The Application of Scenario Planning to Metropolitan's Integrated Area Studies

Final Technical Memorandum

John J. Boland
Thomas W. Chesnutt
Benedykt Dziegielewski
Darwin C. Hall

December 12, 2006

Table of Contents

Foreword

This technical memorandum was originally submitted on November 15, 2006 and revised on November 28. This final version includes a number of minor edits and some reorganization, as well as several significant changes.

- The first report contained discussion of a preliminary set of scenarios prepared by Metropolitan staff. Since these preliminary scenarios are superseded by the scenarios presented in this report, they are no longer discussed here.
- This report includes an expanded presentation of two new scenarios: the Peri-Urban Growth Scenario and the Balanced Development Scenario.
- The scenario definitions have been fine-tuned to facilitate implementation.
- The report has been shortened and tightened to focus more clearly on the proposed scenarios.

Background

The word "scenario" originated as a theatrical term referring to something pinned to scenery.[1] Movie studios in the 1930's used 'scenario' to refer to a possible development of a plot line. Military planners borrowed the term to refer to a description of a possible future that plans could be tested against. DeWeerd (1967) provides an early example of the use of scenarios for military planning.[2]

As a working definition of "scenario" we use that of van der Heijden (1996): "External scenarios are …created as internally consistent and challenging descriptions of possible futures. … What happens in them is essentially outside our control.[3]" For conceptual convenience we can distinguish two parts of a scenario: 1) an alternative future and 2) a path to get from today to that alternative future.

"Scenario-Based Planning" was developed in 1971 by Royal Dutch Shell strategic planners to address business uncertainties. This planning group is generally regarded as the most experienced and sophisticated scenario planning operation in the business world. Shell's methods have been intensively studied and are widely imitated. In particular, Shell planners have paid considerable attention to the way in which scenario planning interfaces with the decision making process and to the advantages that can be claimed for this approach. Shell argues, for example, that it was able to remain profitable throughout the oil shocks of the 1970s and the subsequent 1908s collapse of crude oil price because of prior corporate decisions that could be directly traced to scenario planning.

In a recent publication, Shell planners identify four strengths of scenario planning.[4]

- It helps decision makers **confront assumptions**. "Our decisions about the future depend on how we think the world works.[5]"
- It facilitates **recognizing degrees of uncertainty**. "Scenario planning provides a method for acknowledging--and working with--what we don't know (and what we don't know we don't know).[6]"
- It **widens perspectives**. "Scenarios address blind spots by challenging assumptions, expanding vision and combining information from many different disciplines.[7]"
- It **addresses dilemmas and conflicts**. "Scenarios can help clarify or even resolve the conflicts and dilemmas confronting their users.[8]"

The Shell team goes on to describe the characteristics of a successful scenario planning effort and the sequence of activities that may be required. Many of the points made in the Shell publication are echoed in this report.

---

1 In the Commedia dell'arte the scenario was an outline of entrances, exits, and action describing the plot of a play that was literally pinned to the back of the scenery.
2 DeWeerd, H.A. 1967. *Political-Military Scenarios*, RAND, P-3535, February.
3 Van der Heijden, Kees. 1996. *Scenarios: The Art of Strategic Communication*, John Wiley and Sons.
4 "Scenarios: An Explorer's Guide," Shell Business Environment, Shell International, 2003.
5 Shell, 2003, p. 12.
6 Shell, 2003, p. 14.
7 Shell, 2003, p. 16.
8 Shell, 2003, p. 18.

Fahey and Randall (1997) develop the concept of "Scenario Learning" to include the following additional purposes.[9]

- Augment understanding.--by showing connections through narrative, scenarios can increase the shared understanding of possible future developments.
- Produce new decisions.--by revealing unexpected or avoidable future situations, scenarios can help create new choices that require current decisions.
- Reframe existing decisions.--by challenging accepted assumptions and examining a range of possible end states, scenarios can reframe the basis for existing decisions
- Identify contingent decisions.--by making the timepath of a scenario explicit, scenarios can reveal which decisions depend on other previous or simultaneous decisions.

9 Fahey, Liam and Robert M. Randall. 1997. *Learning from the Future: Competitive Foresight Scenarios.* John Wiley and Sons.

Application of Scenario Planning

Purpose

The Integrated Area Study (IAS) seeks to forecast the demand for imported water in Southern California and to translate that forecast into specific resource and infrastructure requirements. In order to do this, Metropolitan must, in collaboration with member agencies and other stakeholders, forecast the demand for water at various load centers throughout the service area, model the capabilities and characteristics of local supplies, and compute the residual demand that will be imposed on Metropolitan's facilities.

Future water use is a function of a large number of demographic, socio-economic, climatologic, and structural variables. These variables not only change over time, they differ, sometimes dramatically, from one location to another within Metropolitan's service area. Current water use forecasting practice is based on the MWD-MAIN model, an advanced forecasting tool that has been customized for Metropolitan's application. By preparing geographically disaggregate forecasts, it is possible to recognize much of the cross-sectional variation in explanatory variables. This capability is crucial to the planning process, since the location of future growth has a large effect on infrastructure requirements and, to some extent, on the choice of future water sources.

It has been observed, however, that present practice does not adequately deal with the uncertainty in the forecasts, nor does it facilitate discussion among the member agencies of the nature and consequences of uncertainty, or of different sets of assumptions. While the water use models embedded within MWD-MAIN are themselves subject to some degree of error, the largest source of uncertainty is likely to be the projected values for explanatory variables. Assumptions as to the locations within the service area of future growth in population, employment, income, etc., are difficult to make and inevitably controversial. Attempts to use sensitivity analysis for this purpose produce complex and potentially unrealistic alternatives that are difficult to characterize.

Scenario planning offers a way to improve communication and decision-making in this situation. By jointly shaping a small number of internally consistent scenarios, Metropolitan and the member agencies can reach agreement on the major sources and likely extent of uncertainty in the explanatory variables. Applying those scenarios to the MWD-MAIN model will provide a clear view of the implications of uncertainty. A particular strength of the scenario approach is that it facilitates discussion of these issues, even among a relatively large number of interested parties.

Any decision to construct or not construct infrastructure has both upside and downside risks. **Upside risks** refer to cases where actual future water use is greater than forecast, so that delivery capacity will prove inadequate for some or all of the service area. At the least, this will require costly incremental capacity construction whenever the shortfall becomes evident. More seriously, there may be temporary water shortages while capacity is added, or there may be longer term water shortage due to failure to secure sufficient supplies. In both cases, water users bear the costs of shortage. **Downside risks** reflect the possibility that future water use is less than forecast, so that infrastructure is oversized or constructed too soon. This outcome has obvious consequences for the cost of water supply, cost borne by member agencies and passed on to water purveyors and, ultimately, to water users.

Properly designed scenarios help decision-makers weigh the probable magnitudes of upside and downside risks. This information helps to identify strategies that minimize expected risk.

Scenario Building

Criteria

A scenario is a story about a specific plausible future. It is not a story about what will happen in the future; it is a story about one of the sets of conditions which could occur in the future. Following are some criteria for effective scenario building.

- **Scenarios should be built around data, objective analysis, and appropriate theory.** For example, the spatial and temporal growth of population should reflect either historical trends, documented projections (such as RTP-related projections), or explicit and exogenous population drivers. Arbitrary forecasts should be avoided. Where endogenous relationships are known to exist among explanatory variables (for example, among population, employment, and income), scenarios should accurately incorporate those relationships. In this way, scenarios are internally consistent. The Shell report argues that "the dynamics underlying the scenarios are more important that the actual events they describe.[10]" Dynamics are expressed as the underlying (endogenous) relationships existing among explanatory variables.

