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Estimating and Incorporating Trends in Water Efficiency into Water Demand Forecasts for New York City

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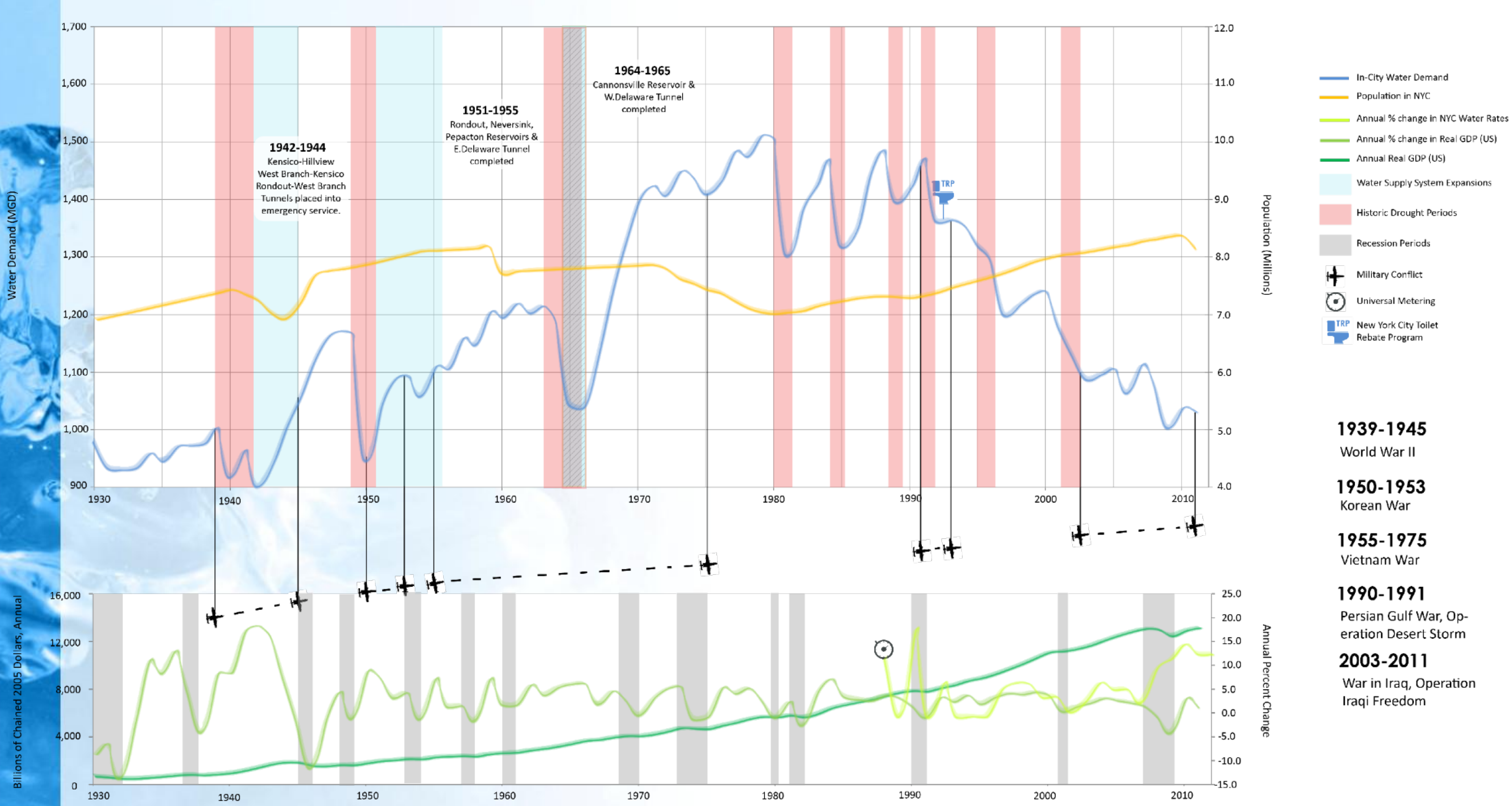
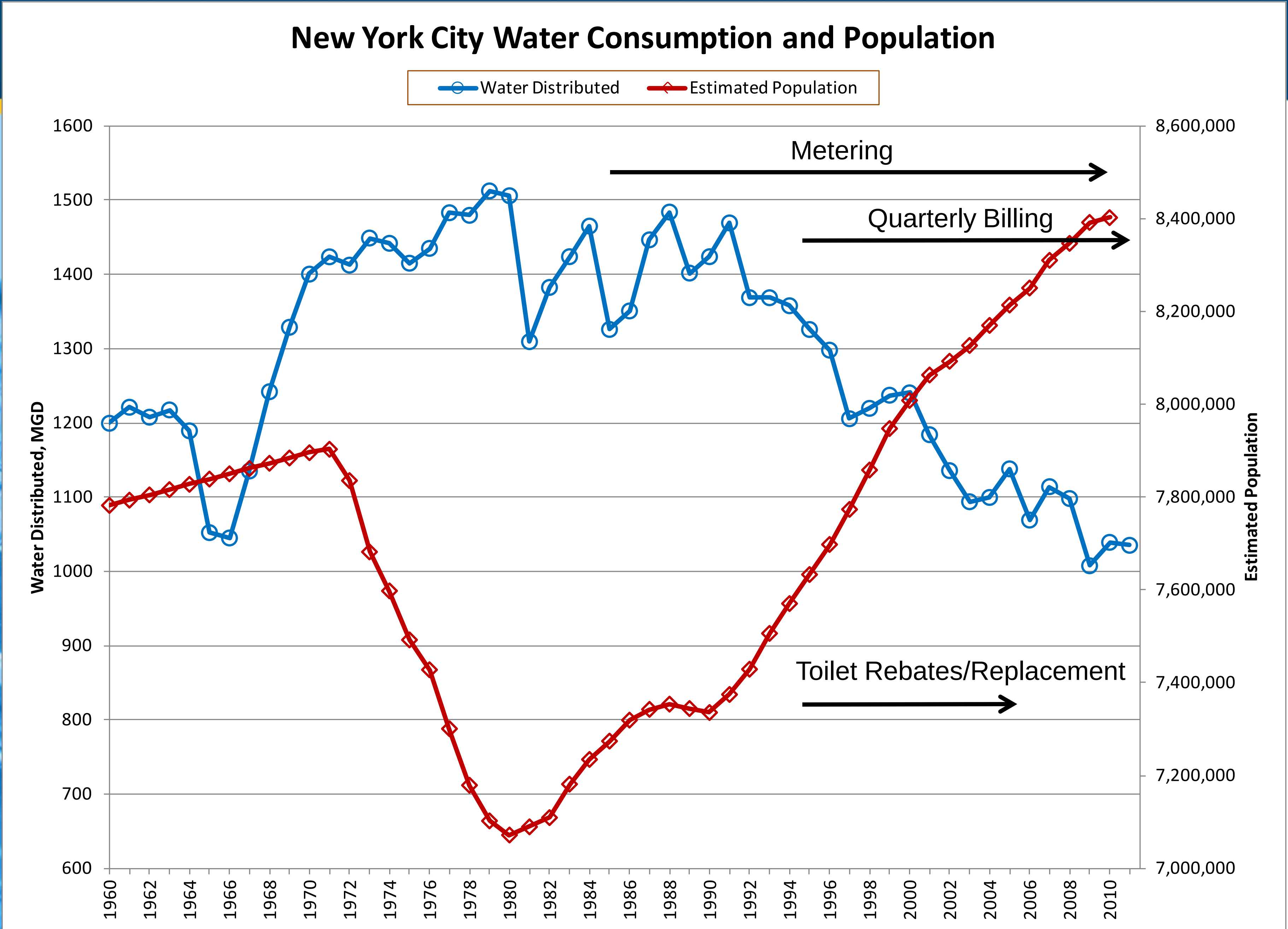
Historic Demand Context





