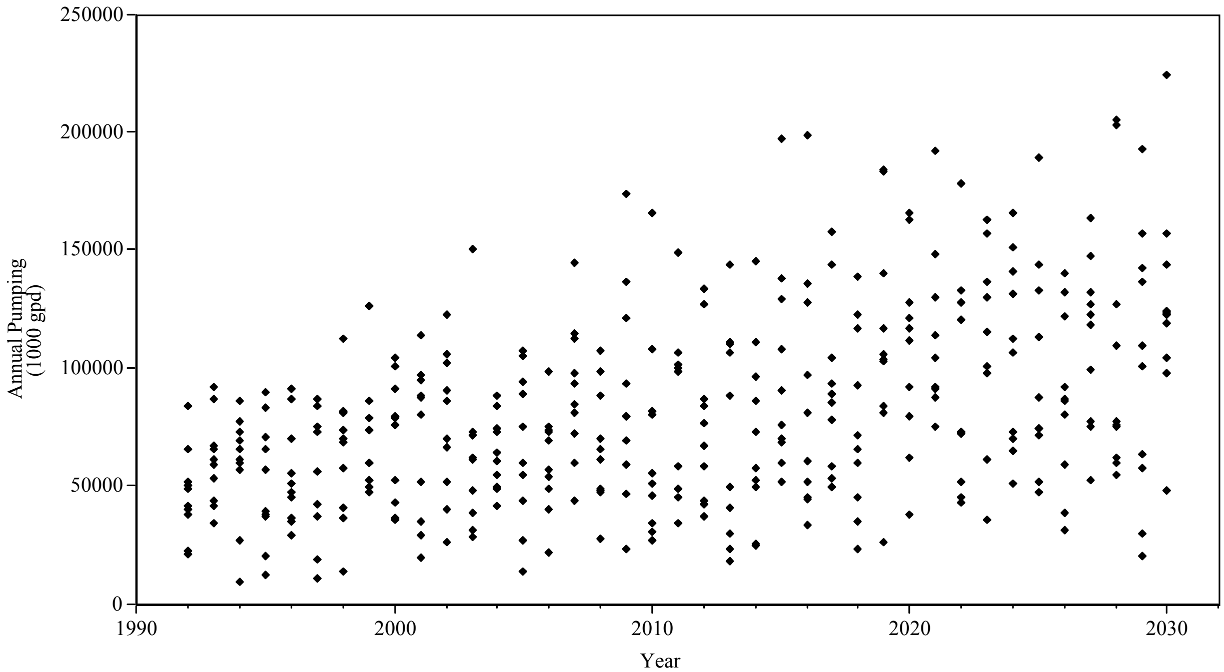

Figure C-4. Statewide pumping rate for 10 simulations for 1992-2030.

Figure C-4 indicates that the maximum pumping rate goes up in response to an increase in irrigated acres. However, note that the minimum rate, which is the response to ample precipitation excess, does not increase. This indicates some years of low demand where the water supply has an opportunity to recover. There could be as many as 10 years of low demand (2018 to 2028) between years of minimum demand, to give the system a chance to recover.

These data are presented in Table C-2. The highest value is 224,286,000 gpd on an annual basis.

Table C-2.Annual pumping rate (1000 gpd) from ten simulations with minimum and maximum values

Year	Average	Standard Deviation	Minimum	Maximum
1992	46081	17772	20925	83521
1993	60286	17790	34210	92143
1994	58338	22192	9264	86277
1995	51084	24678	12176	89822
1996	54569	20320	28963	91030
1997	53927	25080	10814	86450
1998	63501	26361	13780	112227
1999	68582	22988	47216	126531
2000	69531	24729	35211	103956
2001	69527	31356	19711	114041
2002	76012	29319	26180	122836
2003	63363	33221	27970	150664
2004	63611	14862	40969	87855
2005	66675	30917	13497	107022
2006	61129	20529	21464	98745
2007	90239	27658	43598	144631
2008	66154	23976	27598	107495
2009	88057	42611	22841	174017
2010	67772	40808	26672	165453
2011	78977	35315	34295	149196
2012	75676	32006	37011	133594
2013	71850	42657	17801	143665
2014	71962	36345	24210	145109
2015	98714	42828	51578	197231
2016	87362	50101	33071	198544
2017	91161	34407	49730	157425
2018	76898	37221	22701	138422
2019	112670	45216	26247	184240
2020	107580	38889	37421	165734
2021	112386	33558	75142	191762
2022	91593	43036	43062	178258
2023	115877	40736	35819	162749
2024	106552	38173	50977	165620
2025	98463	43085	46840	189215
2026	86754	35126	31446	140304
2027	111388	33089	52330	163696
2028	104839	54078	54713	205403
2029	100856	54283	19807	192638
2030	126327	42862	47972	224286

Finally, a comparison of the eastern shore to the rest of the state was made. Five simulations were run and averages were calculated for the five values for the eastern shore pumping demand and the rest of the state. These results are shown in figure C-5.