- **Each scenario should be built around a specific theme, and named in a way that reflects that theme.** For example, identifying a "High Density" scenario indicates that relatively more growth will occur in developed areas with existing infrastructure. The use of themes helps the scenario-building team to converge on the most important questions. The Shell report notes that it is "useful to arrange the stories around an important theme .... This will highlight that concept and also may provide a helpful framework for storytelling, providing a structure for the narrative and for graphic elements.[11]" In this connection, it is important that the names given to scenarios adequately reflect their main theme and in particular do not imply anything that the scenario is not.

Approaches

- **Direction.**--Scenarios can work forward from today or backwards from the future. DeWeerd terms these methods trend analysis and "reverse decision tree analysis," respectively. Fahey and Randall term these "future forward" and "future backwards." Van der Heijden uses "deductive structuring" and "inductive structuring." Dewar states that because assumption-based planning begins with the end state—the universe of broken assumptions—it usually works backward.
- **Focus.**--Fahey and Randall list four key elements of a scenario 1) driving forces, 2) logics, 3) plot, and 4) end state. Different approaches emphasize different elements.
- **Credibility**.--Drastically negative scenarios can be seen as less credible. Scenarios closest to present are deemed most credible
- **Details.**--Details on strong logical causal path for driving forces yields more credibility
- **Relations among Scenarios.**--Scenarios tend to be judged against each other

10 Shell, 2003, p. 58.
11 Shell, 2003, p. 54.

Metropolitan's IAS Scenarios

General Requirements

- At least three scenarios should be developed, probably not more than five.
- Scenarios must address both temporal and spatial aspects of growth and development.
- Each scenario should have a theme and a name that accurately suggests the theme. The theme encapsulates and generalizes the nature of the assumptions concerning key drivers of growth and development in the service area. An example of a theme and a name is "High Density."
- Each scenario tells a story about the future. Each story reflects the theme and specifies an internally consistent set of assumptions about the principal explanatory variables. Given a "High Density" theme, the scenario would state the spatial pattern of population growth, the expected pattern of housing types, other key drivers affecting employment and income, the resulting employment and income projections, impacts of the cost of water supply, etc.
- One of the scenarios should be specifically designed to act as a reference point for the others. In the following discussion, this scenario is termed the "reference scenario."

Discussion

The Reference Scenario

It is important that the list of scenarios include one which is easily understood by all participants. This reference scenario may be based on extrapolation of historic growth rates, on some set of "business-as-usual" assumptions, or it may be a scenario that is already familiar to everyone involved. In the present application, the best candidate for a reference scenario is the retail demand forecast based on the SCAG 2004 RTP and the SCAG 2030 (SCAG-04/SANDAG 2030) growth projections. As noted elsewhere in this report, this is not a trend-neutral scenario in that it incorporates greater than historical growth in a number of areas, especially with respect to employment and income. However, it is the scenario that participants are most likely to use as a reference, whether or not it is identified as such. So it is appropriate to designate the SCAG-04/SANDAG 2030 projections as the reference scenario.

Historical Growth Scenario

One potential addition would be a scenario that simply extrapolates historical trends with respect to all key variables, creating a trend-neutral scenario. This extrapolation could take place separately for each load area. The value of such a scenario is that it provides a different kind of baseline from that implied by the reference scenario. It reveals the nature of the differential growth assumptions that are embedded in the RTP and other regional forecasts, as well as the sensitivity of water requirements to these assumptions. In particular, deflated median household income in all the scenarios is substantially higher than the historical data. For the individual counties in southern California, the historical data are only available from 1989 to 2003, and show falling median household income over those periods. For the entire state of California, the data are available from 1980 to 2003, during which deflated median household income grew at an average rate of 0.86%, or less than one percent.

The disadvantage is that there is no single protocol for developing trend extrapolations. All of the key variables have likely exhibited non-linear growth in the past. Extrapolations of this growth should therefore follow a non-linear trend line. However, different functional forms for this non-linear trend can result in significantly different projections, especially after 20 or 30 years. Although there are statistical tests that can be used to compare alternative functional forms, the choice of starting and ending points for historical data can affect the results. For example, if the starting point is a period of economic growth, and the ending point is a recession, the historical data will forecast a slower trend than if the starting and ending points have similar characteristics; it is important to take care when selecting the period for estimating historical trends.

Thus there are a number of different possible versions of a historical growth scenario. Although expert judgment and advanced statistical techniques are helpful, there can be disagreement about which is the "correct" version. Appendix A shows one approach to extrapolating employment data.

Other Potential Scenario Themes

Inland Population Growth with Strong Income Growth in Coastal Areas.--This scenario would show relatively higher employment growth in Riverside and San Bernardino Counties, compared to the coastal areas. This leads to higher population growth. Inland (or peri-urban) areas would also exhibit moderate income growth. However, it may be assumed that household income will grow even more strongly in the coastal areas.

Inland Growth Based on Low Income Employment.--The Wells Fargo Economics report on the economy of Southern California argues that employment will largely be driven by health care, education, professional, scientific and technical, and leisure and hospitality industries.[12] Many, if not most of the jobs offered by these industries produce relatively low wages and salaries. It is possible to conceive of a scenario driven by increases in employment in low wage jobs, with immigration of low skilled workers as a result, consistent with flat or low growth in median household income, and an increasing growth in household size, a lower employment to population ratio (more children per household) as well as an increase in the percentage of single-family dwellings. Such a scenario should not only assume growth in Riverside and San Bernardino counties, but also inland areas in San Diego county.

Inland Growth Based on Low Income Employment Plus Decentralized Job Creation.--Some economic development projections speak of the potential for long-term dynamic growth in the inland area of Southern California. It is argued that the inland counties are well positioned to become hubs for manufacturing, wholesaling and transportation activities. This development, combined with region-wide growth in low-wage industries, would imply different population, housing, and income trends for the inland counties.

High Income, Coastal Growth Scenario.--A coastal growth scenario would require more highly paid, higher skilled jobs that would provide the ability to afford housing. Commuting long distances is less possible with the kind of traffic gridlock we experience today. Such a scenario is consistent with growth in the percentage of multi-family housing, a lower household size, higher median household income, and a higher employment to population ratio.

---

12 <https://www.wellsfargo.com/com/research/economics/california/>, navigate to Southern California.

Economic Slowdown.--Even a moderate economic slowdown could have significant effects on the distribution of employment and population growth, and on household incomes. It could be postulated, for example, that a slowdown would shift development from the current peri-urban expansion to a more balanced "infill" growth pattern in urban areas and along transportation corridors. This, in turn, would create a need for major intervention by local governments to maintain the quality of life in these areas, possibly through implementation of some form of high density development policy.

Scenario Dynamics (Endogenous Relationships)

In the construction of scenarios, it is important to preserve the inherent dynamics of the regional economies. This requires attention to the underlying endogenous relationships among a number of the key explanatory variables. Generally it is assumed that most changes are driven by changes in employment. An increase in employment, combined with an assumption regarding labor participation rate, implies an increase in population. The increase in population, combined with an assumption regarding household size, implies a change in number of households. The changes in employment and number of households, combined with median wage rate, imply a change in median household income. Changes in number of households combined with household size and median household income may imply something about the mix of single-family and multi-family dwellings.