New York City Water Consumption and Population
Water Distributed
Estimated Population
Metering
Quarterly Billing
Toilet Rebates/Replacement
Water Distributed, MGD
Estimated Population
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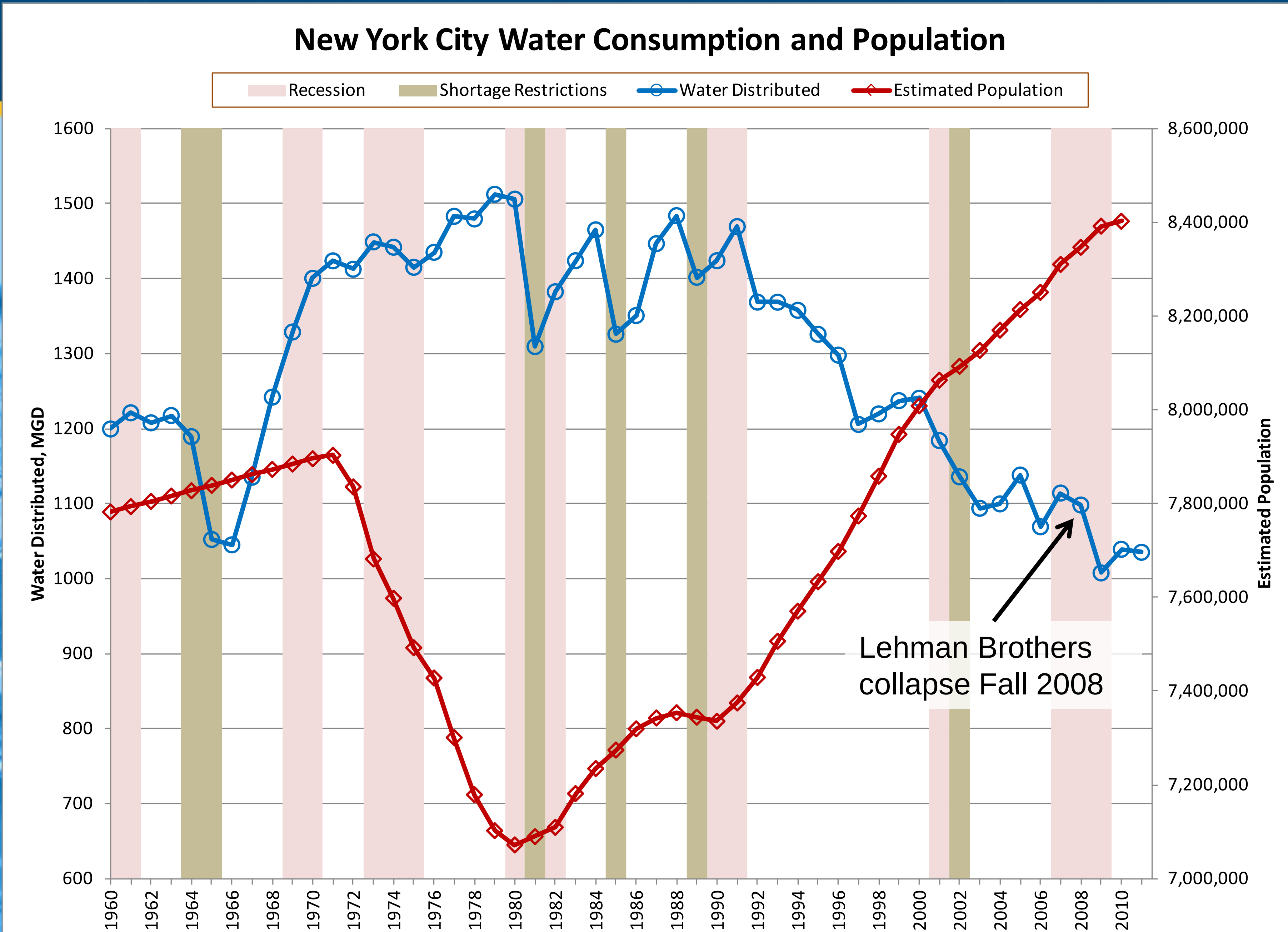
New York City Water Consumption and Population
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Shortage Restrictions
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Estimated Population
Water Distributed, MGD
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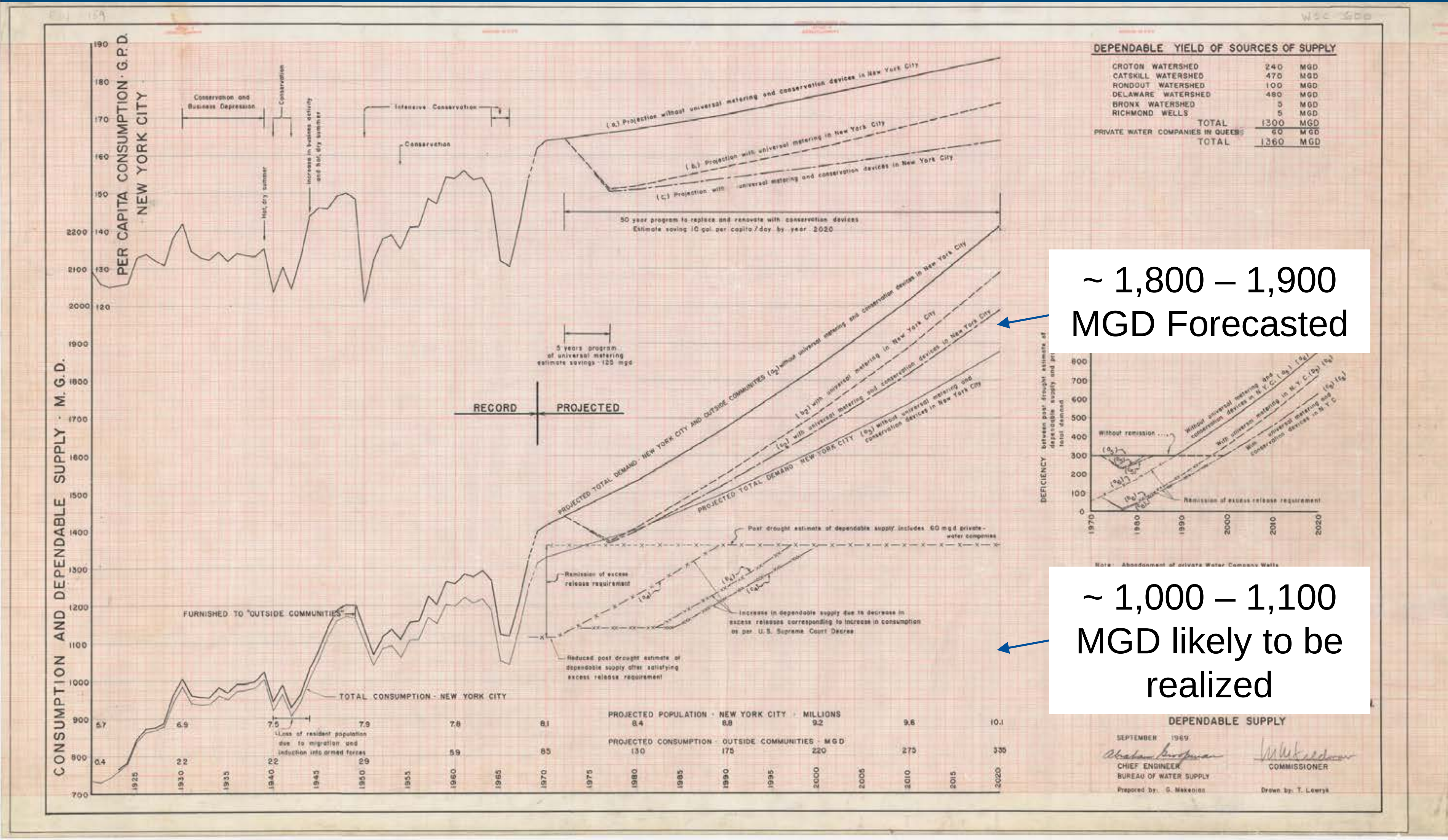
Lehman Brothers collapse Fall 2008

Demand Forecast Circa 1970



General Project Methodology

- "Incremental enhancements" that use output of specific empirical analyses to scale per capita (gpcd) estimates
- Empirical analyses
  - Long-term time trends in water use
  - Impacts of weather and seasonality of NYC water use
  - Residual variability
- Output of empirical analyses provide forecast factors
  - Independent variables (X)
  - Elasticities (β's) that relate changes in X to changes in forecasted consumption

Why this general approach?

- Combination of schedule and data constraints
- Incrementally builds on recent efforts
- Can mimic features of econometric model in relatively short time frame
- Chance to introduce and use some elements of a more useful future framework

Change in General Forecast Model

$$(Total\ Water\ Use)_F =$$

$$Base\ Water\ Use\ \ + (\Delta Population_F * 75\ gpcd)$$

$$\Downarrow$$

$$(Total\ Water\ Use)_F =$$

$$Population_F * \left(\prod_{n=1}^{N} \left(\frac{X_{n,F}}{X_{n,B}} \right)^{\beta_n} * \left(k_{F,Res} * \overline{\text{gpcd}}_{Res} + k_{F,Other} * \overline{\text{gpcd}}_{Other} \right) * (1 \pm V_F) \right)$$

Demand Forecast Factor Model Elements

Assumptions regarding weather and climate

Per capita use split between residential and other

$$(Total\ Water\ Use)_F = Population_F * \left(\prod_{n=1}^{N} \left(\frac{X_{n,F}}{X_{n,B}} \right)^{\beta_n} * \left(k_{F,Res} * \overline{\text{gpcd}}_{Res} + k_{F,Other} * \overline{\text{gpcd}}_{Other} \right) * (1 \pm V_F) \right)$$

Total population and not change in population

Assumptions regarding efficiency

Assumptions regarding residual scenario forecast variance

Derivation of "Efficiency Factor"

- Residential sectors dominate total water consumption in NYC
- Efficiency of toilets fixtures chosen as an indicator of general overall trends in efficiency
- Efficiency factor based on difference between
  - Baseline estimated average flow rate (i.e., flush volume) for existing residential toilets
  - Future estimated average flush volumes over the forecast horizon
- Efficiency factor constructed as a ratio: factor moves proportionally with change in average flow rate assumptions

Key Data Sources

- MapPLUTO—tax appraiser database
- U.S. Census
  - American Community Survey (ACS)
  - American Housing Survey (AHS)
- U.S. EPA National Water Savings Model
- Various literature