In periods when the pumping demand is low (rainfall excess high) the difference between the shore and the rest of the state is approximately 30,000,000 gpd. An example of this is the year 2012. However, when pumping rate goes up, the difference between the shore and the rest of the state is dramatic and dominating. The year 2030 is an example of this. In that year, the shore demand is 73,100,000 gpd (approximately 2.5 times) greater than the entire remainder of Maryland.

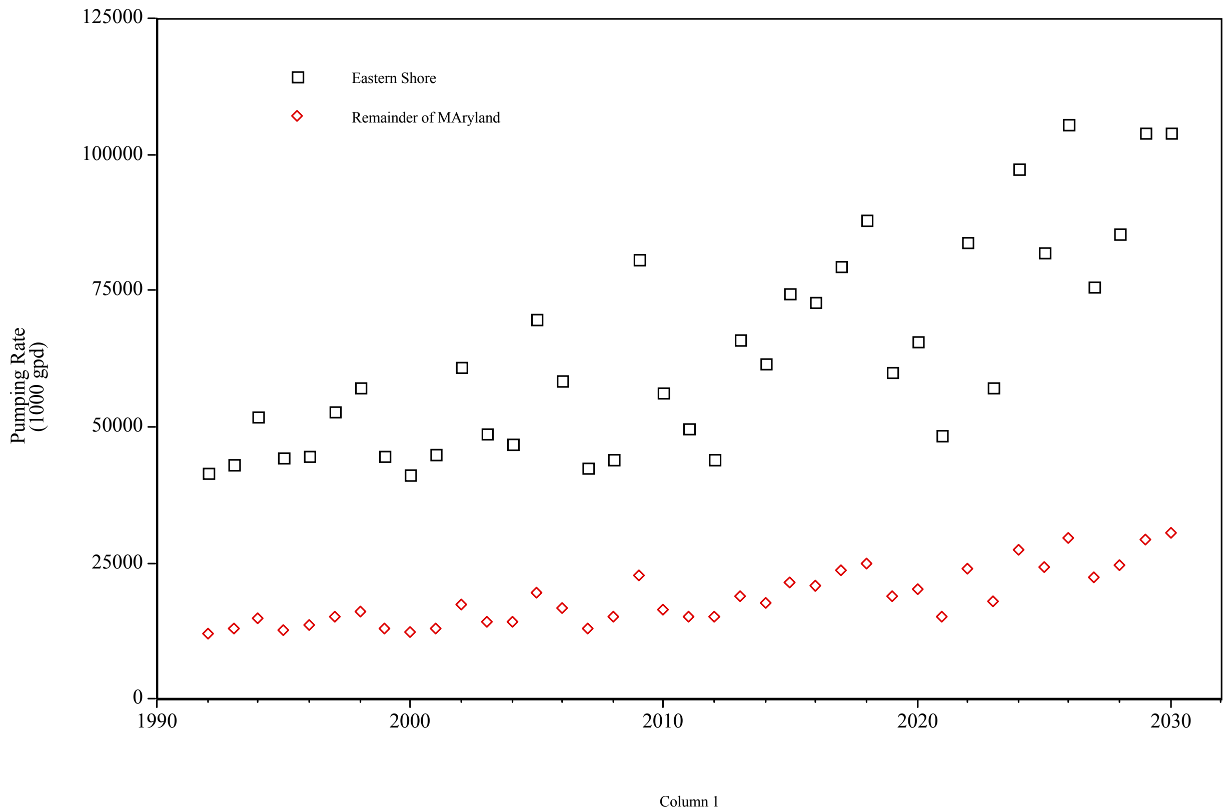

Figure C-5. Comparison of Eastern shore pumping demand and the remainder of the state demand. Average values of five simulations for the time period 1992-2030.