But these relationship are often obscured by other factors, such as job commuting, net migration patterns, differences between average and marginal measures of certain parameters, etc. An alternative approach is to project these variables based on regression analysis of past data. If the regression models are correctly specified (that is, if the relevant variables are all included), then it is possible to obtain useful projections which still reflect the underlying relationships.

It was not possible to thoroughly explore this empirical approach within the context of this report, but preliminary, simplified regressions on median household income appeared promising. A more challenging task (not attempted here) is to estimate regression models for single-family housing density and for fraction single-family housing. To the extent that these variables depend on rate of household formation and household income (note that other variables may be more influential, including location), the values are endogenous and projections must be approached carefully.

Climate Change

While most climate change models are in general agreement on the magnitude and velocity of changes in global climate, their predictions vary considerably with respect to local areas on the scale of Metropolitan's service area, or smaller. In general, it can be said that temperatures will rise and that this impact is already apparent. But whether precipitation will increase or decrease depends on many things. Any consideration of the impact of climate change on Metropolitan would have to consider temperature and precipitation in the service area (which controls demand and local supplies) as well as precipitation (and possibly temperature in the Colorado basin and in the Sierras (which control imported supplies). The interplay of these factors is likely to result in higher levels of water use and lower levels of supply, or at least more variable supply.

It would be possible to construct scenarios which include various alternative assumptions regarding the impact of climate change. However, the nature and the timing of these impacts remains highly uncertain. To combine these (so far) speculative local impacts with the other dimensions of the scenarios would complicate scenario building and evaluation. A better approach is to omit consideration of climate change at this time. Later, when the planning scenario has been selected and its implications thoroughly analyzed, it would be possible to consider some climate change alternatives based on that scenario alone. The possible loss of information (e.g., whether the introduction of climate change would alter the preference order of the scenarios) is probably outweighed by consideration of the high level of uncertainty surrounding local climate change impacts.

The Use of Peak Factors

Given the limited time span of useful peak load data collection (1997 to date), there are limited options with respect to development of a useful peaking factor. These include (1) computing an average annual peaking factor, either for all available years or for a subset of years selected to be consistent with forecast assumptions; (2) using a regression model to estimate an annual peaking factor as a function of selected weather variables; and (3) using a regression model to estimate a monthly peaking factor as a function of selected weather variables.

Average Annual Peaking Factor.--Figure 1 shows mean water demand (average day) and maximum day water demand for the Central Pool for each year from 1997 to 2005. The years are ordered in accordance with decreasing mean water demand. The observed annual peaking factors for the top four years are averaged to give a conservative peaking factor suitable for use in forecasting. Focusing on the four years of high total water demands (2002 to 2005), Figure 1 suggests that the annual peaking factor should be 1.41 for the Central Pool.

Additional analysis of historical peaking factors are shown in Appendix B.

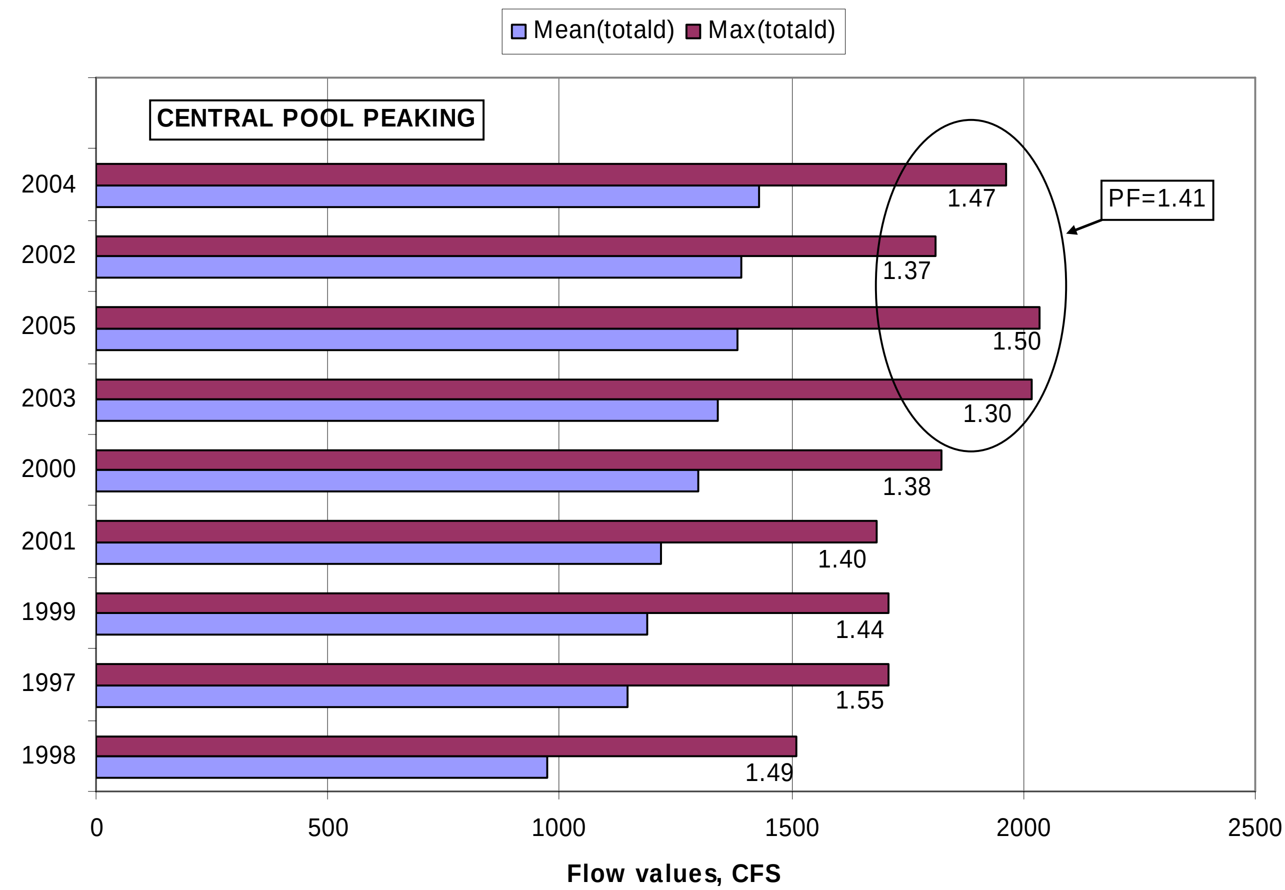


Figure 1.--Annual Peaking Factors for the Central Pool

Annual Peaking Factor Regression.--Appendix B presents several regressions of annual peaking factors on selected weather variables. This demonstrates that regression models are feasible, even with the very limited data available. However, the gains in accuracy are not large, and may not warrant the complexity of applying this method. As additional demand data accumulates, however, the regression approach can be expected to yield greater benefits.

Monthly Peaking Factor Regression.--It has been observed that peaking factors based on the maximum month may be more reliable than annual factors. One reason is that a monthly approach eliminates the sensitivity of the peaking factor to winter water use (or to water use in any other month), thus allowing equal consideration of all years in the data base. However, this approach depends on the availability of credible monthly water use forecasts. At present, no such forecasts exist.

Comparisons of Scenarios

Each scenario implies a critical path of decisions/actions regarding infrastructure investments. The timing of some of these decisions/actions is relatively insensitive to scenario characteristics (e.g., land acquisition, planning, engineering). Other decisions/actions may be very sensitive to the forecasts implied by alternative scenarios. These can be described as deferrable actions.