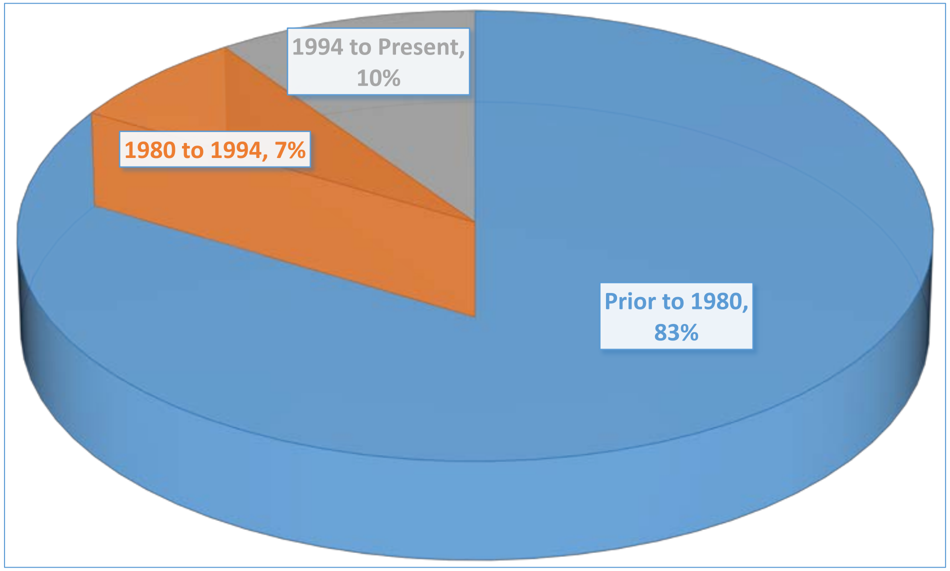
Derivation of “Efficiency Factor”

- To estimate average baseline flush volumes:
  - Establish fixture counts
  - Estimate initial vintage of fixtures
  - Apply assumptions on mechanical efficiency and useful life

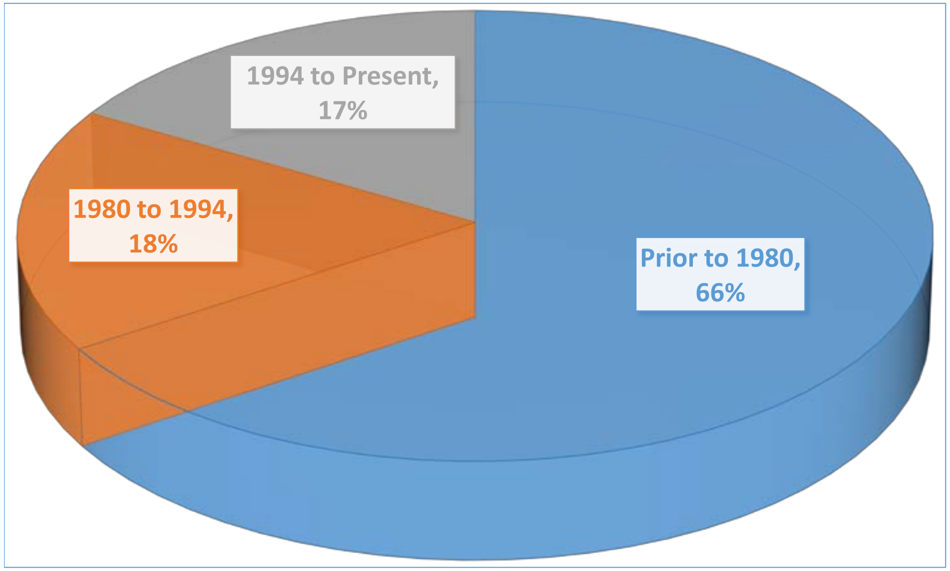
- Use of MapPLUTO database
  - Residential units by year built
  - Alteration date
  - Assumed maximum alteration date as “effective” year built (where applicable)
  - Found nice agreement between ACS and MapPluto for number of housing units

Distribution of MapPLUTO SF/MF Housing Units By Effective Age

Single-Family



Multifamily



- SF has higher proportion of units built prior to 1980
  - 83% (SF) vs. 66% (MF)

- Collectively, citywide unit distribution looks like MF
  - Prior to 1980 = 67%
  - 1980 to 1994 = 17%
  - 1994 to present = 16%

Derivation of "Efficiency Factor"

- Estimated historical **fixtures** by (effective) year built
  - MapPluto provided estimates of housing units
  - Needed assumptions to estimate number of toilet fixtures
  - Census AHS (2003) bathrooms per housing unit
  - Assumed average number of toilets per unit for single-family and multifamily residential sectors

AHS Units by Bathroom Type

Bathroom Type	Single-Family	Multifamily	SF % of Total	MF % of Total
None	15,400	45,800	25%	75%
1	290,800	2,385,000	11%	89%
1.5	286,700	305,700	48%	52%
2+	731,500	332,200	69%	31%

Weighted Average Toilets per Unit

Sector	Toilets	Units	Proportion within Sector	Toilets per Unit (Weighted Average)
Single-Family	1	290,800	22%	1.78
	2	1,018,200	78%	
Multifamily	1	2,385,000	79%	1.21
	2	637,900	21%	

Derivation of "Efficiency Factor"

- Assigned mechanical efficiency assumptions to fixture vintages
  - <1980 = low-efficiency (5.0 gpf)
  - 1980-1993 = medium efficiency (3.5 gpf)
  - 1994 and later = current standard (1.6 gpf)
- Assigned proportion of 1994 and later vintage to high-efficiency (1.28 gpf)
  - U.S. EPA National Water Savings Model
  - Assumptions for passive replacement to 1.28 gpf (2001 – 2011)

National Water Savings Model Assumptions for 1.28 gpf Toilets

- Future market share will reflect increasing market for high-efficiency products
  - Fixed proportion of new and passively replaced toilets post-2001

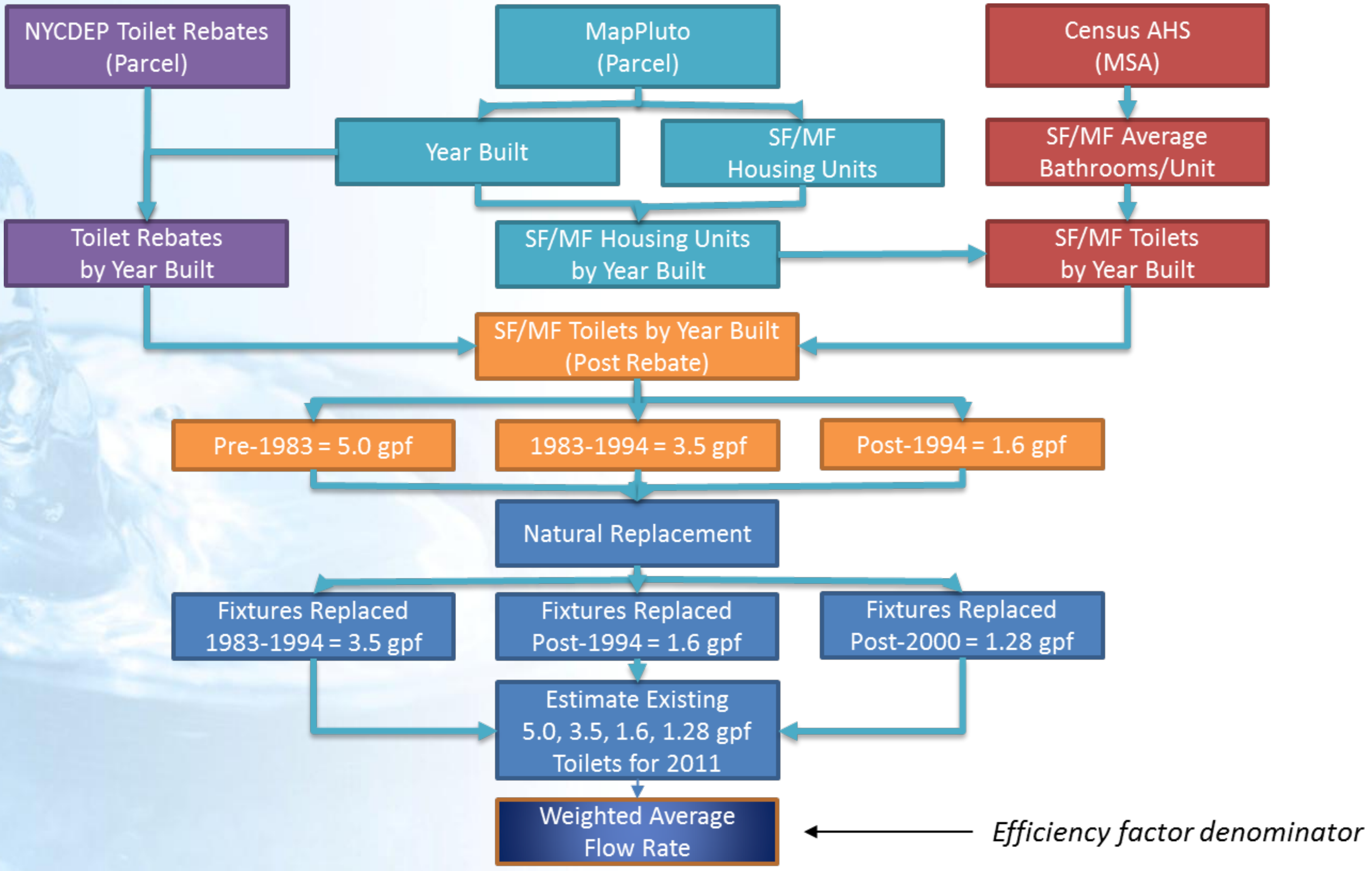
Year	Toilets
2001	1%
2002	1%
2003	1%
2004	2%
2005	3%
2006	5%
2007	5%
2008	5%
2009	5%
2010	5%
2011	8%
2012	9%
2013	10%
2014	11%
2015	13%
2016	15%
2017	19%
2018	21%
2019	24%
2020	28%
2021	32%
2022	36%
2023	39%
2024	43%
2025	47%
2026	51%
2027	54%
2028	58%
2029	62%
2030	66%
2031	66%
2032	66%
2033	66%
2034	66%
2035	66%