In comparing scenarios, one of the key issues is the effect that each scenario has on the deferrable actions. This concept can be extended to also consider the effect of scenarios on load-bearing assumptions (local resource investment and capability, active conservation plans). Analysis of scenarios should identify how each scenario will affect the deferrable infrastructure decisions and the requirement for load-bearing by local agencies.

The next level of comparison considers the signposts that may exist to indicate departures from the chosen scenario. Suppose, for example, a low growth scenario is chosen for planning purposes but actual growth in the early years exceeds the assumptions of the scenario. This may be due to the choice of an inappropriate scenario, or it may simply reflect a short-term excursion from valid trend lines. It is necessary to decide at what point the low growth scenario should be abandoned and replaced with a different set of planning assumptions.

Finally, each scenario implies a program of decisions and actions which are necessary to meet the forecast demand implied by the scenario. In order to provide capacity at the proper time, some decisions may be needed years or decades earlier. Scenarios may differ with respect to when key decisions must be made. Some scenarios may require major commitments to be made at an early date, while others might allow some choices to be deferred until later in the planning period. So long as the actual trends are still in doubt, early commitments may be unnecessarily risky. This concern would argue in favor of scenarios that preserve infrastructure options until trends are better understood.

Proposed Scenarios

Reference Scenario

The SCAG-04/SANDAG 2030 scenario is recommended as the reference scenario. This scenario is based on the projections embodied in the SCAG 2004 Regional Transportation Plan and on SANDAG's Final 2030 growth projections. These sources provide the demographic growth variables for the scenario. Other variables are fixed at levels used in recent Metropolitan forecasts. There are minor revisions to Camp Pendleton's retail demand. Generally, the prediction is for a period of rising income and moderately strong growth. This scenario is chosen as the reference scenario because it has already been reviewed by the member agency Technical Review Team and by the Expert Panel.

Peri-Urban Expansion Scenario

Narrative

This is a higher growth scenario similar to the Reference Scenario but with more strongly differentiated rates of growth within Southern California. Due to coastal growth constraints—increasing regulatory constraints, active anti-growth movements, and degraded coastal amenities—most economic and housing growth occurs in San Bernardino County, Riverside County, and to a lesser degree, Eastern San Diego County. (Growth in Los Angeles County north of the service area is not included in the estimates below.) The growth in coastal areas is limited to some in-fill growth and proceeds at recent historical rates. Rates of growth in inland areas will be higher than historical.

The Scenario is developed by first specifying the employment growth that is consistent with the dynamics of the Peri-Urban Expansion Scenario. Next, labor force participation rates (employment/population) are developed that are consistent with historical trends. Combining labor force participation with projected employment will imply consistent levels of future population. Utilizing historical trends in household size (persons per dwelling unit), it is possible to project the number of housing units that is consistent with the scenario.

Recommended Growth Rates

1. Employment growth

An employment growth model was estimated for each county based on 1979-2003 data. The following trend equation was used:

$$\ln(\text{Employment}) = a + b \cdot t^{0.5}$$

Note that t = 0 for 1979 and t = 71 for 2050. The results of these regressions are shown in columns 2 and 3 of Table 1.

Next, the 2005-2050 predictions of these models were adjusted by the difference between the 2004 model predictions and actual 2004 employment. This adjustment is performed to eliminate the "jumping-off" error which can occur at the transition between actual and predicted numbers.

Application of the the growth models in this form would produce an historical growth scenario, where each county's employment growth is an extrapolation of past growth. In order to achieve a higher overall growth rate, and to direct that growth to the inland counties, the growth coefficients ("b") are altered for Riverside and San Bernardino Counties. Each coefficient is multiplied by a factor (shown in column 4 of Table 1) to produce an adjusted growth coefficient (Column 5 in Table 1).

Table 1.--Recommended Employment Growth Rates--Peri-Urban Expansion

	Trend equation ln(E)=a+b·t^.5 (fitted to 1979-2003 data)		Recommended Growth Coefficient		Implied 2050 Employment
	a	b	Multiplier	Adjusted b'	
Los Angeles County	15.1377	0.0347	1.00	0.0350	4,959,233
Orange County	13.5703	0.1339	1.00	0.1340	2,466,875
San Diego County	13.4573	0.1393	1.00	0.1390	2,294,920
Ventura County	11.8315	0.1626	1.00	0.1630	539,397
Riverside County	11.7668	0.2736	1.20	0.3283	1,970,308
San Bernardino County	12.3304	0.2003	1.20	0.2404	1,643,693
6 County Total					13,874,425

The result of these adjustments can be seen in Table 2.

Table 2.--Comparison of Employment Projections for Peri-Urban Expansion Scenario

	Reference Scenario		**Peri-Urban Exp. Scenario**	
	2050 Employment	2010-2050 %growth	2050 Employment	2010-2050 %growth
Los Angeles County	6,067,052	0.48%	4,959,233	0.25%
Orange County	2,006,597	0.36%	2,466,875	0.94%
San Diego County	2,031,906	0.77%	2,294,920	0.98%
Ventura County	505,067	0.85%	539,397	1.17%
Riverside County	1,563,899	2.01%	1,970,308	2.54%
San Bernardino County	1,521,923	1.73%	1,643,693	1.84%
6 County Total	13,696,444	0.77%	13,874,425	0.93%

It should be noted that the Peri-Urban Expansion Scenario employment projections, which are very close to the Reference Scenario, represent a trend that is based upon a growth parameter, b, 20% greater than the point estimate, which is more than two standard errors above the historical trend line.

2. Population Projection

Population for each county is projected as the employment projection divided by the projected labor participation ratio. In the case of the four coastal counties, the ratio has been decreasing over time for Los Angeles County, but increasing for Ventura, Orange, and San Diego Counties. Furthermore, examination of historical data shows that labor participation ratios have grown disproportionately in the inland counties.

Therefore, for Riverside County, the labor participation ratio is projected to grow linearly from it 2006 value of 0.309 to a 2050 value of 0.418. In San Bernardino County, the labor participation ratio is projected to grow from its 2006 value of 0.340 to a 2050 value of 0.397. These projections reflect the historical trends of labor participation ratios in the two counties. It is suggested that the labor participation ratios for the four coastal counties be extrapolated from historical trends or, alternatively, left constant at their most recent value.

3. Household Size

Household size (persons per household) is assumed to be unchanged for the four coastal counties, but to increase for the inland counties in accordance with recent historical trends. Household size should ramp up to 3.18 persons/household by 2050 for Riverside Co. and to 3.37 for San Bernardino county. These endpoints are based on log-log growth models of household size as a function of time.

Dividing employment projections by household size gives the number of households for each county.

4. Housing Type

The projections should embody a small shift toward multi-family (MF) units in the coastal counties, thus reducing the fraction of single-family (SF) units. The current MF/SF ratio should be maintained in the inland counties.

5. Household Income

The historical data for the State of California show a long-term growth in median household income during the 1980-2004 period from $33,494 in 1980 to $45,439 in 2004 (in constant 2000 dollars). This growth represents an average annual growth rate of 1.3% per year. The historical data are plotted on Figure 2.

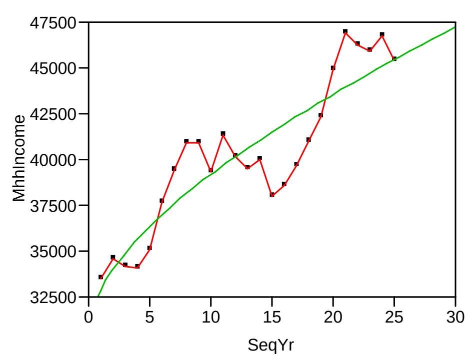


Figure 2.--Historical Growth of Median Household Income in California

Using the indicated trend line, projected median household income for 2050 is $59,903 (constant 2000$), reflecting an average annual growth of 0.60% per year.