Derivation of “Efficiency Factor”

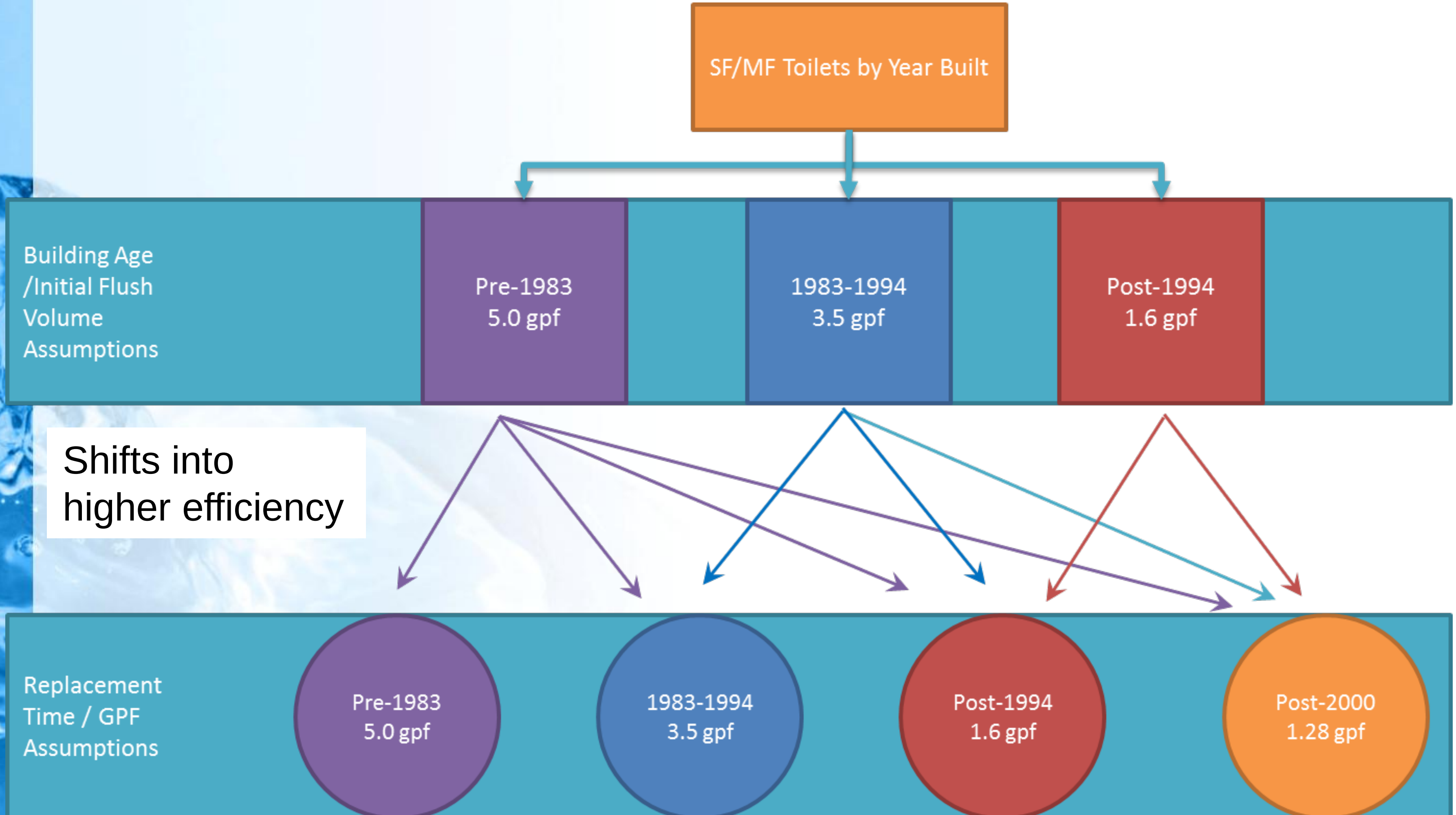
- Accounted for historical DEP toilet rebates/change-outs
  - Ability to match rebate database to MapPluto
  - Toilets rebated by year built
  - DEP rebates/change-outs assumed at current standard

- Useful life assumption for residential toilets tied to natural replacement
  - Compared estimates of flush volumes and saturation rates under 30-year and 25-year useful life with Residential End Use Study estimates
  - Developed natural replacement rate based on 30 year useful life

Estimation of Base-Year Average Flush Volumes



Replacement of Fixtures and Changes in Efficiency



Housing Unit and Fixture Estimates by Building Age and Efficiency Class

Sector	Building Age Cohort	Efficiency Class (GPF)	MapPluto Housing Units	AHS 2003 Toilets / Unit	Total Toilets (Pre-Rebate)	Rebated Toilets	Total Toilets (Post-Rebate)
SF	Pre-1983	5	274,670	1.78	488,321	54,964	433,357
SF	1983-1994	3.5	19,121	1.78	33,994	4,006	29,988
SF	Post-1994	1.6	31,736	1.78	56,422	2,130	54,292
		Total (2011)	**325,527**	**1.78**	**578,737**	**61,100**	**517,637**

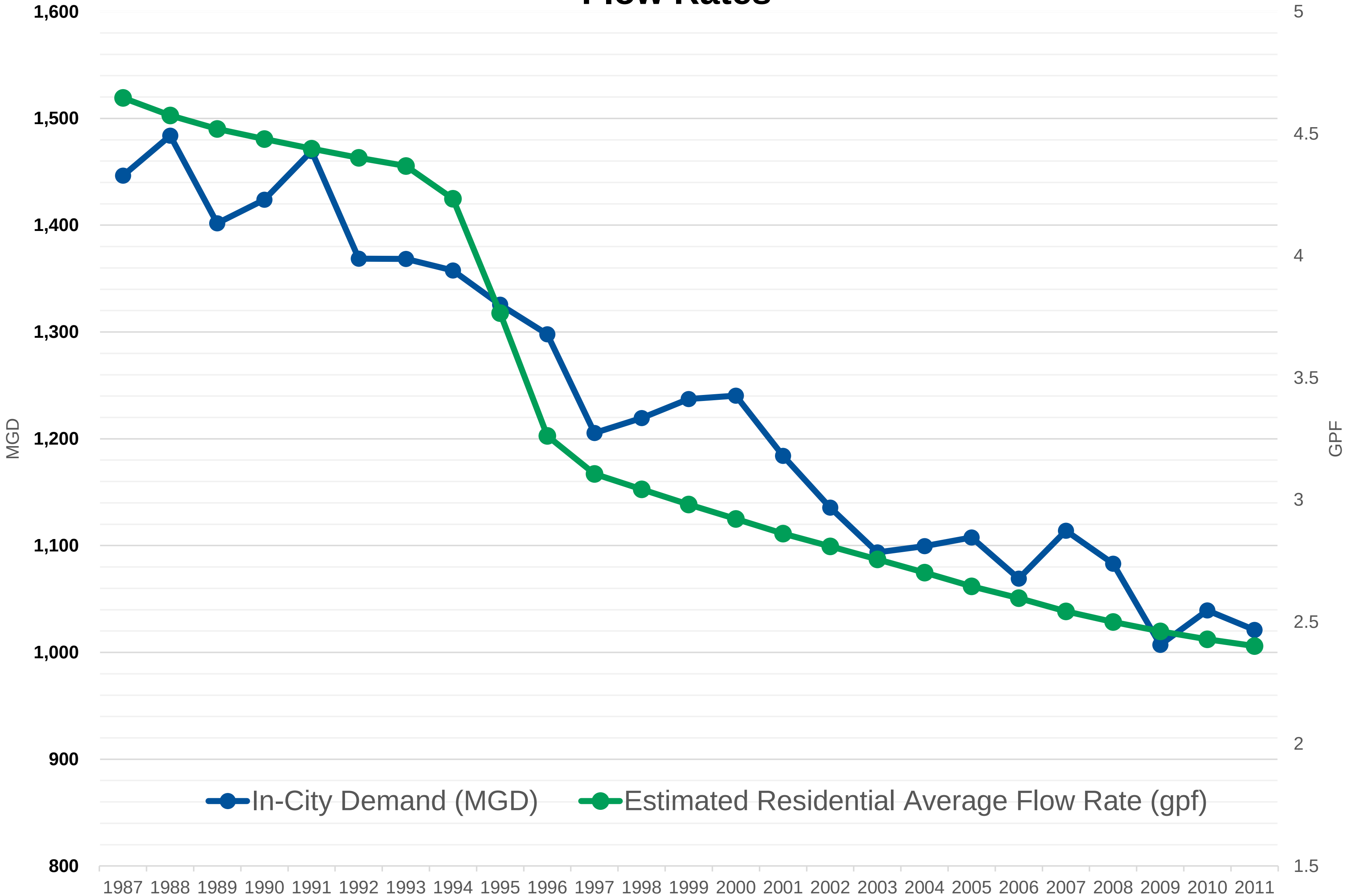
Sector	Building Age Cohort	Efficiency Class (GPF)	MapPluto Housing Units	AHS 2003 Toilets / Unit	Total Toilets (Pre-Rebate)	Rebated Toilets	Total Toilets (Post-Rebate)
MF	Pre-1983	5	2,089,322	1.21	2,530,216	879,268	1,650,948
MF	1983-1994	3.5	462,925	1.21	560,613	181,700	378,913
MF	Post-1994	1.6	509,930	1.21	617,537	64,670	552,867
		Total (2011)	**3,062,177**	**1.21**	**3,708,365**	**1,125,638**	**2,582,727**

Fixtures Remaining and Estimated Average Flow Rate

Sector	Building Age Cohort	Efficiency Class (GPF)	Total Toilets (Pre-Rebate)	Remaining Toilets	Distribution	Weighted Average Flow Rate
SF	Pre-1983	5	488,321	148,504	0.26	
SF	1983-1994	3.5	33,994	97,378	0.17	
SF	Post-1994	1.6	56,422	327,557	0.57	
SF	HE	1.28	-	5,298	0.01	
SF	Total		578,737	578,737	1.00	**2.79**

Sector	Building Age Cohort	Efficiency Class (GPF)	Total Toilets (Pre-Rebate)	Remaining Toilets	Distribution	Weighted Average Flow Rate
MF	Pre-1983	5	2,530,216	399,765	0.11	
MF	1983-1994	3.5	560,613	611,783	0.16	
MF	Post-1994	1.6	617,537	2,656,724	0.72	
MF	HE	1.28	-	40,094	0.01	
MF	Total		3,708,365	3,708,365	1.00	**2.28**

Annual In-City Water Production and Estimated Average Toilet Flow Rates



Development of Fixture Projections

- New housing units (2012 – 2040)
  - AHS fixtures per SF/MF housing unit held constant
- Existing housing units (2012 – 2040)
  - Continuation of passive fixture replacement (30-year useful life)
- National Water Savings model assumptions for future proportion of 1.28 gpf toilets
  - Fixed proportion of new and passively replaced fixtures in each forecast year
- Deducted planned DEP rebates/change-outs from low-efficiency inventory remaining in 2014/2015

Calculation of Efficiency Factor

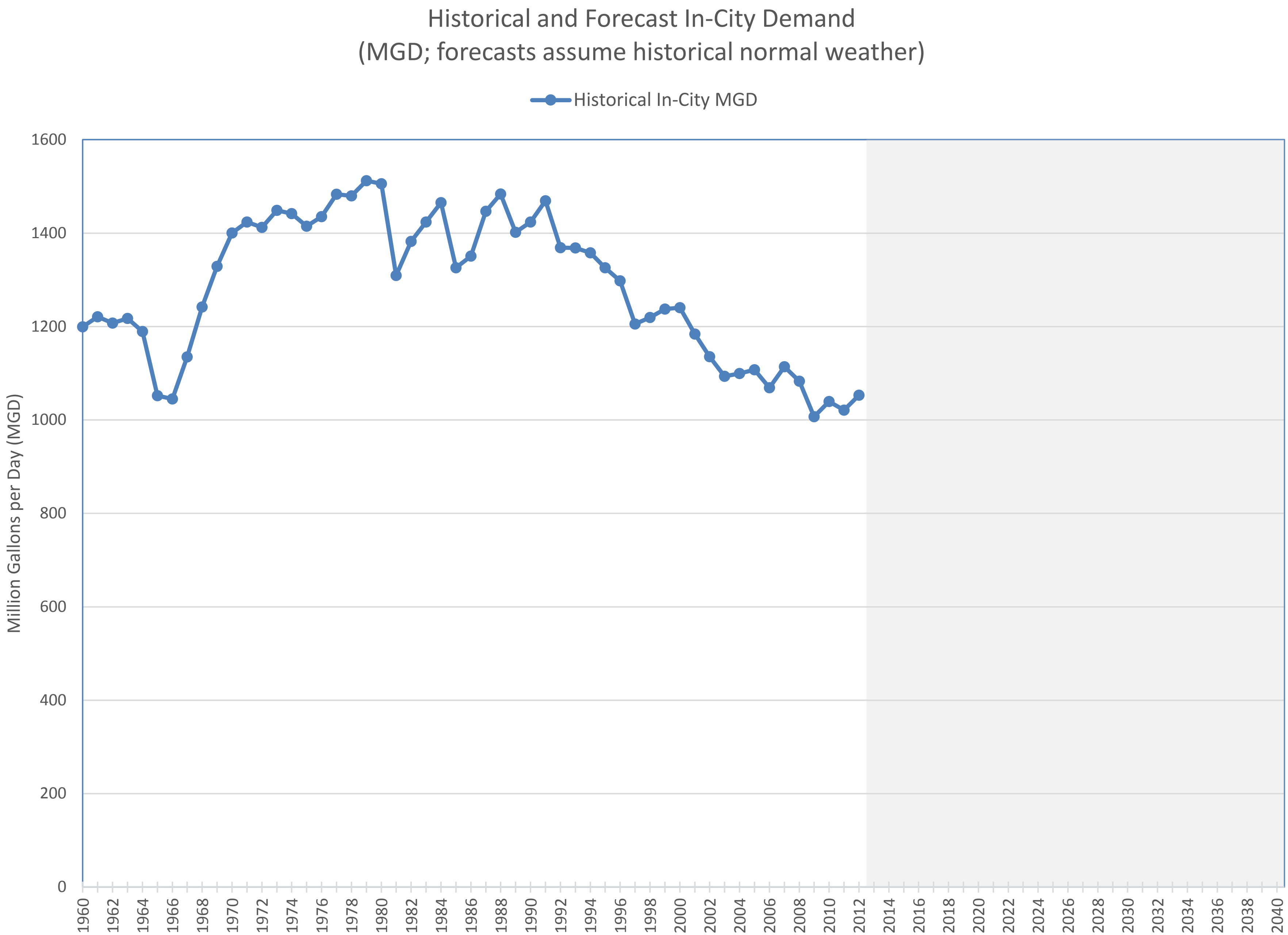
- Future toilet flush volumes
  - Weighted average flush volume across all existing efficiencies
- Efficiency (aka *k*-) factor
  - Baseline average residential toilet flush volume of 2.35 gpf serves as denominator of factor

$$k = \frac{Future\ average\ flush\ volume}{2.35}$$

Year	Weighted Average Flush Volume	Raw k-factor
2011	2.35	1.00
2012	2.32	0.99
2013	2.29	0.98
2014	2.21	0.94
2015	2.15	0.91
2016	2.12	0.91
2017	2.10	0.90
2018	2.08	0.89
2019	2.07	0.88
2020	2.05	0.87
2021	2.03	0.86
2022	2.01	0.86
2023	1.99	0.85
2024	1.97	0.84
2025	1.96	0.83
2026	1.94	0.83
2027	1.92	0.82
2028	1.90	0.81
2029	1.89	0.81
2030	1.87	0.80
2031	1.86	0.79
2032	1.84	0.79
2033	1.83	0.78
2034	1.82	0.78
2035	1.80	0.77
2036	1.79	0.77
2037	1.78	0.76
2038	1.77	0.76
2039	1.77	0.75
2040	1.76	0.75

Application of Efficiency Factor

- Concern over applying residential toilet end use efficiency to total gpcd estimates
  - Split of total gpcd into residential and other reduces impact by construction
  - Can apply different efficiency (or other) rates to other gpcd component
  - Built the model to permit scaling of efficiency effects
    - Ability to raise efficiency factor by an exponent (similar to elasticity)
    - Can reduce the value of residential efficiency factors to reflect lesser efficiency potential associated with other end uses