The historical data for the 6 county region served by MWD from 1989 to 2003 show declining median household income, and a decline in the percentage of median household income for each of the 6 counties relative to the median household income in California statewide.

The trend of the percent of county to state median household income is shown in Table 3.

Table 3: Percent of County to State Median Household Income in Deflated 2000$

	Trend equation ln(%county/state)=a+b·t^.25 (fitted to 1989-2003 data)		Implied 2050 Median Household Income 2000$
	a	b	
Los Angeles County	4.846847	-0.071700	$63,070
Orange County	5.101281	-0.055255	$85,185
San Diego County	4.766996	-0.018365	$67,630
Ventura County	5.086983	-0.044796	$86,477
Riverside County	4.743947	-0.039670	$62,254
San Bernardino County	4.759683	-0.049219	$61,569
California (1980-2003)	10.32192853	0.080529719	$59,903

[Note that the trend equations for county/state ratios assume that 1989 is year 1 and 2050 is year 62; while the regression of California state income was based on 1980 as year 1 (2050 is year 71). Note that results are in terms of year 2000 dollars.]

The last row of Table 3 is a historical trend equation for California median household income as derived from data in Tables D-20 (MHHI) and D-16 (CPI) from the California Department of Finance document found at: http://www.dof.ca.gov/HTML/FS_DATA/STAT-ABS/Sa_home.htm. The estimates are obtained from a natural log equation ln(Median HH Income) = a + b Sqrt(Time) where Time = 1 for 1980 and Time = 24 for 2003, and where median household income is deflated using area Consumer Price Index (CPI) deflators specifically for California, setting the California CPI in 2000$:

ln(median household income for State) = 10.32192853 + 0.080529719 Sqrt(Year No.)

Multiplying the ratio of county to State median household income (projected with trend equations defined in Table 3) by the State projection gives the projection of median household income for the county.

6. Housing Density

There are some data on incremental population densities for California counties (see, http://www-iurd.ced.berkeley.edu/pub/WP-2003-04-screen.pdf). The numbers shown on this table were generated using GIS methods. They suggest incremental densities in urbanization for the 2020-2050 period ranging from 6.9 persons per acre for San Bernardino to 16.7 persons per acre for Orange County. Dividing these incremental population densities by average household size (i.e., persons per housing unit) gives housing density in units per acre for new development. However, the results of these calculations are, in most cases, significantly lower than the density measurements used in MWD-MAIN, apparently because of different conventions for measuring area. Also, the projected values are for incremental development; the impact on average density is not easily determined. Accordingly, no change in housing density is suggested.

7. Marginal Water Rates

One assertion is that the higher growth rates of the Peri-Urban Expansion Scenario would drive up demand for imported water and subsequently future marginal water rates. An alternative solution is that the elasticity of supply is sufficient to make any changes in the cost of marginal water supplies relatively small. In any case, the linkage between changes in supply cost and changes in retail rates is not well understood.

The expert panel recommends no change in Metropolitan's existing assumptions regarding the price of future water supply.

Possible Variant

It would be possible to develop a scenario similar to the Peri-Urban Expansion Scenario, except that certain measures are assumed to limit housing growth in the inland counties and to direct it to the higher density regions of the coastal counties. This would be associated with lower employment growth in inland counties, but higher growth in the coastal counties. Population growth is correspondingly lower. Higher housing costs result in a larger shift to MF units, both in inland and coastal counties.

Balanced Development Scenario

Narrative

This is a lower growth scenario that is designed to complement the Peri-Urban Expansion Scenario. In the Balanced Development Scenario, economic drivers are diminished with the Inland areas bearing the brunt of long term economic slowdown. This implies a shift from the current suburban expansion into more balanced "infill" growth primarily in urban areas and a modest expansion of housing and businesses inland along the transportation corridors. This scenario would imply a major intervention of local governments in improving the livability and quality of life in the urban areas of Southern California (brought about by shifting preferences of residents and immigrants). This could incorporate some Smart Growth restrictions, but in the context of slower overall growth.

The Scenario is developed by first specifying the employment growth that is consistent with the dynamics of the Balanced Development Scenario. Next, labor force participation ratios (employment/population) are developed that are consistent with historical trends. Combining labor force participation with projected employment will imply consistent levels of future population. Utilizing historical trends in household size (persons per dwelling unit), it is possible to project the number of housing units that is consistent with the scenario.

Recommended Growth Rates

1. Employment growth

An employment growth model was estimated for each county based on 1979-2003 data. The results of these regressions are shown in columns 2 and 3 of Table 4.

Next, the 2005-2050 predictions of these models were adjusted by the difference between the 2004 model predictions and actual 2004 employment. This adjustment is performed to eliminate the "jumping-off" error which can occur at the transition between actual and predicted numbers.

Application of the the growth models in this form would produce an historical growth scenario, where each county's employment growth is an extrapolation of past growth. In order to achieve a lower overall growth rate, and to direct that growth to the coastal counties, the growth coefficients ("b") are altered for Riverside and San Bernardino Counties. Each coefficient is multiplied by a factor (shown in column 4 of Table 4) to produce an adjusted growth coefficient (Column 5 in Table 4).

Table 4.--Recommended Employment Growth Rates--Balanced Development

	Trend equation $\ln(E)=a+b\cdot t^{.5}$ (fitted to 1979-2003 data)		Recommended Growth Coefficient		Implied 2050 Employment
	a	b	Multiplier	Adjusted b'	
Los Angeles County	15.1377	0.0347	1.00	0.0350	4,959,233
Orange County	13.5703	0.1339	1.00	0.1340	2,466,875
San Diego County	13.4573	0.1393	1.00	0.1390	2,294,920
Ventura County	11.8315	0.1626	1.00	0.1630	539,397
Riverside County	11.7668	0.2736	0.80	0.2189	1,016,135
San Bernardino County	12.3304	0.2003	0.80	0.1602	1,050,095
6 County Total	15.5438	0.0890			12,326,655

The result of these adjustments can be seen in Table 5.

Table 5.--Comparison of Employment Projections for Balanced Development Scenario

	Reference Scenario		**Balanced Devel. Scenario**	
	2050 Employment	2010-2050 %growth	2050 Employment	2010-2050 %growth
Los Angeles County	6,067,052	0.48%	4,959,233	0.25%
Orange County	2,006,597	0.36%	2,466,875	0.94%
San Diego County	2,031,906	0.77%	2,294,920	0.98%
Ventura County	505,067	0.85%	539,397	1.17%
Riverside County	1,563,899	2.01%	1,016,135	1.17%
San Bernardino County	1,521,923	1.73%	1,050,095	0.92%
6 County Total	13,696,444	0.77%	12,326,655	0.67%

2. *Population Projection*

Population for each county is projected as the employment projection divided by the projected labor participation ratio. It is assumed here that the labor participation ratio remains constant for Riverside, San Bernardino, and San Diego Counties. For the remaining counties, the labor participation ratio is projection by means of a trend equation, estimated from historical data.