Historical and Forecast In-City Demand
(MGD; forecasts assume historical normal weather)
Historical In-City MGD
Million Gallons per Day (MGD)
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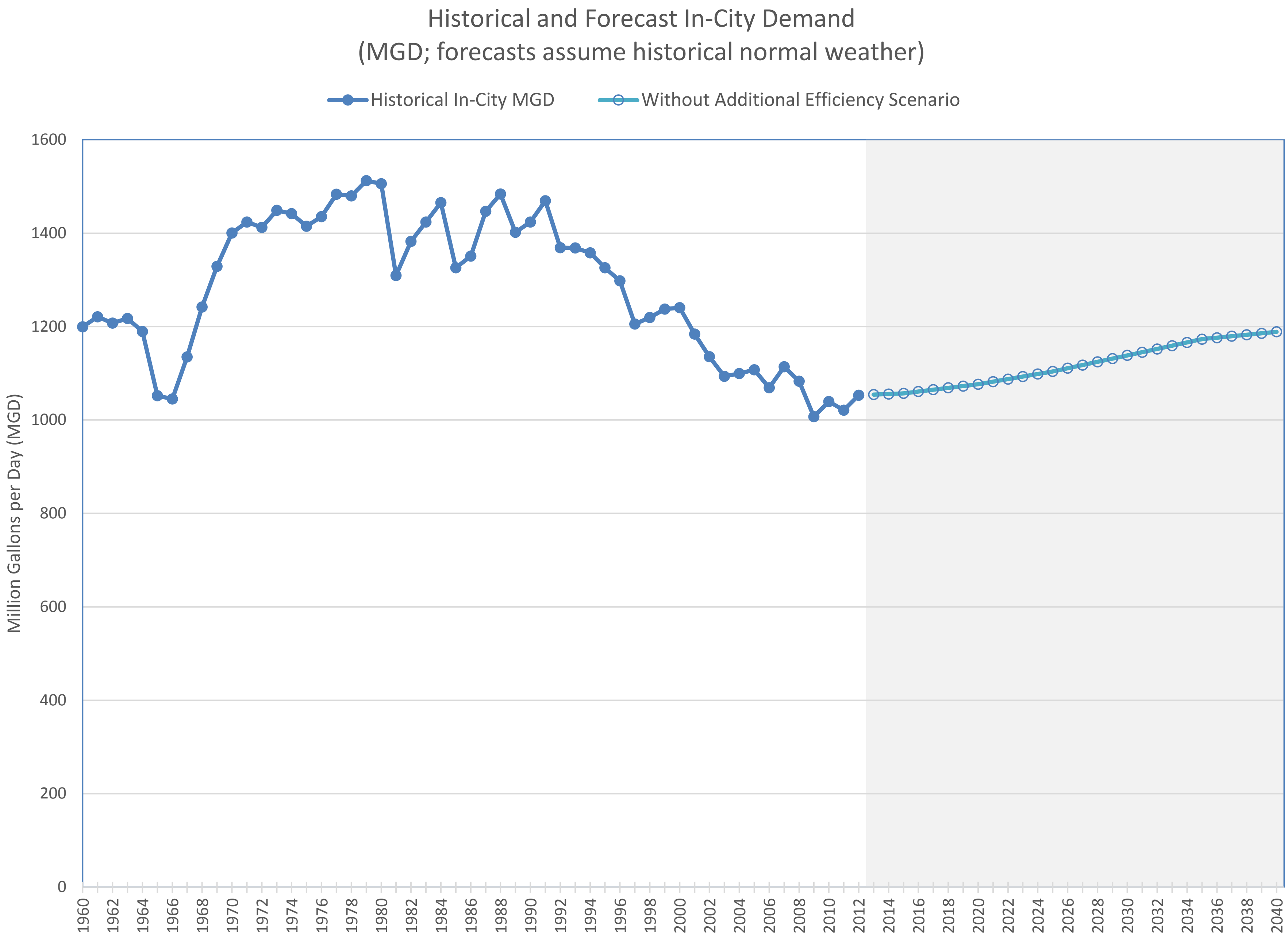
Historical and Forecast In-City Demand
(MGD; forecasts assume historical normal weather)
Historical In-City MGD
Without Additional Efficiency Scenario
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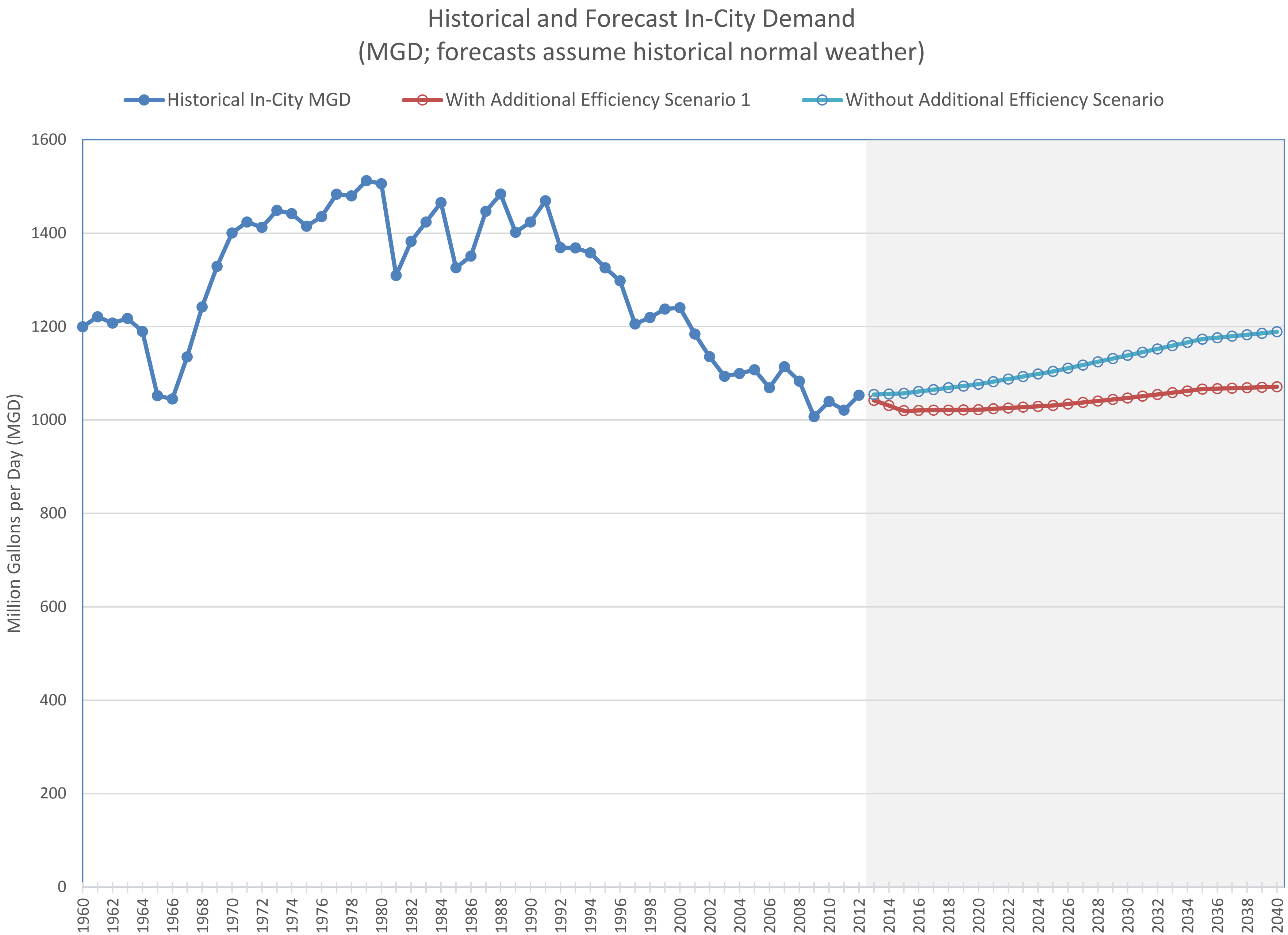
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Historical In-City MGD