The equations for projecting the labor participation ratios are as follows:

Ln(Los Angeles County) = -0.625694 - 0.0338027 Sqrt(SeqYear) where SeqYear=1 for 1980

Ln(Orange County) = -0.791424 + 0.028373 Sqrt(SeqYear)

Ln(Ventura County) = -1.246148 + 0.0626822 Sqrt(SeqYear)

3. *Household Size*

Because of increasing density and a shift to MF housing in the coastal counties, household size is expected to remain constant. However, household size for Riverside County should ramp up to 3.25 persons/household by 2050, reflecting the expected influx of young families with children.

Dividing employment projections by household size gives the number of households for each county.

4. *Housing Type*

This scenario should incorporate a major shift toward multi-family (MF) housing in the coastal areas. This is consistent with the Smart Growth policies expected to direct growth to urban areas and to promote infill development. The current MF/SF ratio should be maintained in the inland counties.

5. Household Income

The historical data for the State of California show a long-term growth in median household income during the 1980-2004 period from $33,494 in 1980 to $45,439 in 2004 (in constant 2000 dollars). This growth represents an average annual growth rate of 1.3% per year. The historical data are plotted on Figure 3.

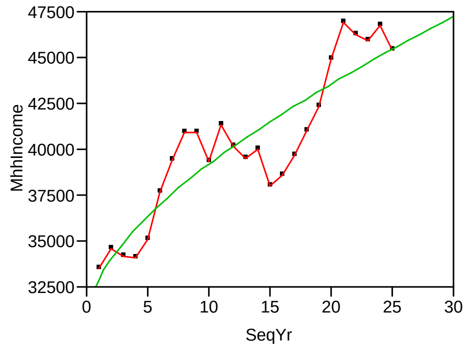


Figure 3.--Historical Growth of Median Household Income in California

Using the indicated trend line, projected median household income for 2050 is $59,903 (constant 2000$), reflecting an average annual growth of 0.60% per year.

The historical data for the 6 county region served by MWD from 1989 to 2003 show declining median household income, and a decline in the percentage of median household income for each of the 6 counties relative to the median household income in California statewide. For the Balanced Development Scenario, income is assumed to decline faster relative to State income. Table 3, above, shows trend equations for the county/state ratios. All have negative trend coefficients. For this scenario, the absolute value of these trend coefficients are increased by 0.00867 (approximately one-half standard deviation) for coastal counties and by 0.01734 (slightly more than one standard deviation) for inland counties.

The trend of the percent of county to state median household income is shown in Table 6.

Table 6: Percent of County to State Median Household Income in Deflated 2000$

	Trend equation ln(%county/state)=a+b·t^.25 (fitted to 1989-2003 data)		Implied 2050 Median Household Income 2000$
	a	b	
Los Angeles County	4.846847	-0.080370	$60,878
Orange County	5.101281	-0.063925	$82,225
San Diego County	4.766996	-0.027035	$65,280
Ventura County	5.086983	-0.053466	$83,472
Riverside County	4.743947	-0.057010	$58,647
San Bernardino County	4.759683	-0.066559	$58,002
California (1980-2003)	10.32192853	0.080529719	$59,903

[Note that the trend equations for county/state ratios assume that 1989 is year 1 and 2050 is year 62; while the regression of California state income was based on 1980 as year 1 (2050 is year 71). Note that results are in terms of year 2000 dollars.]

The last row of Table 6 is a historical trend equation for California median household income as derived from data in Tables D-20 (MHHI) and D-16 (CPI) from the California Department of Finance document found at: http://www.dof.ca.gov/HTML/FS_DATA/STAT-ABS/Sa_home.htm. The estimates are obtained from a natural log equation ln(Median HH Income) = a + b Sqrt(Time) where Time = 1 for 1980 and Time = 24 for 2003, and where median household income is deflated using area Consumer Price Index (CPI) deflators specifically for California, setting the California CPI in 2000$:

ln(median household income for State) = 10.32192853 + 0.080529719 Sqrt(Year No.)

Multiplying the ratio of county to State median household income (projected with trend equations defined in Table 6) by the State projection gives the projection of median household income for the county.

6. *Housing Density*

There are some data on incremental population densities for California counties (see, http://www-iurd.ced.berkeley.edu/pub/WP-2003-04-screen.pdf). The numbers shown on this table were generated using GIS methods. Dividing these incremental population densities by average household size (i.e., persons per housing unit) gives housing density in units per acre for new development. However, the results of these calculations are, in most cases, significantly lower than the density measurements used in MWD-MAIN, apparently because of different conventions for measuring area. Also, the projected values are for incremental development; the impact on average density is not easily determined. Accordingly, no change in housing density is suggested.

7. *Marginal Water Rates*

It may be argued that the lower growth rates of the Balanced Development Scenario would reduce demand for imported water and subsequently future marginal water rates. An alternative solution is that the elasticity of supply is sufficient to make any changes in the cost of marginal water supplies relatively small. In any case, the linkage between changes in supply cost and changes in retail rates is not well understood.

The expert panel recommends no change in Metropolitan's existing assumptions regarding the price of future water supply.

Appendix A -- Extrapolating Employment Trends

Ben Dziegielewski

November 1, 2006

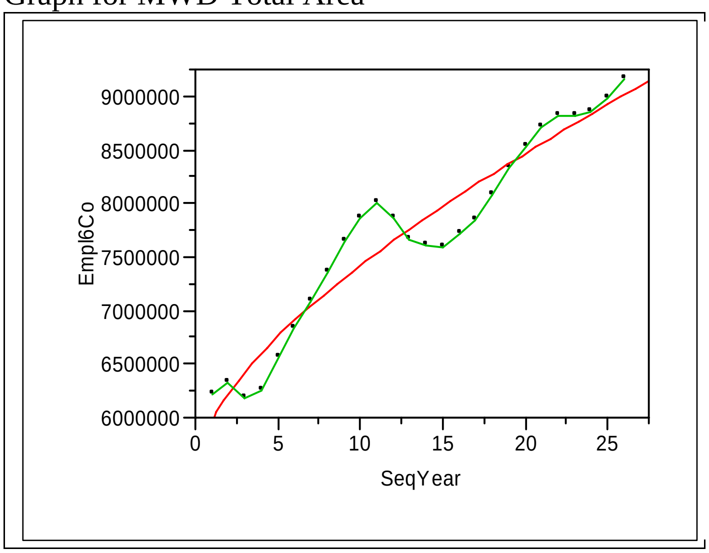
The following discussion is based on 1980-2005 employment data. Trend lines are estimated for the entire six county service area, for the three coastal counties (Los Angeles, Orange, and Ventura), for the three remaining counties (San Bernardino, Riverside, and San Diego).

Total MWD Six County Area

Trend line (red) and its equation (LN(y) = a + b SQRT(year)) (t-values for the coefficients are given below the equation) are:

Log (Empl6Co) = 15.502996 + 0.1003332 Sqrt (SeqYear)
R^2 = 0.93 t = 734.04 t = 17.53

Graph for MWD Total Area



The prediction of total 6 county employment based on this equation compared to the RUWMP numbers would be:

Year	2000	2010	2020	2030	2040	2050
RUWMP	8,714,057	10,068,356	11,120,961	12,124,413	12,910,429	13,696,444
Trend 80-05	--	9,450,967	10,277,236	11,067,444	11,835,610	12,590,065

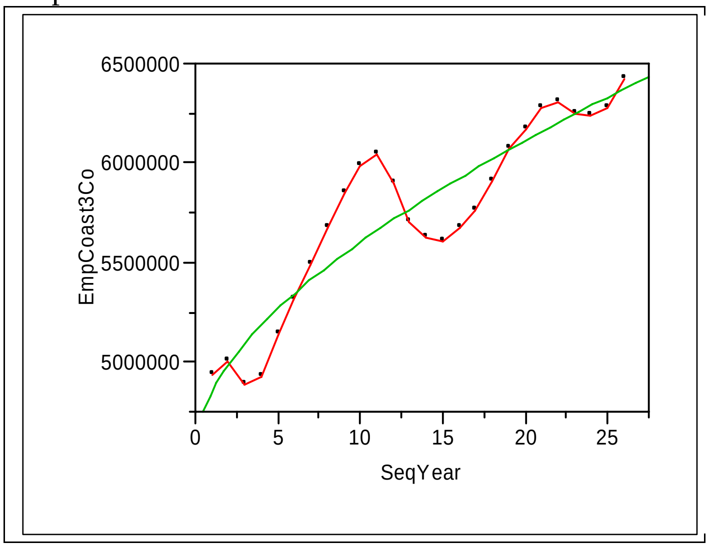
The predicted values are about one million employees lower than the values in the scenario spreadsheet.