With Additional Efficiency Scenario 1
Without Additional Efficiency Scenario
Million Gallons per Day (MGD)
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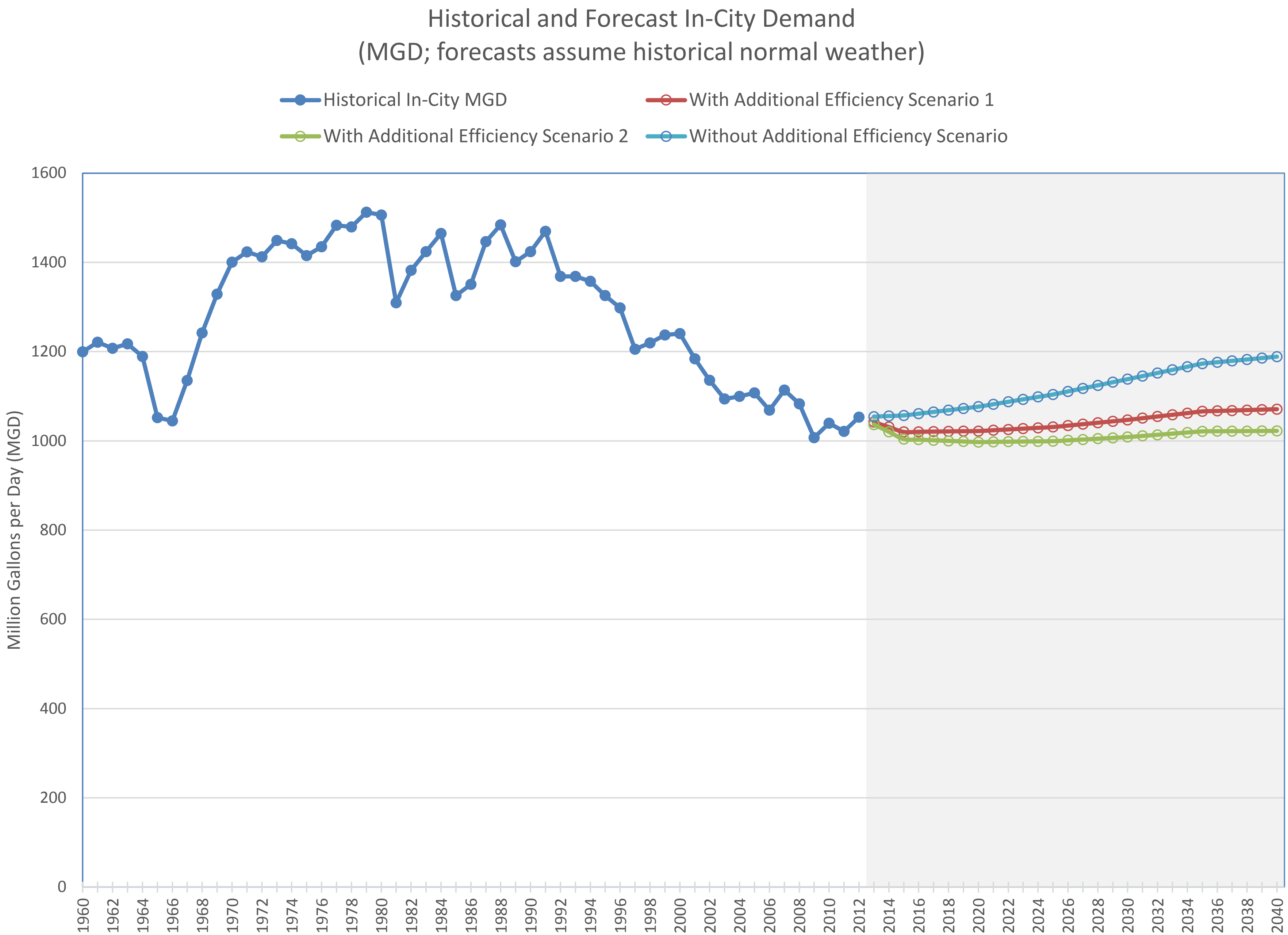
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With Additional Efficiency Scenario 1
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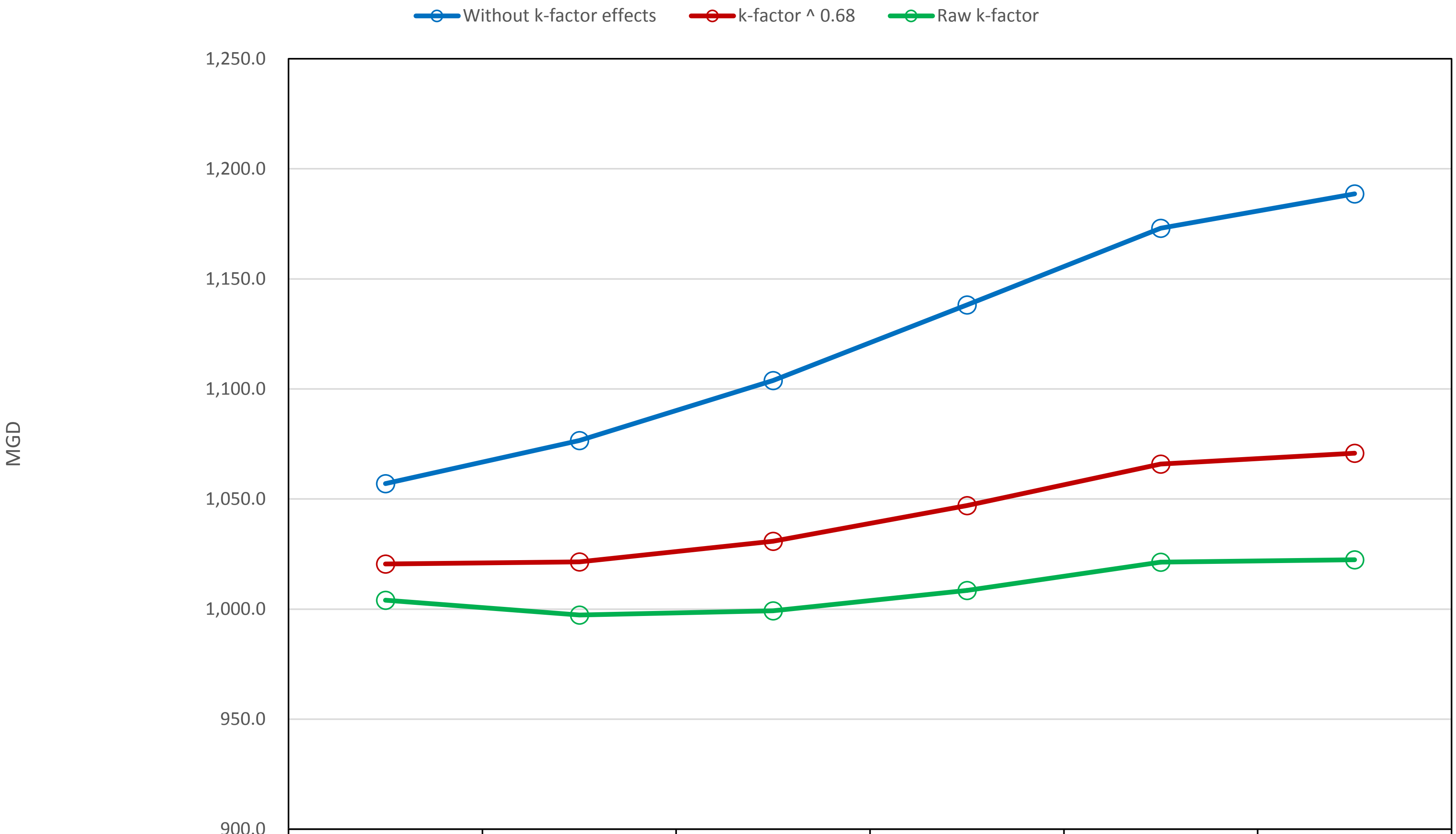
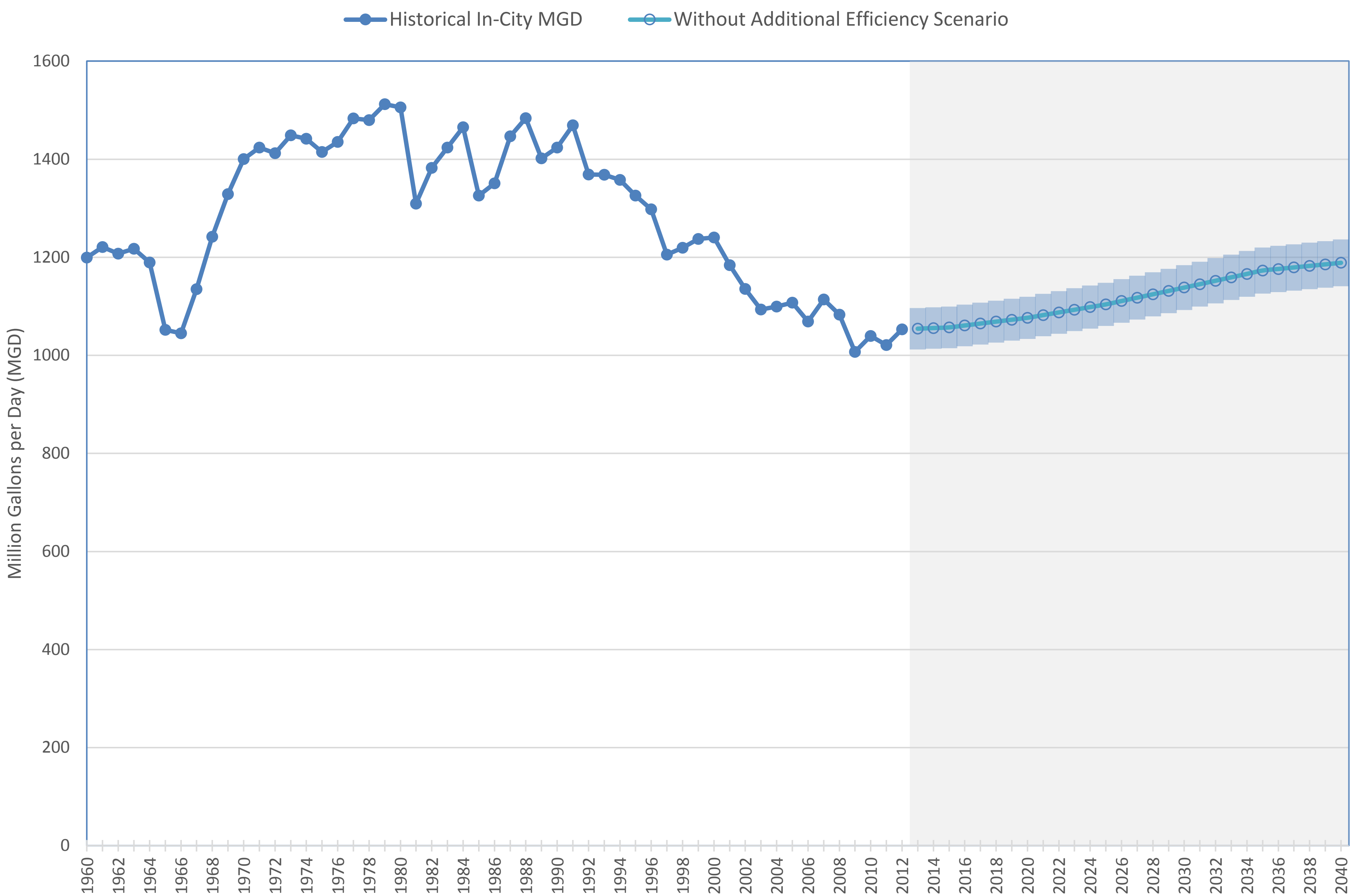
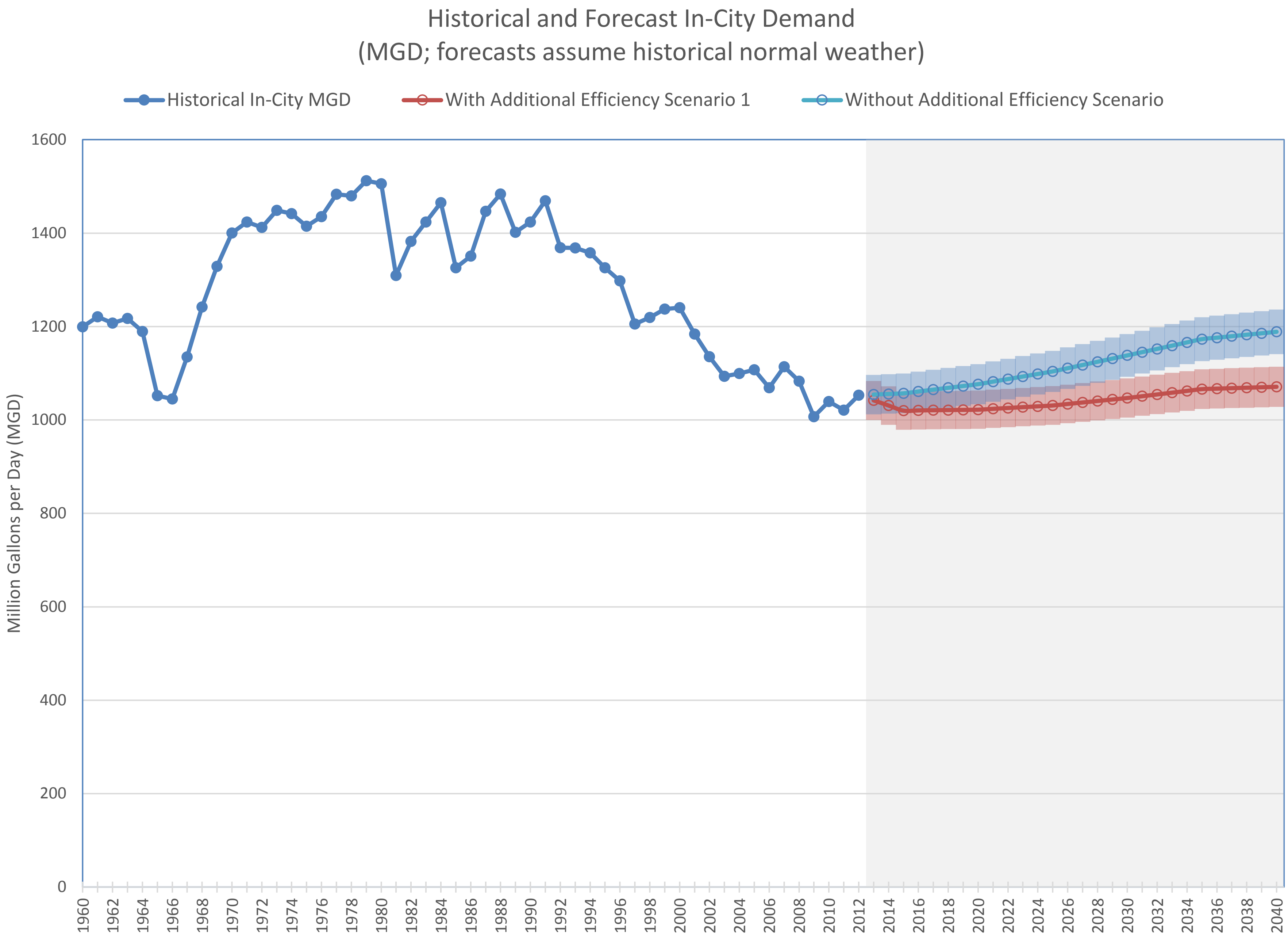
Comparison of Without Additional Efficiency Scenario with 2 With Efficiency Scenarios
(In-City MGD, Normal Weather)