Combined Los Angeles, Orange and Ventura Counties

For the 3 county are served by Central Pool the equation and the graph with fitted trend line (green) are:

Log (EmpCoast3Co) = 15.328997 + 0.0664081 Sqrt (SeqYear)
$R^2 = 0.85$ t = 727.92 t = 11.59

Graph for Central Pool



The predictions of total 3 county employment based on this equation compared to the RUWMP numbers would be:

Year	2000	2010	2020	2030	2040	2050
RUWMP	6,274,519	7,099,583	7,586,476	7,995,212	8,286,964	8,578,716
Trend 80-05		6,574,714	6,949,750	7,298,984	7,630,476	7,949,039

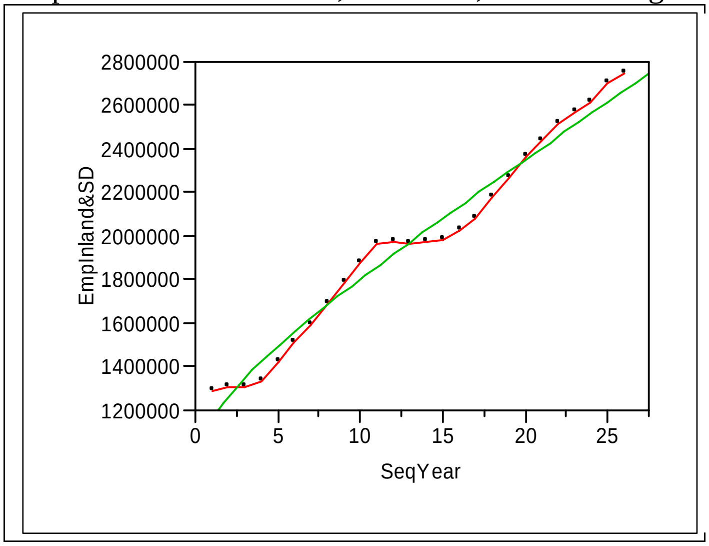
The predicted values are about one-half million employees lower than the values in the RUWMP scenario spreadsheet.

Combined San Bernardino, Riverside and San Diego Counties

For the 3 county area served by San Bernardino, Riverside, and San Diego Counties, the equation for employment trend and the graph with fitted trend line (green) are:

Log (EmpInland&SD) = 13.764538 + 0.2025722 Sqrt (SeqYear)
$R^2 = 0.97$ t = 533.35 t = 28.84

Graph for San Bernardino, Riverside, and San Diego Counties



The prediction of total 3 county employment based on this equation would be:

Year	2000	2010	2020	2030	2040	2050
RUWMP	2,439,538	2,968,773	3,534,485	4,129,201	4,623,465	5,117,728
Trend 80-05	--	2,935,570	3,476,835	4,037,729	4,623,569	5,237,955

The predicted values are very close here to the values in the RUWMP scenario spreadsheet.

Because the three trend equations were fitted to the annual 1980-2005 data independently, the predictions for the two 3-county areas do not add up to the prediction for the entire MWD area but the discrepancies are not great.

Appendix B -- Regression Models for Peaking Factors

Ben Dziegielewski
November 5, 2006

The peaking factors which were calculated by the MWD System Analysis Unit are shown in Table B1. The factors within each load area show significant variability – the difference between the highest and lowest values for individual years ranges from 0.13 to 0.42. This is, in part, a result of the data which include both wet and dry hydrologic conditions in the service areas.

Table B1.--Calculated Daily Peaking Factors in MWD Technical Memorandum

Year	Diemer	Jensen	Weymouth	Common Pool	Central Pool	Mills	San Bernardino	Skinner
2000	1.54	1.58	1.65	1.42	1.52	1.79	2.05	1.86
2001	1.61	1.26	1.99	1.28	1.50	1.59	2.16	1.78
2002	1.45	1.45	1.59	1.26	1.41	1.69	1.74	1.73
2003	1.63	1.48	1.75	1.42	1.55	1.65	2.12	1.85
2004	1.44	1.40	1.68	1.37	1.46	1.72	2.03	1.73
2005	1.56	1.49	1.77	1.32	1.50	1.92	1.92	1.82
Average	1.54	1.44	1.74	1.35	1.49	1.73	2.00	1.80
Range	0.19	0.32	0.40	0.16	0.14	0.33	0.42	0.13
Std. Dev.	0.08	0.11	0.14	0.07	0.05	0.12	0.15	0.06

Because the forecast scenarios will represent historical weather conditions which produced high demands in MWD service area, it would be advisable to match the peaking factors to such weather conditions. Ideally, the peaking factors should represent the annual pattern of daily demands during the historical hot and dry weather used in generating estimates of monthly water use during the forecast years.

The data on daily water demands in the six load areas provided in the Excel data set "MWD Load Data Summary 1997-2006.xls" were examined in order to determine if there are statistically significant relationship between peak flows or peaking factors and weather conditions such as air temperature and precipitation. The results of the regression analyses on the data are discussed below.

Regressions of Annual Peaking in Six Load Areas

The 1997-2005 annual peaking data for six load areas were analyzed using regression analysis. Both peak flows and peaking factors were regressed on several measures of weather conditions. Table B2 shows a regression equation which was estimated using peak annual flows as dependent variable. The equation includes four continuous variables and two binary variables (a binary indicator for Jensen and for Skinner). The regression coefficients for the two weather variables have signs which are contrary to expectations. The mean absolute percent error (MAPE) for in-sample predictions for the estimated equation is 3.9 percent.

Table B2.--Linear Regression of Peak-Day Flows for Six Load Areas

Term	Estimate	t Ratio	Prob.>|t|
Intercept	138.276	7.58	<.0001
Mean daily winter flows	0.250	2.59	0.0128
Mean daily summer flows	0.727	7.31	<.0001
Number of summer days w/ T>90° F	-0.867	-6.49	<.0001
Number of rainy days during summer	1.750	2.60	0.0123
Jensen	-38.315	-4.00	0.0002
Skinner	132.234	5.40	<.0001
N = 54, R^2 = 0.99, Root MSE = 23.4 cfs, MAPE = 3.9%			

Dependent variable = annual peak-day flow

Table B3 shows a regression equation with annual peaking factor as the dependent variable. One important relationship in the model is the negative coefficient of the variable representing mean daily flow. It indicates that peaking factors tend to be lower when mean flows are higher. Overall, the regression results indicate relatively good predictions high R^2 and with MAPE of 4 percent.

Table B3.--Linear Regression of Annual Peaking Factors for Six Load Areas

Term	Estimate	t Ratio	Prob.>|t|
Intercept	-0.9550	-1.23	0.2266
Mean daily annual flows	-0.0009	-5.44	<.0001
Number of rainy days (annual)	0.0061	5.73	<.0001
Mean winter temperature	0.0351	3.32	0.0018
Number of summer days w/T>90°F	-0.0045	-4.00	0.0002
Mills	0.4774	4.62	<.0001
Skinner	0.4623	7.55	<.0001
Weymouth	0.2463	6.09	<.0001
N = 54, R^2 = 0.87, Root MSE = 0.09, MAPE = 4%			

Dependent variable = annual peaking factor

However, despite the high R^2 and low MAPE the accuracy of the regression models in Tables B2 and B3 represents only a moderate improvement over the use of average values of peaking factors. Table B4 compares the accuracy of the regression model from Table B3 to the accuracy obtained by using average values for each of the six load areas.

An alternative specification, using only annual flow and annual rainfall, plus dummy variables for Jensen, Skinner, and Weymouth, produces the following, nearly equivalent representation.

Table B4.--Regression of peaking factors for Six Load Areas on Mean Q and Annual Rainfall

Term	Estimate	Std Error	t Ratio	Prob.>|t|
Intercept	1.9053	0.0456	41.81	<.0001
Binary for Jensen	-0.1349	0.0381	-3.54	0.0009
Binary for Skinner	0.4065	0.0395	10.29	<.0001
Binary for Weymouth	0.1122	0.0385	2.92	0.0054
Average annual flow, cfs	-0.0015	0.0001	-13.15	<.0001
Total annual rainfall, inches	0.0074	0.0020	3.74	0.0005
N= 54, R2=0.84, Root MSE=0.10				

Based on this result the peaking factor for any of the six load areas can be calculated. For Common Pool (or Mills, or Diemer) the formula would be:

$$PF = 1.9053 - 0.0015 Q_{ave} + 0.0074 R_{total}$$

One could also add the effect of E/P ratio from the Central Pool and Riverside/San Diego model but that would not be based on estimation.

The comparisons in Table B5 indicate that the predictions by regression are on average about 30 percent more accurate in terms of average absolute difference between the actual and predicted values and in terms of the absolute percentage error of the in-sample predictions.

Table B5.--Comparison of Accuracy Gain in Predictions by Regression

Load Area	Average Peaking Factor	Predictions by Regression			Prediction by Average Value		
		Absolute Difference	Average Difference	Mean APE,%	Absolute Difference	Average Difference	Mean APE,%
Common Pool	1.32	0.03-0.12	0.05	3.8	0.01-0.12	0.05	3.6
Diemer	1.53	0.02-0.17	0.07	4.7	0.01-0.24	0.09	6.0
Jensen	1.52	0.01-0.12	0.05	3.1	0.02-0.19	0.09	5.8
Mills	1.83	0.01-0.19	0.09	4.8	0.00-0.34	0.13	7.0
Skinner	1.80	0.02-0.17	0.06	3.3	0.01-0.38	0.12	6.6
Weymouth	1.79	0.01-0.17	0.07	4.0	0.02-0.34	0.12	6.7
All 6 areas	1.63	0.01-0.19	0.07	4.0	0.00-0.38	0.10	5.9

Regressions for Central Pool and Riverside/San Diego Areas

In addition to weather variables, limited data on socioeconomic characteristics were available for two aggregated areas: Central Pool and Riverside/San Diego. The socioeconomic variables included: share of single-family homes in hosing stock, ratio of employment to population and average household size. Table B6 shows a regression equation with four independent variables.

Table B6.--Linear Regression of Annual Peaking Factors for Central Pool and Riverside/San Diego Areas

Term	Estimate	t Ratio	Prob.>|t|
Intercept	15.4030	5.90	<.0001
Mean daily annual flows	-0.0011	-6.84	<.0001
Share of single-family homes	-15.2308	-4.93	0.0003
Employment-to-population ratio	-7.8188	-4.54	0.0006
Number of winter days w/T>90°F	-0.0103	-2.19	0.047
N = 18, $R^2 = 0.93$, Root MSE = 0.07, MAPE = 3%			

Dependent variable = annual peaking factor

The in-sample predictions with the equation from Table B6 are shown on Table B7. The level accuracy of the predictions obtained with the regression model is similar to the accuracy for the six load areas discussed earlier. The absolute difference between peaking factors ranges from 0.01 to 0.11 for Central Pool and from 0.01 to 0.10 for Riverside/San Diego. The MAPE obtained for predictions from average values for each area were 4.4% and 6.7%, respectively, for Central Pool and Riverside/San Diego areas.

Table B7.--In-sample Predictions of Annual Peaking Factors for Central Pool and Riverside/San Diego

	Central Pool Area			Riverside/San Diego Area		
Year	Predicted PF	Actual PF	APE, %	Predicted PF	Actual PF	APE, %
1997	1.47	1.49	1.6	1.97	1.96	0.6
1998	1.65	1.55	6.9	2.03	2.13	4.5
1999	1.37	1.44	4.5	1.72	1.75	1.5
2000	1.30	1.40	7.3	1.74	1.73	0.5
2001	1.45	1.38	5.1	1.72	1.74	1.1
2002	1.37	1.30	5.1	1.66	1.58	5.3
2003	1.49	1.50	0.7	1.66	1.62	2.6
2004	1.39	1.37	1.3	1.71	1.70	0.5
2005	1.42	1.47	3.7	1.77	1.79	1.1
Average	1.44	1.44	4.0	1.78	1.78	2.0

The examination of in-sample predictions indicates some improvement in the predictive accuracy as compared to using the average value of the peaking factor for each area. Greater accuracy can be achieved by estimating separate regressions for each area. For example, a regression equation with four independent variables estimated for Riverside/San Diego produced mean APE of 0.5 percent. However, the reliability of the estimates becomes problematic because of the small number of observations for each load area.

Another approach to modeling the peaking factor for the Central and Riverside/San Diego areas utilizes the employment-to-population ratio.

Table B8. Regression of peaking factors for Central and Riverside San Diego on Mean Q and Employment Ratio

Term	Estimate	t Ratio	Prob.>|t|
Intercept	6.6249	5.68	<.0001
Binary for Central Pool	0.9949	3.93	0.0015
Empl-to-Population Ratio	-10.1197	-3.86	0.0017
Average annual flow, cfs	-0.0011	-5.43	<.0001
N= 18, R2= 0.89, Root MSE = 0.08			

This result allows adjustments for peaking factors on the two major facilities by knowing future annual Q and the ratio of employment to population.

For Riverside/San Diego area the formula is:

$$PF = 6.6249 - 10.1197\frac{E}{P} - 0.0011Q_{ave}$$

For Central Pool (i.e., Common Pool, Weymouth, Diemer and Jensen) the formula is:

$$PF = 6.6249 + 0.9949 - 10.1197\frac{E}{P} - 0.0011Q_{ave}$$

Implications of the Regression Results

The sample of regression results indicates that peaking factors can be predicted using regression models with better accuracy than when using the average historical value of the peaking factor for each load area. However, the gains in accuracy are not great and there may be simpler methods for improving the predictions of peak day flows in the load areas.

Summary of Historical Peaking Factors

The following charts show historical peaking factors for the years 1997 to 2005 for various load areas. In each case, the years are rearranged in order of increasing maximum day flow. These charts demonstrate the relative independence of the annual peaking factor and average or maximum flow.