	2015	2020	2025	2030	2035	2040
Without k-factor effects	**1,057.0**	**1,076.6**	**1,103.9**	**1,138.2**	**1,173.0**	**1,188.7**
k-factor ^ 0.68	**1,020.5**	**1,021.5**	**1,030.8**	**1,047.0**	**1,065.8**	**1,070.8**
Raw k-factor	**1,004.0**	**997.3**	**999.3**	**1,008.5**	**1,021.3**	**1,022.4**

Historical and Forecast In-City Demand
(MGD; forecasts assume historical normal weather)

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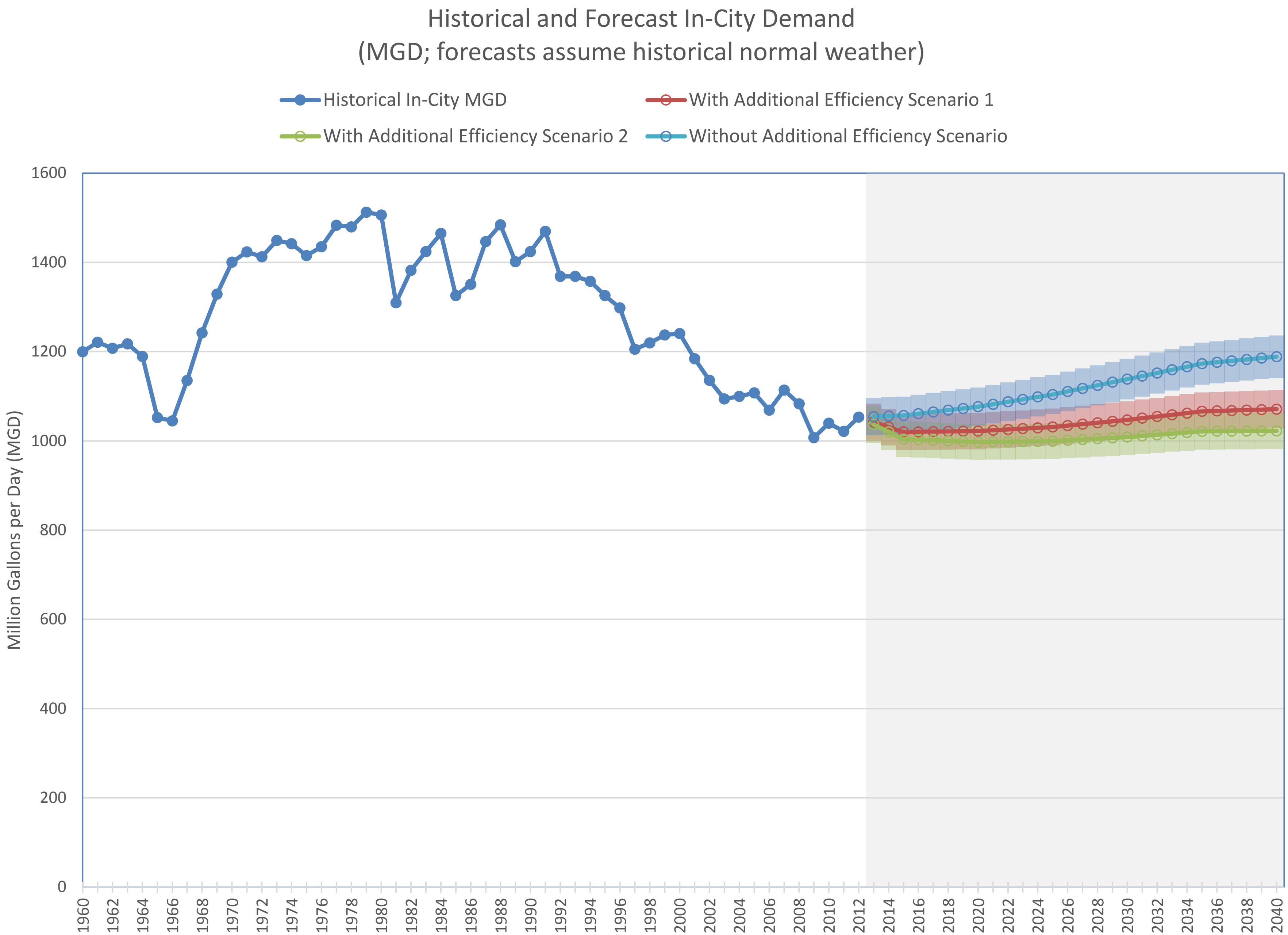
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Summary

- DEP's previous water demand forecasting model has been enhanced on multiple fronts
- The model now explicitly recognizes prospective impacts of future water efficiency
- Derivation of the efficiency forecast factor required extensive use and linkage among data sources
- All embedded assumptions can be varied to construct alternative scenarios
- Updated forecast considered more likely to reflect recent trends

Future Areas of Improvement

- Forecast model still relies on population as primary driver and is essentially still a per capita model
- Much of the underlying structure of demands still hidden
  - Underlying sectoral water use patterns not explicit
  - Geographical differences completely tied to differences in population
  - Per capita usage rates and efficiency factors established at City level and may not be reflective of local trends
- Continue to build spatially and sectorally disaggregate water use database
  - Estimate effects of additional variables
  - Refine water efficiency assumptions

Questions?

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